Geothermal Sources of Energy

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Abstract— In this paper we present basics of *geothermal energy*, we give brief history, usages in heating, and electricity production, and we give overview of three basics *geothermal systems* for extracting heat from underground waters or systems to produce electricity: power plants on hot water, dry steam, or binary cycle. Further, we present *basic elements* of geothermal systems, and we give data about usage of geothermal energy in world, and geothermal impact on economy, and environment. We present steps toward installing geothermal power plant. Geothermal energy presents one of five *renewable energies* (solar energy, wind energy, biomass energy, water energy, geothermal energy) that are used today in substituting energy obtained from gas, fossil fuels, or oils.

Index Terms— geothermal energy, geothermal heating, geothermal electricity generation, geothermal systems for electricity production, geothermal heat pump

1 Introduction

GEOTHERMAL energy is produced from heat inside the earth. Word *geothermal* has roots in Greek word *geo* meaning earth and *thermo* what represents heat. People all around the Earth use geothermal energy for electricity production, for building warming, for generating heat, and for other uses.

Earth core lies almost 6,500 km below the surface. It is consisted of hot melted iron, surrounded with rocks and magma. Mentle is around 3,000 km width, on temperature 2,800-7,800 degrees of Celsius. Heat is constantly produced inside Earth with slow radioactive decay that are naturally present in rocks. The farthest Earth leyer that protects core, is not consisted from continual leyer of rocks, but is consisted from earth peaces that are called *earth's plates*. These pločе of continets and ocean floor are distancing and pushing each other one against other with velocity od 1-2 inches per year what is called continental drifting.

Excess of heat and magma has to be released somehow and pass through Earth's surface (mentle). Magma (melted rocks) can come close to Earth's surface. When heat of this surface leyer is transferred to water it can be *created useful form of geothermal energy*. Geothermal energy is called renewable source of energy since the water can be renewed with rainfalls, and heat is constantly produced inside Earth. On Figure 1 it is shown how heat from Earth is released on sea or surface via volcanic eruptions.

It is not every source of geothermal energy always visible, and it does not come always in contact with Earth's surface. *How geothermal energy looks like?* Some obvious and characteristical sources of geothermal energy are *volcanos, hot springs, geyzers, and fumaroles.* Sometimes it can not be sensed that inside Earth is present geothermal source. Usually, geothermal energy is deep below the surface.

Geologists use many methodes in order to find geothermal resources. They study air photographes and geological maps. They can analyse chemistry of local sources and concentration of metals on the gound. It can be measured variations in *gravity and magnetic fields*. But, the only way in order to be sure that geothermal source of energy is found, is via drilling well in order to *measure underground temperatures*.

Earth is nest of geothermal energy. The most active geothermal resources are found near the boundaries of Earth plates where volcanos and earthqacues are concentrated. Most of the geothermal activity in world appears in area known as *Ring of Fire*. This ring sourounds Pacific Ocean and is bounded with Japan, Philipines, Aleuts islands, North America, Central America, and South America.

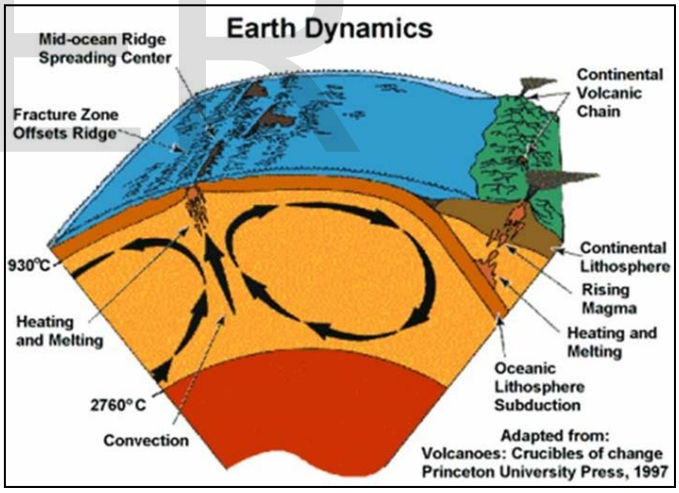

Fig. 1 – Dynamics of Earth

There exist four main kinds of geothermal resources: *hydrothermal, geopressured, hot and dry rocks, and magma.* Todays geothermal sources of energy are the only kind in wide usage. The other three resources are still in phase of development.

Hydrothermal resources are consisted *water* (hydro) and *heat* (thermo). These geothermal resources of steam or hot water appear naturally where magma is susreće with Earth's surface in order to heat the water that is trapped in fractured and porous rocks, or where water circulates in large deep through ground fault. Hydrothermal resources are used gor many different energetic purposes that depends from their *temperature and depth*.

Aside of visible sources, fumaroles, geyzers, and volcanos, the most of geothermal energy can not be seen. On Figure 2 it is shown how magma from Earth's interior, comes to volcanic eruptions and how from rainfalls, or pumping water inside Earth and by heating creates hot waters na dubini which can be extracted with installed pipes and pumps into the surface and serve as heat water or as steam in geothermal stations by using separators and condensators, steam turbines and generators in order to produce electrical energy.

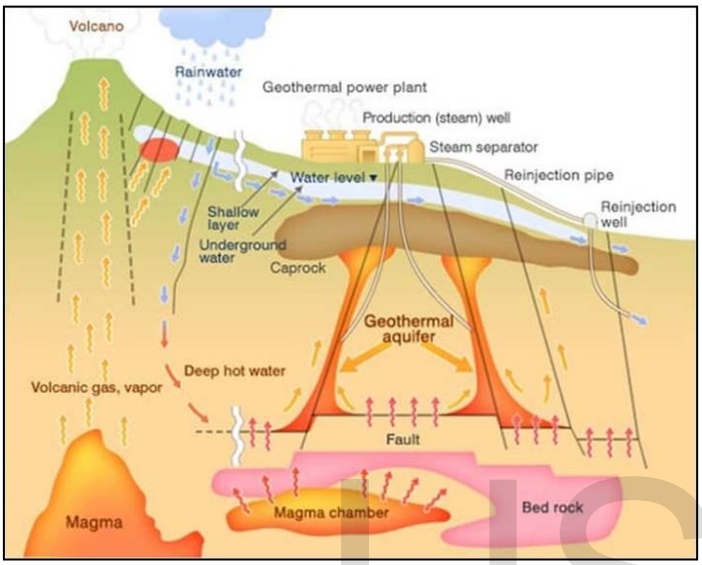

Fig. 2 – How magma and heat from Earths interior can be used for electricity production in geothermal stations

2 History of geothermal energy

According to historical data, first usa of geothermal energy was more than 10,000 years ago in North America from American *paleo Indians*. People used water from hot sources for use in cooking, bathing, and cleaning.

First industrial usage of geothermal energy started near the town of *Pisa, Italy* in late XVIII century. Steam that comes from natural wells and drilled holes is used for extraction or drawing bor acid from hor basins, that is known as *Ladarello fields*. In 1904, Italian scientis *Piero Ginori Conti* invented first geothermal power station where heat is used in order to generate electricity.

With experiment above, first geothermal power station in United States if America started to work in 1922, with capacity of 250 kW. However, in 1946 first geothermal heat pump with source from Earth is installed in *Commonwealth Building in Portland, Oregon.*

In 1960'ies, companies like Pacific gas and Electrical started with work on first large geothermal station in San FRancisko, generating 11 MW of power. Today, there are more then 60 geothermal power stations that works in United States, on 18 locations throughout the country.

In 1973, when oil crisis began many countries started to look renewable sources of energy, and in 1980'ies geothermal heat pump become popular in order to reduce heat and air conditioning costs.

Since the effect of change in climate starts to appear, goverments of different countries are joined in order to fight agains it, and therefore *Kyoto Protocol* is signed in *Japan*, 1997, in order to reduce emission of harmful gases, and from side of wealthy countries is requested to transfer means and technologies to developing countries what 184 countries ratified.

Geothermal power, according to data from 2009 is supllied less then 1% of world energy, where 2050 expect snabdevanje 10-20% of world energetic requests. Geothermal power stations work today in 20 countries, and some have active volcanos and earthqacues.

3 Geothermal energy: Heating and electricity production

Heating, low temperature of geothermal sources – When temperature of hydrothermal resources is around 10 degrees of Celisu or more, it can be directly used in baths or for building warming, growth of crops, the heating of the pond, or for other purposes.

Hydrothermal resources are suitable for heating and are used in United States of America and in almost every country in the world. Most people on Island and more then 500,000 people in France use geothermal energy for heatic public buildings, schools, and homes. In United States of America pumps for geothermal energy are used in 45 states for heating and cooling houses and buildings. Idaho, Oregon, Nevada and some other states use geothermal energy for heating districts.

Electrical energy, high temperatures of geothermal sources – When temperature of hydrothermal resources is more then 100 degrees of Celsius or more, they can be used for *electricity production*. The most of geothermal resources that produce electrical energy have temperatures 150-370 degrees of Celsius, but geothermal sources of energy can achieve temperatures of 540 degrees of Celsius.

Geothermal energy is produced when Earth's core heat water on surface. Under geothermal energy is considered electrical energy produces in geothermal power stations by hot water exploatations or steam and transforming heat by using separators, condensators, heat releasers, turbines and generators into electrical current.

Traditional power stations use steam for turbine rotation, that is further used for activation of generators to produce electricity. However, most of power stations use fosil fuels in order to transform water into steam, by using process of heating. In case of geothermal sources, steam is directly used from Earth, which pipes it to power station, and is therefore needed to drill path for pipes and which hot steam brings to surface.

4 TYPES OF GEOTHERMAL POWER STATIONS

Today, there exists three types of geothermal power stations:

Geothermal power stations on binary cycle. These power stations work when temperatures of water are lower, in range 100-180 degrees of Celsius. Heat is used from hot water in order to warm working fluid that has lower point of boiling in order to produce steam in heat exchanger that is used for turbines start. At the end of cycle, water is returned into Earth by injecting where is heated again from Earth. Since working fluid and water are placed separately in poer stations on binary cycle, there is no gas emissions. Example of geothermal system on binary cycle, is given in Figure 3.

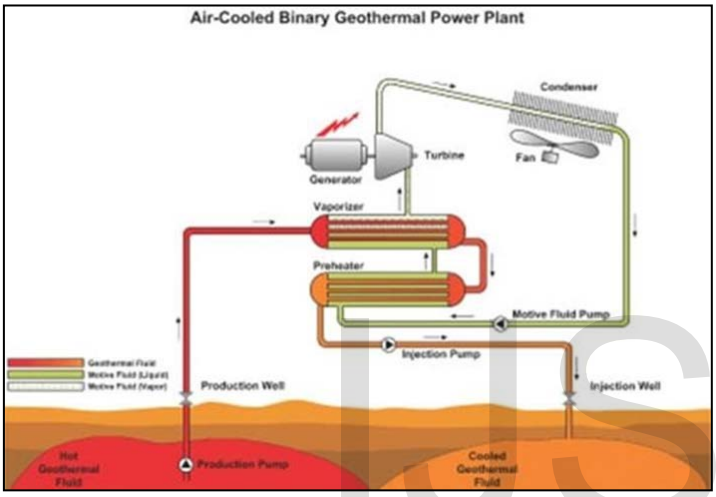

Fig. 3 – Geothermal power station on binary cycle

Geothermal power stations on fast steam. These are the most common types of geothermal power stations that use extremely hot water on about 180 degrees of Celsius. Water pass through Earths wells and is extracted to surface by pipes under the pressure. During the process of transferring above water starts losing its pressure and is transformed into steam that starts rotating turbine, and further generator that produces electrical energy. Once when the process is complete, condensated steam and rest of water is returned into reservoir. One example of geothermal system on fas steam is given in Figure 4.

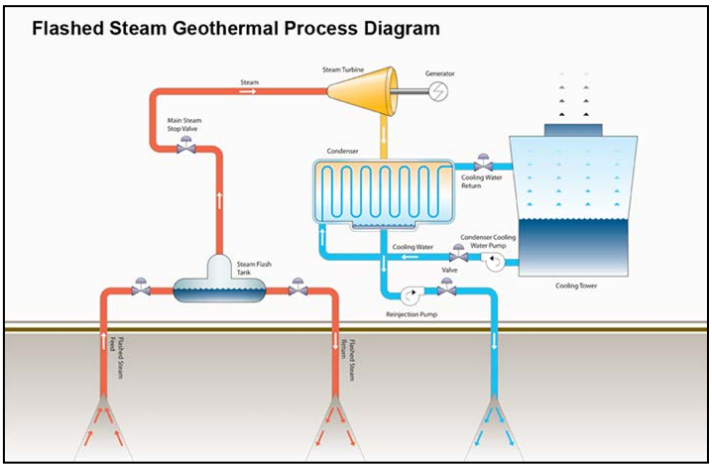

Fig. 4 – Geothermal power station on fast steam

Geothermal power station on dry steam. Dry steam is extracted directly from Earth. Steam goes above through pipes and starts turbines, which further starts generator in order to produce electrical energy. Today there are two the most common sources of dry steam in USA, that are directly used as geothermal sources of energy in Yellowstone National Park – *Old Faithful Geyser*, and in North California – *The Geysers*. One example of geothermal system om dry air is given in Figure 5.

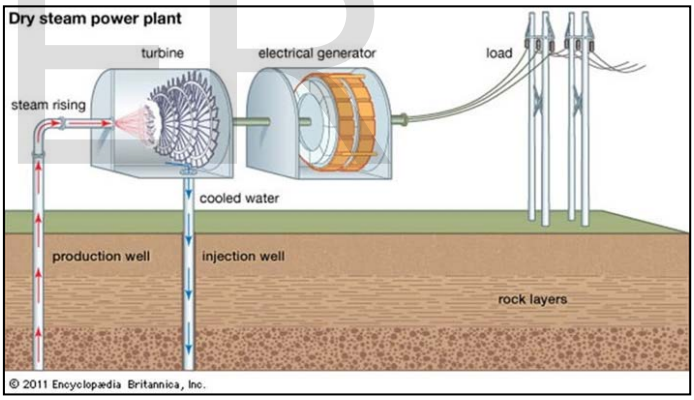

Fig. 5 – Geothermal power station on dry steam

5 THE BASIC ELEMENTS OF GEOTHERMAL POWER STATION

Let us note in all three types of these geothermal power stations **the basic elements:** paths and pipes for cold water injection, which has to be drilled in interior Earth; Paths and pipes for extracting the hot water or dry steam on Earth surface; Pumps; Heat Exchangers; Separators; Condensators; Evaporators; Turbines; electro generators; and other elements, according to need.

From technical devices the main elements are geothermal pumps, turbines and electrogenerators, and from the fluid used and its aggregate state depends whether evaporators, condensators, or separators will be used in order to lower

working pressure, and heat exchangers (some of these elements: compressors, evaporators, condensators – are compound parts of todays geothermal heat pumps.

6 Geothermal solution of home heating

Simple solution of home heating can be constructed by using geothermal energy, with system of pipes installed horizontally (on deep of 1-2 meters) or vertically (on deep of 23-150 meters) in the ground, behind or below house. Under the ground is constant temperature and by using thermodynamical elements for working fluid like refrigerant that pass-through system of pipes it can be extracted heat from ground from temperature 10-15 degrees of Celsius that is by using compressors, heat releasers, and heat pumps can be implemented in house fore further energy distribution.

Fig. 6 – Geothermal system installed under the ground. A) *horizontall*, and B) *vertical construction*

7 World production of geothermal energy

The International Geothermal Association, IGA released data that in every moment online is available 10,715 MW of geothermal power I 24 countries of the world. Comparing increase in 2005 in online capacirties of geothermal energy is 20%. Due to large number of projects lastly, and in countries where exploitation was small – it is increased today usage of geothermal power. It is estimated data for large number of projects lately and in countries where exploitation is small – to be 18,500 MW.

In 2010, United States of America was leading country in geothermal electricity production with 3,086 MW of installed capacity in 77 power stations. The largest group of geothermal fields is in Geyzers, in North California. United States of America today produce 17,415 MW energy from geothermal sources, and China in the biggest producer of geothermal energy with 17,870 MW. Indonesia will possibly become leading country in electricity production from geothermal sources of energy. India announced plan for developing first generation of geothermal stations in *Chhattisgarh*. Canada is the only big country in Pacific Ring of Fire that is not developed yet geothermal power. Region of high potential are Canadian *Cordillera*, where it is estimated that possible geothermal power is 1,550 MW to 5,000 MW. From 2004, five countries Salvadore, Kenia, Philipines, Island, and Costa Rica are generating more then 15% of elecgtrical power in their countries from geothermal sources. In Philipines in 2010, as second the largest producer of geothermal power with 1,904 MW of installed capacity, was 27% of total electricity production in this country. Usage of geothermal energy today is even larger in different countries of the world, and these data are changing every year.

Fig. 7 – Geothermal power stations: a) *Larderello*, *Italy*, b) *Negros*, *Philipines*

Geothermal electrical energy is produced in 24 countries:

TABLE 1
Countries with Installed Geothermal Power

No.	Country	Installed geothermal power (data from 2015)
1	China	17,870
2	United States of America	17,415
3	Turkey	2,886
4	Germany	2,848
5	France	2,347
6	Japan	2,186
7	Island	2,040
8	Italy	1,014
9	Austria	903.4
10	New Zeland	487
11	Russia	308
12	Mexico	155
13	Thailand	128
14	Iran	81.5
15	Portugal	35.2
16	Kenia	22.4
17	Australa	16
18	Philipines	3.3
19	El Salvador	3.3
20	Indonesia	2.3
21	Guatemala	2.3
22	Etiopia	2.2
23	Costa Rica	1
24	New Guinea	0.1

Advanced geothermal systems that are invented in 2012, and that are installed several kilometers deep, work in France or Germany and are developed and tested in at least four other countries.

6 Installation of Geothermal Power Stations

Identification/Characterizing location

1. Developing geological model of potential location via geological, surface, and sensors research.
2. Come to data about temperature gradient, permeability, directions of voltage, resources on location, mechanical properties of rocks, and presents of fluids.
3. Determine wheather necessary characteristics for creating geothermal system in reservoir are satisfied.

Reservoir creation

1. Drill injection earth well in hot rocks with limited amount of fluids and/or permeable.
2. Onjecting the water under enough pressure (or temperature difference) in order to create network of fractures.
3. Continue operation if there exists enough fracturated volume for reservoir creating (velocity of flow, temperature, volume, and sustainability)
4. Drilling production earth well in fracturated network, by injecting created paths of flow.
5. Resulting loop of circulation enables water to flow through reservoir obtaining heat. Hot water is further pumped toward surface through production earth well.

Starting the work of geothermal power station and maintaining the reservoir

1. On surface, water is fastly transformed into steam, or warms working fluid that produce steam.
2. Steam rotates turbine and creates electrical power.
3. Install elements of geothermal system of power station on Earth surface.
4. Original geothermal water is recycled back into reservoir.

7 Economy of Geothermal Power Energy

Geothermal energy is used in many countries worldwide. Geothermal power station can *produce electrical power cheaply* like some conventional power stations. Price is 4,5 to 7 cents per kWh. In order to compare it, for new thermoelectrical power stations costs of producing kWh are 4 cents. Starting construction of costs is high since starting costs include construction of geothermal wells and power stations. However, costs of production of electrical energy due time is lower since price and availability of fuel is stable and predictable. Geothermal poer stations literally are placed on top of list of fuels from which electricity is produced.

State agencies today gives certain exemptions in case of introducing renewable sources of energy which do not pollute environment as *geothermal energy* is.

8 Influence of Geothermal Energy on Environment

Geothermal energy is source of renewable energy that have little little harm the environment. Geothermal steam and hot water contain natural traces of hydrogen sulfide (gas that smell as rotten egg) and other gases and chemicalies that can be štetne in large concentrations. Geothermal power stations use so called *scrubber systems* (devices for cleaning) in order to cleanse air from hydrogen sulfide and other gases. Sometimes fases are converted into market products, as *liquified fertlizers.* New geothermal power stations can return gases back into geothermal wells.

Geothermal power stations do not burn fuel in order to generate electrical power as in case of electrical power stations on fossil fuels. Geothermal power stations release 1-4 % of carbon dioxide comparing to amount that is emitted from power stations on coil (or solid fuel). Emission of compounds that contain sulfurus from motor vehicles and power stations on fossil fuels are also main cause of *acid rains*. Geothermal power stations, from other side, emits only 13 % compounds that contain sulfurus comparing to power stations on fossil fuels or oil. Well designed binary cycle for power stations - have not emission at all.

9 Conclusions

In this paper are reviewd basic information about geothermal sources of energy, as one of five kinds of *renewable sources of energy* (solar energy, wind energy, energy of biomass, energy of water, geotrhermal energy) that are today even more used and exchanged for emission of štetnih gases and their negative influence on environment. Geothermal energy can be used for heating and production of electrical energy. In this paper are reviewd three basic systems where geothermal energy is transformed into electrical energy – power stations on fast steam, power stations on dry steam, and power stations with binary cycle. Basic elements of geothermal system, where main element represents geothermal pump, turbines, and generators, and other devices like compressors, condensators, and other. Here is reviewed usage of geothermal energy in worls, and its influence on economy and environment. Steps for geothermal sources location are given, and steps for geothermal power station installation. Further work will be focused on analyse and design, and innovation of concrete geothermal systems, and their basic elements like geothermal pumps, turbines, nd generators; compressors, evaporators, and condensators, with final aim of concrete implementation of geothermal power stations.

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