DEVELOPING DIRECT USE OF GEOTHERMAL ENERGY IN ORADEA CITY

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Abstract: Thermal energy demand for district heating in the city of Oradea is supplied at present, almost at whole, by the Cogeneration Thermal Power Plant, based on classical fuels, mainly consisting of low grade coal and natural gas, with a small contribution of the geothermal energy.

Geothermal resource at low enthalpy, located within the city area of Oradea, available at an estimated level of 250 GWh/year, exploited at present by 12 production wells, can provide a share of 55 GWh/year for district heating, representing at present about 7 % from the overall thermal demand at the end users inlet.

Geothermal energy is delivered by means of 3 main thermal stations, in order to prepare, especially household warm water, but sometimes also secondary agent for space heating, using additionally heat, based on natural gas.

At present, in the city area of Oradea, more than 7,000 dwellings are supplied by geothermal stations with warm water and in addition for about 3,400 dwellings is assured simultaneously warm water and space heating.

Even if the geothermal energy provides at present only a small part of the overall heating requirement at the city level, nevertheless by increased financial support, in the near future is expected its much more contribution, as an alternative to polluting energy of coal and natural gas.

Keywords: *geothermal resource; improved energy supply.*

1. INTRODUCTION

Energetical services consisting of heating, lighting, food preparing and transporting are essential inside a modern society.

Thermal and electrical energy, representing the most used final energy forms, taking part on a large scale in almost all human activities, are generated at present at global level, as well as in Romania, in a great share in the thermal power plants, based on fuels burning, derived from coal, crude oil and natural gas, named classical fuels. Besides the useable energy, these power plants generate a series of pollutant substances, more consistent at the coal burning, that affect the human health and the environment.

Romania has at its disposal varied classical primary energy resources, at present in lowered amounts, which in addition with a remarkable useable potential of renewable energies.

Has become a requirement to extend in the near future the renewable energies usage, available on the national territory, such as biomass, hidro, wind, solar and geothermal energy, in order to raise their contribution to the overall energy supply at country level, as an alternative to polluting energy of the classical fuels, [4], [5].

At present, in the city of Oradea currently operates a large district heating system supplied, almost entirely, by the Cogeneration Power Plant, which delivers thermal energy based on coal with oil-fuel support and natural gas.

Geothermal resource placed in city area of Oradea provides a small part of the district heating demand, thus displacing a share of the coal and natural gas, in the benefit of the environment quality, [4], [5].

2. GEOTHERMAL RESERVOIR AVAILABLE IN ORADEA AREA

Due to the limited amounts of classical and nuclear fuels, taking into account continuously rising of liquid and gaseous hydrocarbons prices available in Romania, renewable primary energies is of present interest, through their accessibility and abundance, but especially from the environmental protection point of view.

Geothermal energy represents the natural heat of the Earth, continuously coming from its molten interior, together with that resulted from the radioactive materials decay contained inside the underground rocks. On average, the temperature of the Earth increases in depth, with about 25–30˚C/km above the surface ambient temperature, named geothermal gradient, [8].

The heat is transferred, mainly by conduction, towards the earth surface as magma, that usually remains below the crust, heating nearby rocks and underground water. The thermal energy of the Earth is huge, but only a very small fraction could be utilized, in limited areas inside which geological conditions allow the meteoric water penetration along fractured and cracked rocks, near the hot zones, at depths until 4.0-4.5 km, thus accumulating the heat.

Depending on the temperature and pressure, underground hot waters can migrates upwards through fractures and cracks, reaching the surface as geothermal fluid in form of hot springs, but most of it remains underground, stored in permeable and porous collecting rocks, at shallow to moderate depths, under a layer of impermeble rocks, forming hidro-geothermal reservoirs, named thermal aquifers, [2].

Currently are exploited hidro-geothermal reservoirs, located until usually depths of 2.0-2.5 km, rarely below 3 km, easily accessible in favorable economical conditions, in present-day stage of drilling technology. A great part of hidro-geothermal resources comprise of low and medium enthalpy, at 50-160^{o}C, commonly in range of 50-110^{o}C, delivered by wells with deep less than 3 km, suitable for heating purposes, [2], [4], [8].

Geothermal energy is considered a renewable resource because the heat emanating continuously from the Earth depth is limitless, ensuring an abundant, inexhaustible and clean energy supply.

Considerable hidro-geothermal resources have been discovered on the Romanian territory, mainly along the western border, generally at low enthalpy, inside the range temperature of 45–120^{o}C, suitable for direct heating purposes.

Geothermal energy, available in the city area of Oradea at an appreciable thermal potential, can provide only partly, besides classical fuels, the district heating demand, representing a significant, abundant and clean local primary energy source.

Hidro-geothermal reservoir identified in the Oradea's city underground covers an area of 110 km^2, located in limestone and dolomite rocks of Triassic age, placed at variable depths inside of 2.2-3.2 km, with natural recharge from Borod-Aleşd zone, by gravitational penetration of meteoric water, [3], [4].

Another 2 wells were drilled in recent years in the city area of Oradea, so at present the exploitation of thermal reservoir is achieved using 14 wells drilled in the city limits, from which 12 production wells, 1 reinjection well and 1 well comprised in the further development of geothermal energy direct use in Nufarul district, [5].

The pressure existing in aquifer allows the artesian operation of wells at a geothermal water flow between 5-25 l/s per well, depending on the geological structure of rocks in area, with possibility of increasing to about 20-50 l/s in underground pumping system. The overall flow rate of all wells reach about 65-75 l/s by comparison with a total potential evaluated at 140 l/s. Registered temperatures at the outlet of wells are in range of 72-74^{o}C in the eastern (Velenta) and 105-106^{o}C in the western (Iosia-Nord) side of the city area. This change of temperatures over the thermal aquifer take place due to the progressive rise of geothermal gradient from 2.7 (3.5)^{o}C/100 m in est to 4.1 (4.3)^{o}C/100 m in west, at the average operating depth of 2,400 m. The hidro-thermal collector allows reinjection of the used geothermal fluid at pressures below 10 bar and flow rate between 25-40 l/s, [3], [4], [5].

The main technical parameters of the Oradea hidro-geothermal system, are presented in table 1.

Table 1. Main parameters of the hidro-geothermal system in the city area of Oradea

Area	Depth	Temperature at the well outlet	Geothermal gradient	Well flow artesian /pumping regime	Overall mineral salts content
[km^2]	[km]	[^{o}C]	[^{o}C/100 m]	[l/s]	[g/l]
110	2,2-3,2	70-105	2,7-4,1	4-30 /20-50	0,8-1,4

Geothermal waters contain a series of dissolved substances, taken over from the collector, mainly including carbonates and sulphate of calcium, magnesium and sodium, as a r esult of limestone and dolomite presence in aquifer. In a suitable range of temperatures, these dissolved components can be form deposits of scale (crust) on the inner space of thermal circuits, leading to decreased performances of thermal equipments and damages of installations.

Geothermal fluid exploited in city area of Oradea has an overall mineral salts content (disolved) inside a range of 0.8-1.4 g/l (2 g/l in Nufarul district), without major tendency of scaling on the inner surfaces of thermal equipments, reasonable for utilization by means of heat exchangers. Chemical analysis has established thermal waters of calcium-sulphate-bicarbonate type, almost with absence of dissolved gas, [5].

The useable heating potential of a geothermal area (Φ_{ga}), can be calculated by summing the thermal power of all wells, [1]:

$$\Phi_{ga} = 10^{-3} \sum_{n=1}^{k} \varphi_{gw,n} \ \text{[kW]} \qquad (1)$$

$$\varphi_{gw} = D_w \cdot c_{pg} \cdot (T_{wo} - T_r) \ \text{[W]} \qquad (2)$$

where: φ_{gw}[W] – thermal power relating to one well;

D_w[kg/s] – average geothermal fluid flow extracted by the well;

c_{pg}[kJ/kg·K] – medium specific heat at constant pressure of the geothermal fluid; in case of Oradea's geothermal area $c_{pg} = 1.030$ kJ/kg·K ;

T_{wo}, T_r[K] – temperature of the geothermal fluid available at the well head and returned from the consumers, respectively; usually $T_r = (308-313)$K ; (t_r=30-35^{o}C);

k – number of geothermal wells.

Thermal energy produced in a year, by the geothermal area (Q_{ga}), can be expressed in form of :

$$Q_{ga} = 10^{-3} \cdot \sum_{n=1}^{k} q_{gw,n} \ \text{[MJ/year]} \qquad (3)$$

$$q_{gw} = \tau_{op} \cdot \varphi_{gw} \cdot 10^{-3}\ [\text{kWh / year}] = = 3{,}6 \cdot \tau_{op} \cdot \varphi_{gw} \cdot 10^{-3}\ [\text{MJ / year}] \qquad (4)$$

in which: q_{gw}[kWh / year] – yearly geothermal thermal energy production of one well;

τ_{op}[hours / year] – yearly operating time of the wells.

The yearly degree of geothermal energy use (δ) may be defined as the ratio between thermal energy delivered to consumers, established by measurements at their inlet (Q_u) and thermal energy provided by the wells (Q_{ga}), calculated according to relations (3-4) above shown, considering the temperature on the return circuit until 30^oC.

$$\delta = \frac{Q_u}{Q_{ga}} \cdot 100\ [\%] \qquad (5)$$

Nowadays, geothermal resource available in the city area of Oradea has a remarkable potential, estimated at 250 GWh/year, valorised by means of 12 production wells, having a total installed thermal capacity estimated at 14-15 MW_t, delivering a yearly production of about 110 GWh.

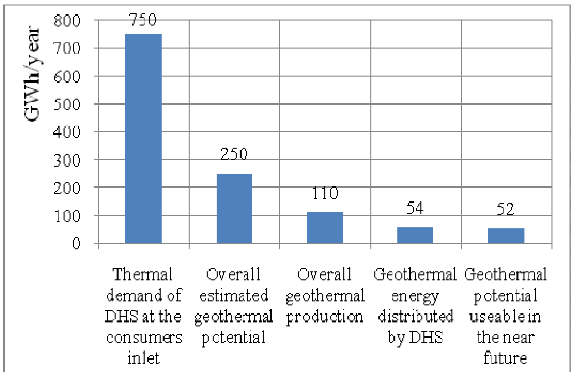

Fig. 1. Geothermal resource potential compared with the district heating demand in Oradea City

Of this production, 52-54 GWh/year, representing almost 7 % from the overall thermal requirement, is distributed through the existing district heating system, thus covering the thermal demand in the areas placed around the geothermal wells, (fig. 1), [4], [5].

3. DIRECT USE OF GEOTHERMAL ENERGY IN ORADEA CITY

Geothermal energy use has been continuously developed in the city area of Oradea during the last years as an alternative heating source to the pollutant energy of coal and natural gas.

Generally, low entalpy geothermal energy exploited in the city area of Oradea and in its neighborhood is used directly, in the most part for heating purposes, including dwellings and industrial spaces, warm water preparation, industrial processes, greenhouse heating, but also for balneology, bathing and swimming, fish farming and aquaculture.

The geothermal fluid coming from Oradea's aquifer allows only direct utilization through heat exchangers, because of its low parameters, being impossible to achieve a cogeneration process based on a thermodynamic cycle, in order to obtain simultaneously thermal and electrical energy. Thus, geothermal energy is only distributed through pipe network and therefore the term „cogeneration geothermal system" sometimes used, have to be replaced with „ geothermal heating system", [4], [5].

Warm water and space heating supply, through the heat exchangers, are among the most significant direct use of the low enthalpy geothermal resources.

Preferred temperature of the geothermal fluid for the simultaneous delivery of warm water and space heating is in the range 90-110°C and commonly the return temperature is between 35-40°C, [5].

The temperatures registered in range of 72-105^{o}C at the geothermal wells head outlet, related to the thermal aquifer of Oradea, alows to provide warm water without temperature limits, for household or industrial purposes throughout the city area. In order to assure in addition space heating besides warm water, usually geothermal energy must be associated with natural gas and heat pumps.

Geothermal energy is delivered from the wells area to the consumers through the geothermal stations, achieved by Transgex Company, the most important operating in the Nufărul, Ioşia-Nord and Calea Aradului districts of the city. Few tehnical parameters of these geothermal stations are shown in the table 2, [4], [5].

Table 2. Main geothermal stations providing district heat in the city area of Oradea

Geothermal station	Parameters of geothermal wells		Geothermal fluid temperature at the outlet of installation	Installed geothermal power capacity	Number of secondary heating stations connected	Number of dwellings supplied with :	
	Temperature at the well outlet	Potential flow rate				warm water	space heating
	[^{o}C]	[l/s]	[^{o}C]	[MWt]	-	-	-
Nufărul	74	40	28	6	7	6,000	-
Ioşia Nord	106	32	38	8	3	3,400	3,400
Calea Aradului	82	10	35	2	2	1,200	-

3.1. Space heating and warm water supply in Iosia-Nord district

The well located in Ioşia-Nord district, that supply the Geotherm Station, operates in artesian mode at an delivery flow of 19-20 l/s, with possibility of increasing to 30-32 l/s in pumping regime, in the cold period of the year, when additional heat is needed to be provide to the consumers, in accordance with the external temperature.

Fig. 2. Geotherm Station in Ioşia-Nord district.

Geotherm Station achieved in the district of Ioşia-Nord is the most updated achievement in the city, being equipped with 3 heat exchangers of plate type, valorising the energy of geothermal fluid in opened primary circuit, between the inlet and return temperatures of (105-106)^{o}C and (30-35)^{o}C respectively, (fig. 2).

Geothermal energy is provided through of 3 circuits, named geothermal (primary), intermediary and geotermic (secondary or distribution) network, that together transfer thermal energy to the consumers as warm water and secondary heating agent, (fig.3). Warm water preparing take place in two stages from 8-15 ^{o}C until 55 ^{o}C, at the same time with heating agent between 55 ^{o}C and 65 ^{o}C at the oultet of secondary thermal stations toward consumers.

The available temperature at the well head, above shown, make possible the space heating delivery simultaneously with the warm water, supposing that the flow rate of well allows, but additionally thermal contribution is required for secondary agent preparation, if the external temperature lowers below a certain limit value. The length and size of this supplementary heat depend on the geothermal fluid temperature available at well head and on the outside temperature registered in the cold period of year. In this view, geothermal stations are equipped with hot water generators operating on natural gas, designed according to the size of heating peak load needed to be supplied, [4], [5].

At the return temperature of 30-35 ^{o}C from primary circuit, geothermal fluid is delivered for bathing and swimming.

The current operation regime of geothermal stations, with a view of providing at the same time, space heating and warm water, have to be established by technical and economical designs, this operation mode being profitable in a range of temperatures in intermediary circuit above 85^{o}C, that can assure on secondary heating circuit at the outlet from thermal stations at least (58-60)^{o}C.

Overall thermal capacity of Geoterm heating station, located in district of Ioşia-Nord, is at about 12 MW_t , composed of 8.0 MW_t coming from geothermal resource and 4.5 MW_t installed in 2 hot water boilers operating on natural gas. In this geothermal station, almost 4 MW_t have been added to the geothermal energy in order to cover the heating peak load, sometimes in the most cold days registered in the last winters, during a short period

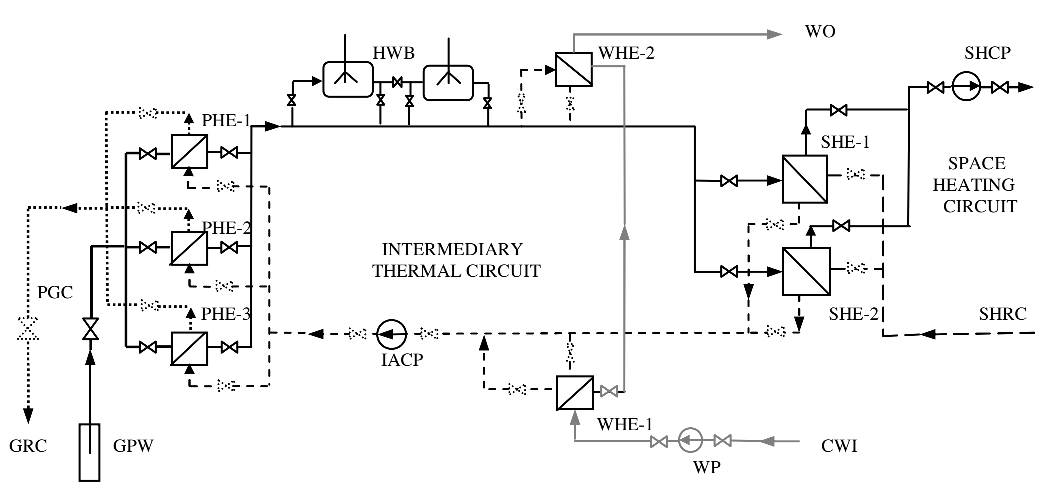

Fig. 3. Principle diagram of the district heating supply using geothermal energy in the Ioşia-Nord district.

PGC-primary geothermal circuit; GPW-geothermal production well; GRC-geothermal return circuit; PHE-1,2,3-geothermal (primary) heat exchangers; HWB-hot water boilers operating on natural gas; IACP-intermediary agent circulating pump; WHE-1,2-warm water heat exchangers; CWI-cold water inlet; WP-warm water circulating pump; WO-warm water outlet to consumers; SHE-1,2 – space heating exchangers; SHRC-space heating return circuit; SHCP-space heating circulating pump.

of 20-25 days/year, (fig. 2), [4].

At present, in Ioşia-Nord district, more than 3,400 dwellings in multi-flats buildings, individual homes, public spaces in field of education, sport, culture are supplied simultaneously with warm water and space heating, [5].

3.2. Warm water supply in Nufarul district

Geothermal resource available in Nufarul district is exploited at present by means of 2 wells, operating in production – reinjection mode, forming a doublet-well system. The geothermal fluid temperature at the well head is about 74°C, registering a maximum flow of 28-30 l/s in artesian regime, that can be more rised, to about 40 l/s in underground pumping operation. Above mentioned temperatures at the well head allows the warm water preparation between 5-15 °C, depending on the season, and 65-68°C at a flow rate of 20-21 l/s. The geothermal fluid leaves the water heating installation at temperature of 30- 35°C, being sent into the underground by reinjection, at an average flow of 21-22 l/s, [5].

Geothermal station placed in Nufarul district has an installed capacity of about 6 MW_t, suppling 7 secondary stations with heat, at present only with the view of warm water preparation, (fig. 4). In Nufărul district, about 6,000 dwellings benefit by the warm water delivery, prepared using geothermal energy, in accordance with the diagram presented in fig 5, [5].

Geothermal resource, located inside the limit of Oradea city, can contribute in a raised measure to improve the district heating supply, by an intensive exploitation of existing available potential, providing a clean, safe and cheap energy, compared with that obtained by fuels burning.

Further development of the geothermal energy use is foreseen in Nufarul district, in order to deliver space heating, besides warm water, to the consumers, usually consisting of multi-flats blocks, together with private houses and small sized public spaces, generally belonging to the trade activities. In this regard, in the

Fig. 4. Geothermal main station Operating in Nufarul district

near future Transgex Company will put into operation a new doublet-well production-reinjection system that in addition with the existing doublet can assure in safe conditions an overall flow rate of about 60 l/s, at temperature of 72-74°C.

According with [7], the thermal load demand in Nufarul district, estimated at 25-26 MW_t including the peak load, will be covered through of a new designed

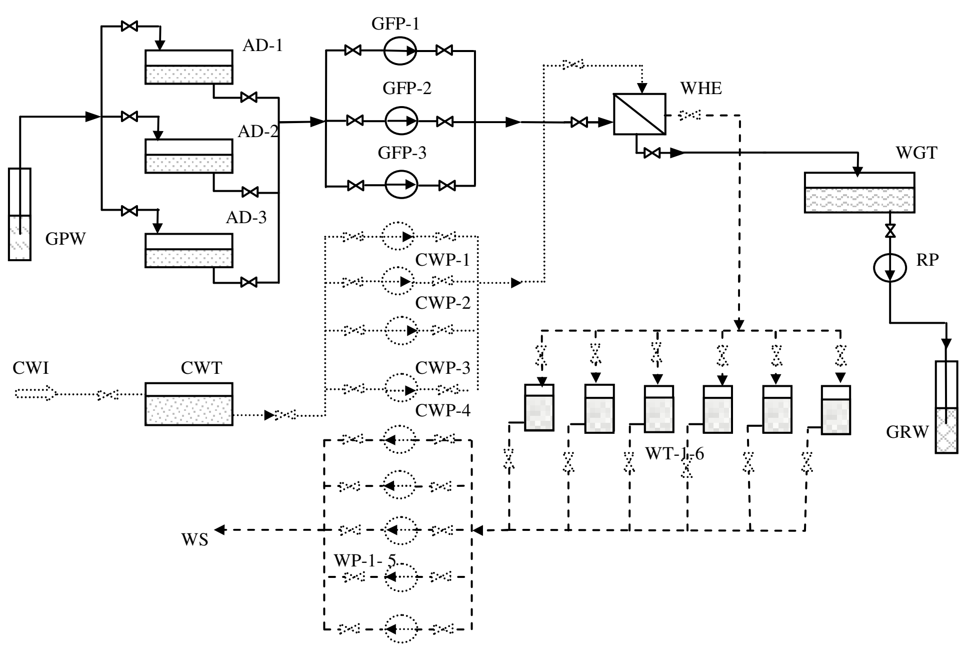

Fig. 5. Principle diagram of the warm water delivery using geothermal heat in the Nufarul district.

GPW-geothermal production well; AD-1,2,3-athmospheric dezaerators; GFP-1,2,3 – geothermal fluid circulating pumps; WHE-warm water heat exchanger;WGT-waste geofluid tank;GRP- geotermal reinjection pump; CWI-cold water inlet; CWT-cold water tank; CWP-1-4 – cold water circulating pump; WT-1-6 – warm water tank; WP-1-5 – warm water circulating pumps; WS-warm water supply to the secondary stations.

geothermal station, in 3 stages of operation, equipped with:

- plate-type heat exchangers (two units), using only the geothermal heat between 72-54°C (5 MW_t),
- heat pump (two units), cooling the geothermal fluid from 54°C to 15 °C (12 MW_t),
- hot water generators (two units), burning natural gas for peak load (8 MW_t).

This technology will assure in the intermediary circuit a temperature of 85°C, enough for the simultaneously providing warm water and space heating. On this way, additional geothermal energy of about 52 GWh will be valorized yearly in Oradea's area, [7].

4. CONCLUSIONS

Thermal energy demand for district heating in the city of Oradea is delivered at present, almost at whole, through an extended district heating system, supplied by the Cogeneration Thermal Power Plant, based on classical fuels, especially consisting of low grade coal and natural gas, on the whole being registered a low energy efficiency.

Geothermal reservoir discovered on the city area of Oradea, available at estimated yearly potential of 250 GWh, can be an alternative to polluting energy of coal and natural gas, providing a clean and cheaper energy for the benefit of local community.

The temperatures registered in range of 72-105°C at the geothermal wells head outlet, related to the thermal aquifer in city area of Oradea, show a low enthalpy resource, proper for direct utilization. The geothermal energy contributes at present with about 54 GWh/year to the district heating, representing a half of the overall production in the area, that is distributed by 3 main geothermal stations, in order to prepare warm water and to deliver space heating, thus covering partly the district thermal demand.

At present, in the city area of Oradea, more than 7,000 dwellings are supplied by geothermal stations with warm water and in addition for about 3,400 dwellings is assured simultaneously warm water and space heating.

Additional heat production is proposed to be achieved by the Transgex Company in the next few years in Nufarul district of Oradea at level of 52 GWh/year, that will increase the contribution of geothermal energy from 6-7 % to about 14 - 15 % of the overall thermal demand at the end users inlet, that will improve the district heating supply in the whole city area.

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