Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Possibility of Highly Efficient Geothermal Energy Utilization in Košice City

Ladislav Böszörményi, Gabriel Böszörményi

Vysokoškolská 4, 042 00 Košice, Slovak republic

Ladislav.Boszormenyi@tuke.sk

Keywords: hybrid combined cycle power plant, district heating, heat pump

ABSTRACT

The demand for more intensive utilization of energy sources became more important with the European Union membership of the Slovak Republic. Lack of resources and poor exploitaition of available resources can be a very difficult problem for energy policy. It is important to use technical solutions to minimize or eliminate this problem. The most beneficial progress could be achieved in the Košice basin where geothermal energy could have effective and multi-purpose use.

1. INTRODUCTION

Slovakia is a country with singificant geothermal potential. Because the Slovak economy is 90 % dependent on imported energy sources, utilization of this non-traditional renewable energy source is very meaningful.

Slovakia is one of the few CEEC where installed capacity is more than 100 MW. Therefore the current exploitation forms only about 6 % of the available geothermal energy resources potential.

This portion could be significantly increased through geothermal energy utilization in Košice District Heating System, which is planned within the framework of Košice Municipal Energy Concept. According to a proposal from Technical University of Košice geothermal energy could have multi-purpose and more efficient use.

Košice is a locality in Eastern Slovakia with very significant geothermal potential. During the geological exploration abundant thermal water site has been found approximately 15 km away from municipal CHP plant. With about 300 MW utilizable heat output it is a massive renewable and clean energy source. The temperature of the thermal water is estimated to be 115 – 130 °C at the depth of 2000 – 2500 m and 130 – 150 °C at the depth of 2500 – 3000 m.

These facts forced the authorities to seriously consider the idea of geothermal energy utilization for power generation. After being disappointed by the results of economic efficiency calculations, feeding into the Košice District Heating System seemed be the most reasonable solution.

Košice is the second biggest city in Slovakia with 240,000 inhabitants, having one of the most significant and well-established district heating systems in Europe, supplying about 190,000 people, as well as industrial factories and public institutions.

At this time energy supply is delivered by Teplaren Košice (TEKO), the regional producer of heat and power. TEKO owns and operates two coal and gas fired CHP plants (TEKO I built from 1965 to 1968 and TEKO II built from 1977 to 1982) as well as the primary network. The total capacity is 876 MWt and 121 MWe). Additional steam is delivered from a waste incineration plant.

TEKO delivers the heat to Tepelne Hospodarstvo (TEHO - Košice Thermal Management) as owner and operator of the secondary distribution network and the connections/off takes to the users. Some delivery stations are owned by the customers.

The Košice CHP plants burn a mixture of coal and gas and supply 430 heating stations with steam and hot water through pipelines of 136 km length. Secondary distribution lines and customer offtakes complete the delivery system. The mixture of gas and coal depends primarily on economics and secondly on environmental contraints but has been about 70 % gas and 30 % coal on a calorific basis with tendency towards 90 % gas in recent years. The replacement of both CHP plants will in about 10 years be inevitable. This problem can be partially resolved by the realization of the investment project „Geothermal Energy for Košice District Heating“.

2. THE PROJECT "GEOTHERMAL ENERGY FOR KOŠICE DISTRICT HEATING"

The Business Plan for this project (see [4]) has been worked out by the Danish engineering company Houe & Olsen in cooperation with Kvistgaard Consult and has been funded by the Danish Environmental Protection Agency within the DANCEE programme. The Business Plan is based on existing feasibility studies, economic evaluations and technical studies and tests.

Within the framework of this project the following goals could be achieved:

- the use of 2600 TJ/a geothermal heat from 5 doublets or
- the use of 2300 TJ/a geothermal heat from 4 doublets.

This project is undoubtedly one of the boldest initiatives of its type in the world today. After the realization, probably by 2007 it could triple the portion of geothermal energy in the energy balance of the country. But it will not resolve the problem of CHP plants replacement. Moreover, according to the analysis performed by TEKO, the heat price for end consumers could increase after the realization of this project. To avoid it, increase in portion of coal in the balance of primary energy consumption would be necessary.

For this reason, the positive contribution of geothermal energy utilization to environmental protection would be partially eliminated by harmful environmental impact about 2 km far from the city centre. Therefore such scenario of Košice municipal energy concept must be innovated.

The aim to replace a part of TEKO which is reaching the end of its working life with a combined cycle CHP plant lead us to thinking of a non-traditional use of geothermal resources to support combined heat and power production. This could lead to an increase in power output for constant fossil fuel consumption or a decrease in fossil fuel consumption for constant power output. This concept requires the construction of a plant of a new generation – a hybrid combined cycle CHP plant or a hybrid combined cycle power plant with heat extraction.

3. THE IDEA OF HYBRID COMBINED CYCLE POWER PLANT WITH HEAT EXTRACION

There are many possible variants based on combination of geothermal energy utilization and cogeneration technology in combined cycle power plant. It is required to search for a very advantageous application through which optimal synergy between the geothermal source and combined cycle plant could be achieved. Under the expected circumstances the most feasible for TEKO seems to be the variant shown in *Fig. 1*. (operation in winter period) and in *Fig. 2.* (operation in summer period).

In this variant use of gas turbine with about 265 MW power output (ISO requirement) without overheating was assumed. Components' parameters are adjusted to this selection.

During operation in summer period 150 kg/s of secondary carrier of geothermal energy will be directly used in the district heating network DHN and only 90 kg/s will be used for heating the feed water in the heat exchanger HEC.

After mixing the returning flows that were cooled down to different degrees, the heat will be pumped from the resulting flow, using the heat pump HP for indirect utilization in the DHN. The heating water will be heated in first stage in the condenser of the heat pump and in the second and third stage overheated in the heat exchangers HE1 and HE2 by extracted steam from the low pressure steam turbine STL.

In the evaporator of the heat pump the secondary geothermal energy carrier can be cooled down to such an extent that it can be used for cooling the condenser C of steam turbine.

If we consider that the heating water will be warmed to 120 °C and the heat pump will cool the secondary geothermal energy carrier by 24 K, the total power output in winter period for 0°C ambient temperature will be about 400 MW and the total heating capacity about 150 MW.

The variant's main contribution to effective operation of this plant is the summer period when the required heating capacity is only about 45 MW (see *Fig. 2.*). This heating capacity could be obtained from the geothermal source using heat pump HP and heat exchanger HE3. In the heat pump condenser the heating water would be warmed to the same temperature as in the winter period. This water would then be overheated to 70 °C in the heat exchanger HE3 by the residual flow of secondary geothermal energy carrier. The cooling capacity of the heat pump HP would be more important in this case.

The total power output would remain unchanged since the decrease in power output of the gas turbine would be compensated by the increase in power output of the steam turbine. In the heat exchangers HEC and HE3 and evaporator of the heat pump HP altogether 85 MW heating capacity would be utilized.

More intensive use of the rest of geothermal capacity for e.g. chilling in absorption chiller AC (as shown in *Fig. 2.*) could improve effectiveness of summer period operation. Secondary geothermal energy carrier would be used for warming up the heating water in the heat exchanger HE3 after being cooled in the absorption chiller AC.

Absorption chillers are commonly used for air conditioning which is justified only for higher ambient temperatures with relatively short duration. In this case, use of this refrigeration duty for cooling the air entering the compressor of the gas cycle in the heat exchanger HEA would be more rational since decrease of air temperature from 20°C by 10 K brings an increase in power output of the gas turbine by 6%. This absorption chiller can be effectively used as power source for consumption peaks, since ambient temperature is higher for peak loads.

In the summer period (according to scheme in *Fig.2.*) utilization of about 12 MW heating capacity during absorption chilling would be possible. Cooling the air from temperatures above 20°C would result in an increase in gas turbine power output by about 19 MW. Acknowledging the fact that with the use of special technologies for low-temperature heat conversion, e.g. ORC (Organic Rankine Cycle) or Kalina cycle, 10 % of this output could be generated, this solution seems to be very reasonable.

Heat losses of the absorption chiller could be removed through the secondary geothermal energy carrier. Heat losses of absorption chillers constitute approximately 170 % of thermal input used for its operation and their branch away requires significant investments.

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The results of the analysis show that a year-round operation of this variant

- would provide the city with more than 3000 TJ geothermal energy from 4 doublets instead of the planned 2500 TJ from 8 doublets (according to the first feasibility study [5]), moreover, a significant part of this energy would be transformed to power,

- would enable to branch away more than 1100 TJ heat loss from the condenser C of the steam turbine and waste heat boiler WHB and absorption chiller AC by the secondary carrier of goethermal energy.

Lowering the number of doublets would bring saving on investment costs of about 25 mil. USD, and operating costs could be reduced by 50 %. About 90 mil. m^3 of natural gas could be saved, which would lead to a reduction of CO_2 by 220 000 t/year. The real savings would be higher when taking into account the emissions produced by the plant being replaced.

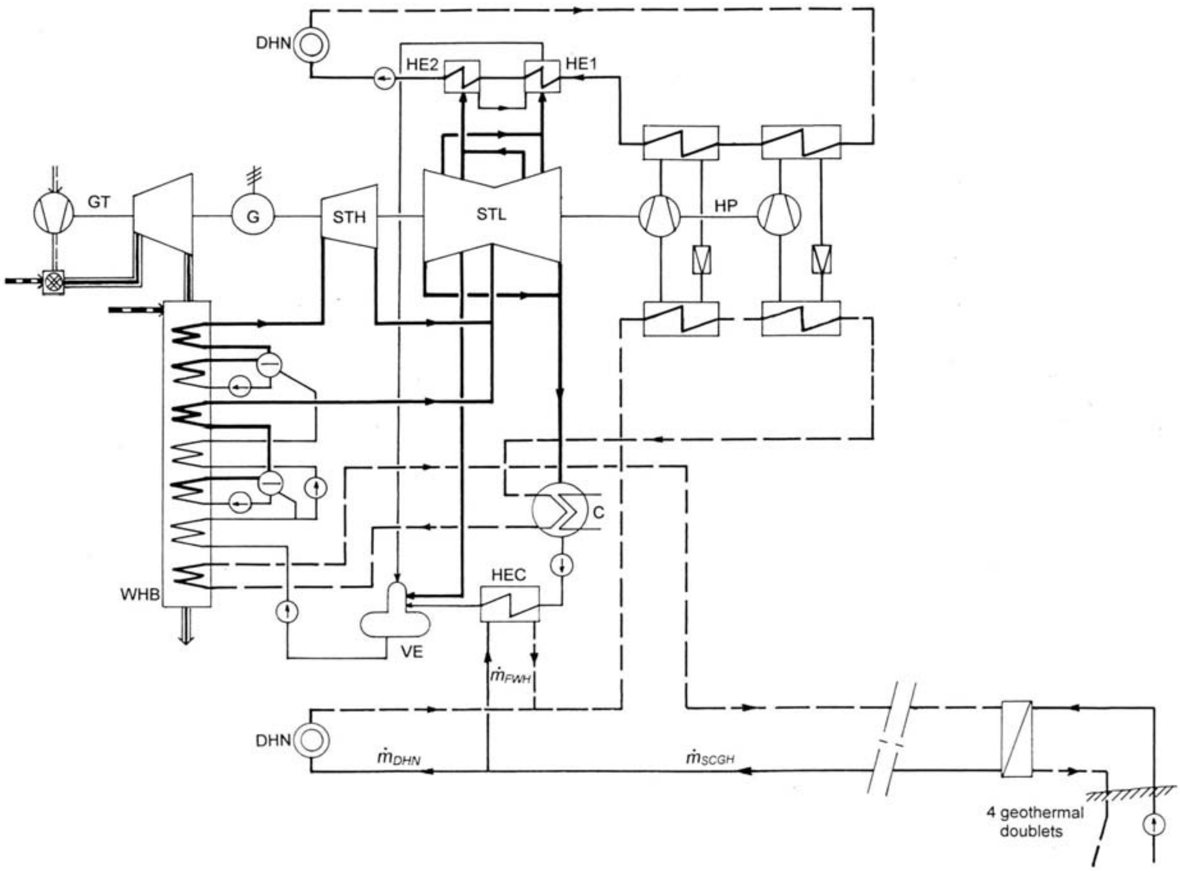

Figure 1: Principal technolgical scheme of combined cycle power plant with heat extraction – operation in winter period

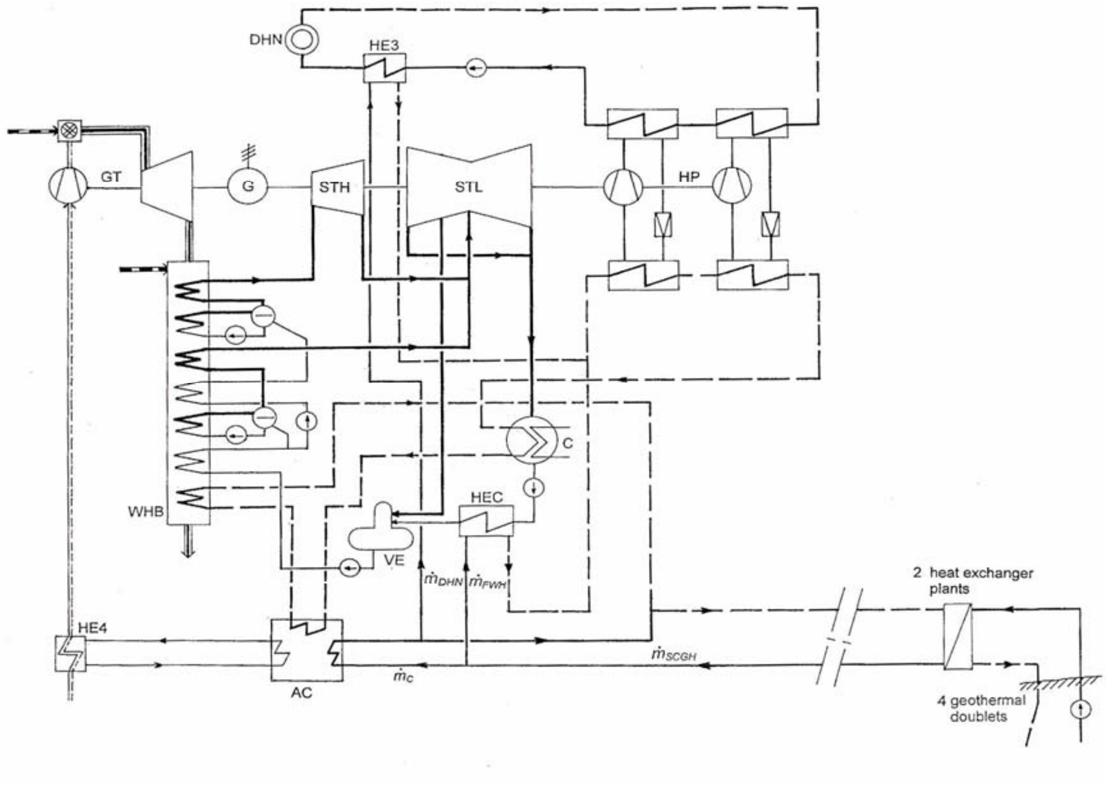

Figure 2: Principal technolgical scheme of combined cycle power plant with heat extraction – operation in summer period

4. CONCLUSIONS

The described concept of hybrid combined cycle power plant with heat extraction would enable very effective simultaneous use of fossil fuel and geothermal source. Use of geothermal energy does not improve the efficiency related to the heat brought into the cycle but reduces the specific consumption of natural gas and consequently the efficency of its use. This means that the power and heat produced in this plant would be "cleaner" than that produced in conventional combined cycle plants with maximum efficiency.

According to described possibilities of intensive geothermal energy utilization a very courageous goal for the vision of Košice Municipal Energy Concept could be formulated, such as to cover

- more than 50 % of annual heat demand in the district heating system,
- nearly 100 % of electricity demand for low potential cold production in the summer period,
- nearly 100 % of electricity demand for increase of high potential cold production caused by high ambient temperatures in the summer period,
- nearly 10 % of annual electricity demand, that is independent of ambient temperature
- from renewable geothermal energy source.

The realization of such energy concept could be Slovakia's most significant contribution to fulfil the main strategic goals of energy and environmental policy of European Union. Therefore it needs to be supported by slovak energy policy and local responsibles (such as local and regional authorities, citizens, interest groups, NGOs, chambers of commerce, associations) too.

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