A time for change?

GAS TURBINE FLAW CREATES OPPORTUNITY FOR LOW COST, GREEN MEGAWATTS

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According to Arnold Schwarzenegger, the Governor of California, it is time to build more power plants again in the state. "A modern society must have abundant and affordable power," he says. This is a turn-around from the past few years, when it was widely believed that California was a microcosm of the entire U.S. power market — over-built. Just like in the state of California, new power plants will need to be built throughout the world in the years to come.

However, there is a better way to solve capacity needs. Simply put, it has been estimated that California has at least 2,000 megawatts "hidden" in its system. Megawatts that can be retrieved at a benefit to the environment for less than half the cost of new generation — $200-300/KW vs. $600-800/KW

The story is the same elsewhere in the world. In fact, many of the gas turbine-powered plants in the world have hidden megawatts that can be retrieved at a fraction of the cost of a new power plant.

The basic flaw

Since the increased load growth occurs mainly during the day in the hot seasons, much of this new generation capacity must consist of the quick-starting and compact gas turbines. However, the gas turbine has a major drawback, a massive fundamental flaw due to basic physics. Its output depends significantly on ambient temperature.

This flaw impacts every gas turbine, some more than others, in the range of 10-40 % of the rated output capacity. The total impact over the global installed base of gas turbines equates to tens of thousands of megawatts. This is the biggest "miss" in the history of power generation.

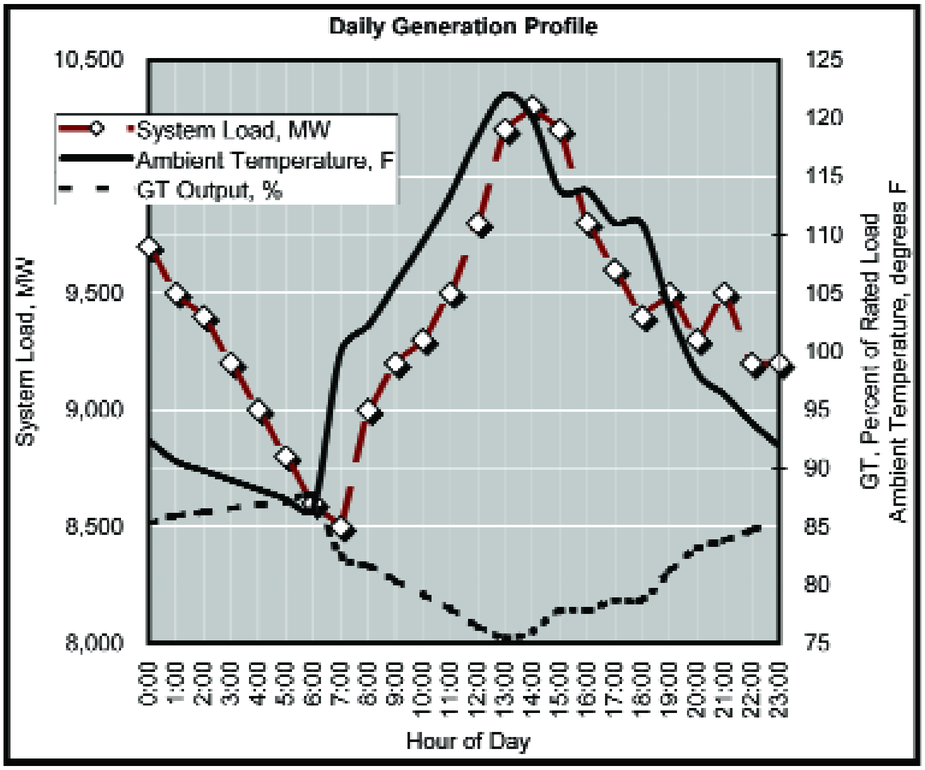

Figure 1: Gas turbine output goes down when it gets hot and demand and price of power go up

Further, these hidden megawatts disappear when we need them the most — as the weather gets hotter the gas turbine output becomes less and less (Figure 1). In most places, the demand for power, and the value (and price) of power go up as it gets hot outside.

The reason the price goes up is due to increased demand. Marginal peaking power supply tends to be old, inefficient, unreliable, costly, and more environmentally unfriendly compared to base-load and intermediate-load gas turbine plants. And this situation has been allowed to exist because it used to be considered that since the power plant owner cannot control the weather he simply lives with it.

In the early days, neither gas turbine compression ratios nor the firing temperatures were as high as they are today. (Figure 2 compares a 1970s unit to a modern aeroderivative.) The impact of hot weather on the gas turbine was not as profound in the early days as it is now.

Further, future gas turbines will have higher pressure ratios and higher firing temperatures and their output will increasingly depend on ambient temperature. In fact, it may become necessary to specify an "alternate rating point" for all gas turbines, at the more commercially realistic point of 95ºF

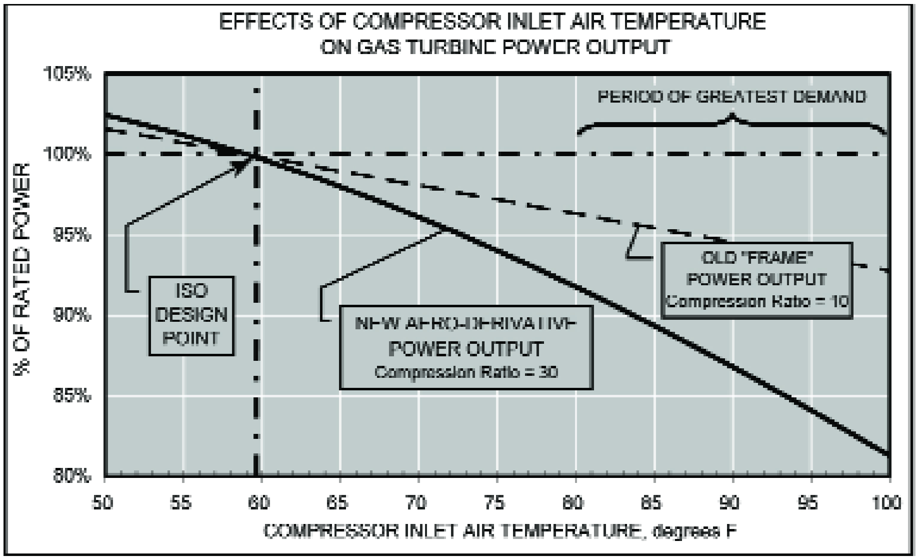

Figure 2: Advanced gas turbines have higher pressure ratios and are more sensitive to changes in ambient temperature

(35ºC), instead of the current 59ºF (15ºC). If accepted by the industry, this will rewrite the economic evaluation of gas turbines.

Power plant developers and owners make up for the reduced turbine output by adding more gas turbines, usually simple cycle peakers — not the most cost effective route to solve this problem. These peakers are neither the most energy-efficient nor the route with the least environmental impact.

But, today, technology exists to allow power plant owners to "control the weather" of their plant. This technology that comes from the air conditioning industry maintains the ideal air temperature for the gas turbine.

The concept of mechanically chilling the inlet air was introduced in aeroderivative (LM) gas turbines in the mid 1980s. These early LM units had relatively steep power-to-temperature (lapse rate) curves, so the value proposition — increased megawatts due to inlet treatment — was big enough to warrant the investment. This concept grew gradually over the next 10 years or so, and created several types of competing technologies: fogging *[1]*, evaporative cooling *[2]*, and mechanical inlet chilling *[3]*.

It took some time for this concept to get accepted because the power world and the refrigeration world did not communicate in those days. GE and Siemens do not own refrigeration technology. Trane and York do not own power generation technology.

These companies did not, and still do not, share ideas or technology organically. It took some cross-industry visionaries to bridge the gap between power and refrigeration. What started as a technology with limited application is today a nearly universal solution.

Competing options

Of the three inlet air treatment technologies, mechanical inlet chilling is the winner in terms of Net Present Value (NPV) *[4]* in over 90% of applications worldwide. In fact, even the U.S. Department of Energy (DOE), as far back as 1996, stated that "evaporative cooling results in a lower $/kW, but also a lower NPV than refrigerative cooling systems." *[5]*

So evaps have lower first-cost, but also possess a lower NPV, which ultimately means a financial hit to both the power plant owner and the ratepayer. The same would be true, more or less, for foggers, which can cool the inlet air only to its wet bulb temperature.

In the same report the DOE stated, "CTAC (Combustion Turbine Air Cooling) was found to be more cost-effective than simply building additional uncooled power plant capacity for all application conditions investigated. This included relatively moderate climates such as San Francisco and applications where storage was limited." Also, the DOE report made the recommendation that "inlet air cooling should be considered a standard practice to be incorporated with combustion turbine installation."

Putting its weight behind inlet chilling, the DOE, in 1996, stated that this technology should be a "standard practice" for combustion turbine installations. "Refrigerative cooling was found to be cost-effective even if evaporative cooling was already in place."

Since 1996, gas turbine technology has become increasingly more sensitive to hot weather due to higher pressure ratios that are driven by higher performance designs. This trend has made the NPV advantage defined by the DOE for mechanical inlet chilling even greater today.

Further, mechanical inlet chilling has lowered its first cost by approximately 50% while increasing efficiencies by 30%. These improvements have been driven by packaging concepts and by improvements in the methods used to generate (and sometimes store) chilled water.

Mechanical inlet chilling plants used to be built in the field, or "stick built." In addition, each project required a tremendous amount of engineering and project management support in the early days. Now, as a result of the benefits of standardization, costs are down dramatically. Granted, fogging and evaps have made some technological improvements, but nothing close to this magnitude.

Contrary to the DOE's wishes, inlet chilling has not become a "standard practice" for combustion turbine applications in the power industry. Instead, power plant owners have stuck to the beaten track, putting up new power plants with unchilled gas turbines. This is not just a U.S. phenomenon, but a worldwide trend.

The reason lies with a major problem: Power plant owners have no method to earn a fair return on their investment for augmenting their existing power plants because of the current power market system structure. The system as it stands today, forces more new greenfield power plants into the system.

Money for hot-day power

The key to encouraging investment necessary to bring out the "hidden" megawatts is the creation of a hot-day capacity market. To continue with the California example, the state can use a tool called "standard offer contracts" that it has used before in the 1980s and 1990s. Standard offer contracts are essentially Power Purchase Agreements (PPA) that define, among other things, how and when power

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plant owners get paid for generation of power.

The state of California could offer to the market these PPAs for MWs only when it needs them — during the hot periods. They then let power plant owners compete to meet the need for additional hot-period MWs. Through this contract, the state tells the market: "We want your hot-day megawatts, and we will make a capacity payment for you to make that investment." Once these contracts are in place, asset managers at every gas turbine power plant will rush to submit proposals for inlet chilling.

If a power plant developer can build a new plant that will sit idle nine to ten months a year and still win a competitive bid against mechanical inlet chilling added to an existing plant only for hot period MWs, then let "the best man win." The markets know what to do and will adjust accordingly. This one minor change will create a huge shift in the business.

This model will work outside of California. It will work throughout the globe. Without a capacity market, bringing this technology to market will be a hit-and-miss game. It is not realistic for investors (power plant owners) to invest with no clear path for earning a return.

Transfer load to night

Such "standard offer" contracts will also encourage big ideas like Thermal Energy Storage (TES), a currently under-utilized concept. With TES, cooling that is produced off-peak (at night) is stored and then used during the peak demand periods the next day.

TES magnifies the NPV of inlet chilling projects in two key ways by:

- Shifting the parasitic electrical load of the chiller plant from day to night, thus maximizing the enhancement of net plant output during critical peak demand periods
- Reducing the neccessary capacity of the chiller plant, thus often reducing net capital investment

The combination of these two factors significantly reduce the unit capital cost-per-megawatt of peak capacity enhancement, even below the levels achieved by inlet air chilling without TES. Further, the use of TES provides global benefits beyond those that impact the inlet air chilling projects themselves. TES moves a significant amount of the demand to the night when power is cheap and in abundance, while simultaneously reducing demand and enhancing net power supply during peak demand periods.

TES improves net energy efficiency, reduces net fossil fuel consumption and reduces environmental emissions, when considering the impact on "source" energy use at power plants. A study [6] conducted by the California Energy Commission (CEC) documented net fuel reductions (for source energy) of 20 to 43% using the CEC's official "Incremental Energy" method (8 to 24% using the "Marginal Plant" method). Reductions in air pollutants and greenhouse gas emissions are on the same level. Similar results have been confirmed by studies in other states as varied as Texas and Wisconsin.

The most cost-effective and environmentally friendly way to meet increasing demand during hot days is a refrigeration solution — mechanical inlet air chilling

Time for change

While the power generation world and the refrigeration world do not directly communicate, they are intrinsically interconnected. What creates the increased demand for peak power during hot days is largely due to an increase in the need for and use of air conditioning. And it just so happens that the most cost-effective and environmentally friendly way to meet this increase in power demand during those hot days (given the number of gas turbines in the world today) is a refrigeration solution — mechanical inlet air chilling.

We need a massive shift in our thinking as an industry — the kind of shift that was thrust upon the power industry in the U.S. in the late 1970s with the passing of the Public Utility Regulatory Policy Act (PURPA). That law forced the industry to get out of the "utility" mindset. PURPA created the Independent Power Producer business. The purpose of PURPA was to benefit the ratepayer, which it did. It is time we put the end-user in mind globally. The gas turbine has a huge flaw. Proven technology is available to fix the flaw and make the entire global power system more efficient.

Jeff Immelt, the chairman and CEO of GE stated during CERA week in Houston this February — "small things today could still be big things in the energy business of the future." Inlet chilling is definitely one of those "small things." Today it is small; but if we keep the ratepayers and the environment in mind, inlet chilling will become a significant part of the power generation business in the years to come. TI

Footnotes

[1] In fogging, water droplets are sprayed at high pressure into the air through nozzles located in the inlet air duct of a gas turbine. The water evaporates and cools the air.

[2] In media-based evaporative cooling, water flows down through a porous material, typically made of plastic or coated cellulose. Air flows horizontally through the porous media and some of the water is evaporated into the air.

[3] Inlet chilling involves cooling the air with chilled water that passes through cooling coils mounted on the gas turbine air intake. The chilled water is produced with a refrigeration system.

[4] Net Present Value (NPV) is the present value of cash inflows minus the present value of cash outflows. NPV is used to analyze the profitability of an investment or project. NPV analysis takes into account the reliability of future cash inflows that an investment or project will yield.

[5] "A Comparative Assessment of Alternative Combustion Turbine Inlet Air Cooling Systems," prepared for the U.S Department of Energy by Pacific Northwest National Laboratory, 1996.

[6] "Source Energy and Environmental Impacts of Thermal Energy Storage," by Tabors Caramanis & Associates, September 1995.

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