THE MODELING OF THE ENSEMBLE HEAT CONSUMER – THERMAL MODULE OPERATION AT STABILIZED REGIMES

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The European Union strongly recommends the development of cogeneration / trigeneration, district heating and energy rehabilitation of public and residential buildings as effective measures of energy policy in order to reduce the fossil fuel consumption and carbon dioxide emissions. Present and future of the district heating systems from large cities of the country are complex issues of great social importance and of extreme relevance. Operational requirements with maximum efficiency of the centralized heat supply systems which used hot water, raises special problems in terms of knowledge and mastery of hydraulic processes occurring in those systems.

This paper presents the modelling of thermal regimes of the ensemble: heat consumer (for heating and hot water) and thermal module. The thermal module is consists of a parallel step for hot water preparation. The modelling is based on consumer requirements in the form of heat demand for heating and hot water. In this case the modelling follows the unnamed stabilized regimes, without having as its object the transitional regimes. The treatment is from the conditions imposed by the consumer to the source of heat production. Modelling is made on subsystems. The inputs in the model are those required by the consumer, and output elements represent the results conditions for upstream subsystem.

Keywords: heating, district heating system, hot water, heat consumer

1. Introduction

National Energy Sector must succeed in front of the main challenges manifesting on global level: the energy supply security, the increasing economic competitiveness and reducing the environmental impact. These challenges are particularly important under conditions in which Romania has to catch the economic performance of the developed countries from the European Union.

The importance of urban energy is shown by the major social impact and the consumption of energy size associated: total annual consumption of Romania, about 30 million tons of oil equivalents, of which a major part is imported at prices increasingly higher. Urban energy sector is the most disadvantaged.

In this work is presented a modelling of thermal regimes of the ensemble: heat consumer (for heating and domestic hot water) and thermal module (MT)

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with a parallel step for hot water preparation. This ensemble is part of a centralized supply heat as hot water. Modelling is made from the consumer, depending on the heat demand for heating and hot water.

2. Hypothesis

To achieve a mathematical model and a computer program are established some assumptions and some technical conditions to clarify certain issues.

The system is divided into parts and the modelling is done on the assemblies. Model inputs data are required for consumer and output data are results for subassembly conditions upstream of the modelling.

In the case of heating customers, it is start from the calculation of the heat, putting into evidence the parameters fixed and variable - either as inputs or outputs elements of the model.

Heat consumers connected are homogenous measured by the thermal load, characterized by the same index structure of consumption: $\rho^0 = q_{ac}^c / q_i^c$.

Modelling is performed on parts. Inputs elements in the model are those required by the consumer and output elements are the conditions results for upstream subsystem.

Thermal agent considered is the hot water. Heat flow depends on the type of adjustment: this can be qualitative, quantitative or qualitative / quantitative.

3. The mathematical model

The mathematical model for consumer

Heat supply of the consumers aims to satisfy the heat demand of each consumer both in terms of quantity, (heat flow necessary) and in terms of quality (level of heat parameters used).

One room will keep the indoor temperature of thermal comfort if there is equality between heat input and heat loss during one period considered.

During the cold season, the desired indoor temperature is achieved on the one hand by the heat input installation heating, the release of heat from people, cars and appliances, solar radiation, and on the other hand the heat loss of outdoor building elements and those caused by infiltration and ventilation air through leaks.

From heating consumers, the model started with the calculation of heat demand.

The expression of thermal balance for room heated is based on calculation of heat consumption for heating chamber, taking into account all losses.

Modelling of the heat demand for heating is achieved starting from thermal balance equation of an enclosure:

$$q_i = q_{pt} + q_{pv} + q_{tr} - (q_d + q_r) \qquad \text{[kW]} \qquad (1)$$

Practical calculation of the heat for heating is made according to STAS - 1907-1981:

$$q_i = q_{pt}\left(1 + \frac{\sum A}{100}\right) + q_{pv} - q_d \qquad \text{[kW]} \qquad (2)$$

where:

$$\sum A = A_o + A_c + A_s \qquad \text{[kW]} \qquad (3)$$

The calculation value of the heat demand for heating is set for calculation values of: indoor temperature (t_i^c), outdoor temperature (t_o^c) and wind speed (w^c).

In order to ensure the setting and proper functioning of heating systems and to assess the economic efficiency of heating installations, is necessary to knowledge the regime of the heat variation of q_i, both for short periods and throughout all the heating period. Because the heat demand for heating depends mostly on the outside temperature, it is necessary that it be studied variation correlated with changes in outside temperature in different periods of time.

In the most general case, for a chamber heated the heat losses are calculated by the relationship:

$$q_{pt} = q_p + q_c + q_s \qquad \text{[kW]} \qquad (4)$$

The heat for hot water preparation is determined based on hourly hot water consumption and the difference between hot water temperature and water temperature whitch provided to consumers to be heated.

Temperature of hot water supplied depends on the nature of consumer for consumption of hygienic purposes is sufficient a temperature of 35-40 ° C, and to kitchen a temperature of 50-60 ° C.

Norms of our country established as a conventional hot water temperature supplied to consumers is 50 ° C. ($t_{hw} = 50^\circ C$).

$$Q_{hw} = G_{hw} c_p (t_{hw} - t_{cw}) \qquad \text{[kW]} \qquad (5)$$

The hot water temperature should be maintained constant and the cold water temperature can also be considered constant over a period of time. In these circumstances it may be considered that the variation of heat flow is practical identicaly with the variation of hot water flow consumed.

So, modeling the variation of heat consumption in the form of hot water actually means the modeling of hot water flow variation. This has a daily and weekly cyclical.

The variation of total heat requirement for a consumer is the simultaneous variation of heat consumption for heating variation and heat consumption for hot water variation.

The two consumptions are independent of each other.

$$\dot{Q}_{tot} = \dot{Q}_i + \dot{Q}_{hw} \quad [\text{kW}] \quad (6)$$

Output elements of consumer subsystem: hot water flow, tour and return temperature of heat carrier for heating, hot water flow and temperature are the conditions results and the inputs elements for modeling of the next subassembly.

Mathematical model for thermal module subassembly with a parallel step for hot water preparation

In this figure is presented the scheme for thermal module with a parallel step for hot water preparation, this scheme is the oldest and most common.

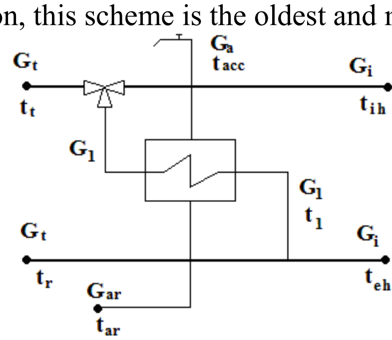

Fig.1 The thermal module scheme with a parallel step for hot water preparation

In Fig. 1 there are defined: G_i - flow required by the consumer of thermal module for heating; t_{ih} - the consumer required flow temperature from thermal module of heating; t_{eh} - the consumer return flow temperature to thermal module of heating; t_{hw} - the temperature of hot water; G_{hw} - the flow of hot water consumed; t_{cw} - the cold water temperature; G_{cw} - the flow of cold water; G_t - total heat flow that enters / exits the heat; t_t -return heat carrier temperature ; t_r - tour heat carrier temperature; G_1 - the flow of heat carrier using for hot water preparation.

The relations for characteristic values are:

- For heating

$$G_i = \frac{q_i}{c \cdot \Delta t_i} \quad \text{[kg/s]} \qquad (7)$$

- For hot water

$$G_{hw} = \frac{q_{hw}}{c \cdot \Delta t_{hw}} \quad \text{[kg/s]} \qquad (8)$$

The input data are determined above based on consumer demand for heat: the flow and temperature of heat necessary for heating and hot water.

Output data are flows and temperatures of the thermal module entrance.

4. Case Study

A heat supply system generally refers to source of heat production in transport and distribution network, the thermal module (MT) or point and the consumer type. In this paper is treated only the consumer and thermal module subassembly.

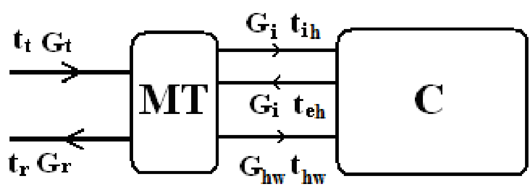

Fig.2 The consumer- thermal module subassembly

Referring to the type of consumer is considered an urban consumer, a building with five levels, form an average climate zones (in terms of temperature) in Romania. The soil temperature at a depth of 50 cm, depth at which is the foundation is 2 °C.

According to STAS 1907/1-97 SR's for Bucharest area outside temperature calculation is -15 ° C.

It is mainly characterized by a thermal energy request afferent to hot water consum during all the year and heat consumption for heating during the winter. Shape and size of such heat demand is a function of specific climate area of consumer.

The length of building is 29 m, the width 10 m and the height 12 m. The indoor temperature required is 22°C. The building has two apartments(A) on the level with three bedrooms and a surface of 82 m^2 and two studios(S) with a surface of 45 m^2.

On the first step the program calculates, according to consumer demand, the flow and the temperature of thermal agent on turn and also on return, for heating and the hot water flow. In other words is calculated the flows and temperatures that must be provided from thermal module to meet the consumer demand.

Tabel 1 present the necessary heat for heating on each level.

Tabel 1

Necessary heat for heating [W]

	1st level	2nd level	3rd level	4th level	5th level
G	**4970**	**4651**	**4651**	**4651**	**6570**
A	**9854**	**9220**	**9220**	**9220**	**11150**
Total on level	**29650**	**27742**	**27742**	**27742**	**37440**
Stairwells	**4473**				
TOTAL	**155644**				

In Table 2 is presented the required heat of the entire building (for heating and hot water).

Tabel 2

Building thermal power required [kW]		
heating	**hot water**	**total**
155.644	**51.881**	**207.525**

Required flows by the consumer for both heating and hot water are determined by the following relations:

$$G_{hw} = \frac{q_{wh}}{c \cdot \Delta t_{hw}} = \frac{q_{wh}}{c \cdot (t_{hw} - t_{cw})} = \frac{51,881}{4,18 \cdot (50 - 15)} = 0,3081 \qquad \text{[kg/s]} \qquad (9)$$

$$G_i = \frac{q_i}{c \cdot \Delta t_i} = \frac{q_i}{c \cdot (t_{ih} - t_{eh})} = \frac{155,644}{4,18 \cdot (85 - 63)} = 1,6925 \qquad \text{[kg/s]} \qquad (10)$$

Input data for the modeling program of thermal module subassembly are: G_{hw}, G_i, t_{ih}, t_{cw}, t_{hw}, t_{eh} and the resulting data are: G_t, t_t, G_1, t_1, t_r.

Using these values of G_{hw}, G_i, it will be calculating the necessary flow of heat carrier for hot water preparation (G_1) and the temperature of heat carrier (t_1) after the hot water preparation.

Table 3

Output data

MT	Heat carrier flow [kg/s]	Temperature [°C]
Entrance	G_t=2.4674	t_t=85
Hot water preparation	G_1=0.7749	t_1=63
Exit	G_r=2.4674	t_r=65,7

In table 3 are presented the output data, the values of this data are high because the heat losses of the building through the construction elements are very high.

5. Conclusion

Urban central heating system concentrates the heat consumption and allow the application of technical and economic solutions to reduce energy losses. This paper presents modeling and simulations of a subassembly of urban heat supply systems in Romania conditions. This program helps to identify and implement new technical solutions with energy, economics and technical performance. With this program you can make a preliminary investigation before an intervention for the rehabilitation of a building or for a all urban heating system.High energy consumption of these types of buildings is due to high losses of heat through building materials, due to poor quality indoor instalations. Because the heat losses of the study building by elements of construction are very high, one method to reduce this assume thermal insulation and and sealing the tire.

NOMENCLATURE

q_{pt} - are loss of heat transmission (convection radiation conduction) and outdoor building elements (walls, windows, doors);
q_{pv} - appropriate heat loss heating air that penetrated through leakages inside the building elements and natural ventilation, opening doors and / or windows;
q_{tr} - the amount of heat stored in the elements of construction;
q_i - the amount of heat introduced by the heating;
q_d - the amount of heat from the heat undercuts;
q_r - the amount of heat from solar radiation received;
A_o - is the addition for orientation of the building, taking into account the different ways of the exposure to solar radiation for exterior construction elements;

A_c - is the addition for the cold surface temperature compensation which takes account of the existence of walls with low thermal inertia;
A_s - the special addition given to the building that heating in which the heating installations are working with interruptions;
q_p - are the transmission heat loss through the external environment through building elements;
q_c - losses of heat to the outside contour of building;
q_s - heat losses on the soil;
t_{hw} - the temperature of hot water required by consumer;
G_{hw} - the flow of hot water consumed in kg / s;
t_{hw} - the hot water temperature;
t_{cw} - the cold water temperature($t_{cw} = 5°C$ for winter, $t_{cw} = 15°C$ for summer);
G_{cw} - the flow of cold water consumed in kg / s;
G_t - total heat flow that enters / exits the heat;
t_t -return heat carrier temperature;
t_r -tour heat carrier temperature;
G_1 - the flow of heat carrier using for hot water preparation;
Δt_{hw} - difference between hot water temperature and cold water temperature.

R E F E R E N C E S

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