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Development of Smart Micro-grid Energy Efficiency Technologies on Workplace Level

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Abstract: The objective of this paper was to understand the increasing importance of building energy consumption, an overview of the comfort needs of the occupants is first deemed necessary in new control strategy for automatic control and to present facts that characterize the energy consumption, most particularly at the workplaces level with new technology strategies. The study's methodology applies functional and hierarchical separation. The contributions of this paper are static and dynamic models of individual users in a proposed existing building to create an office environment. To fulfill the purpose of the study and the research the following research questions will be investigated and analyzed from an architect's perspective: (1) Are there appropriate technologies for improving energy efficiency in new buildings from the point of view the micro-grid, control and evaluation process in strategy? (2) Which sensor technology can determine the zone that needs or needs not to be considered the comfort?

Key words: Intelligent building, building management system, energy efficiency, micro-grid, thermal comfort.

1. Introduction

Rising energy costs and consumption in recent years, especially in buildings, need to be considered in approaches of reducing energy use. Because building energy usage accounts for over 40% of total consumption in the United States [1] and buildings, commercial and residential, account for 38.7% of the total energy consumption in Europe, which justifies a variety of, initiatives for energy consumption reduction [2]. For this reason, energy efficiency in buildings nowadays has become a prime objective for energy policy at regional, national, and international levels [3].

Present days' intelligent buildings are highly adaptable to changing environmental conditions. They have automated systems, including wireless sensor monitoring to facilitate energy efficient, comfortable and cost effective environments by optimising structure, systems, services, building management and their interrelationships [4]. IBMS (Intelligent Building Management System) can be considered part of a larger energy management systems. This system is used by facilities' managers in buildings to manage energy use and reduce energy consumption as well as maintain acceptable indoor environment.

User behavior factors is one of the key factors affecting IEQ (indoor environmental quality) to determine comfort at the workplaces. User behaviors as action that people can adjust and adapt themselves to environmental conditions are different between humans in terms of gender, age, clothing, etc. Adaptive behaviour includes different reaction and behaviour that can be categorized in three types. Three types of adaptive behaviours are distinguished: behavioural adaptation (adjustment), physiological adaptation (acclimatization) and psychological adaptation (habituation) [5]. The behavioural reactions will lead to actions such as switching heating/cooling on/off, opening/closing windows or blinds, the putting-on/taking-off of clothes, switching lights on/off, etc., which are also influenced by occupant's expectations about their actions' effects. As a result, occupant behaviours will affect building performance in terms of energy use [6].

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2. Methodologies

Experimental methods have advantages in measurement of user comfort requirements in workplace, but in this paper, evaluation of processes will be determined by calculated methods, especially simulation programs such as DesignBuilder/Energy Plus, Daysim and Sketch up. This paper is focused on simulation-based performance assessment of an existing building in Bologna, Italy, and it is expected that the building will be changed by the objective function to be an office building. The fact is: there is no best method in optimization of building energy systems to improve indoor environmental conditions (thermal, air quality, light, sound). In this paper, it focused on proposed grids as workplace level and used innovative workplace design strategies to create a comfortable work environment. This method has been developed to identify existing environmental conditions: (1) Total amount of primary energy consumption includes heating, cooling and lighting loads; (2) Analysis of daylighting performance; (3) Development of smart strategies which include new hypothesises to reduce energy consumption energy and lighting.

2.1 Simulation Inputs

In this section, in order to form a basis for energy performance and total amount of primary energy consumption of the proposed building, simulation programs were used, such as DesignBuilder/Energy Plus and Daysim simulation programs. EnergyPlus is a computational program based on the BLAST and DOE-2 programs and distributed by the Department of Energy of the United States, developed for the thermal and energy simulation of buildings and their systems [7]. To analyse lighting there are two classes of daylighting simulation in EnergyPlus such as Daylighting:Controls which calculates the daylighting incidence through the split-flux method, and DELight, which determines the daylighting based on the radiosity method. The program Daysim calculates the annual daylighting by integrating the method of the Radiance program into the Daylight Coefficient method. DesignBuilder is a state-of-the-art software tool for checking building energy, carbon, lighting and comfort performance. Developed to simplify the process of building simulation, DesignBuilder allows rapidly comparing the function and performance of building designs and delivering results on time and on budge [8].

The proposed building (Fig. 1) is an existing single-family house at Bologna (Latitude: 44°31′ N, Longitude: 11°18′ E). The proposed existing building is characterized by a 206.96 m^2 floor area, has two floors that are named ground floor as Thermal Zone 1 (529.8 m^3), first floor as Thermal Zone 2 (529.8 m^3) and Roof (331.3 m^3). Window-to-wall ratio of north, south, east and west envelopes are respectively 23.44%, 21.84%, 0%, 0% and in total is about 12.43%.

In this paper, the methodology for estimating the energy consumption of the proposed building is using ASHRAE 90.1-2004 guideline (4A: Mixed-Humid Climate Zone) on its total primary energy usage. Table 1 shows heating, cooling and cooling and lighting design parameters.

Fig. 1 3D view of the proposed building modelled by DesignBuilder.

Table 1 Internal gains system design parameters.

Internal gains	Design level calculation method	Assumed input value
People	People/Area	0.12 people/m^2
Lighting	Watts/Area	11 W/m^2
Electric Equipment	Watts/Area	10 W/m^2

Table 2 Conversion factors for primary energy sources.

Source energy	Source conversion factor
Electricity	3.167
Natural gas	1.084
District cooling	1.056
District heating	3.613

2.2 Building Reference Heating, Cooling and Lighting System Design Parameters

The building reference characterises of heating, cooling, lighting and equipment system design input parameters are taken from DOE Reference Commercial Buildings-Medium Office example (Table 1). Table 2 shows total fuel consumption to the respective primary fuel.

It is assumed to be 9 occupants with 9 workplaces in the each office floor and in total 18 occupants, which are equipped with personal computers and the pattern is based on hourly variable usage rates within typical working week (from Monday to Friday) and day from 09:00 to18:00, with overall internal heat load of 50 W/m^2.

2.3 Heating, Cooling and Lighting Energy Use and Thermal Comfort Analysis

To determine total energy usage loads of the proposed building, design energy-efficiency strategies should be established. Building natural gas is used as an energy source in the heating system and the electrical energy in the cooling system. The value of air temperature for heating system comfort is 22 ℃ and for cooling system comfort is 25 ℃. In the proposed building, compact fluorescent lamps and lighting power control system are used, which are also assumed to be in use with stepped control that allows us to switch lights on/off according to the availability of natural daylight in discrete steps. Whereas the continuous control described above provides precisely controlled illuminance by dimming the lights, the stepped control models blocks lights in regards to switching on/off in the electric lighting requirement [8]. In lighting control because of electric control system to adjust its output which is related to illuminance workplace level, energy consumption of lighting system is being defined from sensor points in the control zone which can also be defined daylight sensor locations. In the proposed reference building, nine daylight sensors are located and designed in each reference zone to analyse daylighting performance (Fig. 2).

Work plane for daylight illuminance calculations is set to 0.85 m for all sensor points. At this point, it should be to calculate total building energy including some other energy use categories in addition to lighting, such as interior equipment, space heating, cooling, etc. Results of total building energy usage were made by DesignBuilder/EnergyPlus. Outside temperature of

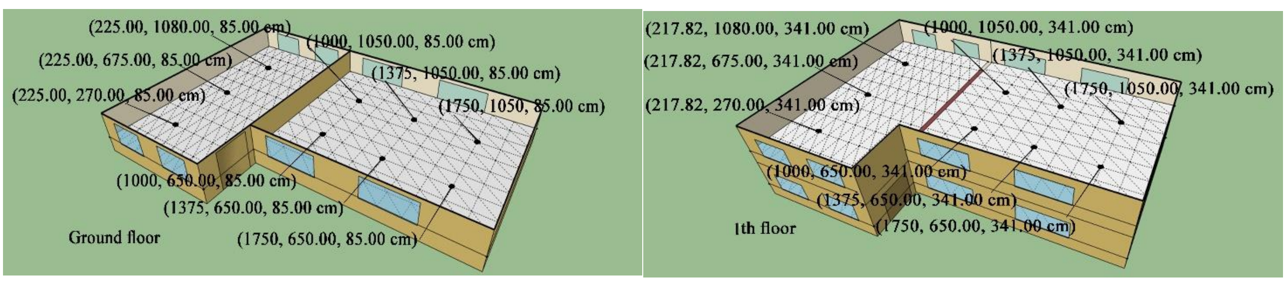


Fig. 2 Position of daylight sensor points in the proposed building modelled by Sketch up.

Table 3 Performance indicators of the proposed building.

Performance indicator (annual performance)	Value (kWh)	Value (kWh/m^2)
Space Heating Loads	80,999.38	195.65
Space Cooling Loads	-2,819,213.32	-6,809.69
Space Electricity Loads	1,408,371.16	3,401.86
Interior Lighting Energy	2,147,941.46	5,188.26
Total Building Energy	6,456,525.32	15,595.47

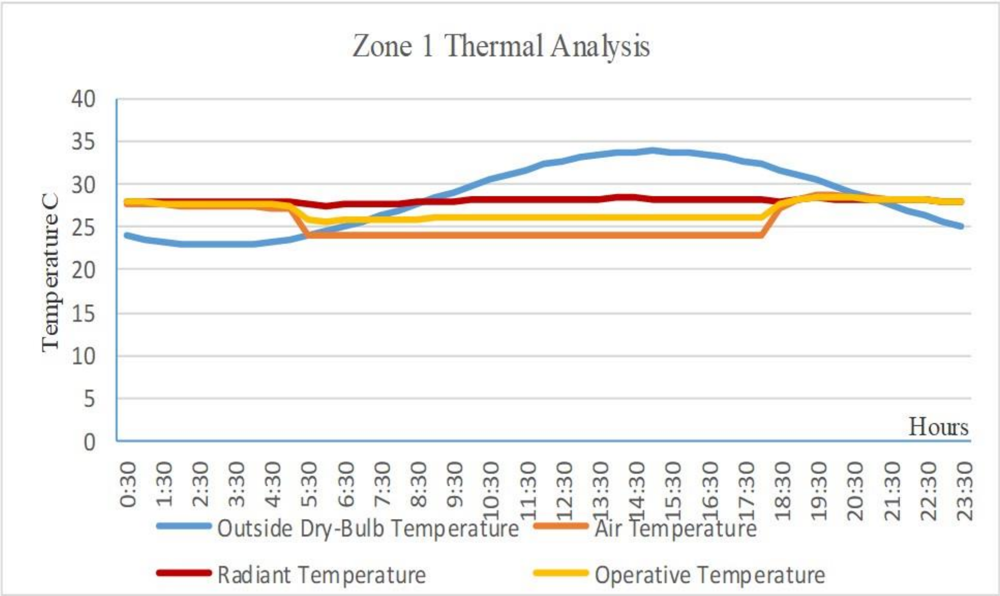


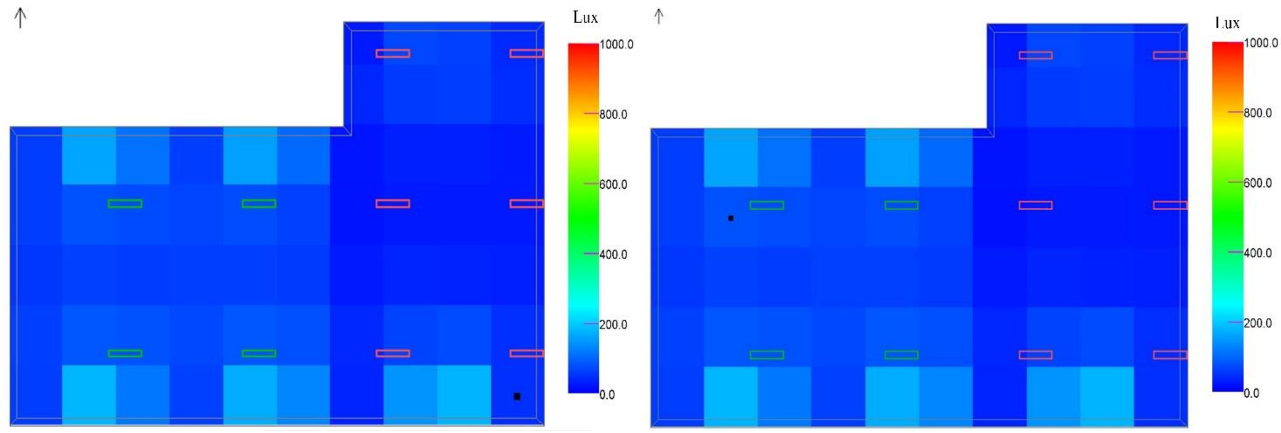
Fig. 3 Temperature of the first floor (zone 1) in relation to outside temperature on 15 July.

Bologna on 15 July (summer design), it is dominant that outside temperature at 15:30 has maximum value (33.81 ℃). Information about operational lighting energy and HVAC system (occupancy hours are taken as 9 h a day from 9 am to 6 pm excluding weekends and holiday) with each of thermal zones having 2,471 h of office occupancy. Table 3 shows the proposed office building's total annual heating, cooling and lighting loads.

The integration thermal analysis leads to showing performance of an energy analysis on a zone. Therefore, to determine indoor environmental condition thermal comfort was compared between outside temperature condition and inside of each zone on 15 July (summer design). There was no prominent difference between temperature of Zone 1 and Zone 2. The proposed methodology of thermal analysis in the proposed building was based on the determination of indoor condition temperature related to thermal comfort. Fig. 3 shows temperature of zone 1 in relation to outside temperature.

2.4 Daylighting Analysis

Performed daylighting measurements were simulated by Daysim v4. In the proposed building sensor point lighting was set in nine points at height of 0.85 m at the workplace level (see Fig. 2). In this section, because of insufficient daylighting levels in winter performance indicator was simulated in January with target 500 Lux to define illuminance of indoor map. Fig. 4 shows a series of daylight illuminance maps (for a single day for working hours of 9 am to 6 pm) for a perimeter office zone (1st Floor). Daylight maps are initially defined as grid points before the start of a simulation run in



(a) (b)

Fig. 4 Analysis of daylight illuminance maps. (a) critical black point 1 (left); (b) critical point 2 (right) in January at 10 am.

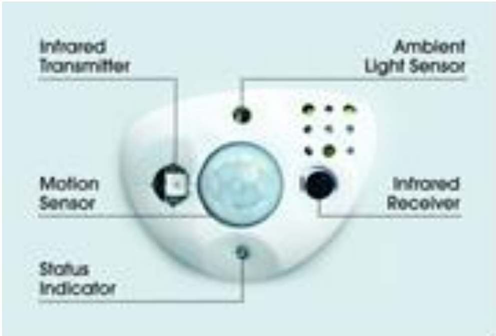
Daysim v4. The program then calculates daylight illuminance levels at each sensor point and represents two critic points that are not suitable and adequate to meet the requirements of the workplace (Fig. 4).

2.5 Technology Application by Development of Smart Micro-workplace to Improve Energy Performance

The results are presented in Table 4 where it is shown that heating, cooling and lighting have influence on building energy demand. As mentioned in the introduction, user behaviour has huge influence on building energy demand thus applying wireless sensors can help to provide energy efficiency in the proposed office building. A sensor is a device that measures a physical quantity and usually converts it into an electrical signal which can be read by an observer or by an instrument. The function of a wireless sensor system can be described in terms of compensation, information processing, communication and integration.

Since total cooling and lighting loads represent the majority of energy use in the proposed building it should be considered reduction energy by new schedule occupancy in relation to user' requirements. Because, it is common environmental condition approximately in each of the two floors (zones) common scenario has been applied by using automation systems. In this process it is required that occupancy sensor be (Fig. 5) installed in each micro-workplace which is defined as 9 points at workplace level and switches off the light if nobody is detected in the office for more than 15 min.

Lighting and occupancy use in one space is consisted of the four conditions: (A) Occupied with the lights on; (B) Occupied with the lights off; (C) Unoccupied with the lights on; (D) Unoccupied with the lights off. It is assumed that it is possible that this mechanism is to be installed in HVAC systems in the proposed building so that cooling systems are controlled by sensors. For instance, if there is condition unoccupied with the lights off it can be unused individual cooling system for user. The used devices also have the light level detection function, in order to turn off the light if unnecessary, but their sensitivity is not high enough (the illuminance threshold is manually selected) and it can suddenly and improperly control the lighting operation. Therefore, installing shading devices fixed/movable can be another an efficient way to control it. In order to determine the effect of solar control elements, shading devices can affect energy saving in the proposed building. Outdoor shading devices are effective in controlling daylighting in buildings whereas interior shading devices are most effective in controlling glare. In developing smart micro-grid strategies to the proposed office building, the design of shading systems can be considered to improve energy efficiency and have been applied to the south elevation of the proposed building.



(a) (b)

Fig. 5 (a) Intelligence-based lighting control; (b) Microwave detector [9].

3. Conclusion and Results

This paper has identified energy-saving strategies in the proposed building, compared energy usage by smart sensor and occupant control. The results from the developed alternatives (wireless sensors and shading devices) are shown in Fig. 7, and it could be deduced that the development of energy efficiency strategies is effective to improve energy efficiency in the proposed building. For instance, there was a reduction 42.17% in total energy loads which indicates an improvement in energy efficiency in the total building energy load per year. Despite the fact that strategies of wireless sensors have not been addressed in DesignBuilder or other simulation programs, it is clear that they will be a noticeable improvements in energy efficient buildings and these improvements are expected to reduce energy consumption by a significant amount. In reduction of energy consumption, wireless sensor technology which is assumed and applied to the proposed building, used scenario switches off the light for more than 15 min. It was assumed that if 50% of the total occupants want to take a meal or coffee break it can be saved 135 min (2.25 h) in each day. With this scenario the total hours was reduced to 1,920 h rather than 2,471 per each year. Figs. 6 and 7 show a comparison between baseline performance and improved performance by scenarios.

Obviously, occupant control by sensors in achieving energy efficiency at workplaces is not only energy saving strategy in the office buildings. Since difference between internal and external environmental factors, the manual control of environmental factors in workplaces is not as effective as intelligent systems therefore

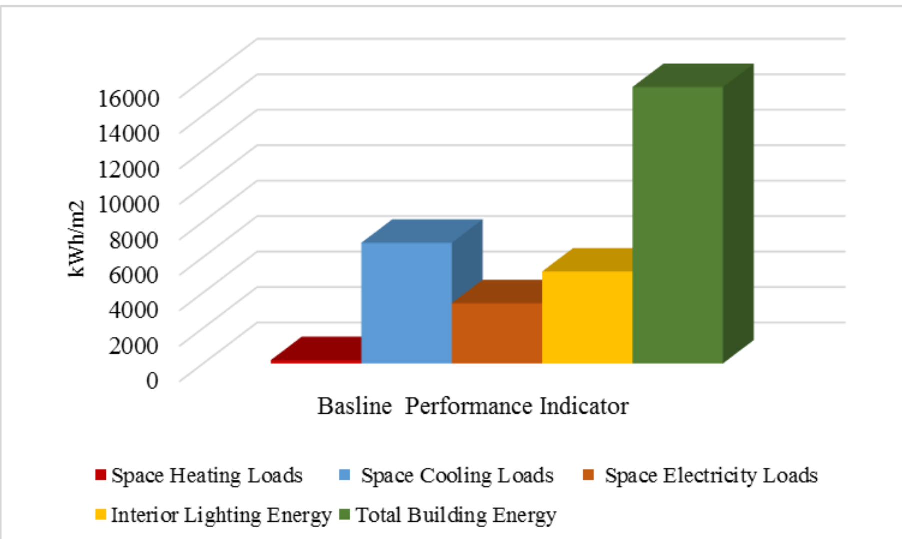


Fig. 6 The results of baseline performance indicator.

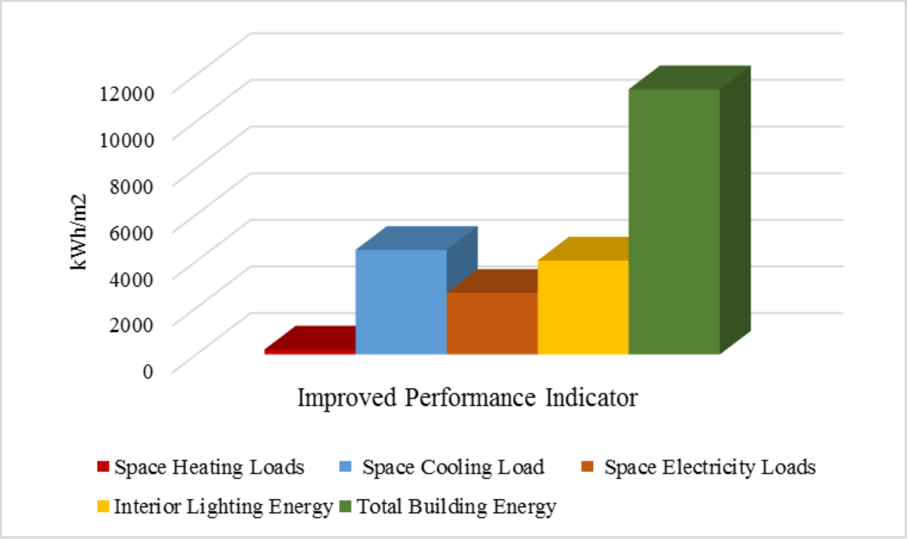


Fig. 7 The results of improved performance indicator.

developing innovation technologies can provide main effective and significant environmental benefits. The implementation of workplace sensors has not yet entered the commercial space extensively but it has considerable potential. Specifically, it can be realized in existing buildings.

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