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Dedicated Sensing Unit for Smart Light Switching in Energy Efficient Eco-Friendly Building

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Abstract:
The concept of Green Building and energy efficient building is the demand of the time now due to the increase in the number of occupants, change in climate, increase in population, gaseous emission and continuously exhausting natural resources .The buildings are the main consumers of electricity and the fields of energy consumption in a building are HVAC, lighting systems, water system, kitchen appliances etc. In this paper focus has been given on lighting consumption in a institute building. Lighting consumption in the institute building is calculated on LPD basis with use of fluorescent tube light and then using same LPD method again the energy consumption of the same building is calculated and a saving of 62% is observed. Using rooftop grid connected solar power plant provided in the institute due to lesser rate of solar power a further cash saving of 30% is observed. In the further step a classroom is considered and occupancy sensors, PIR, LDR and other sensors fitted in dedicated units made and is controlled by central micro controller so as the system can sense and send the signals regarding occupancy, people count and luminance which may be used in Building Management System(BMS) for further controlled power saving and occupant comfort.

Keywords: *Green building, Light power density, occupancy sensors, luminance sensors, energy efficient building*

I. Introduction

In the buildings various kinds of energies are used like cooling, heating, lighting, water heating, cooking, electricity etc. on daily basis for the comfort and safety of the occupants. We are aware that the natural resources of the energy are limited and it is our responsibility to use the natural resources of energy with care so that they last long and our coming generations should get these resources. This is possible only when we intend for minimum use of stored resources of energy and should go for renewable sources of energy like solar, wind energy, geothermal energy, tidal energy, biomass energy etc. Though at starting such renewable sources may sound costly and inconvenient but in the long run their cost comes down and we get used to it and at the same time we can conserve our resources of energy. Hydro power plants are in operation in our country since long but still we are not using our full potential in hydro power because of some practical problems like requirement of large space which requires shifting of people to other places for safety measures and secondly they are to be installed at remote places. We India are lucky to have plenty of sunlight for maximum land and hence our country is best suited for solar power generation geographically however due to our large population density the empty land available for solar PV module installation is restricted and is much less than what it could have been and other factor is of course the high cost which is now coming down day by day with the support of the government. Green buildings which utilizes minimum possible electricity and water, minimizes the carbon emission, designed for natural lighting, minimizing energy consumption in HVAC, more occupant friendly are becoming very popular in today’s world. Green buildings are also referred as green construction and sustainable building.

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Green buildings are referred as structure and application of process which is environmentally friendly and resource-efficient throughout the building cycle i.e. from planning to design, it's construction, building operation, maintenance, renovation followed by demolition. This requires a teamwork incorporated of the contractor, architect, engineers, clients at the project stages and hence the green building design and construction concerns of economy, utility, resource conservation, durability and occupant comfort. Smart building is the combination of green building and the comfortable automation of the building. This automation results in further saving in the energy consumption, maximum utilization of sunlight incident on the building, minimum consumption of water for the same requirement, improvement in indoor air quality to breath in, HVAC at minimum energy consumption. Sensors of different kinds for different purposes are used in smart buildings which may include LDR, humidity sensors, carbon dioxide sensors, humidity sensors, occupancy sensors, counters etc. The study of lighting is a multidirectional area of research since light influences human health and well-being, visual comfort and individual behavior [2].

The main aim of lighting design is to support the visual perception of the eyelid setting. The viewer's usage of the reflected light array from surface for seeing shapes and affordances is known as visual perception. Poor lighting design in the building may result in irritation in eyes if prolonged may cause eye diseases, reduced productivity, occupant discomfort, headache and nausea etc.

II. Methodology

This section gives an explanation of how the search of qualified studies was carried out and also includes the assessment criterion, inclusion and exclusion of criterion followed by aimed analysis. In the first step a building of the institute(G.B.P.I.T. Okhla, New Delhi) has been taken into consideration which is a construction of 1964. In earlier time there was no declared concept of green building as such but as the population density was less hence that time this building was situated in lush green vacant space having enough sunlight, lesser number of students resulting less emission of carbon, less use of electricity and water and other resources. With the due course of time however the spacious campus still exists but the condition have changed with large increase in the number of students in the same building causing heavy increase in electricity consumption, exponentially increased co_2emission due to occupants and machinery, noise pollution and dust, overall continuously degrading air quality of Delhi, reduction in sunlight intensity incident in winter due to heavy pollution in Delhi.

LEED and GRIHA are two major rating systems. LEED (Leadership in energy and environmental design) certifies a building on 69 points whereas GRIHA (Green Rating for Integrated Habitat Assessment) certifies on 33 points.

The distribution of points for certification of a building is given in the Table1

Based on the grading system of LEED, the green buildings are awarded certification as shown in the Table 2.

It is rather easier to construct a green building from the starting like planning to design, construction, maintenance, operation and demolition but for an existing building it needs a thoughtful process , careful techniques, an excellent teamwork, intense study of characteristics of the existing building to make the building energy efficient and eco-friendly green building. In the initial process the building under consideration is analysed with through study of it's characteristics including floor plans and sunlight incidence pattern. Energy consumed in lighting of the building as per ECBC 2017 was calculated referred as Baseline lighting scheme including all the rooms, offices and labs. Electrical energy actually being consumed is calculated using

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LPD (Light Power Density) method considering same rooms and offices and is referred as proposed lighting scheme consumption. An analysis was made by proposed replacement of fluorescent tubes by LEDs in the building. Roof top installation of the institute has been considered installed in institute by government aided agency providing electric power at the rate of Rs. 5.80 per kWh whereas the BSES electricity is available at the rate of Rs. 8.40 per kWh. A distinguishing saving is observed in the above process.

An intelligent smart building is recognized by it's accurate, effective and economic automation. Automation of electric lights LED has been considered in a class room with the use of sensors like lighting sensors, LEDs, occupancy sensors, microcontrollers, dedicated units etc and using Arduino aided unit and Node-red program the signals are processed for people count, luminance and occupancy.

TABLE I
LEED POINTS SYSTEM FOR EVALUATION OF A BUILDING.

S.No.	Criteria	Points
1	Sustainable sites	13
2	Water Efficiency	6
3	Energy & Atmosphere	17
4	Material & Resources	13
5	Indoor Environmental Quality	15
6	Innovation & accredited Points	5
	Total Points	**69**

TABLE 2
CERTIFICATION SYSTEM OF A GREEN BUILDING IN LEED.

S.No.	Rating	Points
1	LEED certified Green Building	26-32
2	Silver Rated LEED certified Building	*33-38*
3	Gold Rated LEED certified Building	39-51
4	Platinum rated LEED certified Building	52-69

III. ANALYSIS OF CHARACTERISTICS OF THE BUILDING AND PERCENTAGE OF SAVING IN ELECTRICITY CONSUMPTION OF LIGHTING USING LEDS LIGHTING REPLACING FLUORESCENT LIGHTS

A building of an institute was selected to perform analysis on energy consumption. The building has two floors including so many rooms, drawing halls, office rooms and washrooms. All the rooms are given a identity number and a drawing map of the building is arranged. The rooms on first floor and ground floor have various orientations and differs also in duration and amount of receiving sunlight. As per energy conservation building codes(ECBC) lighting system differs in their requirement for offices, hospitals, operation theaters, assembly, institutes, washrooms, drawing halls, shopping complex, mixed use buildings. For example the light power density of library is required to be 12.2 watts per meter square and LPD for gymnasium is required to be 10 w/m. sq.

The lighting analysis has been prepared for an institute building having two floors and the total modeling area of the project is approximately 7300 square meter. A whole building energy analysis was performed for estimating the building lighting performance throughout the year. Surface area of all individual rooms was measured and light power density as per ECBC was referred. Scheduled hours of working classes in the rooms was estimated and then total power for a room and the energy consumption in kWh was calculated for each and every room and hence the total energy consumption as per ECBC standard was estimated. Working hours for lighting has been assumed to be 47.87 hours per week and the baseline energy consumption has been calculated for one year.

Detailed floor plan of the ground floor and the first floor was considered clearly indicating the locations of classrooms, laboratories and offices. Calculations of the electricity consumed in lighting of the building was done as per requirement of the ECBC (Baseline Lighting Scheme) and was found to be 195569 kWh per year [3]. Now the calculation of the electricity consumption as per actual fitment of lighting system [Proposed Lighting Scheme] was done by the author in the previous paper and was found to be 154194 kWh per year.[3]

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Now the calculation of the electricity consumption as per actual fitment of lighting system [Proposed Lighting Scheme] was done by the author in the previous paper and was found to be 154194 kWh per year.[3] Sunrise and sunset pattern of the building is available which shows the angle of sunlight incident on the building with respect to time.

Light emitting diodes (LED) have emerged as a very efficient lighting device which consumes comparatively very less electricity and at the same time it's glow is very effective and gaseous emission is within safe limits. A light emitting diode is a p-n junction diode and is a specially doped diode made up of special type of semiconductor in such a way so that when it conducts in forward bias , light is emitted from it.

Here in the study fluorescent tube light is replaced by 15 watt LED giving the required lux of illumination in the classroom.

The rating of the lamp is reduced by a factor of 2.67 with the use of LED and hence the watt per meter square LPD required also reduces by a factor 2.67 for all requirements of the building. The calculation for a proposed lighting scheme is done by using LED instead of using lamps in the previous paper of the author[3].

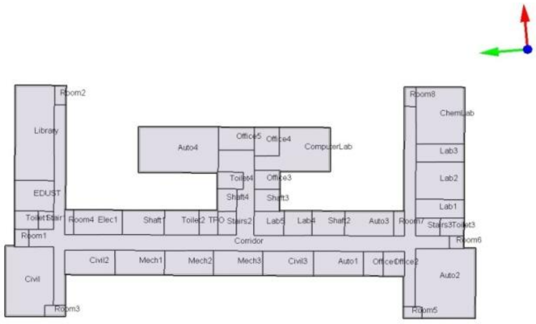

Fig. 1: Floor plan of first floor [3].

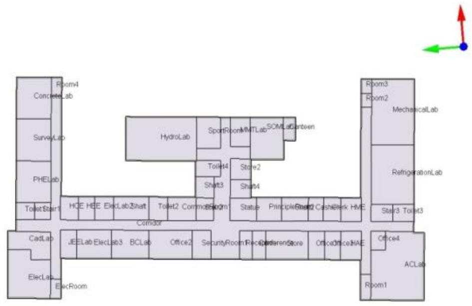

Fig. 2: Floor Plan of Ground Floor [3].

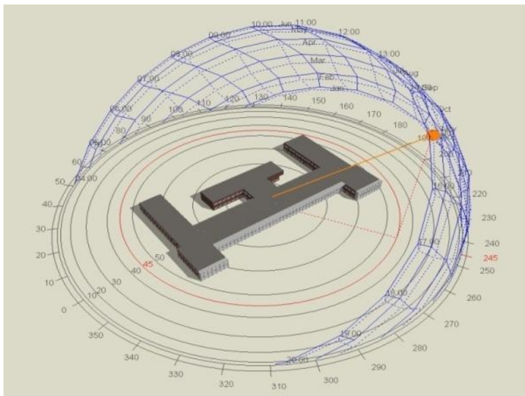

Fig. 3:Sunrise and sunset pattern of the building [3].

TABLE 3
LPD BASED LIGHTING CONSUMPTION OF THE BUILDING USING SPACE BY SPACE METHOD WITH LED LIGHTS

Interior Lighting Details					
Zone	**Lighting Power Density [W/m^2]**	**Zone Area [m^2]**	**Total Power [Watts]**	**Scheduled Hours/Week [hr]**	**Consumption in kWh**
FF:AUTO1	4.05	73.81	298.93	47.87	746.13
FF:AUTO2	4.05	251.1	1016.96	47.87	2538.34
FF:AUTO3	4.05	73.32	296.93	47.87	741.13

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FF:AUTO4	4.05	217.98	882.82	47.87	2203.53
FF:CHEM LAB	4.05	166.42	674.01	47.87	1682.33
FF:CIVIL	4.05	199.12	806.44	47.87	2012.87
FF:CIVIL2	4.05	75.12	304.22	47.87	759.33
FF:CIVIL3	4.05	75.64	306.34	47.87	764.62
FF:COMPUTER LAB	4.05	156.51	633.86	47.87	1582.12
FF:EDUST	4.05	73.98	299.6	47.87	747.8
FF:ELEC1	4.05	72.6	294.02	47.87	733.88
FF:LAB1	4.05	55.51	224.81	47.87	561.12
FF:LAB2	4.05	111.59	451.95	47.87	1128.08
FF:LAB3	4.05	53.2	215.44	47.87	537.73
FF:LAB4	4.05	42.13	170.61	47.87	425.84
FF:LAB5	4.05	44.55	180.43	47.87	450.35
FF:LIBRARY	4.05	227.08	919.65	47.87	2295.46
FF:MECH1	4.05	73.81	298.93	47.87	746.13
FF:MECH2	4.05	73.2	296.46	47.87	739.96
FF:MECH3	4.05	73.2	296.46	47.87	739.96
FF:TPO	4.05	28.47	115.29	47.87	287.76
GF:AC LAB	4.05	242.47	981.98	47.87	2451.02
GF:BC LAB	4.05	76.67	310.51	47.87	775.04
GF:CAD LAB	4.05	70.27	284.6	47.87	710.37
GF:CONCRETE LAB	4.05	102.59	415.49	47.87	1037.07
GF:ELEC LAB	4.05	133.79	541.86	47.87	1352.48
GF:ELECLAB2	4.05	31.42	127.27	47.87	317.66
GF:ELEC LAB 3	4.05	72.18	292.33	47.87	729.67
GF:HAE	4.05	42.8	173.32	47.87	432.62
GF:HCE	4.05	30.71	124.36	47.87	310.39
GF:HEE	4.05	27.46	111.2	47.87	277.55
GF:HME	4.05	34.92	141.43	47.87	353
GF:HYDRO LAB	4.05	218.07	883.16	47.87	2204.38
GF:JEE LAB	4.05	33.75	136.67	47.87	341.13
GF:MECHANICAL LAB	4.05	201.82	817.37	47.87	2040.17
GF:MMT LAB	4.05	41.77	169.16	47.87	422.22
GF:PHE LAB	4.05	104.14	421.74	47.87	1052.67
GF:REFRIGERATION LAB	4.05	185.05	749.45	47.87	1870.64
GF:SOM LAB	4.05	99.41	402.6	47.87	1004.89
GF:SURVEY LAB	4.05	105.25	426.24	47.87	1063.9
GF:CORRIDOR	2.0625	724.26	1493.78	47.87	3728.48
FF:CORRIDOR	2.0625	772.83	1593.95	47.87	3978.51
GF:TOILET4	2.0625	29.02	59.85	47.87	149.39

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GF:TOILET2	2.0625	32.1	66.21	47.87	165.26
GF:TOILET1	2.0625	22.91	47.24	47.87	117.92
GF:TOILET3	2.0625	25.79	53.19	47.87	132.77
FF:TOILET4	2.0625	26.83	55.35	47.87	138.14
FF:TOILET2	2.0625	51.57	106.35	47.87	265.46
FF:TOILET3	2.0625	25.81	53.23	47.87	132.85
FF:TOILET1	2.0625	25.81	53.23	47.87	132.85
GF:STAIR2	1.8749	29.73	55.74	47.87	139.12
GF:STAIR1	1.8749	20.46	38.36	47.87	95.74
GF:STAIR3	1.8749	27.93	52.37	47.87	130.72
FF:STAIRS2	1.8749	27.45	51.47	47.87	128.48
FF:STAIRS3	1.8749	27.97	52.43	47.87	130.88
FF:STAIR1	1.8749	17.74	33.25	47.87	83
GF :PRINCIPAL ROOM	3.0751	42.07	129.38	47.87	322.93
GF:CLERK	3.0751	29.15	89.65	47.87	223.77
GF:CASHIER	3.0751	25.31	77.83	47.87	194.26
GF:ROOM4	3.0751	12.67	38.95	47.87	97.22
GF:OFFICE2	3.0751	89.76	276.02	47.87	688.94
GF:SECURITY ROOM1	3.0751	38.52	118.46	47.87	295.67
GF:OFFICE3	3.0751	33.44	102.82	47.87	256.63
GF:OFFICE1	3.0751	33.44	102.82	47.87	256.63
GF:OFFICE4	3.0751	20	61.5	47.87	153.51
GF:ROOM1	3.0751	17.81	54.76	47.87	136.68
GF:ROOM2	3.0751	9.69	29.81	47.87	74.39
GF:ROOM3	3.0751	9.69	29.81	47.87	74.39
FF:OFFICE3	3.0751	28.89	88.83	47.87	221.71
FF:OFFICE4	3.0751	42.74	131.44	47.87	328.07
FF:OFFICE5	3.0751	49.99	153.73	47.87	383.71
FF:ROOM4	3.0751	13.81	42.47	47.87	106
FF:ROOM2	3.0751	12.35	37.98	47.87	94.79
FF:ROOM7	3.0751	16.26	50.01	47.87	124.82
FF:OFFICE1	3.0751	29.89	91.91	47.87	229.42
FF:OFFICE2	3.0751	31.64	97.28	47.87	242.82
FF:ROOM8	3.0751	12.59	38.7	47.87	96.61
FF:ROOM6	3.0751	10.68	32.85	47.87	81.99
FF:ROOM5	3.0751	11.63	35.76	47.87	89.25
FF:ROOM3	3.0751	12.68	39	47.87	97.34
FF:ROOM1	3.0751	14.9	45.83	47.87	114.4
GF:CONFERENCE	3.0751	27	83.04	47.87	207.26
GF:RECEPTION	3.0751	27	83.04	47.87	207.26

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GF:ELEC. ROOM	2.0626	13.56	27.97	47.87	69.82
GF:STORE2	2.0626	30.3	62.5	47.87	155.99
GF:STORE	2.0626	87.74	180.97	47.87	451.7
GF:SPORT ROOM	2.25	54.26	122.09	47.87	304.75
GF:COMMON ROOM 1	2.25	47.68	107.28	47.87	267.78
GF:CANTEEN	2.25	18.02	40.55	47.87	101.2
GF:STATUE	2.25	44.52	100.16	47.87	250.01
Total	3.32	6960.74	23166.09		57822.61

Result shows that using LED a fair amount of energy is saved and the given table 4 shows the percentage saving in energy consumption using LED lights.

TABLE 3
PERCENTAGE SAVING IN ENERGY CONSUMPTION.

Design Case	**Energy Usage (kWh/year)**	**Energy Cost(₹/year)**	**Energy Savings (%)**	**Energy Cost Savings (%)**
Baseline Lighting Design as per ECBC 2017	1,95,569	15,64,552	-	-
Proposed Lighting Design	1,54,194	12,33,554	21.16%	21.16%
LED Lighting Design	57,823	4,62,580	70.43%	70.43%

IV. Rooftop Solar Plant of the Building Under Distributed Generation

The institute has a rooftop solar plant under government scheme of capacity 187 kVA providing electricity at Rs. 5.80 per kWh whereas supply available from grid is at Rs. 8.50 per kWh hence Rs 2.70 is saved per unit. In the table the cost of energy uses thus reduces by Rs. 1,56,122/- per year for LED lighting design and hence the annual cost of lighting goes down from Rs. 4,62,580/- to 3,06,457/- per year.

V. Concept of Sensors and Their Uses in Smart Buildings

Use of sensors have achieved the ease of atomizing a building in today's modern world and many accurate and sensitive sensors are available in the technical market which uses different physical quantity to activate. The usefulness of the sensors lies behind the principle that sensors after responding to a physical quantity gives output interpretation in the form of electrical signals. The main types of sensors being used in lighting control of an institute building are discussed here.

Occupancy Sensors: *They are mostly passive infrared sensors and they work on detection of heat difference. Inside the device there is a pyroelectric sensor which can detect the sudden presence of humanlike objects who radiate a temperature difference from the temperature of the background like the wall of the room.*

Fig. 4: Occupancy Sensor[5].

Occupancy sensors can also be in the form of environmental sensors such as having capacity to sense temperature, humidity and CO2 which can be detected the change due to presence of a human. Ultrasonic sensors and microwave sensors can also be used for this purpose which not only detects the presence of the human being but also gives information about their motion and in that case they are called motion sensors. A presence detector will give its output high (1) in digital form if even a single person is present whereas if nobody is present in a given area then it will give output as low (0) and digitally it is used for switching lighting circuits on and off respectively. Tracking utilization data allows companies to accurately pinpoint which parts of their property portfolio are working for them, and address problem areas

Light Sensors: Light sensors are the photoelectric devices which can convert the light energy i.e. the energy incident of the photons into an electrical signal which can be used in controlling the operation. According to classical electromagnetic theory, the photoelectric effect can be attributed to the transfer of energy from the light to an electron. From this perspective, an alteration in the intensity of light induces changes in the kinetic energy of the electrons emitted from the metal. According to this theory, a sufficiently dim light is expected to show a time lag between the initial shining of its light and the subsequent emission of an electron. Light sensors includes photo diode, photo transistors, photo conductive cells, photo voltaic cells, photo junction devices, photo conductive cells etc.

Light Detecting Resistor(LDR): As its name implies, the Light Dependent Resistor (LDR) is made from a piece of exposed semiconductor material such as cadmium sulphide that changes its electrical resistance from several thousand Ohms in the dark to only a few hundred Ohms when light falls upon it by creating hole-electron pairs in the material. The net effect is an improvement in its conductivity with a decrease in resistance for an increase in illumination.

Light detecting resistor can be used in the making of light dependent switch as shown in fig. 5. When light of sufficient intensity is incident on the LDR it’s resistance becomes very low and hence the junction get high potential making the transistor ON which in turn operates the relay hence operating the output to change as per programmed requirement.

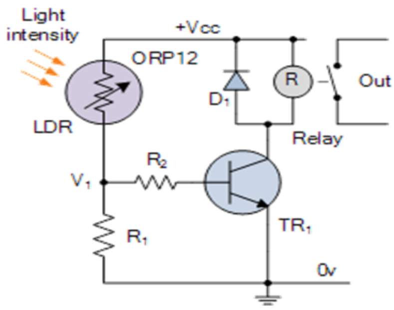

Fig. 5: Light Detecting Resistor as a Switch[5].

VI. Modelling of the Sample Classroom Having Automatic Lighting Control using Sensors

A sample classroom is taken for the modelling of the classroom in which it is assumed that two LEDs are fitted together in place of a tube fitting so that one or two or none lamp may be switched ON and OFF as per the requirement signals sent by sensors. A dedicated unit of sensing assembly is to be put in concern of the fittings which consists of occupancy sensor, light detecting resistor, passive infrared sensor so that in can sense the presence, count and light intensity available at various points of the room. Arduino board is used to connect the signals to the computer and Node- Red software is used to get and evaluate variation in light intensity with respect to time at various places in the room. It can also detect the occupancy in the room.

The LDR is seen at the top of the model to detect intensity of light whereas the occupancy sensor is fixed at the top which can detect the occupancy in such a way that whether at least someone is available in the room or no one is in the room i.e the output is either high or low, 0 or 1 digital signal.

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Controlling sensor units installed on roofs adjacent to tube fittings generates signal variation in respect of luminance, occupancy and count and coordinates with the micro controller near the door. Depending upon the signals the lams will be switched on and off.

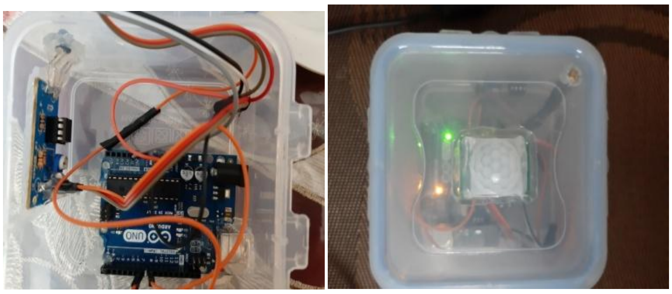

Fig. 6: Sensing unit made for occupancy, count and luminance.

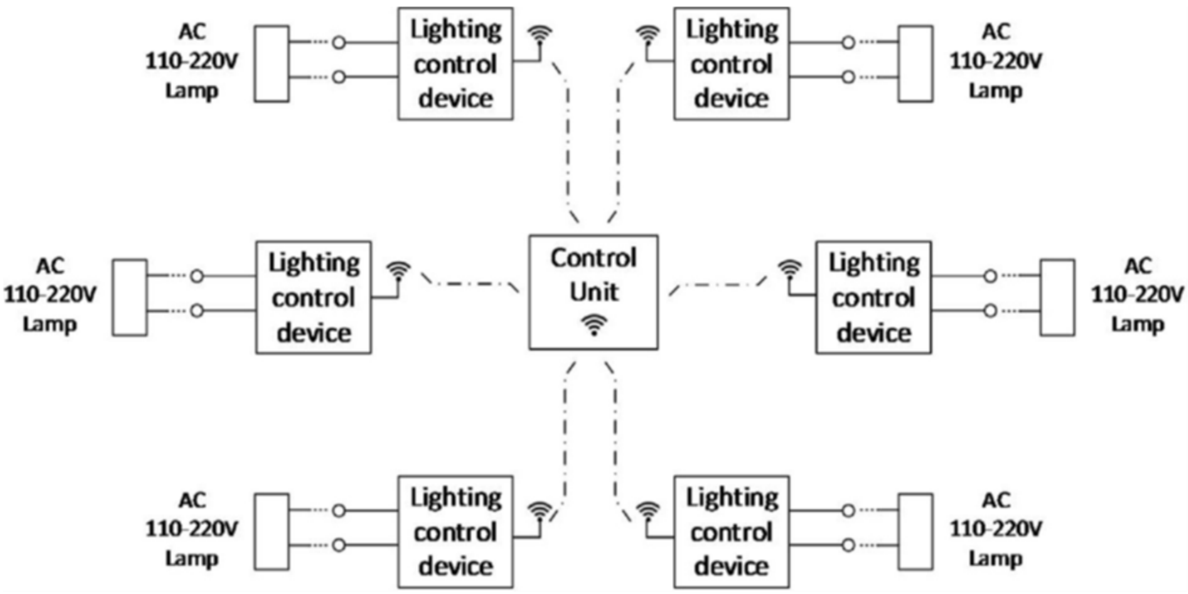

Fig. 7: Installation pattern of sensing units in the room with microcontroller [2].

VII. Results and Discussions

Using LEDs in the building in place of fluorescent tubes and calculating LPD based yearly consumption it is shown that there is a power saving of around 62% for the complete lighting of the building. LEDs used not only saves power and expenditure but also reduces carbon emission as in case of traditional lamps or tubes as they do not have any filament or choke hence they are more eco-friendly.

Taking electrical supply from the rooftop solar plant of the institute providing supply at low rate of Rs. 5.80 per kWh has added to the money saving further by 30% and the excess power can be fed back to the grid. Solar power use has made the institute a energy efficient eco friendly building and has taken the institute a step ahead towards the green building as only sunlight is needed in the process.

With the use of light sensors and light detecting resistors the availability of the sunlight at different parts of the room is being utilized to switch off on and off the pair of LED jointly or individually by receiving of the luminance signal by the micro controller sent by the light sensors.

The aim is that when the light intensity at a point is good under day light, no lamp should glow and when the light available is moderate one lamp should glow and when available light is low both the lamp should glow. If no one is present in the room (0 signal) no lamp should glow irrespective of the sunlight available. This avoids wastage of energy and money and is an important factor of smart

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energy efficient building. This set up restricts the glowing of LEDs when sufficient sunlight is available at that particular place or when nobody is present at that point and the most important is that with the application of sensors the dynamic data and signals are being fed to the controller and hence it is a real time sensing, analysis and controlling energy efficient procedure.

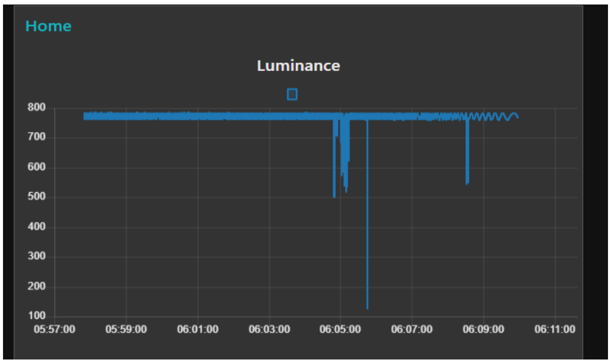

Fig.8: Variation of luminance signal through LDR with varying intensity light.

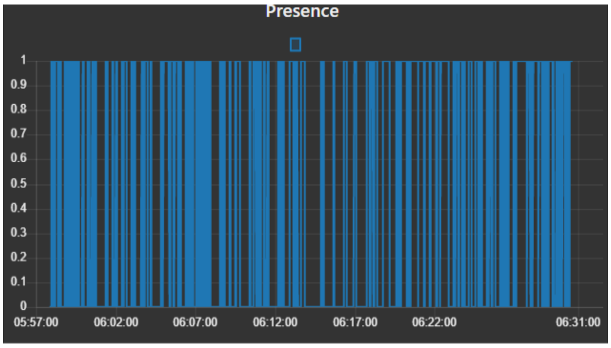

Fig. 9: Presence signal with frequent trial changes in occupancy.

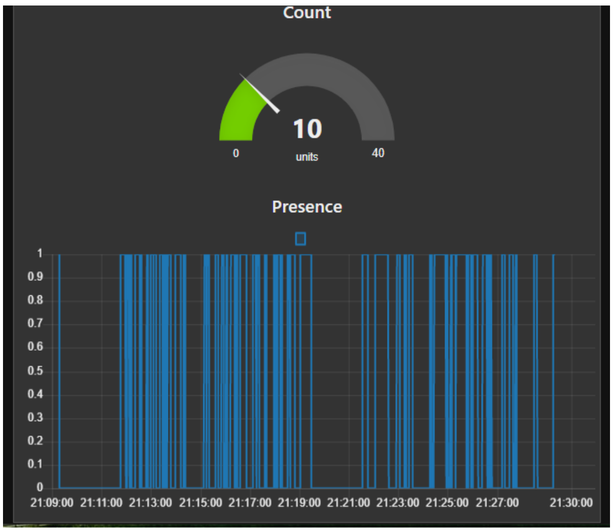

Fig. 10: Presence and count output from the dedicated unit.

VIII. Conclusion

Increased pollution, cities converting into gas chambers, water crisis, decreased resources of energy , limited stock of fuel and gas and the effect of all this on the health of the human being has become a most important matter of concern.

Buildings specially in urban area are the main consumers of power and hence they have to be eco-friendly and occupant comfortable but at the same time they must use less power to be energy efficient building. Combination of all these factors make a building green building. In this study LED application along with the rooftop solar power system has shown a great saving in power consumption and a great concern with green power followed by the application of sensors which makes the building dynamic signal data efficient for better and efficient control of switching lights making the building having smart lighting.

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