A Sulzer Turbo Services Solution for Cogeneration

Flexible and Energy-Efficient

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Cogeneration steam powered systems, also called combined heat and power (CHP) systems, use one power station to simultaneously generate electricity and useful heat from steam, which is a thermodynamically efficient use of fuel. However, changing the ratio of steam and generated electricity sometimes requires significant modifications to the steam turbine. To increase the steam production in a CHP system, Sulzer Turbo Services developed a solution allowing more flexibility than the client had originally considered.

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Conventional power plants emit the heat created as a byproduct of electricity generation into the environment through cooling towers, as flue gas, or by other means. CHP systems make it possible to use byproduct heat for domestic or industrial heating purposes. Using a gas turbine in conjunction with a steam cycle is a very energy efficient way of generating heat and electric power. In a heat recovery steam generator (HRSG), the exhaust gases of the gas turbine produce steam to drive a steam turbine. The generating efficiency of such a combined-cycle power plant (CCPP) can be as high as 58% or even higher, if the excess heat of the steam turbine can be used.

Flexible Solution

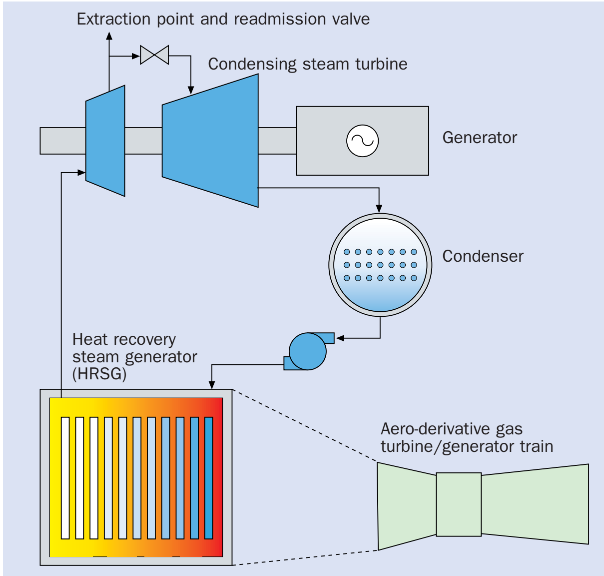
An independent power provider for industrial and institutional customers had realized that it is more profitable to sell steam than electric power. In the generating system, an aero-derivative gas turbine produces 20 MW of electricity, whereas a HRSG produces steam for a 6-MW steam turbine. The demand for steam has recently outweighed the demand for power. To accomplish the goal of maximizing the extraction of steam, the operator originally considered the option of permanently "de-staging" the turbine by removing 6 stages from the turbine rotor. Sulzer Hickham Inc., a company of Sulzer Turbo Services, presented a solution that provides a less damaging approach to the existing design of the turbine. The challenge faced when steam is extracted at the early stages of the turbine is the overheating of the back end of the machine. The solution implemented by Sulzer is the introduction of cooling mist at strategic locations in the turbine casing to remove heat generated from windage and internal steam leakage. This simple solution fits within the physical and operational envelope of the machine's original configuration allowing the operator the flexibility to switch back to generating electricity at full capacity as demand changes.

Generating Heat and Power

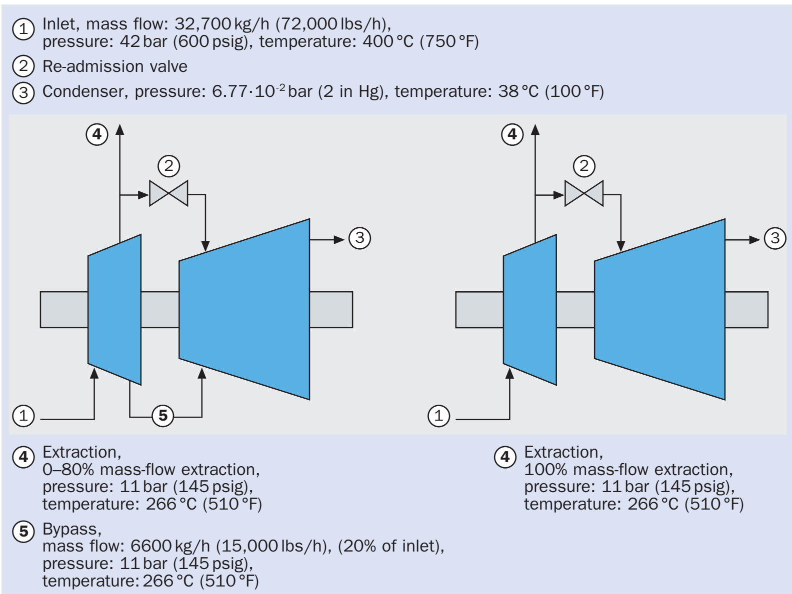
The cycle is a cogeneration gas turbine/steam turbine cycle totaling 26 MW of electricity (Fig. 1). The cogeneration cycle consists of a HRSG that uses the exhaust of a 20-MW aero-derivative gas turbine/generator to create steam. The steam moves a 6-MW condensing steam turbine driving a generator for a total power capacity of 26 MW.

The steam turbine is designed to allow for steam extraction after the second stage of rotating blades. The extracted steam is used at a next-door manufacturing facility and also for building heat during the winter season.

Due to changes in market demand, it has become more lucrative to sell steam extracted after the second stage than to produce additional power. Under the original operating conditions, 0–80% of the steam could be extracted from the steam turbine (Fig. 2). A bypass ensured

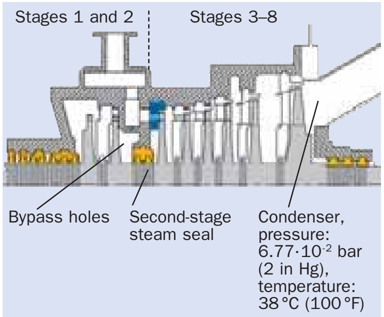


1 The combination of a gas and a steam turbine for the generation of electricity and useful heat is very fuel-efficient. Sulzer Turbo Services modified the steam turbine in such a system to increase the amount of steam produced.

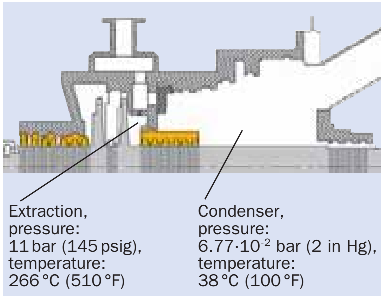


2 The original operating conditions (left) need to be changed to increase the amount of extracted stream.

3 Plugging the bypass holes results in stages 3–8 running at near-vacuum conditions.



4 Taking out the blades of the stages downstream of the steam extraction requires significant and irreversible modifications to the turbine.



at least 20% of the steam mass flowed through the last 6 stages of the steam turbine. This amount was the minimum of flow required to keep the back end of the rotor and casing from overheating.

Maximizing Steam Extraction

In order to maximize the extraction of steam, the bypass holes can be plugged, so when the re-admission valves are fully closed, no flow is allowed towards the condenser (Fig. 3). Under these conditions, stages 3 through 8 operate under condenser conditions, i.e. nearly vacuum. Leakage from the second-stage steam seal is the main contributing heat source to the back end of the machine.

The first option considered by the operator to achieve the desired full extraction was to remove the blades of stages 3–8 and to install atmospheric steam seals after the second stage in order to contain the 11 bar (145 psig) steam.

This option would incur extreme changes from the original design of the machine (Fig. 4). Removing the rotating disks drastically alters the mass distribution on the rotor and changes its dynamic behavior. A rotordynamic study would have to be conducted to evaluate the stability of the new rotor configuration.

The most significant impact would be the inability to return to original operating conditions. If the current steam demand was to change, the operator would have to provide a new rotor in order to return to the original design.

A Better Solution

Considering the current and possible future needs of the client, Sulzer Turbo Services in La Porte, TX (USA) approached the operator with an alternative that would minimize the impact on the case while achieving the desired operating conditions.

The Sulzer engineers suggested adding cooling mist in strategic locations to cool down the heat generated from windage and steam leakage from the second-stage seal (Fig. 5).

Cooling can be achieved through removing energy from the steam by mixing in a fine water mist. At the third stage, a mist of cooling water at 38 °C (100 °F) mainly removes the heat from the second-stage steam leakage.

A spray manifold located downstream from the eighth-stage rotating blades removes energy from the back end generated by the windage effect of the blades rotating with little to no flow through the turbine (Fig. 6).

Reacting on Changed Demand

This option allows the operator to switch from original operating conditions to 100% extraction after the second stage. In the event of falling demand for steam or rising demand for electricity, the operator can change from one mode of operation to another effortlessly.

Solenoid valves tied to the steam turbine digital control system control the application of the cooling mist flows. The system also controls the timing and flow during startup of the steam turbine in order to provide a smooth transition from normal operation to 100% extraction.

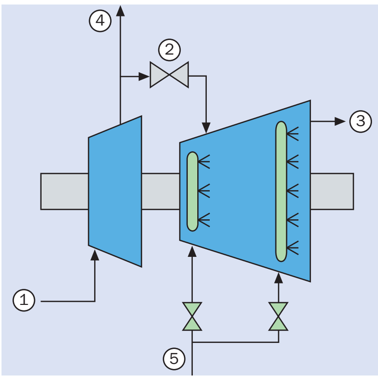
Sensors for pressure and temperature provide alarm signals to the control room in case the cooling flow conditions fall below the required amounts.

Drains at the bottom half of the case facilitate the removal of accumulated water towards the condensor.

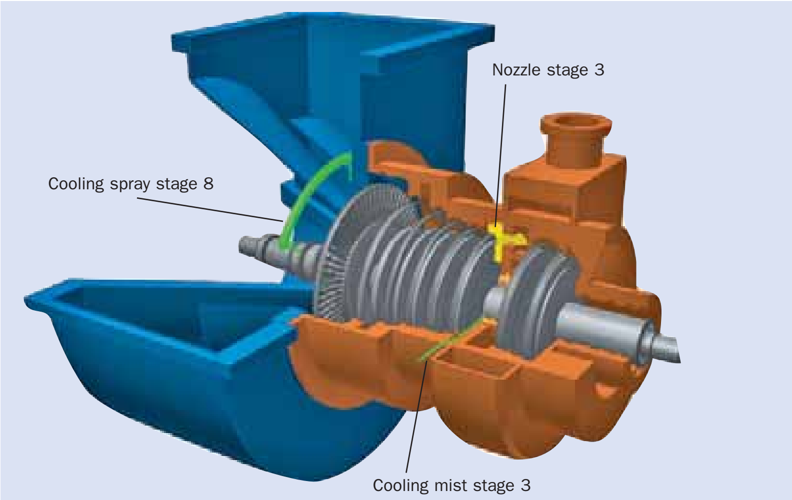
An Idea Put in Practice

Late in 2007, the operator decided to implement the mist cooling system as designed by Sulzer. A Sulzer Turbo Services field service crew dismantled the steam turbine

5 The customer application know-how of Sulzer lead to a different solution than the client had originally in mind.



(1) Inlet, mass flow: 32,700 kg/h (72,000 lbs/h), pressure: 42 bar (600 psig), temperature: 400 °C (750 °F)
(2) Re-admission valve
(3) Condenser, pressure: $6.77\cdot10^{-2}$ bar (2 in Hg), temperature: 38 °C (101 °F)
(4) Extraction, 100% mass-flow extraction, pressure: 11 bar (145 psig), temperature: 266 °C (510 °F)
(5) Cooling mist



6 Adding cooling-mist nozzles and leaving stages 3–8 on the rotor allows to increase power production again, should market demand require this measure.

case and rotor on site and shipped the parts to La Porte for service.

In February 2008, the machine was returned to the site with the modifications in place (Fig. 7). Temperature sensors were installed throughout the case and steam path in order to monitor steam and case metal temperatures stage by stage. In addition to these temperatures, a control system monitors the cooling mist flow and pressure to ensure normal case temperatures are maintained and proper cooling conditions are met.

Expectations Met

In early March 2008, Sulzer Turbo Services technical service personnel commissioned the new steam-turbine mist cooling system. With the use of data acquisition systems, the temperature and flow parameters were recorded on normal startups. Data was recorded at different extraction conditions in order to determine a baseline for operating temperatures. This data was used to establish alarm points for maximum and minimum allowable case temperatures.

Finally, the cooling system was tested and the calculated values of required flow versus operating temperature were confirmed. Over the next couple of days the temperatures were closely monitored to ensure a steady and stable operation of the turbine under the new extraction conditions.

By the end of March the cooling mist system had been fully implemented with very good results. The operators expectations were met when the full 32,700 kg/h (72,000 lbs/h) of steam generated at the HRSG were being extracted after the second stage of the steam turbine, while the back end of the machine steadily maintained normal case temperatures.

7 Assembly of the modified steam turbine at the Sulzer Turbo Services plant.

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