

Daylight Harvesting Optimization for Commercial Buildings using AI Technique

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Abstract – As Energy consumption in buildings increases considerably from year to year due to the increase in human comfort needs and services. In addition to weather conditions, several factors influence the energy consumption for cooling buildings, such as the structure of the walls, the window-to-wall ratio and the orientation of the building. The energy consumption of buildings has been reported to represent a relatively large proportion of global energy consumption.

Keywords: Solar Energy, Daylight harvesting, Optic Fiber, Energy savings, LED luminaires, Artificial Intelligence, Commercial Buildings.

I. INTRODUCTION

Global warming and climate change have become growing problems over the past few decades. Buildings, including commercial and residential buildings, contribute significantly to energy consumption. Buildings are the main consumers of energy, accounting for over 40% of energy consumption in the United States. According to the US Department of Energy, heating, ventilation and air conditioning (HVAC) systems consume approximately 17-20% of a facility or building's total energy costs. The global equipment requirement for HVAC systems grew from about \$ 50 billion in 2004 to over \$ 90 billion in 2014, and for the United States from nearly \$ 11 billion to \$ 19 billion over the same period.

The thermal properties of building envelopes have become increasingly important to planners and homeowners due to their link with reducing energy consumption. Poor thermal insulation in buildings can lead to a higher probability of surface condensation if the air has a relative humidity of more than 80% and the heat transfer coefficients for convection and radiation of the external walls are low [9]. The purpose of this chapter is to discuss the benefits and design guidelines for zero-energy buildings. NZEBs have enormous potential to change the energy use of buildings. In response to regulatory mandates, federal agencies and many other state and local governments are beginning to move closer to the targets for NZEBs.

Many states in the United States are mandating many rules and regulations to reduce the buildings' energy consumption. For example, New York and California, which house more than 20% of the United States' population, produce less than 10% of its carbon emissions. These two states are leading the way in decreasing energy use through the proliferation of net-zero energy building in addition to other strategies.

The definitions apply to network independent facilities. Supply-side option 2 can be used for all definitions if this resource is available during the life of the building [8]. External ZEBs can be achieved by purchasing renewable energy from external sources or, in the case of an external zero-emission building, by purchasing carbon credits. To meet the DOE's ZEB research needs, the following definitions refer to ZEBs using locally available supply-side options. In the case of ZEBs that obtain part of the renewable generation from external sources, these buildings are referred to as "off-site ZEBs".

When the NZEB concept becomes technically and economically feasible, it will be possible to extend its boundaries to groups of buildings, campuses, municipalities, cities, bases or cities. An alternative to individual NZEBs is zero-energy campuses, neighborhoods or communities. The extension of the net zero energy limit beyond a single building takes into account the emergence of communities, neighborhoods and campuses that generate RE for a given group of buildings; However, energy is not necessarily connected directly to the meter of a particular building. This would be considered a Community RE system connected to the grid or to a district heating or cooling system.

II. LITERATURE REVIEW

Doulos, L.T. et al. [1] used a typical classroom in a Greek public school, examined a range of lighting technologies (AC and DC) and two systems for using sun-shine. The former uses a standalone photo sensor per device, while the latter uses one sensor per control zone to calculate energy savings and adequate lighting. The attenuation curves of the DC LEDs were measured with the installed power of the photosensors. The results show that the annual consumption of primary energy available for

lighting can be reduced from 90.5 kWhp/m² to 0.55 kWhp/m². The maximum annual reduction in CO₂ emissions was 32.44 kg/m² for the classrooms, which is converted into 201.29t for the entire country. Clearly the path to zero-energy school buildings goes through the mandatory use of sun-shine control.

Fathalla Selim et al. [2] presented are the most power system planners are interested in the savings of electrical power consumption. Various references demonstrate that the highest consumed power is by the lighting systems standing around 19% of worldwide energy consumption. This article presents novel design methodology leading to maximizing revenue due to savings in electrical energy consumption through energy efficient installations. This hybrid methodology is built by combining benefits of the two traditional lighting design methods (lumen and specific connected load methods). This results in developing a new mathematical and applicable model with many advantages such as: high accuracy, fast calculations and most economical design. This proposed methodology is supported by MATLAB® package to shorten the long time consumed by conventional procedures and simplify the complex manual calculations. The hybrid method verifies its effectiveness and efficiency for achieving the maximum savings in energies and costs through the detailed discussion of case studies.

Mykola Tarasenko et al. [3] analyzed the dependence duration of sun-shine autonomy in office rooms, on the value of sun-shine factor for four European cities. The specific sun-shine autonomy (h/(year·m²)) of office rooms were found. It was proved, that regardless the size of the rooms, the maximum specific sun-shine autonomy in Ternopil city (at illumination of 300 lx, which is prescribed by regulations), with lateral sun-shine, occurs when the sun-shine factor is in the range of 1.7% to 1.9%. Maxima – at 1.8%. At illumination of 500 lx, the maximum specific sun-shine autonomy will occur at a sun-shine factor range of 2.6% to 3.0%. Maxima – at 2.8%.

Evangelos Manolis et al. [4] in the lighting market to fill this gap in the relevant literature by focusing on one European country, Greece, to understand the implications of various European and national directives. In order to increase the informative value of the results, a total of 9,609 desk lamps were selected for the European market. After verifying any errors in the data, a careful statistical analysis was carried out to determine the composition of the market, taking into account technical characteristics such as the type and destination of each luminaire, its luminous efficiency, its color temperature and its color rendering index, and some other attributes that affect the compliance of the luminaires with the directives, but also their suitability for an efficient lighting project. The method used in this article is intended to support future policy making as it provides a solid quantitative basis for studying policy implications, but also for lighting designers to understand the current state, but also future trends, of the environment. Adjust accordingly. Choose. The analysis of the light output showed that around 48% of current office luminaires do not exceed the limit value of 85 lm/W set by the EU. Only 5% or 13% of luminaires can be used for general

lighting and thus for energy-efficient lighting planning for work lighting without creating more luminaires than necessary.

Kateryna Kozak et al. [5] aimed at investigating the parameters of translucent structures of building envelope, and the value of sun-shine factor, for which maximum efficiency of sun-shine usage is achieved in office rooms. The study analyzes the dependence duration of sun-shine autonomy in office rooms, on the value of sun-shine factor for four European cities.

Piotr Pracki et al. [6] examines the influence of room and luminaire properties on general lighting conditions and energy efficiency in interiors. Seventeen types of luminaires with different light distributions were arranged in uniform floor plans in rooms of different sizes and reflectivity. Average brightness, uniformity and normalized power density with respect to two horizontal working levels were calculated. The influence of the reduction of the work load, the environmental index and the degree of reflection, the lighting class and the distribution of the luminous intensity of the luminaire on the parameters considered was examined. Using the reduced operating level resulted in an increase in average luminance (average 7.7%), uniformity (average 33%), and normalized power density (average 23%). The influence of the room index and lighting class on average luminance and normalized power density was significant, while the influence of luminaire light intensity distribution and light reflection was weak. The standard power densities for general electric interior lighting with a luminous efficacy of 100 lm/W are in the order of magnitude of: 1.08-3.42 W/m² per 100 lx. Based on these results, a normalized power density of 2 W/m² per 100 lx is recommended for the design and evaluation of new general electrical building lighting. Energy consumer at the end of the 20th century and today consumes about 40% of total energy consumption.

Arimaz Hangga et al. [7] aimed at determining the effect of the type of anchor light. The results of this research are expected to increase the efficiency of electricity costs and use the optimal lighting system for classrooms according to the Indonesian National Standard (SNI). Two types of lighting fixtures that were used in this research; H. Fittings for LED tubes and fittings for LED lamps. For this survey, room E11-210 in the E11 building of the Department of Electrical Engineering of the Universitas Negeri Semarang was used with a size of 12 mx 9 mx 3.5 m. The simulation of this study used the DialuxEvo 9 software. The results of the observations and simulations show that the E11-210 class at 350 lux had not yet followed the SNI. Based on the simulation results, it shows that the use of LED tube fittings and LED luminaires can achieve the light intensity of classroom E11-210 in accordance with SNI 6197: 2011. The simulation results show that the The use of LED (Power balance Gen2 RC463B) tubular anchors in classroom E11-210 increases electricity cost efficiency by 27.81%. Meanwhile, the use of LED (Lux space Ace Accent RS750B) lights in classroom E11-210 will increase the cost efficiency of electro centricity by 33.96%.

Natalia Sabat et al. [8] uses astronomical relays and motion detectors to determine the cost-effective and energy-efficient use

of artificial light control using different types of light sources for stairwells (floors and stairwells) in multi-story residential buildings. An analysis of the monthly intensity of movement of residents of 9-story residential buildings through house entrances, house entrances and apartment doors was performed. The cost-effectiveness and energy efficiency of using artificial light control systems with astronomical relays and motion detectors with different light sources were determined. Regardless of the type of light source, using the astronomical relay results in a reduction in the energy consumption of artificial lighting by 43.31% - 50.52%. The cost-effectiveness and energy efficiency of using lighting combined with artificial light control for stairwells in multi-storey residential buildings has been demonstrated.

Haq Mohammad et al. [9] have shown that lighting control systems provide significant energy savings and can lead to reduced electricity costs. The decline in electricity demand also has a positive impact on the environment as the carbon footprint is reduced. But each of the control technologies has different properties that affect their performance. The behavior patterns of the residents, the geometric properties of the room or building, the ingress of sun-shine, the type of work performed, etc. have profound effects on lighting control systems, as the discussions in this article show. Only with a good study of these factors can a correct technological implementation be obtained, which can lead to significant energy savings and ensure the comfort of residents.

During a 12-week real-world experiment in six offices with ten participants, Z. Nagy et al. [10] presented investigations into lighting control systems, the basic control of which depended on how workers worked. Users were satisfied with the results, with the exception of those who did not find automatic lighting control important. The lights were always on on time and the shutdown on time was only logged 75% of the time. Thus, 13.4% of electricity could be saved without significantly harming employee comfort. The result is that the electricity savings obtained are 13.4% with no significant impact on the comfort of residents.

III. METHODOLOGY

The Building Energy Building Guideline proposed the Smart Buildings theory to encourage renewable energy generation, versatility, and interaction techniques. Numerous interpretations of Smart Buildings (SBs) have been suggested in the study by multiple research communities. The essence and characteristics of smart buildings are also a bit hazy. The idea of building energy retrofit has been proposed to reduce energy usage and attain the Zero Energy Building benchmark. It is critical to transform current retrofitting methodologies to smart retrofitting approaches so that the goal of near-zero energy buildings can be easily accomplished and different sources including seasonal changes and grid can be easily managed.

Sun shine Collecting- Light sensors detect the luminous intensity from natural sources and transmit data to the control scheme, which is used in the sun-shine collection system. The electronically controlled lights are then adjusted by the controller

based on the measurement scale. In general, there are two different types of sun-shine collecting controller: open-loop and closed-loop systems. The artificial system also isn't needed to provide responses in such a system. A closed-loop system, on the other hand, assessed the quantity of sunlight intensity through both natural and artificial inputs.

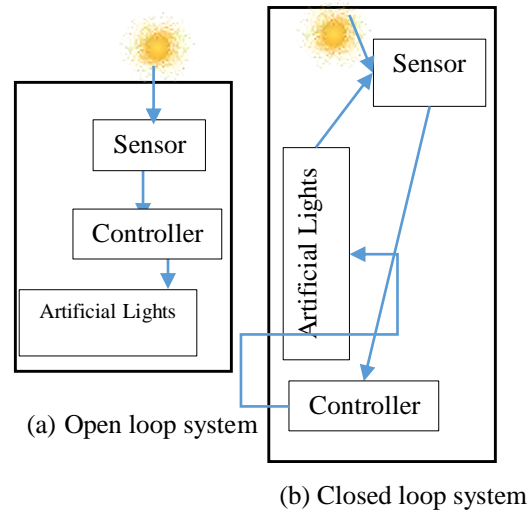


Fig.1. Sun-shine collecting control system

An Artificial Intelligence enabled PhotoVoltaic solar collector, fibre optic directing system, leading lights, and control circuits which are enabled by internet of things make up the smart sun-shine collecting conceptual model. IoT is used to regulate all of these elements.

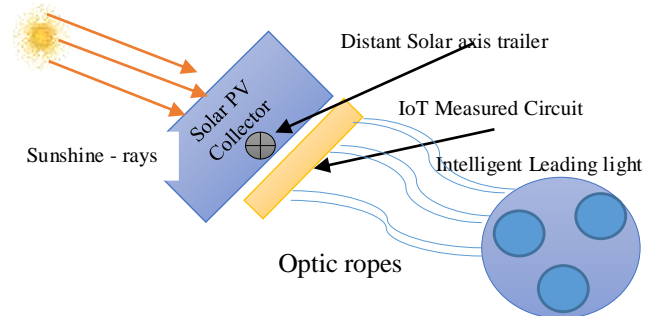


Fig.2. The intelligent sun-shine collecting system

This outline demonstration the assembly prototype for commercial building lighting implementations.

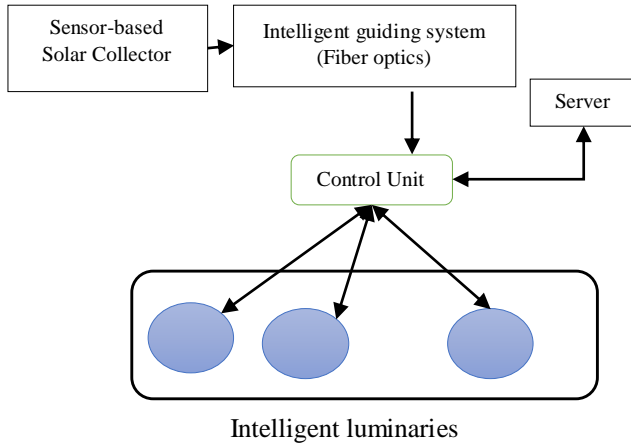


Fig.3. Block diagram for Proposed Architecture

IV. RESULT AND DISCUSSION

The proposed methodology is simulated using MATLAB SIMULINK platform to carry out calculations to obtain the Power output from solar panels and from conventional sources. The model is trained using neuro-fuzzy AI technique that automatically control the power requirement according to need. The simulation is performed in following conditions which are discussed as below:

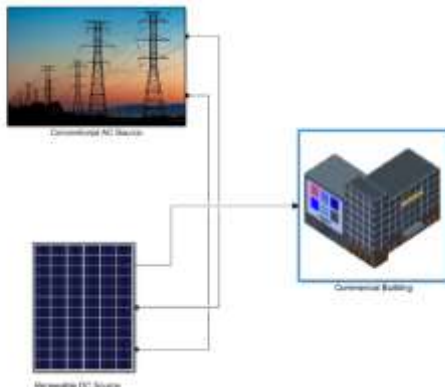


Fig.4. Simulink Model Sun-shine collecting System

This model is designed on Simulink for sun-shine collecting system. To supply in commercial buildings, the model is hybridized with conventional sources and renewable source. The model is designed to maximize the energy supply from sun-shine collecting and minimize the supply from conventional sources.

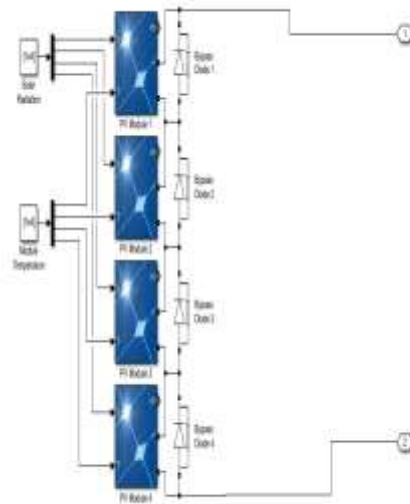


Fig.5. Simulink Model PV Modelling with variable irradiance

The solar radiation level falling on the PV panels varies depending on the location of the panel and the time intervals in a day. Therefore, solar radiation level has a direct effect on the panel power. As a result, a decrease in solar radiation level reduces the panel power. The figure 5 represents the Simulink model for PV modelling to receive variable irradiance. The model is designed to convert the solar energy to electrical energy.

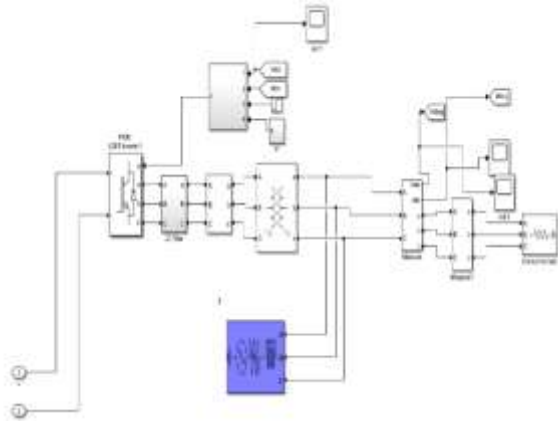


Fig.6. Simulink Model Grid Modelling for AC Supply
 Fig 6 represents the Simulink model for AC supply from the grid and the objective of this simulation is to minimize the usage of this AC supply.

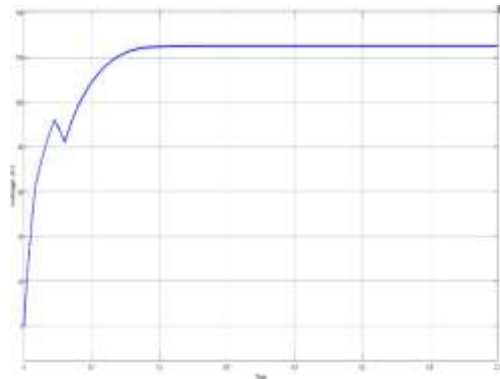


Fig 9. PV with Conventional Source Voltage Analysis
 Figure 9 represents the voltage analysis of PV with conventional source.

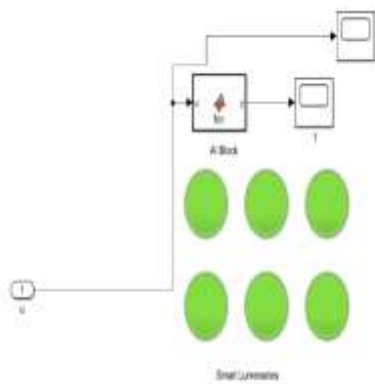


Fig 7. AI Controlled Luminaries

Figure 7 represents the AI implementation for automatic control of power supply either in AC form from conventional sources or in DC form from sun-shine collecting.

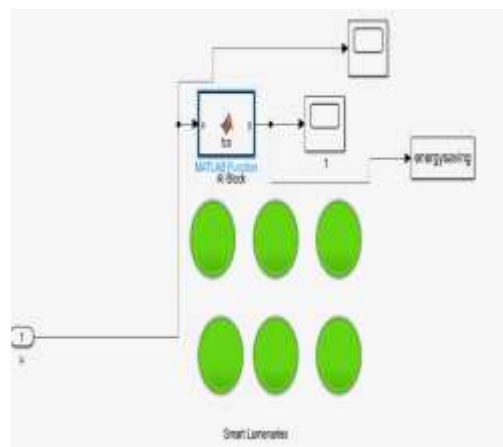


Fig. 10. PV with Conventional Source Power Analysis
 Figure 10 represents the power analysis of PV with conventional source.

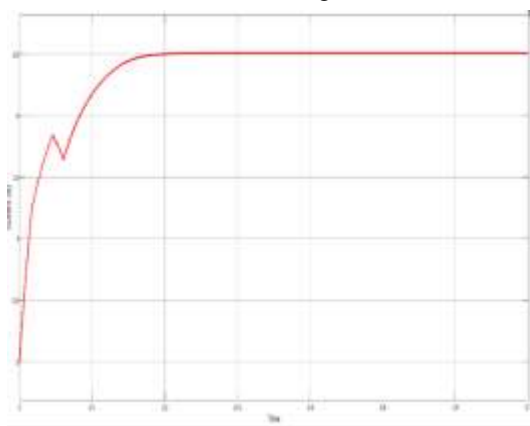


Fig 8. PV with Conventional Source Current Analysis
 Figure 8 represents the current analysis of PV with conventional source.

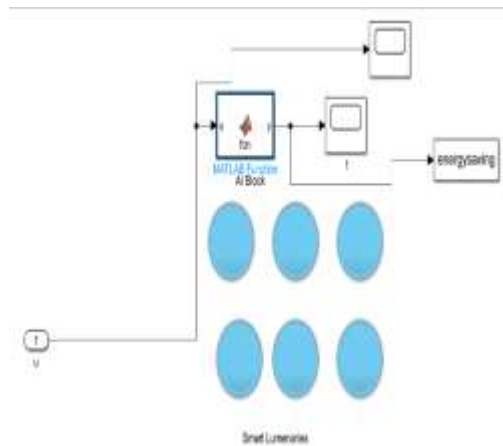


Fig.11. LED Illumination with AC and DC supply
 Figure 11 demonstrates the illumination of LED lights with AC supply (conventional sources) and DC supply (sun-shine collecting). The green represents the AC supply and blue represents the DC supply. This reduces the overall building energy dependency on AC supply. The LED are integrated with

AI block that automatically switches between energy supply, i.e., from AC to DC or from DC to AC according to density and load of the room.

Table I: Energy Saving Evaluation with Variable Load

Load (in Watt)	Energy Saving
50	95.44%
100	92.86%
150	91.02%
200	88.05%
250	84.49%
Average	90.372%

Table II: Energy Saving Evaluation with Variable Time with different density of rooms

Parameters	Energy Saving
1hr	78.73%
2hr	95.44%
3hr	95.44%
4hr	94.30%
5hr	95.44%
Average	91.87%

Table I represents the energy saving evaluation under variable load. It was analyzed from the table that on an average 90.37% of energy are saved, i.e., from conventional sources and table II represents analysis with time under different density of the room. It was observed that on an average 91.87% energy are saved.

Table III: Comparative Performance Evaluation

Methods	Energy Saving
Existing [10]	90.7%
Proposed	91.8%

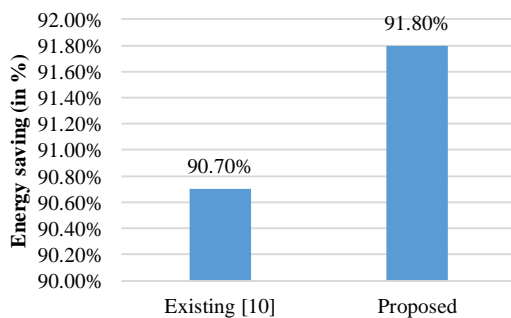


Fig.11. Comparative Performance Evaluation

Various efforts of investigators for sun-shine collection have been discussed in previous portions. The majority of these studies concentrated their efforts on the collector's architecture, position, variety, and region for collecting sunlight. All these parameters are designed for energy saving. But the change in these parameters will not be cost-effective and while considering energy savings infrastructure will result in increasing cost (design and maintenance). So, there is the requirement of integration of some solutions with existing designs to improve their efficiency. Artificial intelligence is the best solution which

pops up. Moreover, there are very few suggestions in this collection that use intelligent automation. Thus, this paper discovers the presentation of AI/ ML to enhance the efficiency of the existing design of a sun-shine collecting system. In this work neuro-fuzzy controller is proposed that can be applied successfully for analysis and control for dynamic changes. Some of the theoretical comparisons of the proposed methodology are discussed in table IV to show the effectiveness of the proposed methodology that makes it energy-effective as well as cost-effective when implemented in the real-time scenario.

Table IV: Comparison of Proposed Method with Existing Methods

Features	Proposed	[18]	[23]	[24]	[29]	[30]
Sun-shine Collecting	Yes	Yes	Yes	Yes	No	Yes
IoT Control	Yes	No	No	No	No	No
Sensor	Yes	Yes	Yes	Yes	Yes	Yes
Artificial Intelligence	Yes	No	No	Yes	No	No
Energy Optimization	Yes	Yes	Yes	No	Yes	Yes
Cost Optimization	Yes	No	No	No	No	No

V. CONCLUSION

The development of smart zero energy buildings results in a building that is ecologically friendly. As the society advances, so does the consumption of energy resources. Building structures today are designed to intake a significant amount of energy globally. Within a few years, all natural resources will be depleted due to this situation. As a result, techniques must be introduced to satisfy current energy requirements while also reducing the waste of conventional energy sources. An efficient as well as less expensive structure is developed in this investigation, which will benefit energy conservation in both new constructions and already available structures. By combining fiber optic cables and solar panels in a hybrid energy sustainability system with Intelligence control systems, power usage within the constructing will be reduced. The effectiveness of a neuro-fuzzy control module that automatically senses the dynamic world and optimises the energy needs was also demonstrated experimentally. The foregoing are some of the work's conclusions:

- This control unit also increases the lifetime of the luminaries by reducing unnecessary wastage of power. In this work a review is presented on the existing methods with AI and without AI integration and found.
- Most of them are integrated with sensors but there are very few research works that propose AI control units. So, the proposed methodology will results better as compared to existing techniques under a dynamic environment and reduce power consumption. Along with power

consumption, the proposed method will also prevent downtime of building equipment, improves sustainability.

- The result shows approx. 1.2% of improvement in energy saving policy due to application smart control unit.

In future work, the focus of this work would be to implement this methodology over large commercial buildings that can be remotely controlled to improve sustainability as well as reduce costs, and increase profit 40.

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