



44TH **TURBOMACHINERY** & 31ST **PUMP SYMPOSIA**
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GEORGE R. BROWN CONVENTION CENTER

Oil & Gas plant experience of Sub-Synchronous Torsional Interactions (SSTI) and operability optimization



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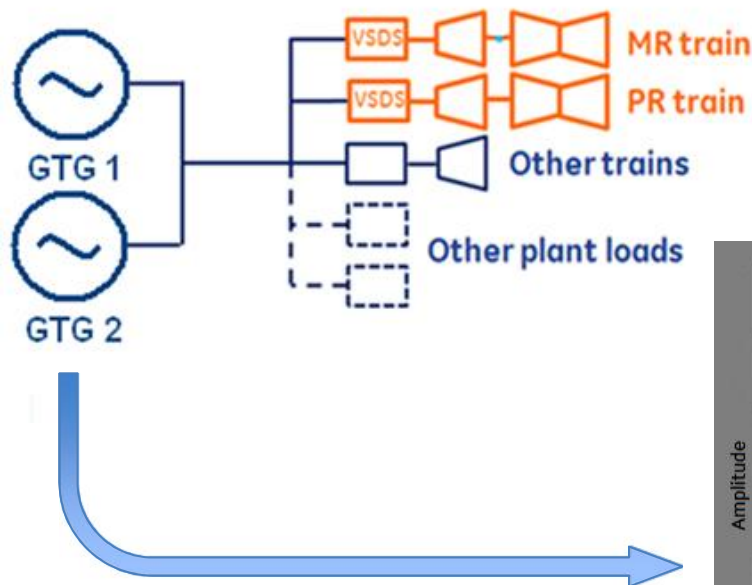
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Education: B.Sc. (2015) in Industrial Engineering from Rome University, Italy

Problem statement: SSTI site issue

During MR/PR compressors start-up, some trips have been observed on Generators Gearbox due to high lateral vibrations, with sub-synchronous component @ ~10 Hz.

NOTE: ~10 Hz is the GTG train 1st TNF.



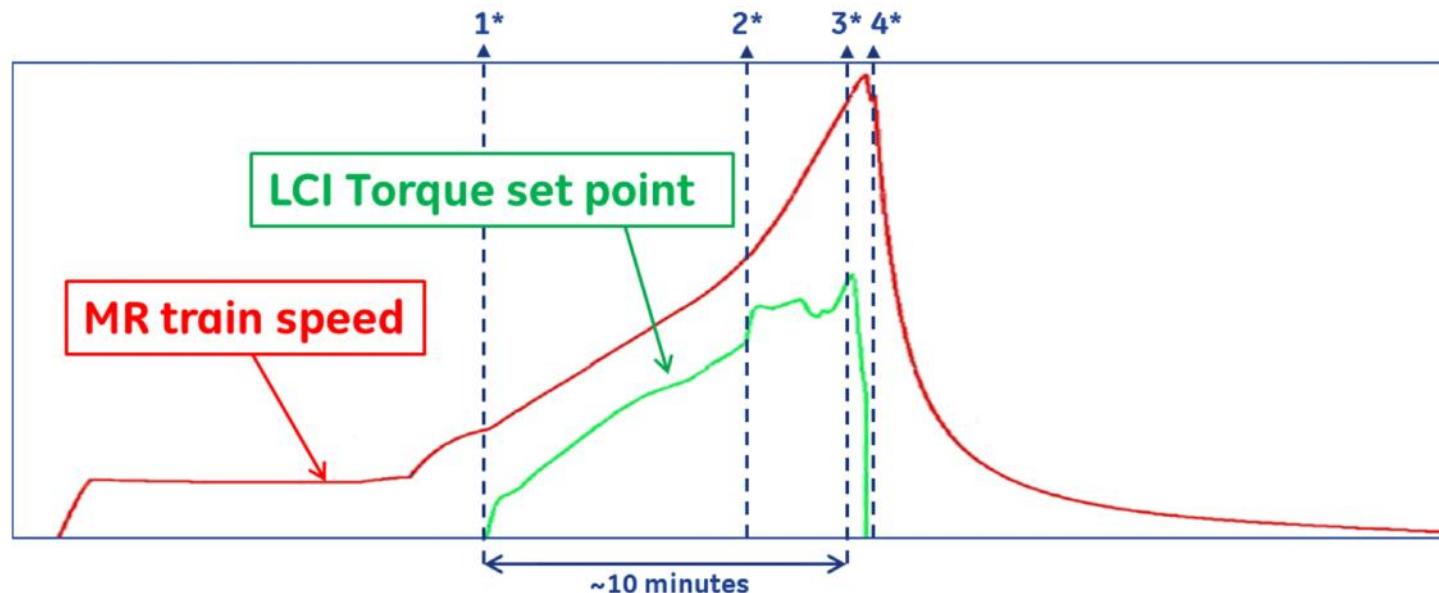
GTG vibrations during MR train start-up



Sub-Synchronous Torsional Interaction (SSTI) phenomenon observed

Problem statement: SSTI site issue

- Island network with #2 GTGs in operation
- MR compressor train start-up (LCI driven)



1* LCI starts to supply torque

2* GT starting motor switched off; Start-up sequence continues with LCI only

3* GTG1 trip (MR train @ ~95% speed)

4* GTG2 trip (MR train @ ~99% speed)

Torsional measurements were not in place...

Sub-Synchronous Torsional Interactions (SSTI)

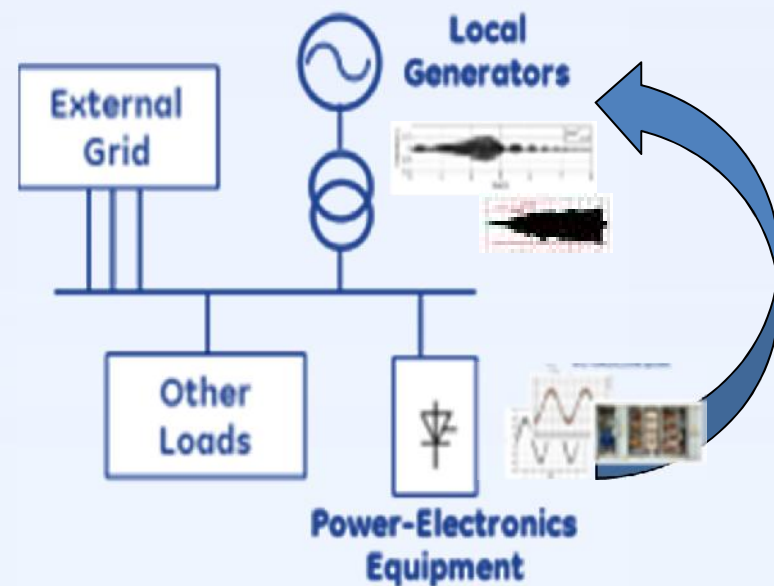
Interactions between Turbo-Generators and large power electronic devices (e.g. VSDS) connected to the same electrical grid

SSTI Causes...

- Direct torsional excitation
- Negative electrical damping

Can lead to....

- Generator vibrations
- Plant blackout
- Generators shaft-line damages



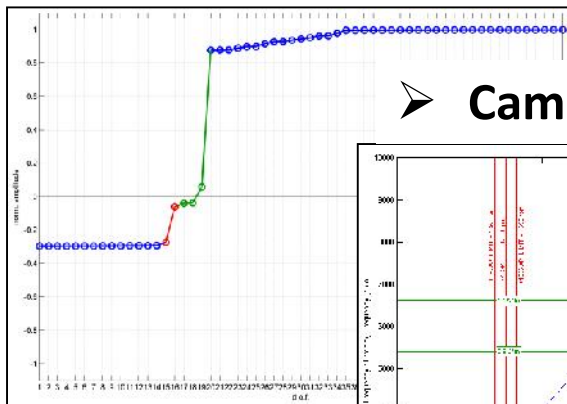
Increasing VSDS loads can lead to SSTI phenomena

Torsional analysis gap vs. SSTI

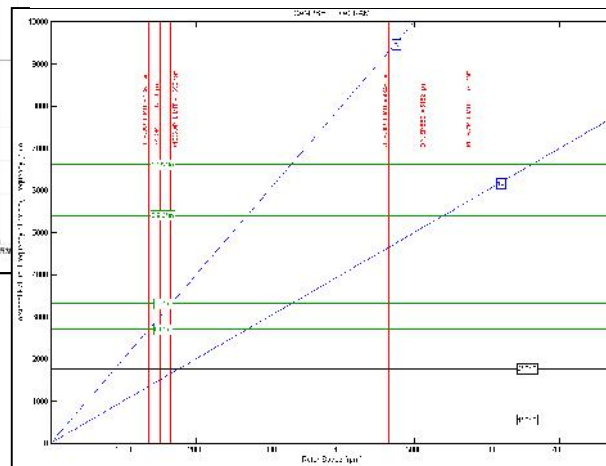
The torsional vibration behavior of the complete train is fundamental to ensure that the individual units will reliably operate when coupled.

The Analysis is performed according to API requirements.

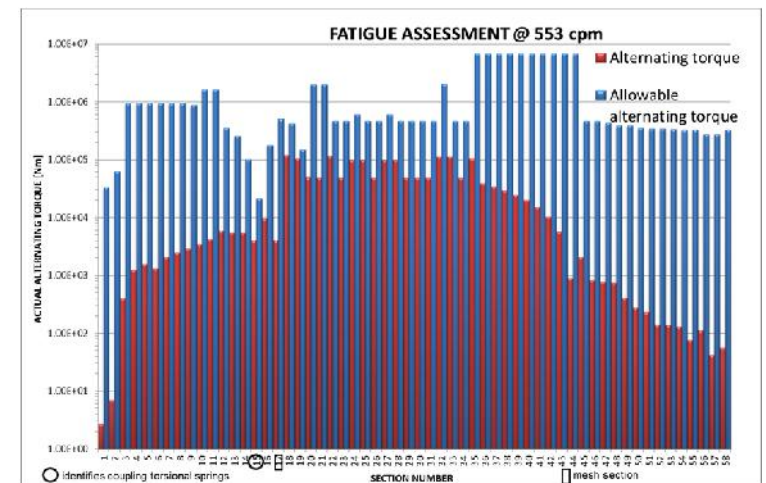
➤ Mode shapes



➤ Campbell diagram



➤ Stress analysis

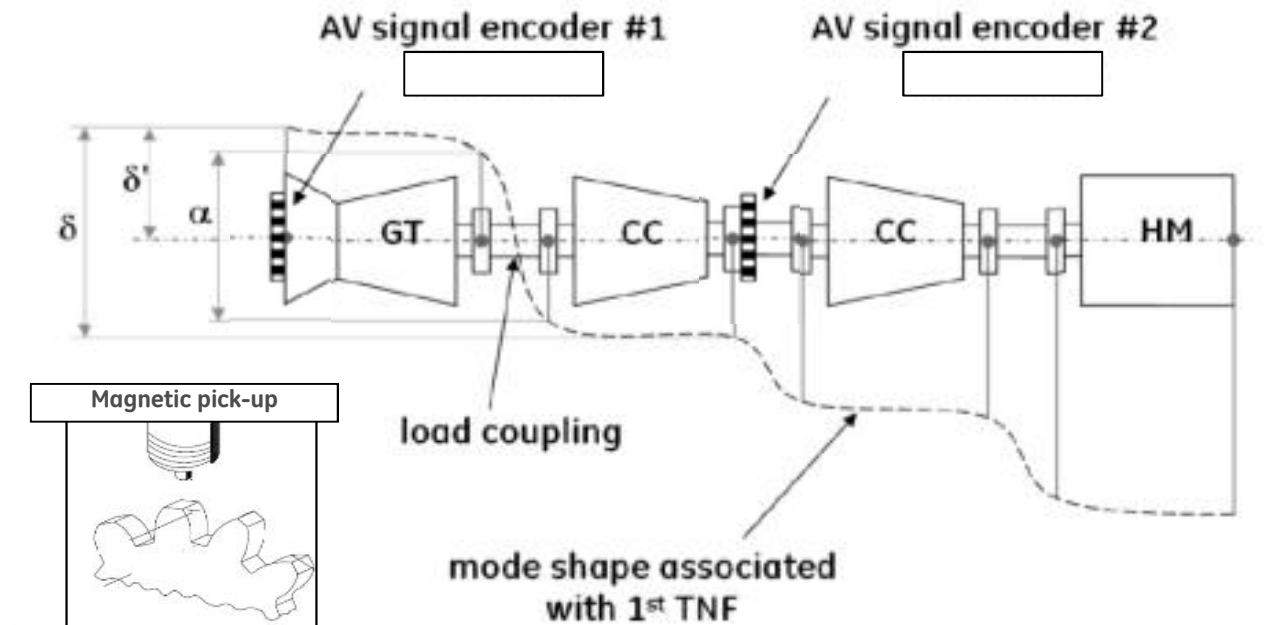


**No additional assessment required by international standards
for potential SSTI**

Torsional measurements: installation study

The purpose is to identify:

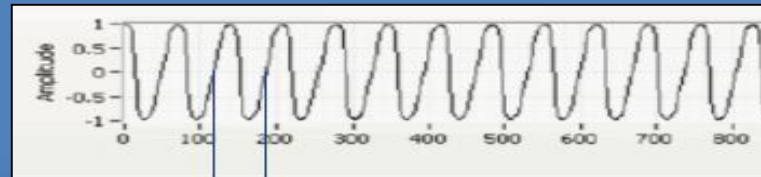
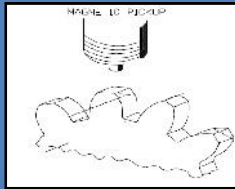
- ✓ Measurement section(s)
- ✓ TNFs to be monitored
- ✓ Torsional measurement resolution



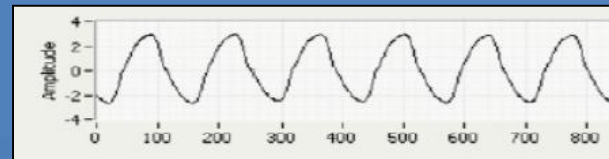
Torsional measurements executed on GTGs and MR/PR trains at site

Torsional measurements: fatigue assessment

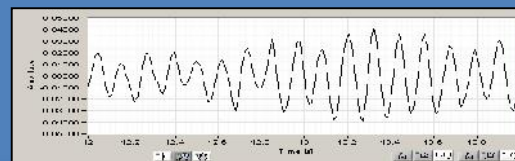
Raw signal from instrumentation (speed pick-up)



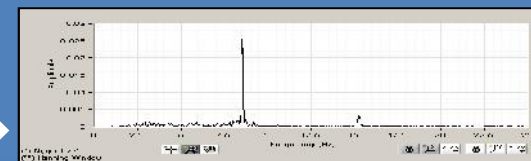
Instantaneous rotational speed



Instantaneous angular oscillation



FFT



Angular oscillation is translated into **oscillating torque** by a **transfer function**, based on the calculated **train torsional modes shapes**. These values are used for the train components **fatigue assessment**.

Site issue highlights:

Electrical grid configuration

- High percentage of the power supplied by the GTG is absorbed by active loads (LCI)

LCI load influence

- Gearbox vibrations increased rapidly after ~40% of torque demand to LCI (GTG trip when LCI reached ~50% load)

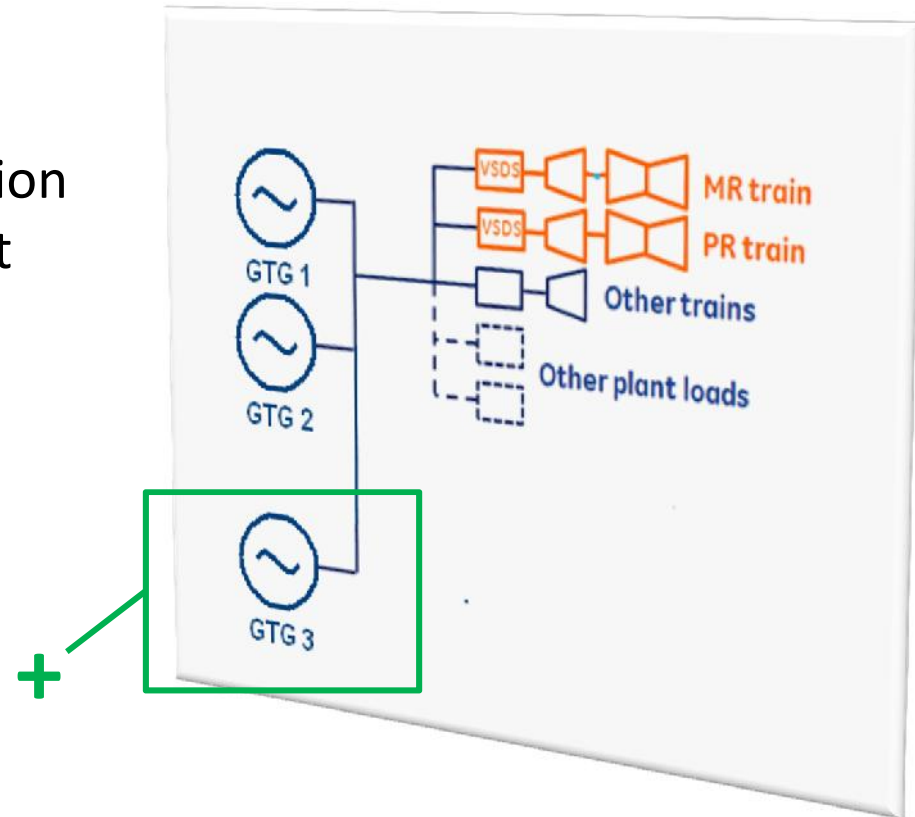
Torsional-to-Lateral interaction

- GTG gearbox lateral vibrations with predominant sub-synchronous component at ~10Hz (1st GTG TNF)

Typical SSTI phenomenon characteristics observed

Implemented actions:

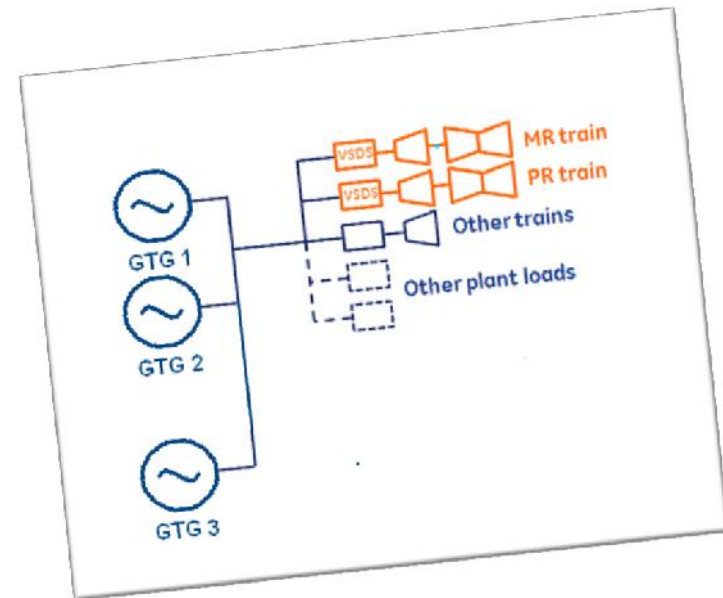
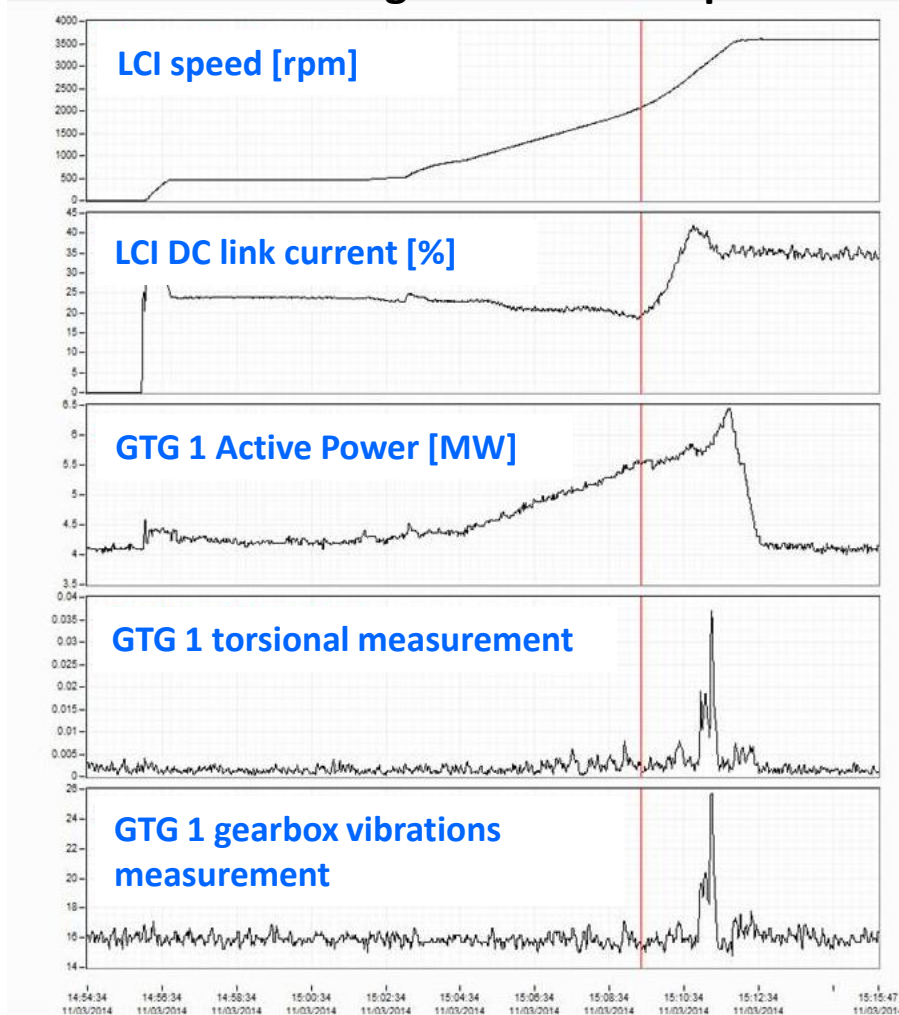
- One **additional GTG** in operation (to increase the network short circuit power)
- **Tuning/adjustment of LCI** control parameters



**SSTI phenomenon reduced within acceptable limits
starting another GTG train**

Site measurements after actions implementation

Data trend during LCI-MR start-up



- With 3 GTGs no plant operability restrictions due to SSTI
- Qualitative torsional-to-lateral vibrations correlatrion

SSTI is a system phenomenon: every case is different from the other being different the corresponding network operating scenario

How to manage SSTI: recommendations

- Include in the plant design scope an **SSTI assessment** (risk evaluation and detailed analysis)
- Increase **plant short circuit power** (add GTGs in operations if available)
- Variable Frequency Drives design and control optimization
- Evaluate not only normal operating conditions but also contingencies and start-up scenarios
- Implement **torsional vibration measurements** on both VSDS units and GTGs shafts to have proper system monitoring

**Include SSTI assessment during preliminary
and detailed engineering phases**

Nomenclature

- **GTG = Gas Turbine Generator**
- **MR = Mixed Refrigerant**
- **PR = Propane**
- **VSDS = Variable Speed Drive System**
- **TNF = Torsional Natural Frequency**
- **LCI = Load Commutated Inverter**
- **GT = Gas Turbine**