Illumination System for Demand Side Management (DSM) In India

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Abstract — *Today, Demand Side Management (DSM) is an integral part of resource planning or least cost planning. The resources are developed in such a way as to minimize present or future costs. Due to increase the fuel and energy costs, utilities have started thinking of energy utilization; penalization for excessive use at peak time has also been considered. The increased awareness of the problem of global warming has led electric utilities to think that improved efficiency utilization is a cost effective methods to reduce environmental damage. In India, a huge gap between the power generation and power requirement. It is not possible to realize this gap by increasing the installed capacity, as the resources are limited and also due to economic constraints. So, the energy being generated should be conserved to the utmost. DSM involves on the Energy - supply demand side and customer side .In this paper, the illumination (Lighting) options for DSM have been discussed in details.*

Keywords—DSM Technology overview, Lighting Technology option, Control Gear Schemes

1. INTRODUCTION :

India has more than 17% of the world's population, but less than 5% of world energy resources. India is the fourth largest energy consumer in the world after the United States, China, and Russia and is poised to become the world's third largest economy by 2030. India has increased the Electrical power Installed Capacity in the last 8 years. But the peak demand and energy deficits of India are increasing. Increased demand is directly related to the per capita consumption of electricity which is shown in Fig. 1, over a period of 8 years [4].

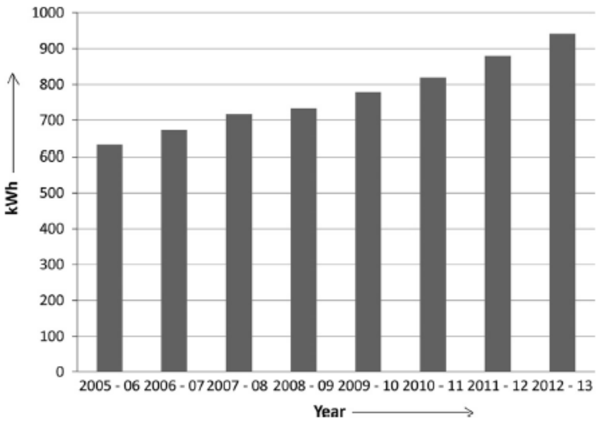

Fig 1. Per Capita Consumption

In order to reduce the gap between the demand and supply of electricity in India, adequate action so measures are taken to manage electric power both at the supply side and also at the demand side. Supply side measures include building new power plants, reducing T&D losses, diversifying fuel-mix, energy storage technologies, thermal storage and soon the total installed capacity for electricity generation in India rose from 112GW as on March 2004 to 232GW as on December 2013.

An increase in electricity supply has a substantial tax revenue benefit to the government. But adequate revenue collection by the electric utilities to cover the costs of supply is lacking as large investments are required for capacity additions and for transmission and distribution and also due to lack of access to capital and limited recovery of revenue. Under such a scenario, utilization of electricity in an efficient manner can be a cheaper alternative to provide reliable electric power service.

Demand side measures include activities affecting customer's behavior of electricity consumption with the aim to change the load curve profile, developing energy efficient appliances and equipment, promoting energy conservation measures.

As per Ministry of power statement, DSM means "Demand Side Management issued to describe the actions of a utility beyond the customer's meter, with the objective of altering the end-use of electricity – whether to increase demand, decrease it, shift it between high and low peak periods, or manage it when there are intermittent load demands – in the overall interests of reducing utility costs". DSM covers several objectives, including that of load management and energy efficiency [3].

1.1 DSM planning and Implementation in India:

Basically, utility is responsible for planning and developing DSM programme implementation strategy. In India, the utilities are bounded to provide reliable supply of electricity to the consumers at minimal costs. With an objective of reduction of energy intensity in the Indian economy and to develop energy conservation and energy efficient Programmes in India, Bureau of Energy Efficiency (BEE) was setup under the Ministry of Power (Mop) in March 2002 under the provision s of the India's Energy Conservation Act, 2001.BEE acts as a nodal agency for formulating an action plan for setting up of a DSM programme in India. Various steps that are followed by Indian utilities for implementing a particular DSM programme are shown in Fig. 2[1].

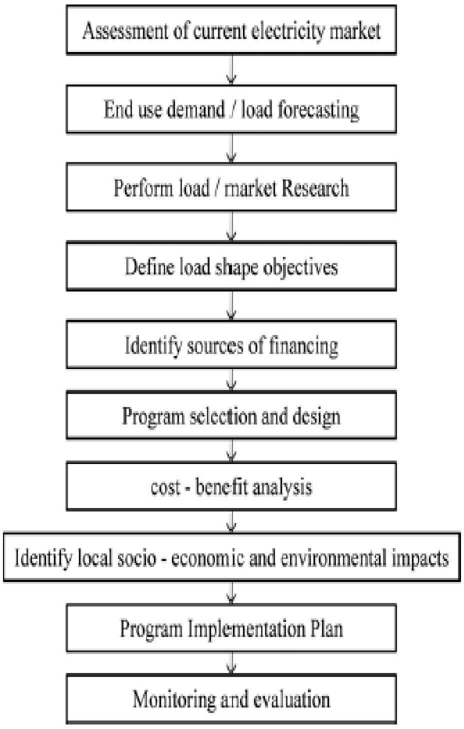

Fig.2 DSM Programme

1.2 DSM Technology Overview:

1.2.1) Sector and End-Use Technology Mapping:

It is imperative to identify the spread of end-use DSM technologies across the different load categories in order to develop the framework for assessing these technologies using appropriate metrics. These end-use technology segments, spread across different load categories, comprises of lighting, ceiling fans, refrigerators, HVAC, cogeneration systems, motor driven equipment, water heaters as shown in Figure 3. Each of these end-use segments has a number of technology variants (for example lighting has CFL, LED, FTL, etc). These technologies differ from each other in several parameters viz., efficacy, wattage, cost, colour rendering index [1].

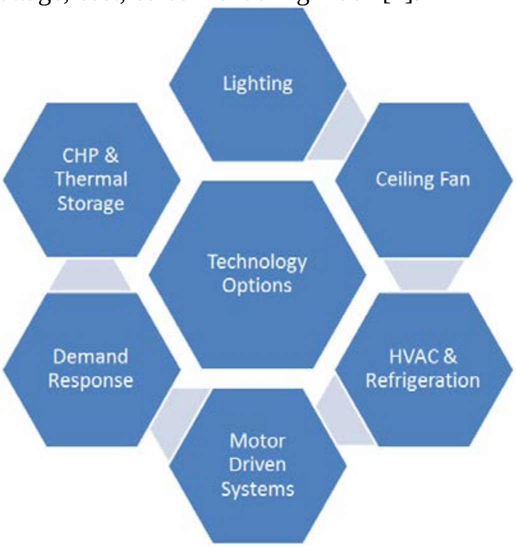

Fig.3 End Use Technology

1.2.2) Domestic End Uses Technology:

DSM also incorporates measures that aim at promoting the installation and use of energy efficient end-use equipment that consume less power without any decrease in the quality of output. There is a need to view energy efficiency as a 'resource option', just like coal, oil, or natural gas for a sustainable future. For a developing country such as India, it provides additional economic value by preserving the resource base. In present scenario, energy efficiency assumes even greater significance because it is the most cost effective and reliable means of mitigating global climate change. Identification of potential for energy efficiency in energy intensive equipment and processes can open vast reserves of savings in terms of cost and available renewable resources [1,5].

Figure 4 shows the sector wise electrical energy consumption share of different sectors in the country. The current peak demand shortage is 14% and the energy deficit is about 8.4%. In such scenarios, efficient use of electricity necessitates persistent energy conservation efforts through reduction in energy usage in a specific product without affecting output or user comfort levels.

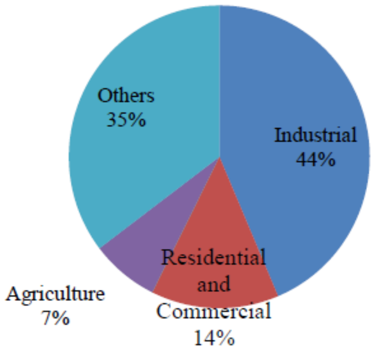

Fig 4.Enrgy Consumption – Sector wise

The following sections in the technology assessment report cover detailed analysis of the above mentioned end-use segments while assessing the cost effectiveness of the technology variants available within each of these end-use load categories using standard metric (cost of saved energy).

Lighting is an essential requirement for people in their daily needs. Lighting consumes a minimum of 5 to 15% of total energy consumption for residential users and 30% for commercial users, and these values increases with the end user requirements. In certain small and medium retail business models, lighting accounts for 80% of total energy usage. As per the 18th Electric Power Survey of CEA, the estimated energy consumption in Indian public lighting sector with 2009-10 as the base year is about 8478 million kWh in 2012-13. This sector is expected to grow at 7% annually during the XII and XIII plan periods. This trend is shown in Figure 5.

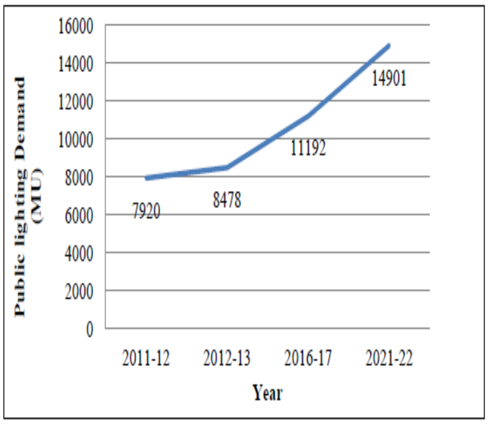

Fig. 5 Public lighting Sector Vs Years

As per BEE estimates, there are over 400 million lighting points in India using incandescent lamps which if replaced with CFLs would reduce approximately 6000-10000 MW and if replaced by LEDs would reduce about 10000-15000 MW of the electricity demand. The large contribution of (domestic, commercial and street) lighting demand to peak load also makes it attractive for the utility to offer incentives for the adoption of efficient lighting practices by consumers. This would result in reduction of costly peak-load power procurement. With improvement in LED technologies, the lighting sector as a whole has immense potential to pursue energy efficiency options.
Shows the % contribution of different sectors in the total electricity consumption in the country with the % share of lighting component in that contribution. Lighting component for some manufacturing and processing industrial sectors can be 15% of industry's total electricity consumption. Similarly, for IT sector, which comes under commercial sector, lighting could account to 40 % or more in total electricity consumption [2].

Table 1: Lighting component in total electricity used for major economic sectors

Sector	Electricity used (% of total)	Lighting Component (% of total electricity used)
Industry	49	4-5
Commercial/Public	17	4-5
Domestic	10	50-90
Others	24	2

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Moreover, strategies for conserving energy in lighting loads will require both technology and design expertise. Use of energy efficient lamps should be complemented with appropriate lighting design for a specific installation point or facility in order to meet the energy conservation goals [1].

2. Lightning Technology Options:

There are three broad categories of lighting based on the physics involved i.e., incandescent, gas discharge and solid state lighting. The technologies used for general lighting purposes in indoor and outdoor locations are classified as shown in Figure 6.

2.1 Technology Comparison and Assessment

The choice of cost effective lighting technology that also scores well on the parameter of energy efficiency requires a comparative data that assesses the different options on a set of metrics. Table 1-6 gives detailed comparison of various technology options in lighting with different metrics. Considering the range of application areas and operating conditions, the choice of energy efficient lamp need metrics such as CRI (Colour Rendering index), Cost, warm-up and re-strike time, heat generated by lamps and lumen depreciation rate, for comparison with existing lamps used for general lighting purposes[1,6]. Some definitions for these metrics are given below:

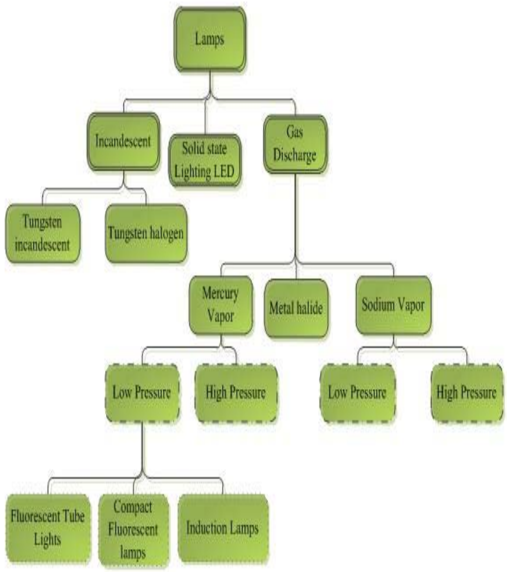

Fig 6 Lighting Technology

Colour Rendering Index: It is a quantitative measure of the ability of a light source to reproduce the colours of various objects faithfully in comparison with an ideal or natural light source.
Efficacy: Luminous efficacy is a measure of how well a light source produces visible light. It is the ratio of luminous flux to power.

Table 1-7 shows the comparative assessment of the available lighting options for domestic sector. The lamp efficacy is the ratio of light output in lumens to power input to lamps in watts. Over the years, development in lamp technology has led to improvements in efficacy of lamps. However, low efficacy lamps, such as incandescent bulbs, still constitute a major share of the lighting load. High efficacy gas discharge lamps with LED and Induction lamp, suitable for different types of application, offer appreciable scope for energy conservation.

Domestic Lighting
Technology Comparison Matrix

Metrics for Comparison	Unit	ICL	CFL	T12	T8	T5	LED
Power Rating	Watt	60	14-15	34	32	21	6-8
Cost	Rs.	15	220	40	48	140	550
Initial Luminous flux	Lumens	840	900	2400	2800	2100	700
Lumen depreciation Rate	%	10 % at 1000 hrs	20% at 10,000	5-10 % at 20000	5-10 % at 20000	5-10 % at 20000	30% at 30,000
CRI	Base 100	100	82	62	78	85	70
Life	hrs	1000	10000	20000	25000	24000	50,000

Energy efficient options in lighting for various sectors are given in Table 2. The savings associated with choice of lighting technology are shown. Based on the time of usage one can calculate the savings in terms of energy.

TABLE 2: ENERGY EFFICIENT REPLACEMENT OPTIONS FOR LIGHTING ACROSS DIFFERENT SECTORS

Sector	Lamp Type: Existing	Lamp Type: Proposed	Power Savings: Watts	Power Savings: %
Domestic	GLS (60 W)	CFL (14W)	46	77
	T12 (40W) Magnetic ballast	T8 (32W) electronic Ballast	8	20
Industry	HPMV (250 W)	HPSV(150 W)	100	40
	Halogen lamp (500 W)	Metal Halide (150 W)	150	37.5
	HPSV (250 W)	Induction lamp (200 W)	50	20
Commercial	T12 with Magnetic ballast (40 W)	T5 With Electronic Ballast (28W)	12	30
	T12 with Magnetic Ballast (40 W)	T8 Electronic Ballast (32 W)	8	20
	CFL(36W)	LED lamp(23W)	13	36
Street Lighting	HPSV(250 W)	LED(150 W)	100	40
	HPSV (250W)	Induction lamp (200 W)	50	20

3.CASE STUDY:

In this case study, the annual cost of saved energy is calculated when an energy efficient technology is replacing existing (conventional) one. In the present case, replacement of ICL with CFL and LED is illustrated. Table 3 gives the input data required for the analysis. The discount rate for utility, society and consumers is assumed to be 10%, 15% and 20-20% respectively.

Table 3: Calculation of Cost of Saved Energy (CSE) for energy efficient lighting replacements at different discount rates

Metrics for Comparison	Unit	GLS	CFL	LED
Luminous Efficacy	Lumens/watt	12	50	120
Rated Wattage	Watt	60	14	6
Luminous flux	Lumens	800	700	720
Cost/unit	Rs.	15	150	1200
Life of Technology	Hours	1000	8000	30000
Life of Technology (n)	Years	0.303	2.42	9.09
Operating Hours per Day	Hrs	10	10	10
Operating Day per Year	Days	330	330	330
Cost of Power	Rs/kWh	5	5	5

The annualized capital cost of energy efficient option and standard option are given by (1) and (2) respectively.

(ACCEE) = CRF x CC --------- (1)

(ACCStd) = CRF x CC --------- (2)

In eq. (1) and (2), CC is the effective capital cost for energy efficient option and CRF is the Capital Recovery Factor defined as

$$CRF = \frac{d(1+d)^n}{(1+d)^n - 1}$$

Where, **d** is the discount rate and **n** is the life of the energy efficient technology. The cost of saved energy is given by

$$\text{Cost of saved energy} = \frac{ACC_{EE} - ACC_{Std}}{\text{Annual energy savings}}$$

The cost of saved energy is a statistic used to compare energy conservation measure among them and with the existing cost of energy. An energy-efficient measure is considered to be cost effective when the cost of saved energy is less than cost of electricity. The discount rate represents the scarcity of capital. Higher the discount rate higher is the scarcity of capital or lesser is the availability of funds to invest in energy efficient technology.

Option 1: Replacement of ICL with CFL – Replacement of ICL with CFL is most popular DSM technique in India. This has also passed the benefit and cost analysis tests. The cost of saved energy by replacing ICL with CFL is calculated for various working hours and discount rates. The results are plotted in Figure 7 . It can be seen that with increase in working hours (usage) of the energy efficient equipment, the cost of saved energy decreases and hence makes the technology option viable, in the present case it is replacement of ICL with CFL[1].

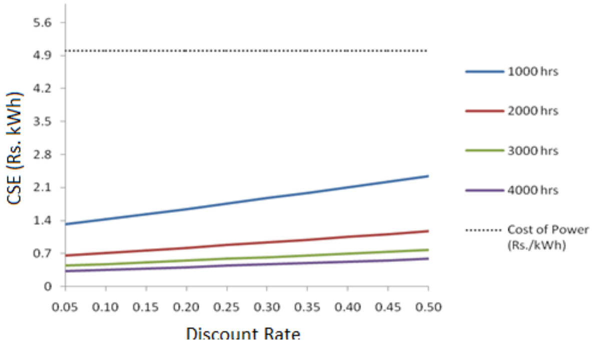

Fig 7 Replacement of ICL with CFL – Saved energy Vs Discount rates

Option 2: Replacement of CFL with LED

Now-a-days LEDs are becoming popular in domestic sector and are seen as future replacement of CFLs. In this context, analysis of cost of saved energy for replacement of CFL with LED for various discount rates and usage hours is done using (1) to (4) and the results are plotted in Figure 8. It can be seen that the cost of saved energy is higher for case with higher discount rate and low working hours, in such cases replacement of CFL with LED is unviable. However, with LED technology promising working hours of 50,000 (approximately) this situation may not arise. It can be seen from Figure 1-6 that for highworking hours (>5000) LED is going to be a good choice (for a discount band of 10-50%).It is also clear from the figure that investment in energy efficient technology becomes more cost effective with increase in the hours of operation for the same investor or stakeholders with same discount rate[1].

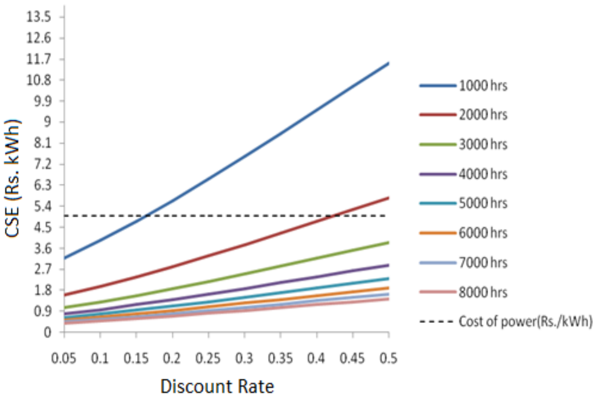

Fig 8 Replacement of CFL with LED – Saved energy Vs Discount rates

Energy efficient measures need to be implemented by agencies that have a lower discount rate. When the market penetration is increased (with time) owing to reduction in the price of energy efficient technology and awareness, such measures will automatically become cost effective to implement for consumers with relatively higher discount rate. LED Village campaign project by BEE, covering 27 villages across the country are efforts in this direction.

4. Control Gear:

In addition to choice of technology, the control gear plays a very important role in reduction of the overall power consumption by the device. It is also possible to reduce the energy consumption in these lighting technologies by using advanced energy management systems like dimming. Control gear in a lighting unit consists of electrical or electronic components which includes ballast, power factor correction capacitor and starter [6]. Some widely used industrial lighting control gears are explained below:

1. **Electronic and magnetic ballasts for fluorescent and HID lamps:** The ballast provides a high initial voltage to initiate the discharge, and then rapidly limits the lamp current to safely sustain the discharge. The features of electronic and magnetic ballast that are used with FTLs and HID lamps

2. **Electronic and magnetic transformers for Low Voltage Tungsten halogen lamps:** Transformers are used as power supply units to reduce the voltage of mains electricity supply (220V) to a lower voltage of 12 V AC, for operating low voltage tungsten halogen lamps. These halogen transformers can be either magnetic or electronic.
Electronic transformers are smaller and lighter than magnetic transformers, and often include output voltage regulation with lamp protection circuitry, soft starting, etc.
Losses occurring at full load represent the majority of losses. These losses vary between 3W and16W per transformer for 50-60VA magnetic transformer. Electronic units of this size generally have losses of around 4W, while a typical magnetic transformer has losses of around 14W.

3. **Constant current and constant voltage drivers for LED lamps:** Constant voltage drivers are used with LED lamps when it is installed in sign boards. It provides a fixed voltage, often 12VDC or 24VDC and the current is usually regulated by either resistors that have been wired in series with the LEDs or by an onboard built-in regulator driver that the LED module may have.
Constant current drivers fix the current, by varying the input voltage. Higher output voltage is set by the driver, till maximum voltage, for increase in number of LEDs connected across the driver.

4. **Dimming controllers for lamps with external ballast:** Lamps with integrated ballast (such as screw base CFL) cannot be dimmed or brightened because the component responsible for light control is integrated within the ballast. But some lamps come with electronic ballast having dimmable controller that enables a lamp to be dimmed or brightened as per requirement. A photocell which detects daylight is attached to this gear for automatic dimming when daylight is detected. This kind of effective light and energy management leads to additional energy savings.

5. **Occupancy Sensors:** Occupancy sensors are used to detect human presence so as to control the switching on and off of lamps according. Infrared (IR) and Ultrasonic occupancy sensors can be used to control lighting in

cabins, large offices and toilets in buildings. Some occupancy sensors have a combination of both IR and ultrasonic for detection. A programmable microprocessor in each unit which continuously memorizes the changing features of the environment and monitors the sensors to adjusts their sensitivity levels to optimize the performance. This ensures the cancellations of false signals from repetitive motion equipment like fans.

5. CONCLUSION:

Awareness needs to be built amongst staff involved in the procurement and maintenance of lighting in government and large corporations, highlighting the sustainable benefits of using efficient lighting. There also needs to be continued education of the population at large of the benefits of using CFLs, as well as the need for careful disposal. Cities can promote efficient lighting through environmental education campaigns, household environmental campaigns and building partnerships with business to address energy efficiency as part of its demand side management (DSM) programme, has indicated that it will subsidies suitable CFL projects by 50%. The money will only be made available subject to project feasibility Study done by energy services companies (ESCOs). These projects can also have CDM benefits if they are large enough. DSM provides a source of funding for cities striving to achieve efficient lighting targets.

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