Advanced concepts and solutions for geothermal heating applied in Oradea, Romania

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Abstract. Approximately 70% of the total population of Oradea benefits from centralized heating, about 55,000 apartments and 159,000 inhabitants are connected. The heating system of Oradea consists of: sources of thermal energy production (Combined heat and power (CHP) I Oradea and geothermal water heating plants); a transport network of heat; heat distribution network for heating and domestic hot water; substations, most of them equipped with worn and obsolete equipment. Recently, only a few heat exchangers were rehabilitated and electric valves were installed to control the water flow.

After heat extraction, geothermal chilled waters from the Oradea area are: discharged into the sewer system of the city, paying a fee to the local water company which manages the city's sewers; discharged into the small river Peta; or re-injected into the reservoir. In order to ensure environmental protection and a sustainable energy development in Oradea, renewable sources of energy have been promoted in recent years. In this respect, the creation of a new well for geothermal water re-injection into the reservoir limits any accidental thermal pollution of the environment, while ensuring the conservation properties of the aquifer by recharging with geothermal chilled water.

The paper presents the achievements of such a project whose aim is to replace thermal energy obtained from coal with geothermal heating. The novelty consists in the fact that within the substation we will replace old heat exchangers, circulation pumps and valves with fully automated substations operating in parallel on both a geothermal system and on a primary heating system of a thermal plant.

1. Introduction

Among the renewable energies, a special place was and is still held by geothermal energy. Introducing the geothermal energy as a viable alternative to fossil fuels has been also supported, besides the technical and economic advantages they present, by the fact that 80 countries have significant geothermal resources. Geothermal energy is continuously available regardless of season and weather conditions.

Use of geothermal energy is divided into two categories: direct use and indirect use for conversion into electricity.
Direct use of geothermal energy means the use of the geothermal fluid thermal energy by heat transfer directly to a user or through another fluid. In general, areas of geothermal energy direct use are divided into 4 groups, namely: space heating and domestic hot water, agricultural uses (greenhouses, aquaculture, fisheries), balneology and industrial uses, [1].

Given the economic issues arising for space heating using classical fuel and the current energy crisis, there were developed many applications using geothermal water for space heating and domestic hot water. Such use of geothermal water is achieved in approximately 40 countries.

In 2007 the Romanian government adopted the "Romania's energy strategy for the period 2007-2020" which greatly emphasizes the development of renewable energy sources (including the geothermal one). The strategy is in line with the principles and EU directives (one of the objectives being the 20% renewable energy contribution to the EU 2020), [2].

Research of the hydro-geothermal deposits began in Romania in the years 1962-1965, by drilling the first well in the Western Plain. Up to now, within the geological research program, about 250 geothermal wells have been drilled and have given indications, wells performed by Transgex and Foradex companies.

The total installed capacity is of approximately 480 MWt, of which, today, 246 MWt is effectively used by exploiting 96 geothermal wells that are producing water with temperatures between 40 and 115 °C.

Main uses in Romania are: space heating and domestic hot water, balneology, greenhouse heating, wood drying, pasteurization of milk, flax and hemp smelting, intensive fish growth etc.

Overall energy savings annually achieved are of over 35000 toe. In balneal-therapeutic purposes there are used approximately 35 wells (with a total flow of 360 l/s, with water temperatures between 38-65 °C) providing the functioning of 16 spa resorts.

The repartition of the geothermal resource in Romania is presented in Figure 1, where in red are represented geothermal systems investigated through drilling and in mauve are represented perspective areas.

Figure 1. Repartition of geothermal resources in Romania
The largest geothermal reservoir in Romania is located in Bihor county, in the Oradea city. The installed capacity is currently about 30 MWt (13 production wells and an reinjection well), but it can be nearly tripled by generalizing production by pumping and reinjection in doublet systems (well production - heat exchangers - reinjection well). Geothermal potential in Oradea is approx. 220,000 Gcal/year, of which the average is used in the 100,000 Gcal/year.

Further development of geothermal water extraction from Oradea geothermal reservoir requires switching to pumping and water reinjection of geothermal waste heat. This can be achieved in the system with doublets, i.e. for each production well a reinjection well has to be installed (with the necessary equipment for reinjection), thus ensuring the maintenance of constant pressure and flow.

Usually, for increasing the production capacity, a deep well pump and relevant equipment have to be installed. By installing such a pump, the flow rate will increase. Geothermal water temperature will increase with higher flow rate.

Usually, the geothermal water is then conveyed to a tank for storing and degassing. Then, through a pump circulation, the geothermal water is transported to the heat station using insulated steel pipes. Here, through plate heat exchangers, the geothermal water is used to heat the water for space heating and to prepare the domestic hot water. After the heat is transferred, the waste geothermal water is discharged into the reinjection well, [3].

In order to automate an industrial process (geothermal complex within the project, in this case), the human operator must be replaced by an automatic control system that can turn, adjust and stop a process, capable of measuring variables in the system in order to obtain the needed output parameters. These objectives are achieved using a control system based on PLC (Programmable Logic Controller). Automation software, specific to each application, is implemented on the PLC using a PC [4].

To achieve fast and efficient links between the human operator and PLC, it is used a graphical interface that allows both permanent monitoring of system parameters and data storage and the possibility for operator to intervene fast and comfortable, if needed. The graphical interface allows the representation of the geothermal complex elements on the computer screen (temperature, pressure, flow, actuating valves, pumps, pipes, heat exchangers etc.). These charts are inactive but next to the transducers and actuators, there are small windows that give the momentary value of the parameters. These values are displayed in real time.

This system consists of transducers and actuators from the geothermal complex, programmable logic controller PLC, graphical interface and links between them, which is called SCADA system (Supervisory Control and Data Acquisition), is used for the geothermal complex in the project presented in this paper.

2. Advances in geothermal heating applied in Oradea

The subject of this paper was the object of a project financed from Icelandic funds called: Best use of geothermal energy to produce heat for consumers connected to Substation PT 902 and reinjection of used geothermal water in thermal reservoir, [5].

The justification of the need of this project starts from the fact that approximately 70% of the population from Oradea benefit from centralized heating, it means about 55,000 apartments and about 159,000 inhabitants connected.

Consumers connected to the centralized heating supply can be structured as follows:
- households: housing associations, apartments and individual houses;
- social-cultural institutions and businesses;
- hospitals, kindergartens, nurseries, schools;
- hotels, banks, shops.

The heating system of Oradea consists of:
- sources of thermal energy production: CHP I Oradea and geothermal water heating plants [2];
- transport network of heat (about 80 km);
- heat distribution network (about 369 km for heating and 177 km for domestic hot water DHW);
- substations: about 150 of which a large part are equipped with worn and obsolete equipment.
Recently, only a few heat exchangers were rehabilitated and electric valves were installed to control the water flow.

Due to the continuous increase in fuel prices, solutions must be found to best solve the problem of ensuring energy for space heating and for the preparation of domestic hot water to the inhabitants of Oradea in terms of cost and affordability. Oradea has a defined strategy for heating through a Master plan approved by City Council in 2010. It includes, besides the renovation of the combined heat and power plant using gas as fuel, renovation of the hot water transportation system and increase of geothermal energy intake.

In order to ensure environmental protection and a sustainable energy development in Oradea, renewable energy sources have been promoted in recent years. In this respect, the creation of a new well for geothermal water re-injection into the reservoir limits any accidental thermal pollution of the environment, while ensuring the conservation properties of the aquifer by recharging with geothermal chilled water, Figure 2.

![Figure 2. Designed network for geothermal energy use](image)

After the heat extraction, the geothermal chilled water from Oradea area is:
- discharged into the sewer system of the city, for a fee paid to the local water company which manages the city's sewers;
- discharged into the small river Peta;
- or they are re-injected into the reservoir.
Peta is a thermal small river which springs from Baile 1 Mai and has a similar mineralization with the geothermal waters. For water that is discharged into the Peta small river, a fee is paid to “Romanian Waters” National Administration (ANAR). Geothermal chilled water from a single well only is re-injected into the reservoir. Nufărul geothermal plant is using geothermal water in the doublet system. Geothermal water is operated through well 4797 and after heat extraction is re-injected in well 4081. Although geothermal chilled water temperature comply with the standard temperatures at discharge, accidental situations may occur where the water temperature is higher.

The objectives of the project were:
- better use of geothermal energy sources available in the deposit of Oradea for the production of heat;
- improving environmental quality;
- reducing emissions of greenhouse gases;
- efficiency and rational use of primary energy resources.

The project’s aim is to replace the thermal energy obtained from the coal with the geothermal heating obtained by the drilling well 4796 from the University of Oradea. The novelty is the fact that within the substation there will be replaced old heat exchangers, circulation pumps and valves with fully automated substations operating in parallel on both geothermal system and on primary heating system of CHP.

By implementing this project the following are expected to be achieved:
- the reduction of fossil fuel consumption by using geothermal energy;
- the reduction the cost of heat production for district heating;
- sustainable exploitation of geothermal water resources and providing the water pressure in the reservoir by injecting used geothermal water;
- increase of heating comfort for population and public institutions, consumers of the substation;
- reducing of \( \text{CO}_2 \) emissions by about 1,800 tons per year.

Regarding the project outputs, when completed, the project will materialize in rehabilitation and/or achievements of: technological equipment, networks, injection new well and re-injection station.

The technological equipment of PT902 substation will be provided with 2 fully automated substations operating in parallel on both geothermal system and primary heating system of CHP. The modules are provided in 2 stages (plate heat exchangers, heat circulation pumps in the secondary circuit, filling station - added). The installed power in substation is 2000 kW for heating and 800 kW for hot water.

Networks will be supplemented with geothermal water transport pipeline from 4796 well to PT 902 with diameter 150/250 and a total length of approximately 1,222 m and a transport pipeline for geothermal chilled water from PT 902 to the well re-injection, of polyethylene PE 160/200 with a total length of approximately 2,214 m.

The injection new well consists in the fact that all the extracted geothermal water will be re-injected, respectively 45 l/s, the depth of re-injection drilling being 2,900 m. Geothermal chilled water from substation PT 902 will be collected and transported via a PE 160 polyethylene pipe to the connecting pit of the geothermal chilled water to the discharge of waste water Oradea University substation, from where it will be transported to the re-injection probe through a PE 200 polyethylene pipe.

Works to the re-injection station implies: the purchase and installation of a 50 cubic meters tank; the purchase and installation of a pumping group with the installed flow of 45 l/s and the pumping height of 10 bars; fencing of re-injection station 15 x 15 linear meters.

It was estimated that the emissions of \( \text{CO}_2 \) will be reduced annually with 1,779 tons/year.

In terms of the thermal energy production, PT 902 geothermal substation will produce energy of 3,000 Gcal (3498 MW) per heating season (it means 172 days = 4128 hours) plus 150 Gcal (175 MW) per season, heating for hot water consumption.

The changes of the network scheme can be observed on Figures 3 to 6 and the legends are presented in Figures 7 and 8.
Figure 3. Pumping module

Figure 4. Heat exchanger module

Figure 5. Hot water exchanger module

Figure 6. Distribution module
The direct beneficiaries of the project are:
- consumers of Substation PT 902, respectively about 75 people living in the 52 buildings located onMatei Basarab, Suceava, Rimanoczy Kalman streets and buildings belonging to the Sports High School;
- the operator of the heating system as well as the costs of exploitation, production and transport of heat will be reduced by upgrading the equipment of PT 902. Indirect beneficiaries are residents of Oradea, as pollutant emissions (dust, CO₂, NOx) are reduced.

3. Conclusions
One of the advanced concepts presented in this paper could be considered the strategy of the use of primary agent, either the geothermal water or the hot water supplied by CHP I Oradea; also the use of heat exchangers separately for heating and hot domestic water, with the possibility to function at the same time in case of damage or interventions at heat exchangers.

Retrofitting of the PT 902 district heating substation permits a dual functioning which ensures thermal agent and hot water for consumers from two distinct sources: primary thermal agent produced by CHP I Oradea and geothermal hot water from 4797 geothermal well.

The new district heating substation consists of two heat exchangers units. The first unit, composed of two heat exchangers with an installed thermal power of 2 MW each, will produce secondary thermal agent for the consumers. The second unit is composed of two heat exchangers with an installed thermal power of 800 kW and will assure the production of domestic hot water.

Using two heat exchangers for hot water and secondary thermal agent production, provides greater security of supply of heat and domestic hot water. If one of the heat exchangers is in maintenance or a fault appears, the second heat exchanger can supply consumers with heat. The change between the two heat exchangers is made through a bypass.

Another advantage of the substation that increases security of supply is provided by the two primary agents used. If the geothermal well is in maintenance or a fault appears that disconnects the well, heat and domestic hot water will be prepared by using primary agent produced by CHP I Oradea. Also, if the supply of primary agent from CHP I Oradea is stopped, heat and hot water will be produced by using geothermal water from 4797 well.
Simultaneously, using pairs of heat exchanger for heat and domestic hot water production and two primary agents – geothermal water and primary agent from CHP I Oradea – ensure a greater flexibility in operation:

- each primary agent can be used for only one module. For example heat can be produced using primary agent form CHP I Oradea, and hot water can be produced using geothermal hot water;
- the installed capacity of the substation can be doubled by using all 4 heat exchangers.

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