Design and Simulation of Intelligent Central Heating System for Smart Buildings in Smart City

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***Abstract*—Today, energy efficiency for a buildings is ensured by a systematic reduction in demand for heating and cooling. The energy consumption in the buildings such as universities, schools, private schools, hospitals, and public institutions are increasing day by day. Approximately 20-40% of the total energy consumption in the world is building systems thus the need of energy saving is increasing. In this study, a control system was designed and simulated in buildings by using central heating system to reduce energy consumption. It is possible to control and monitor the heat energy consumption of building by using the Fuzzy Control System which is one of the artificial intelligence control systems. The proposed model for an intelligent building reduces the energy consumption by improving the comfort of the people inside the building. The proposed model was simulated and implemented by taking the model of Adıyaman University Vocational School. The results show that the use of water flow rate decreases with acceptable rate without disturbing the comfort of the people in the building.**

***Index Terms*-- Central Heating, Energy Efficiency, Fuzzy Logic, Smart Building.**

I. INTRODUCTION

Intelligent buildings are systemic structures that it can control the energy expenditure of the building with its own elements and with additional equipment to increase energy efficiency. Therefore, the most important task of the smart building is to minimize the energy expenditure of the building without compromising user's comfort. Today, energy efficiency for buildings is ensured by a systematic reduction in demand for heating and cooling.

Reduction of sources, and damage to the environment by emitting greenhouse gases by fossil fuels has made energy efficiency mandatory. The buildings are very important places in reducing energy consumption and greenhouse gas emissions. Much of the energy in buildings is wasted due to poor design, inadequate technology and inappropriate behavior. The measures are of great importance as part of the fight against global climate change.

Because the energy consumption in buildings constitutes 30% to 40% of the final energy consumption and CO2 emissions in many countries. In recent years, intelligent building technologies have been used to increase the efficiency of heat energy in buildings. A lot of study for intelligent building with smart home applications and solutions are available in the literature [1-10]. Use of Renewable Energy is one of the basics of achieving smart building and smart city infrastructure. Intelligent measurement, intelligent lighting, smart grid and Energy Internet, Renewable energy, Distribution, Net measurement, LED, Intelligent Building Energy Management Systems (SBEMS), Insulation, Day Lighting, Smart HVAC systems, are some of the main smart technologies. Most intelligent HVAC systems use smart thermostats, smart meters and smartphone-enabled applications. The smart thermostat adjusts the room temperature according to factors such as the current room temperature, humidity and occupancy. [1]. Temperature control algorithm study was performed by using water and air temperature for condensing boiler systems [2]. A typical office building automation system with the intention of introducing a non-invasive building energy management system that coordinates building subsystems related to different and heterogeneous energy available at different levels was investigated [3]. Central control system methods have been proposed by using a fuzzy logic system to reduce the use of heating systems in smart homes to increase energy efficiency [4]. An energy saving system that can optimize the power management and energy efficiency of a home heating facility was designed. [5] . In order to save energy, a building automation system has been done with heating optimization embedded system. [6]. In another study, an energy and comfort management system has been developed for a multi-zone intelligent building, providing the highest possible comfort while reducing the electrical power. [7]. A multi-agent system for collecting data from heat meters to analytical data center using smart GSM modems has been proposed to perform heat energy consumption estimation and analysis of buildings. [8]. Fuzzy logic based heating systems have been applied. [9]. HVAC control applications have been developed using Intermittent Type 2 Fuzzy Logic System (IT2FLS) for adaptive control of multi-zone common areas in intelligent buildings for user comfort and energy efficiency for heating, ventilation and air conditioning. [10]. The design of an overheated steam temperature control using a fuzzy logic controller was made and compared with PI. It has been observed that the fuzzy logic controller was better than the traditional PID controller. [11]. A central heating system was designed using fuzzy control to minimize the use of the heating system when the user meets the temperature rules. [12]. Smart Home Energy Management System (SHEMS) uses fuzzy logic for battery management and

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successful results. [13]. A new light control system using fuzzy logic was designed and simulated to reduce energy consumption in smart offices [14]. Fully functional fuzzy logic systems that monitor and control the power consumption of a house have been tested and analyzed. [15]. Smart building energy and comfort management system has been developed to simulate fuzzy logic, energy consumption model and control heating, ventilation and humidification devices[16]. Intelligent HEMS and heating technologies and trends were researched to provide an overview. [17]. Intelligent Home Technology for energy efficiency is designed and analyzed as part of IoT (Internet of Things) [18]. In the literature, energy management and efficiency studies were conducted for intelligent buildings by using artificial intelligence. Most of these studies have been on electricity usage. The studies on heat energy have generally been about air conditioning.

In this study, smart rooms using artificial intelligence technology are proposed in buildings that use central heating system and an approach of minimizing heat energy consumption is presented. First, the heating control system is designed with Matlab Simulink and simulated in a real scenario in a real building. Second, the proposed intelligent room and the building are designed for the heat control system. Third part describes the Fuzzy Logic system for the control system. Next, the designed model was simulated for university campus building and results were obtained. Finally, information about the future studies are given.

II. Recommended Model

In our country, many of the heating systems used in many public institutions and organizations and in the private sector have central heating or boilers. In most of the central heating systems, system manager with outdoor sensor and room sensor are used. Most of the central heating systems use header sensor and room sensor. Such systems are smart systems that they provide energy efficiency. Regionally, these systems have the disadvantage that they cannot work autonomously. When the heating system is switched on, the whole building will start to heat up and consume energy. Areas that are not in use or not needed should be closed manually. In this way, it is quite difficult to control and implement manual interventions. The proposed method provided a solution to this disadvantage and reduced energy consumption. In order to transform into a smart building, you need to have smart rooms or sections. As shown in Figure 1 there are magnetic sensor, motion sensor, temperature sensor and an electronic card to transmit the data to the network are used in the room. In the proposed model, energy efficiency was tried to be provided according to the following situations.

- The magnetic sensor detects that the window is opened and the radiator temperature is reduced to the minimum reference value.
- If the motion sensor detects the room or area is not used, the radiator temperature is reduced to the minimum reference value.
- The temperature of the room is measured with the sensor, and the adjusted temperature difference in the control panel is determined and the radiator temperature is reduced or increased. Thus, the desired comfort is increased. Uncomfortable and unwanted excessive temperature is prevented.
- With data and access cart, it is possible to connect easily to the control unit in the collector cabinets which is available in most buildings.
- In order to protect the building temperature, the control unit can be adjusted according to the minimum value to be applied to the collectors.

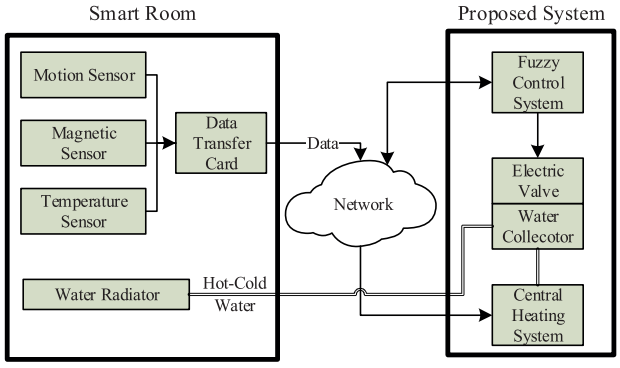

Figure 1. Schematic diagram of proposed design

- Since the control unit adjusts each hot water connection in the collector with the electric valve, this model can be applied to the desired chambers or zones.

Data in the control unit can be processed to send data such as room thermostats for the central heating system

III. Fuzzy Logic Control System

Fuzzy logic system, a system that can be used in uncertain situations with an artificial decision system of input and output variables, provides good results.

TABLE I. Rules of Fuzzy Logic System

Motion Sensor	Magnetic Sensor	Temperature Sensor				
		VL	*L*	*M*	*H*	*VH*
L	L	L	L	VL	VL	VL
M	L	H	M	M	VL	VL
H	L	H	M	M	L	VL
L	M	M	L	L	VL	VL
M	M	H	M	M	L	VL
H	M	H	M	M	VL	VL
L	H	M	L	L	VL	VL
M	H	VH	H	M	L	VL
H	H	VH	VH	M	L	VL

Using data of temperature sensor, motion sensor and magnetic sensor; fuzzy logic control system is used to control the electric valve in the collector. Since the temperature sensor runs from -10 to 80 C, the data are used directly. Motion and magnetic sensor value can be only 0 or 1.

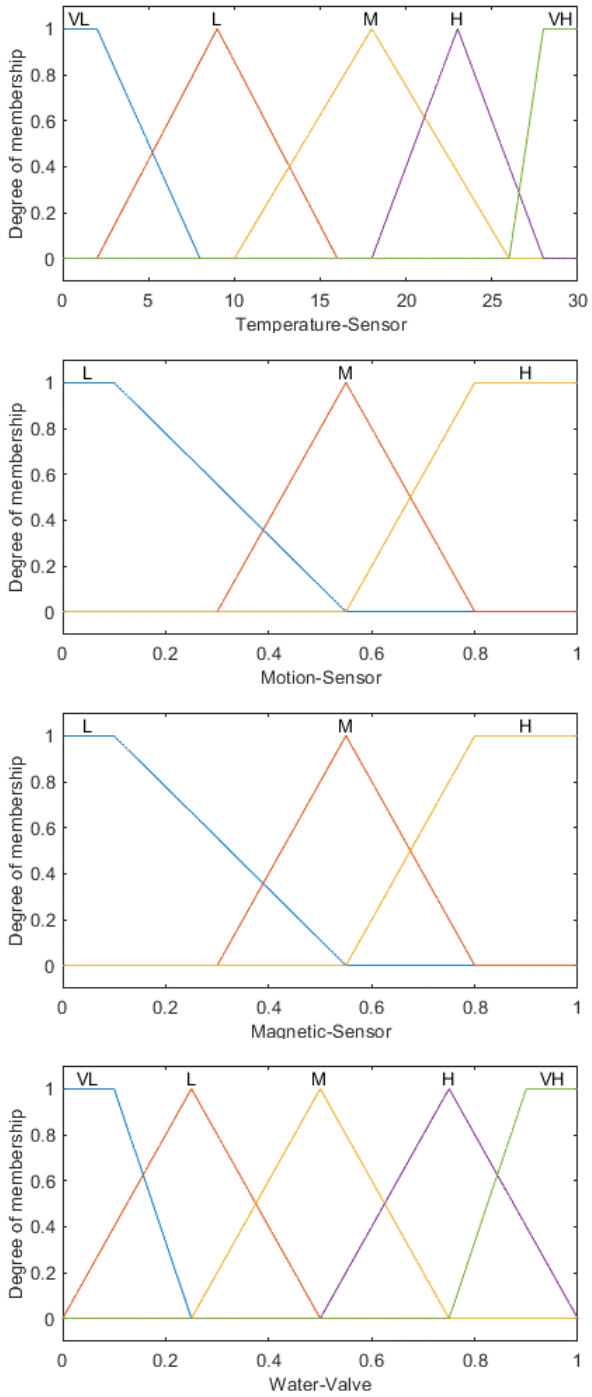

Figure 2. Mempership function of input and output

In order to convert these values to continuous values, equation (1) was applied and signal numbers were used with time periods of 15mins. Thus, the input variables of the system are allowed to be between 0 and 1.

$$Input = \frac{\sum_{1}^{15} last\ signal}{15} \quad (1)$$

The control system is simulated using the Fuzzy Logic Toolbox in the Matlab program. Blurring was performed by using triangular and trapezoidal membership function in the input variables.

The membership function of the system with 3 inputs and 1 output is shown in Figure 2. The first entry has 5 membership functions. The other two entries have 3 membership functions.

Mamdani method was used in the extraction method. Centroid method used for defuzzification methods [19]. Table I shows the output table according to the input variables [20]. Name of Membership functions are Very Low (VL), Low (L), Medium (M), Height (H) and Very Height (VH) in the Table I and Figure 2.

IV. Simulation And Evaluation

In order to simulate real values, the data of the Adiyaman University Vocational School building was used.

According to the weekly schedule, 20 classes with the highest occupancy rate were selected. The use of these classes was evaluated only on weekdays and between 08.00 and 17.00 hours. Heat transfers and other factors have been ignored.

The proposed design is shown in Figure 3. In the simulation tests, analysis of five days data of one room is shown in Figure 4 the data in the simulation results are given in Table II. According to the results, the most effective factor was the occupancy rate of the room.

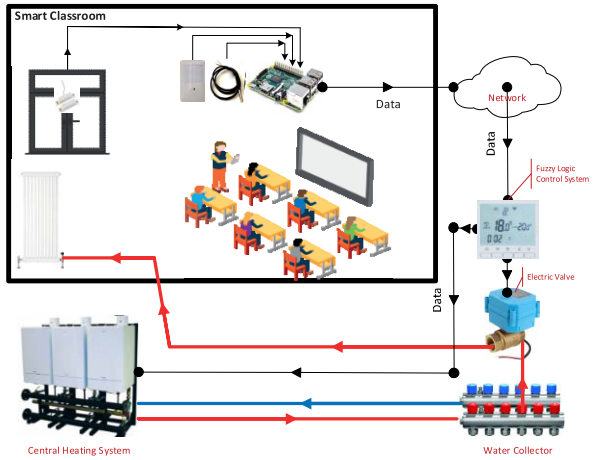

Figure 3. Proposed design

Energy efficiency is ensured by reducing the heat of unused rooms. Temperature sensor usage has affected up to 2% in energy efficiency. The use of the magnetic sensor has been as effective as 0.02% due to the small window opening. Motion sensor usage has affected up to 50% in energy efficiency.

TABLE II. MEAN VALUES OF SIMULATION RESULT

Number of Rooms	1 Day			
	Mean of Temperature	*Mean of Motion*	*Mean of Magnetic*	*Mean of Valve*
1	13.9883	0.4361	0.9864	0.4832
10	13.3429	0.4767	0.9821	0.4206
20	13.1434	0.4562	0.9822	0.4183
	Weekdays			
1	13.2317	0.3204	0.9867	0.4235
10	12.6679	0.4312	0.9800	0.4310
20	12.5836	0.4265	0.9813	0.4318

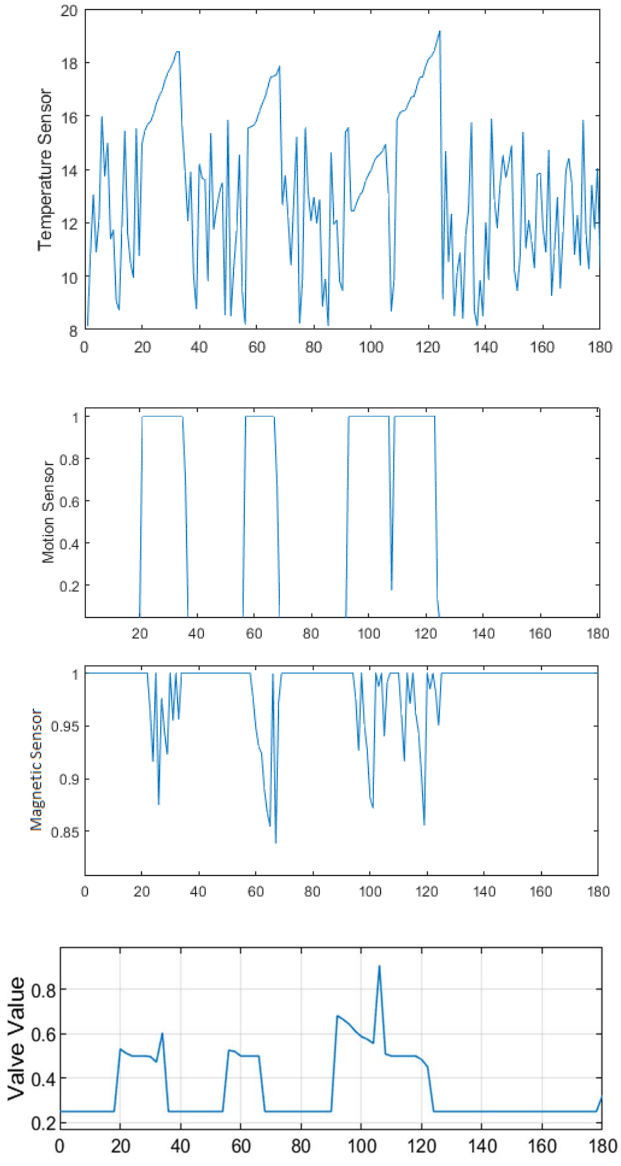

Figure 4. Inputs and output of a room in 5 days

V. CONCLUSIONS

Classic central heating systems distribute hot water to all rooms during the operation and radiators use water in full. Heat calories are consumed by using in all rooms. With smart rooms and intelligent control, unused rooms are detected and hot water usage is restricted so that heat calories are more effectively distributed. This means energy savings and gains.

Central heating system is used in many buildings in Turkey. However, there is also an uncontrollable energy consumption. The day mode is time between 07.00 and 17.00 and the night mode is time between 17.00 and 07.00 in the central heating system. Unused rooms and rooms that has open window and open door are heated uninterrupted in day mode. There is no intelligent system to control the energy consumed in this rooms. In this study used the intelligent system for this rooms. if this system is implemented in university buildings of Turkey, energy consumption is reduced by 20% to 40% similar to graphics in Figure 4. The motion factor is more effective than temperature and magnetic factors. The rate of use in this system is more important. Therefore, energy efficiency in buildings varies depending on the rate of use.

In the next study the real application of the proposed method is in progress. The performance of the proposed method will be compared to the real application. In other countries and especially in Turkey, this study will contribute to energy savings.

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