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ELECTRICAL ENERGY SAVING THROUGH LAMPS REPLACEMENT AND COMPONENTS INCOMPATIBILITY ON LIGHTING SYSTEM ECONOMICS

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ABSTRACT

Modern Buildings of all types relies heavily on the use of electrical energy. This energy has to be properly utilized in order to avoid many problems both to the electric utilities supply companies and also to the consumer. This paper presents energy saving through replacement process of conventional electric lamps known as relighting, and the incompatibility in using different components in a single lighting system. Electricity bills savings of up to 37% - 60% were achieved with no reduction in lighting levels. Despite the cost involved in relighting and by avoiding incompatibility in using different components the payback periods were noted to be about 10 months, and ROI of about 124%, justifying the need for relighting process to be carried out and avoiding the use of different components in most Nigerian buildings.

Key Words: components incompatibility, energy saving, lamps replacement, Luminaires, modernisation, payback period, relighting.

INTRODUCTION

Energy is required in various forms to do useful work. It is also required for the continual improvement in the living standard of any society. Economic development has progressed with increase energy used per capital. There is a strong correlation between the standard of living as measured by the per capital gross national product and the per capital energy consumption (Dorf; 1978). Modern Buildings of all types relies heavily on the use of electrical energy. In the UK, 46% of the total delivered energy consumption by sector in 2000 is used in the buildings. A little above 50% of this energy is consumed by lighting (Good Practice Case Studies-GPCS 309; 2003). This energy has to be properly utilized in order to avoid many problems both to the electric utilities supply companies and also to the consumer. Owners of industrial lighting systems that are more than a few years old would do well to investigate the potential savings they could achieve from modernisation. Many are likely to find out that the cost of implementation of this modernisation would be recovered within two or three years by consequent savings on their electricity bills (Belkacemi, Alghamdi & Basudan, 2002).

Recent developments have led to the introduction of lamps and luminaires that offer dramatic improvements in energy efficiency, so modernisation could be just a question of fitting replacement components. It is also likely to involve the use of automatic control systems with light and/or proximity sensors and time switches. These provide savings by avoiding the use of artificial lighting when available daylight is sufficient, or when people are absent. Good lighting design can reduce the running costs and can also reduce internal heat gains, thus reducing the need for air-conditioning. The Chartered Institute of Building Services Engineers - CIBSE (2005) stated that attention given to fabric details at the sketch design stage to ensure the integration of day lighting is particularly important in achieving this. It is often easier to make energy savings in lighting, since lighting is the type of electricity consumption that of necessity is needed in all modern buildings.

A lighting design has several stages. These are as follows:

1) *Identification of the requirements for the lighting system, illuminance levels, colour requirements, available space, etc;*
2) *Selection of equipment, lamps, luminaires:* lighting systems consist of numerous components, the two most important of which are: ***lamps,*** which influence the lighting level, colour characteristics and efficiency of the lighting system; luminaires affect the efficiency with which the light is distributed and so affect lighting efficiency and uniformity
3) *Design of the lighting system*: lighting systems are designed to achieve a reasonably uniform distribution of light on a particular plane (usually horizontal), avoidance of glare with a minimum expenditure of energy. The most rudimentary form of lighting design is done using a manual calculation – ***the lumen method.*** However lighting design is increasingly done by computer.
4) *System control:* once a lighting system has been designed it can be controlled in such a way as to make maximum use of available daylight, through selection of appropriate switching mechanisms and daylight responsive controls. (CIBSE Guide F 2004)

The most effective modernisation methods on saving in energy and cost of industrial lights are:

- *Relighting*
- *Exploiting daylight*
- *Control of lighting*
- *Non-compatibility of lighting system with components of different origins.*

In relighting, an existing lighting system is to be replaced by a more cost-effective one, precisely, the replacement of filament and fluorescent lamps (conventional electric lights) with sodium ones (new effective one) while maintaining an acceptable level of illumination (Chen, Unglert & Malafa, 1978).

Daylight is a means to fully utilizing the natural lighting through proper use of glass windows instead of artificial or electric lighting. Of course, this way is limited to day activities only.

Control of lighting is based on switching only necessary lights. Voltage supply level that affects the degree of lighting, called dimming, could also be used and that helps also in energy bill cut.

The relighting process is perhaps the most attractive one, especially if one considers that a lighting system (conventional) exists already and needs only a replacement of more effective lamps. Such step does not require much of the added cost as compared to the situation where a complete new system has to be installed and the old one has to be discarded. The conventional types of lamps are of *Incandescent,* mercury-vapour, or fluorescent that can be replaced by modern ones known as High Pressure Sodium (HPS) (Chen, Unglert & Malafa, 1978).

A study on a relighting process done by Westinghouse Electric Corporation in U.S.A has led to a saving in cost of energy of about $3 million per year (Chen & Main, 1981). In such a process, a highly effective HPS lighting system was used as a replacement to an old one based on mercury-vapour lighting system.

Another problem encountered in real life is the use, in a single lighting system, of components (lamp, ballast, capacitor, reflector, igniters) that are different in origin that is, made by different companies. Such a combination may lead to incompatibility and requires an experimental work to decide what best should be used.

This paper thereby presents a report of a case study on relighting of a warehouse and factory building adopting relighting process that replaces conventional lighting system with a modern one based on HPS with a view to evaluate the cost / payback period with a system after relighting. It also emphasised the need to avoid incompatibility of components used in industrial building lighting system.

LITERATURE REVIEW

Lamps basically are of two main types: incandescent (filament) and gas-discharge. In the first, lights is produced by heating a metal filament due to electric current flowing through it whereas, in the second, light is produced by an electric arc through a discharge tube filled by a vapour of a metal (normally mercury or sodium). The life of incandescent lamp ends when its filament burns out (cut or breaks) whereas, for the High-Intensity Discharge (HID), the life ends when loss in sodium has increased. As an indication, a blackening appears around the lamp electrodes (Pritchard, 1985). According to Pritchard (1985), the economic life of HID corresponds to a decrease in the level of light to 70%. At that moment, the lamp should be replaced.

The efficiency (ratio of output lumens to input electric watts) of the HID lamps is much higher than that of incandescent ones. Even though the cost of HID lamps is higher but its life expectation is considerably longer -5 to 12 times (Good Practice Case Studies-GPCS 309; 2003).

Relighting

The relighting process (replacement of lamps in a lighting system) is based on the replacement of incandescent or filament lamps by gas-discharge ones. An evaluation of a relighting process is done through the payback period, defined as follows:

$$\text{Payback period} = \frac{\text{Total cost of replacement}}{\text{Annual cost of energy saved}} \qquad (1)$$

If the payback period is less than 3 to 4 years, then, the relighting process is cost-effective. There are many relighting schemes with a payback period less than one year.

The annual Return on Investment (ROI) is calculated from:

$$\text{ROI}\ \% = \frac{\text{Annual cost of energy saved}}{\text{Total cost of replacement}} \times 100 \qquad (2)$$

The total cost of replacement includes: Costs of luminaries, lamp, igniters, installation, labours, etc. Whereas, the annual cost of energy saved is calculated by knowing the net power saved, the number of operating hours per year, the cost of KWh and the demand charge per kW (Good Practice Case Studies-GPCS 309; 2003).

Pritchard (1985) observed that before starting any relighting process, some information should be collected that includes the existing installation conditions. He further stated the different steps for replacement of existing installations as follows:

He further stated the different steps for replacement of existing installations as follows:

a). The replacement of higher wattage by a lower wattage to obtain a saving in energy and cost of light.

b). The existing lumens should be kept the same whereas, the lamps are replaced by a lower number of lamps.

c). In some cases, only the lamp is replaced to achieve energy saving. The new lamp-lower wattage may be of the same or of different type as the existing lamp but with higher efficiency.

i. *A lower-wattage incandescent lamp may directly replace a higher-wattage one This will reduce energy consumption, but at the expenses of reducing the luminance.*

ii. *The tungsten-ballasted mercury-vapour lamps replace incandescent ones in installations where it is not possible to use other types of high efficiency discharge* *lamps. For example, a 160 Watts (3150 1m) tungsten-mercury lamp may replace a 200 Watts (3150 1m) incandescent lamp. A saving of 40 Watts is obtained.*

iii. *Energy saving can also be attained by removing some lamps from luminaries or installations. For example, if we take out one lamp from a luminaire of 4 fluorescent lamps, a reduction of 25% in energy is obtained. Reduction of energy consumption is obtained at the expense of a reduced lighting level (Abdalla et al., 1988).*

Exploiting Daylight

Daylight can significantly contribute to energy saving in buildings equipped with cleaned glass windows. Work performed during the day can benefit from natural daylight that penetrates glass windows and illuminate interiors. In less exposed buildings to daylight, a combination of natural and artificial light has to be adopted (CIBSE LG 10, 1999).

Control of Lighting

Energy can be wasted in the following cases:

- No switching-on of lamps after working hours.
- No integration of artificial light with daylight
- Connection of a large number of luminaries on one switch.

For propose of energy saving, light control can be achieved through switching and dimming (lowering the light intensity). In the first, the lighting control is implemented by turning on or off some lamps according to lighting requirements. In the second, sensor are used to determine the ambient daylight together with actuators to dim lights when ambient daylight is sufficient to maintain lighting at a prescribed level. An advantage is that lighting level is changed smoothly without visual adaptation problem. It can be implemented manually or automatically using a central microprocessor (Pritchard, 1985).

MATERIALS AND METHODS

This study involves the replacement of old luminaires –a blending of incandescent and Mercury vapour lamps on an almost one-for-one basis by modern, higher efficiency fittings -HPS in an industrial site (Galvanizing Factory and Warehouse) and an evaluation of the pre and post relighting process carried out to establish the payback period of the lighting system after relighting, ensuring no reduction in lighting levels and calculating percentage (%) saving in electricity bills achieved. The previous lighting system was installed in about 1970, based on luminaires with reflector versions of colour-corrected high pressure mercury lamps, fitted with skirt reflectors. Their purpose was to direct the light, reduce glare by partially screening the lamps from direct view, and give the lamps a measure of protection against impact damage. The luminaires has to be changed because by 2010, the cost of replacing failed lamps and control gear was becoming significant. In addition, illuminance provided by the system in many areas had fallen to unacceptable levels due to corroded reflectors, and to ageing and soiling of the remaining original lamps. In view of these problems, the researcher decided to replace the luminaires with modern, higher efficiency fittings, using as much of the original wiring installation as possible. *The results are given in Table1.This particular study resulted in a payback period of about 10 months, and ROI of about 124%. The Code for interior lighting of CIBSE (2002), and Good Practice Guide-GPG 199 (1996) were used as a guide in this experiment. The second sets of experiments are done using various luminaires (-mercury-vapour lamp and HPS lamp luminaries) combinations of different origins. The powers consumed for each were noted and the results were compared with when there were no combinations.*

RESULTS AND DISCUSSION

Several experiments were conducted to investigate the performance of lighting system with components of different origins as follows.

Lighting With Components of Different Origins

In the market, there are various types of lamps and fittings made by different manufacturers. Usually, manufacturers recommend the use of the lighting components made from the same origin to obtain best operating performances. The corresponding cost may be higher than for a system made with components of different origins. The later may be cheaper but may lead to system with degraded performance.

(i). Mercury-Vapour Lamp System

Typical combinations of mercury-vapour lamp luminaries, available in the markets are shown in Table 2. It has been observed that using components of different origins lead to operating life shortening and reduced luminous efficiency. Therefore, components from the same manufacture are recommended.

Table 1: Results of Relighting a Factory and Warehouse

Description	Existing Lighting	New Lighting
Lamp Type	Blended	HPS
Lamp Power, W	510	250
Lamp Power including ballast, W.	500	280
Initial luminous Flux, In	12500	26500
Number of Luminaires	63	61
Number of Lamp per Luminaire	2	1
Total Number of Lamps	126	63
Total Power, kW.	63	17.64
Annual operating hours	5840	5840
Annual energy consumption kWh.	367920	103017.60
Mutual cost of energy, ₦	42310.80	11847.02
<u>Relighting calculations</u>:		
Saving in power = 63- 17.64		
Annual Saving in energy = 45.36 x 5840		45.36kW
Annual Saving in cost of energy = 264902.4 x 0.11		264902.40kWh
Total Investment cost = 63 x 390		₦30,463.78
Payback period = 24570/30463.78		₦24,570.00
R01 = (30463.78/24570) x 100		0.81 Year
		123.99%

Table 2: Mercury–Vapour Luminaire Combinations

COMPONENT	TYPE AND ORIGIN	
	250 watts luminaire	400watts luminaire
Lamp	Phillips, Netherlands	LRF (Poland)
Ballast	POLAMP (Poland)	POLAMP (Poland)
Base	-	-
Capacitor	Japan	Japan
Luminaire Reflector	Egypt	Egypt

(ii). HPS Lamp System

Another experiment was done using a HPS System as shown in table 3.

Table 3: Typical HPS Luminaire Combinations

COMPONENT	TYPE AND ORIGIN	
	250 watts luminaire	400watts luminaire
Lamp	SYLVANIA (USA)	SUNLUX (Japan)
Ballast	Italy	Italy
Base	-	-

Capacitor	Japan	Japan
Luminaire Reflector	Egypt	Egypt
Ignitor	Italy	Italy

The results obtained in the second experiment were compared to the standard ones when no combinations are permitted. It was clear that lamps consume more power than their capacity and therefore shorter lamp life would be expected. The over voltages on the lamps -because using different origin-made components, cause the consumed power to be 270 Watts for the 250 Watts lamp, and 430 Watts for the 400 Watts lamp. The excess power consumed by the lamp increases the temperature of the lamp and the luminaire, and thus degrades the lighting system.

CONCLUSION

This paper reported on impact of lamps replacement on energy saving for the lighting system and consequence of using lighting components made from different origins. High pressure sodium lamps have gained widespread acceptance for use in high and low bay factory applications because they are the most efficient near-white light source available. When new, they achieve over 100 lumens output per watt of power, compared with 40 to 60 lumens from high pressure mercury lamps. In addition, the reduction in light output due to ageing over the average life of a high pressure sodium lamp is less than 20%, compared with almost 50% for mercury lamps (average life is similar for both types — typically 24 000 operating hours). It needs to be noted that there is a marked difference between the warm orange-white light of high pressure sodium lamps and the blue-white light of high pressure mercury types. This was not a problem at the factory spaces considered, but it could be in some situations. If there is any doubt, a mock-up installation may be helpful. It is also important to note that there are two types of high pressure mercury lamps in the 1000 W range. One operates from 240 v (this was the type used in this factory); the other from 440 V. The latter is connected across two phases of the supply, so replacement with high pressure sodium lamps would require changes to the electrical installation. Competent advice should always be obtained when changes of lamp types and/or electrical installations are being considered.The study further recommends that lighting equipment should be obtained from one manufacturer to achieve good efficiency and best performance operation. A combination of components of diverse origins and different manufacturers in a single lighting system may lead to poor efficiency and higher running costs.

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