HEAT EXCHANGERS CONNECTION IN SUBSTATIONS – A TOOL OF DECREASING RETURN TEMPERATURE IN DISTRICT HEATING NETWORKS

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Summary

Nowadays a large number of district heat utilities are faced with excessive cost pressure if they intend to offer district heat at prices comparable to the heating cost of individual heating systems. The return temperature in district heating networks has a great impact on the economy of district heat. Transmission capacity, pumping demands, heat losses, efficiency in case of cogeneration, utilisation of industrial waste heat, solar and geothermal energy for district heating are all dependent on this parameter.
One way to obtain lower return temperature is the suitable connection of heat exchangers in substations. Based on mathematical modelling and simulation the paper shows the temperature differences between three – serial, parallel and two-step - types of heat exchanger connections and its economical impact.

1. WORKABLE AND OPTIMUM SYSTEMS

There are several types of heat exchanger connections used for domestic hot water (DHW) and space heating (SH) water generation in the substations [1]. Considerable effort to increase efficiency in district heating systems stimulates the distinction between workable and optimum systems. The criteria for optimisation in case of district heating substations should be both economical and environmental.
Since the return temperature in district heating networks has a great impact on the economy of heat production and transport, reduction of the return temperature on the primary side is both an economical and an environmental criterion.
The advantages of reducing the return temperature in district heating are the following:

- increased transmission capacity,
- reduced heat losses,
- reduced pumping energy demand,
- better performance potentials of combined heat and power (CHP) plants,
- better potential for the utilisation of industrial waste heat, solar or geothermal energy.

Since these advantages feature potential energy saving and reflect higher performance in reducing the fuel consumption of heat production, they also bring potential environmental benefits. For analysing and comparing different types of heat exchanger connections a mathematical model of substations was developed. The model gives possibility to provide simulation of operation of the substations, and determinate water flow and temperature in the pipes of the substations.

2. ANALYSED INDIRECT CONNECTION SCHEMES

Main principles of connection heat exchangers used for DHW and SH water generation at the substations are serial, parallel and two-step type of connections.

2.1 Serial connection

This type of connection (**Fig. 1.**) commonly used in Hungary for substations of various sizes. The by-pass pipe of the SH heat exchanger and the priority control of DHW are characteristic for this connection.

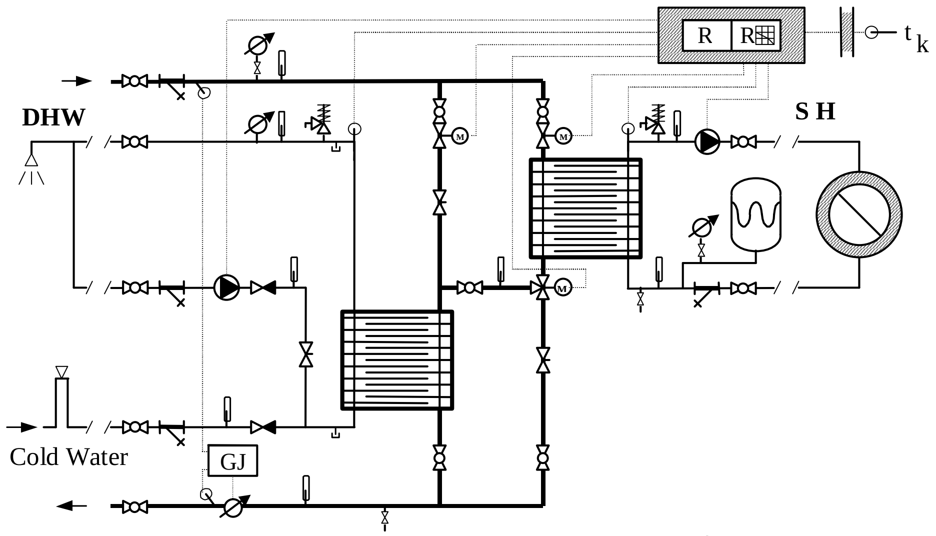

Fig. 1. Consumer substation with serial connection of heat exchangers

2.2 Connection in parallel

This type of connection (**Fig. 2.**) is also commonly used in Hungarian substations.

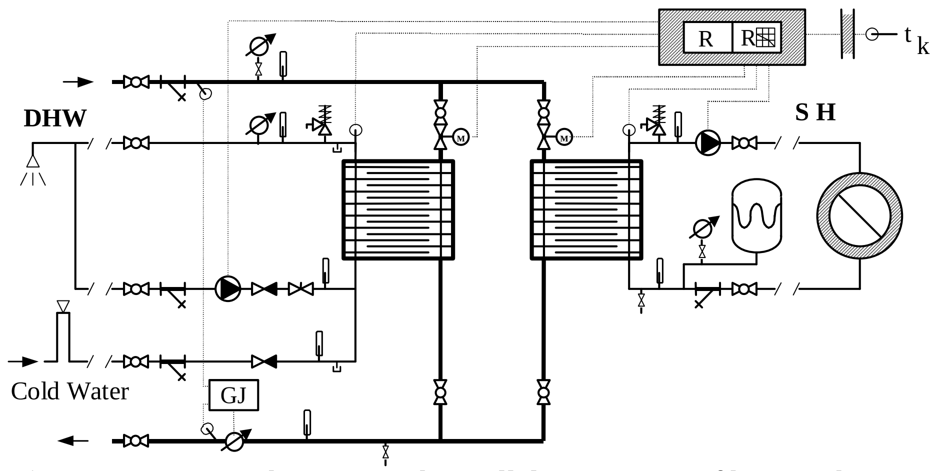

Fig. 2. Consumer substation with parallel connection of heat exchangers

2.3 Two-step connection

This type of connection (**Fig. 3.**) contains two serial connected DHW heat exchangers. (These heat exchangers technically could be separated in two parts, or produced in a special way in one part.)

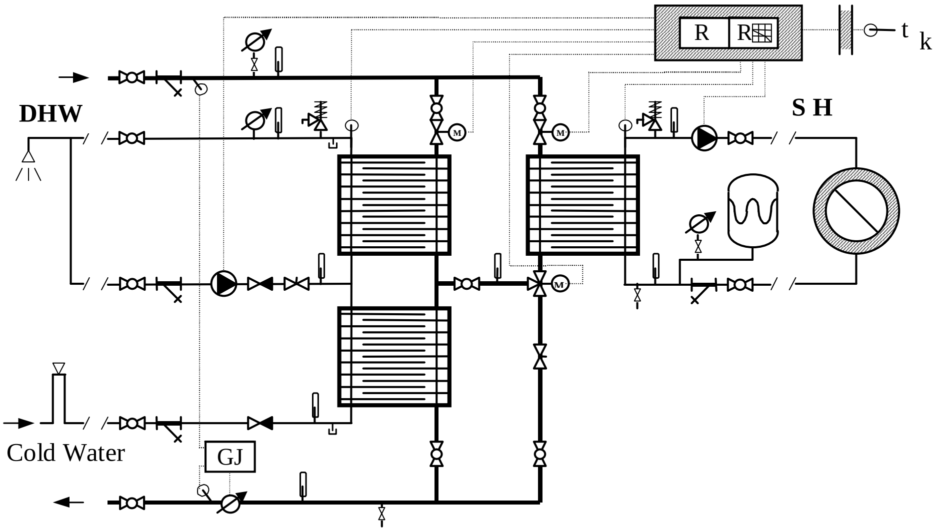

Fig. 3. Consumer substation with two-step connection of heat exchangers

3. DIFFERENCES BETWEEN ANALYSED SCHEMES

Comparing the consumer substation schemes in the Figs. 1. – 3. it can be ascertained, that the number of elements of the substations except for the heat exchangers is the same. In case of serial connection the investment cost will be higher than that of the parallel connection due to the additional cost of the by-pass pipe and its control valve. In case of two-step connection the investment cost will be due to the additional cost of the two-step DHW heat exchanger. These cost differences need to be taken into consideration at the economical evaluation (optimisation).

In the **Figs. 4. – 6.** under the simplified connection schemes one can see the diagrams showing the water flow and the temperature in the pipes of the substations [2]. The diagrams were constructed on the basis of a simulation that assumes that the heat demand on the DHW and SH sides, the temperature of heating and heated waters on the supply side and the heat exchanger sizes (surfaces) were the same. On the diagrams one can notice the differences in water flow needed to meet the heat demand (0,75 – 0,61 – 0,56 kg/s), and differences in return temperature (38-32-29 °C).

The disadvantage of serial connection compared to the other solutions is related to the control of DHW generation. The by-pass pipe of the SH heat exchanger is used for increasing of heating water temperature at the supply side of the DHW exchanger. Since at the beginning and the end of the heating season the supply temperature in a district heating network determines the DHW temperature, in this period the by-pass pipe is in use. As the diagram shows, that heating water flowing through the by-pass pipe is cooling down by cooled water in the SH exchanger. From this reason in many cases for safe satisfaction of heat demand it is not enough to provide a primary supply temperature of 65°C (as we determinate for the simulation for preparing DHW 45 °C), but it is necessary to keep it at a much higher temperature. This results in a wasteful operation of the DH.

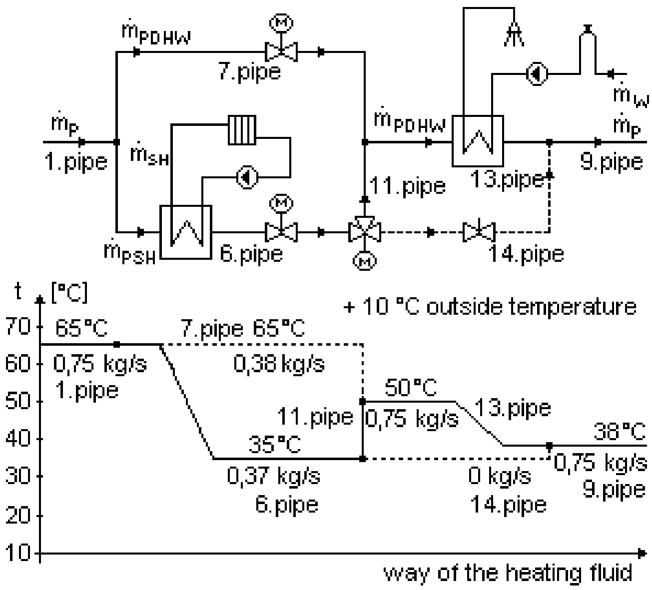

Fig. 4. Simplified scheme of serial connection substation with the results of simulation

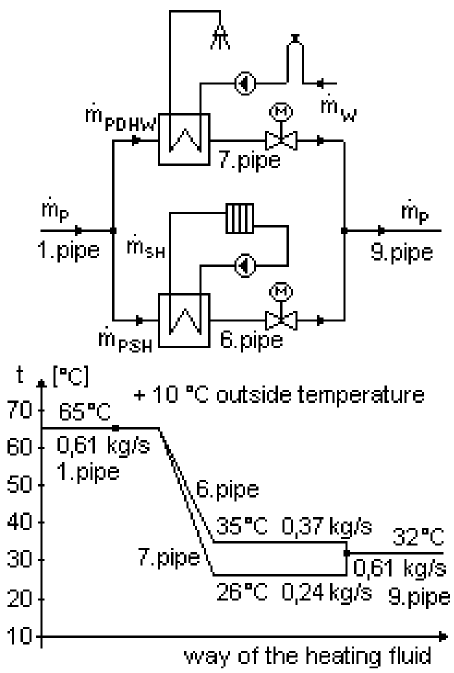

Fig. 5. Simplified scheme of parallel connection substation with the results of simulation

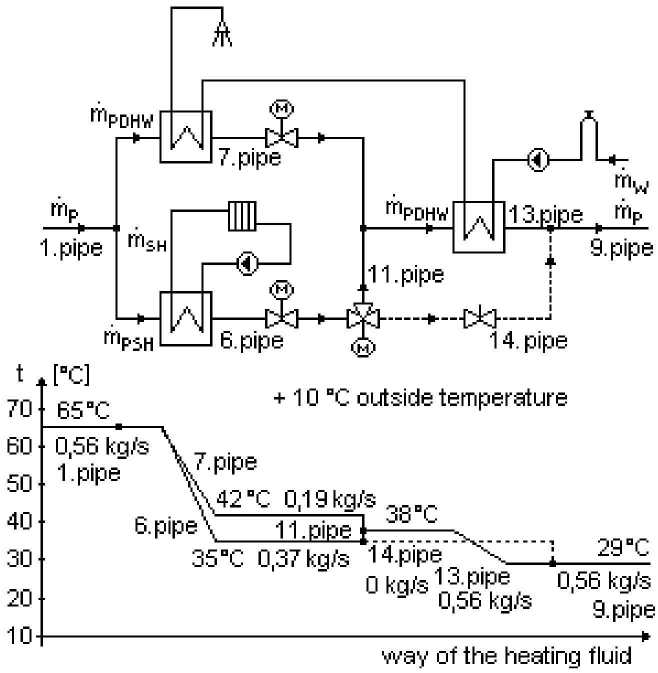

Fig. 6. Simplified scheme of two-step connection substation with the results of simulation

The parallel connection of the DHW and SH heat exchangers compared to the serial connection allows lower primary supply temperature and at the same base date results smaller water flow and lower return temperature.

Leading the return water from the SH heat exchanger to the preheating stage in the exchanger for DHW at the two-step connection, gives specially low return temperature at the primary site of the district heating network.

4. EVALUATION OF SIMULATIONS RESULTS

Since the return temperature is a significant cost factor for the district heating, it should be reduced as much as possible. High return temperatures lead to greater heat losses and smaller temperature differentials. This means that larger amounts of water need to be circulated, resulting in higher pumping capacities, limited capacity of the network and poorer heat generation efficiency in case of co-generation.

4.1 The impact of return temperature on the heat losses

A reduction of the temperature level in the return pipe of the district heat network lowers heat losses since the temperature differential between the district heat water in the return pipe and the environment become smaller.

The average heat losses of district heating networks in the European countries greatly vary and range from 4 to 20% of the heat delivered to the system. The European average is thus about 12% [3]. If the return temperature is reduced, heat losses will be cut by about 0,6% per degree Celsius.

In other words: For each degree Celsius the return temperature is reduced, heat losses will be cut by about 0,07% of the total amount of heat delivered to the system.

According to this thesis, the conversion of serial connection to parallel results in the reduction of return temperature from 38 °C to 32 °C. The conversion of serial to two-step connection from 38 °C to 29 °C. These 6 or 9 C temperature reductions could result in the decreasing of heat losses by 3,6 or 5,4% respectively 0,42 or 0,56%.

4.2 Impact of return temperature on the transportation costs

The reduction of the return temperature increases the temperature differential in the network, thus reduces the necessary flow.
As a result, there is less pumping capacity required, leading to reduced electric power consumption. Taking the water flow necessary to satisfy the heat demand for 100 % in case of serial connection, 81 % of it is enough in case of parallel and 77% in case of two-step connection. Because of the electric power required for pumping is proportionate to the third power of the water flow, the conversion of serial connection to parallel means reduction of electric power consumption by about 47 % and to two-step connection by about 54%.
On the other hand, the transportation capacity of the district heat network can thus be increased so additional users can be connected.

4.3 Impact of return temperature on electric power generation of co-generation plant

A reduction of the return temperature reduces steam tapping at high temperatures, so that higher electric power efficiencies of the co-generation plant can be achieved.
For example, for two-stage heat generation, reduction of the return temperature by 1 °C yields an increase of 0,5 kWh_{el}/MWh_{th} [4].
The 6 or 9 C temperature reductions by conversion of serial connection to parallel or to two-step connection could result in increased electric generation with 3,0 kWh_{el}/MWh_{th} respectively 4,5 kWh_{el}/MWh_{th}.

5. CONCLUSIONS

Because of the efforts towards higher efficiency of district heating systems, the return temperature is becoming more and more important. To ensure economical district heat operation at low return temperatures without sacrificing comfort in the houses measures must be taken along the entire chain – from district heat generation to the radiators in the individual houses. Among the many opportunities of enhancing the system efficiency, the conversion of substations must also be taken into consideration.
Based on the economical evaluation of operating the various substation connections it can be ascertained, that parallel and two-step connections are better than the serial connection with by-pass pipe. There is a consumer heat demand (the critical heat demand) or heat demand range, under which the parallel connection is more economical than two-step connection. Above this threshold the two-step connection is fare better than any other of the discused connections.
The critical heat demand is depending on the

- heat generation and transport system,
- fuel and energy prices and the price structure,
- investment costs of substation elements.

Before the modernisation of substations it is recommended to determine the critical heat demand (based on the actual technical and economical date). Depending on the results parallel or two-step connection substations can be realised.

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