Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

Cove Fort – Binary Power Plant

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Keywords: power plant; binary; custom engineering; ORC

ABSTRACT

Enel Green Power acquired the rights to the Cove Fort geothermal project in 2007. In the past, the project contained an both an operational flash power plant and Organic Rankine Cycle (ORC) equipment, however, over time, the steam resource diminished. Through extensive work, Enel Green Power was able to convert the well field into a sustainable, liquid dominated geothermal resource. Additionally, the challenges of a changing power market and the approaching termination of the ITC cash grant provided a unique set of hurdles for the project to be economically attractive. These hurdles were overcome through a collaboration with Ormat Technologies; coordinating a disciplined power plant design and project execution which resulted in the project meeting its expected performance, deadlines and budget. Today, the Cove Fort geothermal power plant is operating above expectations and has proven, once again, that geothermal power is a sustainable and effective solution for today, and the future.

1. INTRODUCTION

Enel Green Power, chose Ormat to develop this new project, considering its decades of practical experience in all aspects of Organic Rankine Cycle (ORC) based energy generation. These ORC units convert low, medium and high temperature heat into electrical energy that offers flexible, modular solutions, capable of being customized to a given resource. Additionally, the ability to provide full optimization analysis for an entire power plant makes the difference between providing a comprehensive solution and merely providing an energy converting product. The collaboration between the two organizations allowed to maximize the plant return on investment owner.

2. COVE FORT HISTORY

The Cove Fort Sulphurdale (CFS) geothermal resource area spans Millard and Beaver Counties in south-central Utah. After geological studies found there was a potential to generate geothermal energy in the area several concessions were granted to different companies in the early 1970s, which then initiated an exploration effort. Several gradient wells were drilled in the area to define its potential and boundaries, which led to the drilling of four exploration wells that proved a resource of 350°F at 5,200 feet.

3. A NEW ERA, AND NEW DEVELOPMENT

Over the last decades, geothermal development has shifted towards the use of liquid dominated resources, as the steam producing fields were being exhausted as a source for new development, and power generation technologies made lower temperature resources economical to develop and operate. For example, in the last 20 years only 5 new steam dominated geothermal project has been developed in the western United States. Alternatively, there have been over 40 liquid dominated geothermal projects developed in the western United States in the same period, and that trend is expected to continue in the foreseeable future.

In 2007 the Cove Fort project was acquired by Enel Green Power. The first order of business was to evaluate the geothermal resource to determine operating parameters and its sustainability.

Enel Green Power had coordinated the development process from a technical, commercial, and permitting standpoint. After a bidding process, Ormat was awarded the contract to supply the plant in April 2012. The plant commenced operation in November 2013, about a month ahead of its planned schedule.

Figure 1 (a): Site view March 2013.

Figure 1(b): Site view September 2013.

4. RESOURCE, POWER PLANTS AND CHALLENGES

The Cove Fort resource was defined as brine dominated and research conducted by Enel Green Power concluded that the most well suited technology for efficient and economical power generation was an ORC-based configuration.

Considering the thermal characteristics of the resource, in conjunction with its chemical composition, various ORC configurations were evaluated in order to maximize the net generated power, minimize plant life cycle cost, thus maximizing ROI for the plant owner.

However, there were other looming challenges to overcome. Enel Green Power was confronted with a strict timeline and a fixed budget to complete the project. At this time, early in 2012, the DOE's 1603 program provided a 30% of the project's capital investment as a cash grant, if the project was brought online by December 31, 2013. Additionally, the effect of cost overruns for the Cove Fort project would drastically affect the project's ROI, and were therefore deemed unacceptable.

This meant that Enel would be required to choose a technology option and EPC contractor that could reliably complete the Cove Fort project, with the highest capacity for on time completion, lowest risk for cost overruns, and also provide the most reliable and proven technology. For Enel, this is a very careful and rigorous process, which requires endless attention to detail and a very close collaboration with the contractor and technology supplier, unlike most projects today. Additionally, Enel mandates that its projects maintain the strictest safety standards and the highest quality of workmanship.

Enel, a pioneer in geothermal development in Italy, , chose Ormat for this challenging project after extensive evaluation . Ormat is an ORC technology supplier and EPC contractor that offers a single point of responsibility, and has the most experience in the on-time, successful completion of geothermal power plants in the market today. Ormat has been designing, manufacturing, and constructing geothermal power plants for over three decades, 1750 MW in total, and additionally is a successful geothermal developer with over 600 MW of ORC-based geothermal and Recovered Energy Generation (REG) projects.

The Cove Fort project power plant and well field construction was officially released in July, 2012 with commissioning set for December, 2013.

4.1 The Ormat® Energy Converter (OEC)

Ormat's 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 – to generate electrical energy. A single OEC may range in size from 250 kW to 25 MW. 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. 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 an 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 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.

4.2 Custom Engineering

Initial analysis of the Cove Fort data concluded that an estimate of 24 MW can be generated applying a binary unit, see Figure 2.

Further analysis, comparing alternate ORC circuits, 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. This configuration incorporates the use of an additional turbine at a higher pressure, increasing the overall efficiency, see Figure 3. The cost benefit analysis indicated 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.

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% (to about 28.5MW) compared to the ITLU solution is possible. However, in ultimate examination, high feed pump load erases all that gain and actually reduces net generation by 4%.

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

The next step in the customization process, after completing the thermodynamic analysis, is to select and design individual major components. 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.

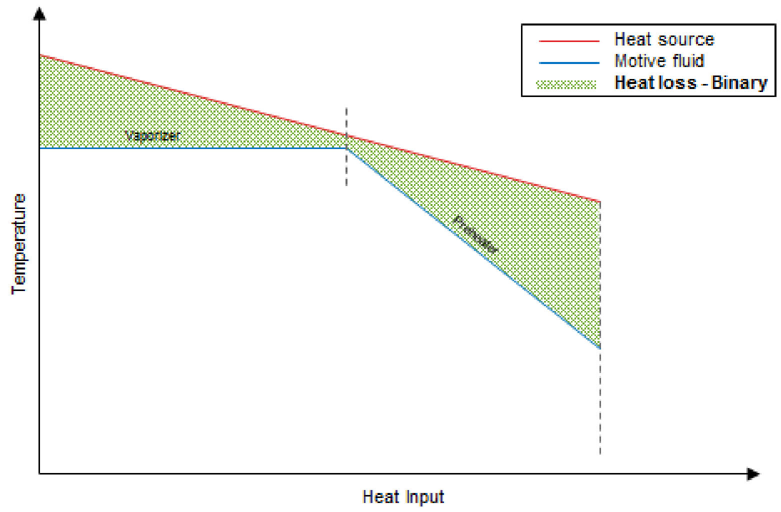

Figure 2: Typical T/Q Diagram.

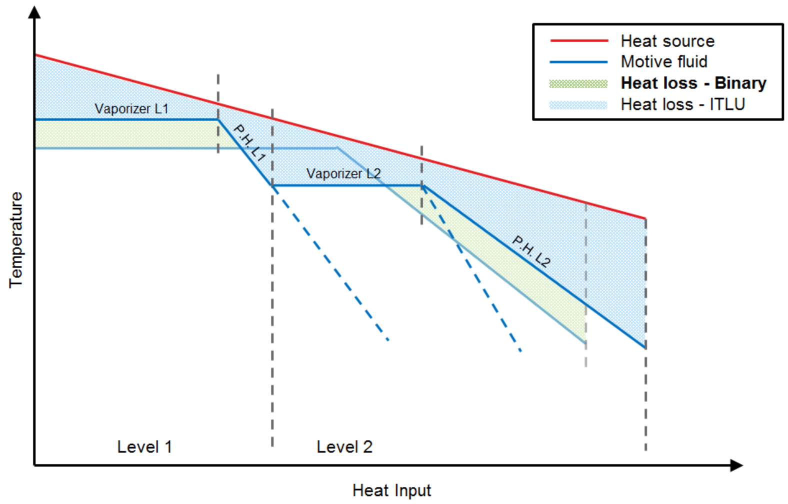

Figure 3: Cascaded OEC- ITLU.

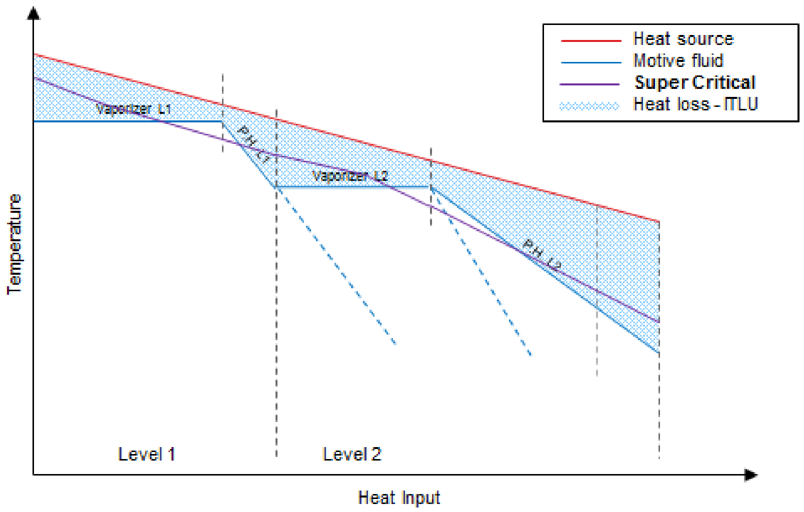

Figure 4: Comparison of super critical and cascaded ITLU diagrams.

5. LIFE CYCLE PERFORMANCE

5.1 Resource Management

When optimizing power plant design, not only should the current status of the resource be considered but also its behavior over time; maintaining resource productivity and equipment flexibility reacting to variation in a resource is 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.

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.

5.2 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, Engineering-Purchasing-Construction and Operation & Maintenance 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 to be carried out concurrently, which would have not been possible if contractual relationships prevailed, shortening overall lead times.
- Each team 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 O&M 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 5 shows the Cove Fort site depicted in construction, merely 12 months after Notice to Proceed was released by the plant owner.

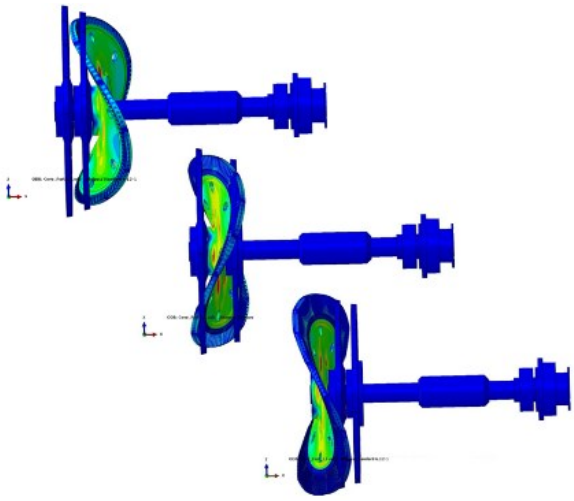

Figure 5: Finite Element Model of shaft assembly.

6. CONTROL PHILOSOPHY

The plant control system is designed to control and monitor all plant subsystems;

- OEC-I
- OEC-II
- Balance Of Plant (BOP)

The control philosophy defines the control loops for these subsystems and describes the OEC operational steps and the required conditions for progressing from step to step. In addition, the control philosophy defines all the I/O's in the plant and determine the logic relations between them. For example, defining the required opening position of a certain valve following a change in a pressure transmitter. The control philosophy defines the alarm and trip set points for each failure or warning in the plant.

The plant can be remotely monitored and controlled which helps the operators to both diagnose and troubleshoot problems and start or stop the unit from a distance. Additional remote monitoring systems are connected to the PLC, such as Vibnode which continuously indicate the turbine vibrations and is used for predictive maintenance studies.

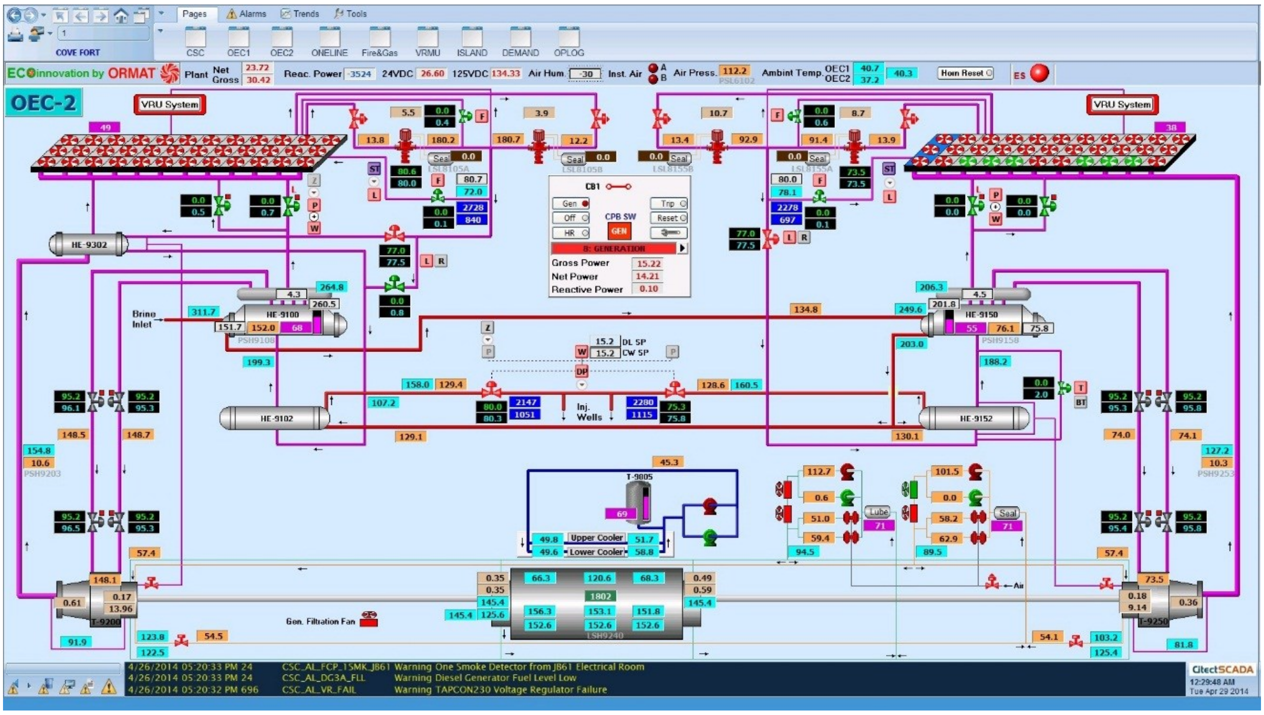

Figure 6: Typical HMI screen shot.

7. ISLAND MODE

Island mode is an operation mode in which the power plant produces power for house loads while the electric transmission grid is unavailable. This allows for continuous operation of the power plant, thus reducing the frequency of the use of the starting and stopping of equipment (such as production pumps) hence minimizing, or even eliminating, the time required for synchronization back to the grid.

During an event of a grid loss or plant main breaker failure, the plant control system will operate the OEC into Island mode step. The initial operation includes precautionary actions in order to protect the turbines and generators from overspeed and damage. After reducing the turbines and generators speed to a defined set point the control system takes over speed control enabling it to control the frequency. The plant will generate the required power according to a continuous calculation of house loads.

Following an operator request, the control system synchronizes back to the grid automatically, and closes the plant's main breaker.

8. CONCLUSIONS

The construction process, currently in advanced completion stages in Cove Fort, Utah, and other past similar initiatives have proven that an underperforming 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 optimisation of 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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