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Heat recovery steam generators

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Authors

Gerhard Schlund, Siemens Energy Global GmbH & Co. KG
Tobias Schulze, Siemens Energy Global GmbH & Co. KG
Jan Brückner, Siemens Energy Global GmbH & Co. KG
Frank Thomas, Siemens Energy Global GmbH & Co. KG

New Benson evaporator for vertical HRSGs exceeds expectations

A new Benson HP evaporator design for vertical-exhaust-gas-flow heat recovery steam generators – deployed for the first time in the 24 HRSGs of the Siemens H-class Egypt Megaproject – has proved highly successful. Commissioning and operation have been trouble free, thanks to innovative design features and simulation-based prior optimisation of the all-important Benson-specific feed-water controller

Gerhard Schlund, Tobias Schulze, Frank Thomas and Jan Brückner, Siemens Gas and Power, Germany



Megaproject HRSGs

Siemens Benson Technology has worked with its licensee Siemens Heat Transfer Technology B.V. to develop a once-through evaporator for the high-pressure stage in vertical-exhaust-gas-flow triple-pressure HRSGs (heat-recovery steam generators) with reheat. The first application of the technology was in the Siemens Egypt megaproject, which saw deployment of 24 boilers of this design in twelve 2-on-1 combined cycle power plants equipped with SGT-8000H gas turbines (see *MPS* July 2017 and November 2018). Innovations in the evaporator design coupled with simulation-based optimisation of the Benson-specific feed-water controller ensured successful commissioning of the high-pressure evaporator and flawless operation subsequently. The successful launch was another milestone for Benson technology.

Figure 1 shows a schematic of the Benson evaporator in the vertical HRSG. The heating surface tubes are arranged horizontally in the vertical flue gas stream. In this specific design case, the tubes are connected in a two-pass formation and routed downward from the evaporator inlet to the evaporator outlet, in a meander against the flue gas flow. The water/steam separator is located downstream

of the HP evaporator. This simple and compact design enables a countercurrent configuration to be achieved, which is ideal for heat transfer and also provides high mechanical flexibility.

Thermohydraulic challenges

Despite the rugged design, which is distinguished by its simplicity, there are thermohydraulic challenges that must be given special attention.

Due to the arrangement of the tube rows and the downward flows in the tubes, this evaporator design runs the risk of fluid temperature imbalances due to heating imbalances. There is potential for excessively high temperatures at the individual evaporator tube outlets that penetrate the evaporator due to hot flue gas streams. The danger is that the design temperature of the evaporator tubes will be exceeded locally.

In addition to imbalance issues, flow stability in the evaporator tubes must be ensured. Static and dynamic stability criteria need to be examined in detail to guarantee reliable operation.

In close collaboration with the boiler manufacturer, a Benson Design Review was

conducted for this evaporator type and the identified thermohydraulic challenges were examined.

Using various investigation methods developed for the purpose, it was possible to establish an optimal evaporator configuration, a combination of tube length, number of rows, tube diameter, and positioning in the flue-gas duct.

The resulting evaporator design meets the identified requirements in terms of correcting imbalances and establishing flow stability using an innovative tube arrangement. This was impressively demonstrated with the aid of temporarily installed wall surface temperature measurements.

In addition to the design optimisation described, another measure was developed to prevent fluid temperature imbalances. This consisted of partition plates to be welded into the evaporator inlet header, dividing it into eight equal segments. This would have made it possible to modify the flow through the eight parallel segments by installing orifices in the individual feed lines, allowing the heating imbalances to be compensated. However, it proved unnecessary to resort to this option due to the evaporator's superior behaviour.

Wall surface temperature measurements at evaporator outlet

To test the HP evaporator's operation and verify the measures taken, one of the 24 boilers was equipped with wall surface temperature measurement sensors at its outlet, as shown in Figure 2. Because of the measurement position, in the unheated area of the tubes, and the installation design, the measured values are a very good approximation of the fluid temperatures in the individual tubes. This means that these measurements are good indicators of flow stability and temperature imbalances across the entire boiler width.

Figure 3 shows the recorded temperatures, GT load, and main steam temperature over a one hour period during a load change from 100% to 50% of full GT load and back. The

Heat recovery steam generators

temperature measurements from the two parallel tube rows are shown in separate graphs (Rows 1 and 2).

The uniform temperature curves during and after the transient phase indicate that

the evaporator's operation was absolutely stable and temperature imbalances were minimal. The lack of "oscillations" following this particular load change emphasises the extremely stable behavior. Considering that

the temperature curves shown here cover the entire boiler width, it is hard to imagine that less of a temperature spread among the tubes could be achieved. The Benson design can therefore be recommended as a perfect fit for vertical once-through evaporators.

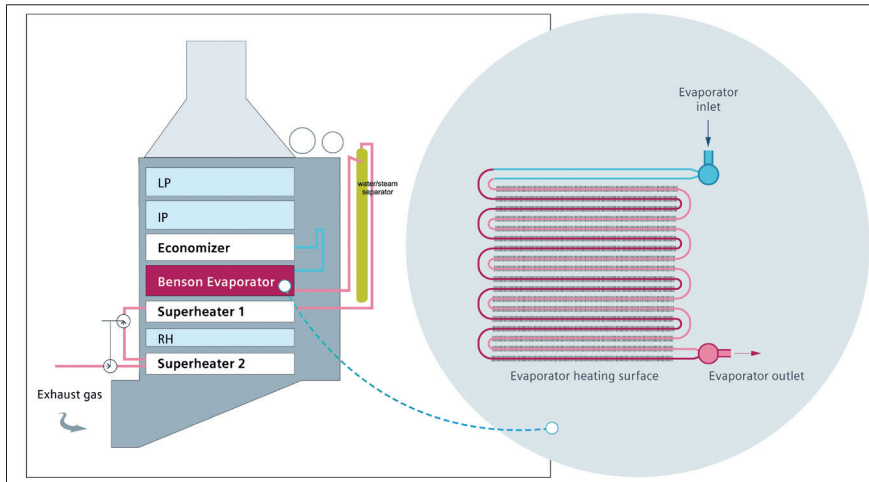


Figure 1. Schematic of vertical triple-pressure HRSG with Benson evaporator and reheat

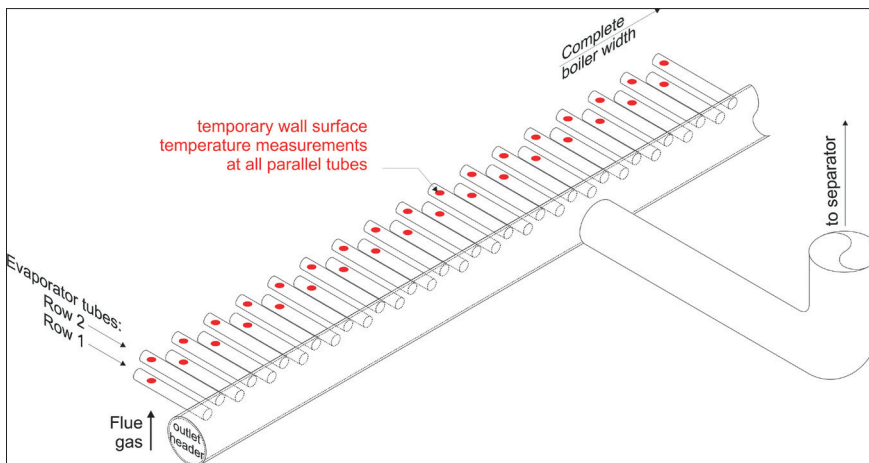


Figure 2. Wall temperature measurements were taken on all of the parallel tubes of one of the evaporators, at the outlets of the individual heating surface tubes. This diagram shows the locations of the measurements

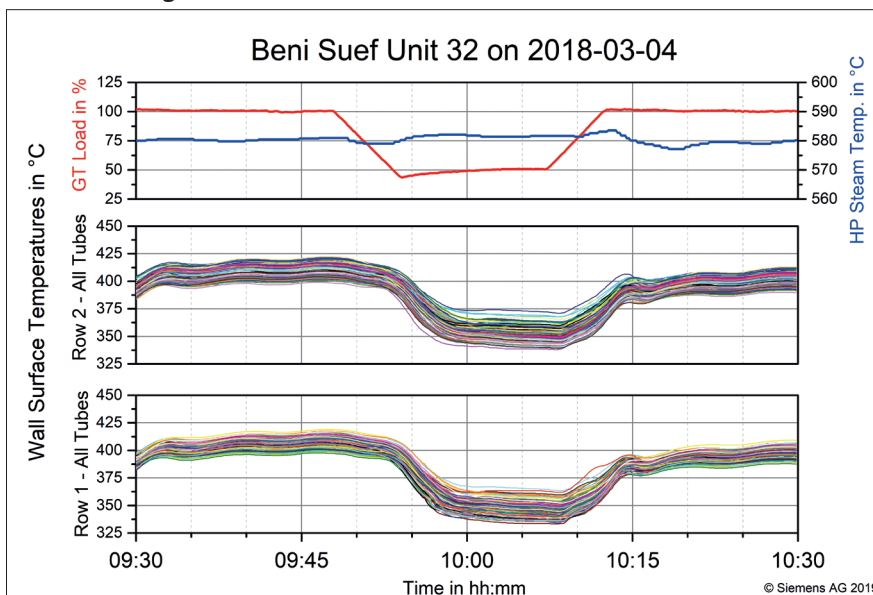


Figure 3. Wall surface temperature measurements, Beni Suef unit 32, taken on 4 March 2018

Simulation-based optimisation of the feed-water controller

The feed-water controller in the Benson HP stage is of central importance to efficient and flexible power plant operation. For horizontal-exhaust-gas-flow HRSGs with a Benson HP stage, a feed-water controller with a feed-forward signal for the feed-water mass flow has been proven time and again. Based on measured and specified plant parameters, the necessary feed-water mass flow is predicted and specified as a basic set-point.

To qualify this concept for use in Benson vertical HRSGs, comprehensive simulations were run in Siemens' Dynaplant simulation environment using a numerical model of the entire vertical HRSG, supplemented by a simplified steam turbine model. The model also included all feed-water control components and other control loops necessary for the simulations.

The simulations showed that the feed-water controller had to be adapted to the Benson vertical HRSG design in order to ensure an optimal feed-water flow in all specified operating states. This adaptation involved both the algorithm for predictively determining the basic set-point and the parameterisation of higher-level correction controllers. The feed-water controller that was optimised in the simulations was transferred to actual plant automation with no modification. It was impressive to see that an additional manual optimisation of the feed-water controller on site during commissioning was not necessary.

In order to validate the Dynaplant simulation model, various load ramps from commissioning were subsequently simulated. From actual plant operations, only the gas turbine load change was entered into the model. All of the other influencing variables that were not yet precisely known before commissioning were intentionally not adapted to actual operating conditions. This was to guarantee a practice-oriented comparison that would take into account the quality of the model itself and any uncertainties about model boundary conditions that still remained in the project execution process. If the results of the simulation under these conditions correlated well with the measurements, it could be concluded that the controller settings optimised by simulation before commissioning also represented the optimum in real plant operation. Figures 4a, 4b and 4c support this conclusion precisely.

The parallel shift of some variables is attributable to the different swallowing capacity of the model steam turbine in the calculations and the real component, and

Figure 4A

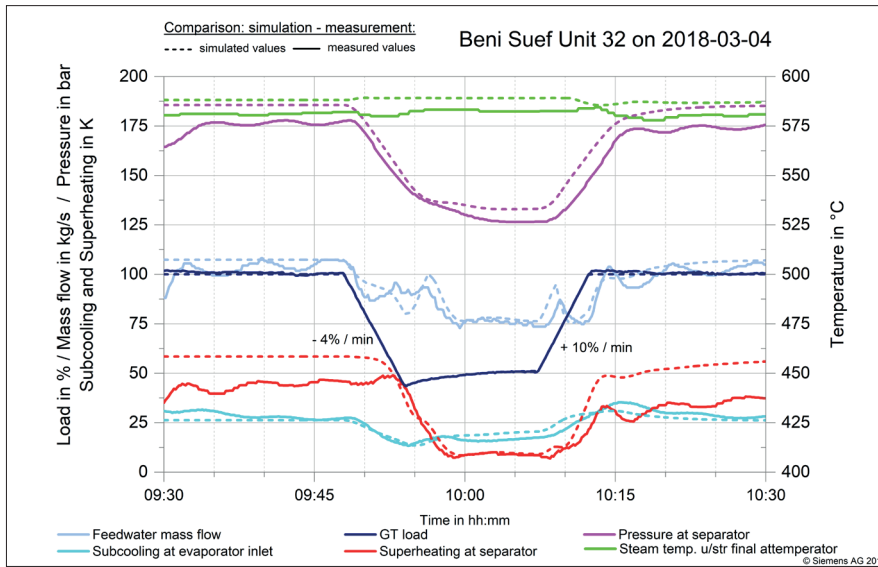


Figure 4B

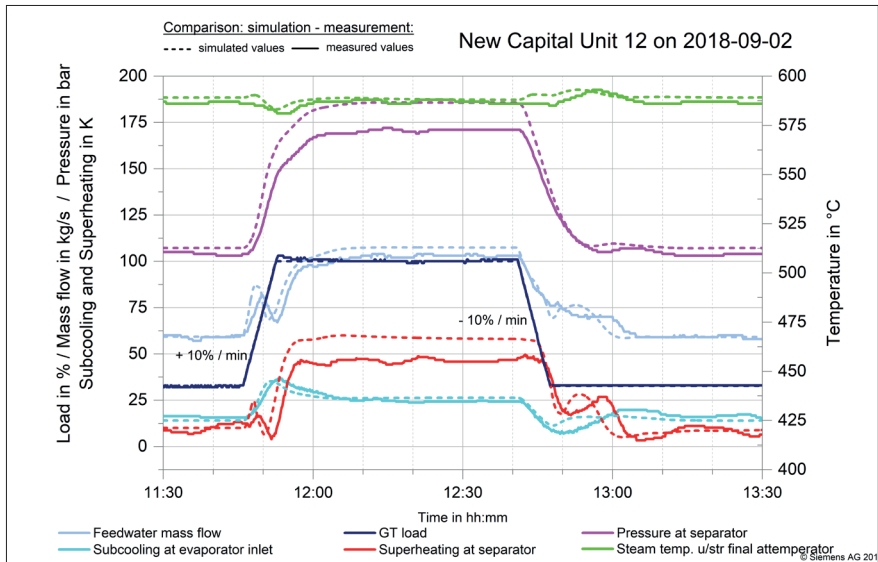
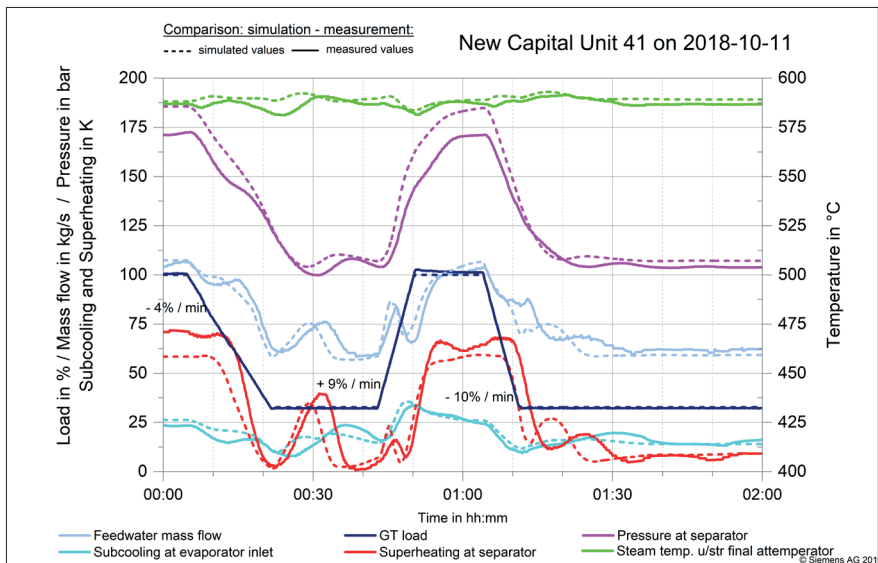


Figure 4C



Figures 4a, 4b and 4c. Comparison of measurements from plant operation with predictive dynamic simulations. 4a: measurements taken on 4 March 2018 in Beni Suef unit 32; 4b: measurements taken on 2 September 2018 in New Capital unit 12; 4c: measurements taken on 11 October 2018 in New Capital unit 41

to varying ambient temperatures of the simulation versus actual operation.

Successful launch

In summary, it was possible to ensure compliance with design requirements in advance using the applied investigation methods. An optimal setting for the feed-water controller for the Benson HP stage was also successfully determined before the actual commissioning took place, solely on the basis of comprehensive dynamic simulations. This guaranteed a smooth and rapid commissioning of this component. Due to the complex technical interrelationships, a similarly comprehensive manual optimisation of the feed-water controller performed only during commissioning would not have been possible within the same limited time period.

The Benson vertical once-through evaporator has been successfully launched. Additional projects using this evaporator type are already pending at South Bangkok in Thailand and Keadby II in the UK. ■



The Megaproject combined cycle plants, from the top: Beni Suef, Burullus, New Capital

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Generation
4400 N Alafaya Trail
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