Turn It on Again... and Again and Again

Fast-cycling (FACY) power plants respond rapidly to demand fluctuations – sparing time, money and the environment. For combined-cycle generation, FACY is the future.

By Eric Johnson

Photo: Peter Boer

Call it the soccer surge, if you will. At halftime or the end of a major match, millions of English citizens go from one Anglo tradition to another, from watching football on television to drinking a cup of hot tea. As households across Albion put the kettle on, typically an electric type that draws about 1,500 W, power demand suddenly spikes. For World Cup games contested by England's national team, the increment often tops 1.5 GW, enough to electrify a typical city of a million people or to max out a couple or more large power plants.

These so-called "TV pick-ups" – which also occur at lower intensity after the endings of popular soap operas and films – have long been well known to utility load planners. So, too, are the other main reasons for demand swings, namely nights and weekends. Nonetheless, the speed and scale of variation is climbing. And at the same time, utilities face ever-increasing pressure to match their supply to users' demand as precisely as possible.

Taken together, these factors are forcing a mind-set change among operators of combined-cycle power plants. Once designed as base load colossi to run uninterrupted (as nuclear and hydro plants do), combined-cycle units increasingly are ramped up and down in tune to daily or weekly demand cycles. "The days of combined-cycle operating only as base load are disappearing," notes Erich Schmid, a Siemens process engineer. "In the coming 5 to 10 years, up to 90 percent or even more of these plants in deregulated power markets will be built or revamped to run flexibly."

Bend Me, Shape Me

Already today, the market is seconding Schmid's notion. Siemens has so far delivered 4 of its flexible "fast-cycling" plants, while another 15 are on order for start-up by 2011. Flexible FACY, as it came to be called, is shaping up to become the new face of combined-cycle power.

Of course, demand for power has always been variable. Daytime and evening consumption – when lights are on, factories humming and most people in action – typically outstrips nighttime consumption by about 50 percent. Consumption on weekdays is well ahead of that at weekends and holidays. Weather and seasons also play key roles. When it sizzles in San Antonio, air conditioners work longer and harder; when it rains in Spain, less cooling is required.

What has changed in recent years, however, is the variability of supply. Whereas combined-cycle output in the mid-1990s tended to be a base load flat line, now it is trending toward a series of peaks and valleys. Utilities want to shut down and start up their plants more often and more quickly. For combined-cycle operators, this generating variability has been forced by two fundamental changes in energy markets. For one, prices of natural gas have risen substantially. In part, this is due the explosion of crude oil tabs, which shot from around 10 US dollars per barrel at the millennium to well over 100 US dollars and are still in the high double digits. The other key is a globalizing trend in trade. Rather than being sold to a monopoly pipeline, gas increasingly can be liquefied and shipped anywhere in the world – which at present is buoying prices. The second factor is that wholesale electricity markets have been deregulated. Exchange trading of not only futures, but also physical power contracts has boomed, with minute-by-minute price movements steadily shifting the incentives to start up or shut down generators.

A final factor for rising supply variability is Mother Nature's whimsy: winds that won't blow, waves that won't churn or a sun that won't shine. According to a recent study by Cambridge University, wind and waves are available no more than 40 percent of the time. Plants fired by biowaste are at best onstream about 75 percent of all hours, well below fossil fuels' 90-plus percent availability.

Start Me Up

Faced with these factors, generators have been trying for a decade to teach

Single-shaft design for the Sloe FACY plant: gas turbine, generator and steam turbine.

Photo: Peter Boer

Sloe is fast: the FACY plant at Sloe, the Netherlands.

FACY Book – an Inside Look at the Technology

For a typical gas turbine, ordinary life is brutal and nasty. Operating temperatures reach a hellish 1,400 °C in the gas turbine combustion chamber, while rotating speeds hit 3,000 to 3,600 revolutions per minute. Adding uncontrolled temperature cycles to that mix can push a turbine over the edge, overstressing it into failure. "It's very demanding to climb to 1,400 °C," explains Erich Schmid. "Our equipment must be robust enough to withstand that, and we need to control thermal stress while ramping up." FACY's approach is to offer a bit of both. Material properties of forgings and castings have been boosted to the highest level (thanks to proprietary know-how). Optionally conventional water/steam separation drums, made of thick-walled, slow-to-heat-and-cool steel, can be swapped for thin-walled BENSON boilers in order to increase the start-up frequency further.

Excess stress is avoided where possible in two ways. One, when the combined-cycle plant is off-line awaiting hot or warm restart, heat retention within the steam generator is kept as high as possible, avoiding the need to endure thermal and mechanical stresses to get going again. Two, during steam turbine start-up, steam temperatures are controlled closely to rotor temperature and increased moderately to achieve fast steam turbine ramp rates at low thermal stress. FACY also adds a condensate-polishing unit to produce highest-purity boiler feed water. This cuts down on metal-damaging contaminants in the water and steam system.

Photos: Peter Boer

combined-cycle elephants to be more nimble. This is FACY's forte. Unlike most trends in power technology – which come from the top down – the market need that led to FACY's development came bottom up. In the late 1990s when a spate of conventional combined-cycle plants came online in the USA and the UK, customers began cycling them even as they were in commissioning. "Operators didn't want to waste expensive fuel by running through the night," recalls Schmid, "so, our engineering people started offering solutions, and before we knew it, we were on our way to developing a full-fledged technology."

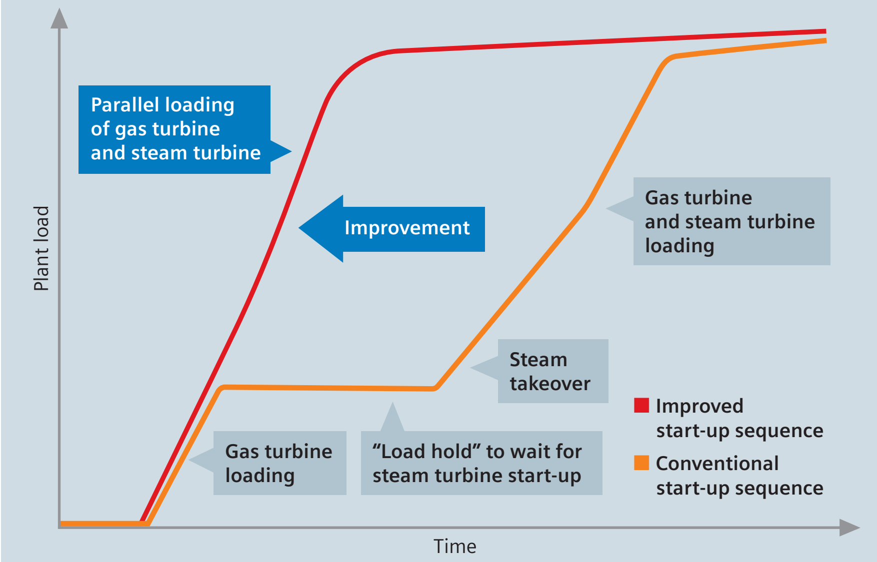
FACY does what its label says, thanks to a number of technical tweaks (see box) best summarized as: more robust ramp-ups, tighter controls and improved insulation. Instead of taking nearly two hours, as a conventional combined cycle would need for a "plant hot start-up" from standby to full operation, it can rise to grid-ready performance in 30 minutes. Its "wake-up call" can be delivered by a few mouse clicks in the control room. Unlike competing technologies that run through low-demand periods inefficiently at partial load, the FACY generator truly shuts down when it is turned off.

"Our plant truly shows high flexibility," says Michel Gasc, Director of the FACY installation at the Sloe electricity power station SLC in Vlissingen-Oost, the Netherlands. Not only can it ramp from zero to 420 MW in 30–35 minutes, it uses less gas in start-up mode than conventional designs.

This flexibility boosts bottom lines. With a FACY retrofit, a reference plant burns about 16 percent less fuel on a nightly stop-and-start. Compared to partial-load operation, the benefit is far greater: FACY forces an 84 percent drop in fuel use. And in this carbon-conscious age, that brings about another major reward, a similar-sized drop in greenhouse gas emissions.

FACY is targeted at operators in deregulated power markets, many of whom are convinced already. New plants or revamps have been fitted in France, the Netherlands, the UK and, most recently, in Germany. Orders for new FACY plants are rolling in from across Europe and the USA. "FACY is a good system for an operator," notes Philippe Triquigneaux, Plant Manager at Sloe power plant, "and good systems over the years tend to become industry standards." Judging from the warm reception, it appears that the move to flexibility is sure to last longer than a soccer surge; FACY is clearly a trend for the long term.

How FACY Fast-Cycles: a Hot Start Load Profile



Fast, Not Furious

Of course, the trick is to balance robustness and gentleness with speed. FACY does this by ramping up according to optimized, dynamic models of thermal and mechanical stress. "Advanced controls allow us to walk a fine line," explains Erich Schmid. "We run as closely as we can to the limits of the system, but we don't overstep them."

The control system offers a range of other benefits, too. Starts can literally be initiated by pushing one button. Diagnosis and monitoring are built in. Command and control can be made remotely over the Internet. And switchyard operations are not separated, but can be steered from the central control panel.

FACY's final tweak is improved insulation and stand-by heating. Through dampers and thermal integration, the unit stays warmer when not generating, making its subsequent ramp-up shorter and less stressful.

All told, the development of FACY is still an ongoing process. Obviously, efforts continue to achieve even faster speeds for firing up the turbines, and the developers believe the top gradient can be pushed further. Although more gains are possible, "FACY is already reaching the limits of ramp-up," says Schmid. "It's like 100-meter sprinters at the Olympics: still getting faster, but not by a great deal." Top gradient, he reckons, probably will peak somewhere around 30-plus MW per minute for a 400-MW-class plant.

***Eric Johnson** writes about technology, business and the environment from Zurich.*

Further Information

www.siemens.com/energy/combined-cycle