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GEOTHERMAL PLANT'S FOR REMOTE COMMUNITIES

Chaya Jivacate[1] N. Forte[2]

[1]EGAT, Nouthaburi, Thailand
[2]Ormat Inc, Sparks, Nevada, USA

INTRODUCTION

Generating electrical power for communities In remote areas or scattered islands has always been a difficult goal to achieve. The Inherent obstacles encountered in order to reach this goal are clear and well known: access difficulties, lack of existing infrastructure and many others. in these areas, also, the power demand is quite low, even though in developing counmes many remote areas would benefit from electrical power, if it were available. In fact, the development of these areas could be achieved at a much more rapid pace with electrical power available, while without it, it would stagnate.

In this paper we will describe a new concept, applicable in those fortunate areas where geothermal activity exists, which allows simple and rapid installation of relatively small geothermal power plants of a few hundred kilowatts to several megawatts, expandable, if required, in a timely manner.

These power plants are based on the well proven technology of self-contained modular Binary Organic Rankine Cycle (ORC) turbogenerator units, to convert geothermal brine heat into elecmcal power.

In the past decade, the extensive operational experience gathered clearly indicates that geothermal energy through the use of binary ORC power plants provides a reliable source of baseload electricity, at costs competitive with other alternative energy sources.

This technology is especially well adapted to remote location applications since:

- It does not require high temperature fluids and therefore does not require deep drilling, (simplifying drilling which sometimes can be done with rotary drilling rigs mounted on trucks) (Olson and Matsunaja, 1988).
- Handles brine mixtures composed of water, steam with high percentage of non condensible gases, therefore remains of simple design and reliable;
- Requires minimum maintenance;
- Does not require highly skilled operators and technicians;
- Does not require imported fossil fuels;
- Is pollution-free and environmentally compatible:
- Suits the scale of the regions' economy.

We will also describe the cooperation between EGAT and ORMAT in the implementation of this concept, leading to the installation of a 300 kW nominal geothermal power plant at FANG. Chiang Mai Province in Thailand. The first months of operation of the plant will be discussed.

In addition, the operation plant of the same concept, applied at Wabuska, Nevada. in the USA will be mentioned .

DESCRIPTION OF THE GEOTHERMAL BINARY POWER PLANT

A Geothermal Binary Power Plant is a Power Plant based on the Organic. Rankine Cycle (ORC). The ORMAT Energy Converter (OEC) is a self-contained modular Binary Power Plant, supplied fully integrated and tested. readv for installation on site. It includes heat exchangers, turbine/generator, motive fluid. lubrication pumps, valves. controls and instruments. All major subassembiies are skid mounted and are packaged within the configuration of a standard 40 foot ISO shipping container. Ail piping between components mounted on the same skid is included. Other than the elecmcnl connection, the OEC only requires connection to the heat source, and to the cooling system (Water or Air Cooled).

The standard OEC skid is presented in modular units in the range of a few hundred kilowatts to 1500kW. These plants can be installed quickly and put on-line in a few months, either singly or in clusters of many units, they are flexible and can be design to accommodate a wide range of geofluid temperatures.

The OEC principle of operation is as follows:

Heat is transferred from the geothermal brines to the organic fluid via heat exchangers (vaporizer) where the organic fluid (or working fluid) is heated and vaporized. It is then expanded in the turbine to a lower pressure and temperature, at which it condenses in the condenser. The liquid phase motive fluid is then pumped back into the vaporizer.

The turbine drives the generator directly. The complete system is fail-proof and operates completely automatically. All possible alarm and failure conditions are automatically handled by the units' computerized control system and its protection features. The unit is suitable for automatic grid synchronization and/or for the stand-alone operation.

By selecting the appropriate working fluid, OEC systems can be designed to operate with inlet temperatures in the range of 80 250°C. The lower temperature limit is primarily restricted by practical and economic considerations.

Larger modules of up to 3.5 MW (Nominal) for utilization of higher temperature steam and brine are also available.

SOME ADVANTAGES OF GEOTHERMAL BINARY POWER PLANTS

Geothermal Binary Power Plants offer a great application flexibility in their ability to accommodate a wide range of brine compositions, including water, steam with high percentage of non condensible gases, as well as a wide range of brine temperatures. They are well suited to making the best use of liquid dominated geothermal reservoirs.

The utilization of liquid (water or brine) dominated geothermal resources, at moderate temperatures, for power generation for which the binary plants are especially well adapted and are the only practical proven solution has substantial advantages including the foliowing, in addition to the ones already mentioned herein:

- More heat can be extracted from geothemial fluids by re-injecting them at lower temperatures than is currently possible with steam turbines operating from flashed stem.
- The use of high vapor pressure working fluid results in a very compact self-starting turbine.
- Using a binary system (where the geothermal fluid is separate from the organic motive fluid) allows the use of relatively hostile geothermal fluids.
- The power system is relatively insensitive to fluctuations of inlet brine flowrate and brine temperature rate as well as to brines comprising high percentage of non-condensibie gases.
- The system is environmental friendlv. and sometimes also pollution abating.

THE MODULAR POWER PLANT CONCEPT

A Modular Power Plant is comprised of a number of ORMAT Energy Converter (OEC) modules which operate on a subcritical organic Rankine cycle. The subcritical cycle results in lower parasitic losses and internal pressures within the power plant. This means that the equipment may be designed with greater simplicity and higher reliability thanks to lower stresses on the components.

In addition, for large size power plants a proprietary cascading principle is used in the interconnection of the modules in order to maximize the overall efficiency of the power plant. With the cascading principle implemented, if one module of the power plant is shut down for maintenance, the remaining modules will utilize nearly the full geothermal fluid flow to operate at increased power levels. The result is that nearly full capacity may be maintained even during periods when major maintenance is being performed on the modules.

Because factory integrated power plant modules are generally employed to construct the full plant, a shorter project implementation period may be anticipated. In fact, it is only the use of the factory integrated module OEC units which allows the execution of projects within a relatively short time frame, with a high degree of confidence.

FANG PROJECT IN THAILAND AND EGAT-ORMAT COOPERATION

Several years ago, EGAT initiated a research and exploration plan aiming at determining the geothermal potential in Thailand for future power generating purposes. Exploration and drilling concentrated in Northern Thailand, specifically in the Fang and Sankanphaeng areas, where shallow reservoirs were discovered. The results of the resource studies effected in the FANG Geothermal Areas near Chang-Mai showed that the present reservoir is water dominated.

Based on these results EGAT decided, in **1988,** to build a Pilot Geothermal Power Plant, at FANG. EGAT looked world-wide for the most renowned and reliable Binary Power Plant equipment, and the ORMAT Energy Converter was chosen. The existing wells flowrate at the beginning of the project determined the size of the power plant: **300** kW Nominal.

A cooperation program was agreed upon between EGAT and ORMAT, under which EGAT would develop the geothermal site, design and construct the entire infrastructure required for the power plant, including wellhead equipment, separator, pumps, piping, valves, and cooling water system, while ORMAT would supply a special small size ORMAT Energy Converter, or Binary Geothermal Power Plant, at a special price, and share its knowledge, expertise and past experience in the field of Binary Power Plants design, and project implementation with EGAT.

This cooperation took the form of an active, open and fruitful informal dialogue between EGATs design engineers team and ORMATs engineers. In fact this dialogue started long before the cooperation agreement was formally signed, and intensified after the signature. The purpose of this cooperation was to optimize the design and finally construct the most reliable, and highest availability Binary Geothermal Power Plant, as well as to provide EGAT with all the back-up interdisciplinary expertise, available to ORMAT, so necessary for the successful completion of EGATs first Binary Cycle Power Plant.

A 300 kW OEC Unit was initially designed based on the available data. At a later stage, when more precise data became available, the unit was adapted to the actual available flow data. The final design Cycle is shown in Figure 2. At the new Design Point, the unit delivers *265* kW.

During the initial design stage, EGAT's engineering team visited one of ORMAT's facilities, and held extensive technical discussions with ORMAT's experts in the fields of advanced thermodynamic design, system design, control system, resource development, materials science, as well as on the subject of ORMATs Power Plant installation, connection operation and maintenance. At a later stage EGAT's design drawings were jointly reviewed, discussed and sometimes adapted to incorporate ORMATs past field experience.

Within the cooperation framework, ORMAT's engineers visited EGAT's offices several times, to continue the dialogue on the system design and power plant interconnection,

ORMAT supplied the ORMAT Energy Converter several months before schedule, and the entire plant is now being commissioned.

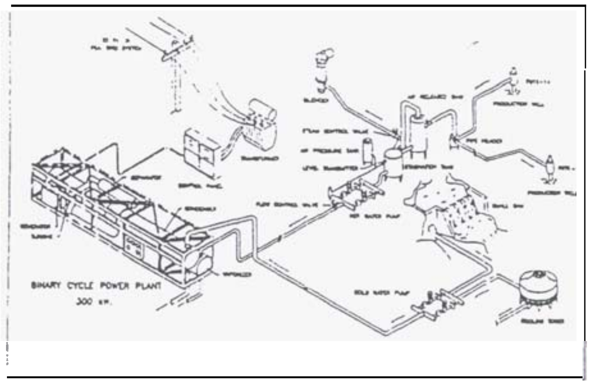

Figure 1 - Fang Project EGAT's Artist's View

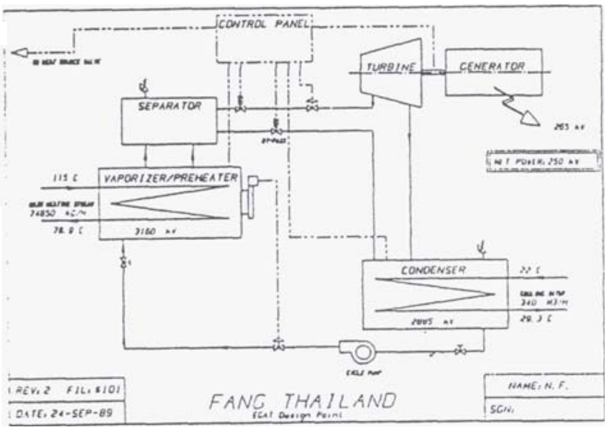

Figure 2 - ORC Diagram

An EGAT artist's overall project schematic view is given in Fig. 1. The corresponding Organic Rankine Cycle of the OEC is shown in Figure 2.

FANG POWER PLANT- INITIAL PERIOD OF OPERATION RESULTS

The 300 kW nominal geothermal binary power plant at FANG was commissioned in mid-December **1989,** and during commissioning tests it generated up to 310 kW **(gross),**

Up to the end of the month of July the unit operated **4,150** hours. The average output power of the plant was **277** kWe in the first month of operation, while the design point is 265 kW. After 3,090 hours of operation the average output power was **172** kWe. This decrease in output power is mainly due to an important decrease of the hot water flow from the well as can be seen in Fig. 3. During this period, the flowrate decreased from 70 m3/h to **22** m3/h, furthermore, the temperature of the hot water source decreased from 120°C to 116°C and the cooling water temperature increased by a few degrees. This decrease in the brine flowrate is due to carbonate scaling in the wells and distribution piping and was foreseen in the design stage. The solution to this carbonate scaling problem, as proven in several other projects, lies in utilizing a downhole pump.

During the first months the overall operation of the power plant was satisfactory. However, some shutdowns, inherent to all running-in periods of plants occurred. Some of the reasons for these shutdowns were due to: Electrical grid failure (generator is asynchronous, however synchronous stand-alone generators are available); allowance for well cleaning, due to carbonate scaling (this problem can be overcome by inserting a downhole pump and maintaining high pressure, thus eliminating flashing in supply pipes); cooling water flow fluctuations (solved after running-in of the cooling water supply system); and to allow for initial period verifications during which minor components were replaced or adjusted. Despite the numerous forced shutdowns of the Power Plant due to the local elecmcal grid failures, the Ormat Energy Converter is functioning to the entire satisfaction of EGAT.

The trip time of the Ormat Energy Converter (OEC) unit represents only **0.1%** of the time elapsed between commissioning, to May **1990,** as shown in Figure **4.** For the following period (months of June - July, **1990),** the OEC mp time remains about the same, while the overall power plant availability increases to about 88%, which is an important improvement, compared to the availability during the power plant running-in **period.**

During commissioning EGAT's operators and engineers were trained on the operation and preventive maintenance of the ORC binary power unit.

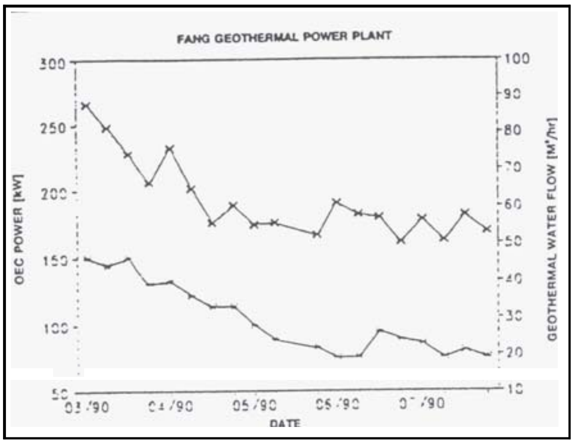

Figure 3 - Fang Output Power

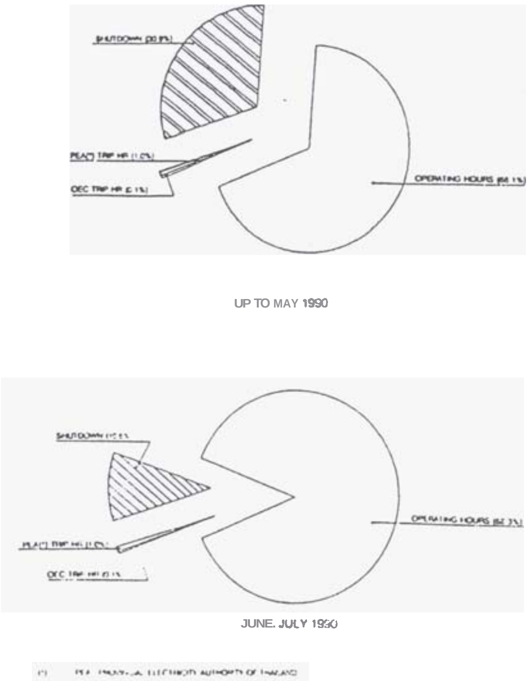

Figure 4 - Operating Hours Distribution

OTHER **SMALL** UNATTENDED REMOTE BINARY POWER **PLANTS**

Descriptions of ORC projects of sizes ranging from few hundred kilowatts to tens of megawatts, can be found elsewhere (3). In this paper we wish to describe one of these objects, with features relevant **to remote** location applications: the Wabuska Geothermal Project, in the State Nevada, **USA.**

This project was the first geothermal power plant to generate elecmcal power in the State of Nevada. It is located a relatively remote area. The first 800 kW turbine has been operating successfully since September **1984.** The operation practically unattended. The availability has exceeded **96%** over the last few years. **Based** on their successful experience with this first units, the owners, TAD's Enterprises, decided to purchase a second OEC of 900 kW. This second unit was installed in early **1987** and is currently in commercial operation. The power produced by the units is sold to Sierra Pacific Power Company (SPPC).

GEOTHERMAL DEVELOPMENT POTENTIAL

Many nations have investigated alternative sources (such as wind, solar, biomass), but have found that none has yet **been** proven **as** applicable in sufficiently large sizes to allow electrification of remote areas by these resources. Both because of the existing, proven technology and because of economical factors, geothermal energy can have a very important role in providing reliable base power for remote areas and islands throughout the world. Countries in Asia and the Pacific, endowed with abundant geothermal resources, seem **to** be natural candidates to utilize the locally available energy for power generation and therefore develop their numerous remote areas and scattered islands.

According to Olson, geothermal energy has many advantages besides being cost-effective and economically competitive with alternate energy sources, it is relatively non polluting and can be developed in a relatively small area. Operating histories clearly show that it *can* be used **as** a reliable baseload **power.**

Modular binary cycle generating units (OECs) are available commercially. They *can* be installed in relatively small incremental generating sizes. They also allow the use of lower temperature geothermal reservoirs, while being adapted to higher temperature brines **as** well. By seeking lower temperature reservoirs, the risk of exploration failure *can* be reduced, and production complications and expenses minimized. Also, according to Olson **(1987),** "Lower temperatures are usually found at shallower depth than higher temperature reservoirs, and it should be possible to drill shallower exploration and production wells with truck-mounted equipment that could **be** off-loaded onto existing port facilities. Truck-mounted drills could traverse existing roads *or* require minimal improvements. Drilling supplies would be less than required for drills used for production drilling on the **U.S.** mainland. Modular binary cycle generating units could be ordered in the **100** and **1,000** kW plus sizes needed for island power requirements, and could **be** expanded quickly **and** at reasonable cost by drilling additional wells and adding additional modular units. By injecting waste brine back into the reservoir, reservoir properties could **be** maintained and **reservoir** life extended, and the cost of expensive surface abatement equipment avoided,'.

CONCLUSION

The operating experience accumulated in the past decade with Geothermal Modular Binary Power Plants shows that this mature technology, when utilized with locally available geothermal resources, can provide efficient, cost effective and reliable baseload electricity **to** remote **areas** and scattered islands, **as** well **as** being built into full scale power plants of several tens of megawatts.

The binary power plants **are** able to accommodate a wide range of brine flows; brine composition including steam, water with high percentage of non condensible gases; and a wide range of brine temperatures.

Their availability in self-contained modular configurations, in addition to speeding-up and simplifying the power plant installation and operation, has the advantage of allowing expansion of the plant and its adaptation to the reservoir *size* in a timely manner.

The Modular Binary Power Plant operation history shows a high level of availability. Specifically, the OEC trip time in the FANG project in Thailand was a bare 0.1 percent during it's first **7** months of operation.

The OEC, allowing the exploitation of low temperature geothermal sources, offers the possibility of economically using shallow reservoirs. The exploration and production costs of such reservoirs **are** lower when compared to high temperature ones, in addition to being of simpler and quicker implementation, especially in remote **areas** *or* in scattered islands.

The Geothermal Binary Power Plant is an excellent solution to providing baseload elecmcal power in such remote areas and scattered islands, in an easily extendible and rapid implementation plan.

ACKNOWLEDGEMENTS

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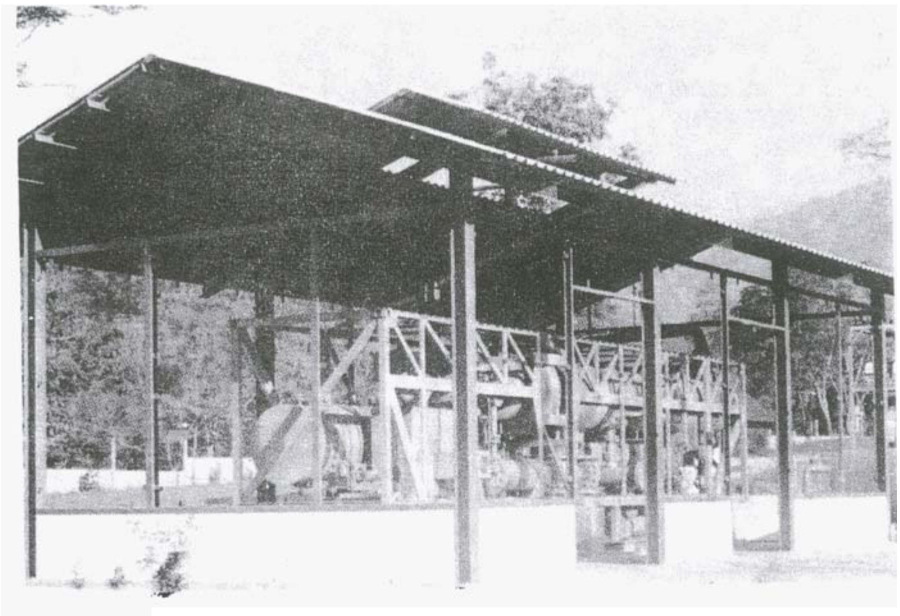

Figure 5 - EGAT Geothermal Power Plant, Fang, Thailand

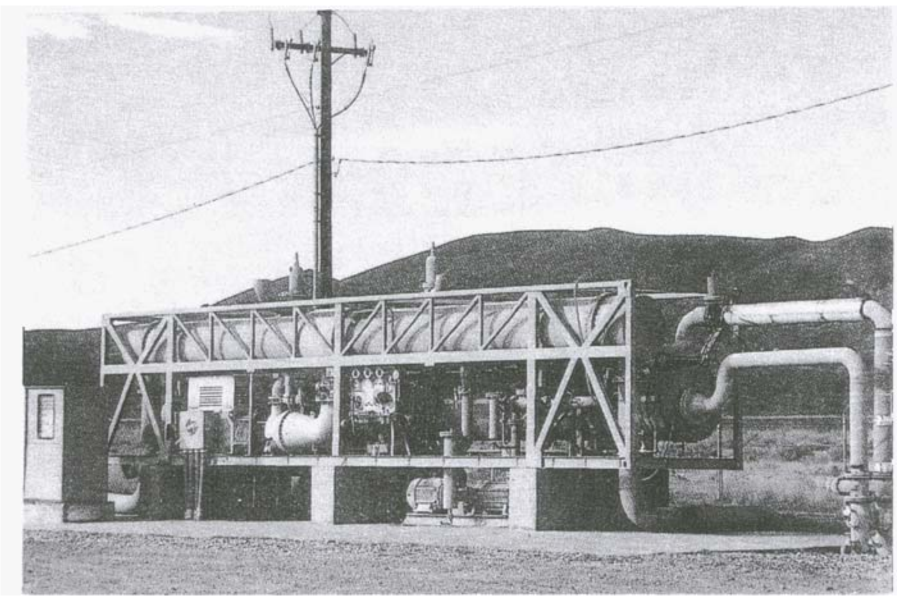

Figure 6 - TAD's Enterprises, Inc., Wabuska, Nevada, USA