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About the production and interconnection of electricity obtained from geothermal energy

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Abstract. *In the context of sustainable development, the use of renewable energy sources and the decrease of greenhouse gas emissions have become global priorities. Geothermal energy represents an important potential for many countries, including our country. If the exploitation of thermal energy has a relatively widespread, the production of electricity is less developed, even if there are countries that cover a significant part of the electricity demand from this resource. In this paper, the authors aim to present the main technical solutions that produce electricity from geothermal sources, but also present some topological models for integrating the obtained electricity in the public network.*

Key words: geothermal energy, electricity, renewable energy sources, interconnectation of electricity

1. Introduction

Geothermal energy is the energy obtained from the heat inside the Earth. It can be classified, in terms of thermal potential, in:
- geothermal energy of high thermal potential;
- geothermal energy of low thermal potential.

Geothermal energy with high thermal potential is characterized by high temperatures (> 150ºC) and can be used for both electricity generation and heat production. Geothermal energy with low thermal potential (temperatures <150ºC) can be used mainly for the production of thermal energy, while for the generation of electricity requires binary technologies [1].

The category of high thermal potential geothermal energy resources includes: volcanoes, hot springs and geysers, the most important resources being found along the "Pacific Circle of Fire".

The use of geothermal energy for the production of thermal energy had applications in our country, especially in the last decades of the 20th century, after the fossil fuel crisis of the '70s, when the importance of using renewable energy resources was highlighted. Thus, research in this field was encouraged, having as result the construction of installations that exploit the geothermal potential of Romania. This should not be neglected, being distributed in the Western Region, in the Getic Depression (Cozia –Căciulata) and the Moesian Platform (Bucharest area) [1].

Currently, the exploitation of low-potential geothermal energy has an important development due to special equipment, namely heat pumps that, as it is known, extract heat from soil, water or air.

In this paper, the authors aim to bring attention to aspects related to electricity production, which in our country did not have direct applications until the time of involvement in the large-scale European project GeoSee [2], in which several countries in Southeast Europe came together to study and develop hybrid systems for producing electricity using geothermal energy in combination with another renewable energy source. At the Oradea power plant, the choice of solar energy produced with photovoltaic panels was chosen as a complementary source.

2. Types of geothermal power plants for electricity production

The statistics published in 2016 shows that geothermal heating energy is exploited in 70 countries, while electricity is produced in 24 countries. Table 1 presents the main countries producing electricity based on geothermal energy. Recently, major power plants have been built in China and Russia.

Table 1

Geothermal power plants installed capacity

Country	Capacity (MWe)	Country	Capacity (MWe)
Costa Rica	142.5	Japan	546.9
El Salvador	161	Mexico	755
Iceland	170	New Zealand	437
Indonesia	589.5	Philippines	1909
Italy	785	United States of America	2228

There are currently three main types of geothermal power plants in the world that are used to transform the power of geothermal water into electricity, which depend on the state of the fluid used (vapor or liquid), or its temperature [3], [4]:

- **Geothermal power plants based on dry steam**; these were the first types of power plants built (Larderello, Italy, in 1904) and use steam at high temperature (> 235^{o}C) and only a small amount of water from the geothermal tank; the steam is brought from the tank through a pipe directly into the turbine, to drive a generator that produces electricity;
- **Wet saturated steam geothermal power plants** (also known as flash power plants); is the usual option for plants with 5 MW up to 100 MW installed capacity; these plants use hot water (> 182^{o}C) from the geothermal tank; the water is pumped into the expander at the pressure provided by the underground tank where a sudden

drop in pressure takes place, which causes some of the water to evaporate, the steam formed driving the turbine.

- **Geothermal power plants with binary cycle**; in binary systems, hot geothermal fluids are conveyed through one of the parts of a heat exchanger to heat a working fluid; the working fluid, with a low boiling point, vaporizes and passes through a turbine to generate electricity.

The usual installed capacity in this category is in the range 500 kWe - 10 MWe.

Since most geothermal reserves are characterized by relatively low temperatures, below the level of 180°C, the following is the diagram of a binary cycle geothermal power plant, which is the optimal solution for the conversion of geothermal energy into electricity, at these temperature values (see figure 1).

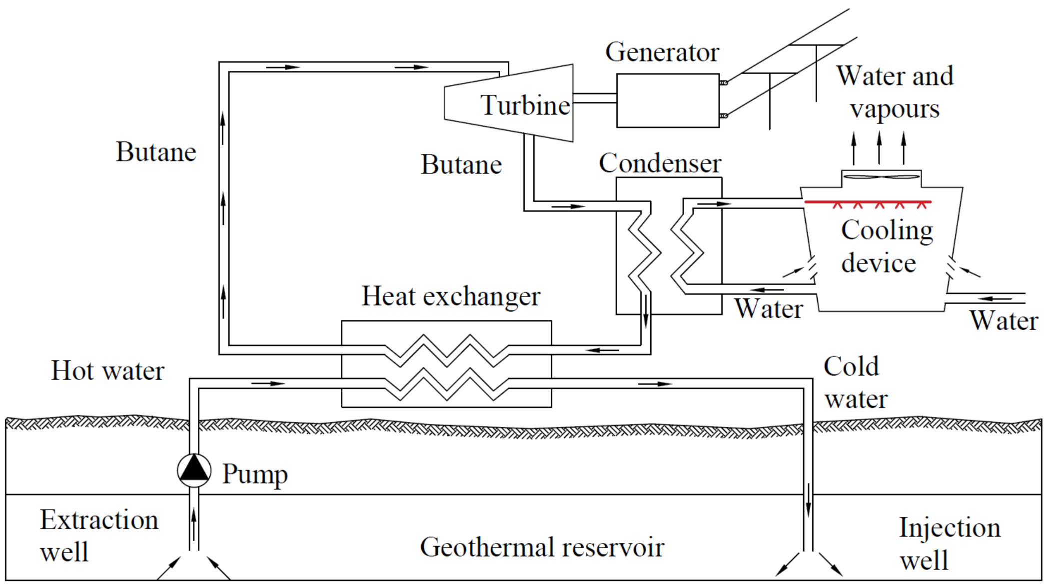

Fig. 1. Binary cycle geothermal power plant.

These types of plants are based on the thermodynamic Organic Rankine Cycle, abbreviated in the technical literature as ORC.

Water from the geothermal source transfers heat through a heat exchanger to a fluid (such as pentane, isopentane, butane) that evolves in the engine cycle of the plant. This fluid is characterized by a significantly lower boiling temperature than water. In this way a relatively low geothermal thermal potential can be used. In addition, due to the two circuits, impure geothermal water can also be used, especially if certain pressure conditions are maintained in the installation (which does not allow boiling), so that it is not possible to release harmful gases into the atmosphere. On the other hand, this is also a disadvantage due to the fact that it requires additional energy consumption [3].

The working agents in the installations, that operate using the Rankine cycle, present different thermodynamic properties, which influence both the working conditions, such as pressures and temperatures, as well as the energetic performances, quantified by means of the efficiencies.

Thus, one can define [5] the thermodynamic efficiency η_m:

$$\eta_m = \frac{L_u}{Q_a} \qquad (1)$$

where, L_u = useful mechanical work,
Q_a = consumed heat,

respectively, the electrical or global efficiency η_e:

$$\eta_e = \frac{E_e}{Q_a} \qquad (2)$$

where, E_e = electricity produced,
Q_a= consumed heat.

Another example of a plant is one that uses the Kalina cycle instead of the Rankine cycle in which an aqueous ammonia-based solution is used as the working agent. Due to the fact that the working fluid is a mixture, the intake and release of heat take place at different temperatures [3], which has the effect of increasing the efficiency of the Kalina cycle by 10-30%.

- **The combined cycle** which consists of a combination between those with steam cycle and those with binary cycle, which allows to achieve a high efficiency of the plant.

In the European project developed in Oradea, after an analysis of specialists, which took into account the temperature, pressure and flow of geothermal water, it was found that the most efficient solution is, in terms of efficiency, the one based on the Kalina cycle and was proposed the scheme of the geothermal power plant presented in figure 2 [2].

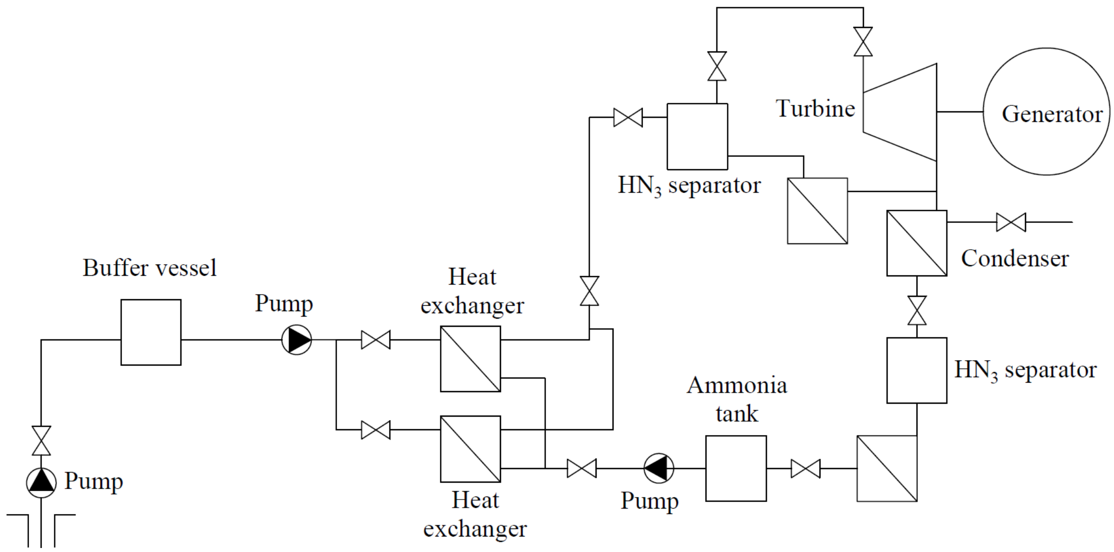

Fig. 2. Diagram of the proposed power plant.

3. Interconnection of electricity obtained from renewable resources

In the production of electricity from renewable sources, given their variable nature, an important role is played by the interconnection or integration into the public grid of electricity. Without a prior study by specialists in the field of electricity, the connection of renewable sources to the grid can cause significant disturbances that affect the quality of electricity in the system. It can also be affected by the operation of frequency converters at the interface between the renewable energy source and the public electricity grid, in the absence of an efficient system for limiting the distortion of the electric current curve [6].

The topological models are chosen according to the renewable source used and the type of current obtained (continuous or alternating). One of the methods that allows increasing the efficiency of generation but also the separation of consumption production, is the storage of electricity, which facilitates the transition from the microgrid that generated energy from RES to the public grid.

Among the methods of interconnection of renewable energy sources that produce direct current, we mention the following topologies: the use of buck (down), boost (fly) or flyback converters, controlled by PWM (pulse-width modulation) followed by an inverter [7], [6].

Figure 3 shows the block diagram of the conversion system in which the connection of the renewable energy source to the grid is made by means of a quasi-resonant buck type converter (descending) with zero current switching followed by an inverter. This reduces the switching losses for the main circuit switch and improves system efficiency. The buck converter switch is PFM controlled. If the quasi-resonant topology is used, the current and the voltage take higher values than in the case of non-resonant topologies, but due to the current technologies for the realization of electronic devices, the voltage drops on the conducting devices are reduced [2].

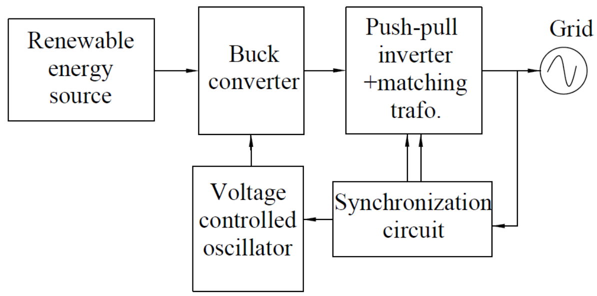

Fig. 3. Block diagram of the conversion system.

In the case of devices interconnected to an AC voltage system, the relationship between the variation of the active power produced and the frequency must be implemented by controlling the interface converters of renewable sources, as well as by a voltage control system.

Figure 4 shows the microgrid through which the energy obtained from a renewable source through which an alternating current was obtained is interconnected, but which is provided with the possibility of storage in batteries [7].

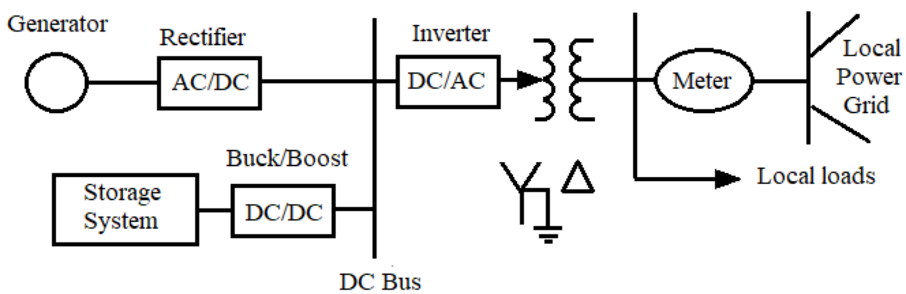

Fig. 4. The interconnection of alternative current to the network.

If it is desired to interconnect several sources that produce electricity to a network (Smart) it is necessary to provide a digital signal processor, which controls the amount of energy and the frequency of the network.

4. Conclusions

As the exploitation of geothermal potential for electricity production is expanding, finding efficient conversion technologies becomes imperative. National research becomes very important, given that the actual sources vary from one country to another, even from one area to another (temperature, flow, constancy, etc.). Of course, there are global solutions, but they must be adapted to particular conditions.

As a general feature, it is mentioned that geothermal power plants must be located and operated in the vicinity of the source.

Prior to making a major investment, a feasibility study is required, which involves both a technical and an economic analysis. The latter is based on, inter alia, the annual operating interval, the period for which the possibility of operation is estimated, the cost, the feasibility and the maintenance costs of the equipment are estimated and obviously the real price at which the Kilowatt of electricity will be obtained.

References

[1] C. Mârza, A. Hoţupan, R. Moldovan, G. Corsiuc, Surse neconvenționale de energie, UT Press, Cluj-Napoca, 2013.
[2] ***Raport Proiect Geo SEE, Oradea 2016, Accesat in 02.05.2020 http://remsis.utcluj.ro/wp-content/uploads/2016/11/Raport-2016-Oradea.pdf.
[3] G. Boyle, Renewable Energy, Renewable Energy – power for sustainable future, Oxford University Press, 2012.
[4] ***https://energyeducation.ca/encyclopedia/Geothermal_power_plants
[5] M. Angelino, M. Gaia, E. Macchi, A review of italian activity in the field of Organic Rankine cycles, Preoceedings of the International VDI- Seminar, Zurich, September, 1984.
[6] ***Raport Holistica impactului surselor regenerabile de energie asupra mediului şi climei 2018, Accesat in 05.05 2020 https://cmu-edu.eu/horesec/wp-content/uploads/sites/17/2019/11/Raportare-stiintifica
[7] A. Keyhani, Design of Smart power grid Renewable energy Systems, Wiley Publications, New Jersey, 2011.