Optimal investigation of daylighting and energy efficiency in industrial building using energy-efficient velux daylighting simulation

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**ABSTRACT**

Daylighting is one of the sustainable methods of controlling the flow of natural light into the interior surfaces of the building. Over past years of research daylighting are analyzed through simulation tools due to consistent and precise predictions. The aim of the research is to evaluate the daylight availability in an industrial building under a fixed level of orientation and design. The research initiates by field measurements on the building by an illuminance meter. For the comparative effectiveness, a simulation method is incorporated in the research for a comparative and optimized validation of the daylighting factor. Velux Daylight Visualizer is utilized in this research to simulate the daylighting by modelling the building surface 3 dimensionally with optimal window and glazing material and rendered it to actual interior surface to measure the daylighting at hourly working time zones. Sequentially, the energy utilization of the building is also measured using Velux EIC Visualizer, where the temperature comfort and the total energy utilized for lighting and ventilation is also measured. Hence by improving the design of building to efficient daylighting and ventilation, the annual energy cost investing in artificial lighting and ventilation for industrial operation in a certain period can be restricted respectively.

**1. Introduction**

Energy consumption is identified as one of the major factor and basic need of the modern industrial economy. Industrial and other working sectors are consuming a large quantity of energy for daily tasks. For the conservation of energy different alternative methods give hands to overcome the vital energy consumption issues. Noticeably, daylighting is prompted as an alternate way of conserving the power in the industries during the daytime. Daylighting is depicted as an approach of laying windows, distinct openings and some reversal surfaces in the count to induce the sunlight to provide the lighting inside the industries during the daytime (Verso et al., 2014; Baetens et al., 2010). In occupying the mechanism the particular mention is inclined to the outlet of the building when the inner desire is to reduce the energy and also to attain comfort in the visual preview respectively. Due to the extensive utilization of the electric power the proposed approach has been considered as an adequate source in the industries to overcome the scarcity of energy. In the past decades, the corresponding daylighting is considered an acknowledged source of illumination in the economic and office buildings (Chel and Kaushik, 2018; Chi, Moreno, and Navarro, 2018). Due to the abundant use of the electric lighting and the mechanical ventilation, the stable relationship between the interior appearances has been broken-down so as that the fenestration was constituted as a redundant fact. Thereafter the importance of the daylighting has raised during 1970 because of the lack of energy caused due to the oil crisis and also raise the interest in the late 2000s on behalf of the concern based on the energy efficiency. The promotion of the natural light inside the building may bring out an adequate effect on the dweller’s comfort. In response to the climatic conditions of the environment, the exterior design plays an imperative role (Kneifel, 2010; Oh et al., 2017).

The energy saving mechanism will tempt to induce the involvement of the natural light into the building interior via openings or ventilation in accordance with a supplementary to the corresponding artificial lighting. As a result, the practice will cause energy consumption in the building and also it will bring visual beauty to the interior platform. Unlike, the natural light the radiation and the excessive light in nature may also constitute the glare which may cause the effect of the daylight (Amasyali and El-Gohary, 2018; Wong, 2017; Kaminska and Andrzej, 2018). In the overall architecture of the building fenestration and the shading equipment’s are considered to be an adequate part of designing a building, also it will enable the entrance of natural light and also the outside...
and section 2

section 3

section 4

Hence forth, the system should be modified to the next level to improve the current lapse in the approach (Sun, Yupeng, and Wilson 2018).

Consequently, the recent surveys are accounting the current interest in the prediction of the new technologies to improve the performance and to the increase the level of the daylight (Trisnawan 2018). Hence the artificial lighting may cause many defects on the stair of energy consumption, so it raises the usage of the energy which leads to the scarcity of energy in the upcoming Genesis (García 2017). In the proposed mechanism the importance of energy conservation is taken into count, so this research will create an impact in the future generation to build a belief in the need for conserving the energy. Conclusively, the Computer Simulations are tempted to be a frequently followed practice to probe the efficiency of the daylight on behalf of the accurate and the reliable prediction of the process respectively (Garwood et al. 2018; Krarti and Dubey 2018). Mostly, the performance of the daylight spaces is being analyzed by the numerical multiplication of the advanced features. The simulations are mainly counted on the basis of two main factors such as the static and the dynamic changes occurring in the climatic condition.

The research work is organized in the following ways, the past literature survey about the concept is discussed in section 2, proposed research methodology about the research work is explained in section 3, field measurements and investigation using software tools and its operations are defined in section 4 and the final output of the research is described in section 5, respectively.

2. Literature survey

Most of the building structure is now actuated to implementing efficient daylighting in building to conserve more energy and green potential to the environment. Daylighting procedure not only provides efficient lighting to the surface of the building but also reduce emission inside the building. When it comesto artificial lighting, natural lighting provides better economic and energy consumption in building energy. Oh et al. (2017) examines the effectiveness of coelostat daylighting systems for enhancing the indoor visual environment of open-plan offices. Computer simulations are followed in the research utilizing Trace Pro and Radiance. The output of the IES is exported for concluding photometric analyses. Conclusively, the output result indicates, the proposed coelostat system can improve the energy efficiency of the buildings. The factor behind energy consumption and temperature variation in the industrial building is due to the level of occupants in the building space. Jia, Srinivasan, and Raheem (2017) developed a survey relevant to the modelling of occupant behaviour in building and simulation strategy in validating energy efficiency in building. Song et al. (2018) developed a strategy for daylighting in larger building utilizing heliostat illumination in interior building space in which the system will induce a new system by which the scheme is proposed to deal with the transmission of the natural light into the rooms even though the sunlight cannot enter the rooms directly. The objective of the research is to attain the natural light into the building even without the presence of the natural light. Hence for estimating the process, a heliostat has been implemented in the mechanism along with a secondary reflector and also the glass path which tempts to implement the light into the building. Therefore, the approach will indicate an improvement in the cost-effectiveness in the designed system. Conclusively the proposed scheme will induce a cost-effective and energy conservative interior to the industries by gaining a light transmission of about 70 m per second.

With rapid construction development in Iran and electrical energy shortage, energy-efficient buildings and sustainable development of buildings have become the focus of the society. Amani (2017) evaluate the energy consumption of atria in hot and dry climate zones. The analysis software of Ecotect can provide a scientific basis for energy-saving planning of the buildings. To understand the optimization of residential building planning, factors such as hourly solar exposure, fabric gains, and energy distribution in the building were also analyzed. Utilization of electric lighting in building consumes a larger number of an annual share than a commercial building. By performing daylighting can optimally reduce the usage of electric lighting and hence increase the industrial productivity and economic benefits. De Luca et al. (2018) conducted an experiment on daylighting in a commercial building at cold climate condition in Finland. The evaluation process utilizes various windows and
light control at different skylight condition. During this evaluation, optimal daylighting can be achieved by using natural lighting in building, respectively.

From this research observation, the research motivates to develop Velux daylighting simulation in an industrial building and to evaluate the daylighting factor and total energy consumption in the building. The most building including industrial and commercial utilizes artificial lighting for operation. When considering the economic crisis, artificial lighting schemes consumes many levels of energy. By optimizing the energy consumption in the building reduce the emissions of carbon inside the building spaces comprehensively. Also the daylighting can improve visual comfort inside the workspaces respectively. In recent years, the motivation for improving the daylighting in the building is increases and efficient designs are proposed to develop better daylighting for consuming less building energy respectively. Utilization of natural light in retail spaces has a positive effect on occupants’ comfort. Energy-efficient luminaires, utilizing daylight and demand-based lighting controls are becoming a common practice in today’s low energy consumption buildings.

3. Proposed daylighting and energy efficiency investigation in industrial building

The industrial building is a large spaced building and operated with exhaustive power for running heavy operated machines. The energy is split up into various phases such as air conditioning, indoor lighting and ventilation etc. Due to the energy demands and economic crisis, industrial building architecture is now focused on sustainable development. Conventionally, the industrial building is considered with larger rooms for holding heaving machines and lighting is one of the fundamental needs of these spaces. Illumination by artificial lighting is a more costly process and due to the financial deployment industries and factories alternative method of providing lighting in industrial workspaces. On the revolution of sustainability in industrialization, daylighting is proposed as an alternative deployment of the lighting process in industrial space by renewable means. The fundamental procedure of daylighting houses wall windows, rooftop windows, glazing, monitor etc. In recent years of research, building simulations are one of the primary method followed in the area of architecture to validate the energy efficiency and lighting condition of the building and it is mandatory in many countries. Therefore, it is essential to measure the efficiency of the architectural building design using simulation before it gets constructed. This research motivates to develop numerical simulation using spatial models to predict the daylighting in the large-sized building structures. For the prediction of efficiency in daylighting and energy consumption in the industrial building, the architecture of the building is simulated with Velux Daylight and EIC Visualizer.

The research starts with field measurements on entire industrial building using the illuminance meter with pre-defined windows and glazing according to the Indian standard of daylighting. The optimal output can be boosted up from the field measurement with a simulation program. Implementation of the simulation program starts with modelling the entire building 3-dimensionally and mounted and rendered with extra glazing material and windows, wall opening for improving the illumination level. The Velux daylight simulation is processed on the model to find the lighting condition of the building at clear sky condition. The illuminance and luminance level of the building is measured for validating the lighting condition of the building. The simulation is undergone for a different time and climate zone in the building measuring the daylighting factor in the interior structure under standard sky descriptions. After the daylight visualization, Velux EIC is utilized in the research to estimate the energy and thermal comfort in the simulated building space. The rendered model is subjected to better ventilation and air quality management for better thermal comfort inside the working area. As a final point, the predefined design is optimized with better daylighting, thermal comfort and air quality in the building, respectively. From the comparative study, the optimal design from the simulation scores better than default building structure evaluated from the field measurements respectively.

4. Investigation of daylighting and energy consumption in industrial building

The experimentation starts by investigating the daylight in industry and simulation is undergone to evaluate and compare the performance of daylighting and energy consumption of industrial building, respectively.

Investigated industrial building

The experiment is conducted on the single floor elevator industrial building situated in Coimbatore, Tamil Nadu of floor area dimension of 156 m length, 162 m wider and a height of 14.5 to 11 m which is shown in Figure 1, respectively. The building is designed with daylighting fenestration such as sidewall windows, top daylighting panels for lighting and ventilation and wall doors, respectively.

The factory is fitted with an electricity monitoring system for measuring the consumption and usage of electricity in the production line, heating, ventilation, air conditioning (HVAC) and reserved power etc. when compared to artificial lighting, natural lighting scores better result and contribute major role of electricity consumption.
Field measurement of daylighting

The illuminance of the building structures is measured using illuminance meters made from Gravity Lab 9.0V with a range of 0–2,00,000 LUX with the accuracy of +5% of reading and working on a power source of 1 × 9.0V (6F22). The dimension of the meter are classified as photo detector of 82(H) x 55(W) x 7(D)mm and meter composed of 148(H) x 70(W) x 40(D)mm, respectively. As the area of factory is restricted to some constraints such as machines, materials and workers, hence around 85–90% pre-planned points were measured.

These estimated values are referenced from the Indian lighting design standard of the buildings (IS 6665–1972). Based on the reflectance, the building is designed and it is provided in the research work respectively. The measurements are undergone for the time period of 9–10 am, 11–12 am, 13–16 pm and 17–16 pm and the illuminance were measured for each time interval and noted. The measurements on the building are conducted on the horizontal plane at a height of 0.75m above the building floor respectively.

In Figure 2, the industrial building is modelled in the software and rendered for the daylighting simulation. For the effectiveness, the compartments are filled with different tools, machines and equipment’s mentioned (in Table 1) as grey for finding the proper daylighting in working building respectively.

4.1. Daylighting simulation using velux daylighting visualizer

The illuminance simulation of factory building is undergone with Velux daylighting visualizer and analyzed for the entire day of factory operations. The

| Surface                        | Reflectance Values |
|--------------------------------|--------------------|
| Ceiling                        | 80–90%             |
| Walls                          | 40–60%             |
| Desks, Bench Tops, Machines And Equipment | 25–45% |
| Floors                         | Not less than 20%  |

Table 1. Reflectance values of building lighting.
configuration of system used in the simulation is mentioned in the Table 2 respectively.

The building model and daylighting simulation is created on the Velux Daylight Visualizer and simulated the building by setting the plane as 0.75m above. The simulation is conducted for the real-time assessment points of the time period from 9–10 am, 11–12 am, 13–16 pm and 17–18 pm under clear sky condition of Energy and Indoor Climate Visualizer was used as the climate condition. Table 1, shows the reflectance of the building envelope and the visible transmittance of the top daylighting panels, side windows and top vertical skylights used for the daylighting simulation. According to the Indian lighting design standard of buildings (IS 6665–1972), the reflectance values of floors, tools, machines and equipment, walls, and ceilings are recommended to be 20%, 25–45%, 40–60% and 80–90%, respectively. Hence, the reflectance values of the floors, tools, machines and equipment, walls, and ceilings for the simulation were estimated to be 35%, 50%, 65% and 85%, respectively. The design specification provided by the designer states a visible transmittance of 50% for the side windows and top vertical skylights and 30% of the top daylighting panels respectively.

In Table 3, the daylighting in the industrial building is analyzed under different work zones. The daylighting is considered under illuminance and luminance ranges for different time zones. During this evaluation, maximum illuminance and luminance ranges are achieved under natural lighting conditions respectively.

In Table 4, the illuminance and luminance level of the industrial building is 3-dimensionally rendered and analyzed under different time zones. During this evaluation, illuminance and luminance ranges of the evaluated zones are measured using Velux Daylight Visualizer during 11–12 am, respectively. The measurements clearly define, the rendered images will clarify that by placing of windows and glazing material can improve the natural light which consumes the usage of the artificial lighting in industrial workspace during the sunny days respectively.

In Figure 3, the daylighting of an industrial building is analyzed for the annual time period. The time period considered for the building is from January to December month with different climate zones. During this evaluation, maximum daylight is achieved in the winter and autumn than other seasons. During these lower daylight, artificial light is considered and consumes more electric energy during these seasons respectively.

In Table 5, the daylighting in the industrial building is analyzed under annual months. The evaluation is undergone with two stages, field experimented and software simulated. The experimental analysis is undergone with illuminance meter in the default building and the simulated with mounting the windows and glazing element for optimal illuminance level. Average daylight lux level during each month is evaluated and achieved maximum lux level of 902.3 and minimum of 550.3 lux than experimented results in above Figure 4, respectively. Hence, from this evaluation, simulated daylighting scores mean lux of 759.7 lux annually and can be considered as optimal daylighting.

4.2. Analyzed daylighting factor

There are two types of daylight factor can be calculated namely Point DF and average DF (DFave). The following equation can be used to evaluate the daylight factor of the industrial building.

\[
DF = \frac{\text{Horizontal Unobstructed Outdoor Illuminance from Light}}{\text{Indoor Illuminance}} \times 100\%
\]

Where, DF be the average ratio of illuminance of indoor daylight to the horizontal unobstructed outdoor illuminance.

The daylighting factor is validated on the industrial building with different time zones such as 9–10 am, 11–12 am, 13–16 pm and 17–16 pm. In Table 6, the daylighting is analyzed in the workspace for the time period of 11–12 am is considered. Validation of daylight factor is achieved when the building is mounted with window sections of absolute shape, size and position. DF is the most widely used indices under
international standardization and one of the disadvantages of daylight factor is these factors are not efficient for calculating direct sunlight. For upgrading the current issues of evaluating the direct sunlight by DF, the illuminance ratio is set to vertical to horizontal, where the light gets decreased over the vertical plane. Therefore the illuminance level is measured by the Daylight Autonomy (DA) and maintained on the basis of certain time as both annually or months.

4.3. Optimizing the energy consumption of the building
Along with daylighting simulation, energy consumption and energy saving potential (ESP) of the daylighting in

Table 4. Illuminance and luminance range of indoor daylighting.

| Daylighting in Industrial Work Space | Illuminance | Luminance | Illuminance | Luminance |
|-------------------------------------|------------|-----------|------------|-----------|
| Inspection Line                     | Machine Line 1 |
| Machine Line 2                      | Stocking Line 1 |
| Stocking Line 2                     | Office |
| R&D                                 | Warehouse |

Figure 3. Measurement of average daylighting in months.
the factory is also evaluated. To forecast the ESP of the daylighting Velux EIC Visualizer is used in the study. The particular simulation underwent the energy consumption of the factory by reducing the artificial lighting. The analyzed geometry is explained in below Table 7 respectively.

The factory building models on top side considering with and without glazing materials are simulated for daylighting and energy utilization under full skylight condition. Since the factory is equipped with electrical heating in particular season like winter for heating the workspace. Therefore, all the simulation constraints consider heating system during the heating time interval. Also, evaluate the effect of quantitative measures of reducing the artificial lighting and total energy consumed for the heating is also evaluated. The simulation starts by modelling the dimensions of the factory building in EIC Visualizer by mounting the glazing windows on the condition of with and without consideration. The industrial space is allocated into several zones and illumination orientation points are fixed at each zone to control the lighting operation of particularly marked zones. The illuminance transducer is placed at the marked points and evaluate the level of illuminance at the regions and feedback the signals to the controller for controlling the artificial lighting in the building. When the daylighting illuminance in the zones increases, the overhead lights in the factory get diminishes and reduces the output of the electric power and consumption of artificial light in the building. When the dimming point level reaches a maximum, the lights are completely switched off. The status of On/Off control in the building is determined based on the daylight autonomy (DA). Therefore, the mathematical

Table 5. Comparison of average daylighting level in industrial building.

| Months      | Experimentally Measured | Simulated |
|-------------|-------------------------|-----------|
| January     | 867.3                   | 877.2     |
| February    | 835.1                   | 843.5     |
| March       | 827.5                   | 838.6     |
| April       | 748.2                   | 755.6     |
| May         | 694.4                   | 701.6     |
| June        | 652.7                   | 664.0     |
| July        | 546.8                   | 550.3     |
| August      | 554.9                   | 563.7     |
| September   | 683.8                   | 702.0     |
| October     | 837.6                   | 840.2     |
| November    | 871.6                   | 884.9     |
| December    | 885.0                   | 902.3     |
| Mean        | 754.0                   | 759.7     |
| Mean*8760.0 hr. | 6,573,577.0 | 6,655,177.0 |
| Min         | 546.8                   | 550.3     |
| Max         | 885.0                   | 902.3     |

Table 7. Analyzed geometry of the building.

| Geometry of the Industrial Building |
|------------------------------------|
| Plots Area | Building Foot Print | Building Volume | Heated Floor Area | Average U-Value | Window to Heated Floor Area Ratio | Façade Window to Heated Floor Area Ratio | Roof Window to Heated Floor Area Ratio | Free Ventilation Opening Area (flaps closed) | Free Ventilation Opening Area (flaps closed) | Free Ventilation Opening area (window opened) |
|-----------|---------------------|-----------------|-------------------|----------------|----------------------------------|-----------------------------------------|-----------------------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|
| Measurements | 176 m² | 604 m³ | 176 m² | 0.4081 W/(K.m²) | 20% | 16% | 4.4% | 0 cm² | 25,450 cm² | 34,020 cm² |

Figure 4. Experimented Vs simulated average daylighting level.
equation to evaluate the daylight autonomy (DA) in the factory building can be expressed in the following equation as below.

$$Elec = \frac{P_{total} \times h_{total} \times (1 - DA)}{DA}$$

(2)

Where, $Elec (kWh)$ is the total consumption of electric power by artificial lighting for the On/Off control, $P_{total}(kW)$ is the total power consumption of artificial lighting in the industrial building, $h_{total}$ is the overall occupied hours in the building.

$$DA = \frac{h_{DA}}{h_{overall}}$$

(3)

Where $h_{DA}(h)$ is the daylighting met the minimum illuminance level for total hours which is evaluated in the simulation process. The targeted measured illuminance level attained at work area above the floor will be 397 lux and density of lighting power inside the building is said to be 13W/m². Simulation runs for the days and months (24 hr. on weekdays and 8760 hr per months). For measuring the energy consumption potential of the building, it is set to be 1824.3 Mwh, which is considered as the total lighting made artificial and turns on full working hours. The primary temperature of the indoor is set to be 23°C based on the design specification.

The simulation is set to the operation schedule of 24 hr on working days during the heating period. Assume, the air change rate per hour of the factory was about 0.5, respectively. The simulation is undergone for evaluating the indoor daylighting performance based on the experimented data and the performance measures of the simulation are noted. For quantitative analysis of the evaluated data, the following equation is used to find the similarity coefficient.

$$SIM_{ij} = \frac{\sum_{k=1}^{m} x_{ik} \cdot x_{jk}}{\sqrt{\sum_{k=1}^{m} x_{ik}^2 \cdot \sum_{k=1}^{m} x_{jk}^2}}$$

(4)

Where, $SIM_{ij}$ is the similarity coefficient, i and j represent the experiment and simulation images, respectively, k is the index of sample points, x is the illuminance of sample points. The value of $SIM_{ij}$ is between $[-1,1]$, $SIM_{ij} = 1$ represents the two images are most similar while represents the two images do not match at all. For further comparison between the evaluated results, the relative error (RE) between the measured and the simulated results were calculated from the following equation.

$$RE = \left| \frac{MI - SI}{MI} \right| \times 100$$

(5)

Where, $MI$ is the measured illuminance value at each measurement point and $SI$ is the corresponding simulated illuminance value. The maximum RE value was
found to be 48% and the minimum RE value was about 1.0%, respectively.

In Table 8, the energy consumption of the industrial building is analyzed under natural daylighting and electric daylighting. The two daylighting strategies are equipped with lighting panels with energy saving potentials as identical. By considering no lighting panels on the top layer, the dimming controller in building performs better outcome than on/off the controller. Thus by considering the natural light, the energy consumption will lower and better energy saving design than artificial electric lighting in industrial buildings respectively.

4.4. Simulation of energy consumption using EIC visualizer

The simulation is conducted for analyzing the energy consumption of building utilizing natural daylight and reduce the consumption of artificial lighting and heating.

In Figure 5 and 6, the energy performance of the industrial building is analyzed under the illuminance level. Natural lighting and air ventilation are mostly consumed during the summer and autumn season in the whole year of 2018, therefore the utilization of interior lighting and air condition is reduced during these periods. From the graph, it clearly shows the energy consumption of electric lighting seems to be lower by utilizing window and glazing elements in the building respectively.

4.5. Ventilation and heating energy consumption

The ventilation and heating energy is analyzed for total energy consumption of the industrial building. The resulting is undergone with top daylighting panels for ventilation and analyzed under on/off control system and dimming control system.

In Table 9, when the heating load increased, it simultaneously consumes larger the electric power. The consumption of electricity can be lowered by utilizing the natural ventilation system through top daylighting panels. The daylighting will open for ventilation when the temperature rises above 20°C. It will reduce the working of electric power-based air conditioning system in industries. Therefore, by considering the top daylighting panels for lighting as well as ventilation, the overall consumption of electric power for heating and cooling will be lowered. Consequently, the total energy saving potential of the industrial building tends to be higher for natural daylighting procedures respectively.

In Tables 10 and 11, the overall concluded results of simulation in EIC visualizer is elaborated in this section.
Figure 6. Energy performance of building including individual windows.

Table 9. Integrated daylighting and ventilation system for heating energy consumption.

| Analyzed Parameter                           | With Top Daylighting Panels | Without Top Daylighting Panels |
|----------------------------------------------|-----------------------------|-------------------------------|
|                                              | Benchmark                   | With/Off Controller          | Dimming Controller         | Benchmark                   | With/Off Controller          | Dimming Controller         |
| Consumption of Heating Energy in (MWh)       | 1502.4                      | 1625.2                        | 1643.6                      | 1478.5                      | 1480.5                        | 1643.6                        |
| Heating Energy Consumption Increase (MWh)    | -                           | 122.6                         | 130.3                       | -                           | 32.7                          | 124.2                        |
| Increasing Proportion (%)                    | -                           | 8.2%                          | 9.5%                        | -                           | 2.5%                          | 7.8%                         |

Table 10. Simulated outcome of EIC daylighting visualizer.
Table 10. (Continued).

Surface Heat Flux

Comfort Temperature

PPD and PMV

Wind Opening

Indoor Air Temperature
Table 11. Simulated outcomes of EIC visualizer.

|                | Ventilation                                                                 | Thermal Comfort                                                                 | Energy                                                                 |
|----------------|------------------------------------------------------------------------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------|
| **Simulation** | ![Ventilation Graph](image1.png)                                             | ![Thermal Comfort Graph](image2.png)                                         | ![Energy Graph](image3.png)                                         |
| **Simulation** | ![Ventilation Graph](image4.png)                                             | ![Thermal Comfort Graph](image5.png)                                         | ![Energy Graph](image6.png)                                         |
| **Simulation** | ![Ventilation Graph](image7.png)                                             | ![Thermal Comfort Graph](image8.png)                                         | ![Energy Graph](image9.png)                                         |
| **Simulation** | ![Ventilation Graph](image10.png)                                            | ![Thermal Comfort Graph](image11.png)                                        | ![Energy Graph](image12.png)                                         |
5. Conclusion

Daylighting is one of the fundamental needs of building structures, even buildings are mounted with glazing materials and windows daylighting is not getting better efficiencies in visualization. Daylighting not only concern lighting in the building but also a sustainable energy efficient discipline of architecture. Conventionally, industrial buildings are mounted with side and rooftop windows for adequate daylighting and thermal comfort into the building. Depending on the climate conditions, it is evident daylight will depend on the glazing control and illuminance level. For the improvement of effective daylighting in industries, proper measures of building orientation, climate, type of glazing and usage of artificial lighting is required. In this research, an investigation is carried out in the industrial building to improve the daylighting and to enhance energy efficiency in building from artificial lighting. A comparative study is contrasted with the actual field experimentation and simulation study. For the effectiveness of daylighting and energy efficiency, this research develops a simulation program is integrated into an industrial building with windows and glazing materials to evaluate the daylighting and thermal comfort in terms of illuminance and luminance level. Intelligent-based lighting control design can effectively increase the daylighting and also improves the total energy consumption of the building. Daylighting simulation tool and techniques are improved and computationally feasible for the research study. These tools are marginally available and liable to modell complex controls. Based on the observation, this research study proposes Velux Daylight Visualizer for modelling the complex structure of the industrial building to analyze the daylight. From the simulation, it is found out that, the maximum level of daylight level is of 902.3 lux. Sequentially, the energy consumption of the building is also measured using Velux EIC visualizer, where top lighting panels are considered for the evaluation. The intelligent-based lighting control with on/off and dimming control measures the total energy consumption of the building. During the evaluation it is found out by mounting the top daylighting panel, a maximum range of ESP as 25% in on/off control and 31.4% in dimming control which is better than without mounting top daylighting panels respectively. Ultimately, this research study gives the solution to effective daylighting and a way to optimize the consumption of energy from building artificial lighting in industries. By utilizing this research observation, it gives guidance for reducing energy consumption and promote better productivity and economic benefits to the organization, respectively.

Disclosure statement

No potential conflict of interest was reported by the authors.

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