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Energy Efficiency Improvement and Optimal Management of CHP District Heating System – Case City of Tuzla

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The climate changes and detailed analysis of the district heating system (DHS) in Tuzla pointed out the demand for revision of all the system. The first time we did the analyses of DHS Tuzla was 5 years ago. Through more survey and analyses which we have done in the past 5 y, it became clear that improving the efficiency of energy production, distribution and consumption will be a key method of climate change mitigation. We have decided to develop and utilize technical solutions by which the total thermal, temperature and electrical losses in district heating distribution systems can be further reduced. Besides technical solutions, it is necessary to develop sustainable development strategy and optimal management of the district heating system (Olofsson et al., 2013). Total energy savings in the last three heating season was 142,473 MWh. We had the best results in savings in the last season – 88,086 MWh. Implementation new technical solutions based on the first time analysis and new methodology in the system management made possible these results.

1. Introduction

In the city of Tuzla, the district heating system is based on cogeneration (CHP) that was spotted as the most efficient and reliable way of heating over the past 30 years. The instantaneous power is 220 MW, with designed temperature regime 145/75 °C at -17 °C outdoor air temperature and steady fluid flow. We have 10 km of main pipeline (DN600-DN250), 132 km heating network and 847 heating substations. There are 17 points of district heating network on the remote control and management and 39 heating substations on the remote control and management. We heat up 21,026 consumers (18,837 flats, 2,189 commercials) and heating area of 1,549,922 m².

The operating environment of the district heating sector is undergoing great changes. Improving the efficiency of energy production, distribution and consumption will become a key method of climate change mitigation (DHC, 2012). A reliable heat supply, which ensures a normal way of life, is a key to a healthy and pleasant life of men (Münster et al., 2012).

Considering all this, it is important to emphasize that the system goal is to be energy efficient, economically successful and environmentally acceptable. The first objective was making energy efficiency improvements for the optimal management of the CHP district heating in Tuzla.

2. Methodology

In the past 10 y information technology (IT) has been gradually implemented in the entire system. This includes remote control and management of district heating systems, SCADA- supervisory, control and data acquisition, Termis - the district energy networks simulation platform for improving system design and operation. The performance analysis of a district heating system is very important (Ljubenko et al., 2013).

In order to have quality analysis, it was necessary to build in heat meters in all heating substations with heating problems. With data from heat meters, we were able to get partial picture of the flow and pressure distribution in the east part of the district heating system. We defined hot spots but it was not enough information for implementation of the proper solution. Next step was to connect hot spots to the SCADA

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system in order to get easier data updating and screening. At same time, we started with the system regulation (flow and pressure) in the west part of the system where operating conditions were much better. All these activities have been followed up the real time analysis and improving operation of the district heating system with Termis. By using live SCADA data, the Termis model is transformed from a planning tool to a decision making tool, integrated in day-to-day operations – with instant and clearly identified benefits and economic advantages. With sufficient number of these data process control is not just watch and react, which is common with a lot of district heating systems, but set up terms for analyses of current condition and prediction of possible changes in the system. All these enable instant reaction for proper and efficient system management.

3. The state of DHS Tuzla in the past 10 years

District heating system substantially enhanced in the past 10 years. Installing capacity has increased for another 61.1 MW, district heating network has expanded for another 65 km and new 638 heating substation connected to district heating system. We have gained another 7,026 new consumers (flats and commercials) which is 579,568 m² of the new heating area. We have also shut down 28 boiler-rooms and expanded zones to connect on to district heating system. We finished connecting the last collective households in 2013. We expect to connect 14 MW to our system by 2015. The Table 1 is presenting the chronology of the system growth.

Table 1: Chronology of the system growth in the past 10 y, respectively

Date	Heating capacity in buildings (MW)	The power of heating substations, (MW)	Number of heating substations
01.01.2001.	157.4	192.3	209
01.01.2007.	184.2	241.6	524
01.01.2009.	191	248.6	591
01.01.2012.	214.8	281.6	772
01.01.2013.	221	288.6	847
Review	Increase of heating capacity in buildings /MW/	Increase of power in heating substations /MW/	Increase of number heating substations
2001.-2013.	63.6	96.3	638

4. Information technology in district heating system

One of the key factors of district heating system management is accurate data from the system. With sufficient number of these data, process control is not just watch and react, which is common with a lot of district heating systems but set up terms for analysis of current condition and prediction of possible changes in the system. All these enable instant reaction for proper and efficient system management. SCADA system (Figure 1) is the central element of economic system management implementation.

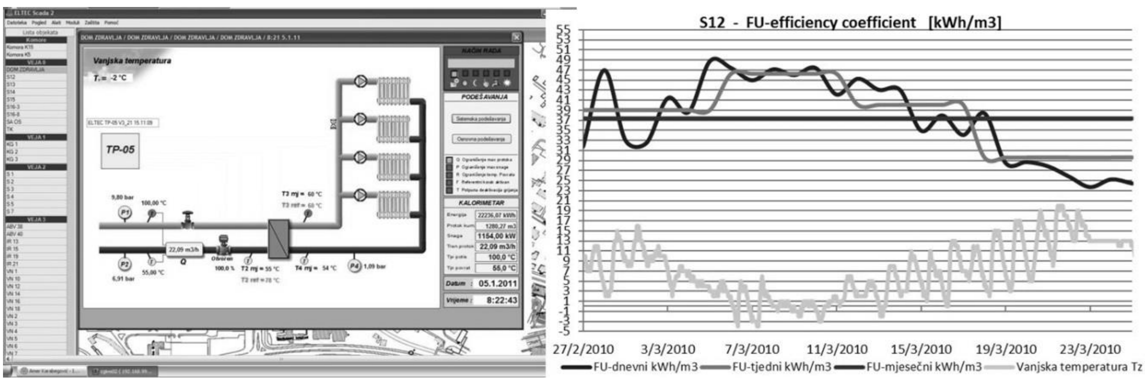

Figure 1: SCADA of PUC Centralno grijanje Tuzla

In order to guarantee an economical energy system management, the most suitable control actions must be adopted, which require a system modelling and a prediction of the future system state (Figure 2: Termis as a tool for economical energy system management). The TERMIS model is fed with live information from the SCADA system as well as with the forecast information about weather conditions. This enables the model to predict future consumption even during periods of quickly changing or extreme weather conditions. Different variables in the network, such as supply and return temperature, pressures and flows - can be displayed. The inlet temperature is adjusted to be as low as possible, taking into account the amount of heat that has to be supplied to the consumers in the net.

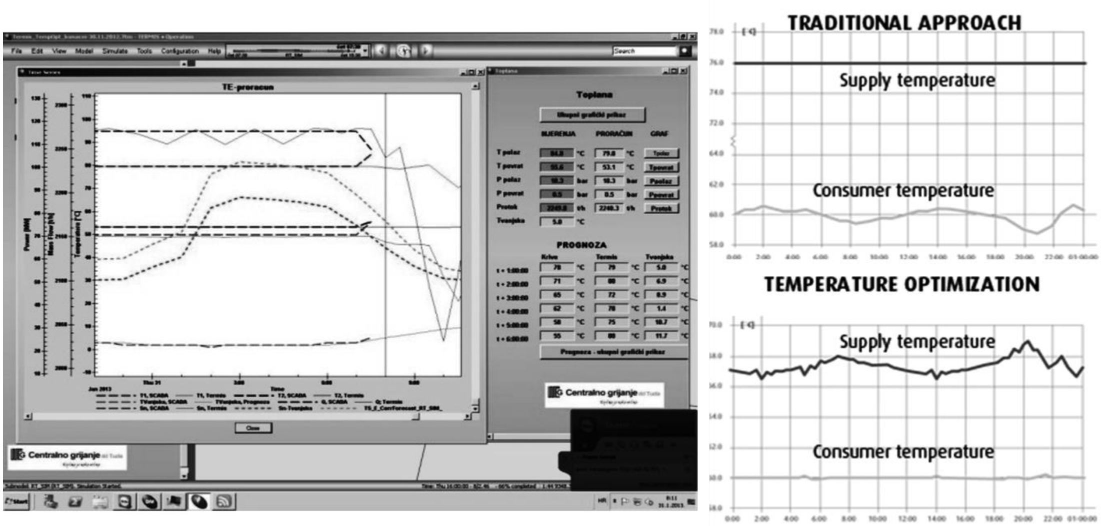

Figure 2: Termis as a tool for economical energy system management

5. Results of the optimization DHS

5.1 Results of the optimization DHS primary side

In November 2010, we started with the first activities on the heating substations reconstruction. In April 2011, we have built in heat meters in order to collect all necessary data. Table 2 shows operating data in the heating substations which were planned for reconstruction.

Table 2: Operating data (2011/04/26) with circulating pumps on the primary side off

Address	Capacity (kW)	Type of HE	Operating flow (m³/h)	Required flow (m³/h)	Pump on the primary side of HS
Sjenjak D2	800	Plate	4.8	9.0	YES
Sjenjak D6	1,651	Shell & Tube	8.3	15.9	NO
Sjenjak D10	800	Plate	4.7	8.3	YES
Sjenjak A2	989	Shell & Tube	5.3	8.0	YES
Sjenjak A6	1,651	Shell & Tube	10.3	12.0	NO

Looking at the Table 2, we can see differences between operating and required flow. Required flow is for the outdoor temperature of -17 °C. The lack of required flow was substituted with circulating pumps on the primary side. All these circulating pumps have been switched off at the measuring time. The second activities were to replace all of the pipe connections after analysing all measurements. We got the first results at the beginning of heating season 2011/2012 when we have eliminated circulating pumps on the primary side of heating substations.

Table 3: Results of reconstruction HS and pipe connections

Address	Operating flow (m³/h)	Outdoor T (°C)	Need for damp	T3 (°C)	Pump on the primary side
Sjenjak D2	6.1	-3	YES	56	NO
Sjenjak D6	8.7	-3	NO	54	NO
Sjenjak D10	5.7	-3	YES	56	NO
Sjenjak A2	5.6	-3	YES	60	NO
Sjenjak A6	12.7	-3	YES	60	NO

In January 2012, we have finished second phase reconstruction of heating substations – replacing shell and tube heat exchangers with plate ones. The results of all these activities are presented in Table 3.

The detailed analysis of working conditions and measurement data after the reconstruction of the heating substations (replacement of pipe connections, heat exchangers and circulating pumps) showed positive effects. We obtained higher available pressure, increase of available operating flow, increase of temperature T3 (Inlet temperature – cold side), decrease of negative influence temperature T2 (Outlet temperature – hot side), electric energy savings and control of heating substations. Energy efficiency improvement and optimal management of CHP district heating system of the city of Tuzla have showed the best result in the last three heating season. Figure 3 presents operating data from season 2010/2011, 2011/2012 and 2012/2013.

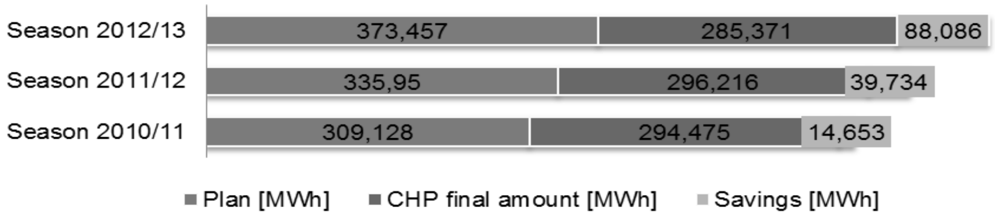

Figure 3: Operating data and resulting savings 2010/201, 2011/2012 and 2012/2013

Total energy savings in season 2010/2011 were 14,653 MWh, 39,734 MWh in season 2011/2012 and in the season 2012/2013 we had the best results in savings - 88,086 MWh. All these are the results of the new optimal management of DH system, rehabilitation and optimization.
Heat accumulator should be a tool for further improvement of the district heating system concept (Volkova et al., 2012). The load curve of the heating system varies depending on the time of day, day of the week, and season (Cugno et al., 2012). The next step in optimization of district heating system of Tuzla is heat storage (Fluch et al., 2013). To decide which type of storage is optimal, it is very important to analyse two possible ways of heat storage: accumulator tank and district heating network as the storage. District heating system Tuzla will consider doing a case study and later on will make a decision.

Table 4: Nominal electric power of circulating pumps in HS

No	Address	Installed power in HS (kW)	Heating capacity in buildings (kW)	El. power of old pump (kW)	El. power of new pump (kW)	Power difference (kW)	Power difference (%)
1	Sjenjak A2	1,200	729	7.5	1.3	-6.2	-82.7
2	Sjenjak A6	1,600	1,425	7.5	3	-4.5	-60.0
3	Sjenjak A10	1,200	868	7.5	1.3	-6.2	-82.7
4	Sjenjak B4	1,800	1,377	7.5	3	-4.5	-60.0
5	Sjenjak B5	1,800	1,139	4.5	3	-1.5	-33.3
6	Sjenjak C2	1,200	912	4.5	3	-1.5	-33.3
7	Sjenjak C6	1,221	1,206	7.5	3	-4.5	-60.0
8	Sjenjak C10	989	912	4.5	1.3	-3.2	-71.1
9	Sjenjak D2	800	752	4.5	2.2	-2.3	-51.1
10	Sjenjak D6	1,651	1,444	7.5	3	-4.5	-60.0
11	Sjenjak D10	800	814	7.5	1.5	-6.0	-80.0
12	Sjenjak E2	989	760	7.5	1.3	-6.2	-82.7
13	Sjenjak E6	1,051	1,035	7.5	3	-4.5	-60.0
14	Sjenjak E10	870	893	7.5	1.3	-6.2	-82.7
15	Kula G	1,221	962	4	2.2	-1.8	-45.0
16	Kula F	1,221	962	4	2.2	-1.8	-45.0
	Total:	19,613	16,191	101	35.6	-65.4	-64.75

5.2 Results of the optimization DHS secondary side
Our company started activities in reconstruction of the heating substations secondary side alongside with analysis of the primary side in the part of the district heating system Tuzla called ‘’Sjenjak’’. The main

activity was analysing potential of electric energy savings. Table 4 shows nominal electric power of circulating pumps in the heating substations, old one and planned one.
After detailed analysis, we decided to make a reconstruction – replacing all circulating pumps with pumps with electronic regulations. All these pumps had big nominal power for required capacity, flow and heat. Maintenance costs were expensive. Figure 4 presents electric energy consumption in the heating substations, before and after replacement.

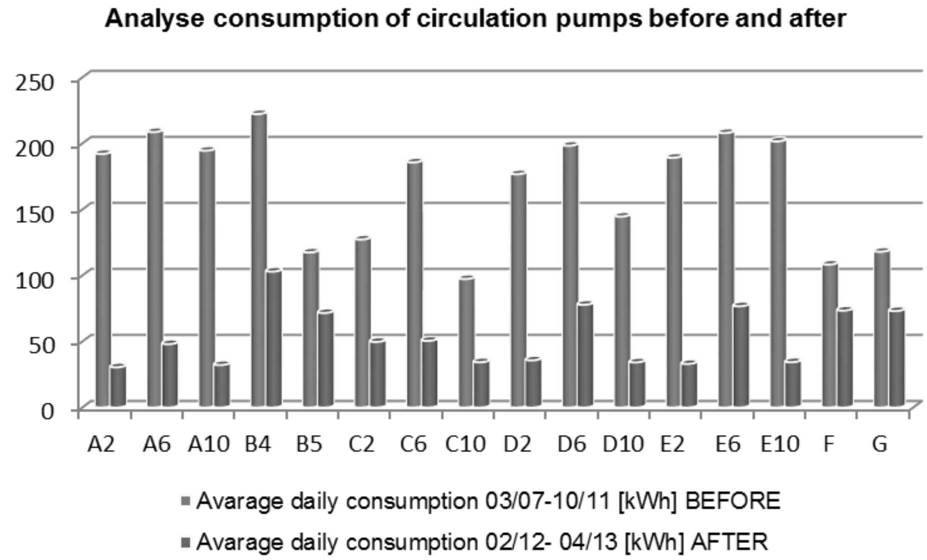

Figure 4: Electric energy consumption of HS before and after replacement circulation pumps

Again, we got the positive effects: increase of temperature T3 (this temperature became higher from 3 to 5 °C), electric energy savings and control of heating substations. Figure 5 presents total electric energy savings in the heating substations after replacement.

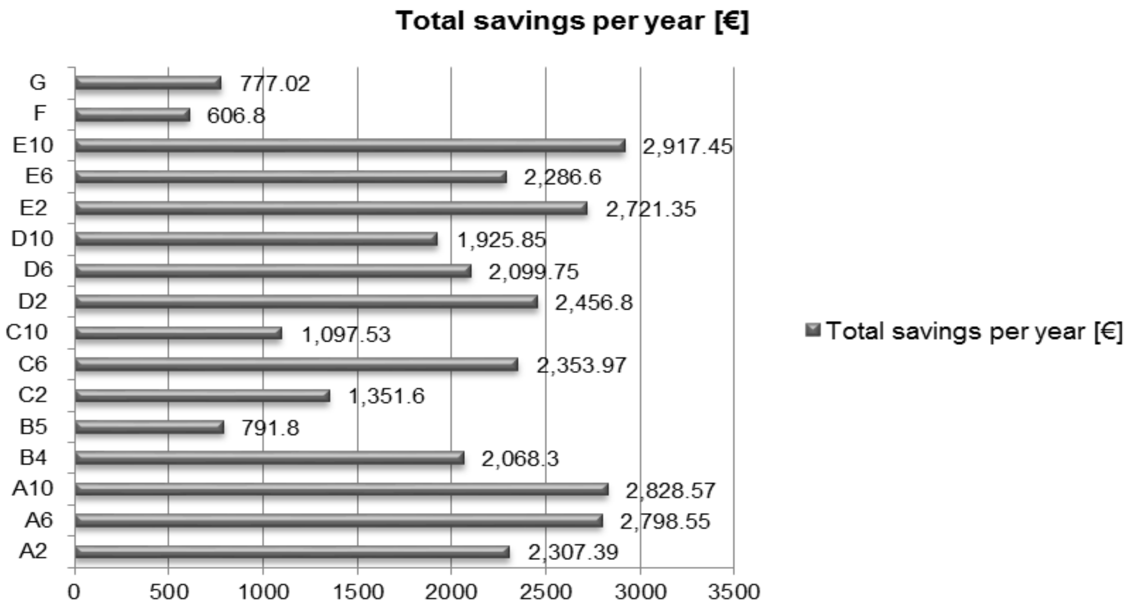

Figure 5: Total electrical power savings after replacement circulation pumps

The investment return for 16 circulation pumps was within one heating season. Table 5 presents investment and savings for circulation pumps in the heating substations after rehabilitation.

Table 5: Investment, savings and ROI for circulation pumps in the heating substations after rehabilitation

	Price of el. energy (€/kwh)	Investment in new pumps (€)	Total savings for one season (kWh)	Total savings for one season (€)	ROI (months)
Total:	0.089	29,313.25	329,597.00	29,334.13	6

Energy efficiency improvement through technology optimisation is a key word in modern industry being the basic factor of competitiveness, sustainability and environment protection (Semkov et al., 2013).

6. Conclusions

This paper presented a proposal of management strategy of similar DH systems to district heating system Tuzla. There is major potential to improve energy efficiency through increased CHP production in many DH networks. The biggest energy saving potential is within the energy sector itself, where CHP will play an important role (Pirouti et al., 2013). This approach to sustainable development strategy and optimal management of DH system Tuzla is the need to improve the energy efficiency, to reduce heating costs and to reduce emissions to the environment. Which steps are necessary to have energy efficient system? These steps include different measures, from technical level to organising and administrative level. The final goal is to develop sustainable development strategy and optimal management of DH system. It will enable the optimization of all the system such as manage all systems more efficiently (temperature, pressure, etc.), facilitate existing algorithm of process and more efficient production of electrical and thermal energy to combine sound economic growth with little environmental impact and to customer convenience (Sanaei et al., 2012). One of the most important elements in the implementation of all these measures and activities is in depth knowledge of the entire system in order to implement a concept like this one. This new approach to system management results in energy savings and customer satisfaction. Making energy efficiency improvement for the optimal management of the CHP district heating system in Tuzla was the first step. The next one is sustainable development strategy of the entire system. The climate changes, energy efficiency, automation of the entire system, knowing real energy demands and big potential of network spreading are the basis of DH system Tuzla development strategy.

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