



ASIA TURBOMACHINERY & PUMP SYMPOSIUM
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Steam Whip phenomenon in Steam turbine

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This case study is designed to outline how the high vibration issue was successfully diagnosed, the root cause for the high vibration found and correction actions recommended. The source of mentioned high vibration - sub synchronous excitations is steam induced instability – steam whip, detected in HP/LP turbine seals, closer to Drive End bearing.

This turbine was initially equipped by Antiswirl packages. It was confirmed that this system is installed or operated not properly, non-original spare parts were installed during last overhaul.



Unit information

GE D11 180MW 3,600RPM

H/IP Steam Turbine

Stages : HP 10 stages, IP 7 stages

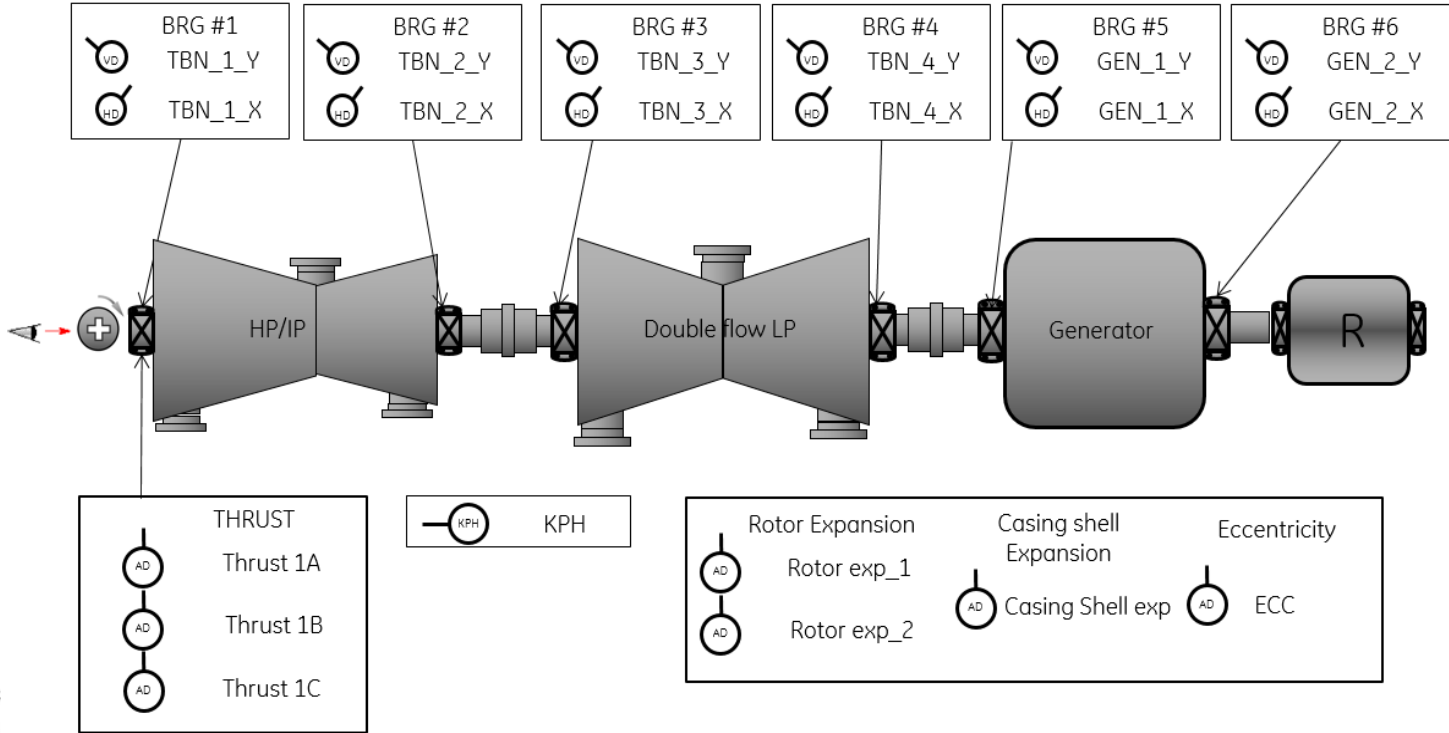
Installed in 1999

81,630 Operation hours

4,585 Starts

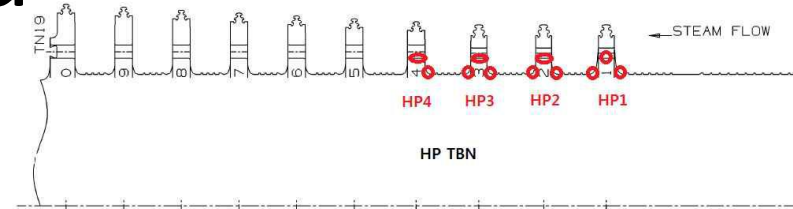


Unit information



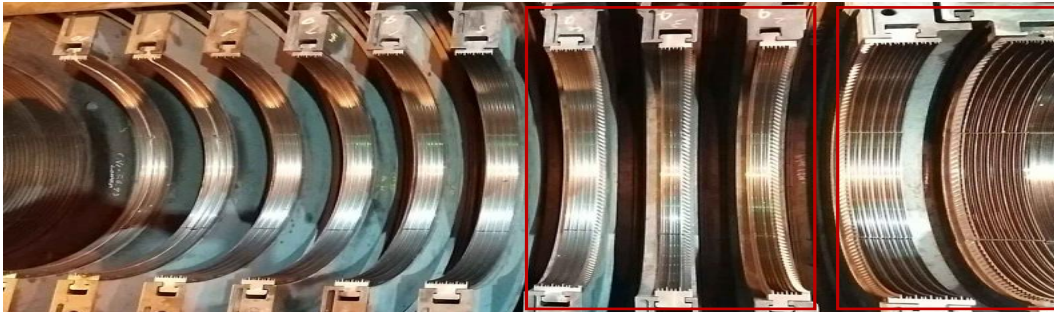
Historical background

- HP #1, 2, 3, 4 stages: Processed to remove cracks from wheel heat grooves & steam balance holes.
- 10 visually identified cracks: 11.2 mm of maximum crack depth (HP 1 stage front)
- Estimated growth speed of cracks of $8.75 \mu\text{m}/\text{cycle}$ (trend analysis)
- Correction of HIP TBN rotor bending: 0.30 mm max.
→ 0.05 mm based on mid-span



Historical background

- Replace to HIP retractable packings (1 anti-swirl conv./14 retr./2 brush) and N2 conventional packings.
- Structural change and removal of sound-absorbing materials to reduce vibrations related to axial resonance of the LP hood
- The vibration values of BRG#2 raised up till 11mils with the 22.5Hz component in first operation test 1 Nov.



Project / Exclusive summary

Multichannel data collector connected to protection system buffered outputs used.

The 22.5Hz component, 0.375 orders component for full speed appeared after 10 minutes in Full load reached.

The vibration amplitude of BRG #2 horizontal was changed from 80 μm pp to 160 μm .

High vibration amplitude 22.5Hz component was disappeared at 3550rpm, just after the Shutdown procedure initiated.



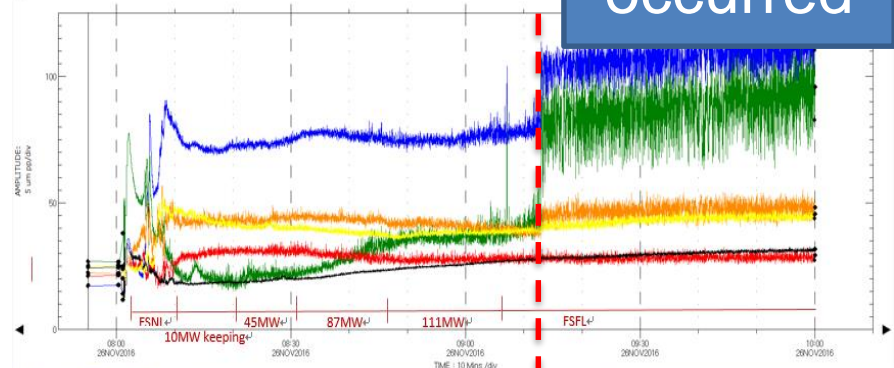
Start-Up and Loading

22.5Hz
occurred

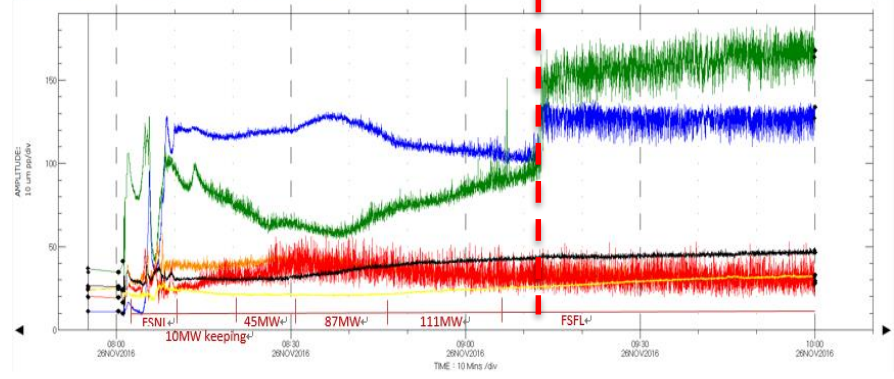
While the load kept Full load, the high vibration situation was suddenly occurred. The vibration amplitude of BRG#2 was raised up 63um and BRG#1 also was observed raised 22um.

The 1X component did not change any vibration value at same time with this situation.

26NOV2016 07:55:06.364	Start Up
26NOV2016 07:55:06.364	Start Up
26NOV2016 07:55:06.364	Start Up
26NOV2016 07:55:06.364	Start Up
26NOV2016 07:55:06.364	Start Up
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26NOV2016 07:55:06.364	Start Up
26NOV2016 07:55:06.364	Start Up



26NOV2016 07:55:06.364	11 um pp	4 rpm
26NOV2016 07:55:06.364	37 um pp	4 rpm
26NOV2016 07:55:06.364	23.90 um pp	4 rpm
26NOV2016 07:55:06.364	19.99 um pp	4 rpm
26NOV2016 07:55:06.364	26.29 um pp	4 rpm
26NOV2016 07:55:06.364	24.59 um pp	4 rpm



Shutdown

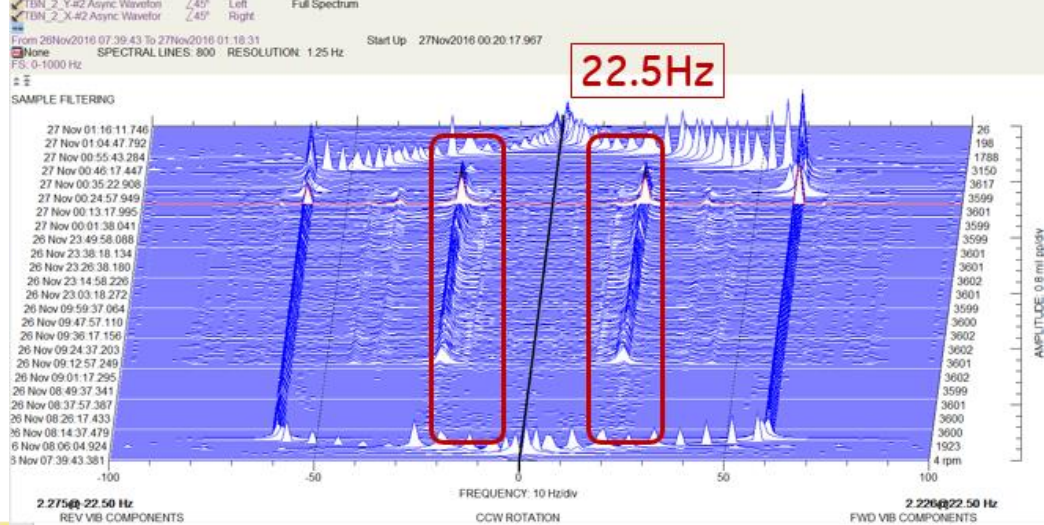
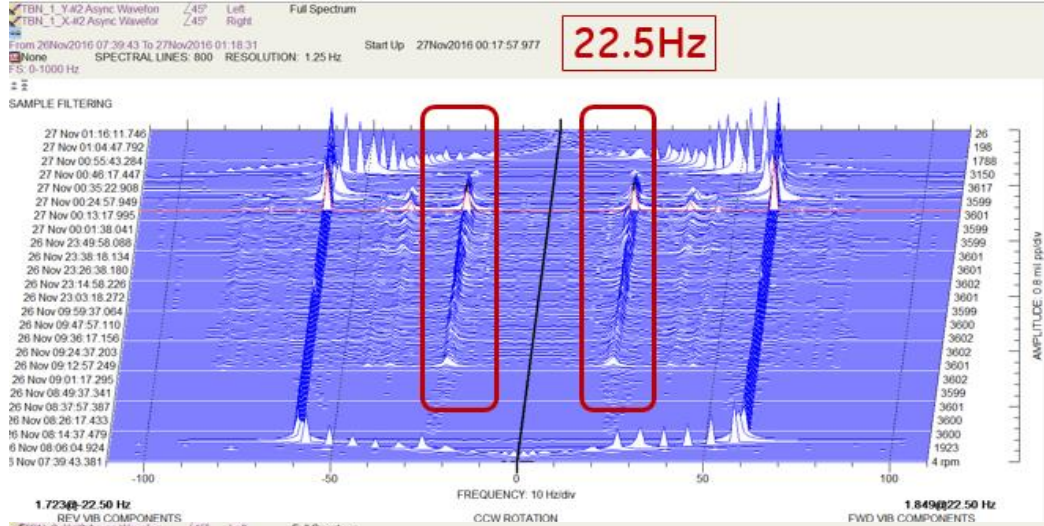
The high vibration level component disappeared immediately after SD command - at 3540 RPM.



SU, Loading, SD

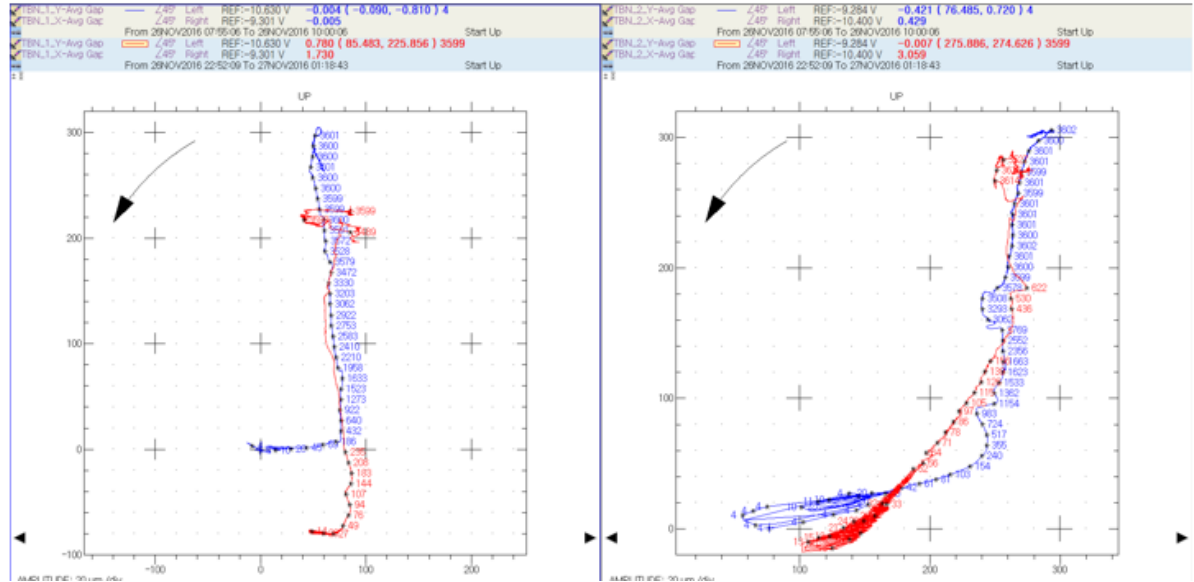
The dominant component of high vibration is 0.375X of shaft rotation speed(22.5Hz).

The high vibration level component disappeared immediately after SD command - at 3540 RPM.



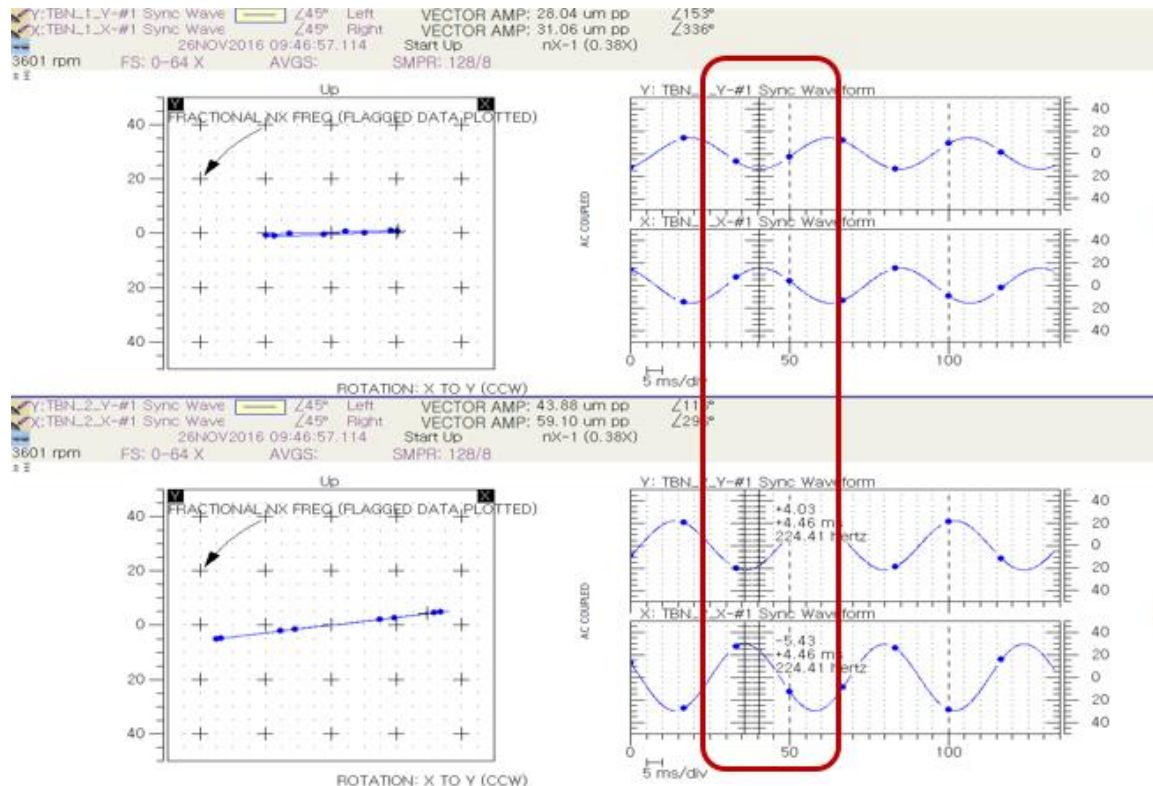
SU, Loading, SD

There are **no any significant changes** in the shaft centerline detected during mentioned 22.5Hz component appearing at FSFL and disappeared during SD.



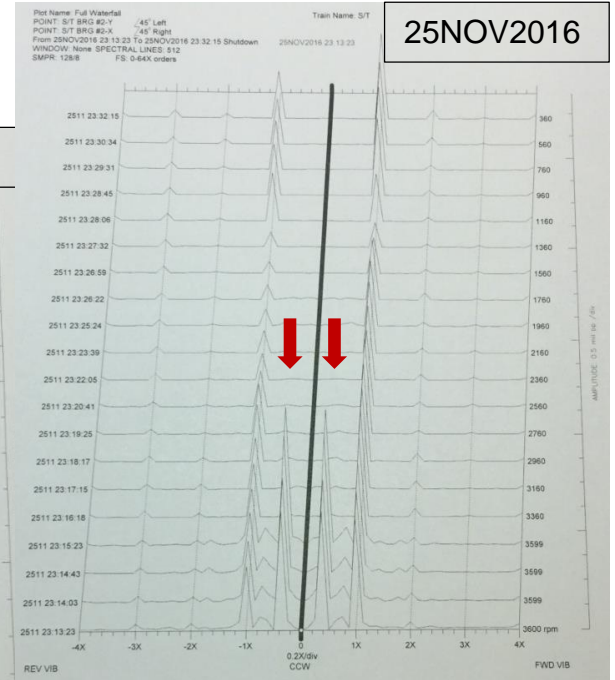
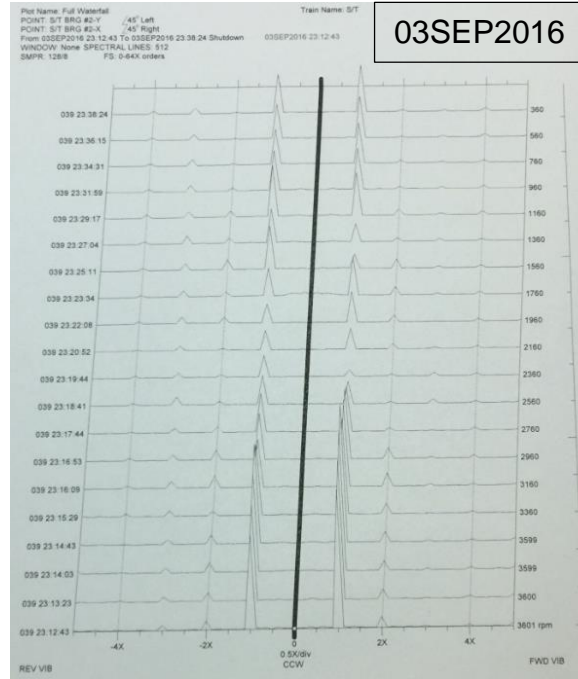
0.375X phase

The phase data analysis of filtered 22.5Hz shaft rotation component demonstrating app.35 degrees phase leading for BRG2 - the instability source location is close to BRG 2 plane.



Before and after overhaul

There is clear sign of discussed 22.5Hz component in the waterfall plot for after overhaul condition, but before overhaul it was absent.



Diagnostic summary

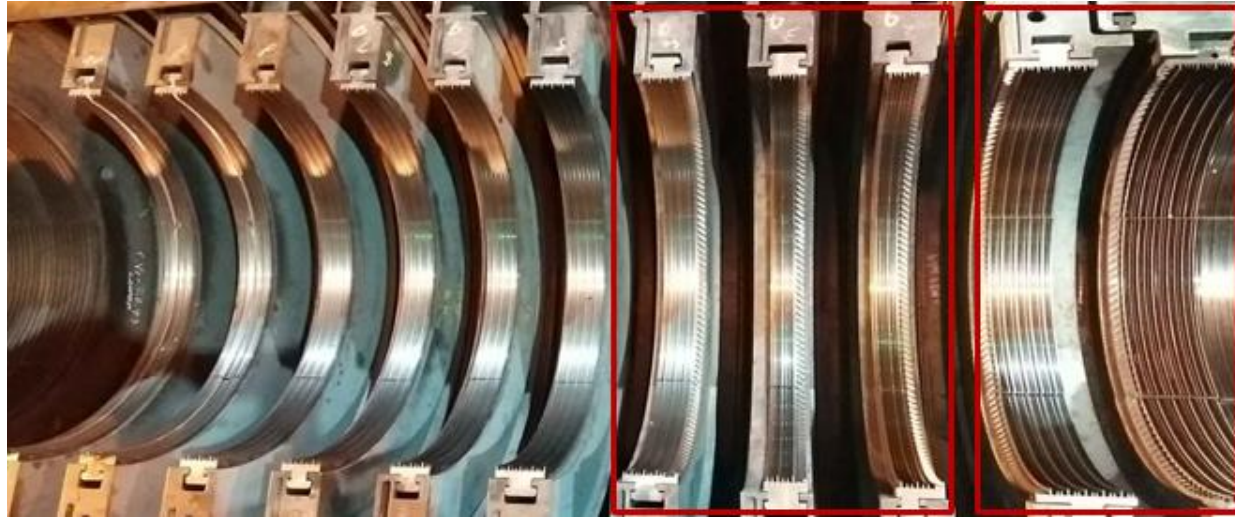
The high vibration of HP/IP stages 22.5Hz component isn't related to the shaft rotation speed, but it is Load related:

- occurred at full load – 163MW, and follow the load conditions at another days.
- wasn't affected by minor load decreasing during day time,
- present during Unit unloading to 0 MW, but immediately fully disappeared after Unit Shutdown command (3540 RPM),
- following speed increasing (from 3380 to 3600) with zero load doesn't generated sub synchronous component.



Anti-swirl

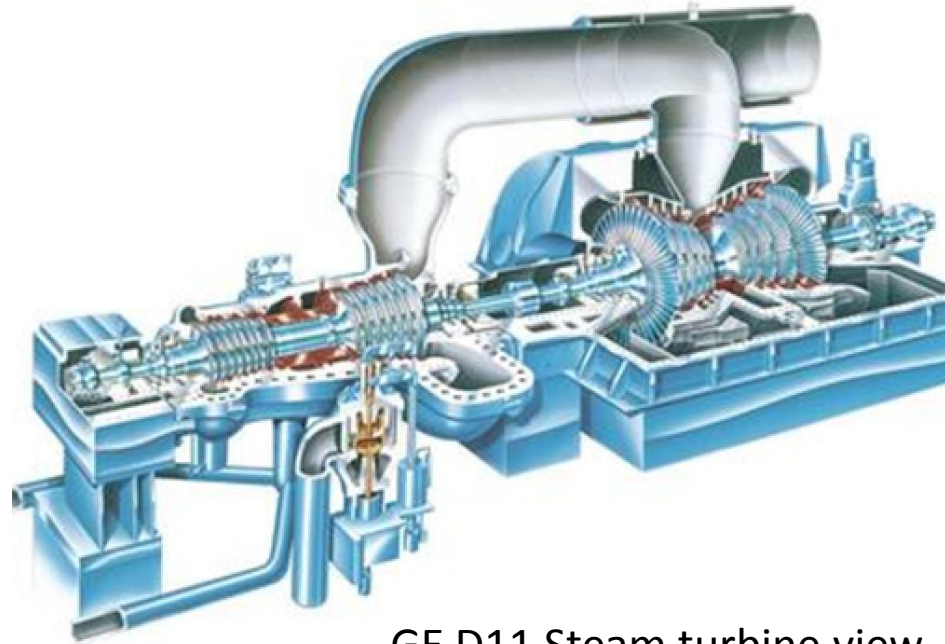
Resent overhaul data:
“Replace to H/IP
retractable packings (1
antiswirl conv./14 retr./2
brush) and N2
conventional packings.”



It is expected that this system is installed or operated not properly. Non-original spare parts were used and installed without OEM installation guide.

End User decision

- Short term:
to limit Unit load, operate below stability threshold, MW
- Long term:
Steam turbine replacement by new, same model Unit, since the designed turbine resource is already expiring



GE D11 Steam turbine view