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A Case Study on Different Lighting Systems

Sreeram K (PG Scholar)[1], Mr. Unnikrishnan L[2]

[1,2]*Dept. of Electrical and Electronics Engineering, Rajagiri School of Engineering and Technology, Rajagiri Valley P.O, Kochi-682039, Kerala, India*

Abstract: Techno-economic performance comparison of Compact Fluorescent Lamps (CFL) with Light Emitting Diodes (LED), fluorescent tubes, incandescent bulbs was carried out in view of worsening power and energy crisis. However, tubes, LED, CFL and External Electrode fluorescent lamps (EEFL) lamps worsen electric power quality of low voltage networks due to high current harmonic distortions (THD) and poor power factors (PF). Expenses of low THD and high PF CFL, incandescent lamps and LED lamps may be four to eight times higher that poor THD and deteriorating PF lamps. Selection of a lighting source hinge on THD, operating PF, shelf life, energy expenditure, power consumption, efficacy, colour rendering index (CRI) and associated physical effects. This paper recommends designing consumer based novelties to avoid low operating power factor. LEDs are the future for lighting in industrial, commercial and residential purposes. Government and commercial buildings may consider full spectrum hybrid thermal photovoltaic and solar fiber optic illumination systems.
IndexTerms— CFL, LED , THD, Efficacy

I. INTRODUCTION

Lighting is the intentional utilization of luminous to attain a effect. Light sources include natural lighting and artificial lighting such as bulbs. Lighting constitutes more than 30 % of the global energy consumption.Expenses of a lighting system depends on factors like power rating , distortion in current, power factor , operating life hours, luminous intensity, efficacy, correlated colour temperature etc. Two lamps of same rated power (10 W), 82 CRI, 2700 CCT, 520 lumens output may cost $9–10 for 8000 h life, high current THD and low PF or $40–50 for 12,000 h life, low current THD and high power factor.CFL initial current is 30–90 times greater than the steady condition current. Even though cost of incandescent bulbs are lesser, they have lower working efficiency. The wattage rating of tube, CFL, LED and EEFL are lesser than bulbs for the similar radiant intensity. Incandescent lamps have shorter operating life (9000 hrs) with respect tube (6000 h), CFL (15,000 h), LED (1,00,000 h).

II. DIFFERENT LIGHTING SOURCES

Various types of lamps used in domestic and industrial lighting are incandescent lamps (GLS), fluorescent lamps (FL), T 12 lamps, T 5 lamps, compact fluorescent lamps (CFL), light emitting diodes (LED), mercury vapour lamps, sodium vapour lamps, halogen lamps and others. Residential lighting is contributed by CFLs, tubes and incandescent lamps and LEDs are mainly used in industrial lighting. LEDs can provide energy efficient lighting leading to savings in energy and cost. There can be several measures that can be taken for energy savings. By controlling the lighting in such a way that the lighting level is always accurately matched to the actual need allows to save on the energy costs and to improve the human comfort and efficiency . Lighting technologies that produces more luminous intensity or lumens per unit of wattage should be widely utilized. Lighting quality can also be improved by using LEDs and graphene lamps instead of conventionally used lighting sources.

A. Incandescent lamps or GLS

It is the most commonly used lighting device lamp for residential and commercial purposes and its efficiency is very low as it produces more heat compared to the light emitted. It gives light by means of a tungsten filament which gets heated up when current passes through it. About 10-12 percentage of energy is used to emit light. This bulb is often used, especially in a fixture that actually controls the light output rather than scattering it everywhere.

B. Fluorescent lamps

They have higher working efficiency compared to incandescent lamps and are mostly involved for interior lighting. They have higher luminous intensity and has lower power rating leading to reduction in energy consumption. It means wattage rating of these lamps reduce giving the same lumens output as of incandescent lamps. The objective is to

Volume 5 Issue V, May 2017
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Fluorescent lamps are of different types such as Compact Fluorescent Lamps (CFLs), tubelights or tube lamps which are further classified into T 5, T 8 and T 12. Among these T 12
lamps are the oldest and most energy inefficient.

C. LED Lamps

An LED bulb consists of an array of LED units connected in series or parallel and integrated into a fixture.LED lamps have greater lifespan and much more efficiency than other lamps. LEDs are perfect for applications where they can be turned on and off by high frequency pulsating current. Initial cost of LEDs are high but the yearend energy savings are large leading to savings in overall cost and energy. The additional expense is due to low lumen output and the drive circuitry and power supplies needed.

III. LIGHTING TERMS AND DEFINITIONS

A. Power Factor

High power factor operation leads to higher efficiency, reduction in size of equipments and wires. The utility provides incentive for high power factor operation and levies additional costs when low power factor is involved.Same rated supply can feed 90–95 kW load at unity PF compared to 50 kW load at 0.5 PF. Term PF reflects efficiency of an electrical power distribution system. Loads that cause poor power factor include induction motors, arc furnaces, machining, stamping, welding, variable speed drives, computers, servers, TV, fluorescent tubes, compact fluorescent lamps.Utility charges industries for poor factor but exempts houses and offices.

Fig.1.Powerguard meter for PF measurement

B. Total Harmonic Distortion(THD)

IEEE Std.519 (1992) recommends keeping voltage THD _ 5% and current THD _ 32% in utility power distribution network <69 kV. ANSI C82.77 (2002) recommends all commercial indoor hard wired ballasts >28W maintain 0.92 .Highest allowable harmonics component per wattage is 3.4 mA (for 3rd harmonic) corresponding to current THD of 78.2%. The total harmonic distortion, or THD, of a signal is the extent of the harmonic distortion in the source current and is the ratio of the RMS amplitude of a set of higher harmonic frequencies to the RMS amplitude of the fundamental frequency. THD can be used to assess the power quality of electric power systems. Low value of THD leads to reduced currents, heating, emissions and lower losses .

Fig.2.Flukemeter for Power quality indices measurement

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C. .LIGHTING TERMS

1) Lumen: Lumen is the SI unit of luminous flux and is the net measure of light produced by a given lighting unit.
2) Watts: -Watts is the overall electric power utilized by the bulb
3) Luminous flux:-The luminous flux is the factor used to describe the brightness of an area expressed in lumens
4) Luminous efficacy:- Luminous efficacy is the total luminous flux or lux emitted by the light source per unit lamp wattage. It is measured in Lumens per Watt (lm/W
5) Burning hours:- It is the useful lifespan of the lamp or the total time in hours in which the light source can provide useful light
6) CRI:- The colour rendering index (CRI), is a quantitative measure of the ability of a lamp to divulge the colour of various objects in comparison with an ideal source or natural lighting.

Fig.3.Measurement of Total Harmonic Distortion

IV. EXPERIMENTAL METHODOLOGY

For comparing the performance in terms of energy cost savings of different lighting sources lamps, one of the parameter like luminous intensity is kept constant. Thus keeping lumens almost constant around 2500, comparison of other parameters is done in Table 1

TABLE I. COMPARISON OF SOME TECHNICAL PARAMETERS OF DOMESTIC LAMPS

Lamp	Lumens	Watts(W)	Burning Hours	Bulb/Lamp Cost in Rupees
Incandescent	2600	150	1200	20
CFL	2600	50	8000	700
Fluorescent Tube	2500	25	15000	140
LED	2600	25	50000	2000

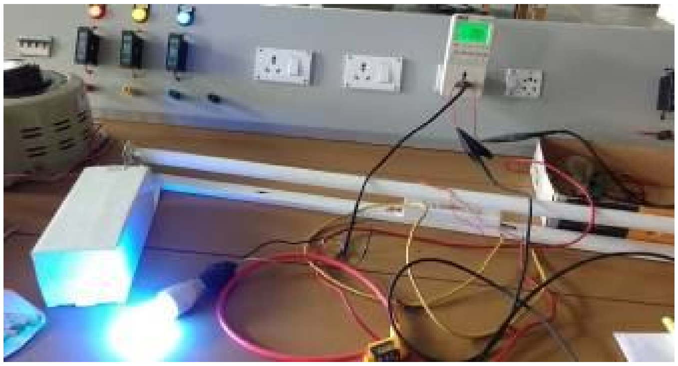

Fig.4.Experimental Setup

Volume 5 Issue V, May 2017
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So taking burning hours of one light source as reference (which is maximum), number ofbulbs required for all other light sources and their cost are calculated. Number of bulbs and cost for light sources taking burning hours of one light source as reference can be calculated as:

(Number of bulbs/ cost) = Number of bulbs required for burning hours * Cost of one bulb

For fixed burning hours energy required can be calculated as:

Energy required in KWh= (Burning hours * Rating in watts)/1000

Taking the local tariff, cost of energy can be calculated as:

Energy cost= Energy required * Tariff

Finally the life cycle cost is calculated by adding the bulbs cost and energy cost as:

Life cycle cost=Energy cost + Bulb cost

It is clear that LEDs have maximum burning hours. The objective is that the light source should have maximum burning hours. So taking 50000 burning hours as reference, all the calculations are evaluated in Table 2.

TABLE 2: LIFE CYCLE COST ESTIMATION OF DIFFERENT LIGHT SOURCES

Lamp	For 50000 hours no of bulbs required	cost of bulbs (Rs)	For 50000 hours energy required (Kwh) (50000*W)/1000	Energy cost (Rs)	Life cycle cost (Rs)
Incandescent	42	840	7500	38625	39465
CFL	6	4200	2500	8000	7000
Fluorescent Tube	4	560	1260	6438	8438
LED	1	2000	800	4056	6998

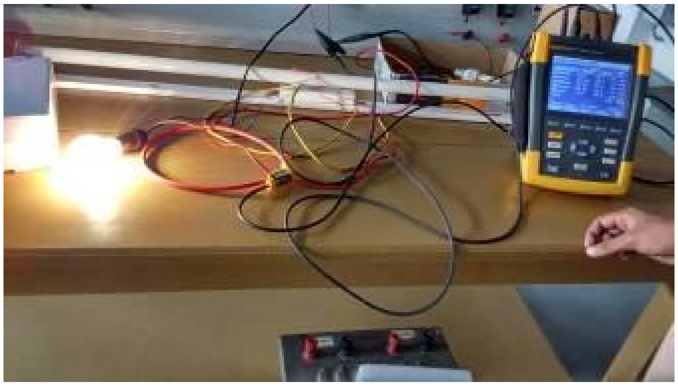

Fig.5.Experimental Setup

As a next experimental test, a flicker meter and a power guard meter is used to measure the operating voltage, current drawn, power consumption, energy consumed, power factor and the Total Harmonic Distortion(THD) and the results are tabulated in Table 3 as a comparison of power quality indices of different lighting sources.

TABLE 3: EVALUATION OF POWER FACTOR AND TOTAL HARMONIC DISTORTION OF VARIOUS LIGHTING SYSTEMS

Lighting source	Power factor	Harmonic content(as a % of fundamental)
Incandescent Bulb	0.99	4.7
CFL	0.92	4.4
Fluorescent Tube	0.55	1.8
Light emitting Diode (LED)	0.98	

Fig.6.Experimental Setup

V. RESULTS AND DISCUSSIONS

For efficient light sources, this should be the objective. Finally the study shows that the life cycle cost is much more for the incandescent lamps while it is far lesser for the other lamps. The life cycle cost is very less for T5 lamps and LEDs. For an efficient light source, it should have high luminous efficacy, minimum power consumption and minimum life cycle cost.The various lighting terms for lighting systems were analysed for the same lumens output and the values were recorded. Star rating indicates the performance of lamps according to their ability of minimum power consumption, maximum luminous efficacy and minimum life cycle cost. More the star rating, more good is the quality or performance according to these factors.The incandescent lamp operates with the highest power factor and has highest harmonic content in the input current while the LED has lowest power factor.

TABLE 4 : PERFORMANCE OF DIFFERENT LAMPS

Lamp	Star Rating	Performance
Incandescent	*	Poor
CFL	**	Satisfactory
Fluorescent Tube	****	Very Good
LED	*****	Excellent

VI. CONCLUSION

The comparative study of various parameters of light sources explains that incandescent lamps are the most inefficient with maximum power consumption and maximum life cycle cost. CFLs are good alternative for incandescent lamps with somewhat lesser power consumption and very less life cycle cost. Similarly tube lamps like T12 and T8 have very less life cycle cost. LED lamps have very low life cycle cost as compared to other lamps but somewhat higher than T5 lamps. This is because their lamp cost is far higher than other lamps. If this cost would be less, they would have least life cycle cost. Only advantage with LEDs is that they have maximum burning hours. The incandescent lamp operates with the highest power factor and has highest harmonic content in the input current while the LED has lowest power factor. It means once the LED lamps are installed, they do not need to be replaced again and again for years. The life cycle assessment shows that replacing older lamps of high power consumption and high cost with new and innovative lamps of comparatively low power consumption and less cost could be beneficial for a particular application from the aspect of both energy and cost saving.

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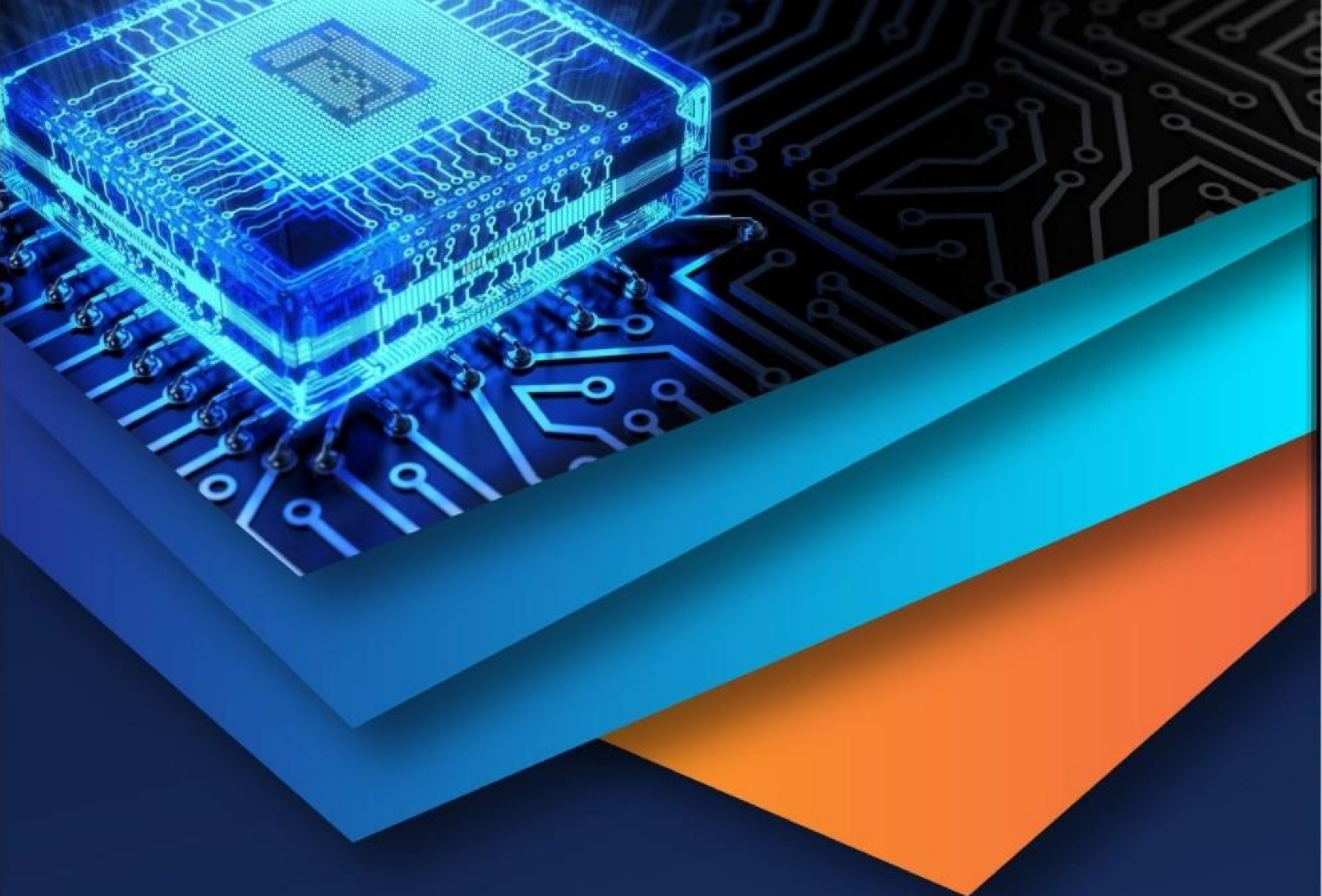

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