NEW FOCUS ON WELLHEAD POWER GENERATION

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ABSTRACT

Geothermal wellhead power generation units are increasing in popularity due to speed and simplicity of installation, portability, and low-operating cost. They can utilize exploration wells, or wells deemed to be sub-commercial but still able to support a small-scale application. A significant benefit to using wellhead units is early generation of power during wellfield development of large projects. The power can be delivered into the local grid, or it can be used in support of drilling activities. Installing wellhead units early in the development phase can also help quantify the response of the reservoir to production, which can assist in calibrating reservoir models. Wellhead units are now either planned or being installed at various sites in Kenya. Geothermal Development Associates (GDA) recently supplied and successfully commissioned the first wellhead unit at Kenya's Eburru geothermal field.

1. WELLHEAD POWER GENERATION

The term "geothermal wellhead power generation" is typically used to describe a power project that utilizes a single production well with the plant located close to the well – perhaps even on the same pad as the well. The implication is that such plants are considered small-scale applications compared to larger plants that utilize a system of many interconnected production wells.

There are many developing countries with governments committed to increasing the role of geothermal power in their electrical generation mix. It typically takes several years from the time drilling commences until a large project is complete. During the drilling phase of development, wellhead plants can be installed to put the first few wells to beneficial use providing power long before a large plant comes on-line. Once the large plant is commissioned, wellhead units designed for portability can be relocated to yet another field under development.

A wellhead plant can also be installed using a well deemed unsuitable for a large project due to low capability. Some wells may not be able to contribute if the production characteristics do not match the balance of the field. In this case, a wellhead plant may make economic sense. Geothermal fields under consideration for intensive development may already have exploration wells that can be used for power production using small-scale wellhead plants.

If the application of a wellhead plant at a specific location is intended to be temporary, such as during wellfield development, consideration should to be given to a plant designed for portability. By designing plant components and systems to be modular, the ease of relocation can be maximized.

2. TYPES OF STEAM WELLHEAD PLANTS

2.1 Non-Condensing Plant

Non-condensing plants where steam is expanded to atmospheric pressure and released, are widely viewed as the simplest of geothermal plants. They have the lowest first cost and often have the quickest timeframe from order to operation. See Figure 1.

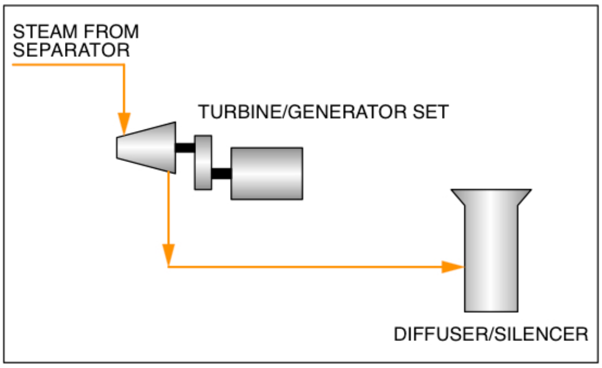

Figure 1. Process Diagram of a Non-Condensing Wellhead Geothermal Power Plant

The highest level of portability, defined by the time and cost to relocate, would typically apply to a non-condensing steam plant. For a given output, this type of plant would likely require the least time to disassemble, transport, and reassemble at a new location. Since minimal civil works are required and the total pieces of equipment are the lowest of any plant type, the cost to install each time is the lowest. This type of plant may be best applied when relocations are expected to be fairly frequent.

As the steam rate (kg/kWh) of this type of plant is comparatively high, the application of non-condensing plants for long-term operation is fairly rare in the industry. However, the impact caused by installing a few small non-condensing plants over the short term on large reservoirs capable of producing hundreds of MW over several decades is likely negligible.

2.2 Condensing Plant

The steam rate of a condensing plant is about half that of a typical non-condensing plant. However, a condensing plant has more equipment and therefore has a higher initial cost than a non-condensing plant on a unit basis (cost per kW). A condensing plant requires comparatively more excavation, foundations, and grading. Additional equipment typically includes a field-erected cooling tower, condenser, cooling water pump, and gas extraction system. More equipment means more electrical cabling and larger electrical gear. The level of complexity, and therefore the cost of instrumentation and control systems, is also higher. See Figure 2.

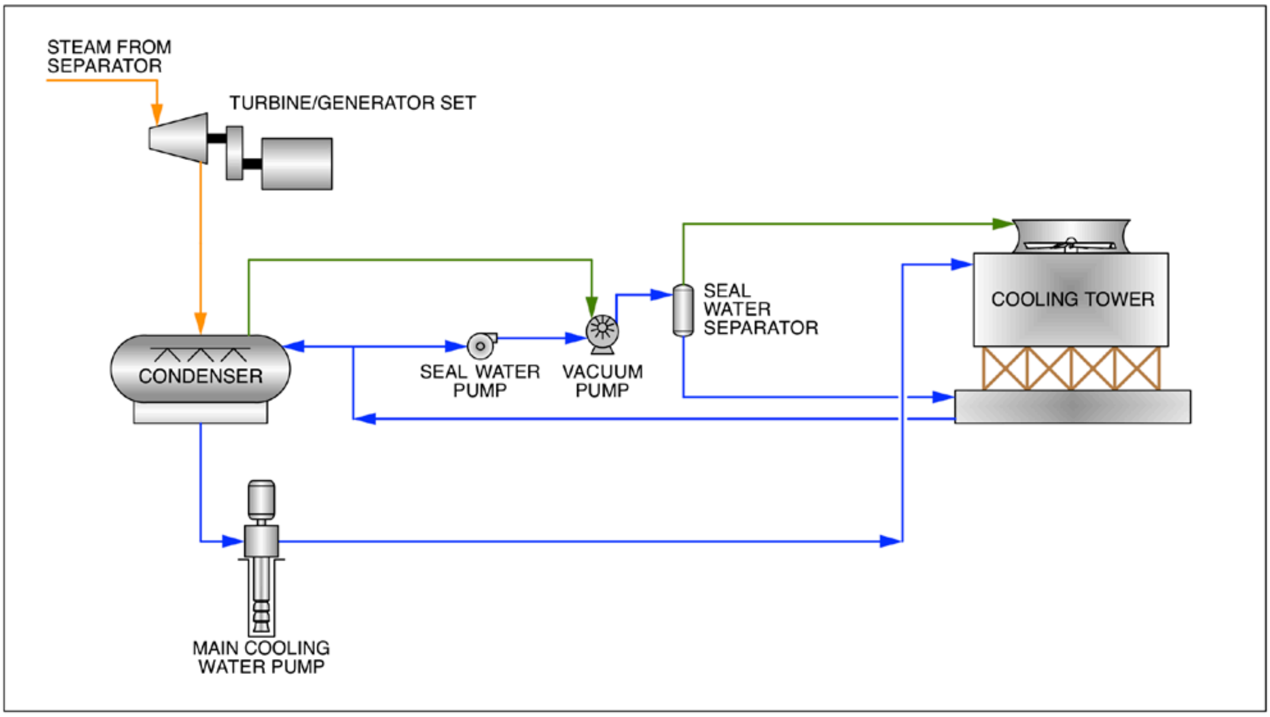

Figure 2. Process Diagram of a Condensing Wellhead Geothermal Power Plant

A condensing steam plant will take more time and incur a higher cost to relocate compared to a non-condensing plant. If the existing location requires restoration, there will be more concrete requiring demolition. If resource utilization efficiency is of prime concern and the need to relocate is not expected to be frequent, this type of plant is likely a better choice than a non-condensing plant.

3. POTENTIAL BENEFITS OF WELLHEAD PLANTS

3.1 Early Economic Return

By installing a wellhead plant and generating electricity sales early in the project, cash flow can begin significantly earlier in the life of the project. A wellhead plant can also be used in place of diesel generators in support of drilling.

3.2 Early Reservoir Response

By installing wellhead units during development of the wellfield, important data can be collected regarding the response of the reservoir to production and injection. Having long-term production data rather than short-term testing data will add to the resolution and confidence of reservoir performance predictions.

3.3 Training Benefit

Small-scale projects offer an excellent way for young professionals working inside geothermal agencies or companies to learn important skills related to successful project development.

Wellhead plants can also provide valuable training for operations personnel. Staff trained at a simple small-scale plant would have a foundation on which to build the additional skills required to operate and maintain a larger plant.

3.4 Political Benefit

Installing a small-scale plant early in the development of a large project can provide intangible benefits relating to the perception of geothermal energy. With small-scale plants, local populations can be introduced to geothermal power in a way that is incremental and less intimidating.

4. ENVIRONMENTAL CONSIDERATIONS

The small scale of these projects minimizes the area required for installation. If installed on an existing wellpad, there may be very little additional surface disturbance required.

Outside the context of a dry steam reservoir, the application of a wellhead plant will require a method of brine disposal. The best case would be if a suitable injection well were properly located to provide pressure support without thermal breakthrough. If the application is intended to be short-term, there may be sites where surface disposal could be approved, particularly if the area has existing geothermal surface manifestations.

Non-condensable gas contained in the steam is another environmental consideration. Although this gas is generally only 1-3% of the total steam flow, it usually includes hydrogen sulfide. If the levels are high enough, hazardous accumulation of H_2S can occur. This can cause an odor issue downwind of the plant. As the steam flow required for a small-scale project is very low in comparison to a larger project, the potential for wide-spread impact is greatly reduced.

5. KENYA GEOTHERMAL DEVELOPMENT

Kenya is an excellent example of a country that has decided to increase the level of geothermal generation as part of its generation mix. Kenya's geothermal resources are located in the African Rift Zone, which is widely held as having tremendous potential for power generation. The country has embarked on an ambitious plan to install thousands of MW of geothermal capacity in the coming decades.

Currently, the installed geothermal capacity operating in Kenya is over 200 MW, representing about 16% of the total power generated. Of this, 150 MW is owned and operated by the Kenya Electricity Generating Company, or KenGen. KenGen is principally a government-owned company that owns and operates about 80% of the power generation facilities in Kenya.

In 2009, the government formed Geothermal Development Corporation (GDC) to focus on developing geothermal resources to sell geothermal energy for electrical generation. Both companies have an interest in the installation of wellhead plants, and each has offered international tenders based on wellhead plants.

5.1 Eburru Project

The Eburru geothermal site is located in Kenya's Rift Valley approximately 140 km northwest of Nairobi, on the flanks of the Ol Doinyo Eburru Volcano, 11 km northwest of Lake Naivasha. Twenty years ago KenGen drilled six exploration wells to an average depth of 2.5 km. The Eburru site is thought to have the potential to support up to 30 MW of geothermal power.

After responding to an international tender issued by KenGen for a wellhead condensing steam plant, GDA was awarded a contract for the engineering design, supply of major equipment, supply of materials, and commissioning of a 2.4 MW wellhead geothermal power plant. Civicon Limited, a Kenyan general contractor selected by KenGen under a separate tendering process, constructed the plant and installed GDA's equipment.

Figure 3. Modular Turbine-Generator Set Ready to Ship from Factory

One well drilled as part of the exploration program encountered a bottom hole temperature of 270°C and therefore was nominated as the production well for the project. Since KenGen decided the existing well pad was to remain as clear as possible to allow for future directional wells, the plant was placed on a new pad adjacent to the well pad. The power shelter, control building, and cooling tower required an area 75 m x 100 m, and the entire plant with wellfield required an area 100 m x 200 m.

GDA utilized an Elliott Company condensing steam turbine designed to make 2.4 MW gross utilizing 21 T/hr of steam at a wellhead pressure of 6.0 bar a. In January of 2012, the plant successfully passed the performance test, generating over 2.5 MW.

The Eburru project is an excellent example of a wellhead plant that provided all of the benefits mentioned above. KenGen elected to provide overall project management in-house to give their young professionals experience with geothermal project development. This included project management tasks such as tendering for construction and managing both GDA and Civicon over the duration of the equipment supply and construction contracts. KenGen personnel were trained in the US at GDA's facility and at major equipment manufacturer's facilities. Operation and maintenance training was given on-site starting with equipment checkout and running through commissioning. KenGen will now be able to gather data regarding the response of the reservoir to production, and gain a better understanding of the ultimate capability of the Eburru resource.

Figure 4. Eburru Wellhead Geothermal Power Plant in Operation

6. CONCLUSION

The concept of installing small-scale wellhead power plants has been part of geothermal power development for decades, but has had only limited application worldwide. By focusing on the benefits offered, particularly regarding early power generation during development of large wellfields, portable wellhead plants may prove to be advantageous.

REFERENCES

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