POTENTIAL OF THE GEOTHERMAL SYSTEM IN PHANG NGA, THAILAND

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ABSTRACT

Geothermal energy as an abundant energy source from the Earth's interior can be changed locally into geothermal electricity and thus will reduce the reliance on fossil oil. Besides this, electricity production from geothermal sources does not create emissions of CO_2, one of the main gases responsible for man-made climate change. Further, in a renewable energy scenario geothermal power plants can provide stable base load in comparison to fluctuating sources like wind and solar. Hot springs are the visible form of active geothermal systems; Thailand has more than 112 hot springs from North to South with exit temperatures of up to 100 °C and more, thus indicating a significant potential for electricity generation. In Northern Thailand, Chiang Mai, Fang, Thailand's first and only geothermal power plant is located and still in operation. In Southern Thailand electrical energy is in demand; hot springs here reach exit temperatures up to 75 °C. Here, the Phang Nag hot spring site, about 100 km north of Phuket, has been investigated with geological, geophysical and geochemical methods, indicating a geothermal reservoir at 1-1.5 km depth with possible 100 to 120 °C reservoir temperatures. This and basic geothermal parameter model with depth show, that, even with a borehole still in planning, a low enthalpy geothermal electrical energy technology is possible.

Keywords: hot spring, geophysics, geochemistry, Phang Nga, Thailand

1. INTRODUCTION

Access to modern forms of energy is an essential pre-requisite for overcoming poverty, promoting economic growth, expanding employment opportunities, supporting the provision of social services, and, in general, promoting human development (Akella et al., 2009). Renewable energy plays an important role in mitigating hardship and ensuring self-sufficiency of the energy supply. Sustainable development can be broadly defined as living, producing and consuming in a manner that meets the needs of the present without compromising the ability of future generations to meet their own needs. Some developing countries have already made plans to produce electrical power from renewable resources, such as solar, wind, and geothermal energy for electricity generation. Among renewable energy options, geothermal power generation has the advantage of providing a stable energy supply and energy security, and is also unaffected by weather conditions, in contrast to solar and wind power generation. Geothermal refers to existing of heat energy in deep rock and sedimentary basins. These formations can provide superheated steam or hot fluid that can be used to generate electricity by means of steam turbine (An et al., 2016). Depending on the state of the geothermal fluid in the reservoir, different power producing cycles may be used, including direct steam, flash-steam, binary and combined flash-binary cycles (Akella et al., 2009).

Thailand currently only geothermal power plant is working in Fang of Chang Mai Province, generating electricity via a binary cycle power plant of about 0.3 MW, which was built as a demonstration plant to supply electricity to the local communities. Shallow wells of about 100 m depth produce about 22 l/s of 125 °C water, and two wells to 500 m produced about 10 l/s. The Department of Groundwater Resource (DGR), Ministry of Natural Resources and Environment of Thailand, and co-organizers are currently surveying geothermal areas in Thailand (e.g. Amatyakul et al., 2015). The Phang Nga hot spring site is the one of five areas recommended for further investigations; it is located in Kapong District, about 40 km north of Phang Nga City or about 100 km north of Phuket (see Figure 1). Altogether seven natural hot springs can be found at this site close to and at the banks of the Pai Phu River covering and area of about 150x200 m with surface exit temperatures from 72 to 78 °C.

Fig. 1 a) Location of the Phang Nga hot spring site in Thailand; b) main pool of the natural hot spring sites at the banks of the Khlong Pai Phu River, and c) one of the tributaries of the Kapong River, which finally is leading to the Andaman Sea in the West

2. PHANG NGA HOT SPRING EXPLORATION

In order to understand the subsurface structure of the Phang Nga hot springs a combination of geological fieldwork, geophysical surveys, and geochemical analysis of water samples has been applied (see also Ngansom and Dürrast, 2015). Altogether fifty 1D vertical electrical sounding measurements were carried out around the hot spring sites with an AB/2 of 150 m in order to delineate the distribution of the hot waters in the shallow subsurface. The deeper structures of the Phang Nga hot spring system are represented with 30 MT stations covering over 50 km^2 of the study area (e.g. Spichak and Manzell, 2009). Measurement profiles were parallel North-South along various hot springs and were oriented East-West as close as possible to lines perpendicular to the mountains with sedimentary and granitic rock units (Watkinson et al., 2008). Water samples were collected, its exit temperatures measured, and its geochemical composition determined in the laboratory of the Faculty of Science, Prince of Songkla University.

Almost all 1D VES of resistivity surveys show low resistivity in shallow parts represent groundwater aquifers at relatively shallow depth, 20 to 80 m, in the northern and at 40 to 50 m in the southern part of the hot spring site (see Figure 2; Spichak and Manzell, 2009). The 3D inversion of MT represents deeper structures defined as resistivity parameters integrating all layers form surface to 2 km depths (Amatyakul et al., 2015). Low resistivity layers extending to depth of down to 50 m, covering an area of over 30 km^2, which can be considered topsoil and freshwater aquifers. Low resistivity values deeper than 1 km and down to 2 km depth indicate possible faults areas of hotter water-rock systems (see Figure 2, e.g. Saetanga et al., 2014). The geochemical analysis of the hot water shows that it has likely been mixed with colder groundwater (Baioumy et al., 2015). Therefore, these hot spring waters could be the result of waters of meteoric origin that circulated deep into fault zones and rises to the surface once it was heated.

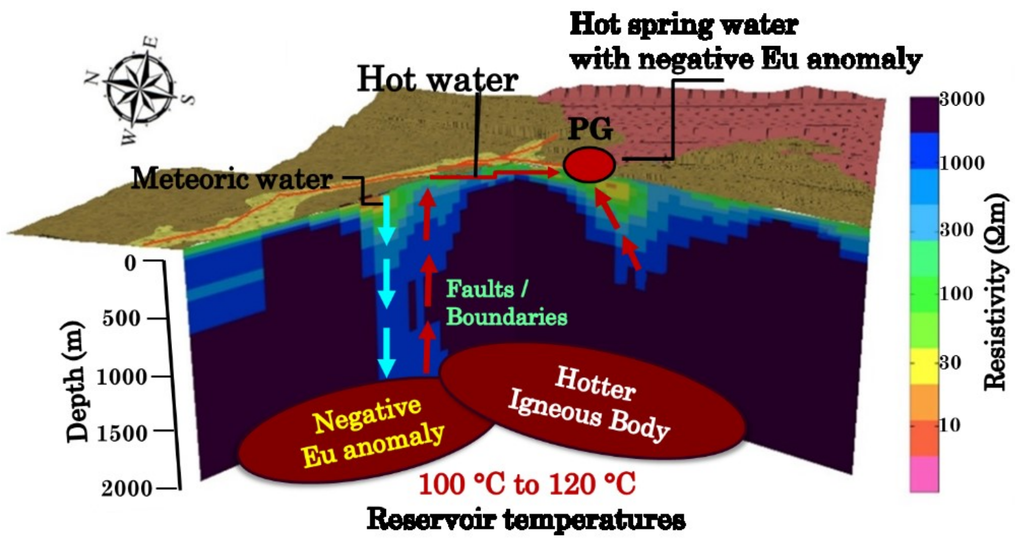

Fig. 2 Schematic geological cross-section of the study area and the geothermal system along a north-south profile with resistivity data are from the MT survey; top is geological map with brown sedimentary/metamorphic units and red granites (Department of Mineral Resources, 2011)

Isotope signatures of hydrogen (δD) and oxygen ($\delta^{18}O$) determined at TINT (Thailand Institute of Nuclear Technology, Bangkok) confirmed that these waters result from meteoric waters. From a negative Eu anomaly in the REE data (determined at the Geochemistry Department of the Goettinger Geoscience Center, GZG, Germany) it can be concluded that hot water has taken the Eu from the granite during the circulation at depth resulting in the temperature increase (see Figure 2). Granites are found as outcrops in the area and geomagnetic data suggest their distribution also at depth (Department of Mineral Resources, 2014). Geothermometry using water chemistry data indicate that the reservoir depth is deeper than 1 km with 100 to 120 °C reservoir temperatures (e.g. Baioumy et al., 2015).

3. POSSSIBLE POWER GENERATION TECHNOLOGIES

Based on the geophysical exploration results and reservoir temperature performances of the Phang Nga geothermal system it can be classified into a low to medium geothermal electricity potential range. A development of the Phang Nga geothermal system for electricity generation should be prioritized regarding the status of possible geothermal technology (see Figure 3), as electrical power is usually generated when exploiting hydrothermal systems. However, the most interesting option for the Phang Nga geothermal system relies on the exploitation of the enhanced geothermal system (EGS) with binary plant technology (Guzovic et al., 2012). Binary plants can generate electricity from geothermal sources in a broad range of temperature as down to 100 °C or less; while the Phang Nga geothermal system has a possible range of 100 to 120 °C reservoir temperature (see Figure 3). A major feature of the electricity generation by the Phang Nga geothermal source is that the technology adopted in the power plant needs be tailored to the geothermal fluid available at the surface (Ngansom and Dürrast, 2015).

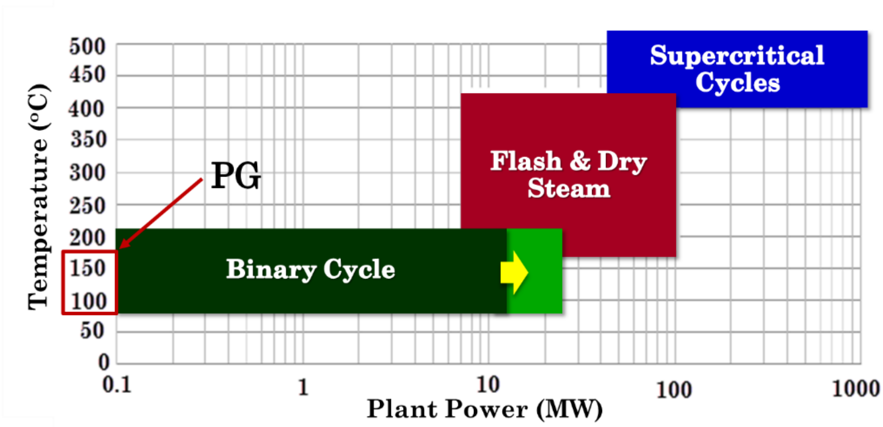

Fig. 3 Possible power generation technologies and power output depending on reservoir temperatures (see An et al., 2016)

4. WELL TEST MODELING

In order to make an estimation of the potential of a geothermal system well tests have to be carried out. A well test is a fluid flow test conducted in wells to obtain data and information on the properties of the reservoir and the well. Well tests are done before exploiting the reservoir, but also after a period of production, to see whether and how much the reservoir properties have changed (Zeng et al., 2016). Here in Phang Nga the drilling of a deep well is in planning. Therefore, based on some estimates with values used shown in Table 1 modeling of well test have been done shown as an example for the application of the methodology used in the plan for small geothermal power plants.

According to the model the first well was drilled below 1 km depth range with to reservoir temperatures of about 100 to 120 °C. The areal extent of the geothermal surface manifestations is in the order of 2 km^2. The resistivity survey with MT method carried out in the Phang Nga area shows a low resistivity anomaly with an aerial extension at 1 km to 2 km depth (see also Figure 3). Based on this assumptions of the model parameter have been done. Data used for the modeling are shown in Table 1, which are then used to calculate depth profiles for the discharge test for borehole, here temperature and pressure profiles (e.g. An et al., 2016).

Table 1 Values used for and from the calculation of a well test model two different feed zones at different depth for the Phang Nga geothermal site

Feed zone	Depth (m)	Flow (kg/s)	Enthalpy (kJ/kg)	Reservoir Press (bar-a)	Saturation (m^3/m^3)	Production Index ($kg/s/m^3$)
1	800.0	0.09	1,520.00	48.90	.00	$1.00x10^{-12}$
2	1,800.0	50.94	1,220.00	119.00	.00	$1.30x10^{-10}$

Two major feed zones are present in the well, one at around 750-800 m, just below the production casing, and the other at the well bottom at 1,800 m depth (see Figure 3). The calculated pressure and temperature profiles are obtained by assuming a wellhead pressure of 32 bar-g and a bottom hole pressure of 117 bar-g. Enthalpy values of 1,520 kJ/kg and 1,220 kJ/kg were assumed for the feed zones at 800 m and 1,800 m depth, respectively.

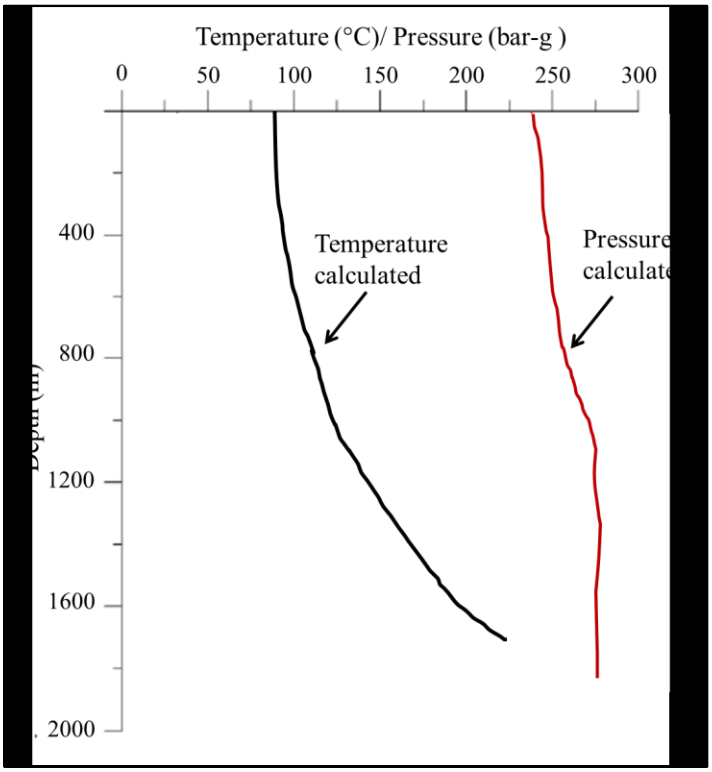

Fig. 4 Calculated temperature and pressure profiles for Phang Nga hot spring site based on the assumptions presented in Table 1 (after Rutagarama, 2012)

The calculations give a total flow rate of 51 kg/s at the wellhead, which is similar to the flow calculated during a possible discharge test (47 kg/s). The productivity index at 800 m depth and at the bottom is $1x10^{-12}$ m^3 and $1.3x10^{-11}$ m^3, respectively, giving a total productivity index of $1.31x10^{-11}$ m^3 or about 7.34 (kg/s)/bar. These data then will have an effect on the electrical power generation output (Guzovic et al., 2012); with the estimates presented here power output is around 5-10 MW. These estimates reflect a more conservative approach; however, final values have to be based on the drilled well and subsequent well tests.

5. CONCLUSIONS

Characteristics of the Phang Nga geothermal system have been explored based on the integration of geological, geophysical and geochemical methods; the geothermal reservoir temperatures at about 1 km and deeper range between 100 and 120 °C. In such case, with medium-temperature sources and a relatively lower temperature of the geothermal waters binary plant technology might be used (An et al., 2016). Investigating the electricity generation potential at 800 m to 1,800 m of a fractured granitic reservoir by water circulating main factors affecting the performance and efficiency were analyzed. Based on the possibilities and limitations of well test modeling, the heat production power and generation power were investigated in detail with focusing on some important influence parameters; the conclusions are as follows: (1) the heat production and power generation increase with the thermal reservoirs depth and different porosity, (2) the heat production and power generation decrease with the increase of thermal reservoirs porosity at different thermal reservoir depths, and (3) a geothermal well with thermal reservoirs could enhance the heat and electric power output depending on the thermal reservoirs conditions.

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