Power Plant Optimization

Oh What a Tune-Up!

It takes around a decade to plan and build a power plant. As a result, within a few years of commissioning, most plants no longer meet the latest technological standards. But in many cases, replacement of key parts and adjustments to a plant’s control system can help it to meet evolving requirements, save huge amounts of energy, and significantly reduce carbon dioxide emissions. Siemens is a leader in upgrading existing facilities.

Author: Jeanne Rubner

When it comes to the quest for optimal performance, nothing beats a well-oiled Formula One racing car team. Here a tightly drilled squad of mechanics waits in the pits, poised to swap tires, tighten bolts and tweak components - all in pursuit of a few more mph or a little extra traction.

In some ways, tuning up a power plant is a similar endeavor. Even if it doesn’t move like a Formula One car, it often has to be run at full load, just like Felipe Massa’s Ferrari at the Nürburgring race circuit. When operating in this mode, a power plant generates a lot of energy, usually in the form of electricity. At other times, when the grid's hunger for power is lower, the plant is operated at partial load.

But unlike racing cars, power plants do best when operated at a relatively uniform pace. No gas turbine or coal-fired boiler, for instance, can reach full power in seconds. In fact, depending on the type of plant, reaching full output may require anything between 10 minutes and several hours.

Increasingly, however, electricity companies need to be able to ramp up generation on short notice, not least because the growing use of renewable sources of energy leads to greater fluctuations in capacity. Since the wind and sun are variable factors, solar and wind farms feed power into the grid on an irregular basis. For this reason, the hours of darkness or periods of calm at sea must be bridged by conventional base load power plants. This, in turn, means that such plants need to operate more flexibly than before in order to compensate for load variations and prevent blackouts.

Older plants in particular have problems cushioning such rapid changes in load. Given the growing trend toward renewable energy sources, a lot of base-load plants now need to be upgraded. And there’s another, equally pressing reason to modernize existing turbines, boilers, and generators: With the cost of fuels such as gas and oil set to become more and more expensive in the long term, operators are looking for optimal efficiency from their power plants. What’s more, as they invest in efficiency improvements, they and their customers stand to benefit from reduced carbon dioxide emissions per kilowatt of energy produced.
Teasing out the maximum

According to estimates by the German Association of Energy and Water Industries (BDEW), a quarter of Germany’s total generating capacity of 130 gigawatts needs to be replaced for climate-protection reasons and due to the fact that many power plants are three or four decades old. That, says the BDEW, will require investment of 40 billion euros between now and 2020. At the same time, the International Energy Agency calculates that the colossal sum of $16 trillion will be needed until 2030 to expand and modernize the world’s energy infrastructure. Around $10 trillion of this is earmarked for power supply systems.

The modernization and upgrading of power plants is an important line of business at Siemens Energy. In the German town of Mülheim an der Ruhr, it’s the job of Ralf Hendricks and his colleagues from the Lifetime Management Unit to turn combined cycle power plants (CCPPs), which are operated at base load, into racing machines. On behalf of a client in the UK, for example, they have recently upgraded a CCPP without having to replace any components. The first step was an inspection tour of the facility to determine its condition, as a prerequisite for putting together a package of measures that is tailored to the customer’s needs. After that, a team of experts from Mülheim and Erlangen traveled to England for three days to optimize all parameters of the 400-megawatt plant, modifying the load ramps of the steam and gas turbines, for example, and adjusting the pressure rates to the boiler.

By fine-tuning these parameters, the team was able to optimize the operations control system, which means full load can now be reached with maximum speed. “Optimizing the open and closed-loop control technology helped us get the best out of the plant”, Hendricks confirms. As a result it now takes only 60 minutes, rather than an two hours, for the turbine to run up to full load after having been shut down for ten hours. In other words, only one hour elapses from the time the gas turbine is started until it runs up to full load - and without the need for any new hardware. In only half the time it used to take, the power plant is up to full load and feeding its total output of 400 MW into the grid.

Such improvements soon pay off. Usually after one to two years time, the operator has recovered the costs of the upgrade. But cost savings are realized not only when running up a CCPP. Using the forced cooling technique reduces the time needed to cool the steam turbine. The trick is to actively cool the steam turbine by extracting air from the turbine hall. “Instead of having to wait 160 hours for the turbine to cool before the plant can be shut down, it now takes only 60 hours”, says Hendricks. That’s a time difference of four days, which is a valuable saving when an operator is waiting to start routine inspection and maintenance. Energy providers that rely on this technique can save millions of euros for every overhaul, for minimal investment costs.

Efficient Megawatts

In addition to shortening start-up and shutdown times, improvements can also be made in other areas. For example, upgrading individual components not only increases the service life of a power plant but also improves its efficiency, which in turn reduces its carbon dioxide emissions.

There is often also scope to extract more performance from the turbines without the need for extra fuel consumption, thereby increasing generating capacity without additionally burdening the environment. The effectiveness of a turbine depends very much on its blades and flow area. In this connection, major advances in the field of 3D computer simulation over the last 20 years have given rise to the development of turbine blades that exhibit very low flow resistance. Moreover, when additional improvements are made to the blade path, this reduces losses even further, thus resulting in very high efficiency. This means that as much thermal energy as possible is transferred from the gas or steam to the turbine blades.

All of this, in turn, allows efficiency to be increased without having to increase the volume of gas swept by the blades and therefore the size of the turbine. That’s important, since turbine enlargements are usually not an option in an existing plant. “This is a huge benefit for customers”, explains Dr. Norbert Henkel, who is responsible for upgrading steam turbines at Siemens in Erlangen, Germany. “We fit between 20 to 25 power plants a year with upgraded turbines.”

Last but not least, there is also the generator, which converts the rotary motion of the turbine into electrical energy. In itself, a generator has an efficiency of almost 100 percent. However, it has to be tailored to other components, which as a rule age faster. In older plants, for example, the turbine blades have to be replaced either because the material has become brittle and there is a danger of failure or in order to make the turbine more efficient. “It’s like a champion cyclist getting onto a normal bike”, says Anastassios Dimtriadis from Siemens Energy in Mülheim. “Obviously we have to check whether the existing generator is up to handling the increased performance.” If necessary, a new rotor has to be installed or the coils rewound.

Time saved due to a reduction in cooling time can cut the cost of overhauling large power plants by millions of euros.
Upgrading Output

Over the years Siemens has ramped up the performance of many power plants. At the Forsmark nuclear power plant in Sweden, for example, all the internal parts of the low-pressure turbines were recently replaced, which not only boosted the capacity of the facility by 30 megawatts - or almost three percent of its total rating of 1,200 megawatts - but also extended its service life. The same applies to coal-fired power plants. Using Siemens technology, the output of the 690-megawatt Mehrum facility, which is situated east of Hannover, in northern Germany, was increased by 38 megawatts, thus boosting efficiency from 38.5 to 40.4 percent.

"Inevitably, the state of technology in the energy industry tends to lag behind the latest technological developments", points out Thomas Sattelmayer, Professor of Thermodynamics at the Technical University in Munich. For this reason, every new power plant that goes online is already to a certain extent out of date. "It therefore makes good sense to upgrade efficiency when conducting routine maintenance", says Sattelmayer, who is spokesman of "Kraftwerk 21", a Bavarian energy research alliance. Sattelmayer sees huge business opportunities in the optimization of power plants.

Whatever the outcome of that prediction, government interest in reducing carbon dioxide emissions from power plants certainly coincides with the goals of utility companies, which want to operate the most efficient plants possible. Considering this, we can expect to see a major increase in the number of projects introduced to upgrade the efficiency and start-up speeds of power plants in the years to come.

Reprinted from: Siemens’ Pictures of the Future’ magazine, Spring, 2009