

Distributed Heating System for Residential Homes

Iulia Clitan, Vlad Muresan, Mihail Abrudean, and Andrei F. Clitan

Abstract—This paper presents a home automation plant, consisting of a distributed heating system. It is a system implemented on a residential home, however it could be extended and used for other buildings as well. The paper presents the distributed heating system's structure, extended from a classical heating system, and the authors also describe the equipment used for the designing and implementation of such a system. The way the system works is depicted, and the authors enfold all the benefits of using such a distributed heating system, such as, increasing the user's thermal comfort on different living areas and reducing the costs of thermal heating.

Index Terms—Home automation, distributed heating system, thermal heating, thermal comfort, central heating unit.

I. INTRODUCTION

Home automation is a topical field, covering all utilities and domestic uses, to ensure, among others, high level of comfort with minimum costs to the end user, arising from the use of intelligence and communications in consumer products. The field of household thermal heating is important from the point of view of ensuring constant thermal comfort, with minimum consumption of thermal energy or electricity [1], [2]. Residential heating, indispensable in life due to seasonal change [3], presents high potential in diminishing domestic energy consumption [1], [4]. In order to minimize the costs of thermal heating during the cold seasons, users take different actions as such as restricting the use of heating to a small number of rooms, thus giving up thermal comfort in favor of costs [1], [5]. Moreover, heating practices varies significantly not only within houses but also between them [6]. In such cases, home automation comes in handy, since in the European Union (EU), households consume a quarter of all energy consumption [7].

At present, part of the household heating uses the centralized method, indoor temperature comes from the efferece of hot water to houses by heating pipelines, resulting in uneven temperatures, thus, more and more people are using individual household heating systems [3]. This means, one heating unit and one heating system exists for temperature control of the entire household.

This paper presents a two-way distributed heating system for homes, that uses only one heat source and control block, incorporated in the Central Heating Unit (CHU), to control the heating process for both heating delivery systems, thus

ensuring the desired temperature level in two distinct areas. Each system has its own heating loop and aims at maintaining the temperature parameters and ensuring thermal comfort for end users, each time the space is used.

The proposed heating system is very useful for large homes, were a part of the living area or some of the rooms are not used all the time, are vacant for large period. The implement method guarantees energy consumption reduction without neglecting thermal conform.

II. CLASSICAL HEATING SYSTEM

In an individual classical heating system, a network of pipes and radiators is used to recirculate hot water as thermal agent, throughout the entire household. The center of the heating network consists of a CHU, with the role of controlling the temperature level by heating hot water in a boiler, using for example gas as supply fuel, as presented in Fig. 1. A pump is needed to circulate the hot water throughout the network, and one thermostat is set in one room to measure and maintain the ambient temperature inside that room.

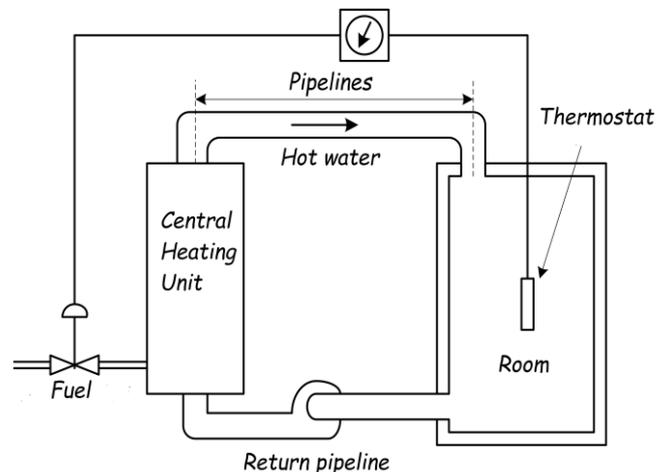


Fig. 1. Classical heating system's representation.

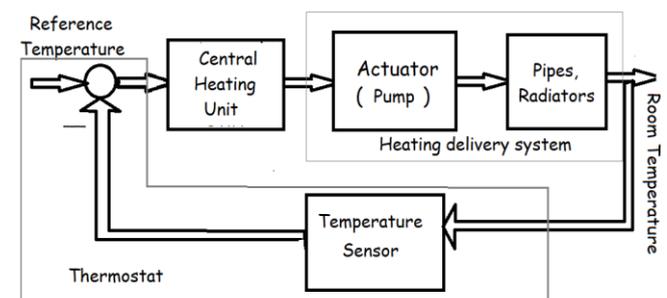


Fig. 2. The classical heating system's control structure.

The classical heating system's control structure is a closed loop control structure with a negative feedback, intended to

Manuscript received April 28, 2020; revised December 23, 2020.

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maintain the room temperature at a constant value, set by the user as a reference temperature level (see Fig. 2).

In a heating system, the CHU contains the temperature controller, which is a two-position controller, the hot water boiler, and it also incorporates the hot water circulation pump, which represents the actuator of the control structure. The rest of the plant, represents the heating delivery system, consisting of pipes and radiators to circulate the hot water, previously heated inside the CHU boiler.

The thermostat has a triple role:

- To measure the ambient temperature, using the temperature sensor,
- To enable users to set the reference temperature,
- To calculate the error signal between the two temperatures.

The functioning of the control structure given in Fig. 2 is hereinafter provided. Once the ambient temperature drops below the reference value, the thermostat generates a signal to the CHU. The CHU's control block starts the heating process of the thermal agent (water) and its distribution by activating the circulation pump. The hot water is circulated throughout the entire network, and the ambient temperature rises. Once the ambient temperature's level, inside the room containing the thermostat, equals or surpasses the level set as the reference temperature, the thermostat's output becomes inactive, thus, the heating of the water is stopped, and the circulation pump is switched off.

For large homes, when cold season comes, users tend to restrict their activities in a small part of the house, thus limiting the amount of living space that is being heated by the individual classical heating system [6]. This is a measure taken in order to reduce the heating costs, as presented before. In this case, radiators are turned off in unused rooms, but the hot water is still recirculated through the entire distribution system, causing the hot water's temperature to decrease, due to thermal exchange. If it is necessary to extend the living space in certain situations, the restart of the radiator is needed, to ensure the thermal heating in that certain room, or rooms, respectively. This process is an arduous one, which does not provide a suitable thermal comfort except for a single room, the room in which the thermostat is located.

The use of a classic thermal system, for domestic heating, can result in rooms with uneven temperatures (higher or lower than the offset temperature), depending on the size of the room, the radiator's size, respectively, the distance to CHU (the longer the distance that the thermal agent has to cover, the lower the temperature at which it will reach the radiator, will be).

III. TWO-WAY DISTRIBUTED HEATING SYSTEM

To avoid all aspect previously depicted, the level of thermal comfort can be increased, in several areas of the house, through a distributed system proposed by the authors, with two separate and independent heating circuits, a system that can be easily extended to several, if necessary.

The proposed system is an extension of a classical heating system, described in the previous section, allowing the end users to heat at different temperatures, areas of the house that are occupied differently. The described system is implemented, and tested, in a large house, and consists in the

use of two distribution circuits of the thermal agent, independent of each other, each circuit covering a certain area.

The house was divided into two living spaces, using the following consideration:

- Permanently inhabited area - with its own distribution circuit and thermostat for setting the reference temperature level;
- area Inhabited only occasionally (from time to time) - with its own distribution circuit and thermostat for setting the reference temperature level.

Using the area division described above, the temperature control structure painted in Fig. 3 was developed.

The CHU incorporates the temperature controller, the boiler, and the circulating pump, as stated before (since the same CHU is used). The thermostats, that incorporate the temperature sensors depicted in Fig. 3 structure, have the same roles as described before for the classical heating control structure.

The main difference between this control structure and the classical one is the existence of two independent heating circuits, separated by relays, to enable temperature control in two distinct rooms, each with its own thermostat, network of pipes and radiators, to increase the ambient temperature when needed. The directional control of hot water, among the two heating delivery systems, is achieved by using a servomotor to control a two-way valve. The servomotor is set in motion by the thermostat's output, activated whenever the measured ambient temperature is lower than the reference temperature, and the controlled two-way valve is physically placed on the return pipeline to the CHU, since it needs 40 seconds to fully open.

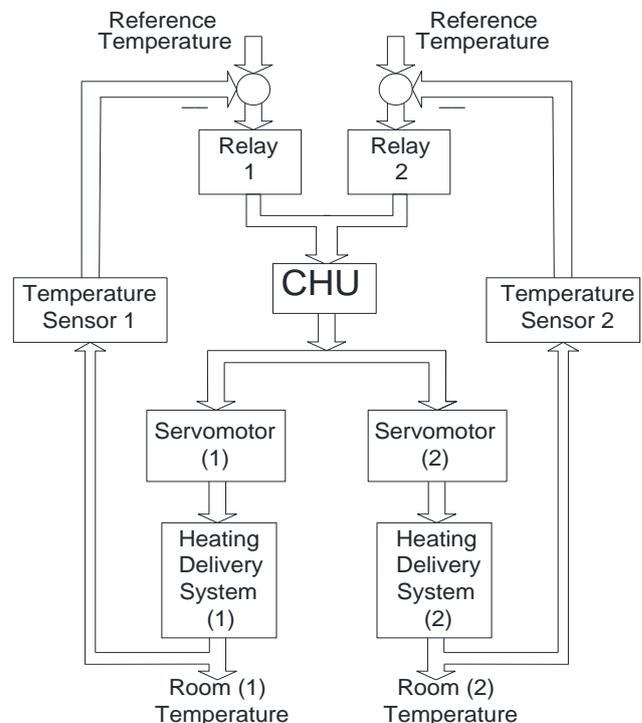


Fig. 3. The distributed heating system's control structure.

Among the advantages of using this system, the authors list the maintenance of the temperature in the less inhabited areas, at a minimum level, of protection against frost (5°C) directly from the thermostat, without having to stop the radiators

when the areas are not inhabited and still generate low heating costs. When these spaces are needed, it only requires the increase of the reference temperature level, and the area will heat up relatively quickly, ensuring the imposed level of comfort throughout the time, in which the space will be destined for housing.

IV. THE TWO-WAY DISTRIBUTED HEATING SYSTEM'S IMPLEMENTATION

In the following, the authors describe the components used in implementing the distributed heating system from Fig. 3. The devices used are identical for both heat distribution systems.

The physical separation between the heat distribution circuits, in the two distinct areas, is performed with a two-way ball valve. This will open / close the return path of the heat agent, being operated by a servomotor.

The servomotor used is ESBE, MBA Series 120 type. Few technical data of the actuator, extracted from [8]:

- Power supply voltage: 230Vac \pm 10%;
- Closing pressure: maximum 10 bar;
- Power consumption - motor operation: 3.5 W;
- Closing time: 40 seconds (for the entire 90 $^{\circ}$);
- Control signal: on / off, 2 wires permanently connected, 3rd receives control signal from a SPST switch contact (see Fig. 4);
- Auxiliary switch: 6 (1) A / 230Vac, normally open SPST.

The servomotor is set on normal closed (NC) mode by activating the auxiliary switch. The control signal of the servomotor (the actuator) is generated by the thermostat and changes its state to normal open (NO).

As a thermostat, the authors used in implementation a wireless non-programmable thermostat, SALUS RT310 [9]. The thermostat consists of a fixed part, that encloses the input and output ports, representing the receiver, and a mobile part, that encloses the temperature sensor, and represents the emitter.



Fig. 4. Servomotor's wiring (detail view from the servomotor).

Here are a few technical data of the thermostat, extracted from [9]:

- Switching Max: 3 (1) A SPST;
- Input/Output: 0 – 230V;
- Outputs: NO/COM/NC;
- Scale: 5 – 35 $^{\circ}$ C;
- Wiring: L – as Input, SL – as Switch live output, and Earth.

The mobile thermostat was used to increase the degree of thermal comfort, since it can be moved by the users in any room they wish. To reduce the fuel consumption even further, a programmable thermostat can be used, which enables to set different temperature levels depending on the time interval.

Since each heating circuit contains a thermostat, in order to separate the two independent control signals, and thus avoiding signal overlapping, on each circuit a NO relay is used. The relay is placed between the thermostat and the CHU, and it also connects to one of the servomotor's control wire, to correctly control the designated servomotor and to properly generate the CHU input signal.

The wiring of all the components for the two-way distributed system and their connection to the 230 Vac power supply, in order to function properly according to what has been described previously, is given in Fig. 5 as an electrical scheme.

The way one of the distributed heating system's works is that once the ambient temperature drops below the reference value, the thermostat's NO output is activated. This will further supply the necessary voltage to the relay, thus changing its NO state and properly activate the thermostat's input port of the CHU (switching on the heating of the thermal agent and the circulating pump). Once the thermostat's NO output is active, and the relay state is changed, the servomotor starts to rotate, and thus opening the two-way valve, allowing the distribution of the thermal agent throughout the corresponding circuit.

The wiring between the relay, the thermostat's fixed part and the servomotors were enclosed in a separate control unit, (see Fig. 6). Fig. 6 contains the annotation of the wiring that is done according to the electrical scheme given in Fig. 5.

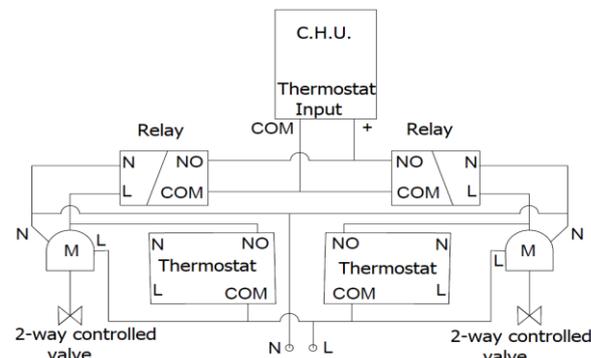


Fig. 5. The two-way distributed heating system's components wiring

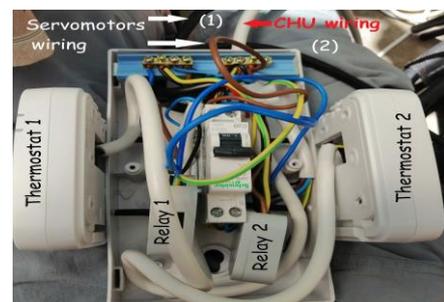


Fig. 6. The unit containing the relay, the thermostats' fixed part and the wiring to servomotors and CHU

We used an auxiliary On / Off Switch for the control unit that incorporates the thermostats, the relays, and the wiring among them, as you can see from Fig. 6.

The two relays make it possible to distribute the hot water correctly, since they make it possible to activate the path of the distribution system only for the thermostat that has the active output. Thus, at one point, only one of the two independent systems may work, or it is also possible to operate the two systems simultaneously.

The heating plant implemented by the authors, started from the idea of an intelligent extension of an existing heating system, with one CHU (used to heat only part of the house), without modifying the current system, but allowing the entire surface of the building to be heated with lower heating costs, compared to the situation where the whole house would be heated permanently, and to ensure distributed level of thermal comfort.

V. CONCLUSIONS

This paper presents the difference between a classical control and a distributed control, for the thermal heating system of a home. The authors focus on the implementation of a system with two distinct distribution channels in order to obtain a heating of the whole household, but with reduced costs.

One of the advantages of using such a system, proposed by the authors, is that it can provide a different level of thermal comfort for different areas of the house, depending on what the users set as the desired reference temperature.

Another advantage of using this system, is the capacity to maintain the temperature in the less inhabited areas, at a minimum level, of protection against frost (5°C), without having to stop the radiators when the areas are not inhabited and still generate low heating costs.

The independent heating systems are based on the use of wireless thermostats, thus, being able to easily modify the room in which the desired level of temperature is ensured, for example between the space used during the day and the space used during the night.

The two-way distributed system, can be easily extended to more areas, meaning a multiple way distributed system can be achieved, using the same components and principles as depicted in this paper. The described system can also be used for office spaces, or industrial buildings, since with such a system the costs of implementation are reduced.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Iulia Clitan, wrote the paper and designed the distributed heating system, Vlad Muresan performed the state of the art, Mihail Abrudean proof read the paper, and Andrei Florin Clitan had done the physical implementation of the system, all the wiring necessary in order to connect the components of the described distributed heating system.

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