Far East Journal of Electronics and Communications

http://www.pphmj.com
http://dx.doi.org/10.17654/EC018010159
Volume 18, Number 1, 2018, Pages 159-164 **ISSN: 0973-7006**

MULTI-OBJECTIVE OPTIMIZATION FOR AUTOMATION OF SMART HOME COMFORT MICROCLIMATE CONTROL

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Received: September 14, 2017; Accepted: October 23, 2017.

Keywords and phrases: intelligent control systems, automation of smart home comfort, multi-zoned building.

Abstract

The methodology of system design of modern intelligent control systems in the electric power industry and their features are considered when providing the required comfort in multi-zone buildings with the use of multi-agent power consumption and comfort management systems. Such a control system covers all the monitored zones of a building and allows providing the greatest possible overall comfort in the building while reducing the required electric power.

A multi-objective genetic algorithm-based optimization is used to find the optimal set points in the comfort ranges in order to reduce power consumption. The purpose of this study is to develop a comfort management system in a multi-zoned building that can provide the greatest possible comfort while reducing the required electric power.

1. Introduction

The quality and productivity of people's lives in buildings depend on the level of comfort inside of it. These conditions include the visual and thermal comforts of the buildings. They provide lighting and heating/conditioning systems. Strategies to ensure sustainable work have become one of the important factors of human life. According to the California Commercial End-use Survey [1], up to 85% of energy consumption in commercial buildings is spent on heating and cooling facilities, lighting of the building, ventilation structures, as well as office equipment [2-4]. The construction of a building requires high energy efficiency to reduce the energy consumption.

The main goal of the control system for a building energy management system (BEMS) is to maintain a high comfort index and reduce the overall energy consumption. Increased energy requirements can be fulfilled properly, giving preference to critical loads. This minimizes the total energy consumption, and stored energy can subsequently be used to satisfy critical loads. Intelligent energy management reduces the total energy consumption, thus achieving efficient use of energy and ensuring the supply of critical loads, thereby giving maximum comfort to humans while minimizing energy loss. This makes commercial buildings energy-efficient. These three main factors determine the quality of life of the residents living in the building [5].

In this paper, we explain optimization method for building energy and comfort management case study, and results' section investigates the simulation results.

2. Optimization Method

There are two objectives in the building energy and comfort management problem: to maximize inhabitants' comfort (or minimize discomfort) and minimize energy consumption. There are four main comforts: thermal comfort, humidity comfort, visual comfort and air quality comfort. Moreover, the energy consumed by the offensive subsystems, including the heating, ventilation and air conditioning (HVAC) system and the lighting system, will be calculated for optimization. The problem is formulated as follows.

Suppose the initial status of the building indoor environment in which any control strategy has not been applied yet, is that of the initial temperature (T_0), initial humidity (h_0), initial light (L_0) and initial CO_2 concentration (A_0). To create objective functions of overall comfort and energy consumption, the target temperature x_1, the target humidity level x_2, the target CO_2 concentration x_3 and the target illumination level x_4 form a set of vectors of decision variables. Then it is necessary to build a power consumption function and a comfort function with respect to the control vectors.

One of the goals of management is to maximize the value of comfort. Maximize the indoor comfort value as described in equation (1) [6]. Maximizing the indoor comfort is equivalent to minimizing the discomfort value. This objective is set as:

$$\begin{aligned} Discomfort = 1 - Comfort = 1 - w_T\left(1 - \left(\frac{x_1 - T_{set}}{T_{set}}\right)^2\right) \\ + w_H\left(1 - \left(\frac{x_2 - H_{set}}{H_{set}}\right)\right) + w_L\left(1 - \left(\frac{x_3 - L_{set}}{L_{set}}\right)^2\right) \\ + w_A\left(1 - \left(\frac{x_4 - A_{set}}{A_{set}}\right)^2\right). \end{aligned} \quad (1)$$

Another objective function is the total energy consumption with respect to the vectors of decision variables. Minimize the total power consumption:

$$E_{totol} = E_T(x_1) + E_H(x_2) + E_L(x_3) + E_A(x_4), \quad (2)$$

where $E_T(x_1)$, $E_H(x_2)$, $E_L(x_3)$ and $E_A(x_4)$ are the energy required to improve the initial environment parameters to the target parameters x_1, x_2, x_3 and x_4, respectively. $E_T(x_1)$ is the energy consumed on the heating/air conditioning subsystem; $E_H(x_2)$ is the energy consumed on the humidifying system; $E_L(x_3)$ is the energy consumed on the lighting system and $E_A(x_4)$ is the energy consumed on the ventilation system. To get the values of $E_T(x_1)$, $E_H(x_2)$, $E_L(x_3)$ and $E_A(x_4)$, the amount of energy consumption corresponding to different target parameters under the set initial status can be obtained by running the building subsystem models.

3. Experimental Results

The optimization method described above is applied to the university building laboratory with an area of approximately $6 \times 3 \times 3\text{m}^3$ (Figure 1) that supplied with a heater, humidifier, and an air conditioning system.

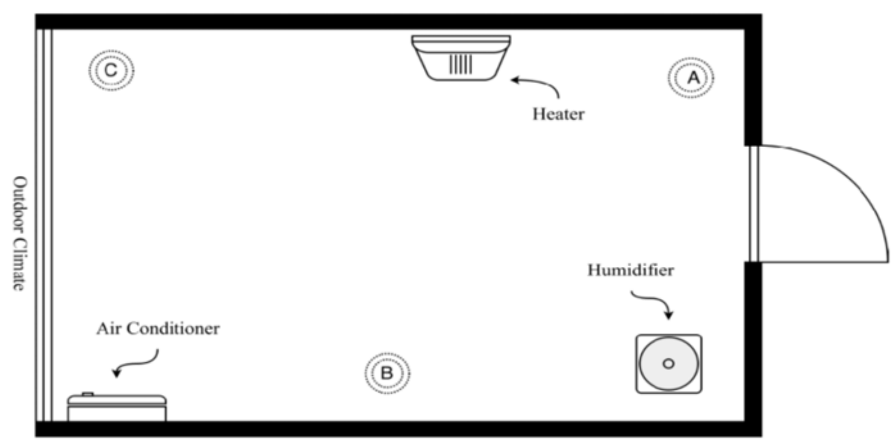

Figure 1. Experimental environment.

The procedure for selecting the optimized strategy can be customized depending on the needs of the user. In this specific case study, the following procedure is adopted:

- prefer solutions with low thermal energy consumption, in order to reduce localized emissions;
- provide an acceptable comfort solution, considering the use of the laboratory room;
- minimize the Net Present Value of the investment;
- minimize CO_2 concentration in the room.

Figure 2 illustrates the simulation results and it demonstrates how the selected strategy permits obtaining a building characterized by high energy and environmental performances, with an investment that can be feasible for the administration. By applying multi-objective genetic algorithm in building energy and comfort management, we reduced total energy consumption for 20% and increased comfort level for home residents.

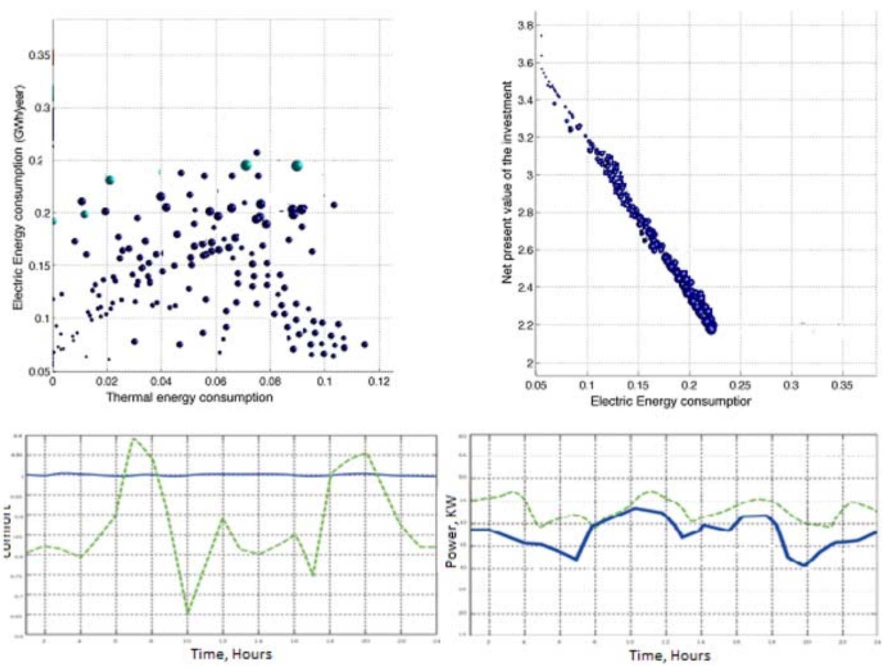

Figure 2. Energy consumption and microclimate comfort.

4. Conclusion

In this work, we explored application of multi-objective genetic algorithm in building energy and comfort management. We considered two objectives: minimization of energy consumption and maximizing of user comfort level. As the case study and experiment environment, we conducted our work in laboratory.

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