Setting new benchmarks in efficiency enhancement

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Renewables like wind and solar power are volatile sources of energy, i.e. the contribution they make to energy supply fluctuates. Renewables-based power generation therefore has to be complemented by production that is independent of the weather and time of day. It should react with a high degree of flexibility to grid requirements and also be as climate-compatible as possible. One option in this respect are natural gas-fired combined cycle power plants, which offer ongoing efficiency enhancement and constitute an ideal complement to renewables. The Irsching 4 combined cycle power plant located in the vicinity of Ingolstadt, Bavaria, which was built by Siemens under contract to E.ON and was handed over to the customer E.ON in July 2011 for commercial operation, is setting new benchmarks in this respect.

Germany is facing radical changes to its energy supply system – the motto in a nutshell is "phase out nuclear energy and introduce even more renewables." The change in energy policy is political will and is in the meantime not only backed by all of the political parties but also welcomed by major sections of the general public. The gradual phase-out of existing nuclear power plants and the accelerated development of renewables will require massive efforts both of a technical and economic nature. Today, we are increasingly confronted with distributed solar- and wind-based power generation. The share of fluctuating feed-in is constantly rising. On the other hand, the possibilities for power storage offered by facilities including pumped-storage and compressed-air storage power plants are limited, and large storage systems on a chemical basis, such as stationary lithium-ion batteries or large-scale production and storage of hydrogen or synthesis methane, are not yet available. For that reason, the role of compensating, fast-response power plants is increasingly gaining in importance for grid stability. In addition, the use of natural gas in such power plants has the positive effect that it is ecofriendly with particulate, NOx, SO_2 and CO_2 emissions significantly lower than with any other fossil-based generating facility. For example, the new Siemens combined cycle power plant emits considerably less than one-third of the CO_2 emitted by the current coal-fired fleet per kWh generated. As replacements for old coal-fired power plants it is thus possible to additionally reduce annual CO_2 emissions by approximately four million tons per 1000 MW of output.

Writing engineering history

In this context, Unit 4 of the Irsching power plant operated by E.ON Kraftwerke GmbH is an exemplary project. More than ten years after the start of the ambitious innovation programme for a new generation of H-Class gas turbines, we have developed in the SGT5-8000H a machine which passed its trials with flying colours and has been in commercial operation since July.

The first plant featuring the new H Class is already writing engineering history because it has become the first gas turbine to top the figure of 60 per cent efficiency in combined cycle duty. The world record figure achieved is exactly 60.75 per cent at an electrical output of 578 megawatts (MW) – a truly historic dimension. Above all, however, the Irsching 4 plant is characterised by its particular operating flexibility, with which the plant can react very quickly to a wide variety of load requirements. In less than 30 minutes it is up to full load, and in less than 30 minutes it has been run back again – properties, which are most welcome for conventional compensation with respect to renewables.

The Siemens "8000H Programme" kicked off back in October 2000 with a fundamental market and requirements analysis. After the first development and engineering phase and the successful preliminary trials of critical components, the turbine was built in our manufacturing plant in Berlin and subsequently installed and tested in the Irsching 4 power plant under real conditions in simple cycle duty. Right from this first phase we succeeded in securing E.ON as a partner for the demanding power plant project – a good choice as it turned out, because the SGT5-8000H developed into a success story in a very short space of time.

All of the project milestones were achieved on schedule after construction had commenced in 2006. Important intermediate steps were first firing in December 2007, first synchronisation with the grid in March 2008, and base-load operation in April 2008. The validation programme was completed in August 2009. The plant has successfully passed all tests under the toughest operating conditions. Trial operation encompassed a total of 123 days, over which over 170 starts and more than 1500 operating hours were clocked up. Following that, work commenced of extending the facility to a combined cycle power plant, which was completed on schedule in December 2010.

Entry in the Guinness Book of Records

The performance of the SGT5-8000H exceeded all expectations. The turbine was released for the market with a rated capacity (ISO) of 375 MW. It is the largest operating gas turbine in the world and has even made it into the Guinness Book of Records. The turbine is available both as a 50-Hertz version and as a smaller scaled 60-Hertz machine. The two versions have complete internal cooling and therefore enable fast startup and load cycling. In addition, the other power plant components and auxiliary and ancillary systems, for example the Benson heat-recovery steam generator, were enhanced and developed further for high temperatures and pressure. For example, the water/steam cycle operates at 600°C and 170 bar. All in all, we have achieved even higher operating flexibility through the optimum interaction between the individual components. And that is urgently required. Because that flexibility will in the future decide whether we in Germany can maintain the high level of assured supply, to which we have been accustomed in the past.

As early as 2020, possibly even earlier, nearly the entire power plant fleet based on non-renewables will have to be started up and shut down on a daily basis because certain regions in Germany can meet the entire power demand on sunny days with a lot of wind for certain periods purely with the aid of wind, solar, hydro and biomass power plants. However, if the weather situation suddenly changes, then we will need approximately 20 to 50 gigawatts from other sources within the space of a few minutes or hours. Such outputs are not to be anticipated within a defined timeframe from large-scale storage systems like hydro power plants. For that reason, power plant solutions are required, which we can start and run up accordingly from standstill within this timeframe to compensate fluctuations in generation. With today's fleet of coal-fired and nuclear power plants, which are also on call, that it only possible with major limitations. This example illustrates that conventional power plants are facing completely new technical challenges.

The provision of additional capacity in the form of high-performance, high-flexibility combined cycle plants is therefore an important possible solution. Against this backdrop, Irsching 4 has passed all the performance and flexibility tests and overfulfilled all of the technical guarantees agreed with E.ON. A key element of plant flexibility for the defined market conditions is the time required for a hot start, which for the most part takes place in the early hours of the day after a standstill of between six and eight hours when the demand in the grid rises again. Here, we demonstrated that the entire plant can be run up very reliably to full load within less than 30 minutes using the fast cycling (FACY) feature. Just as important is the opposite case, when plant load has to be very quickly reduced or the plant even shut down if grid disturbances suddenly occur or if wind- and solar-based power feed-in call for this. Here, too, we demonstrated that shutdown or continued operation at low load are possible within 30 minutes. Despite its world-record performance the plant can be operated stably on demand at approximately 100 MW and thus below 20 per cent of total capacity in combined cycle duty at an efficiency typical of straight peak-load power plants (open cycle). This plant can thus be deployed highly efficiently both in base, intermediate and peak load duty. We have tested the appropriate load ramps to be able to quickly fulfil the requirements for extra and reduced output. The results show that the plant also achieves top performance of as much as 35 MW per minute.

A redefinition of spinning reserve

Implementation of the change in energy policy in Germany calls for a sustainable solution to the problem of spinning reserve. Thanks to their flexible operating options our new combined cycle plants are available for this. For future owners of such power plants a redefinition of compensation for spinning reserve or simply for the provision of on-demand availability would be necessary. A constant equilibrium between power generation and demand is a key prerequisite for stable, reliable grid operation. Power plants making special contributions in this respect should also receive appropriate compensation. Opportunities and risks must also be redistributed when completely revamping energy supply.

In the new 8000H Class Siemens has made available the most advanced and modern technology for cost-effective, ecofriendly gas-based power generation. What seemed impossible at the start of the programme, namely an efficiency level of more than 60 per cent in combined cycle duty, was demonstrated for the first time under real conditions in a power plant in Germany. Combined with high operating flexibility, we have a solution in our portfolio, which fully meets the requirements of the changing energy markets. Following the successful market launch of this technology in Irsching 4, marketing of our standout turbine is making good progress: Orders for another seven machines have in the meantime been secured from the US and South Korea, and further projects are being negotiated. ❑