Torsional Vibration Measurement and Model Based Monitoring of Power Trains

Energiforsk Seminar: Vibrations in nuclear applications
Stockholm

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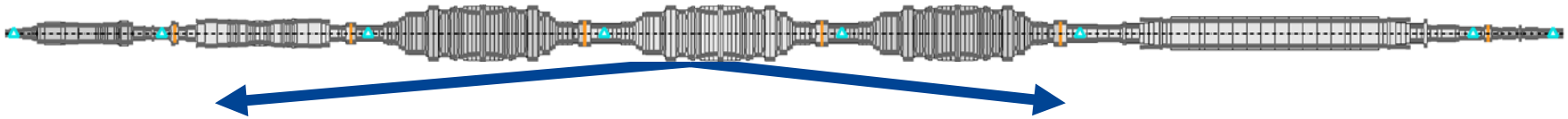
Problem statement

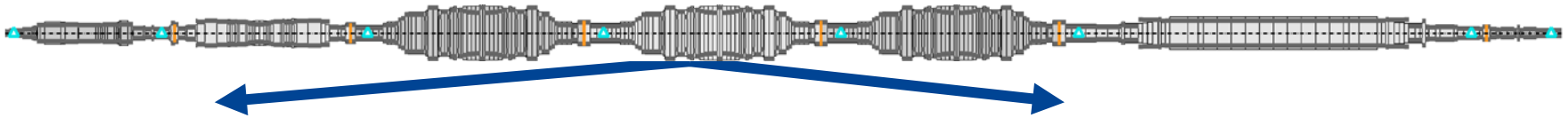
Rotordynamic Characteristics



Lateral dynamics

Torsional dynamics

Rotordynamic Characteristics



Lateral dynamics

- 90 % focus in rotordynamics
- **High damping** (journal bearings)

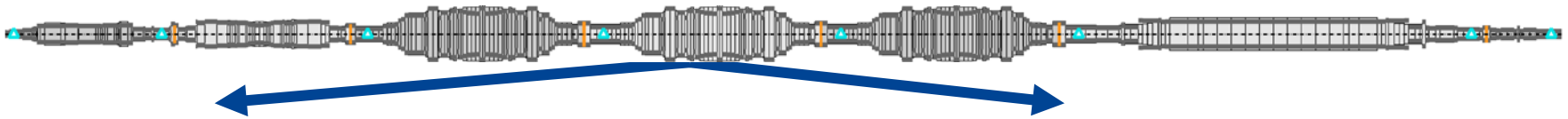
- Vibration limits defined in ISO **standards**
- Measured with **standard instrumentation**
- Included in **monitoring** and **protection** in all shaft trains

Assessment

Critical speeds, stability, unbalance response, …

Torsional dynamics

Rotordynamic Characteristics



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Assessment

Critical speeds, stability, unbalance response, …

Torsional dynamics

- Rotational oscillations of rotor sections
- **Low damping** (material only)
- **Excitation: grid** electromechanical interaction

- **No standards** about vibration limits
- **No standard instrumentation**
- **No monitoring/protection**

Assessment

Eigenfrequency separation margins, shaft stresses and torques, …

Typical OEM torsional assessment and criteria

Considered load cases

- steady state grid excitation
- electrical fault cases:
  - short circuits
  - out-of-phase synchronisation

Criteria

- eigenfrequency separation margin
- assessment of shaft stress vs. limit stress

Validity / Accuracy excellence

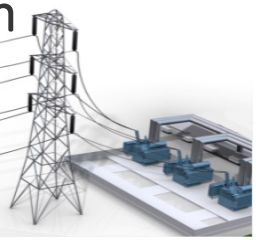
- model quality and design criteria heavily rely on OEM knowledge
  → rotor-blade-interaction
  → generator model
- testing and validating
- leverage fleet experience

New market situation
may add additional boundary conditions.

Situation

electrical system

challenging grid conditions (with renewables)



- **Interaction** with the grid
  can lead to excitation of **S**ubsynchronous **T**orsional **R**esonances (**SSR**)
- **SSR** is a well known phenomenon
  but with **increasing importance** → HVDC lines , share of renewables
- Today's mitigation measures are on the grid side.
- Excitation frequencies depend on:
  grid topology, operation and potential future installations

➔ Wider range of grid-related excitation mechanisms

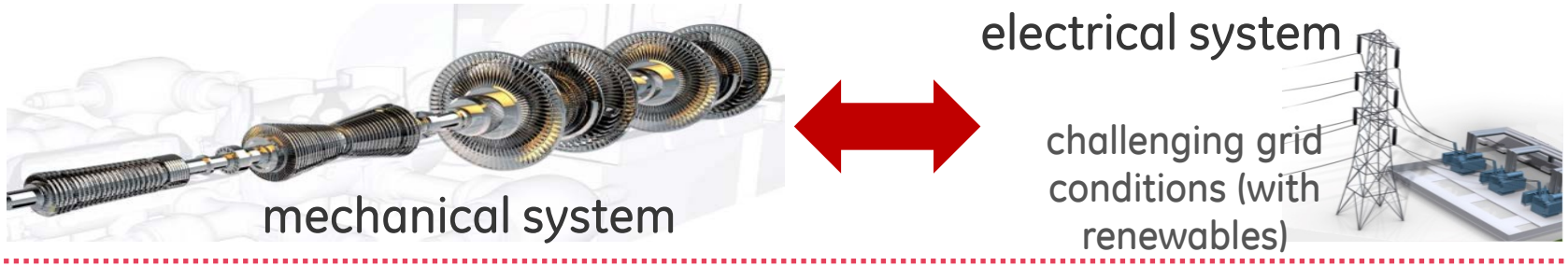
➔ Robustness against excitation of SSR is not achievable on shaft train design level alone

Estimation of impact on shaft trains not possible with standard instrumentation

Solution:
Model Based Monitoring

#poweringeveryone

Model Based Monitoring Principle

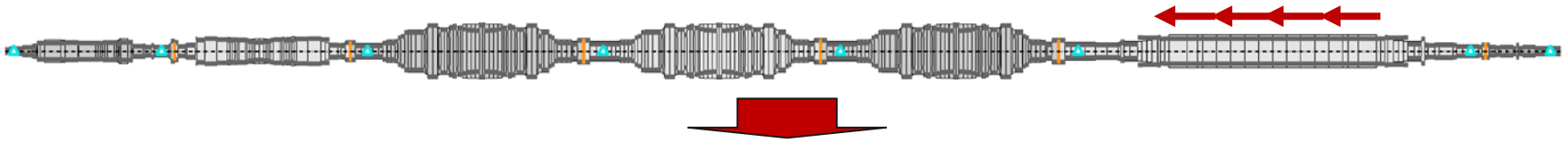


- **Excitation of torsional vibration needs to be estimated on shaft train level**
- Most loaded sections linked to torsional mode shapes → frequency dependent
- OEM rotordynamic models suitable to estimate torques & stresses along the shaft

Model Based Monitoring to estimate shaft stresses

Model Based Torsional Vibration Monitoring

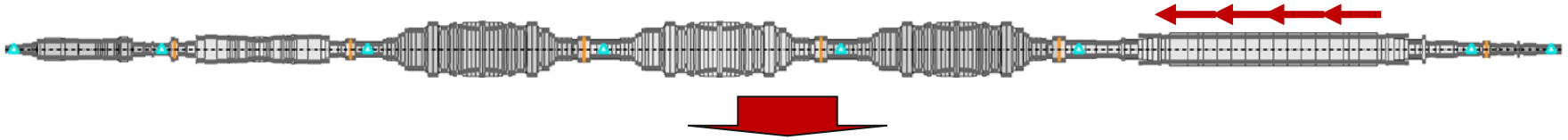
Input:
Normalised harmonic torque



Calculate response and utilisation
for all significant modeshapes and locations including flexible substructures

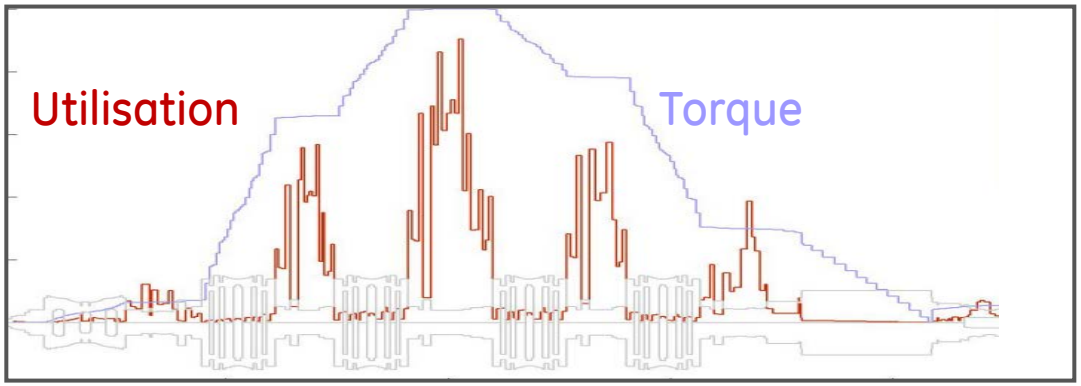
Model Based Torsional Vibration Monitoring

Input:
Normalised harmonic torque



for all signific **ubstructures**

Deflection shape at resonance



Model Based Torsional Vibration Monitoring

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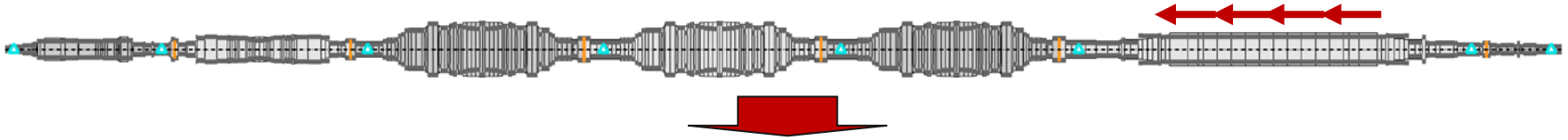
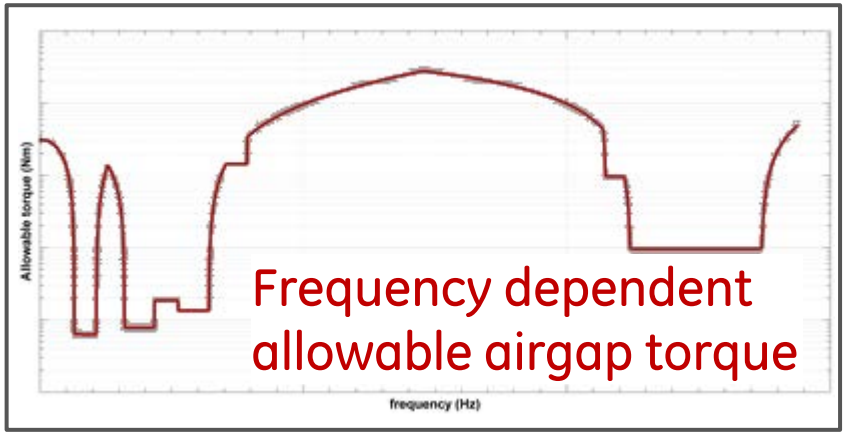


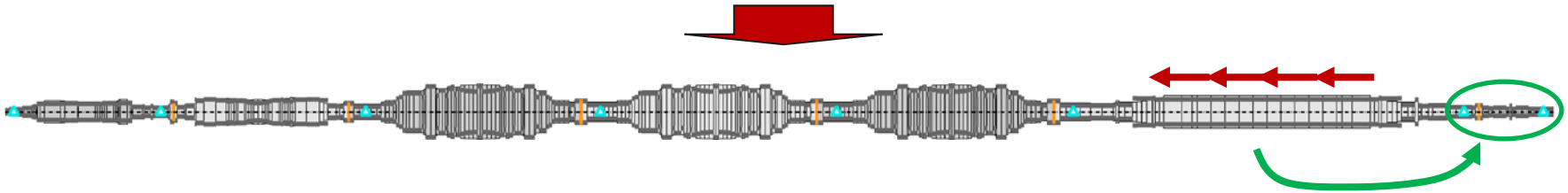
Calculate response and utilisation
for all significant modeshapes and locations including flexible substructures

Scale up to estimate maximum allowable airgap torque

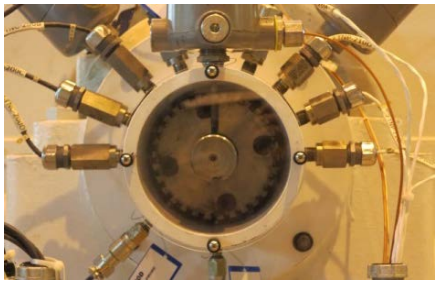


Model Based Torsional Vibration Monitoring

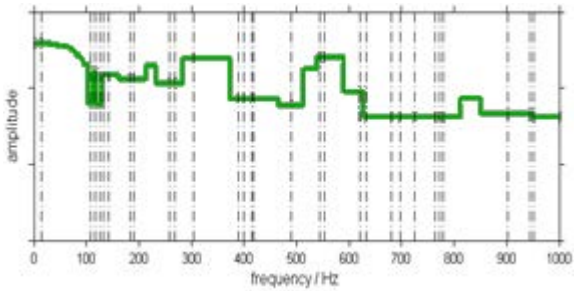
Calculate equivalent amplitudes at sensor positions for measurement



From airgap torques to measurable quantities

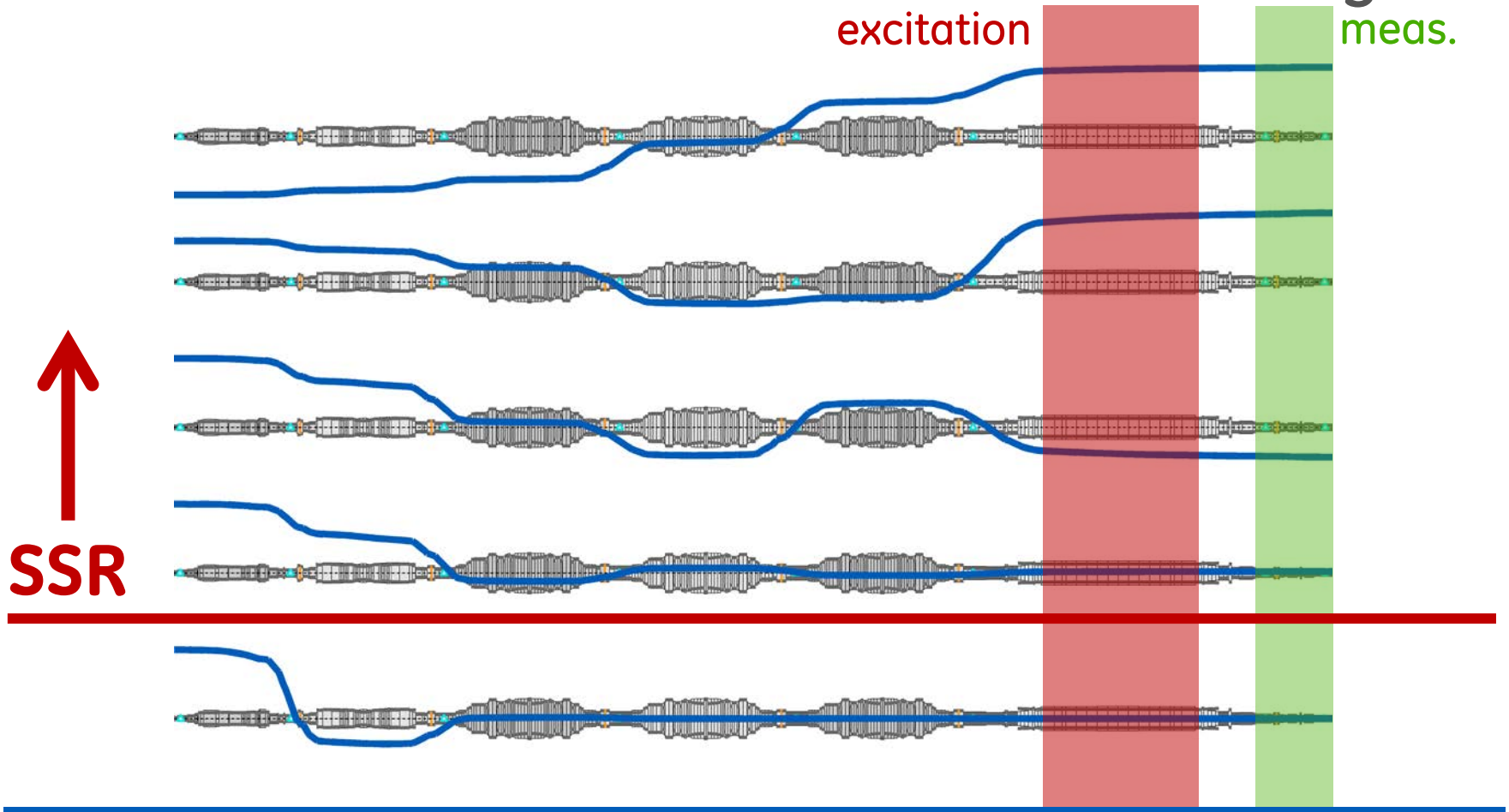


Allowable vibration amplitudes (incl. all components) at sensor location



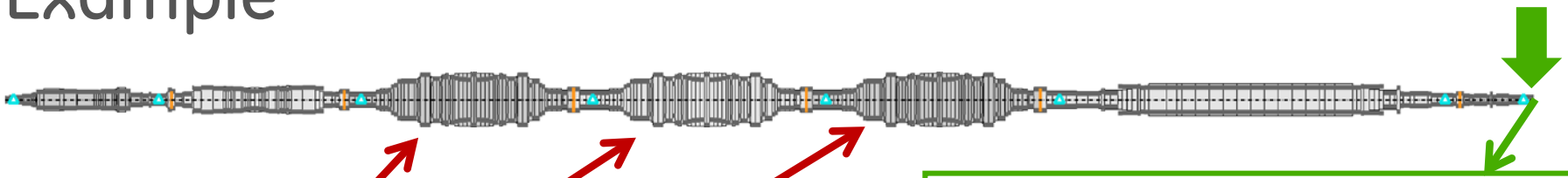
Best suited for long time monitoring: robust & reliable.
An accurate and validated model is a prerequisite → OEM

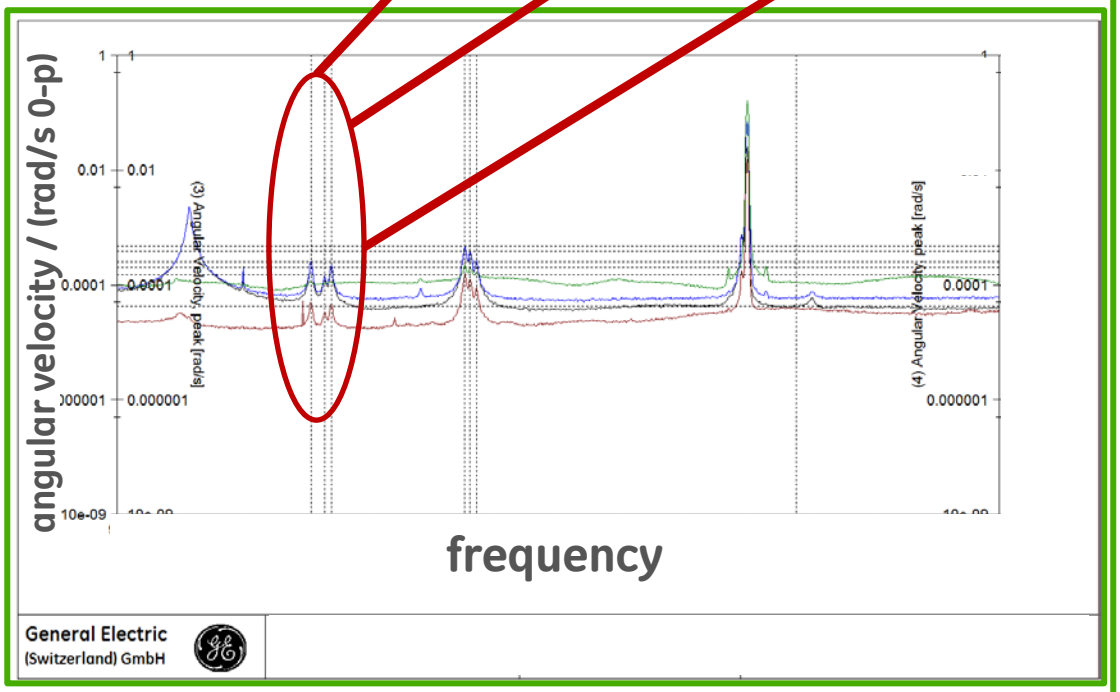
Model Based Torsional Vibration Monitoring

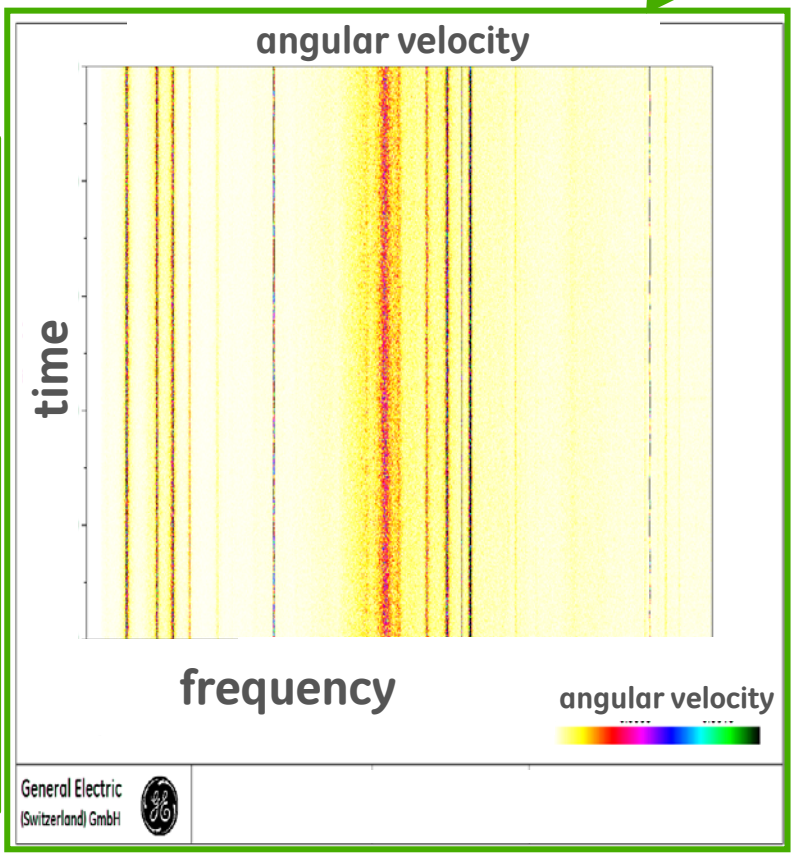


Single sensor position sufficient to monitor the shaft train.
An accurate and validated model is a prerequisite → OEM

Example







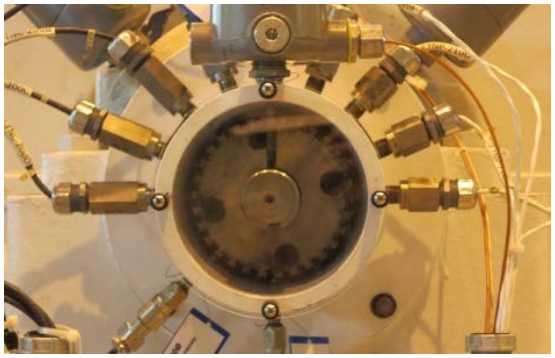
Last stage blade modes identified in off-grid conditions.

Opportunities

- Insight into torsional vibration state
  → transparency of plant condition
  → long term monitoring
- Support targeted maintenance
- Real-time protection against abnormal excitation in off-design conditions (severe SSTI)
- Localization and quantification of faults

Availability of plant … Insight … Long term monitoring

GE – Requirements and Offering

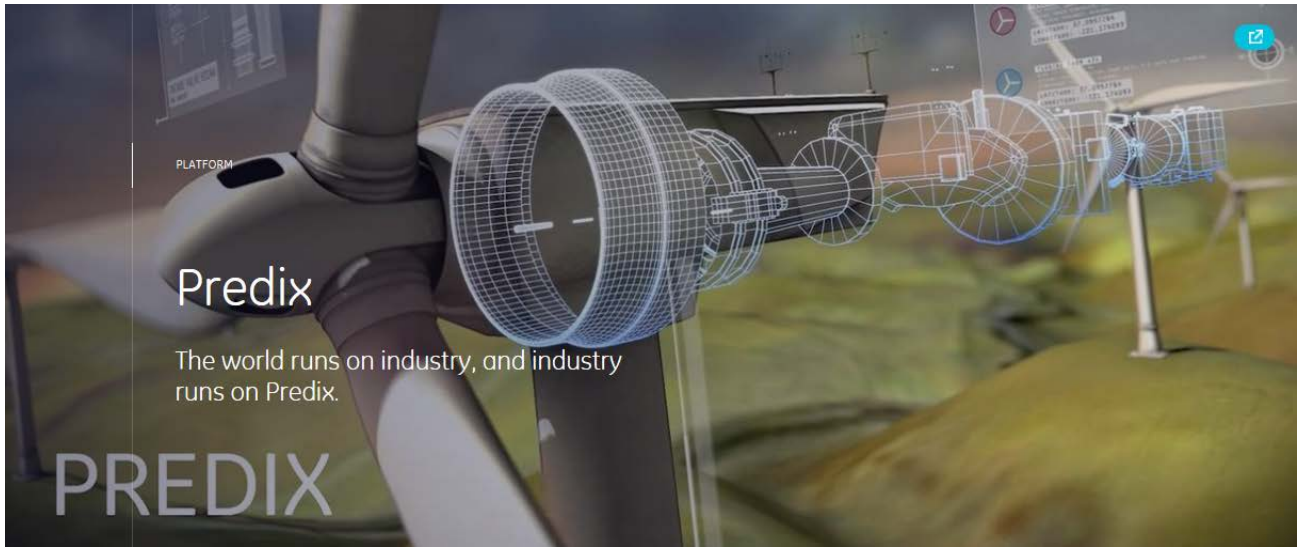


- Sensor position defined according rotordynamic model
- Sensor selection: typically existing speed sensors can be used
- Stress prediction according to rotordynamic model
- Demonstrated resolution
  $\Delta\phi = 0.0001$ mrad
  (= 0.025 um on 500 mm shaft diameter, 50 Hz speed)
- Measurement & signal processing hardware available

GE – Requirements and Offering

- Integration to GE Predix launched

www.ge.com/digital/predix



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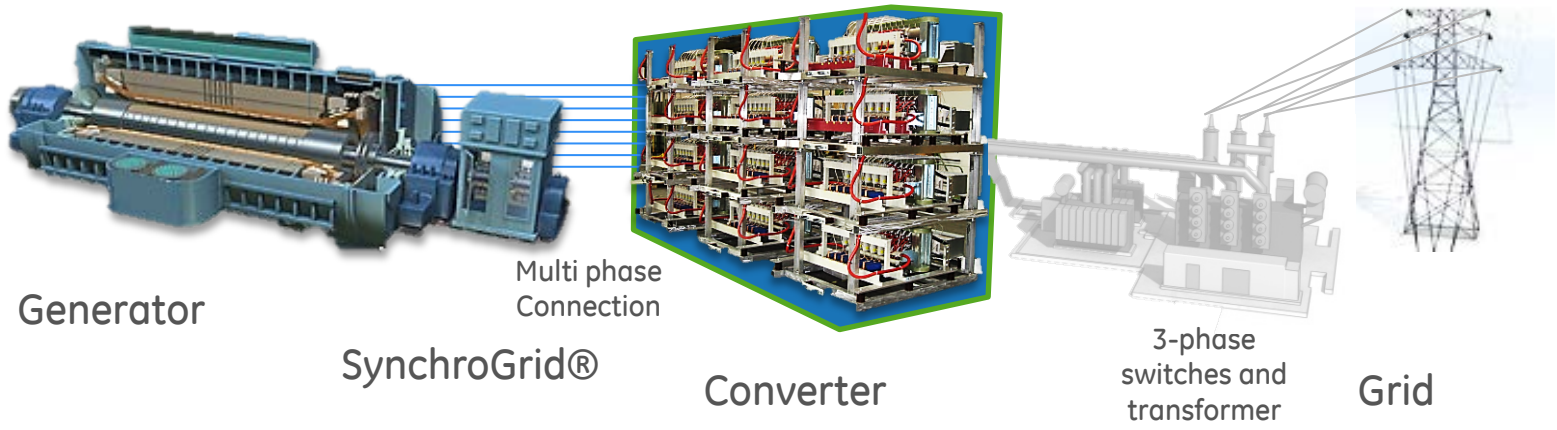
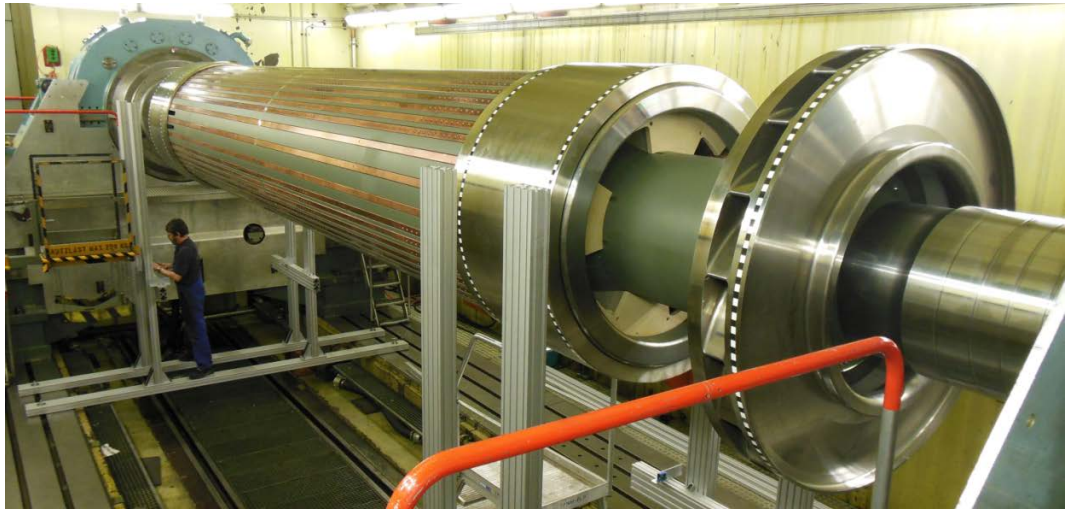
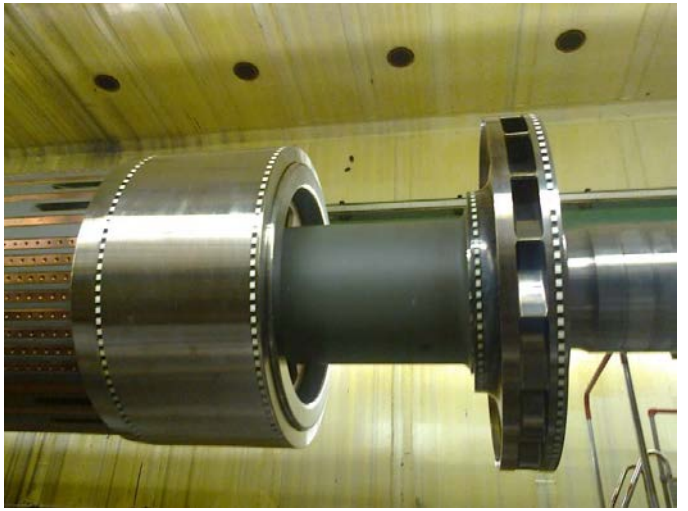


- Converter operated generator in the >350MW class
- Model based torsional measurement fully integrated in shaft protection logic
- > 6 month operational experience, no issues

Torsional Vibration Measurement

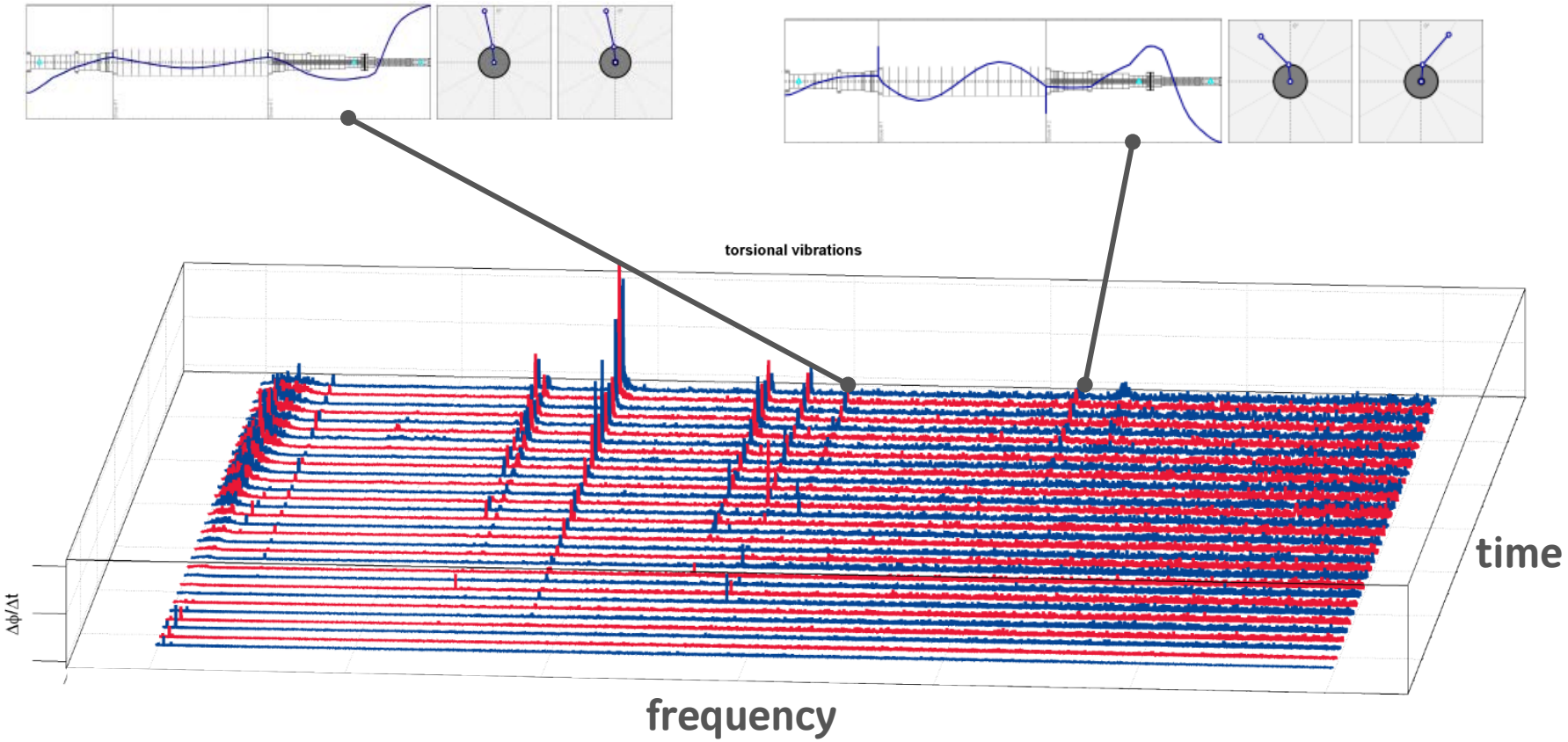
Validation of torsional eigenfrequencies and mode shapes in a wide frequency range on **rotor level**





Encoder based Torsional Vibration Measurement

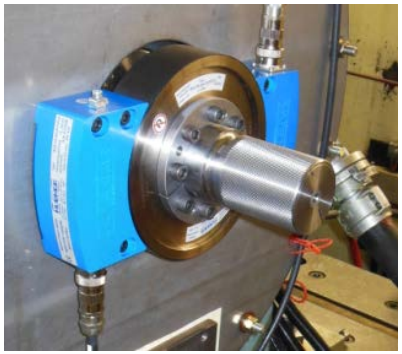
Validation of rotordynamic models



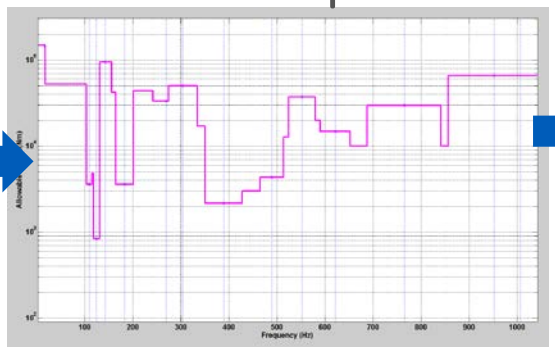
Typical deviation in eigenfrequencies: 1.5 %

Integration in protection logic – online

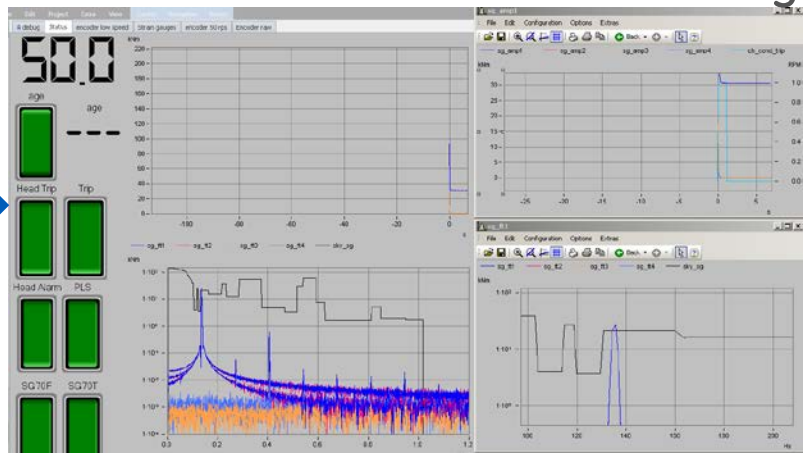
Speed encoder



Frequency dependent vibration amplitudes



User interface – online monitoring

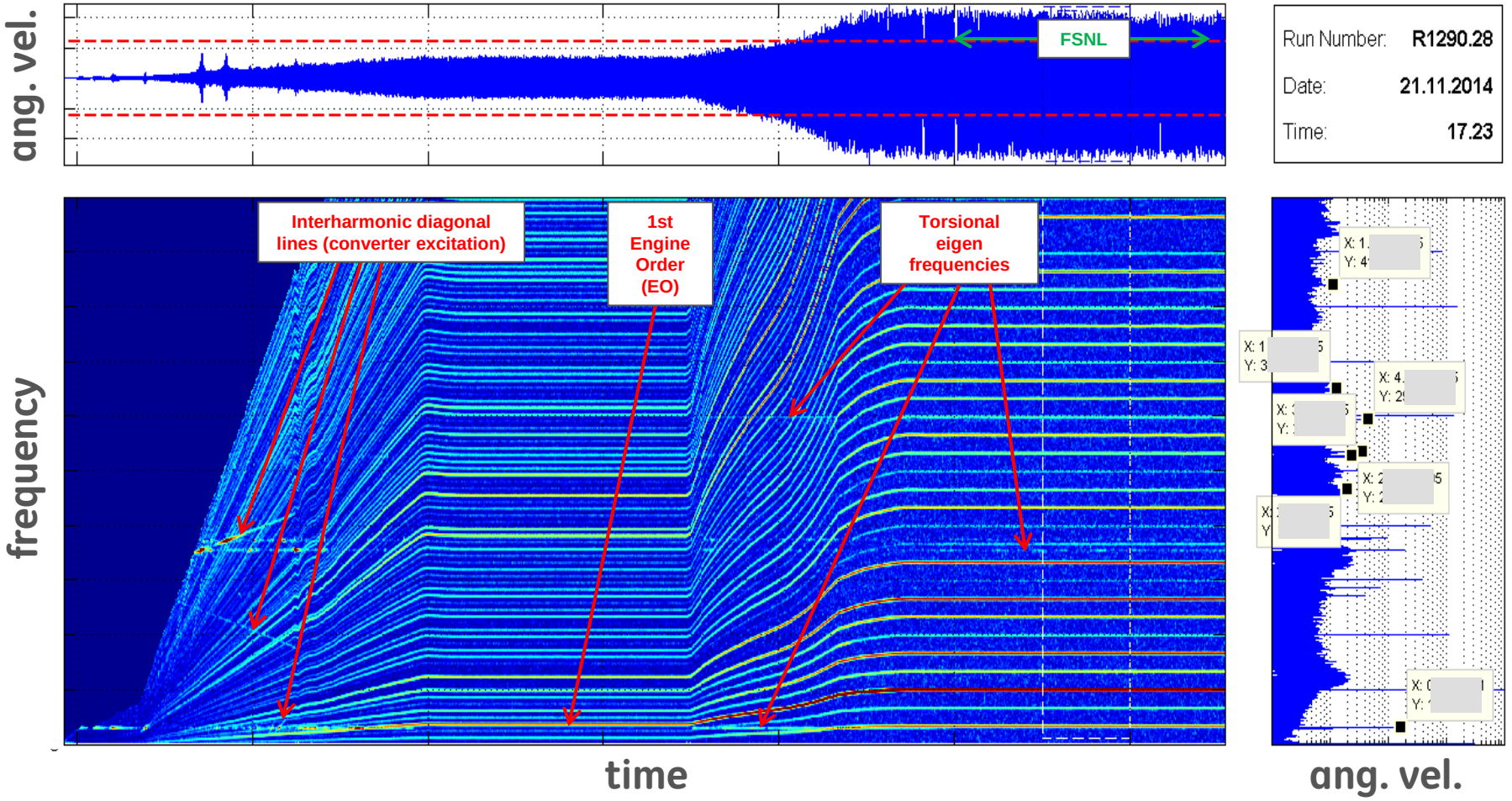


Real-time monitoring

Frequency dependent vibration limits (up to 1000 Hz) including stress limits of → GT blades → rotor → main fan and → retaining ring generator

Full integration in shaft train protection

Postprocessing capabilities



Identification and tracking of modes → long term condition monitoring

GE – Offering

- Best-in-class data acquisition hardware
- OEM know how and in depth knowledge of shaft train dynamics
- Unique knowledge of component-specific stress margins
- Online monitoring capabilities
- Operational experience


DIAGNOSTIC - LEVEL 22/24/28
SCHEDULE APPLICATOR - QUARTER TWO
SCHEDULED MAINTENANCE
ALERT
63%

Thank You!