ABSTRACT

Project plan anticipates the increase of efficiency in district heating (DH) cogeneration heat plants (CHPs) through the introduction of waste heat recovery by means of large scale absorption heat pump implementation, as well as extra heat generation possibility for Municipal water company heat recovery from waste water with consecutive supply of district heating and cooling. Discovered and realized measures give the unique possibility to utilize waste heat in the number of cogeneration plants connected to Riga city district heating network without extra burning fuel. Profitable is to equip cogeneration plants with absorption (instead compression type) pumps/chillers.

OBJECTIVE OF THE ARTICLE

The objective of our article is to implement best available technology (BAT) in city district heating and cooling generation, promote climate tackling activities and to disseminate experience of energy efficiency achievements in both local and international level.

Nations of the world, including those in Europe, are searching for solutions to mitigate climate change with a strong focus on local and renewable energy resources and improved energy efficiency. Experts in local conditions together with local authorities can play a key role in addressing the new challenges in the implementation of specific energy efficiency improvement measures, as well as emission reduction.

Project plan anticipates the increase of efficiency in district heating (DH) cogeneration heat plants (CHPs) through the introduction of waste heat recovery by means of large scale absorption heat pump implementation, as well as extra heat generation possibility for Municipal water company heat recovery from waste water with consecutive supply of district heating and cooling. Discovered and realized measures give the unique possibility to utilize waste heat in the number of cogeneration plants connected to Riga city district heating network without extra burning fuel.

As a part of RIGA Sustainable Energy Action Plan (SEAP) 2010-2020 includes plan to implement an absorption heat pump technology in Riga City DH JSC RIGAS SILTUMS for power production efficiency improvement. The first installation is already commissioned and is used as a best practice research unit for evaluation of technology suitability in particular climate conditions with the aim to generate excess heat from recovered low potential heat waste sources. Future installations can be used also as a starting point for district cooling implementation for Riga city.

JSC RIGAS SILTUMS STARTS THE IMANTA DISTRICT HEATING PLANT (DHP) ABSORPTION CHILLER OPERATION

Our task to improve energy efficiency of the DHP was focused on installing of an absorption heat pump / chiller. As a source of the utilized heat the open cooling towers, that cool CHP process water, were selected. The implemented project involves utilization of the low-grade heat in a volume of 2 MW from natural gas fired combine natural gas fired combine cycle cogeneration, which is not any more released to the atmosphere or drained to the sewerage. The addition of the high-grade thermal energy in a volume of 3 MW is necessary for the technological process of an
absorption heat pump / chiller. That heat is provided by DHP own steam boiler. Total cost for the project is amounted to 700 000 EUR.

Taking into account the constantly rising prices for natural gas, and implying its annual consumption savings to the 842,000 m³, the project is expected to repay in three years. The payback period will be accelerated by the state implemented excise tax on the natural gas, which is also expected to rise in coming years. In addition to the mentioned above, the project will save annually about 1580 CO₂ emission quotas and reduce the consumption of chemically treated water for at least 30%. The technical solution of heat pump/chiller implementation is specified in the picture No1, see above.

**BRIEF DESCRIPTION OF THE CHP**

Current equipment:
- Gas turbine Rolls Royce RB 211-24GT, 31.52 MWel;
- Heat recovery steam generator Transelekstro Power 63 T/h, 67 bar;
- Steam turbine B+V Industrietechnick MARC 4-H01, 16 MWel;
- Steam boiler Vapor, 12 t/h, 13 bar;
- An absorption chiller BROAD BDS183X0.4-65/47-29/55-300-Fb-Mb.

The total installed capacity of the CHP equipment is 48 MWel and 48 MWth (without an absorption chiller), and along with working at full capacity chiller is 53 MWth.

After the CHP erection, during the heating season water boilers operate in parallel with the CHP and in the summer time are in a state of reserve.

In the water boilers’ section of the DHP, at one of the KVGM-100 boiler a condensing economizer with heat capacity of 10 MW is installed. It increases the boiler efficiency by 6%.

**THE TECHNOLOGIES OF THE ABSORPTION TYPE HEAT PUMPS**

The operating principle of the absorption heat pumps is based on the utilization of the physical and thermal principles of the absorption process simultaneously for the cooling of the medium or low potential coolant and dissipation of the heat from the heat pump/chiller with another liquid.

Wasted in the absorption heat pump/chiller heat consequently enters into the evaporator and condenser. In the end of the process, energy,
which drives the absorption, is added to the total useful heat. The volume of the condenser’s heat, which is utilized in the local heating system, is much bigger than utilized heat of an evaporator. Its volume is approximately equal to the sum of the utilized heat and high potential driving heat.

Earlier, the absorption heat pumps were widely spread in the hot and humid climate areas, where they were used to lower the temperature and moisture content in the combustion air and to ensure the most favorable conditions for the combined gas-steam cycle cogeneration units. A solution of the heat pump connection for the hot climate conditions is shown in the picture number 2. In the cold climate areas this solution does not give an essential effect, since the number of hours when the ambient air temperature is above +15°C is very little. When the negative ambient air temperatures are below -5°C, there is a negative impact on the operation of the gas turbine plant in the form of the power reduction.

The planned maintenance costs also are different - compressor heat pumps use oils, which periodically are necessary to change and replenish as well. There is also a minute coolant leakage foreseen (according to the warranty up to 1% per year). Although the costs are relatively small, we mustn’t forget that an absorption unit is completely closed.

The regular maintenance is very important. Annual partial equipment testing and every three years overhaul are mandatory. A few small auxiliary pumps are only driving elements in the absorption systems, and consequently, the maintenance costs are minimal. The errors are easily repairable; thereby losses in the outage periods are minimal too.

The temperature of the used heat is high enough, consequently, the vaporization temperature will be slightly higher than usual, and that in terms of energy efficiency is a very positive moment. Due to the fact, that traditional heat pumps are not suitable for this application, there are also some difficulties. In the compression type heat pumps it is necessary to use a special cooling agent, which is either more expensive either requests for the greater flow for the same output. It also has a so-called greenhouse effect. In this case, you must purchase a more powerful, and of course more expensive compressor. In contrast, an absorption heat pump can use the traditional work environment.
It should be concluded that the use of the absorption process in this particular case has a number of advantages. Installation costs and the environmental impact are listed below.

After the thorough evaluation, taking into account that during the heating season a big amount of heat energy produced by the hot water boilers, it was decided to install an absorption type heat pump.

Afterwards the three connection options were considered:

1. Usage of the superheated water from the heat recovery boilers’ circuit of the cogeneration plant for the needs of an absorption chiller. Considering this option, it was recognized, that particularly at the reduced capacity operation modes, the temperature and the overheating degree are differential. Also, as an unresolved problem, remained the provision of the necessary heat in the event of a cogeneration unit stoppage or insufficiently high temperatures for the cooling process.

2. Steam extraction from the steam turbine. Considering this option the following risks were found:
   - the risk if the steam turbine is not warmed up or not in the normal operation mode, issue is critical for start-up of chiller;
   - the quality of condensate, the contamination of the recovery boilers with liquid lithium bromide or network coolant is possible;
   - the corresponding decrease in electricity generation with the increasing of the number of extracted steam.

3. Steam providing with a steam boiler, which is installed for the DHP own needs. Due to the fact, that the usage of that boiler has been reduced to a minimum, the application exactly of this option was taken as the most appropriate in terms of reducing of the all the above mentioned risks, and from the viewpoint of the efficiency of the heat pump/chiller.

It should be noted, that for Riga district heating is based on a temperature graph 150/70°C (with a max temperature limitation at 118°C), and the fact, that residents are able to adjust the temperature of the heating system and hot water in their lodgings. The last two heating seasons have passed with abnormally low ambient temperatures, and the number of the hours, when return temperature T2 exceeded 46 °C, was pretty big.

When the temperatures are higher than 50°C, the achievement of the dew point of flue gases and recovery of latent heat is much more complicated, that makes up serious problems for the condensing economizers as well as for absorption chiller.

The next useful facts were noted on the installed heat pump/chiller: when the return heating network water temperature (T2) is 40°C, the resulting additional heat energy from the chiller is 4.4 MW, at T2 47°C - 5 MW, and at the maximum T2 63°C is 6.2 MW. If is needed to cool a smaller amount of heat, the amount of steam proportionally reduces. The check of the guaranteed parameters was carried out at T2 47°C.

EFFECTS OF THE HEATING NETWORK MODES ON THE ACTIVITY OF THE HEAT PUMP

The number of hours per year, when the temperature of the return network water is low enough to ensure the efficient operation of the heat pump/chiller and the steam consumption is low is very essential. The picture № 3 displays the dynamics of hourly changes in return network water temperature for the four years.

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It should be noted, that the shown on the picture above the heat pump/chiller of JSC “Rīgasiltums” DH plant “Imanta” - was recognized in the March of 2011 as the most innovative technological project of the year 2010 in Latvian construction industry.

The technical parameters of the installation are summarized in the table number 1 below.

**Table 1.**

The mode chart of the heat pump/chiller BROAD BDS183X0.4-65/47-29/55-300-Fb-Mb.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Min.</th>
<th>0</th>
<th>-5</th>
<th>-10</th>
<th>-20</th>
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<tr>
<td>Heat pump cooling capacity</td>
<td>kw</td>
<td>2142</td>
<td>2126</td>
<td>2000</td>
<td>2000</td>
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<tr>
<td>District heating water temperature after heat pump</td>
<td>°C</td>
<td>58</td>
<td>65</td>
<td>70.5</td>
<td>82.2</td>
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<tr>
<td>District heating water temperature before heat pump</td>
<td>°C</td>
<td>40</td>
<td>47</td>
<td>53</td>
<td>63</td>
</tr>
<tr>
<td>CPU cooling water temperature after heat pump</td>
<td>°C</td>
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<td>29</td>
<td>29</td>
<td>29</td>
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<tr>
<td>CPU cooling water temperature before heat pump</td>
<td>°C</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
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<tr>
<td>Steam pressure before steam reduction valve</td>
<td>bar</td>
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<td>6-7</td>
<td>6-7</td>
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</tr>
<tr>
<td>Condenser temperature</td>
<td>°C</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
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<tr>
<td>CPU cooling circuit chilling capacity</td>
<td>MW</td>
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<td>1.9-</td>
<td>1.9-</td>
<td>1.9-</td>
</tr>
<tr>
<td>Steam consumption</td>
<td>kg/h</td>
<td>4371</td>
<td>4397</td>
<td>4371</td>
<td>5100</td>
</tr>
<tr>
<td>Heating capacity produced by the heat pump</td>
<td>MW</td>
<td>5000</td>
<td>5000</td>
<td>4857</td>
<td>5333</td>
</tr>
</tbody>
</table>

**THE MAIN CONCLUSIONS FOUND BY IMPLEMENTATION OF IMANTA HP PROJECT**

1. Very important is to set the essential objectives – to provide reliable and high quality cooling of the CHP or to get the greatest number of heat to the heating network? The first objective can be achieved by chiller, another by heat pump. It is not possible to ensure the both processes simultaneously in the same quality.

2. Much easier is to equip cogeneration plants with absorption heat pump/chiller, which have simple closed coolers. In the event of severe winter conditions and withdrawal of the most of the water flow to the heat pump it is extremely difficult to prevent the ice formation on the open type cooling towers. When the ambient temperatures are below -10°C and there is an increase in the return water temperature, for the cooling providing it is necessary to consume a much greater amount of heat energy in the form of steam. The number of steam consumed for cooling of the same amount of energy at the min and max T2 differs up to 100%.

3. The important point is the load condition of the heat pump/chiller. Depending on the principle of the cogeneration plant, the unit can be designed for work during the heating season only or also in the summertime with the low heat loads. In the summertime it would be efficiently to use steam extraction from the steam turbine. In Latvia the duration of the heating season in average is about 5200 hours per year. The ability to provide the heat pump working at full capacity beyond the heating period falls very rarely; usually CHP heat load in the summer period is only about 12% comparing to the loads of the heating season and in result the heat pump’s heat reduces the power output of the CHP. In our case, the in-
stalled heat pump is intended to be used primarily in the heating season time.

4. Extreme important is to make the correct choice of the critical parameters. In our case the temperature a cooling loop should to provide is +29°C (the optimal temperature range of 26-27°C). The capacity of the heat pump/chiller is limited by the maximum heat load, which is defined by the installation of the parameters guaranteed. This temperature at the outlet of the heat pump should not be lower than the expected maximum T2, otherwise there might be a need for the compensation of the insufficient cooling capacity at high T2.

5. Steam condensation problem. Usually for the needs of CHP it is used the steam with the high quality standards; for a boiler house own needs, in turn, it is used the lower quality steam, and the mixing or switching from the one type of carrier to another could be a problem in result.

6. When the heat pump is in the continuous operation mode and in case of absence of the heat insulation, the significant heat loses can occur. Carried out heat pump thermograph had helped to improve significantly its thermal insulation, thereby increasing equipment efficiency, reduce the room temperature and reduce the amount of the heat losses.

7. The most sensitive element of the project is the natural gas price. The price rise faster payback, and in our case, taking into account the current high prices, it is extremely important.

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