Juergen Froehlich, Siemens Gas & Power, Germany, talks about Steam 4.0 – the linking element to a sustainable future.

Electricity suppliers worldwide are facing tremendous challenges. They must reliably meet an ever-increasing energy demand, flexibly respond to load changes at all times and keep grids stable, while at the same time, supplying electricity at the lowest possible price. On top of the diversification of the power generation mix, this compounds the industry’s future challenges. By 2030, about one-third of the world’s total power generation will come from renewable energy sources, but coal-fired power plants will still cover approximately the same percentage of the global energy demand. Today’s market perspective – backed by a variety of studies – shows that coal-fired power plants are predicted to remain a significant contributor to the future power supply mix in various countries to meet energy demand.

A combination of the most advanced steam turbine generator technology and innovative digital and lifetime services and solutions will enable us to keep emissions to a minimum and also meet the rapidly growing energy demand at affordable costs. The Siemens Steam 4.0 concept addresses these fundamental requirements. Power generation assets will be the local guarantee of geopolitical independence in terms of fuel supply and grid stability, especially when dealing with the increasing grid variations created by renewable energy sources that produce new and challenging operational flexibility requirements.

A tough challenge
If the world is to meet its emission reduction goals, addressing the efficiency level of the global coal-fired power plant fleet is considered to be the most important strategy in view of an obvious need for significant improvements, both in the installed base and for future capacity expansions. The modernisation and upgrade of old coal-fired power plants is a key success factor, as these plants today operate at an average global efficiency of approximately 33% (according to VGB 2018/19). An upgrade to state-of-the-art ultra-supercritical steam power technology, for example, could reduce today’s CO₂ emissions by approximately one-third, a huge emission reduction.

Steam 4.0 stands for innovative steam turbine-based power generation that targets the highest efficiency, lowest emissions and best economics (HELEBE) by employing state-of-the-art steam turbine technology combined with innovative digital and lifecycle services and solutions. The most advanced steam turbine generator technology enables net plant efficiencies of up to 50%, including below 600 MW for steam power plants. The combination of digital innovations for networking and maximum data utilisation generates maximum added value for plant operators. To complete the comprehensive Siemens approach, the Steam 4.0 concept also includes lifecycle services and solutions for modernising and upgrading of existing plants in order to boost their efficiency and optimise operational costs.

As part of Steam 4.0, the Siemens partnering concept offers maximum flexibility in the scope of supplies and services by employing a strategic collaboration approach with internationally reputable EPC partner companies and boiler suppliers. Investors benefit from a huge synergy potential that results from project-specific, customised and best-fit technology partner pairings and service level partnerships for their projects. This approach is based on proven business collaboration models.

The evolution of steam parameters
Steam turbine applications and their performance have been continuously improving since the steam turbine was first invented. Figure 1 shows the development of steam inlet
temperatures, main steam pressure, power output and thermal efficiency since 1960.

The increase in steam temperature has required the development of new materials, and the growing power output and main steam pressure has required improved mechanical design using existing materials. That is why efficiency was initially driven by a pressure increase up to supercritical conditions. With the development of high chromium steels, it was possible to raise steam temperatures up to 600˚C and achieve ultra-supercritical parameters. For economic reasons, steam power plants in the 250 - 500 MW class have until recently remained primarily subcritical, with temperatures not exceeding 566˚C.

The need for flexibility
Steam-based power generation has typically consisted of base load units operated in steady-state condition with low load change rates. The worldwide expansion of electricity production from renewable energy sources, however, has imposed a completely different operating regime for fossil-fuelled power plants. They are now called on to generate the residual load in the grid. According to the merit order, gas-fired power plants are the first type of power generation assets that have to be shut down once renewables are brought online. Following that logic, the initial approach has been to accommodate high load change rates by bringing online and taking offline those combined cycle power plants that were first to achieve a fast start-up and shutdown times. With the increasing volume of renewable energy available in conjunction with decentralised power generation, coal-fired plants are now experiencing the same requirements as gas-fired units. The expertise acquired from developing the water steam cycle in combined cycle power plants is now helping engineers adapt steam power plants to meet these changed operational requirements.

With the new SST-5000 turbine series, a Siemens steam turbine train in a two-casing (high intermediate and low pressure) design delivers inner turbine efficiency rates as high as those in a three-casing (high, intermediate and low pressure) design, even within ultra-supercritical steam parameters. They are intended for the 250 - 500 MW power output class in order to address the global trend toward smaller power output ratings. The latest technology development of the Steam 4.0 concept includes features that reduce the load to grid to zero with a coupled steam turbine generator, which means that it can increase the load even more rapidly when required.

As the interface of the shaft train to the power grid, the generator is exposed to extremely volatile operating modes, which causes significant thermomechanical stresses and accelerated aging of the active components. Siemens’ answer to growing market requirements is the new pressurised air generator SGen-2000P. It features an innovative combination of verified cooling technologies based on air and water. Air-cooled generators have an excellent track record in terms of robustness, reliability and low operating costs, while Siemens’ stator winding in water-cooled generators deliver the highest output capability and efficiency in the industry. Building on the success of the proven legacy fleet, the new SGen-2000P generator line is set to replace the indirectly hydrogen-cooled SGen-2000H series up to 550 MVA. Replacing hydrogen cooling with pressurised air significantly reduces plant complexity and eliminates gas hazards. Other benefits include reduced first-time installation, commissioning and maintenance costs.

Maximised asset performance, thanks to digital innovations
Ingenuity in engineering is not limited to hardware only. Combining the Steam 4.0 technology with digital services and
solutions provides plant operators with the digital transparency required to continuously monitor the status of their power plant assets.

This new level of transparency allows operators to draw insightful conclusions throughout the entire lifecycle thanks to Siemens’ power industry and OEM domain expertise.

Data analytical capabilities, such as predictive analytics, machine learning and AI, provide actionable insights to further increase system transparency and help operators make informed decisions.

The Siemens Steam 4.0 concept and its related digital and lifecycle services and solutions specifically address the four fundamental business drivers of plant operators:

- Increased revenues of plant operations.
- Reduced operational costs (via productivity improvements to existing and new-build assets).
- Improved capacity utilisation (including availability and reliability).
- Sustainability (prepare assets for future market challenges).

Omnivise™, the Steam 4.0 digital services portfolio for steam power plants, is powered by the cloud-based open Internet of Things operating system Mindsphere™.

Specific use-case combinations derived from its core categories, such as availability, fleet management and connectivity, performance/operational efficiency, include but are not limited to the following examples:

- Connection and monitoring for strategic decision support and anomaly detection.
- Smart contracts based on fully integrated digital twins.
- Recovery of loss degradation.
- Powerful asset performance management systems to increase asset availability/reliability.
- Entire fleet solutions or even autonomous power plants.

Optimisation through digitalisation

While maintenance accounts for approximately 40% of plant operating costs, fuel accounts for the bulk of the remaining 60% and can vary in a range between 47% and 64%, depending on the type of fuel used and the plant’s condition – by far the largest cost position associated with a plant. Operation optimisations and performance improvements result in a 2 - 5% output improvement, a 3% increase in fuel efficiency and about US$2 million/day decrease in outages. Fuel management is based on the principles of operation optimisation and performance improvement, and specific areas such as operations benchmarking, power plant optimisation, outage planning and regulatory compliance that play a key role.

Operation monitoring and benchmarking is performed using KPIs and key metrics to define the health of the plant’s operation. Power plant optimisation introduces flexibility in terms of length of run and load and dispatch optimisation. The ability to predict impending events directly impacts outage decision analysis, outage event management, and system commissioning and decommissioning. This is a paradigm shift from reactive and preventive maintenance strategies to more proactive and predictive maintenance.

Figure 4. These computer images of the two steam turbine trains at Pingshan II show the remarkable design of the Pingshan II steam turbine; the high pressure train will be mounted at a height of approximately 83 m.
Once upon a time, power plants existed as islands that were connected to the grid but were otherwise impervious to the perils of Internet connectivity. But over the past few decades, more and more assets have become automated and connected to vendor systems that have the ability to tap into plants to monitor the health of turbomachinery assets and manage fleets remotely. In certain cases, power plants are just a part of an even more complex industrial process. In those systems, the real benefits lie in harnessing the digital potential from the entire value chain.

For these cases, co-creation projects partnered with Siemens can be the right approach in order to pinpoint the operator’s underlying structural challenges, and to jointly develop tailored digital solution packages addressing those challenges individually and customer-specifically.

By implementing plant modernisations and data-driven solutions, operators gain greater operational control, system protection and sustainability. Plants operate more flexibly based on market demand, while controlling their operations and maintenance costs and ensuring physical and cyber resiliency.

**Initial success stories**

Siemens is the global leader in steam turbine generator technology along with its licences in China, India and Japan and has the world’s largest fleet. Some projects today are already confirming the enormous potential of Steam 4.0.

The most impressive project is Pingshan II in China. The plant will achieve a record-breaking efficiency of more than a net plant efficiency of around 50%, thanks to double reheating and advanced ultra-supercritical steam parameters of up to 325 bar and steam temperatures of up to 630°C. Along with its joint venture partner Shanghai Electric Power Generation Equipment (SEPG), Siemens will supply one of the world’s most advanced and efficient steam turbine generator packages for this project.

The Lünen plant in Germany and the Eemshaven plant in the Netherlands are two other examples.

When Lünen began operations in December 2013 with a power output of 750 MW, it was one of Europe’s cleanest and most efficient coal-fired power plants. The plant supplies electricity and heat to the city of Lünen at a net plant efficiency of 46%, which averts CO\textsubscript{2} emissions of up to 1 million tpy.

The Eemshaven ultra-supercritical steam power plant went into operation in 2015. Thanks to its ultra-supercritical steam parameters, the plant achieves a maximum net plant efficiency of over 46%. This leads to a reduction in CO\textsubscript{2} emissions of 2.5 million tpy. The power plant consists of two units, each of which has an installed electrical capacity of 800 MW.

**Conclusion**

The Siemens Steam 4.0 is able to tackle the challenges faced by new installations, including covering the world’s fast-growing energy demand at an affordable cost and reducing CO\textsubscript{2} emissions to the lowest possible level.

Steam 4.0 stands for the combination of the most advanced steam turbine generator technology with innovative digital services and solutions, leading-edge lifecycle service and solutions. It takes into account the power industry’s key value drivers: HELEBE.

All of these efforts are aimed at responsible, steam-based power generation that meet the challenges of reversing global warming.