Water Chemistry: GE Vernova's Once Through HRSG vs Drum HRSG

Abstract

The energy market continues to transition from traditional fossil fuel fired power plants to renewable and decarbonized sources of electricity. Wind and solar are forecasted to contribute to around 80% of global net capacity additions over the next 30 years as the industry seeks a greener, reliable, affordable and sustainable grid.

However, increased renewables can lead to grid instability and gas fired power plants will remain important for flexible, efficient generation available with fast start-up times. Despite a proportional increase in new renewables, the MW's generated from gas plants is still forecasted to grow 3% by 2050, satisfying the increased global demand.

To support this energy mix, GEV delivers its Once Through (OT) HRSG technology combined with an integrated impurity management [2]. This technology allows the plant to load faster and operate more efficiently by operating at higher steam pressures at base load and minimizing desuperheater spray flows at part load and off design operating conditions [3]. This paper aims to share GEV's experience with OT HRSGs vs. drum water chemistry, utilizing GEV's commissioning and operational data. Long term values for degassed conductivity as well as a decay during startup and startup times in regards of power plant chemistry are shared to show the efficacy of impurity removal and operability of GEV's Once Through HRSGs.

Introduction

GE Vernova's HRSG

A Heat Recovery Steam Generator (HRSG) is a vital component in Combined Cycle Power Plant (CCPP). HRSGs are designed to recover waste heat from gas turbine exhaust and convert it into steam that is used to drive a steam turbine (ST). By doing so, HRSGs significantly improve the plant's overall thermal efficiency, leading to reduced fuel consumption and lower greenhouse gas emissions. This makes CCPP more environmentally friendly compared to simple cycle gas turbine plants [4].

In CCPP, the quality of the water is critical to the efficient and reliable operation of the HRSG [1, 4]. Impurities such as dissolved solids and minerals can cause scaling and corrosion if not properly controlled, leading to reduced turbine efficiency, increased maintenance costs, and compromised plant safety. To maintain water quality, HRSGs employ various water treatment processes, including chemical dosing, and blowdown systems.

a. GE Vernova's Drum-Type HRSG:

Drum-type HRSGs use natural recirculation evaporators in their high-pressure (HP), intermediate-pressure (IP), and low-pressure (LP) circuits. These systems typically feature vertical tubes with horizontal gas flow. The drums are typically horizontaly located at the top of the HRSG. These conventional evaporators are typically limited to a maximum pressure of around 190 bar due to challenges in steam-water separation near supercritical conditions and material constraints [5, 1].

In the LP and IP drums, water quality is controlled by chemical treatments such as solid alkalization or all-volatile treatment (AVT), water blowdowns to remove concentrated impurities, and demisters to separate water droplets from the evaporating steam [6].

In GEV's high-pressure drum systems operating above 160 bar, chemical treatments are typically avoided as the elevated pressures significantly increase the solubility of impurities in the steam [7]. This increased solubility can lead to chemicals being carried over into the superheated steam, potentially damaging the steam turbine. Instead, the water quality in HP drum evaporators is maintained through AVT, water blowdown and/or the use of demisters, ensuring that only high-quality steam is delivered to the turbine. This approach helps preserve the integrity and efficiency of the steam turbine by preventing potential damage from chemical carryover.

b. GE Vernova's Once Through HRSG:

GE Vernova's OT HRSGs utilize once through technology for the high-pressure circuit, while the intermediate-pressure and low-pressure circuits remain drum-type, using solid alkalization for pH control and continuous blow-down to remove impurities [3, 8]. In this configuration water flows in a single pass through drainable horizontal OT tubes with horizontal gas flow, supporting steam pressures above 190 bar.

During startup, a small separator downstream of the HP OT sections collects excess feedwater that has not yet evaporated. This HP separator is also used in the refreshing mode to remove accumulated impurities in wet steam, ensuring the purity and efficiency of the steam generation process [9]. This system helps maintain the purity and efficiency of the steam generation process, ensuring optimal performance and reliability.

This hybrid approach combines the benefits of both once through and drum type designs, offering increased flexibility, efficiency, and daily cycling capabilities [10].

It is important to note that, in this system, the purity of the high pressure steam solely depends on the quality of the inlet HP feedwater. Indeed, during steady-state operation, the HP circuit does not experience any cleaning processes, such as chemical dosing or blowdown. Therefore, the only potential source of contamination is the HP feedwater, which fully evaporates to produce the superheated steam at the OT outlet.

c. Comparison of GE Vernova's Drum and OT HP evaporators on GE Vernova's HRSGs

It is important to note that the OT HRSGs discussed in this work include LP and IP circuits, which utilize drums with chemical treatment for impurity management. In contrast, the high pressure circuit differs between the two designs: drum type HRSGs use drums without chemical treatment, while OT HRSGs employ a once through system.

Table 1. Comparison of GE Vernova's Drum and Once Through HRSGs

	Drum HRSG	OT HRSG
Startup time	Slower ramp rate to heat the HP drum and establish natural circulation due to thick drum wall and large water inventory.	Fast startup due to continuous flow, and less water inventory, which allow for rapid heating.
Flexibility	Some limitations due to the need to protect the magnetite layer in the HP drum.	Highly flexible: can efficiently handle varying loads and quick changes.
Control complexity	Simpler, more forgiving in handling fluctuations.	Increased complexity, requiring precise control of flow and temperature.
Efficiency	Typically operates at lower steam pressures and temperatures, leading to lower thermal efficiency. Continuous and intermittent blowdowns remove impurities but result in water and energy losses.	Operates at higher steam pressures and temperatures, improving thermal efficiency at base load. Minimizing desuperheater spray flows at part load and off design operating conditions results in higher thermal efficiency.
Water Treatment	Can handle low water quality due to separation in the drum – reduces scaling issues.	With high purity water, scaling and corrosion is prevented.

	Note: the GEV plants investigated in this study use the same make up water requirements (Drum-type and OT-type HRSG)	Note: the GEV plants investigated in this study use the same make up water requirements (Drum-type and OT-type HRSG)
Applications	Common in a wide range of power plants, including industrial applications.	Used in high efficiency power plants, and applications requiring rapid load response and frequent cycling. Offers superior off-design and part-load performance, making them ideal for markets with high fuel costs.

Water Chemistry Monitoring

To ensure the proper operation of both drum type and OT HRSGs and to minimize impurities in the water-steam cycle, continuous monitoring and control of key parameters are essential. These parameters include pH, cation and degassed cation conductivity, sodium, silica, iron, and dissolved oxygen [6, 11].

Impurities are managed through several key methods:

a. Water Treatment:

Water treatment plants in CCPP are designed to produce a continuous supply of high-purity makeup water. This is achieved through pre-treatment, deionization, and reverse osmosis, which remove suspended solids, dissolved minerals, and organic matter from the water before it enters the steam cycle.

b. Chemical conditioning of the water steam cycle:

Chemical agents are added to the condensate and drums to adjust the pH, increase impurities removal, and inhibit corrosion. GE Vernova recommends using reagent-grade chemicals to minimize the introduction of impurities into the water-steam cycle.

c. Monitoring and Control:

Automated sampling and dosing systems continuously monitor and adjust the water and steam quality in real-time, ensuring that treatment processes are effective.

Overview of this study

This paper shows that there is no significant difference in steam impurity management between GE Vernova's Drum and Once Through HRSG high-pressure systems. It is crucial to reiterate that, for GEV's CCPP plants operating at high pressures (above 160 bar), the cleaning efficiency of HP drums and OT HP systems is consistent since solid alkalization is not used in HP drums.

Moreover, most of the steam generated in the HRSG is HP steam (ca. 70%), which is the first to reach the required temperature and pressure levels after start-up. Also, as explained above, the HP steam has the highest probability for impurities carryover. Hence, due to this, its purity is crucial in determining when steam can be safely admitted into the steam turbine. To assess this purity, the degassed cation conductivity of the HP steam is commonly used as the chemical release criterion. This ensures that impurities are within acceptable limits before turbine admission. Therefore, this paper will use values of HP degassed conductivity for comparison between the GEV Drum and OT HRSG.

OT and Drum HRSGs in GEV H-Class (HA) CC plants in their first 10 years of commercial operation have been analyzed across Asia, Europe and America. Moreover, the GEV's OT HRSG plants investigated do not have condensate polishing units as they are not required.

Results and discussion

Start-ups performances

In this work, we evaluated the development of thermodynamic steam parameters (pressure, temperature, flow) and steam purity (Degassed Cation Conductivity) after the start of the gas turbine, for both Drum and OT HRSG. Once the steam meets the thermodynamic release requirements for steam turbine operation, it can be admitted to the ST with the conditions that the steam DCC values are below 1 µS/cm.

Our results indicate that the steam reaches the required quality (DCC < 1 µS/cm) on average, 60 minutes before it is admitted to the steam turbine. This observation was consistent for both Drum and OT HRSG (Figure 1). The delay in admitting steam to the ST may be caused either by the operator, or the grid requirements. Figures 2-4 demonstrate that the DCC values are consistently below 1 µS/cm before the steam turbine is switched on (for all: cold, warm and hot start-ups).

Furthermore, during start-ups, the steam chemistry of Drum HRSG closely follows the DCC time allowances set by GE Vernova (see Table 3). In contrast, OT HRSG appear to outperform Drum HRSG in this regard (Figure 1). Indeed, the DCC values of OT HRSG reach levels below 1 µS/cm 1, 5, and 42 minutes earlier than Drum HRSG for hot, warm, and cold start-ups, respectively. This is likely due to OT HP systems generating steam earlier than Drum HP systems, leading to quicker pressure build-up.

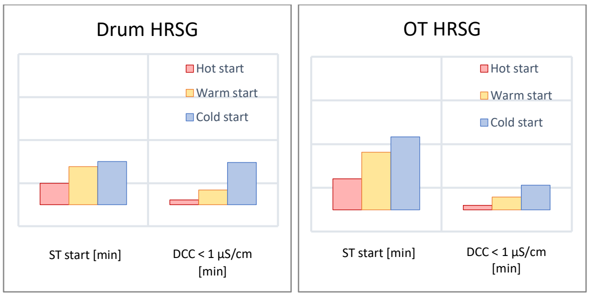

Figure 1. Average time, in minutes, for Drum and OT HRSG to start ST and to reach DCC values below 1 µS/cm (y-scale represents the time in minutes and is the same for both graphs).

Figures 2-4 show typical hot, warm and cold start-ups that we can achieve with OT HRSG plants.

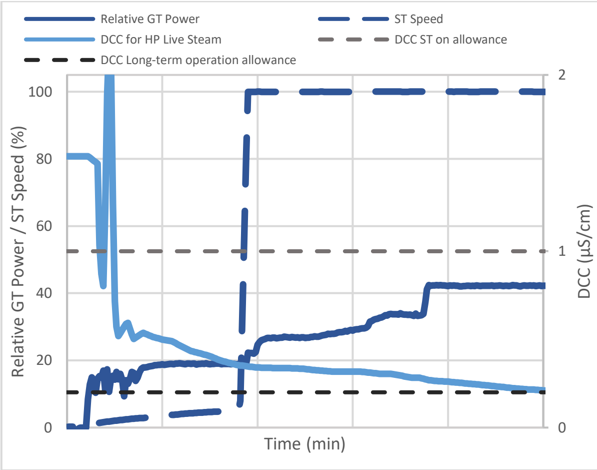

Figure 2. Fast Hot start-up from an OT HRSG (location Europe).

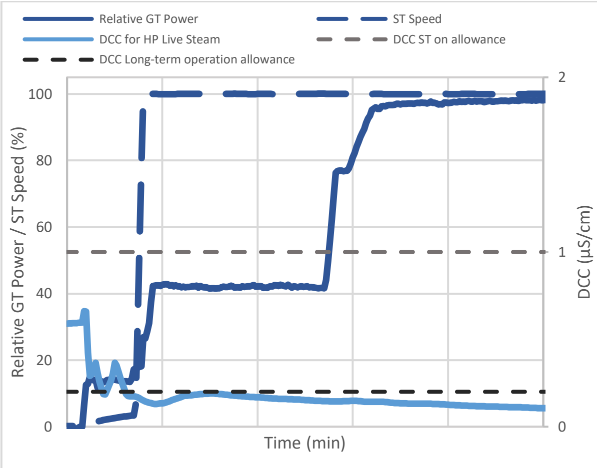

Figure 3. Fast Warm start-up from an OT HRSG (location: Europe).

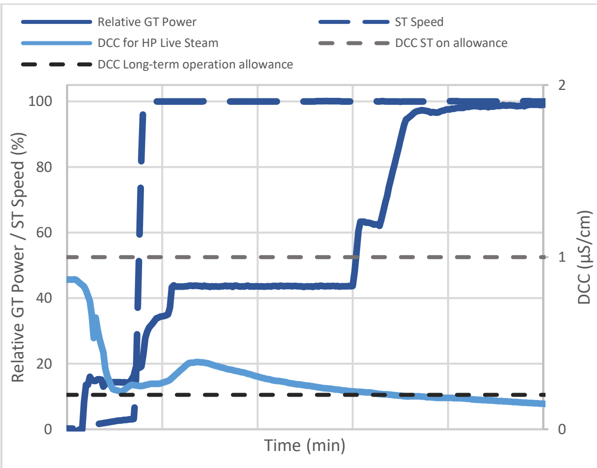

Figure 4. Fast Cold start-up from an OT HRSG (location: Europe).

Overall, the results demonstrate that the steam generated in both Drum and OT HRSG reach DCC values below 1 µS/cm within the time allowances set by GE Vernova (Table 3). We also observe that the steam turbine is not delayed by water chemistry considerations when admitting steam.

Long-term performances

To ensure the long-term operability of CCPP, the water and steam quality need to reach levels lower than those required during start-up procedures (DCC < 0.2 µS/cm).

The results indicate that the time for the HP steam of OT HRSGs to reach long-term Degassed Cation Conductivity (DCC) values (0.2 µS/cm) is similar to that of Drum HRSGs, except during cold start-ups (Figure 5).

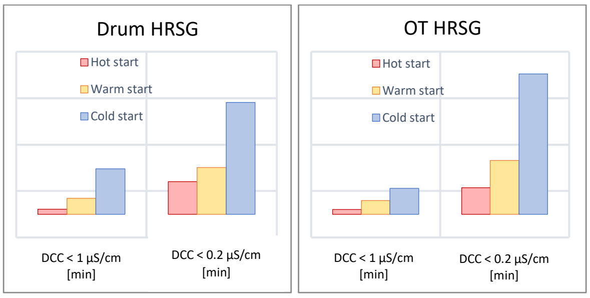

Figure 5. Average time, in minutes, for Drum and OT HRSG to reach DCC values below 1 µS/cm and 0.2 µS/cm (y-scale represents the time in minutes and is the same for both graphs).

Moreover, we have observed that once the long-term DCC levels are reached, they remain below the set threshold for the remaining operation time (Table). On average, the DCC values remain below the acceptable limits fixed by GE Vernova for 96 % and 99 % of the operation time for Drum and OT HRSG, respectively.

Table 2. Percentage of operation time during which DCC remains below 0.2 µS/cm, for Drum and OT HRSG.

	Percentage of operation time during which DCC remains below 0.2 µS/cm [%]	
	Drum HRSG	**OT HRSG**
Hot start-ups	95	98
Warm start-ups	98	99
Cold start-ups	96	98

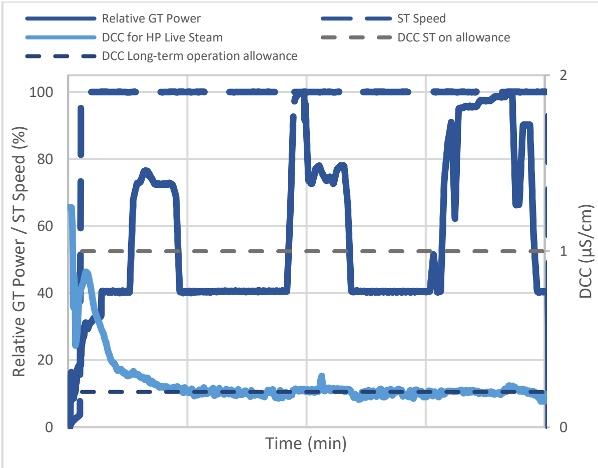

Figure 6. Long-term operation from an OT HRSG (warm start-up; location: Europe).

Overall, the results show that the steam generated in both Drum and OT HRSG remain below DCC values of 0.2 µS/cm for most of the operation time.

Conclusions

To support renewable energy integration, GE Vernova offers Once Through HRSGs, combined with integrated impurity management. This technology enables faster plant loading and more efficient operation by operating at higher steam pressures at base load and minimizing desuperheater spray flows at part load and off design operating conditions [3].

By using Degassed Cation Conductivity measurements as an indicator of HP steam purity, it was observed that OT HRSGs perform similarly to Drum HRSGs. Specifically, long-term DCC values remained below 0.2 µS/cm for 96 and 99 % of the time for Drum and OT HRSGs, respectively. The slight discrepancy is attributed to the purity of chemicals dosed in the LP and IP drums, as well as the efficiency of the water treatment units.

Furthermore, the DCC decay time during start-up (the time for DCC values to reach below 1 µS/cm) is within GE Vernova's specifications for both HRSG types. This ensures that the steam purity is never the limiting factor for the Steam Turbine to receive steam. Nonetheless, OT HRSGs appear to reach the required DCC start-up values faster than Drum HRSGs. This discrepancy is likely due to OT HP systems generating steam earlier than Drum HP systems, leading to quicker pressure build-up.

Methods

<u>Start-ups type definition:</u>

- Hot start-up: plant shutdown time < 8 h
- Warm start-up: plant shutdown time < 72 h
- Cold start-up: plant shutdown time > 72 h

<u>Conductivity measurement:</u>

Direct conductivity (DC): measure of the capability of water to pass electrical flow. This ability directly depends on the concentration of conductive ions in the water (i.e. inorganic materials: cations, anions, and CO_2). This measurement is affected by the chemical dosing (cf. solid alkalisation), the impurities in the water, the CO_2 from air, and the deaeration efficiency of the plant.

Cation conductivity (CC): measure of water after cation exchange. (i.e. inorganic materials: anions and CO_2). This measurement is affected by the impurities in the water, the CO_2 from air, and the deaeration efficiency of the plant.

Degassed Cation conductivity (DCC): measure of water after cation exchange and degassing. (i.e. inorganic materials: anions). This measurement is only affected by the impurities in the water. Therefore, this measurement is the most precise to detect impurities present in the steam.

<u>Degassed Cation Conductivity limits and allowances:</u>

GE Vernova's DCC limits:

- Start-up release of ST operation: DCC ≤ 1 µS/cm
- Continuous stable operation: DCC ≤ 0.2 µS/cm

GE Vernova's DCC allowances:

Table 3. Maximum allowed time by GE Vernova's for DCC values to reach ≤ 1 µS/cm.

	Hot start-up	Warm start-up	Cold start-up
Release time for ST (DCC ≤ 1 µS/cm) [min]	**30**	**50**	**70**

Note: The water steam cycle chemistry concept addressing the above objectives is based on GE Vernova best practices and according to fleet experience. It is aligned to common industry practice.

For start-ups, only starts with more than 3 hours of total operation were considered.

For long-term operation, only starts with more than 20 hours of total operation were considered. The percentage of operating time during which the DCC remains below 0.2 µS/cm was calculated starting from the moment the DCC reaches 0.2 µS/cm. However, if the duration exceeded 10 hours for Cold starts, 4 hours for Warm starts, or 30 minutes for Hot starts, the calculation of the percentage of operation time during which the DCC stays below 0.2 µS/cm was performed starting from 10 hours for Cold starts, 4 hours for Warm starts, and 30 minutes for Hot starts.

Authors

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