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Influence of Different Operating Conditions of a District Heating and Cooling System on Heat Transportation Losses of a District Heating Network

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Abstract. This paper deals with different operating conditions of a District Heating and Cooling (DHC) System and its influence on heat transportation losses of a District Heating Network (DHN). The different operating conditions of the DHC System's mean different flow rate and temperature of the network water flowing in the DHN. These different operating conditions of the DHC System result in the DHNs having variable transportation losses. The analyzed DHC System consists of the Heat Only Boilers (HOB) plant and the DHN with substations and chambers. The DHNs in Poland are usually installed as underground, traditionally insulated piping placed in concrete ducts (large diameter and main pipelines) or pre-insulated piping placed directly in the ground. The result of the analysis was used to verify calculation methods of fluid flow and heat transportation losses of the DHN, when cold for consumers is generated using either absorption or adsorption chillers. The total heat transportation losses of the DHN differ according to individual systems and depend on the size of the DHC System, its heating loads and quality of insulation of the piping. This paper presents the results of the numerical calculation of the temperature distribution in the soil around the piping channel using an FDA model. The results of the numerical simulation of water and heat flow through the DHN allow to determine the total heat transportation losses of the DHN for different operating conditions of the DHC System.

1. Introduction

The District Heating and Cooling (DHC) System consists of the Combined Heat and Power (CHP) or the Heat Only Boilers (HOB) plants and the District Heating Network (DHN) with substations and chambers. The substations transfer heat to heat consumers (for space heating and domestic hot water supply) and cold consumers (heat is converted to cold using absorption or adsorption chillers). The chambers contain pipe fittings, controlling and monitoring accessories. The reference CHP or HOB plants are in operation annually for 200 – 230 days of heating season, and are supplying hot water in the summer season mainly for two purposes i.e. to produce domestic hot water and to generate cold. Heat supply to the consumers takes place through the same DHN during heating and summer seasons. The heat and hydraulic loads of the DHN is changing during operation and depend on present heat demand by the consumers. Obviously, the heat demand during heating season mainly depends on weather conditions. Heat demand in summer season is approximately 4 - 10 times less than nominal heat demand (total) in the coldest wintertime.

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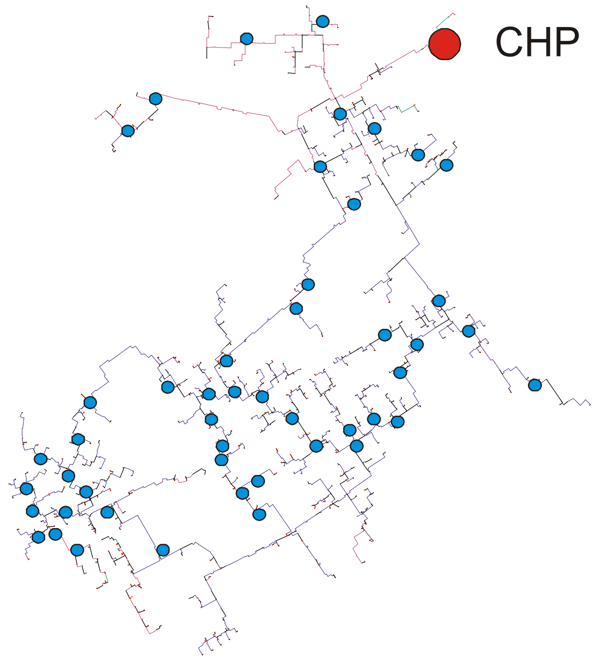

Figure 1. Scheme of analyzed DN (blue points – cold consumers, red point – CHP plant)

Figure 1 presents analyzed District Heating (DH) System in present state and the case when the system will supply heat also for cold generation purposes i.e. the DH System will convert to the DHC System (cold consumers are marked by blue points). Two alternatives were analyzed for the DHC System i.e. cold will be generated by absorption or adsorption chillers. If cold is generating using absorption chillers, necessary to use supply network water with temperature around 85 °C and temperature drop on the chillers is approximately 15 °C. If cold is generating using adsorption chillers water temperature could be around 70 °C and temperature drop on the chillers is approximately 10 °C.

2. Determination of heat losses of the District Heating Network

An application of automatic control equipment on the demand side has enabled control and reduces heat consumption by consumers. The consumers heat demand changes have direct influence on hydraulic and thermal processes in the DHN i.e., the changes in the network water flow rate and temperature [1]. Numerical calculation of heat losses of the DHN shall take into account relationships between hydraulic and thermal processes during heat transportation through the piping [2]. Considering numerous mathematical models of liquid flow and heat transfer in the piping, the paper mentions only ways of mathematical modeling of these processes.

2.1. Models of water flow in the DHN

Mathematical modeling of hydraulic processes in the DN is related with the calculation of water flow and pressure drops in particular sections of the piping. Presently, the most popular calculation methods of hydraulic processes in the DHN are: loop, node, loop – node, node – loop and equivalent resistance methods [2], [3].

2.2. Models of heat losses of the DHN

Heat losses are one of the thermal processes that appear during heat transportation through the DHN [3 -10]. The rate of heat losses depends mainly on the quality of insulation materials surrounding the piping. As a result of continuous extension of DHNs during last decades in Poland, their structure and the quality of insulation differ greatly due to age and the development of insulation technology.

Existing calculation methods of heat losses of the piping can be divided into two groups, i.e., simplified and exact methods [3]. Figure 2 shows the results of the numerical calculation of the temperature distribution in the soil around the piping channel using the Finite Difference Analysis (FDA) model.

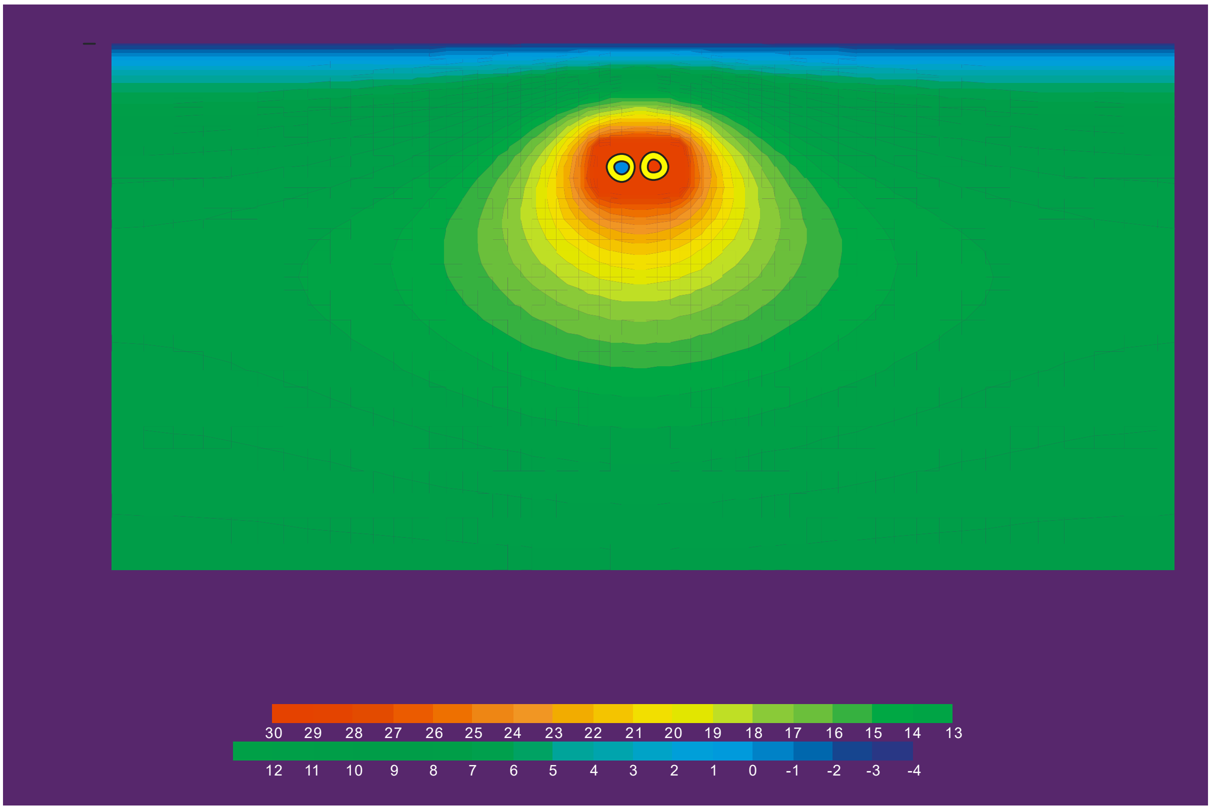

Figure 2. Temperature distribution in the soil around the piping channel.

Estimation of heat losses of the pre-insulating piping can be done with satisfactory accuracy using equations presented in [11].

3. Analysis of the heat losses of DHN under different operating conditions

The total quantity of the heat losses of the DHN is different for individual systems and depends mainly on the size of the DHC System, its heating loads and quality of insulation of the piping. In order to compare the total quantity of the heat losses of the DHN for different systems, it is necessary to refer these losses to the quantity of heat transported through the piping. The indicator presented the percentage of the heat losses in the total heat transported through the DHN is defined below.

$$Us = \frac{El}{Et} * 100 \quad \% \tag{1}$$

The size of the percentage of the heat losses in the total heat transported through the DHN is the indicator of the piping insulation quality. The typical value of this indicator for Polish DH Systems is in the range 10-20% for the heating season and 20-50% for the summer season. However, the lower value from the presented range of the indicator appears for larger District Heating Systems.

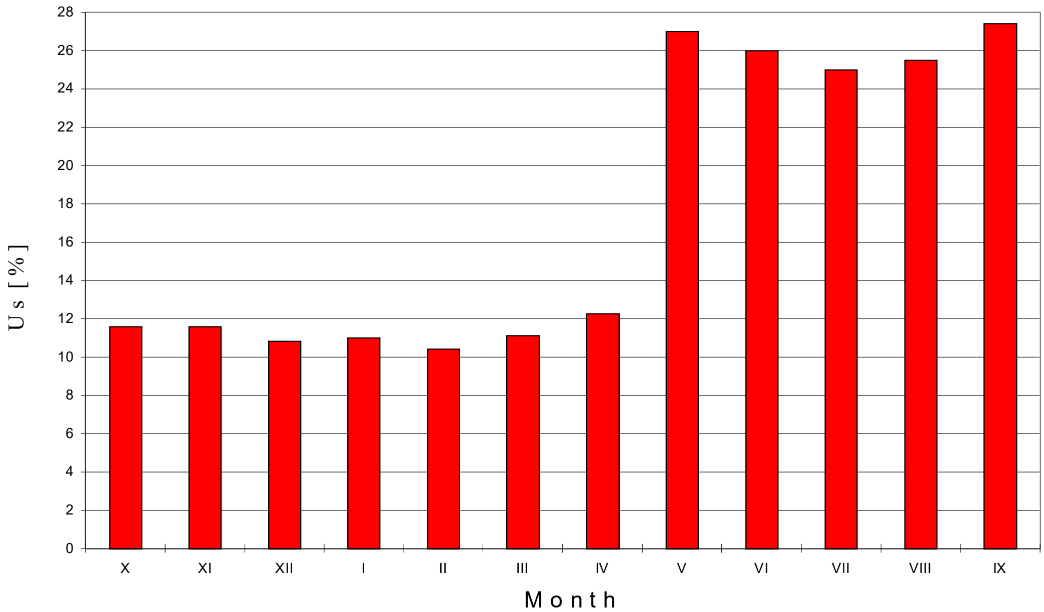

Figure 3. Percentages of the heat losses of the DHN for particular months for a selected DH Systems in Poland.

Figure 3 shows an example bar chart showing changes in percentages of the heat losses in the heat supply for particular months for a DH Systems in Poland. The percentage of the heat losses in the total heat transported through the DHN usually is two, or even more, times higher in the summer season than in the heating season, as can be seen in figure 3.

In Table 1 below basic data and results of calculation are presented for the analyzed DH System in present state and for the case when the system is supplied with heat for cold generation purposes as well. Two alternatives were analyzed, i.e., cold is generated by absorption or adsorption chillers. Total heat demand in the summer season for the DH System in present state is around 9.12 MW, while for future state for the DHC System it is approximately 14.94 MW.

Table 1. Data and results of calculation for DH System (present state) and for analyzed future state for DHC System in case when cold will be generated by absorption chillers or by adsorption chillers.

	DH System Present State	**DHC System Absorption chillers**	**DHC System Adsorption chillers**
Flow rate of network water, Mgt/h	525	860	1027
Heat power of substations, MW	9.12	14.94	14.94
Power of the heat losses, MW	1.23	1.61	1.35
Temperature of supply/return water T_s/ T_r	72.0 / 54.9	85.0 / 68.4	72.0 / 58.3
Relative percentage of the heat losses, %	11.9	9.7	8.3
T_s – heat substation 1, C	67.6	81.8	69.5
T_s – heat substation 2, C	68.5	82.1	69.7

The results of the computer simulation for the DH System in present state and for two alternatives for DHC System presented in table 1 indicate that the power of heat losses increased slightly (from 1.23 MW for DH System to 1.61 MW and 1.35 MW respectively for DHC Systems) though the total heat power of substations increased significantly i.e. from 9.12 to 14.94 MW.

Finally, the relative percentage of the heat losses of the DHN which was 11.9% for the DH System in present state significantly decreased to 9.7% in the case of the DHC System with cold generation by absorption chillers and to 8.3% in the case of the DHC System with cold generation by adsorption

chillers. Both factors related to conversion of the DH System to the DHC Systems, i.e., increasing of heat sold to heat and cold consumers and decreasing of relative percentage of the heat losses by the DHN have a very positive impact on the economy of the operation of the DHC Systems.
The results of the network water temperature (supply piping) in present state (cold is not generated) are shown graphically in figure 4.

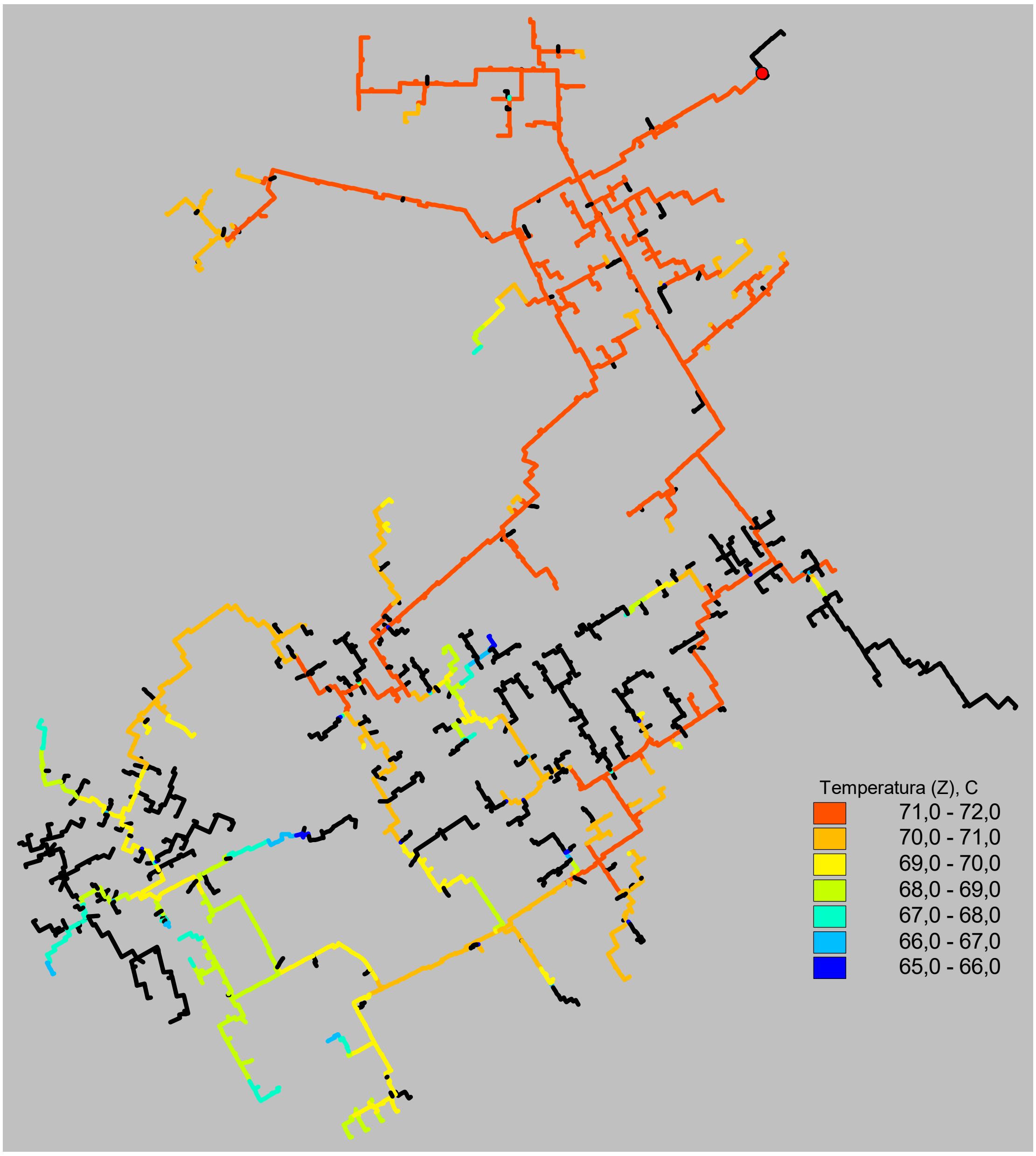

Figure 4. Results of calculation of the network water temperature - preset state.

The results of the network water temperature (supply piping) when cold is generated by absorption chillers are shown graphically in figure 5.

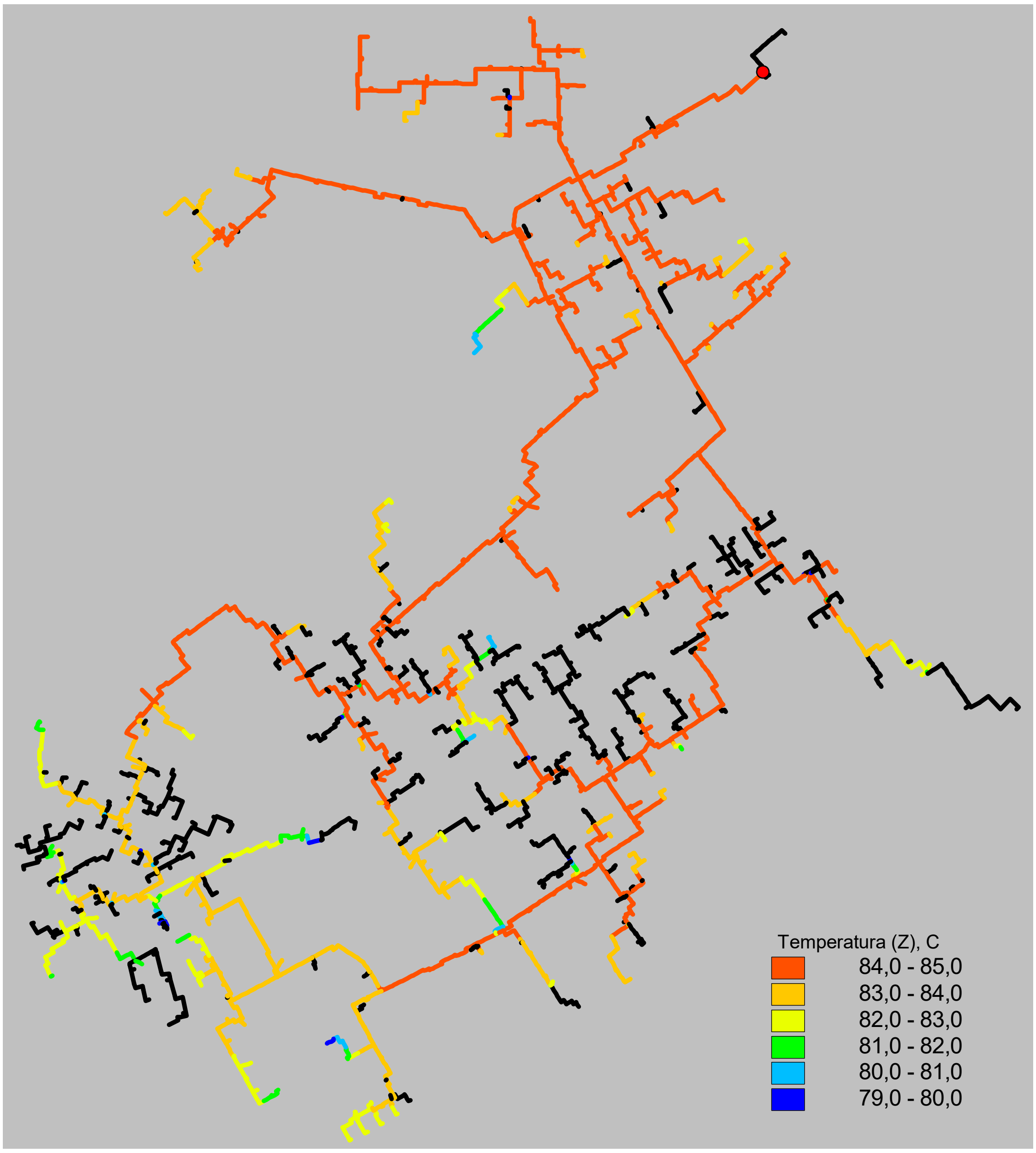

Figure 5. Results of calculation of the network water temperature when cold is generated by absorption chillers.

The results of the network water temperature (supply piping) when cold is generated by adsorption chillers are shown graphically in figure 6.

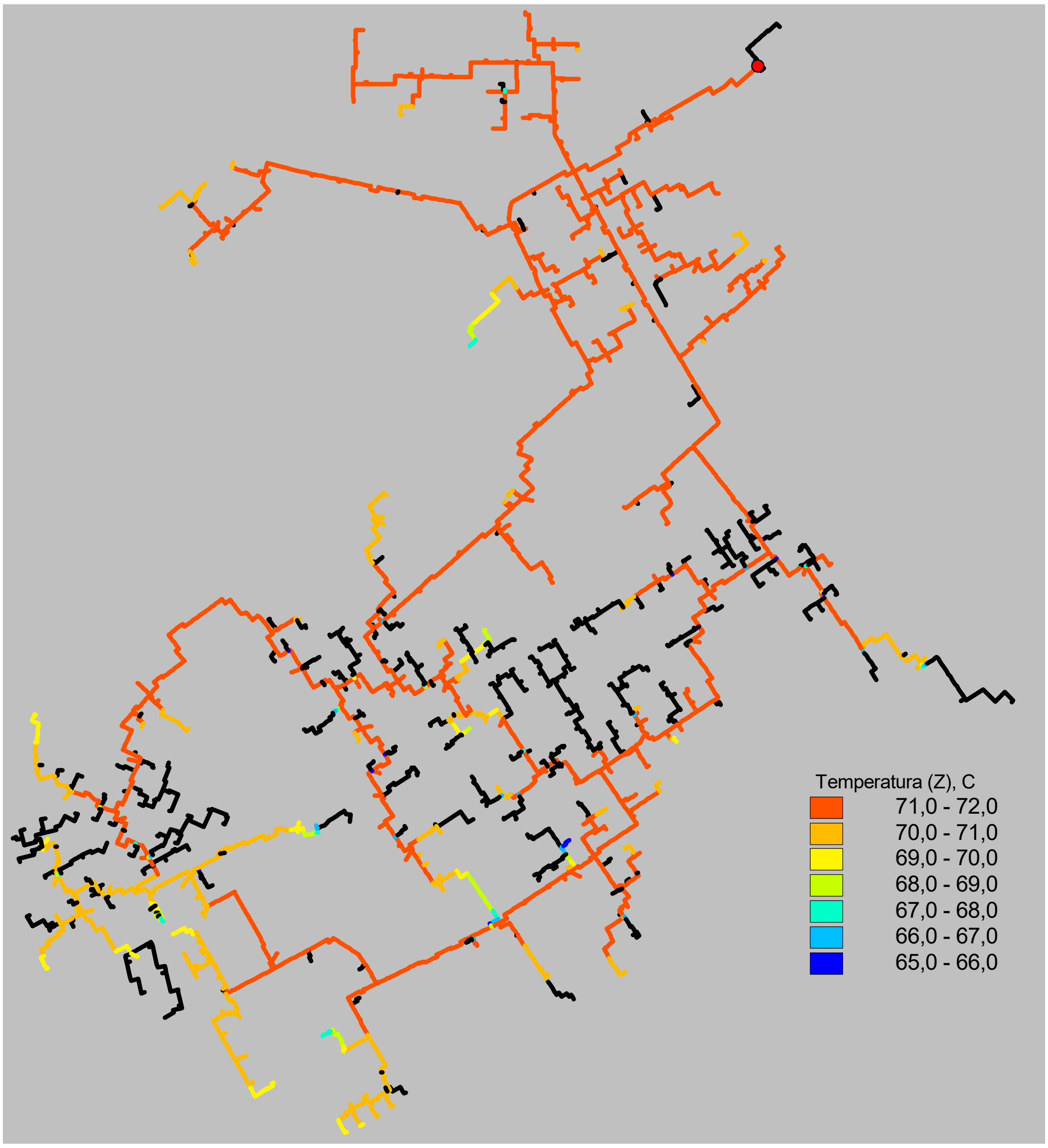

Figure 6. Results of calculation of the network water temperature when cold is generated by adsorption chillers.

4. Conclusions

Assuming as input real changes of the basic parameters of the DH System (temperatures, flow rates, etc.), computer simulations were performed for different operational conditions in order to determine the heat losses of the DHN. Analyses were performed for the DH System in present state and for the case when the system supplies heat for cold generation purposes as well, i.e., the DH System converts to the DHC System. Two alternatives were analyzed for the DHC System, i.e., cold will be generated by absorption or adsorption chillers.

The results of the numerical calculations show that:

- The percentages of the heat losses in the total heat transported through the DHN in the DH Systems in Poland are in the range 7-20% for the heating season and 12-50% for the summer season (usually the losses are two times higher in summer than in the heating season),

- Numerical calculation of the temperature distribution in the soil around the piping of the DHN can be used to improve the mathematical models for the heat loses of the piping traditionally insulated and placed in the concrete ducts [3]. For the pre-insulated piping, satisfactory accuracy offers equation presented in [11],
- The results of computer simulations for the analyzed DH System and for the system converted to DHC show that the power of heat losses increased slightly (from 1.23 MW for DH System to 1.61 MW and 1.35 MW respectively for DHC Systems), while the total heat power of substations increased nearly twice,
- The relative percentage of the heat losses of the DHN which was for 11.9% for the DH System in present state decreased to 9.7% in the case of the DHC System with cold generation by absorption chillers and to 8.3% in the case of the DHC System with cold generation by adsorption chillers.
- Conversion of the DH System to the DHC System could significantly increase heat sold to heat and cold consumers and decrease the relative percentage of the heat losses by the DHN.
- Both of the factors indicated above have a very positive impact on the economy of operation of the DHC Systems.

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