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Study of Geothermal Energy Usage in Electrical Power Generation

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ABSTRACT

Currently 86% of the world energy is being supplied by limited energy resources (e.g. petroleum, coal and uranium) which are considered the available resources of the earth's crust. The only renewable energy resource existing in earth's crust is geothermal energy. World's increasing need to energy on one hand and the increase in pollution on the other hand caused every country to try to replace limited resources with a proper energy resource. In this paper, electrical power production is being studied with using geothermal. Investigations show that this energy in medium term and long term, taking into account its total advantages, can improve and develop a lot and is really desirable in order to get to the unfailing development.

KEY WORDS: geothermal energy, geothermic energy, renewable energy, electrical power.

1. INTRODUCTION

Geothermal energy is the thermal energy existing in earth's crust. In some parts of the earth's crust that the gradient of temperature is high, there are deep underground fractures which allow the earth surface waters such as rain water or waters coming from melting of snows to penetrate kilometers into underground. In there, this water is heated with hot stones and after being heated returns to earth surface and makes Laguna or fractures with steams coming out of them. If this water while coming back to earth's surface reaches to impenetrable stones, it will gather there and make geothermal reservoir. Thermal energy existing in earth's crust is estimated to be 1031 joules which annually its 1021 joules is being wasted (70% of these casualties happen in oceans and 30% of them in continents). Temperature gradient range on the earth's surface is vertically from 10◦c/km to 90◦c/km. For example, if we assume average heat of the earth's surface to be 20◦c/km, considering the temperature gradient 50◦c/km, we will have a temperature of about 220◦c at the depth of 4 km from earth's surface.

Geothermal energy comparing with other renewable energies such as solar energy, wind and tide is an explicitly more advanced energy. In recent years, geothermal energy has assigned to itself 86% of electricity production from renewable energies and this very share in electricity production is due to the high reliability of geothermal plants, because despite the solar energy, the geothermal energy is usable during day and night and unlike the wind energy doesn't depend on weather conditions. Using geothermal energy has two forms: 1) direct-use: in direct applications (in order to use heat and warmth), geothermal energy is used in temperature range of 20◦c to 150◦c. Of this kind of applications, one can name using for annealing houses and dorms, heating greenhouses, fish culturing, food industry and its usage in different parts of agriculture and industry. For instance, in Hungary, 80% of thermal energy needs for planting different agricultural products is supplied this way. 2) Producing electrical energy: there are 21 countries around the world that use geothermal energy to produce electricity. Figure 1 shows a schematic picture of a geothermal resource.

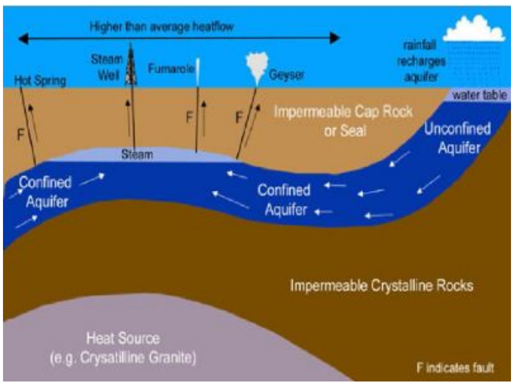

Figure 1: schematic picture of a geothermal resource

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2. LEADING COUNTRIES IN ELECTRICAL ENERGY PRODUCTION USING GEOTHERMAL ENERGY

Electricity production capacity using geothermal energy is 7974 MW around the world. Maximum capacity installed in the U.S is about 2228 MW and among other countries, Philippine has the first rank with 1909 MW. Of course the importance of this type of electricity production for these 2 countries is different; as in Philippine, the electricity production energy from the geothermal is 22% of the total electricity produced in this country; while in America, this proportion is 0.4%. Figure 2 shows the location of 20 sites that supply 75% of the world's produced electricity. Among 21 countries and 85 sites for producing electrical energy using geothermal, there are 8 countries which have 94% of this production in the world: United States (31%), Philippine (19%), Mexico (12%), Indonesia (9%), Italy (9%), Japan (7%), New Zealand (5%), & Island (2%).

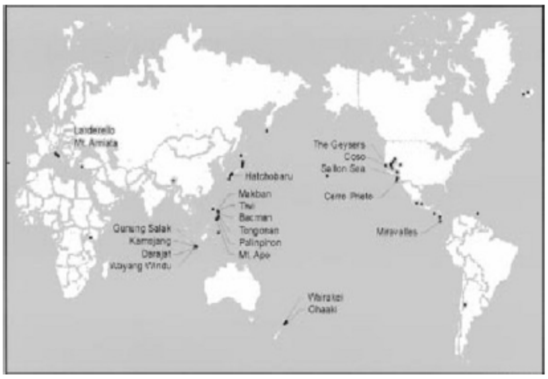

Figure 2: location of 20 sites that supply 75% of the world's produced electricity via geothermal.

Electricity production capacity using geothermal energy in last 20 years has been doubled and in recent 5 years has increased 17%. Capacity of geothermal plants reached from 386 MW in the year 1960 to 7974 MW in 1999.Table 1 shows countries with the most contribution in electrical power production using geothermal energy.

Table 1: Countries with the most Contribution in electrical power production using geothermal energy

country	ratio of electricity power production using geothermal energy (in percents)
Philippine	22
El Salvador	20
Nicaragua	17
Island	15
Costa Rica	10
Kenya	8
New Zealand	6
Indonesia	5

According to the studies and researches conducted in the year 1999 in countries owning known geothermal resources, by means of today's technology, electricity production capacity using geothermal energy is about 70 GW (i.e. about 9 times the current capacity). Of course this amount can reach to around 140 GW due to the advancement of technology which means that 1000 Twh electricity can be produced annually using geothermal. But the thing which led to lack of development in this field is economical issues and its related costs. For example in Indonesia, considering the abundance of geothermal resources, after numerous explorations of geothermal resources, all of the investments in this field in the year 1998 ceased due to the economical issues and political insecurities.

Study of America's experience as one of the leading countries in electrical power production using geothermal energy can be useful.

Thermal energy which exists in the depth of 10 kilometers from earth's crust in the U.S. is about 3×1025 and through this, 105 times the annual required energy of this country has been supplied. Right now, only 6×1016 joule of this energy size in the U.S.A has been used. Of course making use of all of this energy considering economical and technical aspects is not possible; yet using a small percentage of it can be considered as one of the significant resources of renewable energies.

United States has the biggest geothermal capacities made around the world. In the year 2000, the installed capacity of electricity production in America was 2228 Mw. This production capacity in America is replaced with the 30 million barrels of importing petroleum.

According to the USGS report (U.S Geothermal Survey), with the present technology of America, there is a potential of increasing the electrical energy capacity using geothermal to 23400 MW. Figure 3 illustrates the electrical energy growth via geothermal in America since 1960.

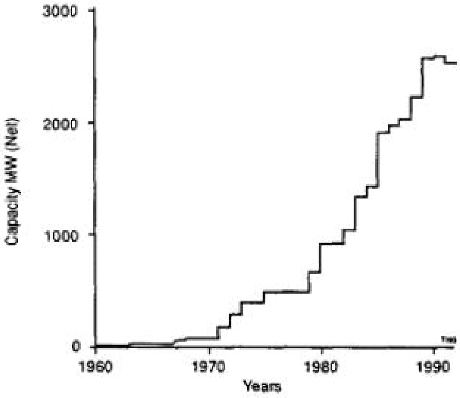

Figure 3: growth of electrical energy production using geothermal in America

3. Geothermal Resources

Geothermal resources can be found in the locales with high temperature gradients; especially these reservoirs are located near the chasms and geysers or fractures with ascending steam. Figure 4 shows geothermal zones in the world.

If a geothermal resource becomes big enough and has high penetrability rate in the temperature range of 240◦c to -320◦c, it's considered as a proper economic geothermal resource. Geology techniques, hydrology, geothermic and geochemistry are being used for identifying geothermal resources. After specifying the location of a geothermal resource, one can say that the definite and proper method for determining the specifications of a geothermal resource is to dig shallow wells in order to specify the temperature gradient and digging many wells to make sure the extracting procedure and other resources are all optimum. Chemical analyses and experiments on the geysers and gases exiting from the volcano skirts fractures can reveal significant information about the temperature and other characteristics of a geothermal resource.

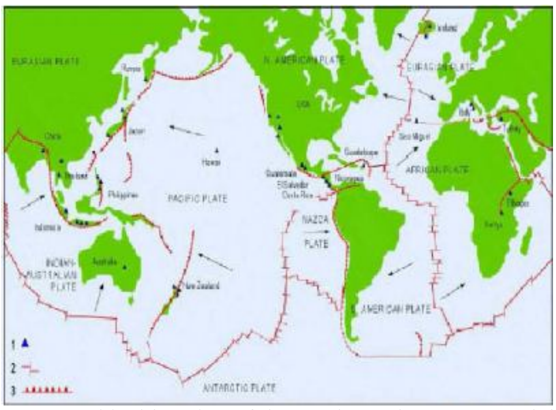

Figure 4: Geographical location of the geothermal zones around the world

4. Types of geothermal resources

4.1. Dry-steam Hydrothermal

These resources have very high temperatures and produce dry-steam. These resources are rare in the world. Biggest resources of dry-steam are located in America and Italy and also in Indonesia, Japan and Mexico. According to the USGS study of "Gersere" Resources, "yellow stone Lassen" in America are of this kind.

4.2. Hot-Water Hydrothermal

These resources produce hot water or a mixture of water and steam. These resources are being used in a large scale in the world in order to produce electricity.

4.3. HDR (Hot-Dry Rock)

In order to make an HDR resource, several wells are dug out in hot dry rock zones. Water is pumped into these wells and then is returned to the earth's surface and in the meantime transfers the heat of hot rocks. Temperature of these resources is about 200◦c to -350◦c.

4.4. GPGT (Geopressured Geothermal)

There are resources with high pressures and high temperatures located in high depths from the earth's surface. An example of these kinds of resources is located in Texas, America in a depth more than 4600 meters and with a pressure more than 70 Mpa and temperature of about 150-180◦c.

4.5. Magma

This includes molten materials and lava near the places with new eruptions of volcanoes which is located at a depth less than 10 kilometers from the earth's surface. After digging numerous wells, in order to create these resources, water will flow within the hardened magma and transfers the heat of magma materials to the earth's surface. Temperature of these resources is from 600◦c to 1400◦c.

5. EXCAVATING OPERATIONS

Excavating the first geothermal well dates back to the early twentieth century. Geothermal excavation operation is a very complicated process and most of the technology in this part is captured directly from the oil and gas excavation industry. But the special conditions of geothermal excavation specify our need to an advanced technology.

Right now, most of the geothermal wells are excavated with the rotary technique which is broadly used in well excavation industry for oil and gas resources. Certainly due to the high temperature and the hard nature of the protective rocks in geothermal environments, geothermal excavation is more difficult and expensive than the excavation for reaching to the oil and gas.

Figures 5 and 6 illustrate how geothermal wells are being excavated. These wells can be dug vertically (figure 5) or with an angle (figure 6). Wells are excavated multi-storied. Diameter of the initial aperture equals 305 mm and after that every storey toward its previous storey has smaller diameter and every built storey is protected by a metal shield. The amount of fluid extraction from the production wells equals the irrigation rate of 150000 to 350000 kg/h.

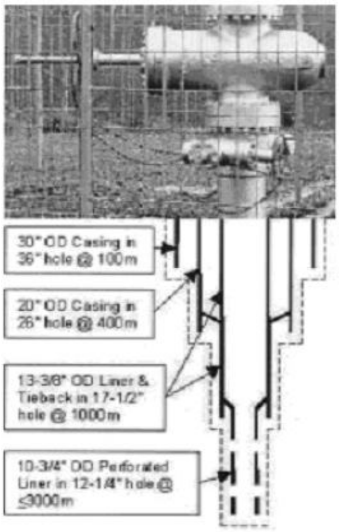

Figure 5: vertically excavation of geothermal wells

Field of geothermal excavation requires an extensive development in the related technologies to increase the amount of permeability and controlling hard rocks and cost reduction. Excavation is the most expensive part in accessing the geothermal energy and bears well exploration, injection and maintenance costs. Often these costs assign more than 50% of the total expense to itself. Ergo, cost reduction in this part has a principal effect on the economical condition of the whole project. With advancing technology of deep excavation and economizing the excavation techniques, one can dig out wells to the depths of 6 to 10 kilometers and reach to a temperature of 500◦c. Accordingly the advancement of this technique can lead to an evolution in the future of energy resources.

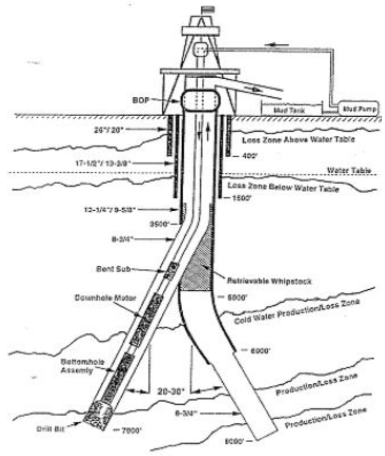

Figure 6: Angled excavation of geothermal well

6. GEOTHERMAL PLANTS

Producing the geothermal power has 3 main technologies: dry-steam, flash-steam and binary cycle systems. Technology being used here depends on the temperature and geothermal resource pressure.

6.1. Dry-steam plant

These plants have the simplest and the most economical technology. They are useful when the exiting steam from the geothermal resources is not mixed with water. In this system the very hot steam of 180◦c to -350◦c is transferred from the production wells to earth's surface. After segregating tiny particles and materials, it goes directly to the turbine in order to spin the generator. The major costs for this plant is about 2200 $/kw.

6.2. Flash-steam plant

Flash-steam systems for hot water geothermal resources are used at temperatures above 175◦c. It has two types: Single-flash and Double-flash.

a) Single-flash plant: in this system, produced hot water from the geothermal resource is transferred to the earth's surface and exits due to the high pressure of deep resource. Sudden drop in pressure causes some water to vaporize. This mixture in separator unit, is used for segregating water and steam and then the steam goes to the turbine in order to spin the generator and next the water returns back to the geothermal resource.

b) Double-flash plant: In double-flash systems, two high pressure (Hp Separator) and low pressure (Lp flasher) separators are used for segregating water and steam. This system has a higher output, yet its costs are more than that of the Single-flash. The major costs of this plants are placed in a range from 1700 $/kw to 2100 $/kw.

According to the USGS survey, resources with a temperature higher than 260◦c are being used in Single-flash system and with temperature between 175◦c and 260◦c in Double-flash system.

Water separated from the water-steam mixture (brine) is either returned directly back to the geothermal resource or being freed in some sites on the earth's surface (Kawerau in New Zealand and Mak-Ban in Philippine) or before going back to geothermal resource, minerals are separated from it during a process. For instance, in 'Salton Sea' site located in California, America, annually 30000 tons of zinc is recovered.

6.3. Binary plant

Since a secondary fluid is being used in this system, it is called Binary. In this system, the hot geothermal fluid passes a heat exchanger in order to anneal the secondary fluid in a separate pipe. Secondary fluid is an organic fluid with a low boiling point like isobutene or isopantene which vaporizes and passes the turbine in order to spin it and make electricity.

Binary plants use geothermal fluid in a temperature range near 105◦c to 180◦c. in low temperatures, CFC (Chlorofluorocarbon) is being used as a secondary fluid.

These plants have more output than that of the Flash-steam plants. Their advantage is that they don't have any pollution and also they allow using geothermal resources in lower temperatures, but still they have more costs (2400 $/kw).

In these plants, the 'Kalina' cycle is also used to increase the output. In Kalina cycle like the Binary cycle, a secondary fluid (mixture of water and ammoniac) is used. Different boiling point of this fluid causes more heat transferring from geothermal fluid and leads to a reduction in heat loss.

Right now, about 700 MW of the world's produced electricity is supplied from the Binary-cycle plants. Since the amount of known geothermal resources in lower temperatures is much more than high temperature resources, this system has a major role in development of the future's geothermal energy.

7. ECONOMICAL ISSUES

Table 2 depicts the construction cost of a plant and geothermal electricity production comparing with other renewable resources. Investment costs for geothermal plants range between 800$ to 3000$ in every kWh and varies depending on a resource temperature, its chemical attributes and the applied technology.

Table 2: Plant construction costs and geothermal electricity production comparing with other renewable energy resources (resource: WEA)

electricity production US cent/kwh	plant construction USD/kw	
5-15	900-3000	Biomass
25-125	5000-10000	Solar
2-10	1000-3500	Hydrothermal
2-10	800-3000	Geothermal
5-13	1100-1700	Wind
8-15	1700-2500	Tide

Figure 7 shows fuel costs in 30 years lifetime of a plant with inflation rate of 4% and also geothermal energy costs with gradient 40◦c/km - 90◦c/km. According to the chart, fossil fuel at the first place has low prices, but eventually in 30 years, it increases threefold, while geothermal energy costs after 10 years reduces to half of the primary amount. Therefore, by reducing primary costs related to excavation and developments in excavation technology and geothermal plant excavation techniques becoming economical, it would be an appropriate alternative for fossil fuel plants.

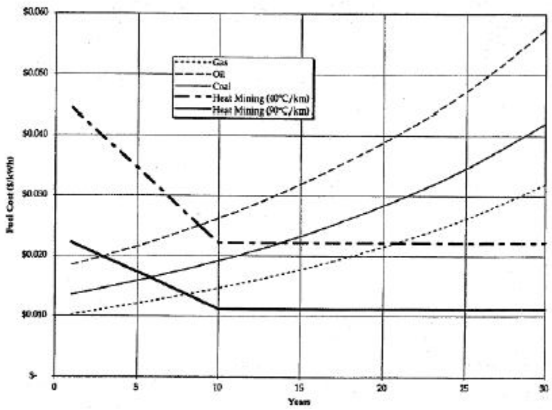

Figure 7: Fuel price in 30 years lifetime of a plant with an inflation rate of 4%.

8. ENVIRONMENTAL EFFECTS

Fossil fuel plants are dispatching 40 million tons of Co2 annually to the atmosphere, while geothermal energy has environmental privileges toward the fossil fuels.

Most of geothermal resources release little amounts of gases like hydrogen sulphide, ammoniac, hydrogen, nitrogen and greenhouse gases like carbon dioxide and methane. In packet-hoop conversion systems like Binary-cycle, these gases are returned wholly to the geothermal resource and don't have any environmental pollutions, but in Dry-steam or Flash-steam systems, these gases are sent into the atmosphere.

If nitrogen oxides and sulphur dioxide do not propagate, acid rain of the locale will be reduced. Sulphur and carbon dioxide dissemination in geothermal plants comparing with that of the fossil fuel plants is too very low. Geothermal facilities need a little piece of land. Table 3 shows the amount of land needed for geothermal plants comparing with that of other plants.

Table 3: The amount of land usage in plants

M2/MW/30years	
0.4	Geothermal
3.64	Coal
3.24	Solar
1.34	Wind

9. CONCLUSION

Reasons that can be recounted for the lack of development in geothermal energy in recent years are:

- Most of the sites identified and explored in developed countries are located in scenic jungle locales and national parks and are undeveloped.
- Economical issues in the past decade in Asia caused other private parts not to invest in this field (especially in Indonesia considering the abundant geothermal resources in this country).
- In recent years, supports and facilities provided by the government for geothermal energy development has been reduced.
- Natural gas low price in the past decade and cost reduction in fossil fuel plants, made it difficult to challenge for geothermal energy in this market.

Obtained results can be depicted as follows:

● replacing renewable energy resources with limited energy resources to get to the permanent development is very desirable.

● geothermal energy has a fundamental and significant role in some countries electricity production.

● the amount of geothermal energy is much more than renewable energy resources.

● existing challenge for geothermal energy development in short-term has its related costs comparing with other energy resources, yet this energy in medium-term and long-term considering its very advantages can lead to much growth and development.

REFERENCES

[1] Kenneth Williamson Richard Gunderon, Gerald M.Hamblin, Darrel.Gallup and Kevin Kitz;"Geothermal Power Technology" PROCEEDINGS OF THE IEEE VOL.89, NO.12, 2001.

[2] ShabanaSheth, Member, IEEE and Mohammad Shahidehpour, Fellow, IEEE; "Geothermal Energy in Power Systems"; Electric Power and Power Electronics Center;Illinois Institute of Technology.

[3] T J. Hammons "GEOTHERMAL POWER GENERATION WORLD WIDE"; Paper accepted for presentation at 2003 IEEE Bologna PowerTech Conference; University of Glasgow; 2003.

[4] GERALD W. BRAUN and H. K. PETE MCCLUER; "Geothermal Power Generation in United States"; PROCEEDINGS OF THE IEEE, VOL. 81, NO. 3, 1993.

[5] Lawrence H. Green and Gary Shulman ; "THE ECONOMIC IMPACT OF REDUCING DEEP DRILLING COSTS FOR HEAT MINING POWER PLANTS" ; IEEE

[6] David A. Glowka; "NEW TECHNOLOGY FOR GEOTHERMAL DRILLING"; Geothermal Research Department

[7] Joel L. Renne; "GEOTHERMAL ENERGY IN THE UNITED STATES"; Idaho National Engineering and Environmental Laboratory, 2002.

[8] Valgardur Stefansson and Reykjavik; "GLOBAL PERSPECTIVE ON GEOTHERMAL ENERGY"; IEEE, 2002.