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Search And Survey

Energy Saving Potential of Daylight Integrated Lighting System in Built-In-Environment for Various Climatic Conditions

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Abstract
One of the recent trends in energy efficient lighting design is integrating daylight with artificial lighting which offers a sufficient amount of energy saving. Daylight illuminance is varying with respect to time of the day as well as the time of the year. Not only that daylight is very much depended on location, calendar date, time of the day, building construction geometry, window position, etc. Thus during the design of daylight integrated lighting system the measurement of daylight availability in a space is important. In this paper, a sample open office area has mainly been considered and lighting design has been done with highly energy efficient LED light sources and potential of energy saving has been studied at various climatic conditions with different building geometry considering integration of daylight with artificial lighting system.

Keywords: Daylight integration, Daylight simulation, Energy analysis, Energy efficiency, Energy saving, LED luminaire.

Introduction

Lighting is one of the major electrical loads in most of the commercial buildings and nearly 20% to 30% of overall electrical energy are in use for illumination purposes in such areas. Especially in developing country like India where about 20% of yearly generated power is being utilized for illumination purpose [1]. Thus the concept of energy efficient lighting design plays a vital role in terms of conservation of energy. With the development of automated lighting control technology the definition of energy efficient lighting has been changed now the energy efficient lighting implies the use of highly energy efficient light sources with proper lighting control and management system which includes the control scheme like daylight integration, occupancy based lighting control, [2] etc. The daylight integrated lighting system has a huge potential of energy saving if the negative effects of sunlight has been minimized such as increasing the HVAC load of a building, penetration of direct sunlight in the building and causing glare, [3] etc. Thus in this paper potential of energy saving through daylight integrated lighting system has been studied at built in environment and various climatic condition through simulation.

Integration of daylight with artificial Lighting

Daylight is considered as the best source of light with good colour rendering and its quality is one of the light sources that most closely match human visual response. It gives a sense of cheerfulness

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and brightness that can have significant positive impact on the people. Thus use of daylight in commercial building provides a good and healthy working environment.

Human needs a specific illuminance level to perform a particular task and this quantity of light has been depends on the type and size of task, age, [4] etc. of the perceivers and on so many factors, but the main problem of daylight is its dynamic nature. Daylight is not constant in an place at various time of day as well as various seasons of the year so to provide a constant illuminance in working area like open plan office daylight must be integrated with artificial light and automated control system [5] should be provided that dim the artificial lights according to the available daylight in the work plane. Thus design steps of daylight integrated lighting system should be as follows [6]:

1. Measurement and prediction of daylight availability in the space.
2. Selection of sensors and light controllers.
3. Luminaire grouping or scheduling.
4. Prediction of energy saving.

The building and artificial lighting system

To analysis the energy saving in built-in-environment using daylight integration a comparative study of daylight availability in an open work space has been done. The details of room parameters and artificial lighting system have been discussed.

Room Geometry

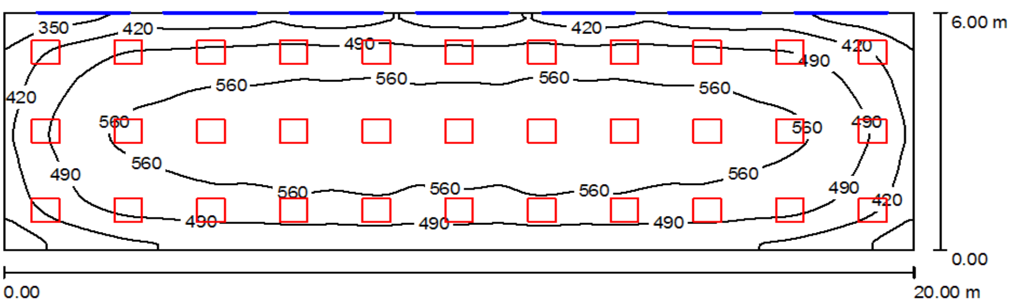
For this study an open office has been considered having the dimension of 20m(L) x 6m(W) x 3m(H) and it has 7 numbers of windows of 2m(W) and 1.2m(H) in one side of the 20m wall. Reflectance of various room surfaces has been considered [7], as listed below:

Room surface	Reflectance
Ceiling	0.7
Wall	0.5
Floor	0.2

Artificial Lighting system

As per the Indian standard (IS-3646 : Code of practice for interior illumination) artificial lighting system for the room has been designed with highly energy efficient 36W 2ftx2ft LED lumininaire. The details of artificial lighting design of the room using DIALux software, have been given below:

System wattage	36W
Nominal voltage	230V
Mains current	0.160A
Nominal power factor	> 0.9
Nominal efficacy	>75lm/W
LOR	100%
CCT	5500K
CRI	>75
Ingress protection	IP20
Glare class	Class I



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.80 Values in Lux, Scale 1:143

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	507	290	605	0.571
Floor	20	459	282	548	0.613
Ceiling	70	109	96	1093	0.883
Walls (4)	50	278	105	413	/

Figure 1 : Calculation Summary of Artificial lighting system

Here the lighting system has been designed considering the average of 500lux on the working plane and the total power required is 1188W and Lighting power density (LPD) [8] is coming 9.9W/ m^2 which is within the prescribe limit of Energy Conservation Building Code(ECBC).

Studies on daylight availability

To design daylight integrated lighting system, measurement of available daylight is very much important and here as the objective of the study is energy analysis of built-in-environment in various climatic conditions thus daylight simulation for the room has been done on various season of the year with different building orientation.

Simulation of daylight

To study the daylight availability in the room DIALux simulation has been done. DIALux software has the option to calculate available daylight in any indoor space with windows and skylights. As a base for the calculation the DIN: 5034-3 (Daylight in interiors – Part 3: Calculation), and the CIE publication: CIE-110(Spatial distribution of daylight-luminance distribution of various reference sky) were used. The sky dome is divided into small luminous surfaces, which get a luminance depending on the sky model, location, date and time. By the option "use direct sunlight" it is also calculated with the Sun as a light source. The calculation occurs in the following steps [9]:

1. Calculation of the skylight on all surfaces (inside and outside)
2. Calculation of the direct sunlight on all surfaces
3. Calculation of the direct light through luminaires (if available)
4. Calculation of the indirect component

Now in this study the various input parameters of the software for daylight simulation has been given below:

Location of the Room	New Delhi, (77.20°E,28.60°N)
Time Deviation from GMT	+5:30 Hr
Window specification	Window with solar control glass
Window transmittance	50%
Framing factor of the Window	0.85
Sky type selected	Mixed type of sky without direct Sunlight

Note: Daylight data of Capital Delhi has been considered for DIALux software reference.

A typical result of a DIALux daylight simulation for the room has been given below considering the series of windows face the north direction on 22nd June at 10:00AM;

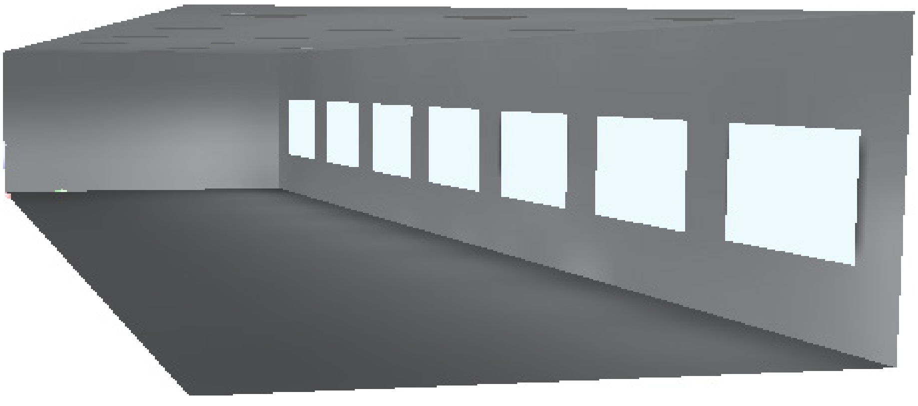


Figure 2: 3D rendering view of open work space using daylight simulation on DIALux

From the above simulation result it has been observed that daylight available in the workspace is not uniform it is higher near to windows than other space of the room thus dimming of the luminaire in all over the room has to be different based on the available daylight in that position. Thus three row of luminiare can be grouped in separate electrical circuits for providing an appropriate uniform illuminance [10] with the combination of artificial and daylight.

Variation of daylight

The availability of daylight is generally depends on the time of the day and year as well as window position thus the details of daylight availability has been studied through simulation.

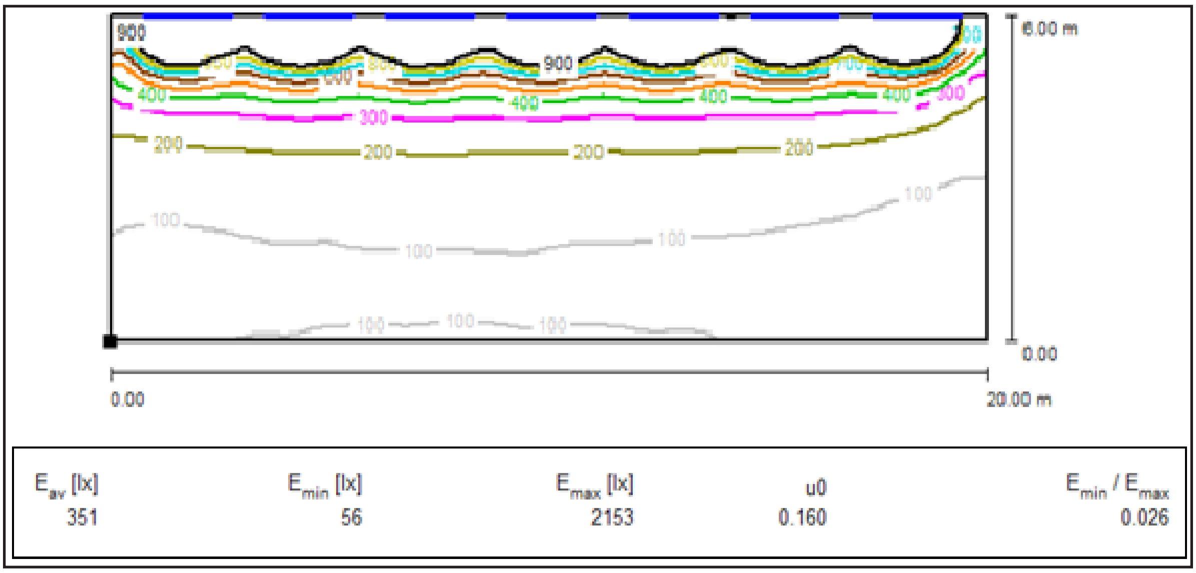


Figure 3 : Calculation Summary of daylight simulation

Here average daylight illuminance available on the working plane has been calculated in various time of year.

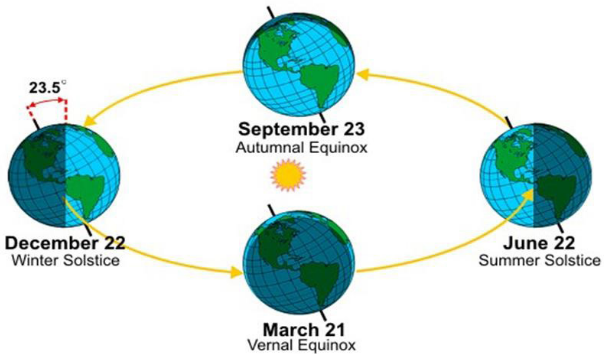


Figure 4: Yearly Sun and Earth relative positions.

Four major days of the year have been considered for analysis, which are 22nd June, 23rd September, 22nd December and 21st March. The bases of the selection of such dates are 21st June and 22nd December are dates of summer and winter solstice. 23rd September and 21st March are dates of two equinox.

During daylight simulation through DIALux building orientation has been made so that windows in the room has been aligned towards on the north, west, south and east directions, respectively.

The summary of available average daylight illuminance on work plane at various climatic and built-in-conditions is given below:

Table 1: Average Illuminance value of daylight illuminance in lux with different building orientation at different time of day and calendar date of year.

Window at north wall									
Date	Time								
	9:00AM	10:00AM	11:00AM	12:00PM	1:00PM	2:00PM	3:00PM	4:00PM	5:00PM
22-Jun	471	351	225	235	247	385	438	426	224
23-Sep	321	292	241	228	267	315	300	191	57
22-Dec	151	195	209	211	206	183	127	51	0
21-Mar	314	304	252	227	254	305	311	222	85

Window at west wall									
Date	Time								
	9:00AM	10:00AM	11:00AM	12:00PM	1:00PM	2:00PM	3:00PM	4:00PM	5:00PM
22-Jun	241	218	186	279	383	672	850	705	358
23-Sep	245	289	329	427	612	769	690	379	93
22-Dec	156	249	340	427	483	445	286	98	0
21-Mar	229	280	318	396	563	745	734	461	146

Window at south wall									
Date	Time								
	9:00AM	10:00AM	11:00AM	12:00PM	1:00PM	2:00PM	3:00PM	4:00PM	5:00PM
22-Jun	444	218	186	279	383	672	850	705	358
23-Sep	604	694	675	662	693	665	495	249	62
22-Dec	362	589	735	772	697	517	281	87	0
21-Mar	558	687	687	665	689	606	549	308	97

Window at east wall									
Date	Time								
	9:00AM	10:00AM	11:00AM	12:00PM	1:00PM	2:00PM	3:00PM	4:00PM	5:00PM
22-Jun	340	593	331	225	190	227	239	197	117
23-Sep	769	669	502	361	303	268	208	120	37
22-Dec	350	471	469	397	308	216	124	44	0
21-Mar	740	737	552	389	314	278	225	143	54

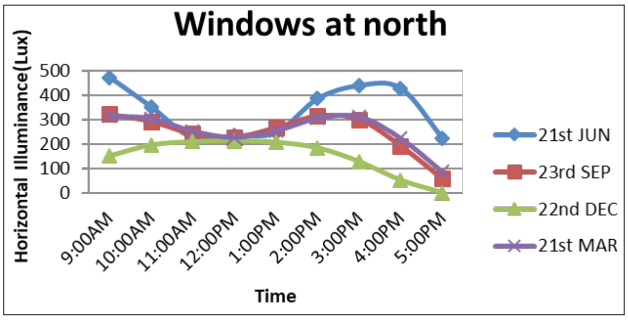


Figure 5: Available horizontal daylight illuminance when building oriented at North direction at different time of day and calendar date of year.

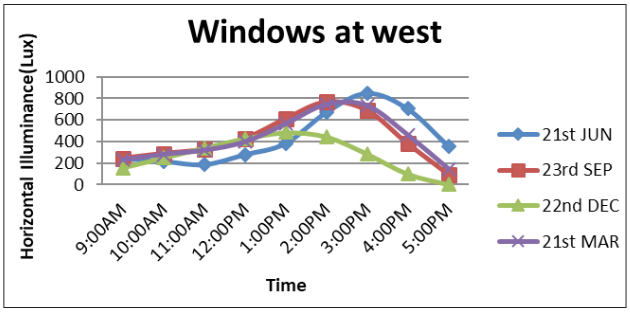


Figure 6: Available horizontal daylight illuminance when building oriented at West direction at different time of day and calendar date of year.

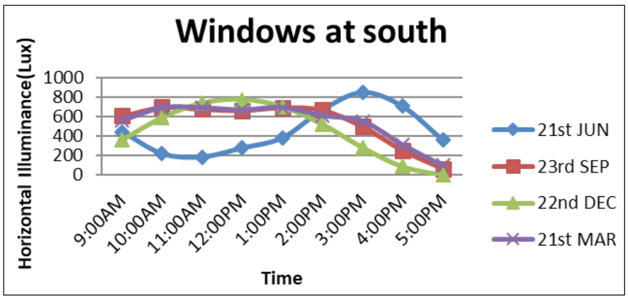


Figure 7: Available horizontal daylight illuminance when building oriented at South direction at different time of day and calendar date of year.

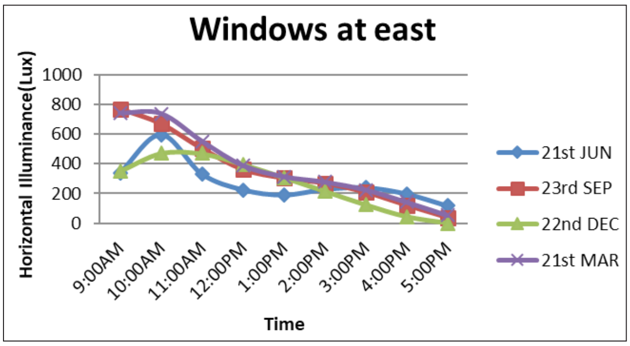


Figure 8: Available horizontal daylight illuminance when building oriented at east direction at different time of day and calendar date of year.

Note: During summer Sun is in the northern hemisphere and in winter it is on southern hemisphere, Figure 5 and 7 also show the same result.

Prediction on energy saving

In daylight integrated lighting system it is very difficult to predict the actual energy saving because the nature of daylight availability in a room is very dynamic. So to evaluate the actual energy saving real energy measurement is needed. Thus it become very difficult and not possible at design stage, so to predict the approximate energy saving a thumb rule can be use that is energy saving using daylight integration with artificial is equivalent to dimming required to artificial light due to presence of daylight [11]. Now if average daylight present on workplane is E_d and artificial illuminance on workplane (considering all luminaire are kept in operation) E_a then it can be said that artificial light can be dimmed upto:

$$\frac{(E_a - E_d)}{E_a} \times 100\% \text{ value,}$$

For an example average daylight available throughout the day (from 9:00AM to 5:00PM) on 22nd June (windows aligned at north direction) is 333.55lux and artificial illuminance available at work plane is 507 lux. Thus artificial light can be approximately dimmed upto 34.21% thus nearly 65% of energy can be saved using daylight integration in that situation.

Thus considering worst condition that means in winter season when minimum daylight is available energy saving in various window orientation is given in the Table 2.

Table 2: Prediction on energy saving using daylight integration

Date	Average Daylight avaible through out the day(lux)	Artificial Illuminance (lux)	Artficial light can be dimmed upto(%)	Percentage of approximate energy saving(%)
Window at north Wall				
22-Jun	333.55	507.00	34.21	65.79
23-Sep	245.77	507.00	51.52	48.48
22-Dec	148.11	507.00	70.79	29.21
21-Mar	252.66	507.00	50.17	49.83
Window at west wall				
22-Jun	432.44	507.00	14.71	85.29
23-Sep	425.88	507.00	16.00	84.00
22-Dec	276.00	507.00	45.56	54.44
21-Mar	430.22	507.00	15.14	84.86
Window at south wall				
22-Jun	455.00	507.00	10.26	89.74
23-Sep	533.00	507.00	0.00	100.00
22-Dec	448.88	507.00	11.46	88.54
21-Mar	538.44	507.00	0.00	100.00
Window at east wall				
22-Jun	273.22	507.00	46.11	53.89
23-Sep	359.66	507.00	29.06	70.94
22-Dec	264.33	507.00	47.86	52.14
21-Mar	381.33	507.00	24.79	75.21

Conclusions

In this paper effort has been made for model studies where potential of energy saving can be predicted through daylight integrated lighting system at various climatic conditions and building orientations. However the availability of daylight is very much dynamic it depends on the window configuration, location, time of day, calendar date of the year thus prediction of energy saving in daylight integrated lighting system is very difficult. In this paper a simple approaches is implemented to predict energy saving using daylight integration. The initial simulated design through the software and equivalent can be done for initial estimation purpose and arrangement of lighting circuit along with group switching can be implemented.

The limitation of this study is nowadays most of the building situated in city areas are surrounded by obstructions like multistoried buildings, trees and other obstructions. Thus here the study has been done without considering any external daylight obstruction so presence of external daylight obstruction will reduce the available daylight inside the room. Thus in future similar studies can be done considering daylight obstructions like adjacent building(s), trees etc. Same can also be optimized by adding daylight obstruction features of DIALux software and in practice better building construction with suitable reflectors etc. can be developed for diversion of sunlight to adjacent buildings.

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