Geothermal Energy in Power Systems

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***Abstract*--This paper discusses the use of geothermal energy in restructured power systems. The paper defines the resources as well as the ways in which geothermal energy is converted into electricity. The paper also reviews a few geothermal projects in the United States and some other parts of world. Finally a comparative review of renewable energy sources is presented and conclusions are outlined.**

1. INTRODUCTION

Geothermal comes from the Greek words *thermal* which means *heat* and *geo* which means *earth*. Georthemal is the thermal energy contained in the rock and fluid in the earth's crust. It is almost 4,000 miles from the surface of the earth to its center; the deeper it is the hotter it gets. The outer layer of the earth, the crust, is 35 miles thick and insulates the surface from the hot interior [1,2].

After the Second World War many countries started using geothermal energy, considering it to be economically competitive with other forms of energy [4]. Geothermal energy did not have to be imported and, in some cases, it was the only energy source available locally.

As of 1999, 8,217 MW of electricity were being produced from some 250 geothermal power plants running day and night in 22 countries around the world. These plants provide reliable base-load power for well over 60 million people, mostly in developing countries. About 2,850 MW of geothermal generation capacity is available from power plants in the western United States. Geothermal energy generates about 2% of the electricity in Utah, 6% of the electricity in California and almost 10% of the electricity in northern Nevada.

As of the year 2000, the electrical energy generated in the US from geothermal resources was more than twice that from solar and wind combined. However, theses figures may change as more states resort to various forms of distributed and renewable generation for supplying their customer loads.

Geothermal power can play a fairly significant role in the energy balance of some areas of the world [9]. For non-electric applications of geothermal energy, the year 2000 worldwide figures show an installed capacity (15,145 MWt) and energy use (190,699 TJ/yr) for this renewable source [4]. The most common non-electric use worldwide (in terms of installed capacity) is for heat pumps (34.80%) followed by bathing (26.20%), space heating (21.62%), greenhouses (8.22%), aquaculture (3.93%), and industrial processes (3.13%).

Geothermal systems can be found in regions with high geothermal gradient, and especially in regions around plate margins. Fig. 1 shows that the most important geothermal areas of the world are located around plate margins. Arrows show the direction of movement of the plates towards the subduction zones. (1) Geothermal fields producing electricity; (2) mid-oceanic ridges crossed by transform faults (long transversal fractures); (3) subduction zones, where the subducting plate bends downwards and melts in the asthenosphere [3].

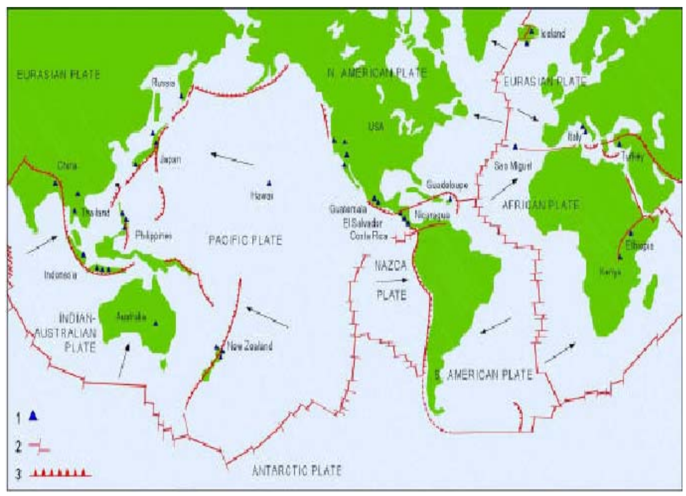

Figure 1: Geothermal areas worldwide

2. FORMATION OF GEOTHERMAL RESERVOIRS

The earth's heat flows form its interior to the outer crust. This outward flow of heat from the earth's interior drives a drift of earth's crustal plates [2]. As plates move apart, magma rises up into the rift and forms a new crust. As plates collide, one plate is forced (sub ducted) beneath the other. As a sub ducted plate slides slowly downward into regions with ever-increasing heat, it can reach certain conditions with pressure, temperature and water contents that cause a melt down to form magma. This molten magma rises with force to the surface of earth with a vast quantity of heat [5].

As magma reaches the surface it can build volcanoes. But most magma stays well below the ground and creates huge subterranean regions of hot rock with underlying areas as large as a mountain range. Cooling can take from 5,000 to more than 1 million years. These shallow regions of relatively elevated crustal heat have high temperature gradients. The first measurements by thermometer were probably performed in 1740 in a mine near Belfort, France (Bullard, 1965). By 1870 modern scientific methods were used to study the thermal regime of the earth, but it was in the twentieth century when the study was done with the discovery of radiogenic heat.

The high temperature gradients cause deep subterranean faults and cracks in some regions which allow rainwater and snowmelt to seep underground, sometimes for miles. This water is heated by the hot rock and circulates back up to the surface, as hot springs, mud pots, geysers, and fumaroles. If this hot water meets an impermeable rock layer, the water will be trapped underground where it fills the pores and cracks and comprises 2% - 5% of the volume of the surrounding rock by forming a geothermal reservoir. This reservoir is hotter than surface hot springs by 350°C (700°F), which renders them powerful sources of energy.

Geothermal resources can be classified based on the enthalpy of geothermal fluids that act as a carrier for transporting the heat from deep hot rocks to the surface. Enthalpy is used to express the heat (thermal energy) content of fluids. Geothermal resources are divided into low, medium, and high enthalpy. Depending on temperature and pressure conditions, these resources can produce hot water and steam mixtures [5].

Another distinction among geothermal resources comes from the reservoir equilibrium state, which is based on the circulation of the reservoir fluid and the mechanism of heat transfer. The geopressured reservoirs consist of permeable sedimentary rocks, containing pressurized hot water that remained trapped at the moment of deposition of the sediments.

A geothermal system is made up of three main elements: a heat source, a reservoir, and a fluid. The heat source can be either a very high temperature (> 600 °C) magmatic intrusion that has reached relatively shallow depths (5-10 km) or the earth's normal temperature. Fig. 2 depicts the cross section of a geothermal site [1].

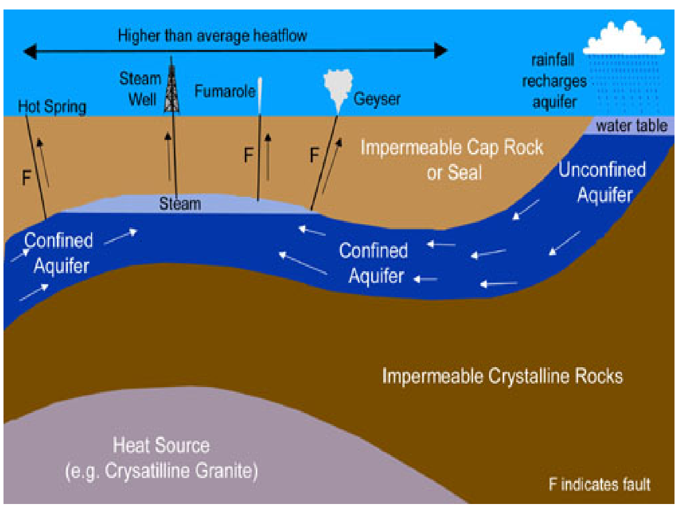

Fig.2. Simplified cross section of a geothermal site

3. UTILIZATION OF GEOTHERMAL ENERGY

Geothermal energy can be utilized as either direct heat or electricity generation, as discussed below:

3.1 Direct Use. It includes the following applications.

Hydrothermal: Hydrothermal resources of low to moderate temperature (20° -150°C) are utilized to provide direct heating in residential, commercial, and industrial sectors[1][3]. These resources include space heating, water heating, greenhouse heating, heating for aquaculture, food dehydration, laundries, and textile processes. These applications are commonly used in Iceland, the United States, Japan, and France.

Agriculture: Geothermal resources are used worldwide for agricultural production. Water from geothermal reservoirs is used to warm greenhouses to help in cultivation. In Hungary, thermal waters provide 80% of the energy demand of vegetable farmers, making Hungary the world's geothermal greenhouse leader. There are dozens of geothermal greenhouses in Iceland and in the western United States.

Industry: The heat from geothermal water is used worldwide for industrial purposes. Some of these uses include drying fish, fruits, vegetables and timber products, washing wool, dying cloth, manufacturing paper, and pasteurizing milk. Geothermally heated water can be piped under sidewalks and roads to keep them from icing over in a freezing weather. Thermal waters are also used to help extract gold and silver from ore and even for refrigeration and ice-making.

3.2 Geothermal Power Plants

Geothermal power plants use the natural hot water and steam from the earth to turn turbine generators for producing electricity. Unlike fossil fuel power plants, no fuel is burned in these plants. Geothermal power plants give off water vapors but have no smoky emissions. Geothermal electricity is for the base load power as well as the peak load demand. Geothermal electricity has become competitive with conventional energy sources in many parts of the world. The geothermal power plants are listed as follows.

Dry Steam Power Plant: Dry steam power plants are the simplest and most economical technology, and therefore are widespread. The dry steam power plant is suitable where the geothermal steam is not mixed with water. Production wells are drilled down to the aquifer and the superheated, pressurized steam (180 - 350°C) is brought to the surface at high speeds, and passed through a steam turbine to generate electricity [2,7]. In simple power plants, the low pressure steam output from the turbine is vented to the atmosphere. This improves the efficiency of the turbine and avoids the environmental problems associated with the direct release of steam into the atmosphere. The United States and Italy have the largest dry steam geothermal resources; these resources are also found in Indonesia, Japan and Mexico.

Flash Steam Power Plant: In a single flash steam technology, hydrothermal resource is in a liquid form. The fluid is sprayed into a flash tank, which is held at a much lower pressure than the fluid, causing it to vaporize (or flash) rapidly to steam [2,6]. The steam is then passed through a turbine coupled to a generator in dry steam plants. To prevent the geothermal fluid flashing inside the well, the well is kept under high pressure. Flash steam plant generators range from 10 MW to 55 MW; a standard size of 20 MW is used in several countries.

Binary Cycle Power Plant: Binary cycle power plants are used where the geothermal resource is insufficiently hot to produce steam, or where the resource contains too many chemical impurities to allow flashing [5,6]. In addition, the fluid remaining in the tank of flash steam plants can be utilized in binary cycle plants (e.g. Kawerau in New Zealand). In the binary cycle process, the geothermal fluid is passed through a heat exchanger. The secondary fluid (e.g. isobutene or pentane) which has a lower boiling point than water is vaporized and expanded through a turbine to generate electricity. The working fluid is condensed and recycled for another cycle. All of the geothermal fluid is reinjected into the ground in a closed-cycle system. Binary cycle power plants can achieve higher efficiencies than flash steam plants and allow the utilization of lower temperature resources. In addition, corrosion problems are avoided.

4. BENEFITS OF GEOTHERMAL ENERGY

1. Geothermal energy is an abundant, secure, and, if properly utilized, a renewable source of energy.
2. Modern geothermal plants emit less than 0.2% of the carbon dioxide of the cleanest fossil fuel plant, less than 1% of the sulphur dioxide, and less than 0.1% of particulates, particularly with respect to greenhouse gas emissions.
3. Geothermal energy is not associated with environmental impacts such as acid rain, mine spoils, open pits, oil spills, radioactive waste disposal or the damming of rivers.
4. Geothermal power stations are very reliable compared to conventional power plants. They have a high availability and capacity factor.
5. Geothermal energy has an inherent energy storage capability.
6. Geothermal power stations have a very small land area requirement.

5. CONSTRAINTS TO GEOTHERMAL ENERGY USE

1. Geothermal energy produces non-condensable gaseous pollutants, mainly carbon dioxide, hydrogen sulphide, sulphur dioxide, and methane. The condensed geothermal fluid also contains dissolved silica, heavy metals, sodium and potassium chlorides, and sometimes carbonates.
2. There is a potential for geothermal production to cause ground subsidence. This is rare in dry steam resources, but possible in liquid-dominated fields (e.g. Wairakai, New Zealand). However, reinjection techniques can effectively mitigate this risk [7].
3. Geothermal energy production has been associated with induced seismic activity.
4. Geothermal energy is not strictly renewable, and on a site-by-site basis is not currently utilized in a sustainable manner.
5. Geothermal plants produce noise pollution during construction (e.g. drilling of wells and the escape of high pressure steam during testing). Once plants are operational, the noise pollution is insignificant.
6. Geothermal energy is constrained by energy policies, taxes, and subsidies which encourage the use of fossil fuel sources.
7. During drilling or flow tests undesirable gases may be discharged into the atmosphere. The impact on the environment caused by drilling could mostly end once the drilling is completed. The next stage which is the installation of pipelines for transporting geothermal fluids and the construction of utilization plants, could also affect animal and plant life.

6. GEOTHERMAL PROJECTS IN THE US

According to undergoing studies, the western part of United States is world's richest source of geothermal energy. The installed electric power capacity in the active region is 2500 MWe. The following are a snapshot of case studies in the US.

6.1 Correctional Center, Susanville, California

This center is located in Honey Lake Valley of the northwestern California which was converted to geothermal heating in 1983. There are two wells of approximately 1400 feet deep installed by the Carson Energy Group, Inc., of Sacramento which are operated by the city of Susanville but the royalties are paid to landowners. One well produces 169^0 F water and the other produces 162^0 F - 165^0 F water [9].

Utilization: Geothermal heat is used for domestic water heating as well as for a medium-sized greenhouse. It is supplemented by the existing diesel power plant. The geothermal heating is mainly used to heat the dormitories and not the staff areas. Heat is supplied by a centralized forced-air duct system to individual rooms. The estimated peak heating load is 158 therms/hr and the annual load is 434,000 therms for a utilization factor of 0.255 and a peak capacity of 4.65 MWt.

Operating Costs: The initial capital cost of the system installed in 1980 is unknown and has probably been amortized over the past 22 years. The wells are estimated to have cost around $180,000. At present, the state of California pays the city of Susanville $17,062 per month on a "take-or-pay" basis, which allows them to use up to 525,000 therms/year. This cost includes the well pump, electricity cost, maintenance, and overhead for the city. In addition, it is estimated that $1,000 per year is spent for repairing pipe leaks and other routine maintenance work. This then works out to about $0.39/therm. If the measured usage exceeds 525,000 therms/year, then a charge of $0.39/therm is accessed for the additional amount.

Environmental Impact: While the system does not have an injection well, the disposal of the geothermal water on the application area and associated ponds appear to have minimal environmental impact. There does not appear to be any corrosion or scaling problems in the system, especially since plate heat exchangers are used to isolate most of the secondary system.

Problems and Solutions: The only major problems are the replacing of the well pump bearings, bowls or shafts about every three years at a cost of $10,000, and breaks in the supply line (about one per year) at a cost of $800/year. These, however, appear to be normal operating costs. They recently upgraded the variable-speed drive on the well pump from fluid coupling to variable frequency, due to the cost of replacement parts for the older system. One well did collapse after 20 years and is no longer used.

Conclusion and Recommendations: The system appears to be operating without major problems and is cheaper than current alternative fuel costs. Cheaper gas from a state-owned natural gas pipeline may replace the geothermal heat in 2007; however, the price has not been established at this point.

6.2 Hot Springs Pool, Ouray, Colorado

The Ouray Hot Springs Pool is located on US highway 505 at the north end of the town of Ouray. The town is located in a valley surrounded by 12,000 to 13,000 ft peaks of San Juan Mountains at an elevation of approx. 8,000 ft. In 1927 the original construction was completed by Ouray Recreation Association. Two years later the city took over and since then it has been operated as a public facility. There are numerous hot springs in locations both in and around the town of Ouray. These springs produce fluids in the 80^0F to 150^0F range and are used for heating the pool and some local privately owned facilities [8].

Utilization: Water from the hot springs is supplied to the pool and in the winter months to a heating system for the pool buildings. For the pool itself, the combined flow from the spring and the well is delivered to a concrete tank on the west side of the facility. Here chlorine is added and the water is pumped to the filter room. The geothermal water is passed through two sand pre-filters to remove iron and manganese and then is mixed with pool water after it has passed through the main filters. Three distinct temperature zones are maintained in the pool, a small 104^0F section, a larger 98^0F section and the main portion of the pool has whatever geothermal water is left after satisfying the warmer sections. Temperature is maintained by manually adjusting valves which mix the geothermal water with the filtered pool water.

Operating Costs: No pumping of the geothermal fluids for this facility is required. The spring is located uphill from the pool and flows by gravity through the pipeline. The only pump located on the geothermal side of the system is the one that transfers the water from the concrete tank to the pool filter room. The 15-hp pump operates continuously resulting in an annual cost of approximately $7,800. The plate of heat exchanger must be cleaned and descaled yearly and this incurs a cost of $200. The total budgets to operate the pool amounts to approximately $540,000 per year and revenues from its operation are $660,000 per year.

Environmental Impact: Due to its early establishment, many regulatory issues and rules are not followed. The pool operates as a flow through design and disposes directly to the Uncompagre River. The natural solvents in the river do not support a fish population and in recent years, a chlorination system has been added to the pool and a residual chlorine level of 1.0 ppm is maintained in the pool water. This is well below the level required in conventional pools. Disposal of the water to the river is governed by a state surface disposal permit which specifies flow, TDS, temperature, chlorine and ammonia limitations.

Problems and Solutions: There has not been much problem in operating the facility. Other than the replacement of the pipeline, no major mechanical issues have surfaced with the system. The drilling done by the town in the 1980s, though not directly connected with the pool, did cause some problem with one local spa and the town agreed to supply a small flow (30 gpm) to the spa owner as compensation.

Conclusions and Recommendations: The pool is a very successful operation and one which generates substantial tourist activity for the town which is the primary industry in Ouray. Given the age of the pool, the low level of maintenance is impressive.

6.3 Geothermal District Heating, Philip, South Dakota

This facility is located in the south western part of the state, on US highway 14. The district heating project was one of the 23 whose cost is shared by USDOE starting in 1978. A single 4,266-foot deep well was drilled in 1980 which provides a maximum artesian flow of 340 gpm at 157^0F. The dissolved solids content of the water is 1,112 ppm. Radium-226 at 100 pCi/L as radium sulfate must be removed from the spent water with a barium chloride mixture before discharging to the Bad River [8].

Utilization: The geothermal energy is used in district space heating and the discharge from the schools is transported in a single pipe through the downtown area. A disposal line begins at the upstream end of the business district and parallels the supply line from the schools to the last user on the system, the fire station. From there, a single line continues to the radium removal plants and disposal to the Bad River. Water leaving the business district flows to the water treatment plant where Radium-226 is removed.

Operating Cost: The capital costs of the entire system are estimated at $1,218,884 of which 77% was DOE funds. Annual operating and maintenance cost for the entire system is nearly $8,000 (updated from 1983 data). The initial costs to the city businesses were for cast iron heat exchangers at $30,000. However, due to corrosion, these exchangers were replaced with stainless steel heat exchangers. The Philip Geothermal Corporation now pays the school district $5,000, carries a $1,000 liability policy, pays taxes, and spends about $500 for repairs, for a total annual cost of about $6,500.

Environmental Impact: A discharge permit is required by the South Dakota Department of Environment and Natural Resources. This is renewed every two years. Samples of the discharge water are sent to Pierre. EPA in Denver requires flow and temperature readings every two to three weeks. The Radium-226 must be reduced to 5 ppm (from 80 ppm) with a maximum daily reading of 15 ppm.

Problems and Solutions: The cast iron heat exchangers had to be replaced with stainless plate heat exchangers due to corrosion. Since then, there have been no problems with scaling and corrosion in the city system. The iron pipes in the school well have to be replaced every four to five years due to corrosion. Plugging of pipes at the water treatment plan has been a significant operating problem. Sulfate deposits initially partially plugged the mixer and pipe downstream, thus requiring frequent cleaning. Installation of the current trough system for the barium chloride additional and mixing has solved this problem. The pipe from the second cell to the creek has to be augered every two years at a cost of $250 to $300. the resources are not utilized properly. The system only supples 75 to 90% of the energy demands for the city buildings. A backup boiler is provided from the school system installation to peak the system during the colder periods.

Conclusions: Except for some inefficiency in the energy utilization, and the requirement for treating the Radium-226, the system operates well. Building owners are only paying about 20% of the corresponding cost for alternate fuels. However, the main contribution to this project is done by USDOE grant which subsidized 77% of the initial capital cost. The system probably would not have been feasible otherwise.

6.4 Nevada Geothermal Industry, Nevada

Nevada is the second largest state to utilize the geothermal power in United States. Nevada's geothermal power plants generate approximately 210 MWe of electricity, enough for about 200,000 households. Typical installations operate at temperatures between 120°C and 180°C, and use either pentane or iso-pentane as a secondary working fluid [10].

Utilization: Nevada is highest in direct use of geothermal energy in United States. Mining, aquaculture and agriculture benefit from the direct utilization of geothermal resources. The Elko County School District and the Elko Heat Company operate geothermal district space heating systems that provide hot water to municipal, residential and commercial establishments. The Elko Heat Company, one of Nevada's largest geothermal district heating systems, has provided service to Elko since 1982.

Operating Cost: Many of the power plants in Nevada receive higher-than avoided cost payments for electric power. Two power plants in Nevada were constructed as a result of competitive bids with conventional power plants because of higher fuel prices in 1989. Electric power generated from geothermal resources is purchased by two utility companies: Sierra Pacific Power Company of Reno, Nevada and Southern California Edison Company. Nevada benefits from the use of geothermal energy, due to various revenues earned from geothermal operations. The actual gross proceeds in 1989 were $58,876,628 and in 1993 were $102,164,450 which shows that there were almost double gross proceeds. The actual net proceeds also doubled from $18,114,494 in 1989 to $37,432,245 in 1993.

Environmental impact: The power plant produces 210 MWe out of which certain amount of fossil fuels are released: 821,100 tons of coal, or 3,066,000 barrels of oil, or 18,396,000 million cubic feet of natural gas. The electric power generation and the preservation of the environment are of tremendous importance to the Nevada's utility industry.

Conclusions: According to the projection made by EIA in 1991 the geothermal capacity and generation in the US could realistically increase from 2,590 MWe in 1990 to 23,400 MWe in the year 2030. These forecast amounts were based on expected expansions from fields developed in California, Nevada and Utah, as well as the development of new fields in Oregon, Hawaii, and New Mexico. However, these assessments require that renewable energies receive a share of the power market along with existing electricity generation technologies.

7. GEOTHERMAL POWER PRODUCTION WORLDWIDE

Some of the international geothermal projects are outlined as follows [9].

7.1 Geothermal Energy in Iceland, Australia and New Zealand

Only limited amounts of geothermal energy are used in Australia, in stark contrast to New Zealand which produces 75% of its total energy requirements from geothermal sources. There are a few projects in Australia which at present are under operation. These projects include the Garden East Apartments, South Australia, Hot Dry Energy and Mulka Cattle Station, South Australia.

7.1.1 Svartsengi Geothermal Project, Reykjanes Peninsula, Iceland

The original plants which were built in 1978 and 1980 generated 8 MW. To improve the performance of the geothermal power plant, the Sudernes Regional Heating Corporation started the Svartsengi Geothermal Power Plant as a re-powering process. Sudernes installed 1.3 MW water-cooled OEC binary modules in 1989 which was generating 3.6 MW and now it supplies heat and electricity to the Reykjanes Peninsula in the Southwest Iceland. There are shallow and deep wells where the former produces dry steam and the latter produce fluids of about 290°C. In 1994, 4 more 1.3 MW air-cooled OEC binary modules were added which are generating 4.8 MW, bringing the total capacity to 16.4 MW [11]. For the last 10 years, OEC modules have been running continuously at over 97% availability.

The major advantages of this plant are that the waste steam is used to produce additional power of 8.4 MW, and the re-powering was done in 2 steps which reduced its investment risks. Since the availability factor has increased, the overall thermal efficiency is increased. The cost has also reduced which has promoted the use of geothermal energy for district heating and electricity. The plant has eliminated the damage caused by acid rain from the exhaust steam. OEC coolers condense the non-condensable gases like CO_2 and are being used for making of dry ice.

7.1.2 Bay of Plenty Geothermal Power Plants, Kawerau, North Island, New Zealand

The Kawerau geothermal field is one of the most explored geothermal fields in the world with a total capacity of 200 MWe. The field has 31 drilled wells with a maximum bottom hole temperature of 310°C. Earlier the geothermal energy was used by surface discharging the brine at 174°C, both as steam into the atmosphere and brine into the Tarawera river [11]. To improve the plant, the Bay of Plenty installed two 1.3 MW air-cooled modular binary OEC units in 1989 and one 3.8 MW air -cooled modular binary OEC in 1993. The OEC units use the 174°C brine and cool it to 110°C within the first two units of

1.3 MW units and then further down to 80°C in the 3.8 MW unit. The total electricity generated is 7.1 MW.

The plant has many benefits including environmental and technical. It supplies electricity and heat to the local residential and commercial areas. OEC units are working continuously for 10 years making the availability of the plant over 98%. OEC units have nearly negligible environmental effects and have solved the problem with the surface discharge of dangerous geothermal brine.

7.2 Geothermal Energy in Asia

The Philippines, Indonesia, and Thailand use geothermal energy for electricity production. China and Taiwan have direct use geothermal applications and to a lesser extent electricity production. The Philippines is the second largest producer of geothermal electricity in the world with an installed capacity of 1,848 MW [9].

Geothermal resources are extensive in the Philippines due to its location on the edge of the Philippine and Eurasian plates. The first geothermal plant commenced operation in 1979. There is an active development of new fields in the Philippines, which may soon make it the largest producer of geothermal electricity in the world. The Indonesian islands are located on the boundary between Eurasian and Australian plates which result in a very good geothermal resource. The first geothermal development was the dry steam resource at Kamojang in the 1920s, which now produces 140 MW of electricity. Currently, the largest field is Gunung Salak which has an installed capacity of 330 MW.

7.2.1 Leyte Geothermal Optimization Project, The Philippines

After the four projects were awarded in 1995 to ORMAT, the work to convert the untapped geothermal energy started in 1997. The Leyte geothermal plant has a capacity of producing 50 MW. ORMAT along with PNOC-EDC (Philippines National Oil Company-Energy Development Corp.) has a 10-year agreement to convert 50 MW worth of geothermal energy [11]. Later the PNOC-EDC decided to use the unused geothermal energy produced by the existing capitalized facilities which in turn generated an additional 49 MW. The four plants are

Tongonan Topping Unit: The main plant has a capacity of 112.5 MW and requires 1,008 tons/hr of steam at 6.83 bar at the plant inlet. The Tongonan Topping Plant comprises of three topping units producint 16.95 net power.

Mahanagdong A and Mahanagdong B Topping Units: The Mahanagdong A produces 180 MW and requires 6.83 bar steam flows at 817 tons/hr whereas the Mahanagdong B produces 60 MW with the 6.83 bar steam flows at 410.0 tons/hr. Using the two topping units they together produce 12.45 MW net power. While with one topping unit MAhanagdong B produces 6.25 MW net power.

Malitbog Bottoming Unit: The main Malibog Power Plants have a capacity of 213 MW and require 5.85 bar steam flows of 109 tons/hr. It produces second flash steam, which is used by condensing steam turbine Bottoming Cycle to generate 13.35 MW net power.

8. CONCLUSIONS

Due to the steady heat flow from the inner parts of the earth, geothermal resources can be regarded as renewable. A geothermal system can in many cases be recharged as a battery. Utilizing the natural flow from geothermal springs does not affect them. Exploitation through drill holes and by the application of down hole pumps nearly always leads to some physical or chemical changes in the reservoir and/or its near vicinity, which could lead to a reduction or depletion of geothermal resources so far as a particular utility is concerned.

Geothermal energy has a high availability and capacity factor of about 80% - 90% [10]. In comparison with wind, solar, and tidal energy, geothermal is clearly an advanced energy source with 61% of the total installed capacity and 86% of the renewable electricity production in recent years. The relatively high share in the electricity production reflects the reliability of geothermal plants. The generation reliability also demonstrates one of the strongest comparative points of geothermal energy. Unlike solar energy, geothermal is available day and night throughout the year and is not dependent on climatic conditions like in the case of wind energy.

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