Energy Conservation with Energy Efficient Lighting

ARVIND DHINGRA
Deptt. Of Electrical Engineering
Guru Nanak Dev Engineering College
Gill Road, Ludhiana
INDIA
arvinddhingra@hotmail.com

TEJINDER SINGH
Department of EIE
Thapar University
Patiala
INDIA
sagguboyz@yahoo.com

Abstract: The energy resources of the world are under severe pressure to cope up with the growing need of energy. The technological changes and changes in the lifestyle have increased the demand for energy tremendously. With the resources become scarce and energy costs growing, it becomes imperative for everyone to save energy or to use the available energy judiciously. The need is to either find new sources of energy or to use the energy available carefully. Lighting forms a major chunk of load on our electrical power system. With the resources become scarce and energy costs growing, it becomes imperative for everyone to save energy or to use the available energy judiciously. Energy efficiency in lighting involves building architecture, selection of proper luminaries and light sources. This paper presents the study of energy conservation measures adopted in a spinning unit. The payback period is also calculated.

Key words: Energy Conservation, Energy efficient luminaries, HID lamps, Compact Fluorescent lamps, T5 luminaries, Payback period

1. Introduction

Energy is an important measure of prosperity of a nation. Energy has been the life-blood for continual progress of human civilization. Since the beginning of industrial revolution around two centuries ago, the global energy consumption has increased by leaps and bounds to accelerate the human living standard, particularly in the industrialized nations of the world.

In fact, per-capita energy consumption has been a barometer of a nation's economic prosperity. The USA has the highest living standard in the world. With only 5% of world population, it consumes 25% of total energy. The higher the per capita consumption of energy of a country, the more prosperous is the nation. The developed nations have much higher per capita energy consumption than the developing world. The available resources of energy are limited. There is a need to locate and harness new sources of energy or to use the available ones judiciously so as to make them last longer. Energy conservation is a step in this direction. Broadly stated energy conservation means is the practice of decreasing the quantity of energy used. It may be achieved through efficient energy use, in which case energy use is decreased while achieving a similar outcome, or by reduced consumption of energy services. Energy conservation may result in increase of financial capital, environmental value, national security, personal security, and human comfort. Individuals and organizations that are direct consumers of energy want to conserve energy in order to reduce energy costs and promote economic security. Industrial and commercial users desire to increase efficiency and thus maximize profit. Infact industrial sector is the area in which there is highest consumption of energy and therefore there exists a huge scope for adopting energy conservation measures in industry. Today, energy efficiency assumes even greater importance because it is the most cost effective and reliable means of mitigating global climate change.

2. Literature Survey

There are various approaches to conserving energy. In the paper titled Daylighting and Energy Savings with Tubular Light Guides by Jitka Mohelinikova, the author has discussed the tubular light guides are systems which serve for natural illumination of internal windowless parts of buildings. Their function is based on the principle of light transport from outdoor to distant indoor places due to multi-reflections on their high reflective internal surfaces. Advantage of these systems is in the possibility of dynamic daylighting in internal parts of buildings and electric energy savings for artificial lighting. The design of the building has to be modified to re model it is as an energy efficient building, the machinery could be replaced by energy efficient machinery etc. Buildings may have to be design for low energy consumption. Energy savings in buildings can be achieved by reduction of energy consumption for heating, ventilation and artificial lighting. The design of buildings with respect of solar radiation and daylighting gives possibility for energy efficient buildings. Saving of electric energy for permanent artificial lighting is important technical problem in internal parts in buildings without daylighting. Modern technologies have brought possibility to solve these problems.

Pumps are major energy consumers as far as industrial environment is concerned. In the paper titled Basis of Energy Efficiency Economical and Ecological Approach Method for Pumping Equipments and Systems by Mircea Grigoriu has presented the basis of an original economical and ecological approach of the pumping systems energy efficiency, offering a holistic picture of the pumping efficiency, with emphasis in economical and GHGs emissions mitigation effects. The main contributions consists in the original energy efficiency evaluation method of pumping equipments, a particularization of the pumping systems optimal operation characteristic determination for variable requested flow conditions, and a practical application for parallel operation variable speed driving adjustment, the actual most applied system.

In their paper titled, “Energy Efficiency in Croatian Residential and Service Sector – Analysis of Potentials, Barriers and Policy Instruments” Vesna Bukarica and Zeljko Tomsic have addressed the energy end-use efficiency potentials in Croatia with special emphasis on residential and service sectors. They have analyzed the process of designing, implementing and evaluating policy instruments based on the results of the on-going UNDP/GEF project. Their main emphasis is that energy efficiency is basically a demand side management. Energy use is seen as a cost to society in this paper.

3. Energy Consumption Patterns in India

In order to have sustainable growth rate, it is imperative to have sufficient energy for systematic development in various sectors. India ranks 5th in the world, in terms of energy consumption. Energy sector has received top priority in all the five year plans so far. Though installed capacity of electric power has increased from 1362MW at the time of independence in 1947 to 150000 MW in 2008. India is the Fifth largest producer of electrical energy in the world. Despite such achievements the gap between demand and supply of electrical energy is increasing every year and power sector is highly capital – intensive. Thus the deficit in installed capacity exceeded 10000MW per year or a deficit of 52513 Million Units. The capacity addition is a costly affair. Conservation is cheaper than new production. It is a silent generator with no fuel input and clean energy. It is also termed as energy produced at 'Zero Cost'. Conservation has two fold approach, one using available electrical energy efficiently and the other reduction in the losses. Presently the energy conservation would assume more significant globally on the basis of the effect of burning of coal fossil fuel on environment, particularly global warming, rather than the depletion of fossil fuel reserves and other considerations. It is imperative for India to seriously work towards energy conservation through energy saving actions and energy efficiency improvement programmes.

India has a vast scope in the field of energy conservation. Outdated technologies mixed with poor maintenance have made Indian systems highly energy inefficient.

The following table shows the energy consumption patterns in India sector wise:

From the table it is clear that lighting forms an important constituent of the total electricity consumption. Rising costs of electricity and scarcity of resources has led to demand for energy efficiency.

Table: Total electricity used and electricity used for lighting purposes in major economic sectors

Sector	Energy Used (Percentage of Total)	Lighting Component (Percentage of Total electricity Used)
Industry	49	4-5
Commercial /Public	17	4-5
Domestic	10	50-90
Other	24	2

4. Measures for energy efficient and economic use of lighting:

Measures which can contribute for energy efficient and economic use of lighting are as under:

(i) Segregation of general and task lighting.
(ii) Automatic switching on and Off of lighting by using sensors.
(iii) Maximum use of sunlight.
(iv) Light surrounding décor.
(v) Use of energy efficient lamps (HPMV, HPSV, CFL, Slimline tubes TL5 tubes etc. etc).
(vi) Use of dimmers to reduce the intensity of artificial light as the sunlight is used.
(vii) High efficiency luminaries.
(viii) High frequency chokes

5. Light Sources and Luminaries

The light sources are those that give out visible light by using electricity. The luminaries are the accouterments that in conjunction with light sources provide visible light. The luminaries are the devices that make it possible to harness energy efficiently. They give the direction to light. Various light sources are available such as GLS lamps, LPSV lamps, HPSV lamps, MH lamps, Fluorescent tubes, HPMV lamps, CFL etc. Of these the LPSV lamps are the most efficient ones.

Our basic requirement is that a light source should be giving out light whose spectrum resembles that of day light. A light source that has its spectrum nearer to day light is preferred light source. It gives proper color redention and has good efficacy. Fluorescent tube lights and Metal halide lamps give light that has spectrum closest to day light. Their efficiency is not so high. Another recent development in the light sources is that of LED's- Light emitting diodes. Although in the inception stage they are likely to revolutionize the world of illumination. The LED's consume very less power, offer advantage of a very long life and also have a spectrum that matches the daylight. But as of now they are not cost effective and hence, we have not included them in our present study.

6. Conventional Lighting V/s Energy Efficient Lighting

Conventionally, the General Light Source (GLS) lamp or the filament lamps were an integral and basic part of any lighting scheme. These lamps are cheaply available and no control gear is required to run these. But these are highly inefficient light sources. Also the amount of pollution produced by them is enormous and hence they are gradually being phased out. A lot of development has taken place on the fluorescent tube side. Generally what we used to have was the 40W tube which could give light equivalent to 2450 lumens. Then 36W tubes were developed which could give 2650 lumens. But with the growing demand for efficient sources, a new series of 36W tubes were invented which had a different coating to give enhanced lumens (2850 lumens for 36W). Then came the invention of compact fluorescent lamps. With the wattage as low as 5 watts and as high as 36/48 watts these lamps perfectly matched that need for giving efficient light sources. A 9W compact fluorescent lamp could give the same lumens as 60W GLS lamp thereby resulting in saving of 85% electricity. Such is the effect of these lamps, that most of the state governments in India like Haryana, Gujarat etc. have themselves taken upon the task of replacing the inefficient GLS lamps with CFLs. They have announced free distribution of CFL lamps. This is being seen as a major step towards energy conservation in lighting.

Another invention that is set to revolutionize the energy consumption patterns for lighting is the T8 tubes. These are fluorescent tubes having diameter equivalent to $1/8^{th}$ of an inch. There efficiency is much more than the conventional Fluorescent tubes. A 28W T6 tube gives 3950 lumens and hence is more efficient. Besides these tubes require electronic control circuitry for operation which consumes very small amount of power. In the conventional Fluorescent tube, the control gear required is a copper or aluminium ballast which consumes upto 9 watts of electrical power. Hence, these T8 tubes are for saving lot of electrical energy.

There are other steps being taken the world over to bring about efficiency in lighting. Some of these are:

- Lighting upgrades yield quick savings on energy bills but more efficient lights release less heat—an indirect benefit for the air-conditioning systems.
- The light quality, the lighting quantity, and the type of light fittings are dependent on the task at hand. Thus, efforts to promote efficient lighting that ignore the users' needs are likely to fail.
- For optimal lighting solutions, the total system involving day lighting, lamps, fixtures, controls, configuration, materials, and furnishing needs to be considered holistically.
- Broader impacts of lighting choices, including the persistence of energy efficiency measures, with implications for the type of technologies, are to be considered.
- It is necessary to upgrade information on energy-efficient lighting technologies, which have been changing continuously over the past 60 years

There is a lot of resistance to the approach to energy efficient lighting. Some of the stumbling blocks are :

- Emphasis on minimization of first cost by end-users
- Capital availability constraints
- Manufacture of inefficient products in parts of the unorganized sector
- Aversion to taking risks associated with new technologies
- Shortage of skilled staff
- Lack of information.
- The government on its part has been doing a lot to encourage energy saving in lighting. The energy conservation Act 2002 also advocates use of energy efficient lighting. In addition following steps are likely to be helpful to increase energy efficiency: Prescribing energy conservation building codes for efficient use of energy and its conservation in commercial buildings
- Formulating energy conservation building codes to suit regional and local climatic conditions
- Directing owners/occupants of commercial buildings to comply with the provisions of the energy conservation building code.
- Organizing training programmes for personnel and specialists in the techniques of efficient energy use and conservation
- Creating awareness and disseminating information
- Promoting research and development
- Promoting the use of energy-efficient products, fittings, devices, and systems (The cost of energy-efficient equipment in India is higher compared to other developed countries.)
- Encouraging the use of energy-efficient equipment by giving preferential treatment.

7. Energy Conservation in Spinning Unit

Since spinning is one of the major types of industry that consumes lot of energy, it becomes pertinent to see if there exists a scope for energy conservation. In this direction, we targeted one of the medium size spinning units located near the industrial city of Ludhiana in Punjab State of India. The unit has a capacity of 1200 spindles. In order to find out how the energy was consumed by this unit a preliminary energy audit was carried out. The major steps involved in the audit were:

a) Carrying out of Preliminary Audit: It was a walk through audit to just find out where the energy was being consumed and also to understand the process of the unit. A number of areas where energy could be conserved were listed out viz. blow room, boiler room, spinning area, humidification plant etc. to name a few
b) Detailed Audit: After the preliminary audit and discussions wit the management of the organization, it was decided not to disturb the process and decision was taken not change any of the machinery. Also during the preliminary audit, illumination emerged as one area consuming a large chunk of energy. It was decided to concentrate on this area only.
It was found that the major chunk of the energy was being used by motors. Illumination also consumed a substantial share of energy (approximately 20%) of the total energy consumed. It was decided to target this area for energy conservation.

8. Problem solution

During the audit part, it was observed that the plant was using twin tubelight industrial luminaries having two fluorescent tube of 40W each for lighting of area on machines. There were around 400 such sets of luminaries. The luminaries were equipped with copper ballasts and were without the reflectors at most places. The available light levels were low. The lux level available was an average of 250 lux (approximately) against a standard requirement of 300 lux..

To change this system, various lighting system for industry were studied. Knowing the strengths and weakness of each lamp type will act as an aid in the selection of an energy efficient lamp that meets the needs of a facility. We give below the characteristics of various light sources available with their possible advantages and disadvantages.

Incandescent lamps : Incandescent lamps are constructed with a tungsten filament suspended inside a glass bulb filled with inert gas. These lamps come in a variety of shapes/sizes and are commonly seen in many households.

The advantages are : Low cost; excellent color rendition; start instantly; inexpensive dimming; small size; good for focusing light; simple maintenance.

The disadvantages are : less than 10 percent of input energy goes to producing light with the rest going to heat and adding to cooling load, low efficacy of under 20 lumens per watt; relatively short useful life dependent on voltage; filament sensitive to movement shock and vibration; bulb can get hot during operation; must be properly shielded to avoid glare.

It was suggested that these luminaries be replaced by the new energy efficient luminaries available in the market. Also the exterior lighting was being done using 250W sodium HID lamps which have low efficiency. The number of such luminaries for exterior lighting was 25. The lighting in the office area also was using older non energy efficient luminaries. The number of luminaries installed in the office area was 30. Each of these luminaries was using 4x20W fluorescent tubelights and the lux level available hovered around 220 lux.

Fluorescent lamps contain mercury vapor and other gases. Ultraviolet light is emitted and converted to visible light through the phosphor coating on the inside of the glass tube. Fluorescent lamps are four to five times more efficient than incandescent lamps and come in a wide range of sizes– typically circular, straight or "U" shaped. Recent developments in the color of these lamps allow them to closely duplicate incandescent coloring. Fluorescent lights can be seen in residential, commercial and industrial applications. Efficiency of these lamps increases slightly with length (8-foot is more efficient than 4-foot) and with a decrease in tube diameter (one-inch diameter T-8 lamp is more efficient than a 1.5 inch T-12 lamp). Efficacy is in the average of 30 to 80 lumens per watt.

Compact fluorescent lamps (CFLs) can be installed directly into an incandescent socket when they are configured with an adaptor module that has a screw base and contains an electronic ballast. The tubes of CFLs appear bent several times or bent in the shape of a corkscrew. These lamps last seven to 10 times longer than incandescent lamps and use a quarter of the electricity.

The advantage is that it is inexpensive; 16 to 20 percent of input energy becomes visible light; long life, averaging from 6,000 to more than 20,000 hours, but lifespan is affected by the number of hours cycles on and off; available in a range of color temperatures and rendering; relatively insensitive to change in voltage; cooler operation.

The disadvantage is that it requires large and relatively expensive fixtures with heavy ballast; dimming requires special, expensive ballasts; magnetic ballast can be noisy; lumen output drops at low temperatures; special ballasts are required to start at low temperatures; focusing light is not possible.

For street lighting or exterior lighting HID- High Intensity discharge lamps are commonly used in which the interaction of an electric arc and the gases in a small bulb creates a high amount of light in a small package when compared to fluorescent and incandescent lamps. HID lamps are commonly used when high levels of light are required over large areas and efficiency and long life are important, as in gymnasiums, warehouses, parking lots, etc.

The three main types of HID lamps: mercury vapor (MV), metal halide (MH), and high pressure sodium (HPS).

The advantages are highly efficacious; range of color temperature and rendering; long life.

The disadvantages are : require ballast; if power is lost the arc tube must cool to a given temperature before the arc can restrike; require a few minutes to reach full light output; generally more expensive.

After going through this exercise, it was decided to replace the old luminaries with the new energy efficient luminaries. By energy efficient luminaries we mean that the per watt illumination provided by these luminaries and light sources is higher than the conventional available luminaries and light sources. The following data presents the calculations for energy saving achieved by adopting above energy conservation measures. Here the ballast loss for copper ballasts has been taken as 9W per ballast. Also the ballast loss for HID lamps has not been included as the same ballasts would serve the purpose when we replace the 250W sodium HID lamps with 250W metal halide HID lamps. The 2x20W luminaries have two ballasts each.

Total energy consumption by the conventional luminaries and light sources already installed

2x40x400= 32000W for Tubes
2x9x400 =7200W For Ballasts
25x250= 12500W for sodium lamps
4x20x30=2400W for tubes
2x9x30= 540W for ballasts

These were replaced with the following:
2x40W Fluorescent tube light luminaries with 2x28W T5 luminaries. The ballast loss in T5 luminaries is negligible.
4x20W Fluorescent tube lights with 2x36W Compact Fluorescent luminaries.
250W sodium HID lamps with 250W Metal Halide lamps
All bulbs (approximately 20nos 60W bulbs and 20 nos. 100W bulbs for facilities) to be replaced by 11W CFL
The power consumption in the earlier existing arrangement
20x60= 1200W
20x100= 2000W
The total power consumption in the earlier arrangement
32000+7200+12500+2400+540+ 1200+2000= 57840W

Energy Consumption in new arrangement:

The new arrangement in the spinning area required 362 luminaries of 2x28W for achieving a lux level of 300lux. The number of luminaries required for exterior lighting also reduced to 22. The number of luminaries in the office area could not be reduced due to the constraints of different office cabins but the lux level here improved due to new luminaries to 290 lux. Also the number of CFL's to replace the existing Bulbs remains same due to different locations of these bulbs.

Therefore the calculations for new energy efficient illumination scheme are:

2x28x382 =21392W
22x250=5500W
2x36x30=2160W
40x11= 440W
Total energy consumption =
21392+5500+2160+440=29492W
Therefore the net saving in energy consumption is
57840-29492= 28348W

Taking the energy rate per unit @ Rs.6/- and assuming 12 hours of working for 25 days a month the net saving in energy costs comes to
28348x6x12x25/1000= Rs.51026.40

The cost of new luminaries is
For 2x28W @ Rs.600/-
For 2x36W @ Rs.2100/-
For 250W metal halide lamp @ Rs.1050/-
For 11W CFL @ Rs.88/-

The total cost for new arrangement is
600x382= Rs.229200
22x1050= Rs.23100
30x2100= Rs.63000
40x88 = Rs.3520
Total = Rs. 318820

Therefore simple payback period
318820/51026.4=6.24 months

9. Conclusions

It is seen from the above calculations that the net payback period for replacing the old installation with new one is just over 6 months. Besides resulting in energy savings this has led to additional benefits in terms of enhanced lux levels and decreased maintenance costs. The maintenance costs decrease because the life of all the new energy efficient light sources is more than the existing fixtures. This clearly puts forward the case for replacing old installations with new energy efficient installations.

References:

1. www.wikipedia.org
2. www.cglonline.com
3. www.beee-india.org
4. Energy efficient lighting CEA,2004
5. Energy Efficient Lighting, Crompton Greaves Limited, Mumbai
6. G. R. Davis, “Energy for planet earth,” *Scientific American*, pp. 1–10,1991.
7. U.S. Department of Commerce, *Statistical Abstract of the United States*,114th ed., 1998.
8. S. Rahman and A. D. Castro, “Environmental impacts of electricity generation: A global perspective,” *IEEE Trans. Energy Conv.*, vol. 10
9. Jitka Mohelnikova , “Daylighting and Energy Savings with Tubular Light Guides“ WSEAS Transactions on Environment and Development Issue 3, Volume 4, March 2008 ISSN: 1790-5079 pp 201-210
10. Mircea Grigoriu, ”Basis of Energy Efficiency Economical and Ecological Approach Method for Pumping Equipments and Systems” WSEAS Transactions on Environment

and Development Issue 1, Volume 5, ISSN:1790-5079 pp 1-12

11. Vesna Bukarica, Zeljko Tomsic,"Energy Efficiency in Croatian Residential and Service Sector – Analysis of Potentials, Barriers and Policy Instruments" WSEAS Transactions on Advances in Engineering Education, Issue 12, Volume 4, December 2007 ISSN: 1790-1979