Repowering of the Cove Fort Power Plant

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ABSTRACT

The Cove Fort geothermal resource has been explored since the 1970s and generated electricity from 1985 to 2003. The original power plant consisted of Ormat Energy Converters (OEC), a topping turbine and a condensing steam turbine totaling just over 10 MW. Enel Green Power acquired the project rights in 2007. The resource characteristics were evaluated for repowering the power plant and several alternatives were considered in order to maximize the owner's return on investment (ROI). Namely, the design objective is to maximize generation output given the resource data. Ormat did not propose an off-the-shelf pre-engineered unit, rather analyzed the resource, carried out various custom engineering alternative schemes for that resource and chose the most efficient option.

1. INTRODUCTION

After producing for almost two decades the Cove Fort geothermal power plant was decommissioned for another decade before its new owners, Enel Green Power, chose Ormat to repower the site.

Ormat is a vertically-integrated company with decades of practical experience in all aspects of Organic Rankine Cycle (ORC) based energy generation. These units convert low, medium and high temperature heat into electrical energy offering flexible, modular solutions, specifically designed for customization to the resource. The ability to provide full optimization analysis to an entire power plant makes the difference between providing a comprehensive solution and merely providing an energy converting product. All this gives Ormat the ability to maximize the return on investment for the plant owner.

2. COVE FORT HISTORY

The Cove Fort-Sulphurdale (CFS) Known Geothermal Resource Area (KGRA) is located in Millard and Beaver Counties in south-central Utah. After geological studies found there is a potential to generate geothermal energy in the area several different types of concessions were granted to different companies in the early 1970s, which then started an exploration effort. Several gradient wells have been drilled in the area to define its potential and boundaries which led to drilling four exploration wells that proved a resource of 177°C at 1,600m.

With exploration completed, field development was carried out in phases. In 1985 four Ormat Energy Converters with a combined generating capacity of approximately 1.5 MW were installed. In 1988 a 1.8 MW non-condensing topping turbine was added. Finally, in 1990, the third phase added a 7.5 MW condensing turbine utilizing steam from other wells in the area.

Over the years electricity generation suffered from some changes in the resource. In 2003 the plant was finally shut down and has not worked since. In 2007 the plant was acquired by Enel Green Power that had coordinated the repowering process from a technical, commercial and permitting standpoint. After a bidding process, in April 2012 Ormat was awarded the contract to repower the plant which is scheduled to commence commercial operation by year end 2013.



Figure 1: Ormat's old binary unit in Cove Fort

3. RESOURCE CHARACTERISTICS & POWER PLANT TECHNOLOGIES

The Cove Fort resource is defined as brine dominated resource. The thermodynamic analysis conducted by Enel Green Power concluded that the most suited technology for efficient and economical power generation is ORC configuration.

Considering the thermal characteristics of the resource, in conjunction with its chemical

composition, various ORC configurations were evaluated and in order to maximize the net generated power and the plant life cycle cost, thus maximizing ROI for the plant owner.

3.1 The Ormat® Energy Converter (OEC)

The OEC is a power generation unit, enabling geothermal developers to efficiently and economically use the full range of naturally occurring geothermal resources found throughout the world - from low temperature geothermal water to high pressure steam. A single OEC may range in size from 250 kW to 25 MW. All OEC units are self-contained, fully automatic and produce grid compatible power. The OEC is based on the Organic Rankine Cycle (ORC) and uses organic working fluid which is more efficient than steam when operating at low to moderate temperature heat sources. The working fluid is selected to optimize the power output from a particular heat source, temperature and flow. Under production conditions, the working fluid is vaporized by the heat of carried by the stream flowing through the vaporizer and preheater. The vapor expands as it passes through the organic vapor turbine, which is mechanically coupled to the generator. The exhaust vapor is subsequently condensed in an air cooled condenser and is recycled to the vaporizer by the motive fluid cycle pump. OECs are designed for the specific conditions of a wide variety of heat sources. Its main components include a vaporizer/preheater, turbo generator, air-cooled or water-cooled condenser, feed pump and controls.

3.2 Custom Engineering

On first analysis of the Cove Fort data, it was estimated that 24 MW can be generated applying a simple binary unit, see Figure 2.

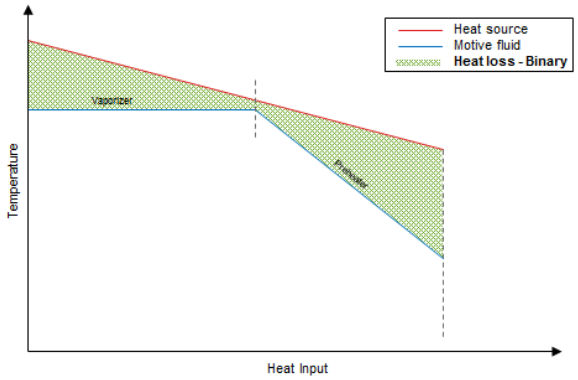


Figure 2: Typical T/Q Diagram

Further analysis indicated that the same resource characteristics can actually generate 26.4 MWe, or 15%, more if a two-level cascaded ORC (Integrated Two Level Unit - ITLU) is applied, see Figure 3. The cost benefit analysis showed that the marginal economic gain during the life of the project far exceeds the cost associated with additional required equipment necessary for this configuration, hence lowering the unitized cost per kW.

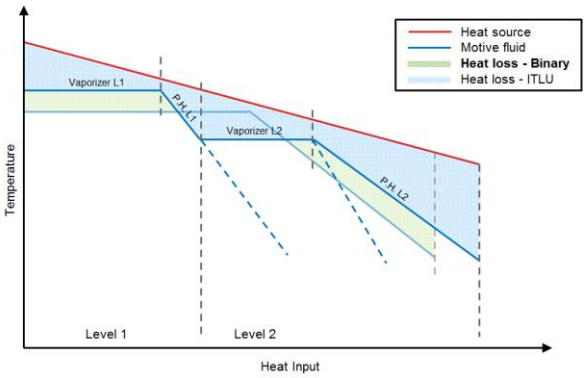


Figure 3: Cascaded OEC- ITLU

While the results looked promising, additional studies indicated that higher absolute generation potential is technically feasible. A Super Critical unit proved that an increase of gross output by 8% compared to the ITLU solution is possible. However, in ultimate examination, high feed pump load erases all that gain and actually **reduce** net generation by 4%.

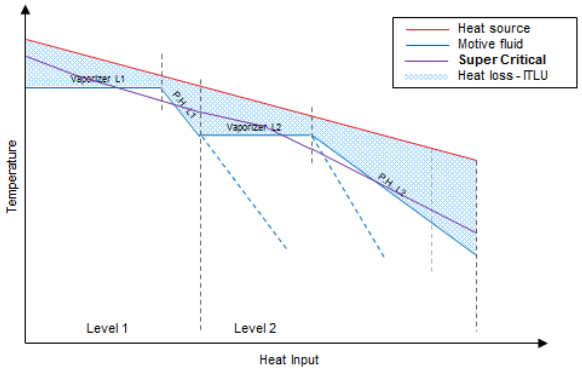


Figure 4: Comparison of super critical and cascaded ITLU diagrams

Taking all these factors into consideration, the engineering team finally concluded that the optimal configuration for this project is ITLU.

Once the custom engineering process is completed from the thermodynamic process standpoint, individual components are designed for its implementation. Some rotating components, such as turbines shaft assemblies, are individually analysed using a Finite Element Model to simulate the stresses the equipment will sustain during its expected design lifetime. Figure 5 shows an exaggerated distortion of the behavior of each of the three turbine stages under maximum design criteria, hence ensuring that their predicted natural frequencies under stress are phased away from other known system excitations.

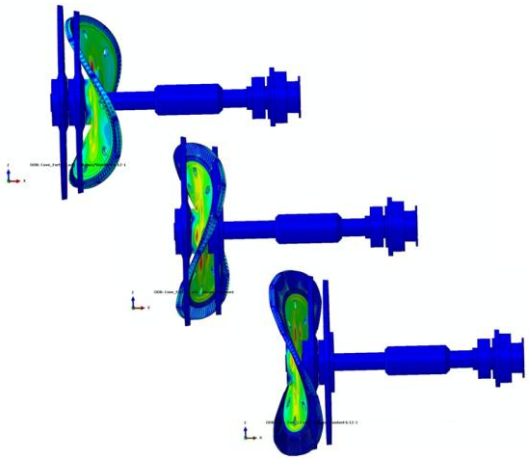


Figure 5: Finite Element Model of shaft assembly

4. LIFE CYCLE PERFORMANCE

4.1 Resource Management

When optimizing power plant design, not only the current status of the resource should be considered but also its behavior over time; maintaining resource productivity and equipment flexibility to react to varying resource are key. Such reliability is vital to maximizing the project ROI.

Not all wells are created equal - Field development may result in any combination of high-gas, high-enthalpy, low-gas, low-enthalpy wells, varying percentage of steam vs. brine and chemical composition.

Plant design influences future well production - 100% reinjection of geothermal fluids minimizes reservoir decline and composition change at a relatively low cost. This is the best practice to ensure the sustainability of a geothermal field. In the last decade, unfortunate experience of major resource decline proved lethal for a number of large projects, largely typified in The Geysers site that lost over half of its strength over time.

Well production will change over time – as a result, design must be flexible and versatile, able to produce electricity when enthalpy declines or increases, and also if it changes its composition, to the extent possible.

4.2 Vertical Integration

Geothermal power plant projects are usually group efforts, bringing together a number of different companies, each expert in a specific stage of the process. Such is the case for reservoir engineering, exploration, drilling, process engineering, equipment manufacturing, EPC construction and O&M services. Ormat is the only company that chose a vertically integrated strategy developing geothermal projects, developing know how and experience in all aspects of geothermal project development. Furthermore, aspects of project financing, permitting, PPA negotiations, and interconnection agreements all intertwine to successfully complete quality projects on time and within budget. The following summarizes the benefits of such approach:

- Greater communication between the teams in charge of different aspects of the project.
- Different elements of the project can be carried out concurrently which would have not been possible if contractual relationships prevailed, shortening overall lead times.
- Each department is aware of others requirements and therefore works to create a product that will best fit the needs of other departments. For example, the engineering team is aware of the needs of plant operators and they in turn share their Operations & Maintenance experience with the engineering team, hence constantly improving the end product.

This extensive in-house knowledge base gained over three decades of power plant operations and development enables Ormat to offer its customers the benefits of its experience.

Figure 6 shows the Cove Fort site depicted in construction, merely 12 months after Notice to Proceed was released by the plant owner.



Figure 6: Views of Cove Fort under construction

5. OTHER RECENT REPOWERING

Another recent example of repowering a non-producing geothermal site was recently completed also in Utah; the Thermo I power plant. Thermo I, located near Thermo Hot Springs, 16 miles west of Minersville, Utah, covers an area of approximately 400 hectares, 0.4 of which are utilized by the power plant itself. The old power plant consisted of 50 PureCycle units of 250 kW each, totaling 10MW. In practice, the units only generated 6.6 MW.

The repowering contract was awarded to Ormat in December 2011. In April 2013, 15 months after receiving Notice to Proceed, the plant was

commissioned. The Ormat unit utilizes all the available brine previously consumed by the old power plant and during commissioning produced 13.5 MW, more than double the generation prior to the repowering efforts. The entire repowering project consisted of undertaking the design, engineering, procurement, delivery to the site, construction, fabrication, commissioning, start-up and testing of a new power plant on site. Spent fluids are disposed of by reinjection into existing injection wells; both production and injection will take place using the existing gathering system lines.

The Power Plant configuration consists of one (1) Integrated Two Level Ormat Energy Converter (OEC) unit, incorporating one (1) 14 MW double ended shaft generator driven by two (2) 1800 RPM direct coupled organic fluid turbines, heat exchangers, cycle feed pumps and all other related equipment.



Figure 6: Thermo I geothermal power plant

6. CONCLUSIONS

The repowering process, currently in advanced stages in Cove Fort, Utah, the Thermo I near Thermo Hot Springs, Utah and other past repowering initiatives proved that a poorly performing geothermal power plant can be an opportunity for a successful turnaround. Careful analysis of a thermodynamic solution fit for the existing resource, coupled with meticulous customisation of the plant components, can provide new life to underachieving developments. This is of particular interest for older plants, utilizing geothermal resources that changed over time, often declining in enthalpy. Core competence over all aspects of these ventures ensures the completion of successful growth of base load electricity generation, obtaining the cleanest of all renewable sources of energy.

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