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Extending the Operating Life of a Geothermal Project

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ABSTRACT

After some years, or a decade, of operation of a geothermal power station, the plant and reservoir conditions are usually different from the initial design, and continue to change as the reservoir evolves.

Experience and knowledge of the field, and the inevitable changes in operating conditions, normally lead to continuing adjustments to wellfield, plant, and operating conditions.

In all cases the field is optimised by adjusting plant and operation during field life, rather than working to a fixed design.

Introduction

Once a geothermal plant begins operation, a large amount of money has been spent. After some years of operation, a substantial amount is known about the performance of the reservoir. Plant is in place and variations in generation give immediate corresponding variations in revenue and profitability. Marginal improvements in performance are often extremely cost-effective.

The continuing operation of the field and plant can be modified, and lifetime extended, by modifying the physical plant. These changes are primarily engineering modifications, made with the benefit of knowledge about the performance of the field.

Thus the plant normally evolves as the reservoir evolves. This is a natural process and not an indication of faulty initial design.

There are a number of such options that have been taken to extend the life of the project, and to optimise the generation from the fluid available.

These options can be broadly divided into:

- Modify the wellfield
- Modify the well control
- Modify the power plant

We now consider each of these in turn.

Modifying the Wellfield

Inevitably wells decline and makeup wells are drilled. Usually the new wells will be in a different location or a different sector of the field. Frequently injection wells are closed and replaced with more distant injectors. The combined effect is that the location of the production and injection areas of the wellfield moves with time. Usually the new location is the area that would have been drilled originally, had the developer known the reservoir structure.

Sometimes the expansion of the wellfield into the upflow area brings with it problems of higher gas or silica content, and possibly abatement plant may be needed, or different operating pressures.

Moving the Production Wellfield

An example of modifying the production wellfield has been the evolution of production at Wairakei (Thain & White 1993). Initial exploration and drilling, and development, and construction of the power station, was focussed around the original springs. Only with later exploration was the upflow zone, and slightly higher temperatures, discovered at Te Mihi.

With exploitation a steam zone formed in the reservoir. This zone had its highest pressure at Te Mihi. In the 1980s the first of a series of steam wells was drilled at Te Mihi, and connected to the power station. More such wells were drilled and connected over subsequent years to maintain steam flow to the station.

Reinjection is also in the process of implementation, with wells near the power station. The end result of this redevelopment will be to move production toward Te Mihi, and site reinjection near the original production area. The "centre of gravity" of production is moving steadily across the reservoir with the years.

Moving the Injection Wellfield

Palinpinon in The Philippines, like a number of other fields, has experienced very substantial injection returns. The project is described by Seastres et al (1995). The development is located in mountainous country with high rainfall. Sites for roads, pipelines, and power stations are very difficult and costly to create. The development was planned to be very compact at the surface, relying on deviated wells to access the reservoir.

The centre of the reinjection area was 1-1.5 km from the production. As it has now been learnt, the field has very marked structural control, with strongly preferential paths along which fluid rapidly returned to the production area.

As in other fields with injection return problems, the solution was to relocate the injection wells to a more distant site. In all such fields the decision to spend on new injection wells and pipelines is a decision to spend more capital in order to extend the field life. The additional capital expenditure buys additional life for the productive asset.

Adding Injection

For liquid-dominated fields reinjection is primarily a matter of waste disposal. Beneficial effects exist in theory, but are conjectural in practice, and adverse effects of thermal returns are common.

However in the case of vapor-dominated fields, injection is expected to extend field life, and field tests confirm this (Enedy et al 1991).. So most vapor fields now have trial injection systems being commissioned or contingency plans in place for their future use.

Thus injection has been carried out at moderate levels at The Geysers for years, and recent plans to bring additional water from distant source will substantially increase the level of injection.

Modifying the Well Control

The primary change involved here is a change in wellhead pressure, and separation pressure, and turbine inlet pressure, combined with some modification of the turbine.

Design Practice

There have been changes over the last two decades in design decisions on wellhead and turbine pressure. In the 1950s and earlier, Wairakei and Larderello plants were designed for measured well performance, with little rundown allowance. As the extent of reservoir rundown became known there was a reaction toward lower design pressures, to accommodate the expected performance at the end of field life.

More recently, particularly in the high-temperature fields of Indonesia and The Philippines, field optimisation has led to higher pressures. See for example Mills (1995).

For liquid-dominated reservoirs, the higher WHP is a consequence of the higher resource temperatures (typically 280°C), which mean that the wells will sustain high wellhead pressures longer in field life, and against large drawdown in reservoir pressure, than at lower temperatures.

Higher operating pressure can also have advantages in reducing deposition problems by reducing the pressure drop experienced by the fluid in its passage from reservoir to wellhead. The location of deposition depends on pressure: calcite deposits at first flashing and silica deposits in steam wells where water evaporates. Raising operating pressures moves deposition downstream, from the reservoir toward surface. The higher pressure also reduces the capital cost. Later in field life a lower wellhead pressure may be acceptable. Thus operating initially at higher wellhead pressure and reducing this with time can increase total heat recovery. If the higher wellhead pressure is used for additional generation with topping units, efficiency of conversion is increased.

Changes With Time

Whatever the initial design pressures, the field will run down with time. If the wells have declined so that there is insufficient steam to fully load the turbines, more electricity can often be generated by reducing the wellhead and separation pressures as the field runs down, and correspondingly reducing the turbine pressure. There is a balance between the increased well flow at lower pressure, against the increased steam rate of the turbines.

At Ohaaki field, the reservoir has changed very rapidly with time since commissioning. (Clotworthy & Brooks 1993) The field has a two-pressure system, with both HP and IP steam lines and turbines. The HP sets were installed as topping units to use the extra pressure available during the first third of the field's expected life. This two-pressure system permits considerable adjustment, with wells being derated from HP to IP operation, and the HP and IP pressures both being decreased with time. There has been a continual process of re-optimising the pressures and the allocation of the wells. The adjustment of the wells has seen several MW of additional generation for little capital cost or increase in fluid take from the reservoir.

Modify the Power Plant

More usually a field will have a single-pressure system. Changes in operation are then adjustment of this pressure, with associated adjustment of the turbine and the surface pipework (Reimann, 1993).

As the inlet pressure of the turbine is decreased it is necessary to improve the swallowing capacity of the turbine to maximise output at this pressure. This is done by:

- Removing blades rows
- Provision of modified nozzles or blading

Improvement of the swallowing capacity means an increase of the mass flow in relation to pressure. There may be other limitations in the steam piping or turbine inlet valve size.

Apart from the adjustments to inlet pressure, plant can be added or replaced. The commonest incremental change is the addition of a bottoming plant, or a binary plant, to use wastewater. Occasionally topping plant is added with the intention of removing it partway through field life.

Because the generation available from wastewater is low, the economics of bottoming plant can be difficult and such additions are not usually made until the project is confident about field performance. In the past silica deposition was often a problem, but it is now argued that some degree of supersaturation can be accepted. In any event bottoming plant can be evaluated in light of the known chemistry once reservoir behaviour has been established.

Reservoir Chemistry

Silica saturation temperatures in geothermal systems are the temperatures at which the discharged water is just saturated with amorphous silica. This has normally been used as a guideline to minimum wastewater temperature, to avoid deposition of silica in surface pipelines and injection wells.

In high temperature systems with high silica levels the saturation temperatures are correspondingly high. A large amount of energy is unavailable although the wastewater may contribute to some heat recharge when recirculated in the reservoir from the reinjection wells.

Recent advances have been made in using fluids with high silica levels in binary plant. Such plants are reported to have operated successfully at some degree of supersaturation without adverse effects. (Harper et al 1992, Legmann 1992). This approach allows more energy to be extracted from the reservoir.

Binary and Modular Units

Use of combined steam/binary plant allows some flexibility. With a steam turbine using separated steam, combined with binary units using the brine and the exhaust steam, there is considerable capacity to modify the pressures and flows through the plant as the fluid supply characteristics change.

Similarly the use of modular condensing steam units in parallel gives greater flexibility to take more fluid early in field life, then later move the units to another field. This approach is suitable for a developer with several fields.

The modular units give a shorter installation time, and this gives some compensation for the greater cost. However, larger turbines are significantly cheaper per MW. Optimising capital cost leads toward larger units.

Concluding Remarks

Continuing modification of a project can extend its life and increase the efficiency with which the geothermal resource is used. Such modification is a normal part of the history of most long-running projects, and a natural response to the continuing changes in field performance with time, and increasing certainty of knowledge of these changes.

It is frequently the case that a field is optimised by a design with a higher initial operating pressure, and later plant modification to a lower pressure. Such a changing design is often superior to attempting to fix a single design for the life of the plant. As with the initial sizing of the plant (Grant 1996), it is not optimal to try for perfection — the time taken is too expensive.

There is also a balancing between station size and the degree of field modification. With a larger station, closer to the limits of field capacity, there will probably be greater need for continuing modification during field life.

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