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Mixed 0–1 sequential linear programming optimization of heat distribution in a district-heating system

M. Bojic [a,b,*], N. Trifunovic [a], S.I. Gustafsson [c]

[a] Masinski fakultet, Sestre Janjic 6, 34000 Kragujevac, Yugoslavia
[b] Department of Building Services Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, People's Republic of China
[c] IKP / Energy Systems, Institute of Technology, 581 83 Linkoping, Sweden

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Abstract

A district-heating system transports heat from the heat plant by using primary pipe network, via substation, to secondary pipe network where heat is finally distributed to buildings. When this system is designed its operational characteristics were selected to provide thermal comfort (TC) in all buildings served by this district heating system. After several years of operation, the system characteristics may change and TC in buildings deteriorates; some buildings are overheated and other buildings are underheated. The study investigates an optimum strategy to mitigate the problem caused by changes of three of system characteristics: hydraulic resistance of secondary pipe network, heat transmittance of radiators inside buildings, and heat transmittance of building envelope. A strategy of problem mitigation consists of the adjustment of hydraulic resistance of existing valves and retrofitting the local heating system with new substation heat exchanger and additional pumps. We used a steady state, bottom-up approach and mixed 0–1 sequential linear programming to find optimal mitigation strategy, i.e. optimum combination of valves' hydraulic resistances, new pumps placement and new size of substation heat exchanger. The results indicate that the calculated optimal strategy does not effectively improve TC in buildings only in cases when TC is deteriorated by higher than nominal values of heat transmittance of some building envelopes.

Keywords: Heat distribution; District-heating system; Sequential linear programming

1. Introduction

As district heating and cooling systems spend great quantities of fuel at national economies level to provide heating, cooling and domestic hot water in buildings, these systems attracted great attention in the literature [1–5].

A district-heating system analyzed in this paper (Fig. 1) provides heating to three buildings. In this system, heat is generated in the heat plant, and first transported to the substation by using a primary pipe network, and then from the substation to the buildings by using a secondary pipe network. When this system was designed, its characteristics were selected to provide thermal comfort (TC) in these buildings. Here, we studied the situation that may arise after several years from the system design when its characteristics change, causing a deterioration of TC in these buildings. Then, some buildings are overheated, while other buildings are underheated. In overheated buildings, occupants open windows to decrease the space temperature, and in underheated buildings, they turn on additional heating devices to increase space temperature. So, this situation in district-heating systems yields not only to the loss of TC, but also to higher energy consumption in heated buildings.

We investigated changes of three district system characteristics from design value: (1) the hydraulic resistance of the secondary-pipe network, (2) the heat transmittance of radiators in the heated buildings, and (3) the heat transmittance of envelope of the heated buildings. Then, to arrive at the best TC in the heated buildings, we may correct flow rates and temperatures of secondary hot water by using

* Corresponding author. Department of Building Services Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, People's Republic of China. Fax: +381-34-330-196.

E-mail address: bojic@knez.uis.kg.ac.yu (M. Bojic).

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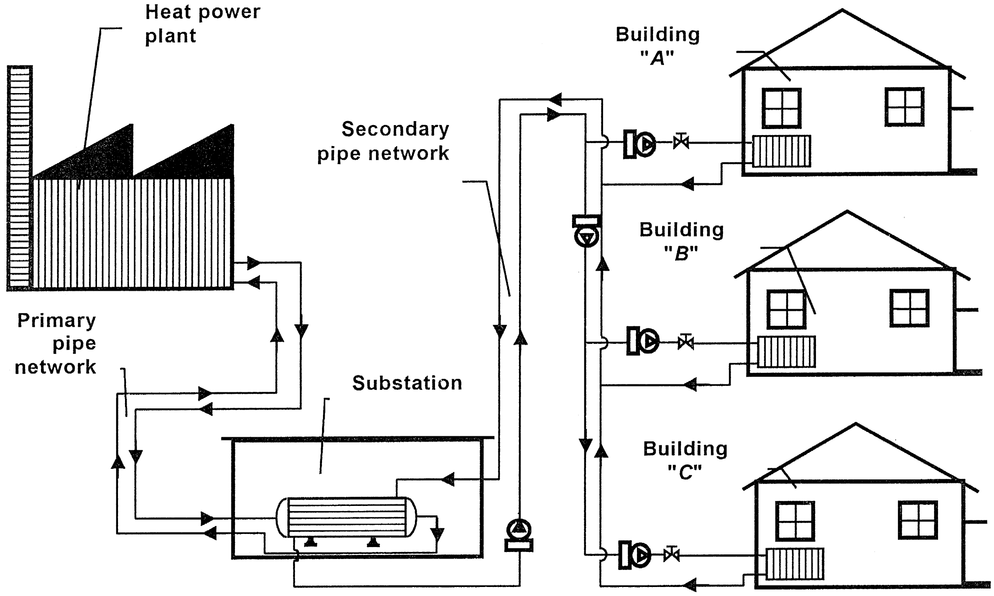

Fig. 1. Schematic of the district-heating system.

some available techniques. In previous work [6,7], we used only one technique consisting of installation of additional pumps at the proper locations of the secondary pipe network. Our research revealed that this technique only improved TC when hydraulic resistance of secondary pipe network was different from design value. To approach to TC in the building spaces when other system parameters such as the heat transmittance of radiators in heated buildings, and the heat transmittance of building envelope are different from design values, we investigated the combination of previous techniques with two additional techniques: (1) adjustment of the hydraulic resistance of valves of the secondary pipe network, and (2) resizing of heat exchangers in substation.

We used a steady-state, bottom-up approach to design an energy module network corresponding to the district-heating system, and then derive a set of equations that describes the behavior of the system [8]. Furthermore, we

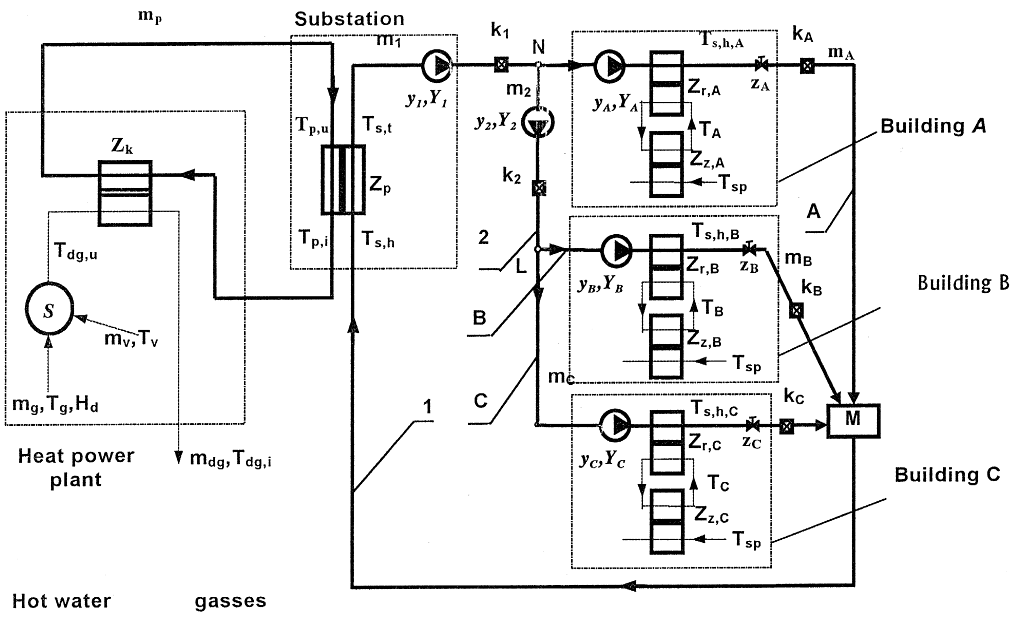

Fig. 2. Network of energy-object modules.