Geothermal Energy Association Issue Brief: Firm and Flexible Power Services Available from Geothermal Facilities

Introduction

With well-structured and appropriately priced contracts, geothermal plants can provide both flexible and baseload power production. Although traditionally operated as a source of baseload power, the advancement of power plant and control technology allow geothermal power plants to work in several variable modes, such as grid support, regulation, load following, spinning reserve, non-spinning reserve, and replacement or supplemental reserve. These modes are commonly referred to as "ancillary services," which are performed by entities that generate, control and transmit electricity in support of the basic services of generating capacity, energy supply and power delivery.[1] While baseload power has its advantages and unique benefits (*see: The Benefits of Baseload Renewables: A Misunderstood Energy Technology)*[2] the future electricity grid, dominated by variable energy resources (primarily wind and solar), will have particularly important values for technologies that can be flexible.

Flexible geothermal operations have been demonstrated by several projects, including the Puna Geothermal Venture plant which generates 38 MW, and has contracted 16 MW of flexible capacity in Hawaii. This plant provides ancillary services for grid support and these services are identical to those of the existing oil- fired peak generating resources on the Big Island. This plant is considered a first-of-its-kind and could be expanded to other facilities given the right contracts and retrofits.[3] Additionally, geothermal plants at the world's largest geothermal field - The Geysers, located in northern California – have operated in various modes, including traditional baseload, peaking and load-following. The flexible modes were offered as an appropriate response to the needs of one of the utilities purchasing geothermal power from The Geysers. Flexible operations ceased in the early 1990s in response to a combination of low demand and lower costs of generation within the utility's system from hydro, coal, and natural gas power plants.[4]

These examples are consistent with a 2014 industry survey of geothermal power developers conducted by GEA that found two primary reasons why most geothermal power plants operate in baseload mode rather than as more flexible sources of electricity:

1. Sufficient economic considerations to ensure an acceptable return on investment have not historically been offered for geothermal plants operating in a flexible mode.
2. Further research & development to couple geothermal power production and with energy storage technology could further enhance the ability of geothermal plants to operate in a flexible manner.

For most geothermal power plants, flexibility is more of an economic issue than a technical one. For dispatchable power, future contracts need to encourage geothermal operators to offer flexibility in

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[1] Kirby, B.J. "Frequency Regulation Basics and Trends," Oak Ridge National Laboratory Report TM-2004/291, December 2004.

[2] Matek, Benjamin, and Karl Gawell. "The Benefits of Baseload Renewables: A Misunderstood Energy Technology." The Electricity Journal 28, no. 2 (2015): 101-112.

[3] Nordquist, J., Tom Buchanan, and Michael Kaleikini. "Automatic Generation Control and Ancillary Services" GRC Transactions, Vol. 37, 2013.

[4] Cooley, D. A report on cycling operations at the Geysers Power Plant. No. CONF-960913--. Geothermal Resources Council, Davis, CA (United States), 1996.

power delivery, enabling it to compete with natural gas power plants. Geothermal energy is one of the few renewable energy sources to date that can provide both ancillary services and baseload power to a power system.

How can solicitations and contracts promote more flexible geothermal power? One recent study from Livermore Lawrence Laboratory[5] examined several principles that should be incorporated into future geothermal power contracts to encourage flexibility. Two of these are highlighted below.

1. When geothermal plants are intended to be operated in a flexible, load-following mode, contracts should be negotiated to include payment schedules that define the price of power in response to a dispatch signal transmitted by the independent system operator or other load-serving entity.
2. To increase the ability of geothermal plants for frequency regulation (*i.e.*, ramping generation assets up or down over a period of a few minutes), power pricing in future contracts should be negotiated to include payments specifically for frequency regulation services.

Other suggestions in the geothermal industry on how to incorporate geothermal power in more flexible contracts include but are not limited to:

- Utilities could buy capacity from a geothermal plant and then purchase energy as they regulate its output, within the plant's technical limits. Flexible contracts with pricing structures that account for geothermal energy's unique capital structure, would enable flexible geothermal power to compete with natural gas.
- Utilizing storage technologies for geothermal power plants to store power and release the electricity as needed, instead of constantly exporting electricity directly to the grid.[6]
- Ancillary services in the past have traditionally been provided by fossil fuel sources such as natural gas. In many cases these contracts are very highly priced due to spot market gas purchases. Renewables can offer a more economical alternative, since there is no volatility in fuel pricing.

Types of Geothermal Plants and Ancillary Services

The range of ancillary services provided by geothermal technology can be divided into several broad categories. However, the flexibility of a geothermal power plant can depend on the subsurface resource that supplies it. Individual geothermal resources are unique, with wide variations in depth, temperature, chemistry, pressure, permeability and other characteristics. This means that any two fields in the same state or country could be vastly different. However, all geothermal power plants can support the grid frequency during disturbance, within utility specifications, thereby improving the ability of the utility system to ride-through the disruption.[7]

Additionally, while it is physically possible for a geothermal power facility to provide spinning, non-spinning and supplemental reserve it likely would not be economical under traditional power purchase agreement contract terms for a geothermal developer to run a facility in this manner. Terms would have to be modified for geothermal power facilities to be compensated for not operating as baseload and instead compensated as a reserve facility.

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[5] Thomas A. Edmunds and Pedro Sotorrio. "Ancillary Service Revenue Potential for Geothermal Generators in California." In Proceedings, Fortieth Workshop on Geothermal Reservoir Engineering, 2015.

[6] Communication with Pete McGrail, Pacific Northwest National Laboratory.

[7] Linvill, C., J. Candelaria and C. Elder. "The Value of Geothermal Energy Generation Attributes: Aspen Report to Ormat Technologies." Aspen Environmental Group, 2013.

Ancillary Services from ORC Geothermal Plants

An Organic Rankine Cycle (ORC) based geothermal power plant can be equipped with the telemetry and controls required for Automatic Governor Control (AGC) operation. With predetermined unloaded capacity, it can also respond to upward and downward regulation signals. The normal ramp rate for dispatch is 15% of nominal power per minute. The ramp rate for dispatch in a flexible operating mode is 30% of nominal power per minute.[8] Additionally, operating an ORC in a flexible mode does not normally raise operation and maintenance (O&M) costs.[9]

Ancillary Services from Flash and Dry Steam Geothermal Plants

While there are a number of ways to load follow with a flash based geothermal power plants, the published ramp rate for flash plants is about 2% to 5% nominal power per minute at typical running loads, although ramping from a cold start generally takes longer.[10]

There are a few methods for operating a flash geothermal plant flexibly. The first involves venting steam or otherwise by-passing the turbine, while continuing to operate the wellfield normally. This can be implemented quickly, allowing a flash plant to ramp and load follow but with slightly higher O&M costs. Additionally, the geothermal resource can be depleted in this method without having realized the full economic and societal benefit that geothermal power brings. The second and more ideal method, which conserves the resource but is less suitable for rapid load changes, is to gradually throttle the multiple productions wells back to reduce the total geothermal fluid flow to the plant.[11]

For dry steam facilities, compensating a geothermal operator for additional O&M costs would help enable these plants to operate more flexibly. It is generally possible to cycle, ramp and load follow with dry steam plants, although, past experiences with using geothermal technology in this manner have shown increased operation and maintenance problems with equipment and systems.[12] Studies are currently underway to find ways to improve the flexibility of dry steam geothermal facilities.[13]

Conclusion

The technology to provide ancillary services is available for most operating geothermal power plant facilities today, and likely for all new power plant facilities. However, usually there are economic reasons working against these options. Simply put, the reason geothermal power does not currently operate flexibly is that current contracts with geothermal operators did not request or address these ancillary services. Utility companies or balancing authorities who wish to contract for flexible geothermal resources can now do so with confidence, and should be prepared to structure solicitations and offer contract pricing accordingly. Additionally, further R&D focused on coupling energy storage technology

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[8] *Ibid.*

[9] Communication with Josh Nordquist, Ormat Nevada Inc.

[10] Wallace, K. and Harvey, W. "Geothermal Plants Load Following Capabilities and Challenges." EPRI, 2013.

[11] *Ibid.*

[12] Cooley, D. A report on cycling operations at the Geysers Power Plant. No. CONF-960913--. Geothermal Resources Council, Davis, CA (United States), 1996.

[13] "Calpine to Receive California Energy Commission Grant to Study Flexibility Enhancements at The Geysers." Sacramento, Calif. September 30, 2014

with geothermal plants can improve the flexibility of geothermal power. This research would particularly help large flash plants to operate effectively and economically in a flexible mode.

The continuing trend of increasing flexibility in the electricity grid results from many factors, notably including an influx of intermittent power resources, changing demand, and the increased presence of electric vehicles.

Geothermal power remains one the cleanest energy resources with some of the lowest land use of any energy technology, including other renewable sources. Although traditionally a baseload source of electricity, which will continue to be important because of retirements of coal and nuclear resources, geothermal power can and does offer flexibility. Increasing the flexibility in generating and dispatching geothermal power can be achieved through appropriate pricing structures that recognize geothermal power's up-front costs and acknowledge its stability on power grids. Geothermal power producers have already demonstrated the ability to operate flexibly, and geothermal facilities engineered or incentivize to do are fully capable of providing ancillary services such as regulation, load following, spinning reserve, non-spinning reserve, and replacement or supplemental reserve.

Glossary of Terms

Contingency Spinning Reserve is generation (or responsive load) that is poised and ready to respond immediately, in case a generator or transmission line fails unexpectedly. Spinning reserve begins to respond immediately and must normally fully respond within 10 minutes. Enough contingency reserve (spinning and non-spinning) must be available to deal with the largest failure that is anticipated.

Dry Steam, Flash, and **Binary (or ORC)** are the three main types of geothermal power conversion technologies. In dry steam technology, steam is withdrawn directly from a subsurface geothermal reservoir and used to run the turbines that power the generator. In flash plants, high-pressure and high - temperature geothermal fluids separate ("flash") into steam and water either in the reservoir, in the well, or in a surface separator as a result of pressure decrease. The steam is delivered to a turbine that powers a generator and the resulting condensed steam and separated water are injected back into the reservoir. In binary or ORC (i.e., organic Rankine cycle) plants, geothermal fluid is prevented from flashing by maintaining the pressure and is used to heat a secondary liquid called a working fluid, which boils at a lower temperature than water. Heat exchangers are used to transfer the heat energy from the geothermal fluid to vaporize the working fluid. The vaporized working fluid, like steam in flash plants, turns the turbines that power the generators. The geothermal water is injected back into the reservoir. The binary configuration is a closed-loop system with zero emissions that maintains complete separation from groundwater sources.

Frequency Response is the ability of generators to help ride through a system disturbance. If the total interconnection generation exceeds customer demand, the frequency increases beyond the target value (typically 60 Hz) until energy balance is achieved.

Load Following is a slower response (from several minutes to a few hours) whereby available resources are dispatched to follow system ramping requirements. Load following is not a defined FERC service, but is obtained from intra-hour and hourly energy markets. Furthermore, a load following power plant is a power plant that adjusts its power output as demand for electricity fluctuates throughout the day and typically falls between baseload and peaking power plants in efficiency, speed of startup and shutdown, construction cost, cost of electricity, and capacity factor.

Non-Spinning Reserve is similar to spinning reserve, except that response does not need to begin immediately. However, it must be synchronized to the grid within 10 minutes, and capable of producing power for at least two hours.

Regulation is the time frame during which generation (and potentially load) automatically responds to minute-by-minute deviations in a supply-demand balance. Typically, signals are sent by an automatic generation control (AGC) system to one or more generators to increase or decrease output to match the change in load. The frequency regulation control portion of the AGC system is typically called the load frequency control (LFC). Changes in load during the regulation time are typically not predicted or scheduled in advance and must be followed by generation reserve capacity that is online and grid-synchronized.

Replacement or Supplemental Reserve is an additional reserve required in some regions. It begins responding in 30 to 60 minutes. It is distinguished from non-spinning reserve by the response time frame.

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