Realizing the Potential of Base Load Electricity Generation from Geothermal Sources: the San Jacinto-Tizate Field

KEITH D. ALDRIDGE                                        DAVID G. TOOLE
Graduate program in Earth and Space Science          Hellenic Geothermal Holdings
York University                                      Corporate Office
4700 Keele Street,                                                 1290 Central Parkway West,
Toronto, Ontario CANADA                                    Mississauga, Ontario CANADA

Abstract: - Production of electricity in the San Jacinto-Tizate geothermal field, Nicaragua is a unique example of beginning to realize Earth's vast geothermal potential. With an estimated potential up to 2000 MWe, Nicaragua can become an important producer of geothermal energy for both internal and export consumption. While it has been producing electricity from geothermal sources for the past 2 decades using only 2% of its potential capacity, development of the San Jacinto-Tizate geothermal field will increase that proportion up to 5% and represents a major step towards energy self-sufficiency. This increase is brought about through the skilful management of international geothermal development at a time of high demand for baseload electricity from non-fossil fuels. As this demand continues to grow, driven in large part by rapidly rising oil prices, the need for realizing known geothermal potential is inevitable. Development of the San Jacinto-Tizate geothermal field serves as a guide to how we might double the worldwide production of geothermally generated electricity.

Key-Words: - baseload electricity, geothermal, potential capacity

1 Introduction

While fossil fuels account for over 80% of today's energy sources, the need to find alternative sources of energy has never been higher. Earth is certainly undergoing damage though climate change, primarily from carbon dioxide produced in our use of fossil fuels. Accordingly, we must reduce our dependence on these sources of energy. Coupled with the rapidly increasing financial and political costs of oil and gas, both their inevitable shortage and their deadly effect on Earth compels us to find a substantial alternative, sustainable source of base load energy.

There have been great successes in the use of wind and solar energy as well as more recently bio-fuels in supplementing oil and gas. But the scale and availability around-the-clock of these alternatives require that we look further. Nuclear energy is used to produce electricity in almost all industrialized nations, but the long half-life of its radioactive by-products leave behind a large scale, potentially lethal storage problem.

Radioactive decay within Earth over the lifetime of this planet, has given us a vast reservoir of thermal energy that can ultimately be used for controlling our environment and as well as producing electricity. Although our planet was likely molten when it formed, it would only be about 65 million years old to reach its present temperature through cooling as Lord Kelvin calculated in the late nineteenth century. Since we know that Earth is some 4500 million years old from radiometric dating, radioactive heating accounts for the huge difference in age between Kelvin's estimate and the currently accepted age of Earth.

Thus Earth's heat engine that drives convection in the solid mantle, is responsible for driving Earth's plates on the surface to build mountains and form volcanoes. It is primarily the heat associated with Earth's plate tectonics that is the source of geothermal energy.

Since the grinding of Earth's plates in convergent zones is responsible for the crustal heating that produces volcanoes, plate boundaries are a likely place to find significant geothermal sources. Equally important are spreading centers under oceanic and continental rift zones which are high temperature regions of Earth's crust. Transform faults at plate boundaries where plates slide past...
each other are also potential locations of anomalously high temperatures. Thus all the regions where geothermal sources are likely to occur are in a very narrow region close to plate boundaries where most of Earth's earthquakes are found.

Knowledge of plate boundaries is a firm basis for the location of potential geothermal sources for the generation of electricity. While geophysical and geochemical methods are available for finding geothermal sites, these are often used only to delineate the source after the sites have been found by observing steam coming out of the ground. Ultimately the extent of a reservoir can only be known through drilling.

Conversion of geothermal into electrical energy is a well established procedure. At high temperatures above boiling point of groundwater, steam is captured to drive a turbine directly. At lower temperatures or if the groundwater is caustic, a binary system is used to buffer the steam turbine.

Installed capacity for generation of electricity from geothermal sources worldwide in 2005 was 8933 MWe [1]. While geothermally generated electricity worldwide is only about 0.4% of total electricity generation from all sources, there remains vast geothermal potential for the production of electricity. One of the best examples is Nicaragua where a very limited amount of the unused geothermal sources is being developed.

2 Geothermal fields in the Nicaragua Region

Like many parts of the world, the Central American countries have vast and undeveloped geothermal reserves that potentially could generate significant amounts of clean or “green” electricity. These geothermal fields extend through Guatemala, San Salvador, Nicaragua and Costa Rica. The volcanic activity along the west coast of these countries is caused by the steep (60° angle) [2] and rapid (8cm/year) [3] subduction of the Cocos plate under the Caribbean plate along Middle America Trench.

Geothermal fields in Guatemala are currently estimated to have about 150MWe in three geothermal fields with exploration under way in four additional fields [1]. San Salvador’s geothermal reserves are currently estimated to be about 300MWe and potentially exist in two developed fields and four additional fields under the early stages of exploration [1]. In Costa Rica, one geothermal field has been extensively developed with a total installed capacity of 162.5MWe with two additional fields in the early stages of exploration. [1].

Geothermal fields in Nicaragua exist along the Cordillera de los Marrabios volcanic range on the west coast of Nicaragua as shown in Figure 1. The Momotombo field at the southeastern end of this range has been developed since the 1980’s and currently has an installed capacity of 77.5 MWe although actual output is currently only about half of this because of steam production limitations related to the initial development and subsequent management of the reservoir. The San Jacinto-Tizate geothermal concession lies midway along the Cordillera de los Marrabios volcanic 90 kilometers northwest of the capital Managua and is described in more depth later in this paper. Total estimated Nicaraguan usable geothermal potential was estimated in 2005 to be about 1000MWe [1] while current estimates range as high as 2000 MWe.

3 What is behind the successful development at San Jacinto-Tizate?

Historically, capacities of geothermal energy have been underestimated around the globe. The San Jacinto-Tizate field shown in the inset in Figure 1, has followed this pattern even though established geological, geophysical and geochemical methods had been used [4]. Some 40 years ago, the geothermal potential was estimated to be possibly as high as 100 MWe. However, following more recent significant geoscientific investigations as well as additional drilling and analysis of temperatures and flow rates, it has been estimated that the resource has a 90% probability of being able to support 200 MWe production of geothermal power for at least 20 years.
What can be learned from this jump in estimates of geothermal power in the San Jacinto-Tizate field? Aside from the fact that it appears to be at least as difficult to estimate geothermal resource potential as it is for oil and gas reserves, it appears that there are other significant factors that the management of the San Jacinto-Tizate field development have used to create the successful accelerated development of geothermal resources at the San Jacinto-Tizate field. These successful factors are a combination of:

**A Common Vision for San Jacinto-Tizate** – From the acquisition of the site by a geothermal corporation (Polaris Geothermal Inc. of Canada) and the creation of a local subsidiary [Polaris Energy Nicaragua S.A. (PENSA)] to the present, there has been a common and singular development strategy and vision of the concession. This involved a science based understanding that the potential for extensive geothermal reserves existed. These would be mapped and developed in a staged factual manner that is driven by a shared vision among all stakeholders – management, government, major customers, local people, technical contributors and investors.

**Partners for Mutual Benefit** – The Nicaraguan government and Polaris have operated hand-in-hand throughout to ensure the proper development of San Jacinto-Tizate. For example, the Nicaraguan congress expressed its support for the responsible development of geothermal resources by amending the Law of Exploration and Exploitation of Geothermal Resources. Significantly this amendment provides for a minimum tariff of US$8.5 per kWh for geothermal sourced energy, an increased tax holiday from 7 to 10 years and improved concession rights for new geothermal concessions. In fact, this informal partnership with Nicaragua extends beyond the government since the majority of the staff working on the development of the San Jacinto-Tizate geothermal concession are Nicaraguan.

**The Geothermal Resource** – The rapid subduction of the Cocos plate below the Carribean plate has produced a string of volcanoes paralleling the plate boundary with a number of potential geothermal systems being hosted in the related active fault structures. Following an extended period of investigation by a number of agencies, an exploration drilling program at San Jacinto was undertaken in the 1990’s. Of 7 wells started, 3 potential production wells were obtained, with one well being a significant producer. The recent use of improved well targeting techniques and deviated drilling to strike across identified fault structures has resulted in a significantly higher well success rate, with two new production wells reported with capacities of 16.2 and 22.8 MWe, as well as very useful injection capacity. The field now has over 50 MWe of steam production already under the well head, which is more than 70% of the total production required for the planned 72 MW development of the eastern sector of the field. Following completion of drilling in this eastern sector, drilling of the western sector will be commenced to provide production capacity for the planned additional 130 MWe development of that sector. Coupled with this high quality resource is the presence of a high voltage electrical transmission line as shown in Figure 2.

![Figure 1: Location of San Jacinto – Tizate geothermal concession in Nicaragua. - By permission, White (2008)](image)

![Figure 2: Transmission Corridor – San Jacinto-Tizate](image)
Contrary to some traditional development models, Polaris decided to make use of the existing limited production capacity in the steamfield to operate a commercial pilot plant with 2 x 5 MW back-pressure turbines, which offered the advantage of quick and low cost installation to provide very early income from the project and to demonstrate to investors and lenders that a geothermal project could be constructed, operated and receive revenue in Nicaragua. This initial development, undertaken before the high expenditure (and associated risk) associated with fully drilling the resource, has been a key element in providing confidence to the financial community and attracting subsequent investment. Polaris has continued with the staged approach by conducting a first drilling campaign to provide steam for a 24 MW expansion, which has provided invaluable additional information about the resource and well targeting to expand the production up to that required for the second and third condensing unit.

**Technical Excellence** – A highly experienced, engineering and management organization was retained to provide much needed technical expertise. Sinclair Knight Merz (SKM), a world-class provider of geoscientific, engineering and project management skills has participated in more than half of all geothermal power projects developed worldwide. SKM is a 6,000+ person strong organization, with extensive engineering, scientific and project management expertise that has been extensively involved in geothermal projects worldwide since 1975. SKM's geothermal Centre of Excellence, based in Auckland, New Zealand, has a track record of successfully delivering geothermal energy projects across the globe. SKM has conducted significant scientific study into the San Jacinto-Tizate field on an ongoing basis for Polaris, as evidenced by the 3D resistivity modeling shown in Figure 3 and the hydrogeological modeling shown in Figure 4 that incorporate the growing level of knowledge of the resource available to a skilled and experienced developer. Details of the geological interpretation and modeling of this data are given elsewhere [4].

Implementation of the engineering designs has been and is being undertaken by highly experienced, international contractors, competitively selected,
with the first stage, commercial pilot program work being undertaken by The Industrial Company (TIC) of USA (figure 5) and the subsequent full scale development by Construtora Queiroz Galvão of Brazil.

The 2 x 5 MW back-pressure turbines used for the commercial pilot stage were purchased second hand from LaGeo, the geothermal operator company from El Salvador. LaGeo dismantled the units from their original location at the Berlin geothermal field in El Salvador and re-installed at San Jacinto (figure 6). LaGeo then provided skilled operations and maintenance services for the initial 3 years of operation of this plant, at which stage Polaris were able to take over the operation and maintenance function themselves, using the Nicaraguan staff which had by then been trained by LaGeo.

**Higher Order Values** – Polaris has had a value set of treating the local environment with extreme care. In fact, there have been no problematic environmental situations at San Jacinto-Tizate. Further, there is organizational pride regarding the ability to create a profitably sustainable geothermal operation while delivering socio-economic value not only to Nicaragua but also on a larger global scale. In order to comply with the Kyoto Protocol, clean development mechanism ("CDM") projects in developing countries, which capture or cut-down these gases, are being granted credits ("CER’s"). Polluting companies, governments and other agencies are able to buy CER's from companies such as Polaris that qualify as CDM projects allowing them to meet their quotas for reducing their greenhouse gas emissions. When San Jacinto-Tizate generates 66MW per year, it expects to be able to sell 340,000 tonnes of carbon credits annually. This is equal to saving the equivalent of more than 145,000 barrels of oil annually or reducing the CO₂ produced by the power consumed by more than 40,000 North American homes annually.

**4 Conclusions**

This paper provides a ‘recipe’ for the successful development of a project to generate electricity from a geothermal source in Nicaragua. From the initial exploration through to the production of electricity, classical geoscience has been combined with sophisticated engineering design and construction to produce a clean, constant flow of electrical energy. Development of the San Jacinto-Tizate field in Nicaragua shows how science and engineering under the direction of a visionary and skilful management can successfully produce electricity from geothermal energy. Thus our dependence on fossil fuels can be reduced while we produce electricity locally in an environmentally sound manner.

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[1] Bertani, R., World geothermal power generation

