GEOTHERMAL POWER PLANT UTILIZATION OF EAST SLOVAKIA POTENTIAL

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This paper describes the use of geothermal energy in Eastern Slovakia through geothermal power plant.

K e y w o r d s: geothermal energy, geothermal power plant.

1 INTRODUCTION

The earth's crust is a rich source of energy and fossil fuels are only part of the story. Thermal energy or heat is stored deep inside the earth. To put it in perspective, the heat in the upper ten kilometers of the Earth's crust is 50000 times the energy of all oil and gas reserves in the world!

The word "geothermal" literally means "Earth" plus "heat. Geothermal Resources is the largest source of energy worldwide and used by people for centuries.

This is a renewable resource and can be produced over and over again for years to come since earth has abudant amount of heat energy stored inside it, therefore it will not disrupt the ecological balance of our planet.

Geothermal power plants operating around the world are proof that the heat inside the earth is easily converted to electricity in geologically active areas. For owners of a house or building anywhere in the world, the emergence of geothermal heat pumps brings the benefits of geothermal energy at their doorstep.

Deep underground there are rivers just like on the surface. They are really hot, as the magma is close to the river or around them, warming the surface of the rock.

Geothermal energy works by drilling holes in the underground river and extraction of groundwater to the surface. Once at the surface this hot water is circulated through pipes over an additional pipe containing a fluid that has a lower boiling point.

This low boiling point means that the steam will be capable of powering turbines to produce electricity. After the couple used to drive turbines, condensed and recycled back into the system.

Recirculation of liquid water means that geothermal energy is a renewable energy source and produce low emissions. Geothermal energy produce few emissions harmful gases as the water contains small quantities of nitric acid, sulfur and other contaminants that causes low pollution.

However, the amount released is less than 1% of carbon emitted or other conventional energy sources.

There are many advantages of geothermal energy. It is pure: geothermal energy plants do not have to burn fuel to produce steam turbines, which will help conserve and reduce consumption of non-renewable fossil fuels, which in turn reduces emissions of greenhouse gases.

Moreover, geothermal plants use less land per megawatt than almost any other kind of energy that does not damage the environment through dams and mining.

Geothermal plants are reliable and can be used 24 hours a day, every day of the year. Because geothermal power plant sits on top of the fuel source, they are less prone to the interventions in the production of electricity due to weather, natural disasters or issues of transport; therefore it is ideal for developing countries. [3]

2 ADVANTAGES AND DISADVANTAGES OF GEOTHERMAL ENERGY:

ADVANTAGES:

Significant Cost Saving: Geothermal energy generally involves low running costs since it saves 80% costs over fossil fuels and no fuel is used to generate the power.

Reduce Reliance on Fossil Fuels: Dependence on fossil fuels decreases with the increase in the use of geothermal energy. With the sky-rocketing prices of oil, many countries are pushing companies to adopt these clean sources of energy.

Environmental Benefits: Being the renewable source of energy, geothermal energy has helped in reducing global warming and pollution. Moreover, Geothermal systems does not create any pollution as it releases some gases from deep within the earth which are not very harmful to the environment.

Direct Use: Since ancient times, people having been using this source of energy for taking bath, heating homes, preparing food and today this is also used for direct heating of homes and offices.

Job Creation and Economic Benefits: Geothermal energy on the other hand has created many jobs for the local people. [3]

DISADVANTAGES:

Not Widespread Source of Energy: Since, this type of energy is not widely used therefore the unavailability of equipment, staff, infrastructure, training pose hindrance to the installation of geothermal plants across the globe.

High Installation Costs: To get geothermal energy, requires installation of power plants, to get steam from deep within the earth and this require huge one time investment and require to hire a certified installer and skilled staff needs to be recruited and relocated to plant location. Moreover, electricity towers, stations need to set up to move the power from geothermal plant to consumer.

Can Run Out Of Steam: Geothermal sites can run out of steam over a period of time due to drop in temperature or if too much water is injected to cool the rocks and this may result huge loss for the companies which have invested heavily in these plants.

Suited To Particular Region: It is only suitable for regions where temperature below the earth are quite low and can produce steam over a long period of time. For this great research is required which is done by the companies before setting up the plant.

May Release Harmful Gases: Geothermal sites may contain some poisonous gases and they can escape deep within the earth, through the holes drilled by the constructors. [3]

3 GEOTHERMAL CHARACTERISTICS OF TOPIC REGION

Generally Slovakia belongs to the countries with comparable young underground conditions created by latest movement of the earth in the Europe. By this movement there where many water lakes covered underground as well as the underground structure allows to cumulate the ground water long time and heat it up by natural earth deep heat. There are hot water sources as well as hot rocks which both may be available as a renewable source of geothermal energy.

Recently there is geothermal heat frequently used for tourist attractions and thermal baths, which are having also medical treatment effects and are very popular worls wide. These sources are available shortly underground and are sign of better conditions in the deeper distances.

During the stage of governmental investigation of potential fields of fossil fuels there where executed more that 120 exploration drills over Slovakia in different regions and different deepness. The results are cumulated in several studies and professional reports and today are the best library for evaluating also the Slovakian Geothermal potential and availability of geothermal sources. [2]

Based on the executed drills there was issued a complete map of geothermal sources within Slovakia (see picture below):

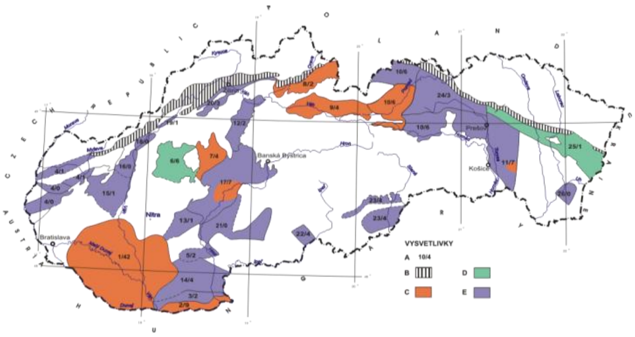

Fig. 1 Based on the executed drills there was issued a complete map of geothermal sources within Slovakia [2]

The geothermal gradient of indicated prospective regions is above 58°C/km and the avarage in Slovakia is about 38°C/km.

The density of heat flow is from 60 mW/m2 up to 120 mW/m2 in the most active undergrounds. The total geothermal potential available in the form of geothermal water is around 5 538 MW, considering the sources already confirmed as well as most probably available and assumed.

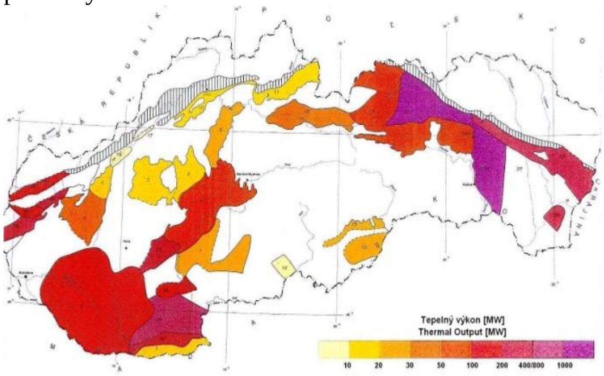

Fig. 2 The map of the individual geothermal sources and potential is below [2]

4 PROSPECT OF GEOTHERMAL ENERGY RESOURCES USE IN THE EAST SLOVAK BASIN AREA

The Eastern Slovakian Basin is situated between the West and East Carpathians. The surface of the pre-Tertiary substratum is very rugged and is characterized by four main structures. In the west, the pre-Tertiary formations of the Košice Basin and volcanic complexes of the Slanske vrchy Mts. and form several benches separated by north-south faults. Another major morphologic structure, most conspicuous morphological element of the basin's pre-Tertiary substratum, the Trebišov depression as much as 7 000 m deep, lies amidst the above structures. This depression includes several partial elevations and depressions.

In the East Slovak Basin there were delineated 16 hydrogeothermal structures in Neogene, volcanic and clastic sedimentary rocks or in Mesozoic carbonate underlier. The most prospective of them are Ďurkov in Mesozoic carbonate underlier, Trebišov in Neogene formations and Beša-Čičarovce in a buried stratovolcano. Besides that there is a possibility of dry rocks heat utilization from crystaline rocks complex of deeper underlier

East Slovak Basin is from geographic-geological viewpoint situated in a dividing area between the West and East Carpathians. This basin represents western part of a higher order regional unit so called Trans-Carpathian Depression, eastern part of which is situated in Ukrainian territory. (Fig. 1).

From genetic viewpoint this area represents longitudinal intramount depression filled by Neogene sediments and volcanics. This basin morphologically represents north-eastern promontory of Pannonian Basins System.

During more than 50 years of systematic oil-geological exploration a quantity of knowledge was gathered here, as on geological structure and hydrocarbon fields as on thermal setting and geothermal waters. It is a case of nearly 20 000 analyzed water samples and temperature measurements in the depth span from surface up to 4200 m what enables us to distinguish in this region several prospective geothermal areas. Geothermal energy resources can be gained either from aquifers or by utilization of hot dry rocks. [2]

5 GEOLOGICAL SETTING AND HYDROGEOLOGICAL CONDITIONS

Geothermal water is bound to three types of rock environment:

- Mesosoic carbonate rocks with secondary void and fracture porosity in the undrelier of Neogene sedimentary filling,
- Sands and sadstones with primary porosity in Neogene sedimentary filling,
- Fractured andesites and volcanoclastics of buried Sarmatian stratovolcanoes. [2]

Hot dry rocks energy can be gained from Young-Palaeozoic low-metamorphosed clastic rocks and Old-Palaeozoic crystalline complexes of Neogene sedimentary filling underlier.

Evaluation of the East Slovak Basin thermal setting is based on measurements of stabilized temperatures in 45 deep wells. Thermal field in 1000 m depth below the surface is a relatively stable. In marginal parts of the basin temperatures fluctuate about 50 °C and in central part about 60 °C. Temperatures on pre-Neogene underlier surface fluctuate in a very wide span, depending on depth of burial, from 25 °C in marginal parts up to more than 325°C in central parts of the basin. [2]

Knowledge of thermal properties of rocks has an extraordinary significance primarily for structures recovered by re-injection system because of their need for the modeling of geothermal water recovery and its re-injection regarding to the optimization of withdrawal - re-injection systems life. Heat capacity of geothermal water reservoir rocks, i.e. Neogene sands and sandstones, has a mean value of 1091.2 ± 46.2 J/kg.K, Sarmathian volcanics 1175.0 ± 111.3 J/kg.K and Mesozoic carbonates 811.4 ± 14.5 J/kg.K. Earth's heat flow density in the East Slovak Basin was established on 30 wells and fluctuates in span of 82.1 - 121.6 MW/m2.

Mineralization of geothermal waters in the East Slovak Basin depends the same on depth of their burial and position. Water in shallow horizons (approximately to 1500 m) and on basin margin is low to medium mineralized up to 10 g/1. In deeper parts of the basin there are very highly mineralized brines with a total mineralization frequently above 100 g/I. [2]

Hydrogeothermal structure Ďurkov

Hydrogeothermal structure Ďurkov was proven by 3 wells in western part of the East Slovak Basin. It is possible to gain from depth between 2200 to 3200 m by one well free flow of water in quantity of 60 -170 I/sec with a well head temperature approximately of 130 °C and mineralization of 30 g/I here. It is a case of closed structure requiring withdrawal - re-injection system. This very good result impulses a judgement of geothermal energy resources utilization possibilities in the whole East Slovak Basin. Based on processing of quantity of data 14 prospective areas of interesting amount of geothermal water occurrence and 7 geothermic regions suitable to use hot dry rocks with a reservoir temperature of 130° and 180 °C were set in the East Slovak Basin [2]

Trebišov depression

Enhanced geothermal activity in Eastern Slovakian Basin refer to it's geodynamic and tectonic evolution which was increased by volcanism.

High amounts of heat flow density from 0 – to 110 mW/m2 and average amount 101 W/m2 are reflexion of it.

Heat flow higher than 110 mW/m2 is typical for south – eastern part of Basin. Geothermal gradient fluctuates from 35 to 53°C/km and in rocks of underlier temperature fluctuate from 25 do 33 °C /km. Geothermal water inflow with reservoir rocks temperature of 130 - 140 °C can be expected from depth approximately of 2500 - 4000 m. There are expected better conditions with geothermal gradient as in the Košice Basin. Regarding this effectiveness prospective thermal-energy potential of Trebišov depression then represents 110.0 MW. [2]

Hydrogeothermal structure Beša-Čičarovce

Another delineated hydrogeothermal structure of buried Sarmatian stratovolcano Beša-Čičarovce has an approximate acreage of 86.5 km2. Surface of the stratovolcano is situated in depth from 350 to 2000 m with an ascertained maximum thickness of 3000 m. Heat flow density is approximately 120 MW/m2. Temperature on stratovolcano surface, depending on its burial depth, fluctuates in span of 30° to 120 °C. Geothermal water inflow with reservoir rocks temperature of 135 °C can be expected from depth approximately of 2500 m: Porosity fluctuates in interval from 7.3 to 24.6 %. Cumulative thickness of reservoir rocks based on logging of oil and gas wells is about 300 m. Hydrogeothermal structure Beša-Čičarovce has an accumulated prospective thermal energy potential of 288.75 x 106 GJ of geothermal energy. For its use there is required a withdrawal - re-injection system. Life of 40 years can by assured for withdrawal - re--injection wells using suitable area distribution and optimal way of recovery of these wells. Prospective thermal-energy potential of geothermal energy resources of this structure then represents 228.9 MW.

Present effectiveness of operated geothermal resources utilization in Slovakia, conditioned above all by technical and economic possibilities, represents 48.5 %. Regarding this effectiveness prospective thermal-energy potential of Beša-Čičarovce then represents 111.0 MW.

These large resources of geothermal energy in the East Slovak Basin would not be unnoticed. It can be believed they will attract interest of potential investors and will be profitable not only for those investors but also for the whole area. [2]

6 DEFINITION OF UNDERGROUND WATER PARAMETERS

After detailed study of Slovak geothermal potential and expected geothermal water sources there is strong probability that the selected region may have even better geothermal conditions that already tested and widely investigated neighbouring locality Durkov. In selected Trebišov surrounding region there where also executed several test drills by company exploring fossil fuels and they find enough resources of thermal water with acceptable salinity and suitable temperature. Considering development of the drilling technology and latest investigation possibilities investor and engineers of this study decided to start the project development with using the base geothermal water quality as follows. [2]

7 ECONOMICAL EVALUATION

Geothermal applications are characterized by a high initial cost and relatively low operation and maintenance costs. For the generation of electricity, about 50% of total costs are due to the production and reinjection of the geothermal fluid, 40% are due to the power plant construction, and the remaining 10% is due to other expenses. The cost of drilling and development of the production and reinjection wells varies from $500 to $4000 per kW generated and the cost of construction of the power plant varies from $1500 to $1700 per kW generated. Therefore, the total cost may vary from $2000/kW to $6000/kW. Operation and maintenance costs represent 10 to 20% of the total cost of power generation. The production cost of electricity can vary from 3 to 12 cents/kW h. Production cost of a kW h from oil, coal, and nuclear is 6 cents and it is 3 to 9 cents for hydropower. Geothermal power plants can be built economically in relatively much smaller units than hydropower stations. The cost of a non-condensing geothermal power plant alone is $1050–1250/kW while a non-condensing plant alone costs $1485–1690/kW and a binary plant costs about $1900/kW.

The cost of a geothermal direct-use application is influenced by the following characteristics: depth of resource, distance between resource location and application site, well flow rate, resource temperature, temperature drop, load size, load factor, composition of fluid, ease of disposal, and resource life. [1,3]

Geothermal district heating and cooling systems require large investments and the economic benefits may not be realized in a short time. Consequently, the worldwide investments in power generation is about twice as much as the investments in direct uses. [1,3]

For the purpose of economical evaluation, the geothermal plant has been considered as an independent economic unit purchasing media and services and producing electricity and heat. Method „incomes-costs" was used.

Economic evaluation is performed using the following main input data on prices of year:

- Price of sold heat Euro/GJ
- Price of electricity sold to the network: Euro/MWh
- Price of water from geo-source: Euro/t
- Price of transfer medium : Euro/t
- Labour costs: Euro/month.man
- Annual price increase: %
- Discount rate: %

Material balance of electricity and heat production, and individual media consumption represents a quantitative evaluation of produced electricity and heat, as well as the all operational media and works quantification. [2]

8 MAIN INDICATORS OF ECONOMICAL EFFICIENCY

Present Value (PV) and Net present Value (NPV)

Present Value (PV) represents cumulative value of cash flows in individual years of the evaluated period while the cash flow represents net profit of the evaluated economic unit including tax payments and repayment of installments, i.e. it expresses profit from the investment for the whole evaluated period.

Net Present Value (NPV) is expressed as cumulative value of discounted cash flows in individual years of the evaluated period, i.e. it expresses the profit from the investment for the whole evaluated period taking into account depreciation of currency with time. A project is profitable if NPV is positive. [1]

Pay back period

Pay Back Period (PBP) expresses a period in years during which invested funds will pay back, i.e. when the cumulative cash flow equals zero.

Simple pay back period is calculated from cash flows in individual years. It is sufficient to promptly compare various alternatives. To express correct values, it is necessary to calculate the pay back period with discounted cash flows in individual years that takes into account depreciation of currency with time. [1]

Internal rate of return

Internal Rate of Return (IRR) represents a discount rate in percentage that, if applied to the discounted cumulative cash flow, makes it equal zero at the end of evaluation period. The IRR of the project should be higher than the assumed discount rate. In opposite case, the expected depreciation of currency with time is faster than the profit increase. When comparing several alternatives, financially more beneficial will be that with a higher IRR. [1]

Sensitivity analysis

Sensitivity analysis serves to project evaluation at other main economical parameters evolution trend then the supposed one, as well as to the economical power of different media evaluation. So called optimistic and pessimistic scenario is modeled through variation of basic parameters, which determine project successfulness. Otherwise said, the project reserves, but also the project risks are taken into account.

Sale price of electricity delivered to the distribution network and water source richness will have a decisive influence on project profitability, influence rate being identical. Influence of other items is considerably lesser. Influence of water price is shown as example. [1]

9 CONCLUSION

Geothermal energy is best suited for heating and, to a lesser extent, for cooling applications. The temperature of the geothermal fluid leaving the heat exchanger of a binary power plant can be as high as 100°C, which is very suitable for low-temperature uses such as space heating and preheating of process water, but is unsuitable for economical power generation, and is discarded. So it is no surprise that the electricity generated by a geothermal power plant is only about one-thirteenth of the heat that can be harvested and sold to prospective users for space, water, and process heating. As a result, the revenues from a geothermal site can be tripled by selling geothermal heat and/or geothermal cooling instead of producing and selling electricity. Therefore, for a specified geothermal resource, a greater initial investment can be justified if a geothermal heat plant (including the circulation loop) or a geothermal absorption cooling system is built at that site instead of a geothermal power plant. [4]

From a thermodynamic point of view, it may not wise to use a geothermal resource at a temperature greater than 150°C for space heating or cooling alone. Calculations for those cases are done for their sole economic comparison. Co-generation may be a wiser approach for such resources. Co-generation would be particularly practical when a power plant is already in operation. From thermodynamic considerations alone, the entropy generation, and thus the energy destruction, will be minimized by matching the end-use resource by using the portion of geothermal energy above 115°C for power generation, the portion between 115°C and 90°C for cooling, and the remaining part for heating.[4]

Generation of electricity is advantageous over geothermal heating and cooling in that heating and cooling can only be sold if the geothermal resource is located at a location reasonably close to a customer base even though electricity can be sold widely because of the ease of transport. Initial and operation and maintenance costs considerations also appear to favor power generation since the simple payback periods are typically smaller in power generation than in heating and cooling.

BIBLIOGRAPHY

[1] Čulková, K.: Ekonomické hodnotenie vplyvu výroby magnezitu na životné prostredie Slovenska, 2008. In: Uhlí - Rudy - Geologický průzkum. - ISSN 1210-7697. - Vol. 15, no. 9 (2008), p. 25-28.

[2] Feasibility Study Project: Geothermal Power Plant

[3] GPP-Trebišov, Slovakia, 2009.

[4] http://www.conserve-energy-future.com/GeothermalEnergy.php

[5] http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V2S-3WJFG2F-4&_user=3838213&_coverDate=06%2F30%2F1999&_rdoc=1&_fmt=high&_orig=search&_origin=search&_sort=d&_docanchor=&view=c&_searchStrId=1515984681&_rerunOrigin=google&_acct=C000061502&_version=1&_urlVersion=0&_userid=3838213&md5=cbe6fd315618f104f85911d2ebac9c3d&searchtype=a

[6] Muchová, M., Takáč, F., Behún, M., Eftimov,T., Koblen ,I.: Financial evaluation of the minerals industry based on the software support. Acta Avionica, 19/2010, Technical University Kosice, Faculty of Aeronautics, Košice, 2010, ISSN 1335-9479, s.144-150.

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