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A REPORT ON CYCLING OPERATIONS AT THE GEYSERS POWER PLANT

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ABSTRACT

In August 1994, Pacific Gas and Electric Company (PG&E) and the steam suppliers for the majority of its Geysers Power Plant executed new steam sales agreements that allow PG&E to dispatch or cycle generation from its geothermal units. PG&E began cycling those units that month and between then and May 1996 had deferred more than 3,500,000 megawatthours of geothermal generation when lower cost power could be purchased elsewhere.

There are several reasons, including economic and technical reasons, for cycling a geothermal field or project, but there are also a number of problems associated with this type of operation. The purpose of this paper is to briefly discuss some of the benefits and problems and to report on several of the solutions that have been applied or are being tried to insure continued operation of this resource.

BACKGROUND

PG&E began operating the first unit at its Geysers Power Plant in 1960 with steam purchased from Magma-Thermal Company. At that time geothermal generation was considered a "baseload" electrical resource. A simple definition of baseload is that the resource operates at full available load as continuously as possible. The initial Agreements for the Sale and Purchase of Geothermal Steam which PG&E entered into with its geothermal steam suppliers called for PG&E to operate these units "as close to full capability and as continuously as practicable". The agreements did qualify this statement to allow PG&E to curtail its geothermal generation "for proper operation and maintenance and replacement" and so that PG&E did not "cause water to bypass" hydroelectric generating units, but for years these units were considered part of PG&E's baseload generation resource.

The Geysers Power Plant operated under the above steam supply agreement for thirty-three years, but then in August 1994 PG&E executed new steam sales agreements with Union Oil Company, NEC, and Thermal Power Company. These new Agreements for the Sale of Geothermal Steam allow PG&E to dispatch twelve of its fourteen remaining Geysers units. Five of the nineteen Geysers Units that PG&E has constructed have been retired (Units 1-4 and Unit 15) and its other two units (Unit 13 and Unit 16) are still supplied with steam under the older type of agreement and consequently continue to operate in a baseload mode.

In contrast to baseload operations, a "cycling", "dispatchable", or "load following" resource increases or decreases (curtails) its generation output to meet changes in customer or system electrical demand.

On a typical day PG&E's system demand will vary by several thousand megawatts, from a low of between 6,000 to 10,000 megawatts in the early morning when most customers are sleeping to peaks of 13,000 to greater than 20,000 megawatts in the evenings of extremely hot summer days when people come home from work and turn on stoves, televisions, air conditioners, and other appliances. As people go to bed the system demand subsides, and the cycle repeats itself the next day.

System demand also varies on a weekly basis, because of lower commercial and industrial loads on weekends than on weekdays, and seasonally in response to winter and summer temperatures. Figure 1 depicts typical daily winter and summer load curves for PG&E's system. Note that not only do the peak demands differ, but the characteristic shape of the two curves is different.

The curtailed or restrained phase of cycling operations occurs when customer demand is low (e.g. from 1:00 a.m. to 5:00 a.m. and on weekends) or when the cost of alternative power sources (e.g. hydro, coal, and natural gas fueled generation) are less than the variable cost of

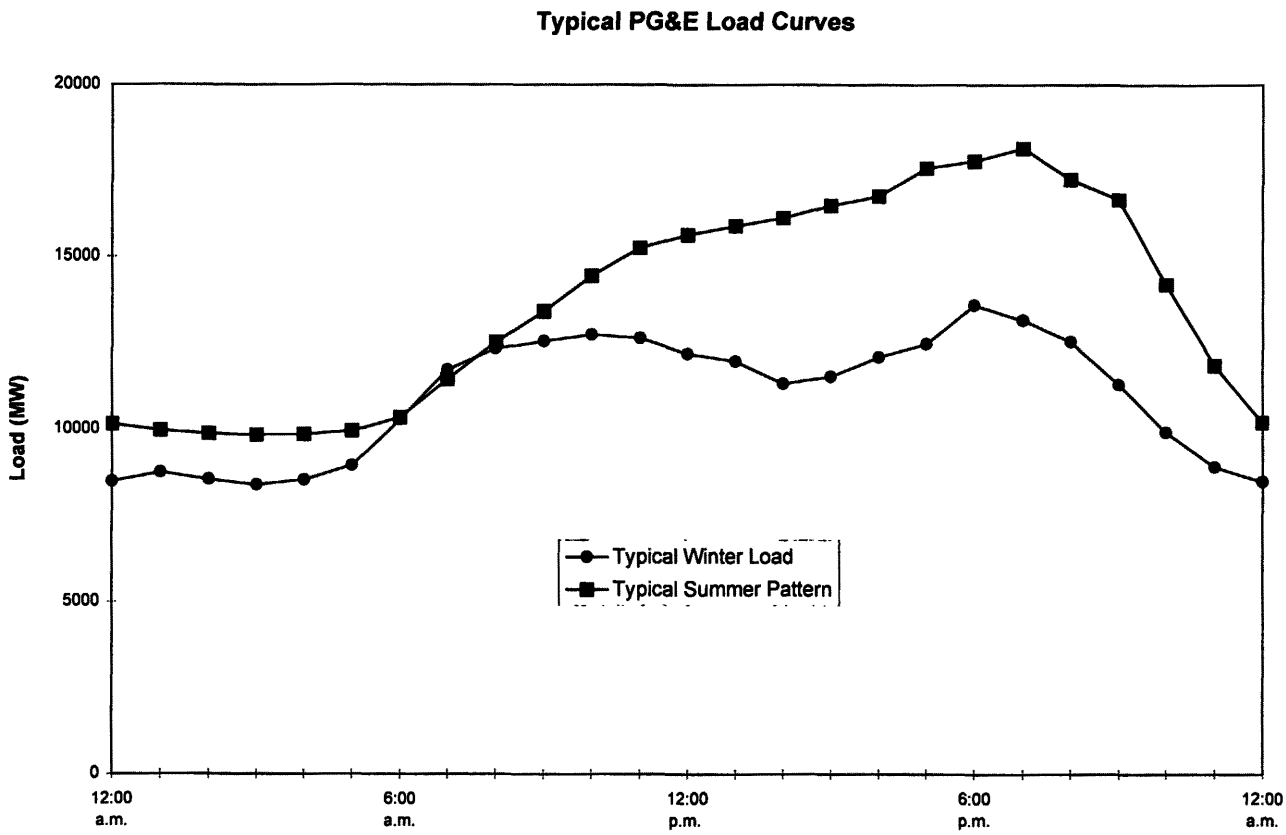

Figure 1

geothermal generation. The practice of curtailing one electrical resource while purchasing cheaper power from another resource is called "economic dispatch".

Most geothermal operations are considered "baseload" resources. The first Geysers generator to incorporate cycling in its operations was Northern California Power Agency in 1988.[1] Some geothermal QFs with Standard Offer 4 (SO4) contracts may operate under a form of cycling if their sales contracts have curtailment provisions during minimum system conditions.

The 1994 agreements allow PG&E to cycle its geothermal generation to reliably, efficiently, and economically serve its customers. PG&E has certain obligations under these agreements including maintaining at least a twenty-five percent capacity factor on a monthly basis and forty percent capacity factor on an annual basis, but otherwise has the discretion to determine why and when it will cycle generation from its Geysers Power Plant.

During the later part of 1994 PG&E's Geysers generation was curtailed for economic dispatch approximately 320,000 megawatthours, generally at night and on weekends to match the peaks and valleys of the PG&E electrical system.

In 1995, PG&E curtailed for economy or did not dispatch several of its Geysers units for as long as five months because it was best able to meet system demands with increased hydroelectric generation from heavy winter storms and with fossil generation fueled by very low priced natural gas. Almost two million

megawatthours of generation from the Geysers was deferred for economy dispatch in 1995 alone.

The curtailment pattern in 1996 is closer to that seen in 1994, but the total deferred Geysers generation will again approach two million megawatthours because of lower cost alternative resources and reduced system demand.

BENEFITS ASSOCIATED WITH CYCLING OPERATIONS AT THE GEYSERS POWER PLANT

There are several benefits of cycling operations at geothermal resources.

First, from a utility standpoint, cycling helps keep customer utility bills lower by allowing the utility to curtail or defer geothermal generation when lower cost power is available.

Cycling should also extend the life of geothermal resources since steam that is not used to generate electricity today remains in the reservoir to be used in the future. This is why we sometimes refer to this generation as being "deferred". Since less steam is produced, reservoir decline rates should decrease and peak generation capability should be sustained. There are even some reports of a temporary reversal in reservoir decline when the amount of power being generated is reduced.[2]

Since 1988, when the steam decline at The Geysers became evident, PG&E's geothermal capability has decreased each year. However, cycling operations and an aggressive water injection program by Unocal has lowered the steam decline rate in PG&E's portion of the Geysers from greater than 10% in 1988 to less than 5% in 1996. The following Table shows that Geysers peak capability has also stabilized, at least partially as a result of cycling operations.

Geysers Peak Generation Capability

1993	824 MW
1994	782 MW
1995	758 MW
1996	774 MW

A third benefit is a short term increase ("puff") in generation over the usual base level of generation following a curtailed or restrained phase of a cycle. The size of the "puff" is dependent on the amount and duration of the restrained period preceding it, and on the characteristics of the steam reservoir, but in some cases a "puff" can exceed 10% of the prior baseline generation level.

PROBLEMS ASSOCIATED WITH CYCLING OPERATIONS AT THE GEYSERS POWER PLANT

Among the problems associated with cycling operations are decreased revenues to geothermal developers and generators, thermal cycling of steam well bores, water collection in steam gathering systems, water carryover to separators and turbines, increased equipment wear and maintenance requirements, and an increase in non-condensible gases when generation is increased following a period of restrained operation.

Because generation is curtailed or deferred, revenues and cash flows based on that generation are reduced. Under the 1994 agreements PG&E pays a monthly curtailment fee to its steam suppliers but that fee does not make up for the revenues lost during a year with large amounts of hydro generation or extremely low alternative power prices. Since every company needs a minimum level of cash flow to stay in business, reduced revenues is a significant cycling operations issue.

Air emission regulations often force steam field operators to close in wells during periods of curtailment or unit shutdown, and the subsequent condensing of steam in the well bore can result in thermal cycling of the wells. Depending on the integrity of the rock formation, or lack thereof, this may lead to bridging and other steam production problems. PG&E and Unocal have instituted several changes in operating practices, such as targeting minimum fieldwide steam flows and setting limits on the duration that wells are in no-flow conditions. These changes have lessened, but have not eliminated this problem.

Reduced steam flow during periods of curtailed generation results in increased condensation within the steam gathering system. This condensation often collects at points in the gathering system other than those where it typically collects with full steam flow. Increased monitoring by steam field operators and the installation of additional moisture traps or drop pots help manage this problem, but the danger of water carry-over to separators and turbines, particularly when

steam flow is increased following a period of restrained operations, remains a problem to be guarded against.

Cycling operations can create increased operation and maintenance problems with equipment and systems. Geysers units have experienced an increased frequency of stuck steam valves, cooling tower water evaporation rates exceeding condensed steam flow, and one incident of water-hammer that severely damaged a section of steam supply pipeline. These have been addressed with changes in operating and preventive maintenance practices. One example is that we only run two or three (of up to eleven) cooling tower fans at a unit while at minimum loads to minimize evaporation losses.

Steam condensation in low or non-flowing wellbores allows increased volumes of non-condensible gases to build up near the wellbore. When the wellhead control valve is opened and these gases pass through the gathering system to the generating station the condenser or abatement system can quickly become overloaded resulting in reliability or environmental compliance problems.

PG&E and Unocal are continuing to work to determine what additional changes in operating procedures and practices, and what physical changes to equipment, are needed at The Geysers Power Plant to mitigate or eliminate these and other problems related to cycling operations.

CONCLUSIONS

While geothermal generation is generally considered a baseload resource, PG&E and another generator at The Geysers are now operating their units there as cycling or dispatchable sources of electrical generation.

Cycling operations has its benefits, providing more flexibility to the utility, lower electricity rates to customers, and possibly extending the life of the reservoir; but it also creates a number of technical, operational, and economic challenges.

PG&E and Unocal have made changes in the way they had traditionally operated at The Geysers, and are continuing to review operating procedures and practices and equipment modifications needed so that they can continue to be a source of inexpensive electricity when the customer wants it.

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[1] Northern California Power Agency Status Report, Geothermal Project Number 3, January 26, 1989.
[2] Ibid.