About the Geothermal Electric Power Plant from the University of Oradea, Romania

Mircea I. Gordan and Teodor Maghiar
University of Oradea, Str.Armatei Române, nr.5, 3700 Oradea, Romania

ABSTRACT

The purpose of this paper consists in the exposure of a short description of the geothermal electric power plant from Oradea, Romania, and of the research directions regarding the optimization of the behaviour of this plant, especially the determination of the optimal thermodynamic cycle based on the analysis of the practical results.

Introduction

The largest known geothermal area in Romania is situated in the western region of the country and is part of the Pannonian Basin Geotermal system. There were indentified 28 aquifers covering on area of 2.500 km^2. The reservoir are relatively small and the draw-down depends on the extracted amont of water. Diagrams presenting draw-down versus cumulative production during 12 to 14 years of eploitation show that on average the extraction of 3-5$\cdot$10^5 m^3 of fluid from these reservoirs causes a pressure draw-down of 1 bar (Roşca, 1993).

The city of Oradea is situated in the western part of Romania. The reservoirs indentified in the area are very different from those indicated above, located in the Pannonian Basin. Three geothermal reservoirs have been indentified within the city of Oradea and the surrounding area know as the geothermal Oradea area. The main reservoir is situated almost entirely within the city limits of the city of Oradea. It is hydrodynamically connected with a second one in the Felix Spa Resort, about 10 km south-east from Oradea. The third one area is near the village Borş, 6 km north-west from Oradea.

From the reservoirs of Oradea, in the last 15 years, about 50l/sec have been withdrawn on continuous basis and no measurable draw-down encoutered. Draw-down became significant only when production rate was increased to 150 l/sec.

Of 12 bareholes that have been drilled into the Oradea reservoir, 11 are used as production wells and one for reinjection. The total installated capacity is at present of 35 MW corresponding to a flow rate of 150 l/sec of geothermal water at a mean temperature of 85°C. The production wells are currently discharged in artesian flow. The possibility to double the yield of the wells by pumping is considered a realistic estimate (Cohut, 1992).

The Oradea Electrogeothermal Power Plant

The geothermal electric power plants realizes the conversion of thermal water resources into electric energy. To be able to behave in such a way a power plant has to use a working medium (fluid) which evolves in a closed circuit, according with a thermodynamic motor cycle between two heat resources -water at high temperature and cooling water, respectively.

For the design of that kind of power plants the correlation between the heat exchange processes, the expansion and compression of the working agent in the driving element, pump and the thermodynamic cycle according with what the working agent evolves, must be developed with the purpose of obtaining the maximum power in given conditions and, as far as possible, with the lowest cost. Based on technico-economical and functional assumptions, the optimization of heat exchange surfaces and of cooling agent must be achieved in order to ensure the minimum cost per kWh energy.

In 1981 the National Geothermal Research Institute of Romania designed and developed a pilot binary cycle power plant using the carbon dioxide (CO_2) as working fluid. The first installation used a piston engine for the working fluid expansion and produced 1 MW electric power. A new pilot power plant has now been designed, the piston engine being replaced by a turbine. Both are experimental installations and therefore used for testing usually during the warm period of the year, when more geothermal water is available for the evaporator.

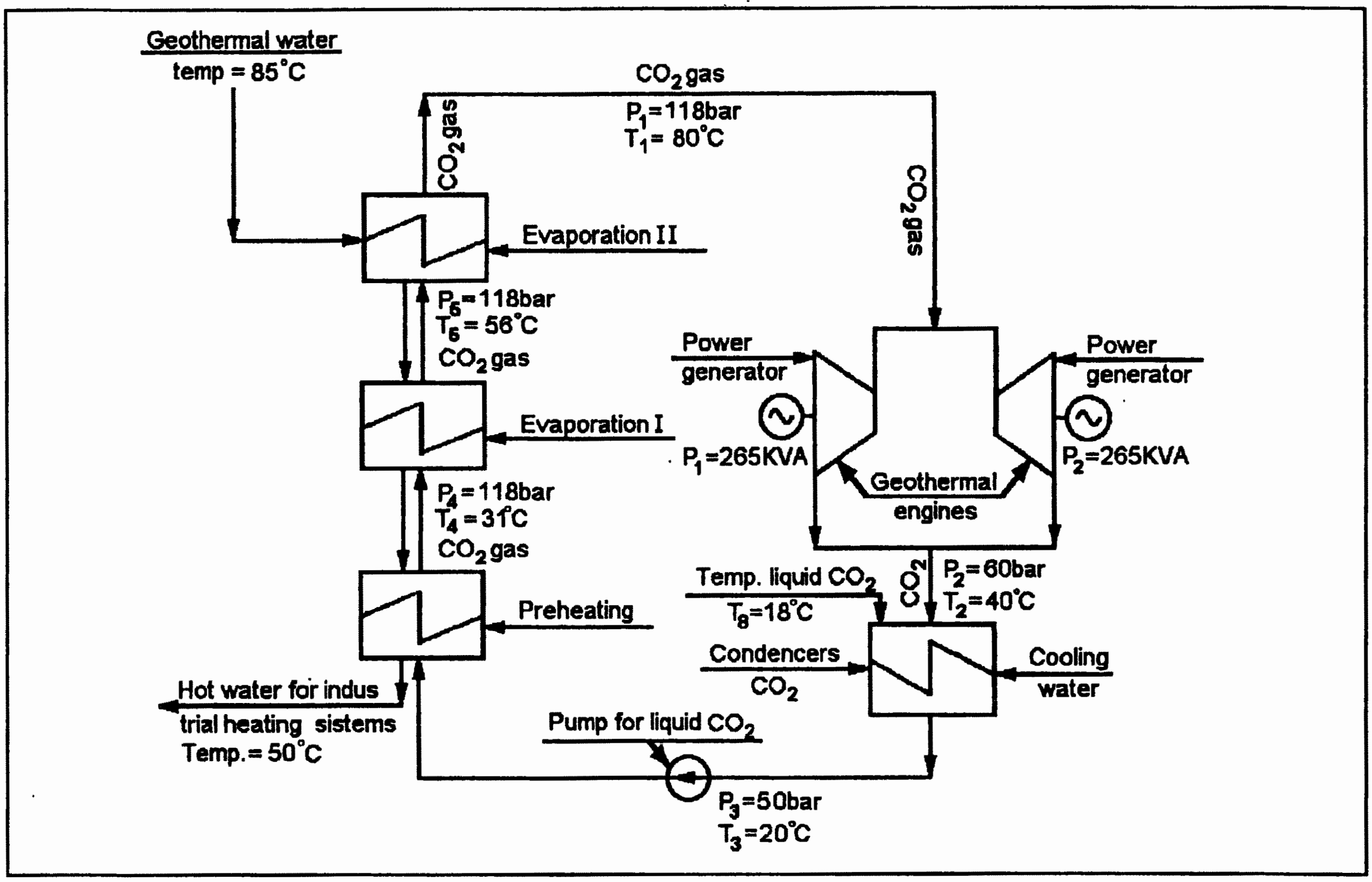

Figure 1. The functional layout of the electrogeothermal plant from the university campus of Oradea.

The geothermal water is piped to the heating station located about 400 m from the well. The thermal energy is transferred to the space heating water and to the fresh water in shell and tube heat exchangers. In 1994 these were replaced by new stainless steel plate heat exchangers, made in Romania. The geothermal water flow rate through the heat exchangers is regulated by orifices and, for the space heating water, also by regulation valves. At present, the entire control and regulation is done manually.

The geothermal heating system at the University of Oradea was set on line in 1981. The existing heating system can be developed to supply the total heat demand in the future, considering that all the planned objectives will be obtained. For these conditions, the maximum thermal power demand of the heating system is about 3.4 MW (Roşca, 1993).

- The functional layout of the electrogeothermal plant from the University of Oradea, is shown in Figure 1. The geothermal water is pumped by a deep well pump to the storage and degassing tank, through a surface steel pipe insulated with rach wool and protected by aluminum sheet. It is recommended to equip the pump with a frequency regulator. To avoid corrosion, the pressure in the storage and degassing tank is higher than the atmospheric pressure to prevent oxygen from entering into the water. This also avoids calcite scaling by keeping part of the carbon dioxide in solution. From the tank the geothermal water is fed by a group of circulation pumps to the binary power plant and to the space heating and tap water heating system. Three pumps are envisaged for this group, out of which one is going to be supplied with a frequency regulator, thus allowing operation at partial loads, to deliver any required flowrate to the users

The plant has the following parts:

- The system of CO_2 preheating and evaporation, which contains stainless steel plate heat exchangers for the transfer of the heat from the geothermal water to the space heating water. These heat exchangers are made by IUC Borzesti-Romania have an evaporation surface of 30 m^2 each and work at a pressure of 118 bar.
- The condensing system composed of six condensers, made by IUC Borzesti-Romania, need a cooling fluid which is the fresh water produced by a shallow well. The condensers have the same working surface as the evaporators (heat exchangers) described above.
- The electrogeothermal power producing system has two parts, each of them containing two EK-720 pumps made by IM Ploiesti-Romania, which are connected trough differential reducing gears (made by "Neptun" factories

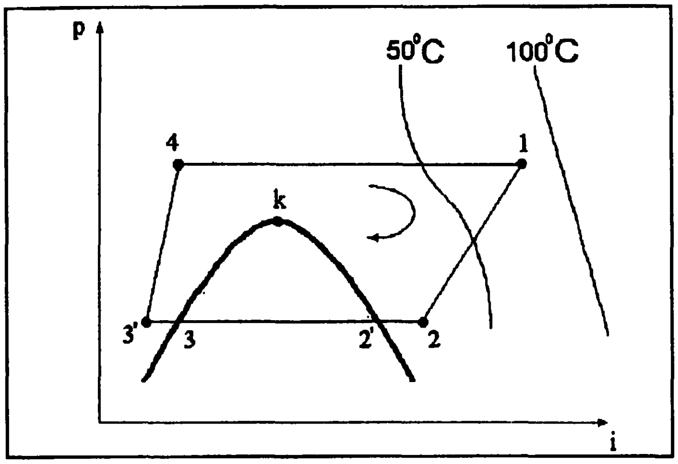

Figure 2. The thermodynamic cycle within the CO_2 diagram pressure-enthalpy.

from Câmpina-Romania) with an a.c. power generator. This generator is characterized by a 265 kVA working power at 400 V voltage.

- The control and command system, which is used in order to follow and verify the variations of the flow, pressures and temperatures from the plant.
- The system used for the process of connecting the plant to the national power system, composed by two panels made by "23 August" factories from Bucharest-Romania. It contains also the synchronizing and control apparate.
- The system for CO_2 loading into the geothermal installations.

A circulation pump drives the geothermal water out flow to industrial and private heating system, and to recreational and health bathing.

The Determinations of the Optimal Thermodynamic Cycle

The working agent used in the plant from Oradea is CO_2. Starting by the initial proposed thermodynamic cycle (Maghiar, et al., 1992) (Figure 2.), the range of the possible thermodynamic cycles was extended both in the liquid field and superheated vapors. In this way, for the transformation 3' - 4 (the evolution of liquid CO_2 within pump) not to lead to the appearance of cavitation in the pump suction, it is necessary that the working liquid reaches such a temperature that when the pressure decreases because of suction that it not reach to the two phase zone. So, we considered an additional cooling of the liquid CO_2 by continuing the isobaric cooling into the liquid zone (the 3 -3' region) until getting to that value of the temperature for which the cavitation phenomenon is eliminated. Point 4 moves to left. We should mention that the super-cooling is correlated with the geothermal and functional parameters of the pump (Maghiar, et al., 1992). Taking into account the available temperatures for hot and cold water and the CO_2 characteristics, the overall thermodynamic cycle was achieved. This cycle is presented in Figure 2.

For the possible thermodynamic cycles having the same shape as the one presented in figure 2, a software programme was developed for the determination of optimal cycles depending on the input data. We emphasize that the thermodynamic cycle is determined when the pressure and the temperature from point 2 are known.

The determination of the optimal thermodynamic cycle was repeated for different values of the input data (hot water flow, input temperature for cold water).

The results of the computations can be presented in a graphical form. For example, in Figure 3 we present the range of the pressure values defining point 2 (the geothermal water flow is 30kg/sec with the input temperature of the cold water at 10°C), when the limit of these values is around the value of the pressure corresponding to the optimal cycle. This limit was obtained by keeping for pressure p_2 only those values for which P_u/P_{umax} falls inside the range (0,8-1), where P_u represents the effective power. From the graphic form (Figure 3) the range for p_2 is between 56-67 bar.

Analyzing the results obtained after the computations for the variations taken into account for the intersection of the domains of three parameters (p_1,p_2,p_3), produced a domain where the thermodynamic cycles matched the analyzed ranges:

- For the pressure from point 1: p_1 = 108 -118 barn
- For the temperature from point 1: t_1 = 70 -78°C
- For the pressure from point 2 : p_2 = 60 - 66 bar

For obtaining a maximum rate power is necessary to maintain the optimal thermodynamic cycle for every operational engine of the power plant, thus is necessary to maintain the CO_2 parameters when disturbances occur.

In certain steady states of the power plant some disturbances may occur resulting in the modification of CO_2 parameters, geothermal and cold water parameters, and geothermal engine pa-

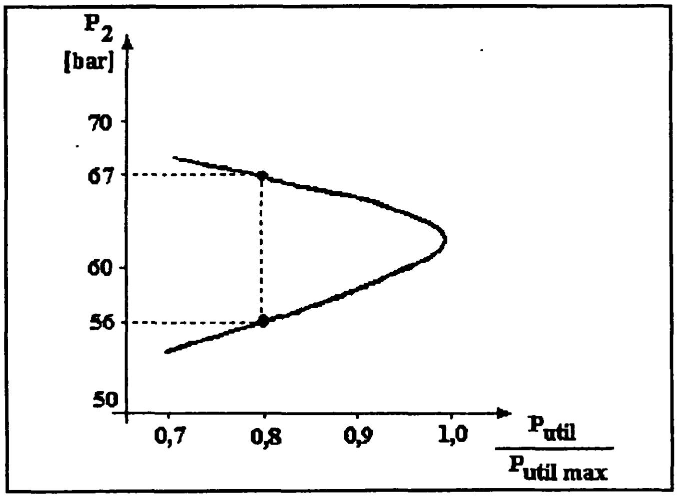

Figure 3. The distribution of the pressure values p_2=function of ratio $P_{useful}/P_{useful\ max}$.

rameters (i.e., the pressure and temperature fluctuations of CO_2 in different points of the plant, flows and temperature fluctuations of the geothermal water and of the cooling water and variations of the geothermal engine speed, etc.).

The method for self regulation of CO_2 parameters when disturbances occur, was developed starting with the interdependence between the parameters mentioned above. This interdependence was analyzed for every situation based on the CO_2 diagram, the phenomena of overall heat transfer from the heat exchange of the liquid CO_2 pump operational characteristics and the geothermal engine. This method is presented in another paper (Gordan, 1996).

Conclusions

By performing an analysis of the results obtained, we can conclude that for every group of input and output parameters (flow rate and temperature of geothermal water, and of cooling water respectively) an optimal thermodynamic cycle exists which enables us to obtain the maximum useful power. To obtain this thermodynamic cycle the automatization of power system is required.

For example, the processor TI305 can follow all the control loops adjusting the plant parameters with the purpose of reaching an operational behaviour of the power plant.

References

Cohut, I., 1992. "Current Status and Prospects of the Romanian Geothermal Industry," Report presented at the *International Seminar on Geothermal Energy*, Oradea, Romania, 5 p

Gordan, M., 1996. "Programme used for the optimal design of an electrogeothermal plant," Elektroenergetika, Košice 1996, Slovakia.

Maghiar, T., Leuca, T., Gordan, M., Gordan, C., Antal, C., Gavrilescu, O., Popa, M., Manole, A. and Naşcu, G., 1992. "Computer Aid Design of Geothermal Electric Power Plants", University of Oradea Annals, vol.2., p. 327-332.

Roşca, M., 1993. "Economical and Technical Assessment of some Geothermal Development Scenarious for Oradea, Romania," UNU Geothermal Training Programme, Reykjavik, Iceland, Rep.13, 44 p.