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Small scale geothermal power plants with less than 5.0 MW capacity

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ABSTRACT

With the current interest in small-scale geothermal power plants for rural local generation and off grid power, this paper examines five case histones of such small power plants in terms **of** technology, economic and infrastructure issues. From a technology standpoint ORMAT® has supplied over 200 power modules ranging in size from 0.3 MW to 6.5 *MW*, either singly as small power plants or in combination as larger power plants. These binary technology based power plant modules operate with geothermal fluids at temperatures of 100°C to 315°C. Power plant modules of this type were installed in the cases considered herein as follows: (a) Tad's Enterprises, Nevada USA, with *2* modules rated at 1.75 *MW* total; (b) Empire Geothermal, Nevada USA, with 4 modules rated at 4.8 *MW* total; (c) EGAT Fang Geothermal, Thailand, with one module rated at 300 kW; (d) NAGQU geothermal, Tibet PRC, with one module rated at 1.3 MW and **(e)** Sao Miguel Geothermal No.1, Azores, Portugal, with 2 modules rated at 5.5 MW total.

This presentation details economic, maintenance and resource issues. Conclusions reached are that: (a) small geothermal power projects are technically and economically feasible, with plant and well utilization technologies proven and power costs acceptable, and (b) most of the problems in developing and operating these plants relate to availability of financing and maintenance infrastructure.

KEYWORDS

Geothermal power plants, reliable energy, small scale plants

Introduction

Over 200 ORMAT® Energy Converter (OEC) power modules have been installed, ranging in size from 0.3 *MW* to *6.5 MW*, either singly as small power plants or in combination as larger power plants. These binary based power plant modules operate with geothermal fluids at temperatures of 100°C to 315°C. For low temperature fluids from 100°C to 175°C, the modular Organic Rankine Cycle (ORC) binary technology, shown schematically in figure 1, is the most appropriate. In this technology the heat from the flow of the geothermal fluid is transferred to the organic working fluid in a heat exchanger. The working fluid is vaporized and the vapors drive the turbine and the generator. These power units are simple to install and operate, and have near zero environmental impacts.

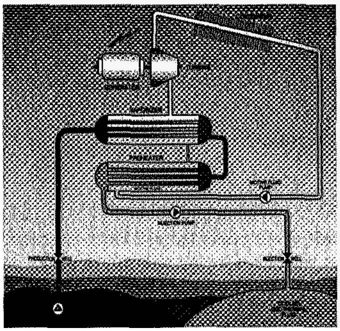

Figure 1: ORMAT® air cooled geothermal power plant.

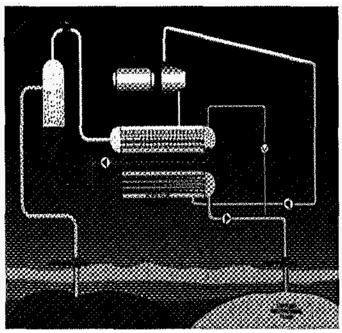

Figure 2: ORMAT® two-phase binary geothermal power plant.

An example of a small scale plant of this type is the Nagqu Geothermal Plant, which will be described in this presentation (figure 8). With two phase geothermal steam/brine flow, a binary ORC configuration, which utilizes all the geothermal energy is employed, as shown schematically in figure 2. In this case the low pressure wet steam is condensed in the vaporizer of the binary ORC system with the brine is used to preheat the working fluid. An example of the use of this configuration in a small scale plant is the Sao Miguel I Geothermal Power Plant, in the Azores, which will be described in this presentation (figure. 9).

For high temperature resources, from 175°C to 315°C, other than pure dry steam, the Geothermal Combined Cycle shown in figure **3** is employed. This process uses a back pressure turbine with the high pressure steam. The wet low pressure steam is condensed in the vaporizer of a binary system ORC, and the brine is used in the process to preheat the organic working fluid. An example of the very successful application of this process is the Puna Geothermal Plant in Hawaii, where ten **3** MW combined cycle modules have been providing ***30*** MW of continuous base load power since 1992 (figure **3).**

The economic and operational issues **are** different for each of the case histories selected, as follows.

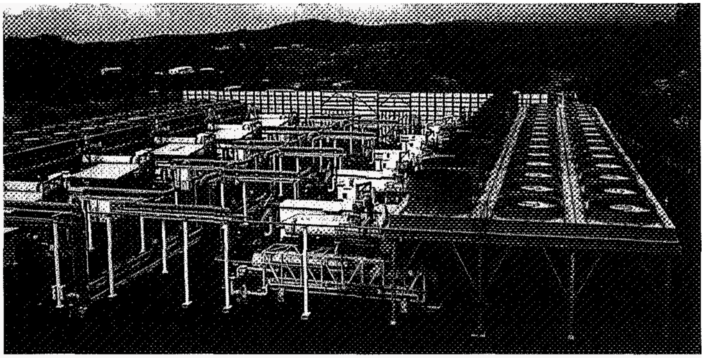

Figure 3: 30 MW Puna geothermal combined cycle power plant.

Tad's geothermal power plant, Wabuska, Nevada, USA

The Wahuska, geothermal resource is located some 100 kilometers southeast of the City of Reno, and produces up to 3,600 liters per minute of hot water at a temperature of 104°C from two pumped wells. The geothermal fluid was originally produced for agricultural processing but has been utilized for power production since 1984. The power plant, which is comprised of two binary OEC modular power units, is rated at 1,750 kW generator capacity. The plant uses water cooled condensers, with a cooling pond.

OEC modular power unit no.1, rated at 750 kW output and shown in figure 4, was installed and started into operation in 1984, and power unit n0.2, rated at 1,000kW output was installed and started into operation in 1987. The units operate automatically, mostly unattended, with maintenance and operation provided by a two person staff. The project is privately owned by Tad's Enterprises, and sells its output power to Sierra Pacific Power Company, at a power price in the range of $0.06/kWh, under a **30** year power purchase agreement (PPA) signed in 1985.

The project experienced minor outages from 1985 through 1990. During very cold weather in 1990 several power tripped outages during unmanned periods resulted in freezing in the condensers and pumps. The plant was repaired and operated commercially until 1996. From 1996 the plant was shutdown due to the unavailability. If Freon 114, which then was the working fluid. The plant was converted to Iso-Pentane as the working fluid in early 1998 and is currently operating profitably, at level of 1,250kW.

This case demonstrates the need for careful maintenance and operating procedures to assure reliable and economically viable operation of small scale geothermal power plants.

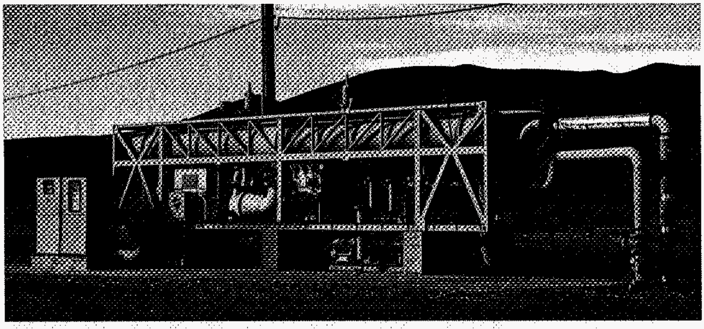

Figure 4: Tad's Enterprise 750 kW unit No. 1

Empire L. P. geothermal power plant, Empire, Nevada, USA

The Empire geothermal resource is located 100 kilometers north of the City of Reno, and currently produces geothermal fluid at 150°C to supply energy to the power plant and process heat to a nearby agricultural processing facility. The power plant is comprised of four (4) 1.2 MW binary OEC modular power units. The plant uses water cooled condensers with an originally installed cooling pond, which was adversely affected by local wind conditions and later supplemented with cooling towers. The plant was placed in operation as an independent power project in late 1987, to supply up to 3.6 MW to Sierra Pacific Power Company under a long term PPA.

The power plant geothermal fluid temperature, which was 137°C in 1987, dropped to 118°C, average of two wells, by 1989 due to injection cooling. Subsequently both the power plant and the agricultural processing facilities were acquired by Empire L.P., and the geothermal resource management was unified. A program of partial surface discharge was instituted to create a wildlife wetland and the injection configuration was modified. By 1997 additional geothermal fluid at 150°C was introduced into the plant supply and a three cell cooling tower was added. The cooler production wells were shut in.

The power plant, as shown in figure 5, is currently operating at 3.85 MW, some 7% above its design output capacity, and the agricultural processing plant operates at full capacity. The improvement in the electrical production of the plant is shown in figure 6.

This case clearly demonstrates the need for careful site specific design criteria and prudent unified resource management to support reliable cost effective operation of small scale power plants.

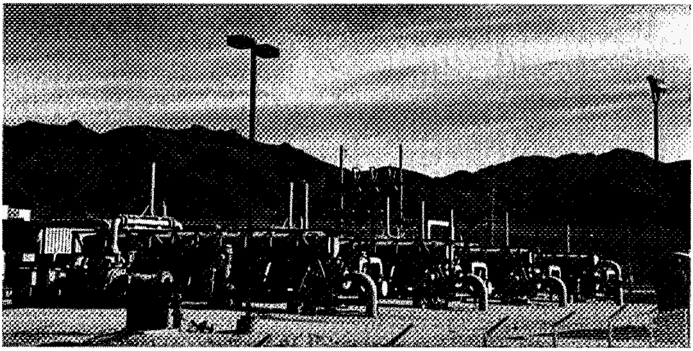

Figure 5 Empire geothermal power plant.

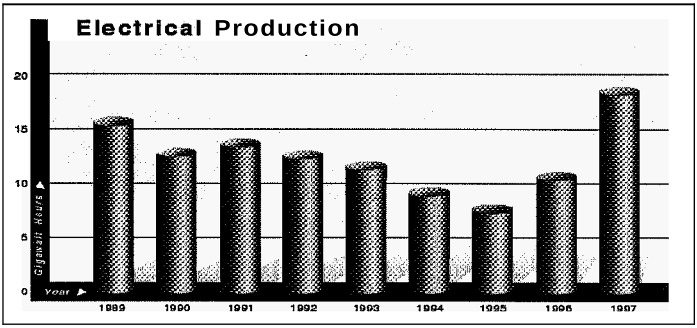

Figure 6: Empire power plant electrical production.

Fang geothermal power plant, Thailand

The Fang geothermal resource, located in a rural agricultural setting near Chang Mai in north central Thailand, utilizes three free flowing wells producing approximately 500 liters/minute of hot water at 116°C. One binary OEC module, rated at 300 kW was installed in 1989 (figure **7).** The OEC condenser is water cooled by a once through flow of river water. The project produces between 150 and 250 kW, with seasonal variations, with excess heat used for cold storage, crop drying and a spa.

The Plant, the only operating geothermal power plant in Thailand, is owned and operated by the Electrical Generating Authority of Thailand (EGAT), and has been in continuous operation since 1989. It has excellent scheduled maintenance, including cleaning of well scaling. Overall plant availability is 94%, and EGAT estimates that **the** cost of the electricity produced **is** between US$0.063 and $0.086.

This demonstrates that a very small power plant may be operated to produce reliable and cost effective electrical power, if it is owned and operated by an experienced and well motivated infrastructure agency.

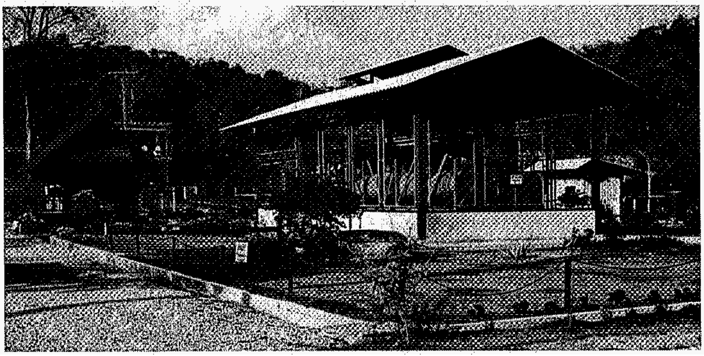

Figure 7. Fang 300 kW modular OEC binary geothermal power plant.

Nagqu geothermal power plant, Tibet, PRC

The Nagqu geothermal power plant, which is located approximately 200 kilometers north of Lhasa, is the highest geothermal plant in the world at 4,500 meters ASL This plant is also the only completely stand alone, off grid geothermal power project The project was funded by the UNDP and is owned and operated by the Nagqu Power Bureau It consists of two wells, drilled under GENZL supervision, and one 1 3 **MW** air cooled OEC bmary modular power plant, installed and commissioned in 1993 (figure 8) The wells are pumped and produce 4,200 liters per minute of geothermal fluid at 110°C

The plant initially operated for 6,400 hours and was shut down following failures of the down-hole pumps **A** cable failure occurred after 15 days and a pump seal failed after 7 months of operation The wells were then operated without the pumps and subsequent severe scaling resulted in the plant bemg shut down The down hole pumps were subsequently replaced and the plant was re-commissioned in August 1998. It is currently operating properly.

This case demonstrates that continuous reliable operation can be achieved with small scale power plants, even in very remote areas, if proper maintenance support is provided. There is no doubt that the Nagqu geothermal provides more cost effective power than the small diesel generators, which it replaced.

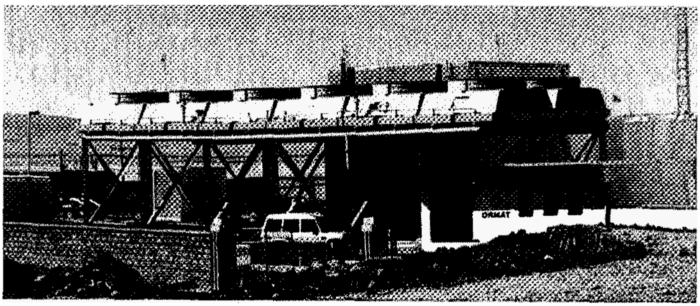

Figure 8: Nagqu 1.3 MW modular OEC binary geothermal power plant.

Sao Miguel No. 1 geothermal power plant, Azores, Portugal

The privately owned Sao Miguel No. 1 power plant, consisting of two dual air cooled OEC modules, (figure 9), commissioned in 1994, and generating approximately **5 MW** which is sold to Electricity of the Azores, Ltd. The project utilizes two free flowing production wells providing 52 t/h of 4.5 bara steam and 180 t/h of 149°C geothermal fluid. The two phase flow is used in a modular binary system, which also makes use of the steam condensate to dilute the injected brine so as to lower the injection temperature and thus extract more heat from the produced geothermal fluids.

The plant has operated continuously, producing a significant portion of the Island of Sao Miguel's base load power, with an availability factor of 98%. Air cooling and 100% injection of all geothermal fluids and gases has resulted in a very low (near zero) environmental impact. With the development of additional production wells the construction of the second 9 MW phase was implemented and recently completed in late 1998.

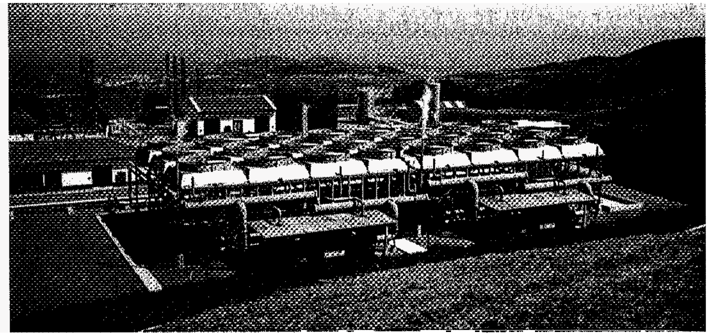

Figure 9: Sao Miguel 1,5 MW OEC two-phase geothermalpowerplant.

Conclusions

Small scale and off-grid power projects are technically and economically feasible. Power plant technologies and well field drilling, production and utilization technologies are proven. In addition project owners find the costs of power production commercially acceptable. Operational problems relate mainly to infrastructure and maintenance. Reservoir management, well field facility maintenance and power plant maintenance issues must be properly addressed. In the opinion of the author, the best way to accomplish these objectives, and obtain the financing required for implementing these projects, is to involve the local interested parties and agencies as active participants in the development and operation of these small scale projects.