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Geothermal development progress in Japan after earthquake, 2011

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ABSTRACT

After serious nuclear accident with big earthquake at 2011, the research and development of geothermal restarted and several regulations changed in Japan. And to progress geothermal development, we had several problems as follows, 1) High initial cost, 2) 80% of geothermal potential exists inside special region of national park and we cannot develop at these region, 3) several hot spring owners resist to development due to afraid decreasing hot spring fluid.

To solve these problems, our government decided to introduce the Feed-In Tariff for geothermal energy as 27.3JPY/kW (about 0.3AUD/kW) and to permit to development in the low class part of special region in national park at 2012. Then, research and development started at several site especially north of Japan and the first flush type geothermal power plant after nuclear accident will start in Yuzawa site with 40 MW at 2019.

And to get the understanding from hot spring owners, we are developing the simulator to estimate the relationship between geothermal reservoir and hot spring reservoir. And we proposed to introduce small binary system (about 50kW) using waste high temperature (about 100 degreeC) hot spring water. Several Japanese companies developed HFC binary system and several hot spring sites introduced this system. And the production test using Kalina system is progressing at Matsunoyama site.

We still have several problems as follows, 1) longer reading time than other countries, 2) High cost of small binary system, 3) scale and corrosion of geothermal generation system, 4) education and risk communication.

And we have to promote the GHP system and try to restart the research of EGS in Japan.

1. INTRODUCTION

In Japan, about 500MW electric power is generated from 17 geothermal power plant sites. All of them established and started generation before 1999. And after 2002, our government, Ministry of Economy, Trade and Industry (METI), broke off the support for research and development of geothermal energy. The revival of geothermal development came around 2008 due to prevent climate change. The release rate of carbon dioxide from geothermal power plant is much lesser than oil and gas power generation. And this revival was supported by new estimation of geothermal power potential by Muraoka et al. (2008). The geothermal potential in Japan was estimated about 23,000MW of conventional hydrothermal excluding EGS and 3rd ranking high next to Indonesia and United States of America. Before this, the potential map of EGS of United States was published by Massachusetts Institute of Technology (2006). According to this report, the geothermal research and development of United States rapidly accelerated especially EGS. But in Japan, small project started by Ministry of Environment (MOE) from 2010 but it is considered to use about 50 nuclear power plants for decreasing carbon dioxide and preventing climate change. In 2010, about 30 % electric power was supplied from nuclear power plants.

However, the big earthquake occurred near north-east Japan at March 11, 2011 with 9.0 of magnitude and big tsunami. The tsunami killed over 20,000 people, destroyed many towns face to ocean and caused severe accident of Fukushima Dai-ichi nuclear power plant of Tokyo electric company due to flowed away of cooling system. After the sever accident, many radioactive material precipitated surrounding area including ocean. Now we cannot live in 30 km area from nuclear power plant and still high radioactive level at many parts of Fukushima prefecture including Fukushima city and Koriyama city and about 300,000 populations in both cities.

After nuclear power plant accident, many citizen resist to operating nuclear power plants to afraid of similar accident. Operating nuclear power plants rapidly decreased and all nuclear power station stopped at May of 2012. After that 2 nuclear power plants operated during summer of 2013.

Then, the government decided to promote renewable energy including geothermal energy. And even if this situation, several problems remain. For example, 1) high initial cost and long lead time are needed for new geothermal power plant, 2) 80% of geothermal potential exists inside special region of national park and we cannot develop at these region, 3) several hot spring owners resist to development due to afraid decreasing hot spring fluid.

In this paper, the progressing of environment of geothermal development in Japan is mentioned after nuclear power plant accident.

2. POTICAL CHANGE TO COST SAVING

After big earthquake, our government decided to introduce the Feed-In Tariff for several renewable energy including solar power (PV), wind, biomass, small scale hydro power and geothermal. According to this law, the electric companies have to buy the electric power generated using renewable energy. The rate and period of FIT are depend on power and source.

About geothermal energy, in the case of higher than 15,000kW with large conventional flush power plant, the rate of FIT is 27.3JPY/kW (about 0.3AUD/kW) during first 15 years and in the case of lower than 15,000kW with small binary power plant, the rate of FIT is 42JPY/kW (about 0.5AUD/kW) during first 15 years.

And we have the problem of longer lead-time than other countries. The long lead-time is cause to the higher cost of geothermal energy due to much interest until operation. One of reason of the long lead-time is long environmental assessment. For example, next Japanese geothermal power plant will be constructed at Yuzawa, Akita prefecture and this site is under environmental assessment and the additional drilling and construction of power plant will start at 2015 and the operation will start at 2019. This project started at 2009 and this means 10 years lead-time. We have to try to shorter lead-time for following development.

Of course, the financial support for exploration and drilling is important. Until 2002, the developing financial for geothermal was supported by the New Energy and Industrial Technology Development Organization (NEDO). But several years before earthquake, there is no financial support. From 2012, Japan Oil, Gas and Metals National Corporation (JOGMEC) start to support developing financial and at 16 sites, the survey for developing new power plant started.

3. ISSUE OF THE NATIONAL PARK

At the early stage of Japanese geothermal development, several geothermal power plants are developed inside the national park. But at 1972, according to discussion between METI and MOE, the development of geothermal was prohibited inside the national park.

In Japan, due to the surrounding area of volcano is almost belong the national park to protect the Alpine plants and landscape, about 80 percent of Japanese geothermal potential exists inside the national park. Then, several companies had to develop the lower potential area and need more production wells. This is one of reason that high geothermal cost. If we can develop the higher potential area, need less production well and the cost of geothermal energy will become lower.

Then, at 2012, the Ministry of Environment (MOE) permitted survey by remote sensing and MT survey in all area. But we can exploration and drilling only in lower grade region with understanding of local citizen. The development in lower grade is estimated lower cost than developed power plants.

4. ISSUE OF THE HOT SPRING RESORT

To develop geothermal plant, one of problems is the understanding of hot spring resort owners. Usually the reservoir of geothermal power plants exist about 2 or 3 km depth and that for bathing of hot springs exist shallower than 1 km depth. But due to the hopeful geothermal reservoir exist close to hot spring reservoir, several hot spring owner resist to develop geothermal power plants due to afraid to decrease the hot spring water production.

As one of geothermal direct use, bathing in hot spring is used for many people and countries, especially in Japan In Japan, about 28,000 hot springs (Onsen) and 15,000 hotels related hot springs exist at 2010. And total guests staying hotels of hot springs are about 130 million as same as population in Japan. And the range of temperature of hot springs is very wide from 25 to over 100 degreeC. In non-volcanic area, for example Shikoku Island, in Kanto plane etc., the temperature of over 95% of hot springs is lower than 42 degreeC. In this case, the owners of springs, mainly official public bath, have to heat water using boiler to bathing temperature and people living non volcanic area is able to enter the springs in living area.

And in volcanic area, for example Hokkaido, Tohoku-area, Kyushu Island etc., the temperature of of over 60% of hot spring is higher than 42 degreeC. And Kimbara (2005) collected temperature data of 4,536 hot springs. According to this data, the temperature of about 15 % of hot spring is higher than 60 degreeC and 4 % is higher than 90 degreeC.

Then, we have to solve the problems about relationship between geothermal power plant developer and hot springs owners. As one of trial to solve this problem, the project “Development of an advanced geothermal reservoir management system for the harmonious utilization with hot spring resources” had been done from 2010 supported by MOE (Yasukawa et al., 2013).

An integrated geothermal reservoir operation system for adequately controlled utilization was developed to avoid interference to nearby hot springs. The system consists of four parts: geothermal system modeling, monitoring technology, estimation of reservoir change by numerical simulation and integration of a reservoir operation system. Hachijojima and Minami-Izu geothermal areas were selected as model fields to apply this system and various field surveys and monitoring were conducted. The final product is an integrated system that enables to evaluate impacts of geothermal development on surrounding hot springs a priori and to design geothermal exploitation without negative impacts on hot springs. The system may contribute to promote geothermal exploitation.

5. BINARY SYSTEMS USING HOT SPRING FLUID

Recentry, several hot springs owners and power generation companies have recently expressed interest in small binary power system using hot spring fluids (Muraoka et al., 2008) as shown in Figure 1. After the nuclear power plant accident, the Feed-in Tariff (FIT) for small geothermal power plant was set up at 42 JPY/kW which is sufficient to support the development of small binary system using fluids from the hot springs. And the hot spring owner’s preference is on small binary systems that utilized waste high temperature hot spring fluids without the need of drilling new wells.

Starting in 2010, the Ministry of the Environment (MOE) of Japan gave its support on the hot spring generation project, titled "Development and Demonstration of Small-Grid Power Generation System using Hot Spring Heat Source". This project is managed by the Geothermal Energy Research & Development Co., Ltd. (GERD), the Institute for Geo-Resources and Environment of AIST and Hirosaki University.

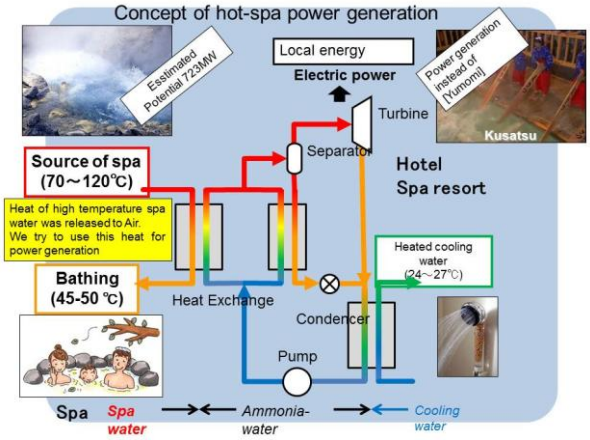

Figure 1: The concept of power generation using hot spring fluids.

Under this project, power generation testing for the 50kW class Kalina cycle system was conducted using a 100 degreeC fluid from the Matsunoyama hot spring field in Nigata prefecture, middle part of Japan. The project mainly consists of several components: (1) estimation of long term sustainability and maximum power generation with the existing hot spring flowrate, (2) monitoring of production impact on the surrounding hot spring system. The hot spring owners' major concern is on the sustainability of production if it turned out that more volume of fluids is needed to generate the target power output.

And several Japanese companies ventured into production of new small binary system. For example, KOBELCO (Kobe Steel, Ltd) developed a 72kW binary system that was made available in October, 2011. This system was installed at Beppu hot spring field in Oita prefecture and at Obama field in Nagasaki prefecture, all in Kyushu Island near a volcanic area. IHI Co. Ltd. likewise developed a 20kW class binary system which was released in August, 2013 while ULVAC-RIKO. Inc. developed a 3kW binary system (Yanagisawa et al. 2013).

These binary systems use Hydro Fluoro Carbon (HFC) as the heating medium. Since HFC is non-toxic and has low flammability, owners of the HFC binary systems below 300kW size have no need for a special licensed engineer for boiler and turbine in Japan. On the other hand, owners of Hydrocarbon binary and Kalina (water-ammonia) cycle systems have to employ a special licensed engineer. With this, the personnel expense cost for the HFC binary system is a lot cheaper which greatly influenced the choice of several hot spring owners in favor of the HFC binary system.

However, the HFC binary system has several issues. . One is that the Global Warming Potential (GWP) of HFC is very high, about 1,000 times that of the Carbon Dioxide gas (CO_2). Second, the cost of HFC gas may become higher in future due to increase in demand. And third, the electrical efficiency of ORC using HFC gas or Hydrocarbon is lower compared to the Kalina system especially at temperature lower than 100^{o}C as shown in Figure 2.

The Kalina cycle system has relatively high electrical efficiency for hot spring fluid, with no impact on global warming. However, the Kalina cycle system running cost is high due to the need for a special licensed engineer, which can be reduced if the safety and stability of the Kalina cycle system can be established. In Japan, the Kalina cycle system has already been utilized at Kashima works of Nippon Steel and Sumitomo Metal Co. Ltd. (3,400kW) since 1999, and at Sodegaura works of Fuji Oil Co. Ltd. (3,300kW) since 2007. These systems have been operational for several years now without any issue. Currently, the ongoing production test of a 50kW Kalina cycle system at Matsunoyama hot spring field using a small generator (Welch et al., 2011) aims to estimate safety and stability of the Kalina cycle system and the sustainability of production from the hot spring.

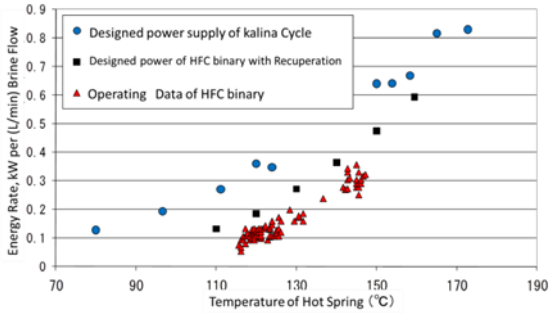

Figure 2: Comparison between the inlet temperature and net electricity of Kalina and organic Rankine cycles (Osato, 2005).

6. GEO-HEAT PUMP SYSTEM

In Japan, GHP can be used for space heating and cooling in most parts of the country. It can also supply hot water to domestic systems, public spas and indoor swimming pools. Snow melting systems with GHP are used in northern districts. Although GHP market is still small in Japan, they are applied to a variety of buildings, such as public facilities (museum, schools, etc.), offices, hotels and individual houses. GHP utilization in Japan: the number of installation, 990 in total, based on 2011 statistics (Geo-Heat Promotion Association of Japan) and this is about 1/1000 than United States.

7. EGS

Until 2002, two EGS (HDR) projects were carried out at Hijiori and Ogachi test site. Especially, at Hijiori , 2 years circulation test was carried out and heat exchange efficiency (Tenma et al., 2008) , tracer response and reservoir estimation (Yanagisawa et al., 2006) and scale precipitation survey (Yanagisawa et al., 2008).

After 2003, we mainly EGS study carried out European country and Australia. For example, we supported the tracer test of Cooper-Basin, Habanero site (Yanagisawa et al., 2009). And after earthquake, we try to propose new EGS project below the brittle-ductile boundary (Asanuma et al., 2012).

8. SUMMARY

To progress geothermal development, our government decided to introduce the Feed-In Tariff for geothermal energy as 27.3JPY/kW (about 0.3AUD/kW) and to permit to development in the low class part of special region in national park at 2012.

And to get the understanding from hot spring owners, we are developing the simulator to estimate the relationship between geothermal reservoir and hot spring reservoir. And we proposed to introduce small binary system (about 50kW) using waste high temperature (about 100 degreeC) hot spring water. Several Japanese companies developed HFC binary system and several hot spring sites introduced this system. And we have to promote the GHP system.

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