Application of thermohydraulic dispatcher in low temperature district heating systems for decreasing heat carrier transportation energy cost and increasing reliability of heat supply

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Abstract. Low pressure district heating systems have low breakdown rate and allow decreasing heat carrier transportation energy cost by means of avoiding throttling of available water head. One of the basic elements of such systems is thermohydraulic dispatcher (THD) which separates primary circuit and secondary circuit (or circuits) that allows avoiding mutual hydraulic influence of circuits on each other and reducing water heads of network pumps. Analysis of perspective ways of using thermohydraulic dispatcher (THD) in low temperature district heating systems is made in this paper. Principal scheme and mathematical model of low pressure and temperature district heating system based on CHP generation with THD are considered. The main advantages of such systems are pointed out.

1. Introduction

At the present time low temperature district heating systems are of great interest in European countries. First of all, it is caused by the fact that such systems have broad perspectives of using alternatives and renewables in order to reduce carbon dioxide emission, to increase share of alternatives and renewables in total energy consumption according to the Europe 20-20-20 Strategy [1]. There are also some researches intended to create smart low temperature district heating systems [2] which allows consumers to buy heating energy as well as sell it in case of individual local generation. One more advantage of low temperature district heating systems is that more electricity can be generated by means of cogeneration mode and the efficiency of CHP plant can be increased as well [3]. Reducing temperature of water in supply pipeline from 130 °C to 80 °C, for example, leads to decreasing pressure and temperature of steam extraction on CHP plant and to increasing specific combined generation of electricity on 34-50 kWh/GJ (30-50%) depending on the initial steam parameters before a turbine. At the same time low temperature district heating systems have higher flowrate of heat carrier which can lead to high operating costs and exploitation problems (Figure 1).
2. Perspectives of using thermohydraulic separators and dispatchers (THD) in heat supply systems

Using thermohydraulic separators and THD (vertical or horizontal pipe manifold of large diameter with low hydraulic resistance) in heat supply systems, it is possible to create low temperature and pressure systems, which results in increasing reliability of power engineering equipment, decreasing breakdown rate of heat supply network, implementing the idea of smart heat supply systems. Moreover, low temperature and pressure district heating systems allows wide use of polymeric pipelines that are well-known for high resistance to corrosion, long operational life, light weight, low coefficient of roughness and heat conduction.

Other possible advantage of implementing THD in low temperature district heating systems is providing hydraulic stability of heat supply network under low available water head. Decreasing designed temperatures of network water (decreasing temperature chart) implies that so-called “fracture zone” expands and begins with lower outside air temperature. It leads to increasing of heating load control range by means of variable flow adjustment as well as increasing of depth of adjustment. In this case it is possible to reduce flowrate fluctuations in main pipelines of heat supply network using THD.

District heating systems with distributed variable speed pumps (DVSP DH systems) and with conventional central circulating pumps (CCCP DH systems) are compared in paper [4]. Simplified schemes of both systems are shown below (Figure 2). There is a hydraulic connector in DVSP DH system which is very similar to thermohydraulic dispatcher. Piezometer charts are presented on figure 3 for both systems. Special feature of piezometer chart for DVSP DH system is that pressure lines of supply and return pipelines have crossing point and after this point pressure line of return pipeline goes up while supply pressure line goes down.

Figure 1. Total specific costs of heat carrier transportation depending on pipeline diameter (0.1; 0.2; 0.3; 0.4; 0.5 m) and mass flowrate.
Model of DVSP DH system was applied in Kuerle, China, where CCCP DH system operated originally. In result, pumps power decreased from 238 kW to 194 kW. It was also found out that DVSP DH systems consume, at least, 30% less electric energy than CCCP DH systems under changing flowrates of one or several consumers. It means that there is great energy saving potential in going from CCCP DH systems to DVSP DH systems which will result in providing more electric energy for industrial, public and other consumers.

3. Simulation of heat supply systems with thermohydraulic dispatchers

Simplified mathematic models of heat supply systems with THD have been already developed by the authors of papers [5, 6]. Simplified mathematic model of the scheme shown on figure 4 was proposed in paper [5]:

\[ S_\Sigma k \cdot Q_k \cdot |Q_k| + S_p \cdot Q_p \cdot |Q_p| - H_{k0} = 0 \]

\[ S_\Sigma ts \cdot Q_{ts} \cdot |Q_{ts}| - S_p \cdot Q_p \cdot |Q_p| - H_{ts0} = 0 \]

\[ Q_k - Q_{ts} - Q_p = 0 \]
This mathematical model describes flowrates and water heads distribution quite well, but it gives no insight into heat and hydraulic processes inside THD. To solve this problem 3D-model of THD was developed in software package ANSYS. Two THD configurations were considered (Figure 5 and Figure 6). The first one (Figure 5) is typical for conventional boilers while the second one (Figure 6) is typical for condensation boilers. During the simulation flowrates and inlet velocities of THD changed in wide range. In result of numerical simulation temperature field and velocity vectors of heat carrier were obtained.

**Figure 5.** THD configuration for conventional boilers, temperature distribution and the field of velocity vectors in axial section of THD at 50% flowrate delivered to consumer.
When analyzing the results of simulation, it was found out that temperature of water \( T_2 \) coming from THD to a heat supply source is almost not affected by velocity of water delivered from the source to THD. This temperature significantly depends on ratio of flowrates delivered to a consumer and bypassed through THD. Moreover, the dependence is close to inverse proportion (Figure 7).

**Figure 6.** THD configuration for condensation boilers, temperature distribution and the field of velocity vectors in axial section of THD at 90% flowrate delivered to consumer.

**Figure 7.** Dependence of temperature of water delivered to consumer from THD \( T_{01}, ^\circ\text{C} \) and temperature of water returned to source from THD \( T_2, ^\circ\text{C} \) on proportion of flowrate delivered to consumer.

4. Conclusions
The following results were obtained for both THD configurations:
- temperature of heat carrier delivered to consumer from THD (T01) is almost equal to temperature of heat carrier delivered to THD from heat source (T1) and affected by neither inlet velocity of THD nor proportion of flowrate delivered to consumer;
- temperature of water coming from THD to heat source (T2) also doesn’t depend on velocity of water coming from heat source to THD. This temperature is almost inversely proportional to proportion of flowrate delivered to consumer;
- THD configuration for conventional boilers is characterized by uniform distribution of temperatures along the height of TDH, absence of significant swirls within wide range of flowrates; 
- THD configuration for condensation boilers is nonuniform distribution of temperatures along the height of TDH and also significant swirls.

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