

Potential of Energy Conservation of Daylight Linked Lighting System in India

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Abstract—Demand of energy is increasing faster than the generation. It leads shortage of power in all sectors of society. At peak hours this shortage is higher. Unless we utilize energy efficient technology, it is very difficult to minimize the shortage of energy. So energy efficiency program and energy conservation has an important role. Energy efficient technologies are cost intensive hence it is always not possible to implement in country like India. In the recent study, an educational building with operating hours from 10:00 a.m. to 05:00 p.m. has been selected to quantify the possibility of lighting energy conservation. As the operating hour is in daytime, integration of daylight with artificial lighting system will definitely reduce the lighting energy consumption. Moreover the initial investment has been given priority and hence the existing lighting installation was unaltered. An automatic controller has been designed which will be operated as a function of daylight through windows and the lighting system of the room will function accordingly. The result of the study of integrating daylight gave quite satisfactory for visual comfort as well as energy conservation.

Keywords—Lighting energy, energy efficiency, daylight, illumination, energy conservation.

I. INTRODUCTION

DEMAND of energy in India is increasing day by day. But the generation of energy is not as high as demand of energy. Besides generation of energy, it is equally important to conserve energy to breeze the short fall between demand and generation. In an energy efficiency program of a US utility, an energy audit was conducted to identify lighting energy efficiency in an office building, an industrial manufacturing plant and a city hospital. It is found that in all the cases lighting energy savings were around 30% of the projected energy savings [1]. In a study conducted in 18 UK dwellings during one week in spring 2007 to calculate electrical consumption for lighting purpose and found that on average, households could have reduced lighting electricity consumption by 50.9% if all incandescent bulbs were replaced with CFLs [2]. In Lithuania, it is observed that replacing only two most used 60W incandescent lamp per household by CFLs would annually save 190GWh electrical energy taking four hours of daily operation [3].

A sub-hourly occupancy-based control model (SHOCC), aiming at quantifying the total energy impact of manual control over lights and window blinds were studied. Results show that building occupants that actively seek day lighting

rather than systematically relying on artificial lighting can reduce overall primary energy expenditure by more than 40%, when compared to occupants who rely on constant artificial lighting. This underlines the importance of defining suitable reference cases for benchmarking the performance of automated lighting controls [4]. It is also found that the integration of daylight from windows in buildings in seven cities in Brazil and one in the UK results energy savings ranging from 17.7% to 92.0% in the seven cities in Brazil and savings ranging from 10.8% to 44.0% could be achieved in the UK [5]. A study in subtropical Hong Kong indicates that the lighting energy for a fully air- open- plan office can be reduced by 21.2% when solar control films together with daylight-linked lighting control is used [6]. It is found that the potential of lighting energy savings in office rooms by using different control systems for four main orientations in Europe vary from 45 to 61% and it slightly depends on the room orientation and the location [7].

It is observed that there is significant possibility of lighting energy conservation in domestic, commercial as well as industrial sector. The main constraint of energy efficiency and conservation program is its huge initial investment. In the present study concentration was given to low cost solution for the lighting energy conservation in an existing educational institute. In these purpose a room in the institute has been selected for experimental evaluation. In the present study the existing lighting installations was unaltered and just an automatic day light linked lighting is employed and its performance was quantified.

II. ENERGY CONSUMPTION OF THE BUILDING

The study was conducted in an existing educational institute of India. The institute has three buildings and a workshop building. Among these the major load is associated with the main building of the institute. Hence the extensive study was conducted in the main building of the institute during 2013. Calculating the different type of installed load in the building is a simple process but calculating the energy consumption by different types of load of the building in a particular year is quite difficult because the year round consumption of energy in different part of the building is different depending on the functional purpose of the different parts of the building. The main functional parts of the building are class room, laboratory, office, corridor and staircase. Again, no of laboratories are grouped in two category namely computer lab and electronics lab for the purpose of simplicity in calculation.

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A. Overview of the Main Building

The main building is a four storied building and consists of a number of class rooms, computer labs, electronics labs, offices, and staircases and toilets. The details of the main building are given in Table I. In the table corridor includes toilet and staircase also.

TABLE I
 CONNECTED LOADS OF THE BUILDING

Type	No.	Total connected load (kw)	In % of total connected load
Class room	9	12.142	13
Computer Labs	4	37.908	40
Electronics Labs	13	36.031	38
Office	8	4.795	5
Corridor	5	3.194	4

B. Connected Load and Annual Energy Consumption

Different connected load of the building and annual energy consumption by individual loads are summarized to Tables II and III. It is found that connected AC load is maximum (30%) and lighting load (28%) is very close to AC load. in terms of annual energy consumption, it is found that lighting load consumes maximum energy in the year. The main cause of it is that lighting load operates round the year and it is independent of season.

TABLE II
 DIFFERENT TYPE OF CONNECTED LOAD OF THE BUILDING

Sl. No	Type of load	Load in kW	In percentage of total connected load
1	Lighting	27	28%
2	Fan	15.73	17%
3	Computer & Printer	15.95	17%
4	AC	28	30%
5	Equipment & others	7.39	8%
Total connected load (kW)		94.07	100%

TABLE III
 ANNUAL ENERGY CONSUMPTION BY DIFFERENT CONNECTED LOAD

Sl. No.	Type of load	Annual consumption in kWh	In percentage of total consumption
1	Lighting	15897.59	44%
2	Fan	6039.735	17%
3	Computer & Printer	5144.7	14%
4	AC	7770	21%
5	Equipment & others	1426	4%
Total Consumption (kWh)		36278.025	100%

III. EXPERIMENTAL METHODOLOGY

It is found that the lighting load consumes maximum annual energy (Table III). A number of energy savings technologies are there among this daylight linked lighting is one of the effective way to conserve lighting energy. To evaluate the effect of day light linked lighting, a room is chosen in the building. It is found that for most commercial buildings with glass transmittance values above 0.5, increasing window area to floor area ratio above 0.5, day lighting does not provide significant additional lighting energy savings [8]. In our study there is possibility energy savings with day lighting as clear

glass was used as window and the window area to floor area ratio is well below 0.5.

The plan of the room under study is shown in Fig. 1. The room under study is located in the 1st floor of the main building of the institution. It is 7m in length, 7m in width and 4.2m in height. Its window area to floor area ratio is 0.125. It consists of two glass window (W) and a wooden door (D) as shown in Fig. 1. The front wall of the room is faced towards common passage of the building, the two side walls are the common walls to the adjacent rooms, the rear side of the room i.e. the wall containing the two windows are exposed to the ambient and contributes daylight inside the room. The wall containing windows is in west side. Six set of lamps are connected for lighting purpose of the room. Each set consist of two fluorescent lamps of T12 type and total lighting load is 624W including ballast. Position of the lamp sets are shown in Fig. 1. For the proper investigation of the light flux on the working plane of the room, the room is divided into 7 columns and 7 rows along length and width and hence 49 grids are formed for measurement. All the grids are marked with corresponding row and column number. The windows are of clear glass.

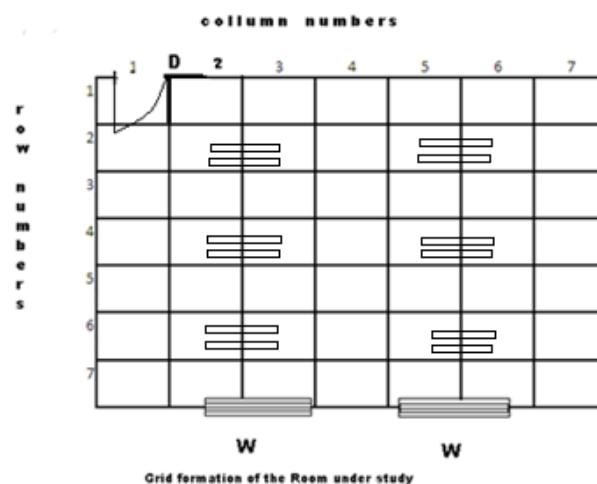


Fig. 1 Floor plan of the room along with window, door and lamp set position

IV. LIGHT FLUX OF THE ROOM UNDER STUDY

It is important to mention that the table height is the working plane as the building is an educational institute. It is assumed that the table height is 0.9m from the floor level. LUX level in different grid of the room was measured in that height. The light flux was measured in two conditions i.e. without day light through windows and with daylight. The illumination pattern in different grids without daylight is shown in Fig. 2. The illumination pattern of different zones shows good uniformity except the illumination level of four corner zones.

	1	2	3	4	5	6	7
1	80	107	187	213	153	116	77
2	97	140	197	231	190	141	95
3	105	153	206	226	195	130	111
4	110	140	197	213	197	144	100
5	100	136	175	215	185	145	109
6	97	125	177	220	189	150	119
7	66	116	175	198	204	125	78

Fig. 2 Room illumination on different grids on a particular day without daylight

But, the light flux on the working plane will differ time to time when day light comes through the windows. The variation of light flux on the working plane in this condition is highly time dependent. A number of illumination patterns were measured to identify the diurnal variation of illumination pattern of the working plane. A few of this pattern are shown in Figs. 3 and 4. Highlighted zone of the illumination pattern of the room in different time certainly indicates the presence of good amount of daylight throughout the day. Hence the integration of the daylight with lighting load will definitely be beneficial from the point of view of conservation of energy. It is also found that the grids adjacent to windows are mostly benefited of daylight.

	1	2	3	4	5	6	7
1	135	190	278	335	305	208	155
2	190	320	350	385	335	245	185
3	230	330	396	400	390	290	200
4	295	400	496	475	475	345	245
5	480	480	540	590	590	480	220
6	770	840	590	620	1070	900	300
7	1150	1950	600	1050	1920	1820	530

Fig. 3 Room illumination on different grids on a particular day with daylight at 01:00 p.m

	1	2	3	4	5	6	7
1	100	195	225	283	265	140	145
2	186	265	302	323	305	210	156
3	210	300	360	480	380	300	195
4	295	365	400	500	540	375	220
5	1020	533	460	611	1010	500	175
6	1080	1000	465	520	1115	1080	270
7	1210	2150	550	630	1600	11690	1050

Fig. 4 Room illumination on different grids on a particular day with daylight at 03:00 p.m

V. AUTOMATIC DAYLIGHT LINKED LIGHTING SYSTEM

From the result of diurnal variation of the illumination profile of the room it is found that a number of zones are there with higher illumination. It is possible to conserve energy

linking the lighting system of those zones of the room with day light. In this study two LDR (light dependent register) was used as day light sensor and is placed to the higher illuminated zone. A simple on-off controller was designed to operate the lighting system of the higher illumination zone between 250 to 300 LUX. From the illumination pattern, it is clear that the two set of lamps located near the windows can be linked with the controller to switch on and off according to the availability of daylight. The study was conducted throughout the year and the impact of daylight on energy consumption in different season was studied.

VI. RESULT WITH AUTOMATIC DAYLIGHT LINKED LIGHTING SYSTEM

Control of room lighting system with availability of day light is studied in different hours of a number of days. A few of illumination pattern of a day in different hours are given in Figs. 5 and 6 below. It is clear from the figure that the employment of automatic daylight linked lighting system will give satisfactory illumination level in the controlled zone. Moreover the employment of automatic daylight linked lighting system save energy consumption.

	1	2	3	4	5	6	7
1	97	120	230	238	217	129	135
2	110	220	230	246	260	140	166
3	159	234	246	350	270	290	195
4	173	266	324	355	320	340	125
5	264	345	236	307	762	520	280
6	555	500	450	430	790	1544	746
7	1850	1204	650	700	1824	1618	915

Fig. 5 Room illumination pattern at 01:00 p.m. with automatic control

	1	2	3	4	5	6	7
1	110	182	234	270	228	219	116
2	133	170	235	284	280	250	129
3	197	214	240	302	262	304	215
4	285	270	290	378	502	364	148
5	311	353	363	391	640	410	203
6	470	427	433	430	850	1816	920
7	720	771	1470	288	1235	1610	1170

Fig. 6 Room illumination pattern at 03:00 p.m. with automatic control

VII. ENERGY SAVINGS IN WITH AUTOMATIC CONTROL OVER WITHOUT CONTROL

It is found that the lighting energy consumption for the normal operating period i.e. 7 hours from 10:00 am to 05:00 pm of the room is 5.04 kWh when there is no control to the higher illuminating zone. When automatic control is employed, energy consumption in a Sunny day of summer is 3.584 kWh and in partly cloudy day is 4.312 kWh. Hence

energy savings for the particular room of the building is around 14 to 29% depending on the climatic condition of the particular day.

VIII. CONCLUSION

The experimental study was conducted to quantify the potential of lighting energy in the educational institute. The functional period of the institute is 10:00 am to 05:00 pm. So it is beneficial to integrate daylight to conserve lighting energy. Most of the energy conservation approach need high initial investment and become difficult to implement in practice. Keeping this in mind, a low cost solution is essential and hence the installation of existing lighting system keeps unaltered. Only a simple on off controller is designed and employed to control the lamp set of over illuminated zones which is very economic as far as initial investment is concern. From the result it is obvious that the employment of control to the lighting system by no way reduce the illumination level below the visual comfort level. More over the savings of lighting energy varies from 14 to 29% depending on seasonal variation and climatic condition of the particular day. Energy savings may increase further by using higher number of sensors and linking more set of lamp set with the controller.

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