In addition to supplying a new SGT-800 industrial gas turbine, Siemens will install a battery storage system for black-start. GTW discusses the gas turbine replacement and the technical and economic advantages of the start-up system.

The BASF combined cycle power plant in Schwarzheide started operation in 1994, with two industrial gas turbines from Siemens as well two industrial steam turbines from another OEM. In addition to generating power, the plant also provides process steam for the production plants on site.

BASF Schwarzheide, the plant operator, recently decided to replace one of the existing other OEM turbines with an SGT-800 gas turbine with a capacity of 57 MW, along with installing a SIESTART battery storage solution for black-start of the turbine.

The SGT-800 upgrades the unit from the current output capacity of 45 MW to a capacity of 57 MW. BASF will be operating the unit at 52 MW. The upgrade results in the plant having a higher efficiency, lower fuel cost/kWh, as well as lower emission levels.

Replacing the turbine

Reza Azimi, Senior Sales Manager M&U with Siemens, noted that replacing the turbine of one OEM with that of another can involve technical issues that need to be resolved.

In this particular instance, there were numerous differences in basic design elements between the old turbine and the new. The generator rotors spin in different rotations; the SGT-800 gas turbine has a cold-end drive, while the gas turbine it replaces has a hot-end drive; the general layout is different, requiring modifications to enable connections to be made; the original gas turbine has a vertical exhaust, while the SGT-800 has an axial exhaust.

Azimi said that space was limited at the site, with a boiler on one side, and a firewall on the other. The SGT-800 is able to fit in the available space, but space is often an issue in projects where one OEM’s turbine is replaced with another. The logistics involved in replacing a different design of turbine need to take account of spatial issues, and connections need to be arranged.
Foundations may need modification, and replacing a foundation can add to the cost of replacement. In addition, the installer needs to plan to arrange the connections and the logistics of the installation.

The SGT-800 will be run at a constant 52 MW, rather than at its full capacity of 57 MW at Schwarheide, because of the capacity of the generator. The customer will be maintaining the current steam production levels.

The NOx emission levels will be 15 ppm (gas turbine only, while in the range of 60-100% load).

**Turbine replacement market**

With the market for gas turbines being highly competitive, and with operators constantly seeking economic advantage from their plant, upgrading units is an increasingly attractive option. Because customers are incentivised to seek the best upgrade for their situation, they are increasingly prepared to replace with a unit from a different OEM if they feel that a different supplier can provide a unit that is more economically attractive.

At present, the market trend is for higher efficiencies combined with lower NOx levels. This will always be the case, but there are many other factors involved for an operator, including: increased output levels; increased ramp-rates; longer periods between maintenance outages; reduced fuel costs; greater fuel flexibility; and multi-fuel options.

**GT black-start**

Most plant operators prefer diesel generators for black-starts, as these are a well-known and reliable technology. They tend to be more cautious about using modern battery storage in power generation because they see this as a relatively new and unknown entrant.

Gas turbines require an external source to start-up. The hybrid solution of battery storage system and gas turbine enables black-start of gas turbines in the event of loss of external power source, and therefore the capability to enable the power plant to support grid restoration. Black-start capability of conventional power plants was previously based on the use of diesel generators or gas engines. Applications for these diesel generators are generally limited to black-start, while a hybrid solution with an integrated BESS offers a larger number of further opportunities.

Many industrial power stations cannot do a black-start because they are simply not equipped with a black-start facility that would enable a rapid re-start on demand, in the unlikely event that power from the national grid is not available. In some ways, battery storage systems fill the same niche for power generation that hybrid engines fill for cars.

In addition to the black-start capability, plant operators increasingly demand flexibility and optimisation from their generation. A battery storage system, such as SIESTART, enables black-starts for gas turbines, as well as enhancing operational plant flexibility and offers higher revenues from better serving the grid balancing markets.

From the operators’ point of view, the instantaneous availability of full power from battery storage provides considerable flexibility and many opportunities. With higher penetration of renewables, less rotating equipment is available for providing the required inertia needed to stabilise the grid. Synthetic inertia provided by batteries can be used to compensate for the reduced rotating inertia. Activated power from the battery, in either direction in less than one second, is used for enhanced and very fast frequency response.

![Image](https://www.gasturbineworld.com/)

**Figure 2. Cutaway of the SGT-800 industrial gas turbine.** With a capacity of 57 MW, it will cut fuel costs and CO₂ emissions at Schwarheide.

"Both black-start units (the new SIESTART system and the old diesel generator) can provide the black-start capability independently to its assigned turbine, which will increase significantly the reliability of the plant. Each of the two black-start units has its technical advantages and disadvantages, but as the technology is so different, it is very unlikely that both will fail at the same time in the worst-case scenario."

The Schwarheide project is a pilot project for the SIESTART for black-start operations. The design criteria for the project was that the battery system needed to have the power and capacity to provide three sequential black-starts of the newly installed SGT-800 gas turbine without recharging.

If a blackout emergency takes place with a hot machine, then the restart procedure is as follows:

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Uwe Fuchs, of Sales and Business Development of Energy Storage Solutions with Siemens, described the technical aspects of the SIESTART system as used at the refurbishment project for BASF Schwarzheide.

"The plant operators of BASF Schwarzheide have had a contingency plan for black-start in place for decades. As part of the refurbishment project, the new SGT-800 will be equipped with a modern lithium-ion battery system, while the older gas turbine, which will remain in operation for some time, will still rely on its small black-start diesel generator."
Firstly, the gas turbine is rotated at a cooling down speed of 600 rpm for up to two hours;
- With the turbine in safe mode, the revised black-start procedure for the SGT800 is executed and the issue that caused the alert is located. Any potential problems that may hinder the restart process are resolved;
- Prior to any restart attempt, the turbine needs to be purged with air for 10-15 minutes to ensure that all fuel vapour is removed from the system;
- The start motor brings the turbine up to ignition speed;
- After successful start, the battery island grid is synchronised with the gas turbine grid, which is then synchronised with the public grid.

The SIESTART system has been designed to provide the maximum loads of the start motor and of the auxiliary equipment that are required to perform at least three sequential black-starts. Aging of the battery and its capacity degradation was one of the customer’s concerns discussed. The battery system is designed for a 10-year operation and allows a capacity extension at the end of its designed lifetime, to compensate for the calendric capacity degradation. The system at BASF Schwarzheide has been designed purely for black-start capability. A future upgrade of the system can enable it to offer the ability to provide greater operational flexibility to gas turbine operation, and potentially gain revenues from participating in the ancillary service markets.

The maximum loads of the load profile have been identified with:
- 1.8 MW for the starter motor;
- 0.4-0.5 MW for auxiliary equipment such as air conditioning and pumps.

At Schwarzheide, the SIESTART system has been designed for an output power of 2.4 MW and an installed battery capacity of 1.7 MWh.

The SIESTART system enables a gas turbine to operate at a specific, optimised output level, allowing it to achieve peak efficiency. When the required level of plant output is below the output of the gas turbine, the extra output can be used to charge the batteries. When the required level of plant output is above the output of the gas turbine, the batteries can provide the additional output required.

**Other benefits**

Black-start is just one of the applications of battery storage. While diesel generators can only provide black-start support, battery storage can provide additional functions improving the operational flexibility and the economics of the plant. Frequency control of the grid, for example, requires ramp rates that only batteries can achieve. The ability to provide frequency control can give an

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<td><strong>New SGT-800 gas turbine performance</strong></td>
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<td>Power output (MW)</td>
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<tr>
<td>Heat rate (kJ/kWh)</td>
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<td>Turbine speed (rpm)</td>
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additional revenue stream for the plant.

When retrofitting pre-existing turbines with a black-start unit, the advantages and disadvantages of a battery system versus diesel generator are often debated. In the industry, there is no common agreement yet for the preference of either solution.

Batteries are attractive due to their versatility, while diesel generators are still seen as the more robust technology. A diesel generator requires fuel feed lines; space for fuel storage; it has to be started monthly; and fuel needs to be changed annually if not used. However, a diesel generator has endless capacity, provided it has a fuel supply, while a battery has a specific capacity.

After the first project at VEO Eisenhüttenstadt in Germany and the second project due to be commissioned at the end of 2019 at C-Energy Planá s.r.o. in the Czech Republic, this is the third project for Siemens where the customer has decided to choose a battery system for the black-start purpose.

“There is a lot of interest in black-start options in regions where industrial plant operators have a growing fear of grid failures disrupting their power-critical processes,” Fuchs said.

Frequency regulation

An energy storage system is ideal for frequency regulation, because it can act as a generator or load, and switch between the two very rapidly. If the regulation component is successfully extracted from the load profile, it should be as close to net-zero energy as possible.

This matches well with energy storage systems. To be effective as a frequency regulation service, an energy storage system has to deal with high ramp rates and high charge/discharge requirements. Batteries are one of the best energy storage systems for frequency regulation.

There is a need for new super-fast-to-respond options to maintain grid stability. Uncertainties regarding future investment in critical baseload power plants, peaking plants and interconnectors, and threats of cyber-attacks make grids increasingly vulnerable.

Co-locating battery energy storage systems with combined cycle gas turbines can provide solutions to such challenges. It enhances the start-up of combined cycle gas turbines, enabling them to provide much faster services while still being available and running to provide longer duration services such as short-term operating reserve.

It can also be used to replace a diesel generator normally used to provide power for a black-start to a gas turbine in the event of a blackout, thus providing a much faster restoration device. It is also a resource that can be used to support fast ramping to meet peak power demand requirements.

Further developments

Extending the capability by increasing power capacity with larger batteries is the probable next step. Fuchs anticipates batteries of up to 50 MW next to a gas turbine for additional export. The combination of batteries and gas turbine already provides many potential revenue streams.