THERMAL BEHAVIOR ANALYSIS OF A DISTRICT HEATING SYSTEM TO THE OUTDOOR TEMPERATURE VARIATION. Part 2

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ABSTRACT:
The second part of the paper presents the obtained results of the making analysis of the district heating system operation to outdoor temperature variation over a period of 24 hours, starting at 0:00 dated 18-01-2012 till 24:00. This is made in quasi-stabilized non-nominal regimes due to the building inertia and also large time interval parameter variation. Also, the district heating system thermal behavior at the outdoor temperature variation during the considered period is presented in details. It was chosen the indoor temperature variation calculation because this is one of the main characteristics that determines the thermal comfort feeling, meaning, the consumers’ satisfaction. In order to highlight the results, the standard deviation of the indoor temperature for each consumer has been calculated taking into consideration each considered adjustment type.

Keywords: consumers, thermal adjustment, district heating system, energy efficiency.

3. Obtained results
The determination of system behavior to external temperature variation

The figure 6 show the heat demand variation depending on the outdoor temperature of consumers which are connected to each substation, and the sum of heat demand variations, taking into account the phase shift due to the thermal inertia index of each consumer / building.
Consumers which are connected to distant substations have small distances between them, the time gaps due to heat transport are neglected.

In order to determine the heat demand for the output of thermal point heating, heat losses in the secondary network were calculated depending on its structure and the characteristics listed above. Heat losses for hot water were also determined. Heat distribution delays were not accounted for regarding the thermal secondary network because these delays are small due to short ranges.

Fig. 6 Heat demand variation depending on the outdoor temperature of each consumer
a) TP1, b) TP2, c) TP3, d) TP4
Total heat demand request by consumers at TP1

Total heat demand requested by consumers at TP2

Total heat demand requested by the consumers at TP3
Fig. 7. Heat demand variations requested at the substations
a) TP1, b)TP2, c)TP3, d)TP4

Taking into account the thermal point adjustment schedule that was shown above, the heat demand that must be provided to the substation and used for hot water preparation was calculated in order to satisfy consumers’ demand. Heat demand variations that must be provided to the substations are shown for each substation in fig. 8.
Fig. 8 Heat demand variations that must be provided to the substations
a) TP1, b)TP2, c)TP3, d)TP4

In order to determine the heat demand or the source, thermal losses on the primary thermal network were calculated. The heat demand variations that the source requires are shown in fig. 9.

Fig. 9 Heat demand variations requested at the source

Indoor temperature variation depending on the adopted thermal adjustment

Indoor temperature variation will be shown, depending on the adopted thermal adjustment at the system’s level, resulting in finding out what the optimal adjustment is for the considered system. After presenting the heat quantity variations in specific points, a comparison will be made between the different consumers indoors temperature variation for the three analyzed control cases: semi centralized, centralized and combined.

A) Centralized source thermal adjustment

Heat demand variation that is required by the system for the source and the average value of heat quantity that is provided by the system source used in case of centralized adjustment are shown in fig. 10.
Next, the heat quantity provided by the source to each thermal point and each consumer will be determined, and the consumers’ indoor temperature in case of a qualitative centralized thermal adjustment will also be calculated. Heat losses have been determined towards the exterior environment on each secondary thermal network section and heat quantity variations for every consumer’s provided heating. Based on consumers’ thermo-physical characteristics, the indoor temperature variation has been calculated for each consumer.

**B) Semi-centralized adjustment for each thermal point**

A semi-centralized heat setting is implied, for each thermal point level. The required and received amount of heat by consumers which are connected to one from the 4 thermal points will be determined, and then the consumers’ interior temperature variation will also be calculated. The same steps as for the centralized adjustment that has been described above will be followed.
Fig. 11 The required and received amount of heat by consumers in case of Semi-centralized adjustment
a) TP1, b) TP2, c) TP3, d) TP4

C) Centralized source adjustment and semi-centralized adjustment for thermal point
A thermal combined control is considered, both at the source’s level and semi-centralized for each PT. The received and required heat quantity by each consumer which is connected to one of the 4 thermal point will be determined, and then the consumers’ interior temperature variation will also be calculated. The heat amount required by the consumer and provided by the source at the consumers’ level in case of combined adjustment for some consumers are shown in fig. 12. Received

![Graph of Heat amount at C2](image1)

![Graph of Heat amount at C3](image2)

![Graph of Heat amount at C9](image3)
Fig. 12. Heat amount required by the consumer and provided by the source at the consumers’ level in case of combined adjustment a) C2; b) C3; c) C9 d) C18 e) C29;

A graphical representation of interior temperature variations for a few consumers in case of the three considered adjustment types is shown in fig. 13.
Fig. 13 Variația temperaturii interioare a consumatorilor pentru cele trei tipuri de reglaje considerate a) C3; b) C7; c) C15; d) C20; e) C28;
In order for the results to be visible, the interior temperature deviation ($\sigma_{it}$) using the considered interval of time for each adjustment type is calculated. The deviation was chosen to be determined because its value is higher as the individual value variations from which it was determined is higher. The deviation is expressed in the studied characteristics’ unit of measurement, in this case, in Celsius degrees.

Each consumer’s deviation for each adjustment type is shown in fig. 14. Looking at this figure, you can see that in case of the combined adjustment, the interior temperature deviation is the smallest, having values between 0,5÷1,15ºC, and in the case of centralized adjustment, the deviation value is higher, having values between 1,45÷2,42 ºC. The deviation, in case of semi-centralized adjustment, is between 0,7÷1,81 ºC.

![Fig. 14 Standard deviation of indoor temperature in all of three types of thermal adjustment](image)

Using the standard deviation, a qualitative and also a quantitative assessment for the achievement of thermal comfort conditions at the consumers’ level can be made.

According to SR 7730, interior temperature deviation $\sigma_{it}$ must be smaller than 1,5 ºC in order to achieve the thermal comfort conditions.

It can be seen in fig. 14 that, in case of a centralized adjustment, the only consumer which meets the thermal comfort condition is consumer C10. In case of semi-centralized adjustment, there are only 5 consumers that don’t meet the thermal comfort condition, and in case of a combined adjustment, all consumers meet the thermal comfort condition.

4. Conclusion

The paper is an analysis on the thermal variation for a heat supply system at the outdoor temperature variation on a given interval of time. The exterior temperature is the main factor that influences the consumer’s thermal energy consumption and also influences the thermal energy losses among the heat trail.

Heat adjustment means knowing the heat temperature variation type in different system points from the consumer unit to the heat source in order to meet the consumers’ requests.

In order to know the heat variation, the heat consumption character must be kept in mind and also the thermal characteristics for different subassemblies that form the system. The elements that influence the thermal conditions are the heat exchange units that are components of the system.
The outdoor temperature is the main parameter that influences the heat supply systems run. This variation determines the consumers’ heat demand and also it influences the thermal distribution and transportation network losses.

The resulted data, used for the heat supply system analysis, are graphically shown for an easier reading.

From these graphics, the following can be seen:

- The variation of the thermal demand that is used for heating at the thermal point exit has lower amplitudes as the consumers’ number connected to this substation is higher and these consumers are different from the thermal inertia point of view.
- The thermal inertia phase difference is due to the thermal inertia coefficient and to the thermal assimilation coefficient for each consumer/building.
- Heat amount variation for heating water does not directly depend on the outdoor temperature variation, the dependence is indirect through the cold water temperature (during winter, it is considered steady: +5ºC);
- Diurnal variations of heat consumers for hot water supply is due to the consumed hot water flow diurnal variations. The variation depends on the hot water consumer’s type. If the consumers’ number raises, the variations will diminish due to the consumption that is not simultaneously.
- The heat consumption value used for hot water preparation is a lot lower than the heat consumption used for heating during this period (January), but this strongly influences the total heat demand variation in the urban substation.
- The substations must provide the required heat for heating and for hot water preparation. Unlike the thermal point at the MT level, there is the possibility to apply the thermal and hydraulic conditions according to some consumers’ groups’ requests.
- The best time for a source intervention, regardless the adopted thermal adjustment, must take account of the time difference in order for it not to affect many consumers.
- In case of a semi centralized adjustment, there can be seen a received heat quantity by the consumer a lot closer to the requested heat quantity and also a smaller indoor temperature variation. This is due to the thermal point reply, (in case of a semi centralized adjustment) according to a smaller consumers’ number requests.
- In order to highlight the results, the standard deviation of the indoor temperature for each consumer has been calculated taking into consideration each considered adjustment type. In fig. 7.24 shows that, in case of a centralized adjustment, the deviation is a lot higher, only one consumer meeting the thermal comfort condition. In case of a semi centralized adjustment, the indoor temperature deviation is smaller, but also considering this case, there are 5 consumers which do not meet the thermal comfort condition. The only case when consumers met the thermal comfort condition ($\sigma_\dot{q} < 1.5^\circ C$) is the combined adjustment.
- If the system’s amplitude is greater, then its run, based only on a source centralized adjustment, cannot be done because the intervention will be felt by all consumers but at different times.
- This is why the adjustment must be done in a multi-stage process:
  - The centralized adjustment step done at the source’s level;
  - The centralized adjustment step at the thermal point level;
  - A local adjustment step at the consumers’ level – temperature controllers for consuming devices;
- The additional or the minus heat differences distributed to consumers are lower when all adjustment types are applied.

It was chosen the indoor temperature variation calculation because this is one of the main characteristics that determines the thermal comfort feeling, meaning, the consumers’ satisfaction.

Permanently ensuring an indoor climate that meets the normal thermal comfort conditions determines the client’s satisfaction and his loyalty.

Bibliografie

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