

## **Effects of structural and ample composition and process activities of a substation at district heating systems on energy efficiency**

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### **INTRODUCTION**

The district heating system should be accepted as a technical system, functionally and workable to provide heat for thermo technical needs of a higher number of different and connected users being located on a wider area usually in urban environment. The thermo technical needs of users mean the needs for heating, ventilation, air conditioning, and preparation of consume sanitary hot water and/or for special purposes. The district heating system on defined quality level provides heating and its delivery to users. The district heating systems are complex in their contents, conditioned in structure and non-alternative in processes and they may be active during heating season or during the entire calendar year.

The DHS is projected on the bases of established and emphasized requirements in written project task, on the level of consciences and expertise of engaged designers, of material, equipment and components being present on open market; after that it is realized by contractors having references and routines and after tests, regulations, technical checks and acceptances they are given to an investor for use in accordance with culture of users. The district heating system is projected and dimensioned for needs of defined environment but also for a longer period of its development; therefore it is constantly developed, reconstructed, revitalized and maintained up to limits of technical, ecological and economic justification in lifetime.

General model of structural arrangement of the DHS, on the level of a subsystem is timely defined [8]. The structure is composed of seven constitutive subsystems from No 1 to No 7, where No 4 subsystem is recognized between them, being defined for direct exchange of heat in the sense of delivery of heat to users connected actively to the DHS. Practically, the No 4 subsystem integrates all substations in the one DHS and regularly with not a low number; for example in the town of Pozarevac there are cca 300 active substations in one DHS, and in the city of Kragujevac there are cca 1500 active substations in three DHS. Indisputably there are no DHS without the No 4 subsystem but the No 4 subsystem considerably effects representative quality of the DHS as a whole [10].

### **SUBSTATION AT DHS**

The substation is an universal time determinant that in thermo-technical has single sense and meaning. The substation in thermo-technical is understood as a space, equipment and process for exchange of heat among tube exchanger (primary carrier of heat) and collector (secondary carrier of heat) within technical and technological control. The substation is real, physical and direct limited connection of the DHS and user.

The substation space belongs to the No 7 subsystem, the primary carrier of heat to the No 2, subsystem and the primary equipment to the No 4 subsystem. The secondary equipment in substations belongs to users connected to the DHS [8].

Algorithm composition is characterized for a thermo-technical substation regardless it is about single, group or zone substation [1]. Besides others, any substation equipment is adopted to type of heat, way of heat exchange, needs of users and the DHS concept in composition, contents and capacity.

Any substation consists of a defined group entity, namely of a constitutive group to provide certain process activities [6,7,8,9,10].

Any substation has to have its own particular functional and particular work capacity, and all together makes partial functional and partial work capacity of the No 4 subsystem [10]. Indicators and parameters being featured to the k substation are presented in the figure 1.

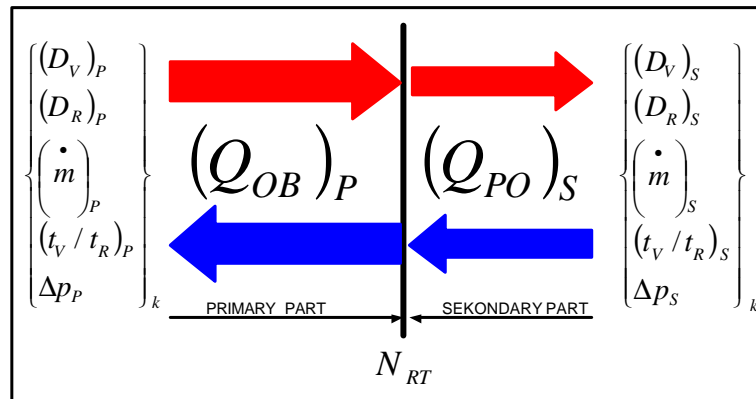


Figure 1. Indicators and parameters of autonomous substation of the DHS.

The process of heat exchanger, between the primary and the secondary heat carrier may substation, and then number, type and operating conditions of users are unchanged input parameters and quantity of heat required by users is changed input value. At any moment of exploitation period the users be recuperative done by surface heat exchanger and mixing, i.e. by elevators. In practice the first principle of heat exchange is more used.

The substation does not produce any heat but it may save some . Such saved heat has higher value than the newly produced one. The basic starting criteria for identification of substations are as follows: location of an object where the substation is located relating to the source (No 1 subsystem); disposition of the substation in the object relating to the magistrate primary pipeline; number, type, operating conditions and quantity of required heat from the subject substation; type and parameters of primary and secondary carrier of heat and way of heat exchange; presence of content components in the substation; structural component arrangement of substation; level of regularity and level of process control on activities in substation.

Users of substation of k subsystem may have status of active, passive and potential user.

Nominal required heat power of substation has to meet the needs for heat of all users connected to that substation.

## **SUBSTATION AND THERMO-TECHNICAL DOUBTS**

Substation is projected based on the group of reliable starting data such as data on number, type, operating conditions and required heat quantity of every user connected to the substation and for projected conditions, for example outside project heat temperature. It is tacitly considered that in that way quantitative and qualitative needs of users are provided at any moment of exploitation period. Based on final project the substation is constructed and its structural and content complete works are done. Conditionally may be accepted that structural and content composition of substation, and then number, type and operating conditions of users are unchanged input parameters and quantity of heat required by users is changed input value. At any moment of exploitation period the users of k substation require certain quantity of heat from the system that is provided directly through the substation. Such required quantity of heat goes from 0 to maximum, i.e. higher limited value. It is undisputedly that the heat exchanger has to provide, on the secondary side, every required heat quantity, even the maximal one. It is also undisputedly that necessary conditions for fulfill of primary task have to be realized by structural and content composition of substation. When the parity of required and provided quantity of heat is realized during the exploitation period, it is said that such substation owns particular functional capacity [10]. A serious question is made: Is it possible, on reliable and energetically effective way, to provide parity of required and delivered quantity of heat at any moment of the exploitation period by conventional, structural and content substation composition? Since it is very complex and important question, and having in mind there is no much room in this paper but to give answer to this question we further analyze the heat exchanger in the k substation only. In this analyze we start with the following assumptions: users use heat during the heating season; projected heat conditions are known for zone of users; heat exchanger is recuperative, in standard; on projected conditions the users require defined heat quantity; selection on producer, type and size of heat exchanger for projected conditions are selected; the heat exchanger has appropriate heat power; regulation of heat efficiency for heat exchanger is made on qualitative principle which means that mass flow rate of heat carriers from primary and secondary heat exchanger sides are stable.

### **Heat exchanger and thermotechnical doubts**

In selected prospect for producer of heat exchanger it is usually mentioned data «heat power of exchanger» is presented as entire number in tens but it is not mentioned if the heat power is on primary or secondary side. Due to unavoidable disipational processes during exchange of heat in the exchanger, the unparity  $(NRT)_P > (NRT)_S$  is uncontested. At calculation and selection of heat exchanger it is usual to reach needed heat power which number value is not the whole number and not in tens. A projector always takes higher value, i.e. higher tens value while selecting heat exchanger. Calculation of heat exchanger is made for outside project temperature, even it is rare during the heating season, for which average outside temperature is prevailingly. Practically, heat exchanger is used during the heating season, under optimal performances. Inertia of primary side, static construction of heat exchanger and dynamism of secondary side based on required heat quantity cause absence of acceptable correlation between the required and delivered heat quantity. Practically, oscillatory unsynchronized exchange of heat is present within limited surplus and deficit state.

Changing of temperature of primary and secondary heat carriers during heating season stipulates variability of coefficient of heat flow and heat flux in the heat exchanger.

Process of exchange of heat in the heat exchanger is done through firm surfaces which they are disturbed with two heat carriers of various temperature initiating formation of deposit on such surfaces and in that way resistance to heat conduct is increased with obligatory reduce of exchange efficiency.

The primary heat carrier circulates through the whole DHS, taking in and out firm, fluid and gas contents.

A part of that content comes also to the heat exchanger, surely to the primary side, going through it or stopping there. These unwanted contents disturb circulation of the heat carrier and in that way they reduce efficiency of the exchange. Similar happens to the secondary side of the heat exchanger. The heat exchanger owns a conceived sensibility to any degradation and/or loss of system functional and/or work capacity that may directly affect the exchange efficiency [2,3].

Outside conditions may inflict needs to users for quantity of heat with even higher values than being calculated for the projected conditions, which objectively exceed real possibilities of the heat exchanger and it becomes insufficiently strong. Circumstances, conditions and function of the heat exchanger in substation point out undoubtedly that we cannot speak on acceptable and reliable energetic determinism.

## **SUBSTATIONS AND ENERGETIC EFFICIENCY**

Heat quantity, requested by users during exploitation period, is surely indeterminist value.

Nominal heat power of the substation is a fix value during exploitation period.

Heat driving power of the substation is understood as substation heat power being equal to real exchanged heat quantity under real conditions, between the primary and secondary heat carriers, at defined time, during substation active function. We differ the driving heat power on projected work regime and on current work regime. Nominal heat power of the substation is understood as substation heat power at ideal heat exchange and it does not depend on real exchanged heat quantity between the primary and secondary heat carriers. Energetic efficiency of the substation goes from 0 to 1 and it means the relationship between the driving and regular substation heat power. During the exploitation period the energetic efficiency of the substation vary within possible values, it represents an indicator for defined k substation and it differs in values for every substation of the same district heating system. The intention is to overcome discrepancy between the requested and delivered heat quantity by constitutive group No 4.8, but it still does not mean that the substation energetic efficiency is improved. The provided heat quantity is possible to vary on three characteristic ways such as: using temperature of the primary heat carrier; changing the flow of the primary heat carrier; and changing simultaneously the temperature and flow of the primary heat carrier; but under condition that involved heat quantity is higher than the provided one, namely the requested one, since there is no sense for inverted combination. Practically, the requested heat quantity is formed from the provided one and the provided heat quantity is formed from the involved one as being presented in the figure 2.

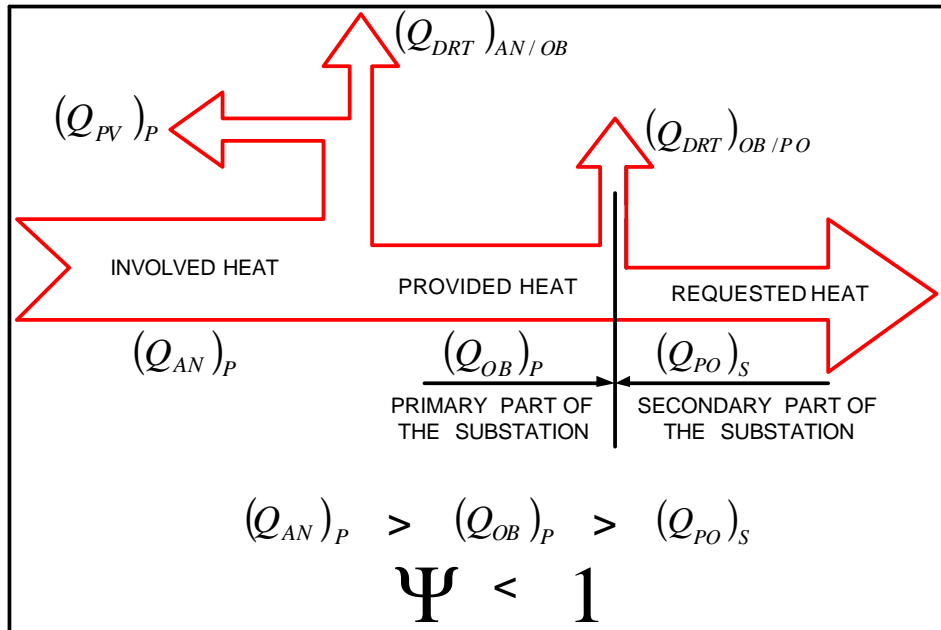


Figure 2. Diagram of heat flows in substation.

By technical-technological improvement of the structure and content composition of the substation and by improvement of the process activity it is possible to reduce the difference between the involved, provided and requested heat quantity.

### SUBSTATIONS AT DHS IN THE TOWN OF POZAREVAC

The district heating system of the town of Pozarevac is unique in Serbia or wider in many specific features. The source of heat is located in thermal plant „KOSTOLAC“, where appropriate exchanging substation is constructed that practically makes the subsystem No 1, in the subject district heating system [11].

For needs in heat of places such as Kostolac, Klenovnik, Cirikovac and the town of Pozarevac, regular heat power of 315 MW is reserved. The magistrate conduit of cca 10 kilometers is made of seam steel tubes of  $\varnothing 660,4 \times 7,1$  mm diameter and it connects the No 1 subsystem with users from the town of Pozarevac. The primary heat carrier on the projected regime ( $-18^\circ\text{C}$ ), is hot water of  $130/75^\circ\text{C}$  temperature and with pressure of NP 16 bars. The secondary heat carrier is hot water of  $90/70^\circ\text{C}$  temperature on the projected conditions. Until now for users in the town of Pozarevac, cca 150 MW of heat power has been involved, which is less than 50% of reserved regular available heat power.

The users are connected to the system through individual, group and zone substations. For now there are cca 170 of individual substations with regular heat power of 10 to 100 KW, and cca 100 of group and zone substations with regular heat power of 80 to 5300 KW. Drum or plate recuperative heat exchangers are installed into substations. The difference between regular heat power and driving heat power on projected conditions is evident of cca 30%. If it is known that average temperature for the town of Pozarevac is  $+4,5^\circ\text{C}$ , than we reach a serious data that the process activity in the substations of this district heating system is performed under unfavorable energetic efficiency.

## CONCLUSION

Nominal heat power of the substation is mostly increased by 30% regarding driving heat power on projected conditions, namely, increased by 60% regarding driving heat power at average heating temperature. Heat is not effectively used and the thermotechnical complex is seriously jeopardized. We cannot be satisfied with the existing condition and processes in substations of the district heating systems from the aspects of energetic efficiency. Practically, all advantages and opportunities offered by the district heating systems are not used, namely they are disgraced, according to traditional structural and content composition and process activities in existing substations. Samples of such conditions are numerous, and known, thus the following should be done to improve the conditions and eliminate the sequent: work on and application of standards and regulations in the field of district heating systems; improvement of existing and development of new components, apparatus and equipment used for substations and district heating systems; wean of projectors out of dangerous habits and procedures, based on their inertial brains; training of construction workers in the sense of development of new capabilities; development of culture of users; care of „heating“ cult, as a precondition to keep the development of thermo-technical complex and urgently, with results and global reconstructive improvement of the existing district heating system.

Special attention should be paid to innovation of the heat exchanger in the sense of its „revival“.

Energetic efficiency as a criterion parameter is very grateful in analyses as also being confirmed in this occasion.

## ABBREVIATIONS, DESIGNATIONS, SYMBOLS AND INDEXES

DHS	district heating system	<b>Indexes</b>	
N (KW)	heat power	P	Primary
$\Psi$ (-)	energetic efficiency of substation	S	Secondary
No ...	numbering of subsystem or constitutive group	HE	Heat exchanger
Q (W)	heat quantity	L	Logarithm
q (W/m <sup>2</sup> )	heat flux	DHO	Dissipation heat outlay
R (m <sup>2</sup> K/W)	heat resistance in heat duct	Z	Dirtiness
A (m <sup>2</sup> )	Surface of heat exchange	HD	Heat duct
k (W/m <sup>2</sup> K)	Coefficient of heat duct	e	external
c (KJ/kgK)	Specific heat capacity	I	internal
t (°C)	Temperature	OPT	Outside projected temperature
$\Delta T$ (K)	Temperature difference	H	heating
t(s)	time	AV	average
$\dot{m}$ (kg/s)	Mass flow of heat carrier	IN	involved
D (mm)	Tube diameter	PR	provided
$\Delta p$ (bar)	Dissipation pressure outlay	RE	required
		RT	return

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