Improving Turbomachinery Health Monitoring using Advanced Shaft Telemetry

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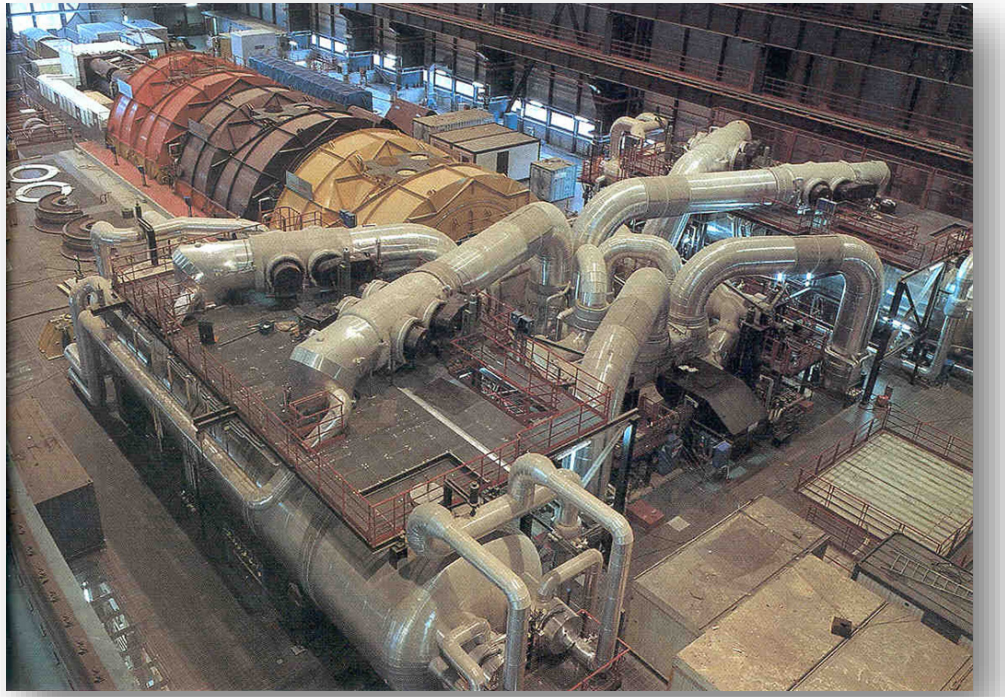
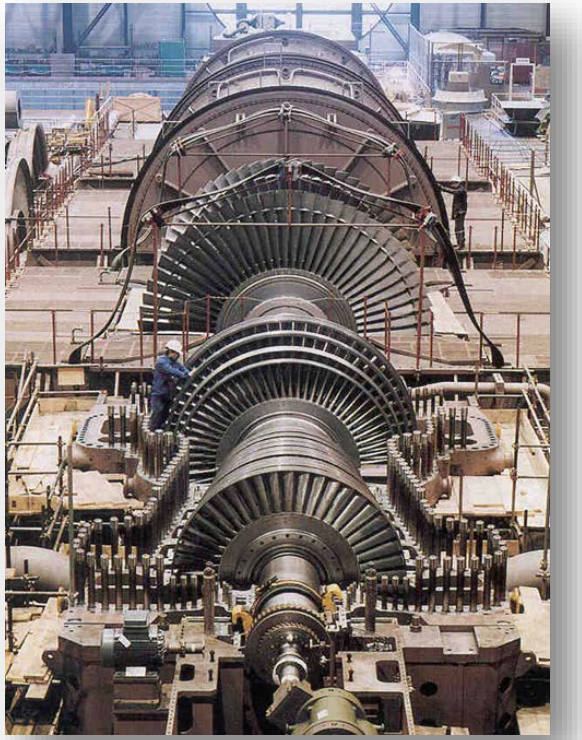
Presentation Outline

- Project motivation, industry need
- Technology description
- Field applications
- Future applications of shaft sensing



Background



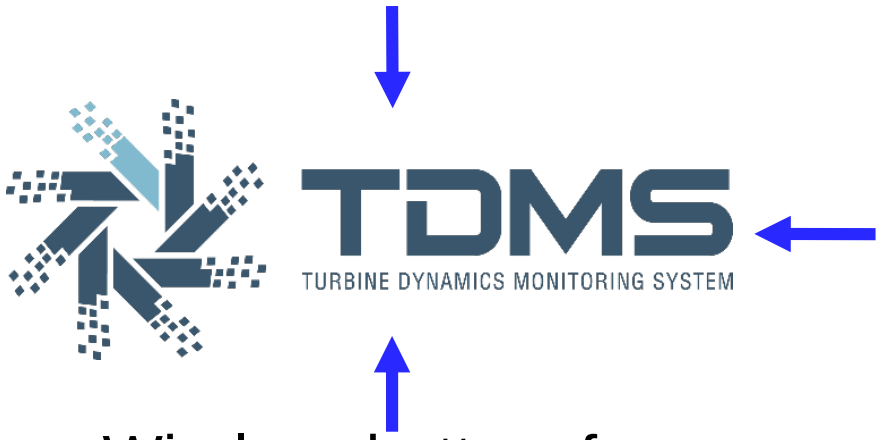
- Grid-connected turbine-generators are torsionally excited by:
  - "Normal" phase imbalance and negative sequence currents; producing 2X grid frequency torsional stimulation
  - Grid electrical resonances, if aligned with shaft system resonances
  - Repeated transient grid disturbances (very large single-phase loads nearby)
- Proximity of modes to 2X grid frequency… a major risk factor
  - Modes are common in the 100-120 Hz range, often involve large blades
  - Designing to avoid this is challenging due to modeling uncertainties
  - Testing advised, often mandated by insurers
  - Any changes to shaft train components could affect mode frequencies

Industry Need

- EPRI assessment of commercially available shaft torsional vibration sensing options in 2013 revealed that key improvements could be made in:
  - Telemetry powering options
  - Sensitivity and low noise, to clearly observe higher order shaft modes
  - Wireless data rate (high time resolution)
  - Ability for simultaneous measurement of shaft strain and motion parameters
  - Option for use in oil mist environment
  - Ability for continuous operation
  - Ease of use by plant staff

Telemetry Specification

- Torsional strain
- Tangential acceleration
- Lateral (bending) strain
- Radial acceleration

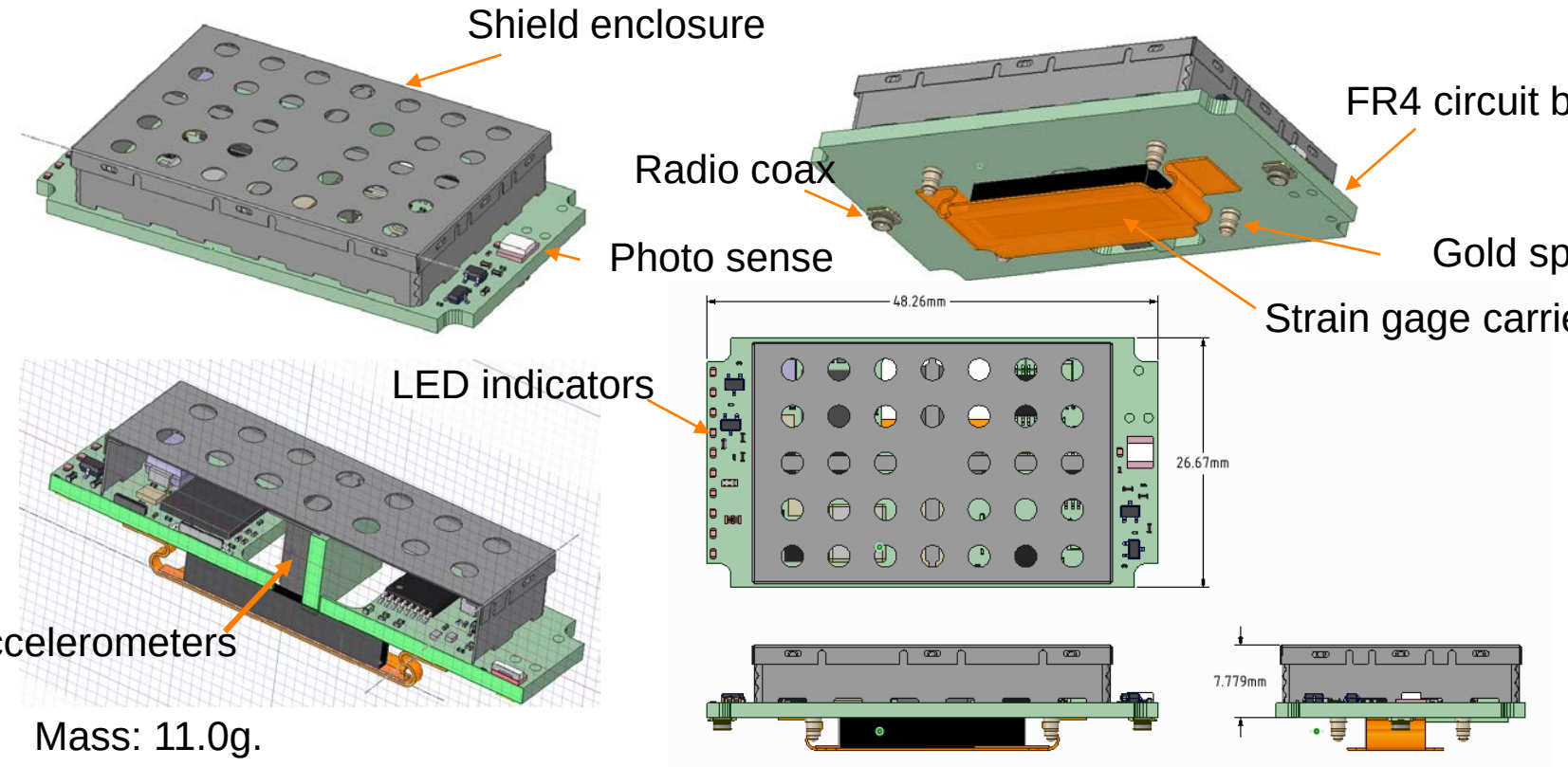


- Wireless battery free
- Rapid field installation
- User friendly DAQ software
- Simple post processing

- Synchronous data acquisition from elastic and kinematic variables.
- On-telemetry oversampling and decimation ensuring data quality.
- Maximal bit depth matching mechanical and electrical noise floor.
- No amplifiers to saturate offset or drift. Direct digitization.

- 1Msps on telemetry. 7.8ksps per channel on-air
- Differential sensor resolution of 2.9e-7 volts.
  - Single point strain resolution 4.9074e-11 mm/mm
  - Single point acceleration resolution 2.9e-4 g

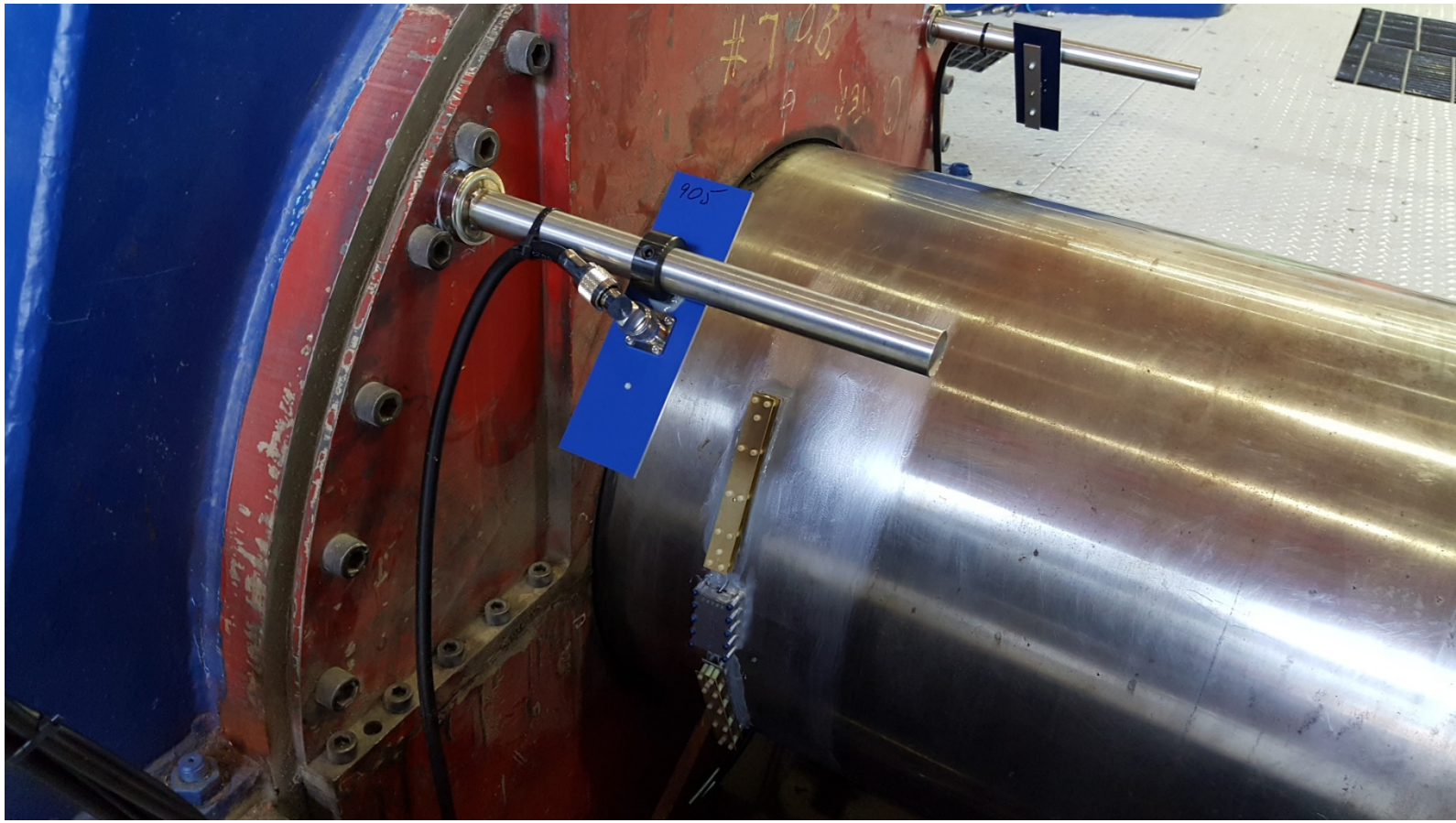
TDMS Quad Telemetry, internals sans case (pass around unit)



- Mass: 11.0g.
- Technology: PCB and solid state assemblies.
- Materials: Silicon, FR4, steel, polyamide, gold, silver, polyethylene, Teflon.
- Sensors: Torsional strain, Lateral strain, Tangential acceleration, Radial acceleration, onboard photo tachometer, temperature.
- Passive (externally excited) circuit. Contains no batteries, electrolytes, or soluables.

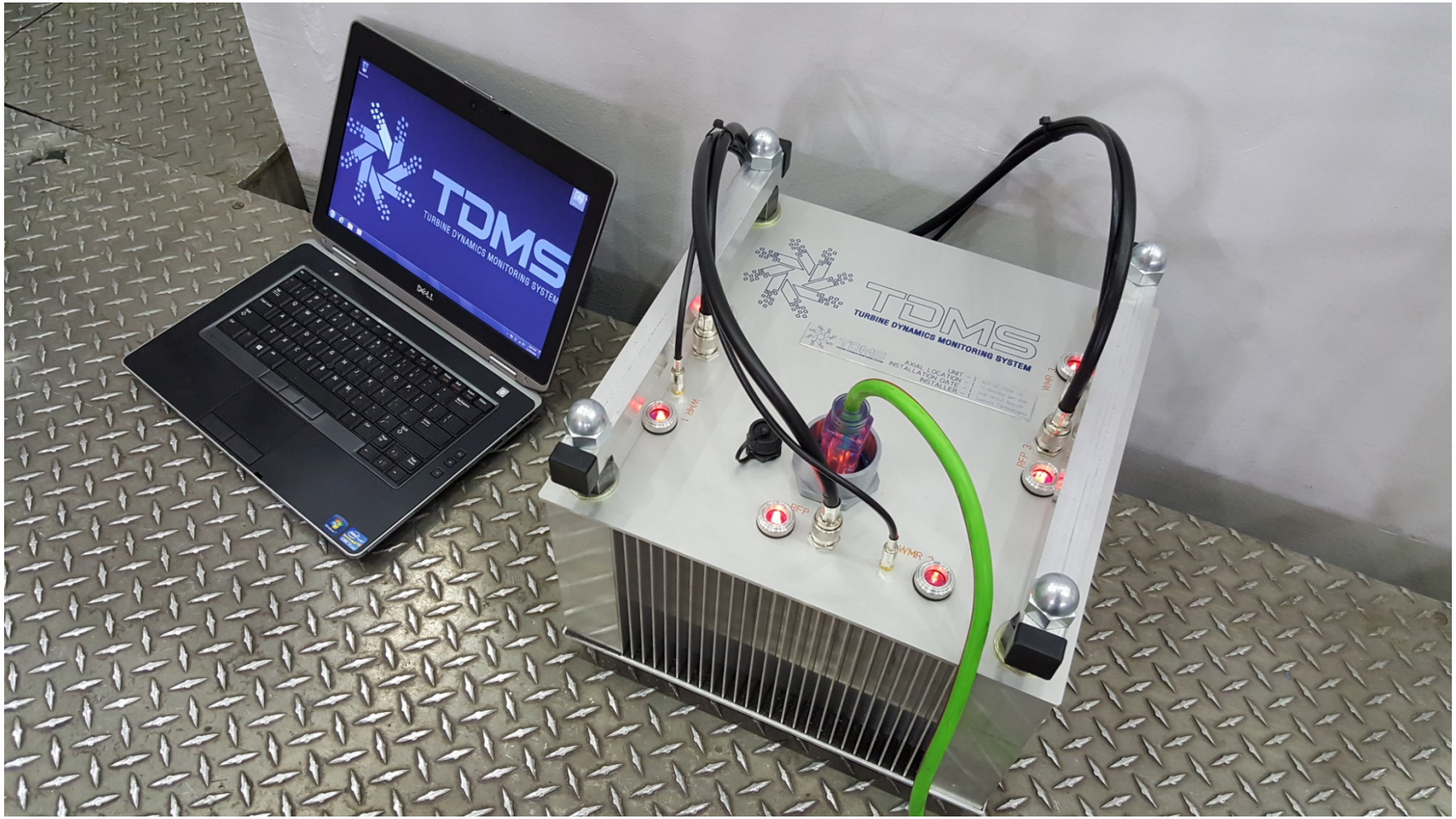
Typical Quad Telemetry Application

- Nuclear steam turbine-generator.
- Stationary antennae.
- Quad telemetry + rotary antennae.



Stationary telemetry

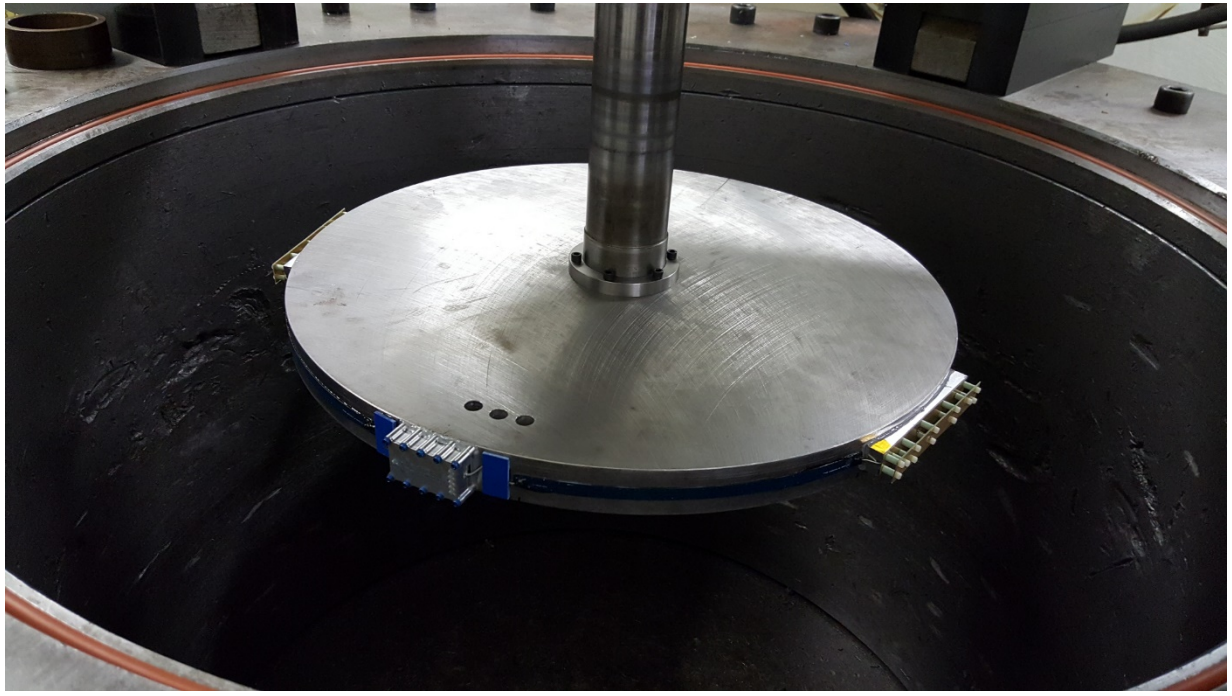
- Within 10-20m of the rotor mounted telemetry.



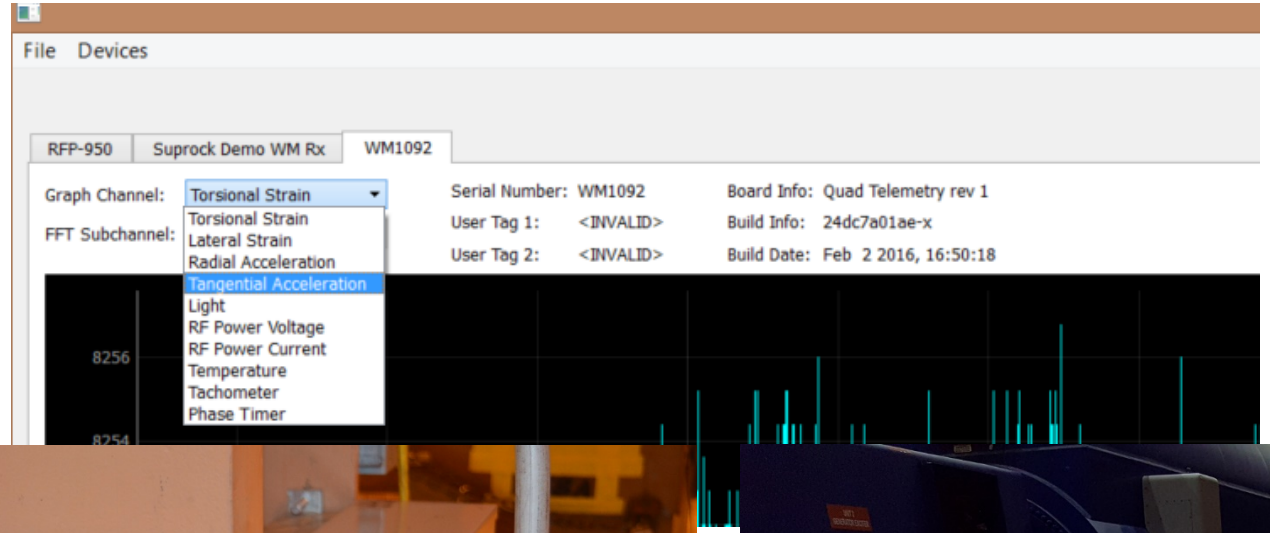
Telemetry Mechanical Specifications

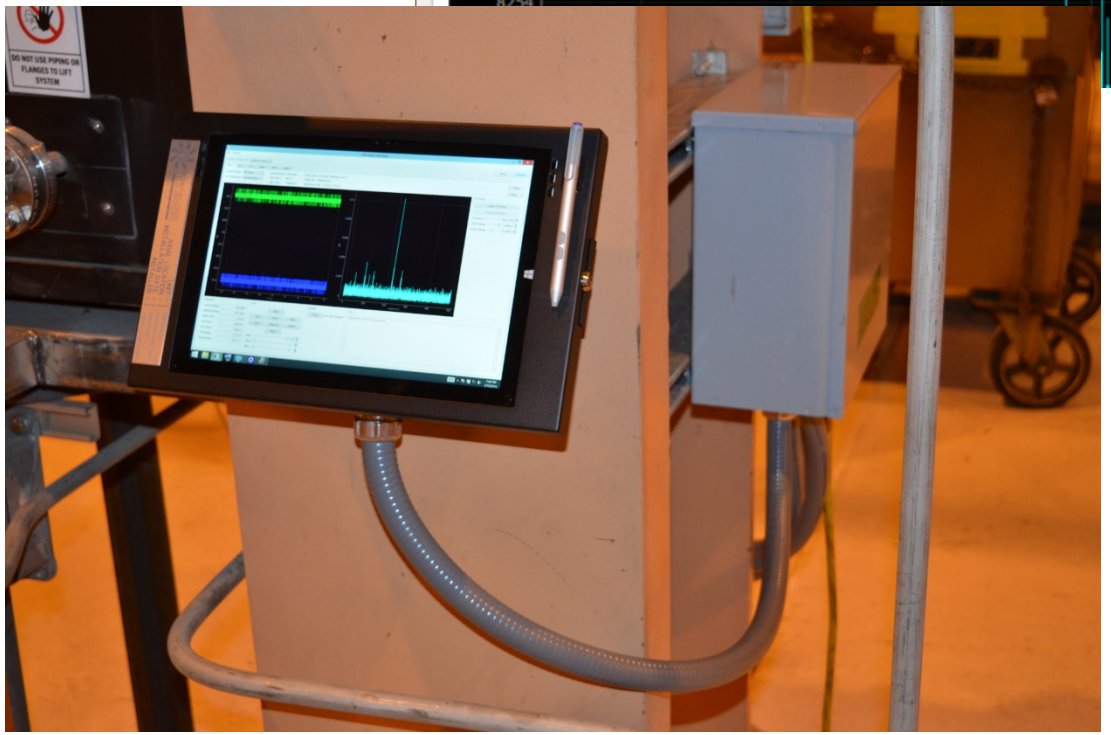
- Proven to withstand 6000RPM at 24” diameter in a spin pit test.
  - Test conducted in atmosphere.
  - Test did not result in telemetry failure (aerodynamic limit of spin pit motor torque).

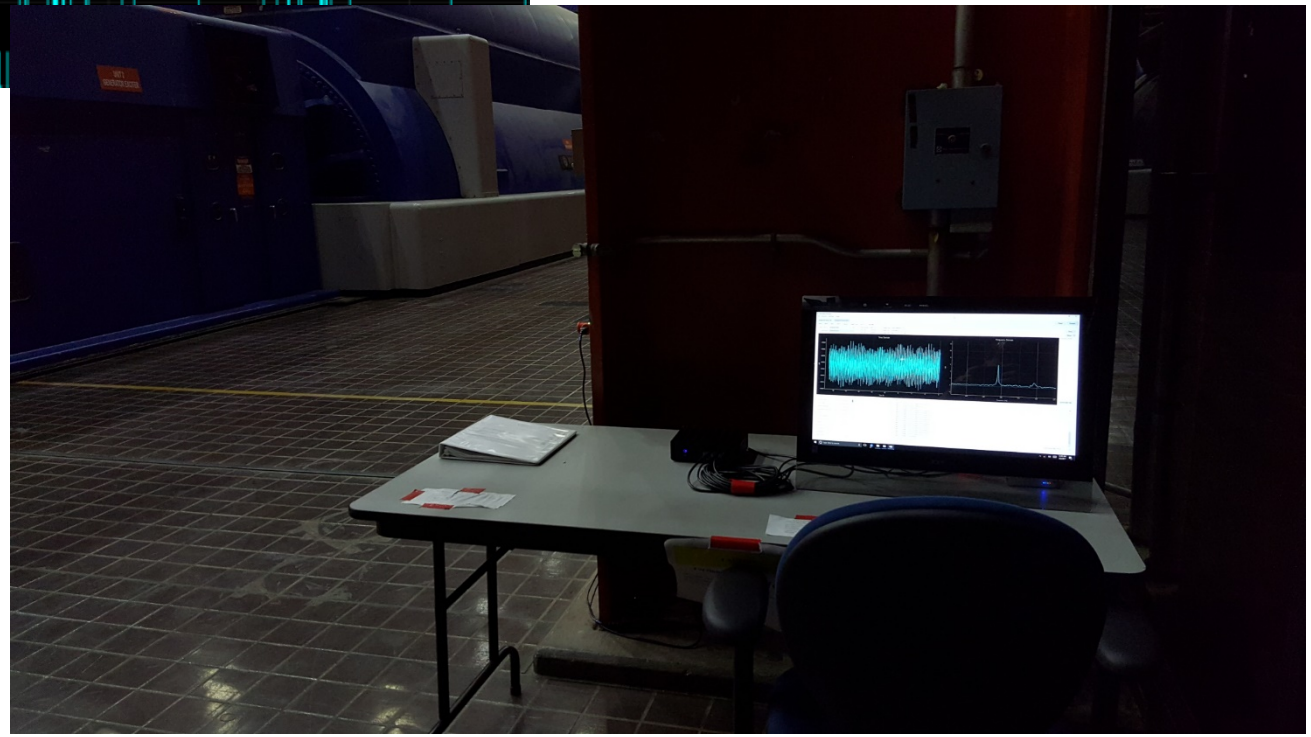
- Electronic tests conducted to temperature of 150C



Data Acquisition Interface







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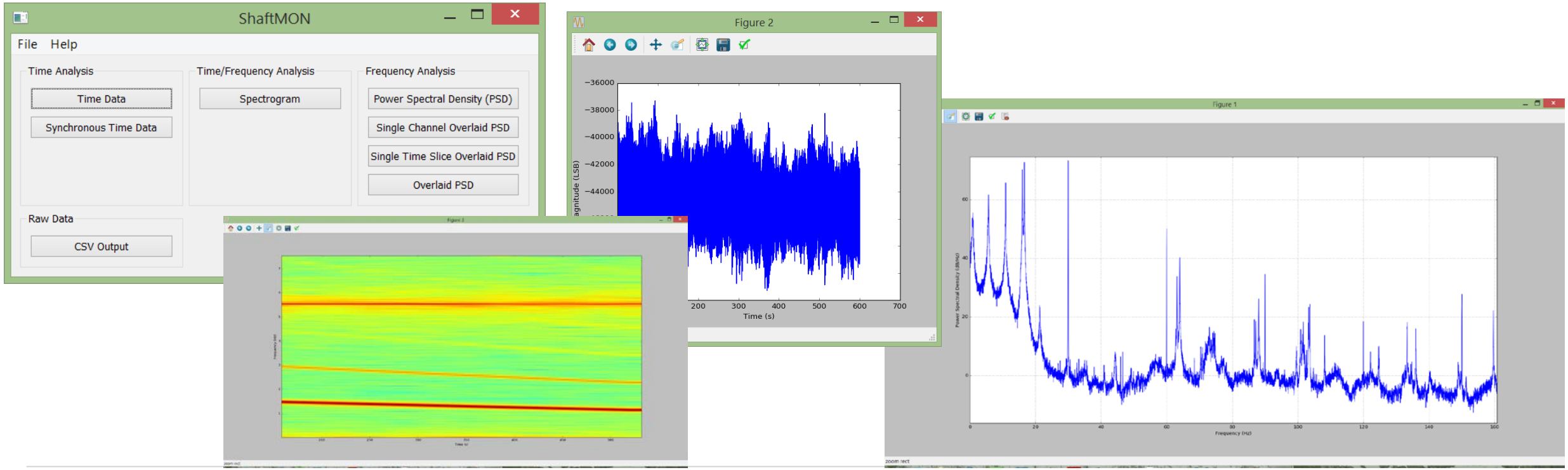
Data Post Processing Tool

- Produces various common plots useful for communicating turbine performance.
  - PSD plots of frequency
  - Spectrograms
  - Time data
  - Overlaid spectral data (various sensors or various time windows)



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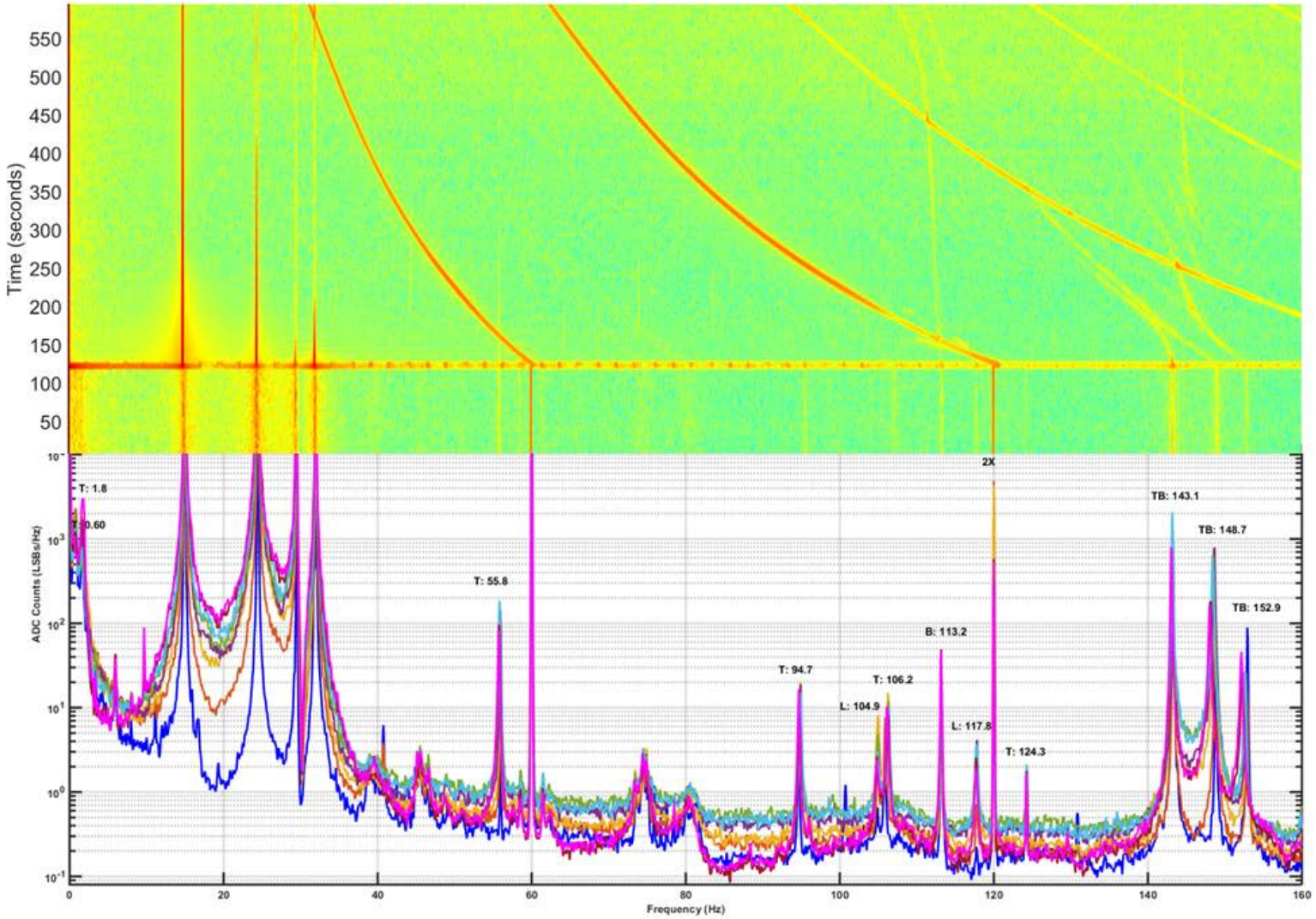
800MW/3600RPM steam turbine-generator



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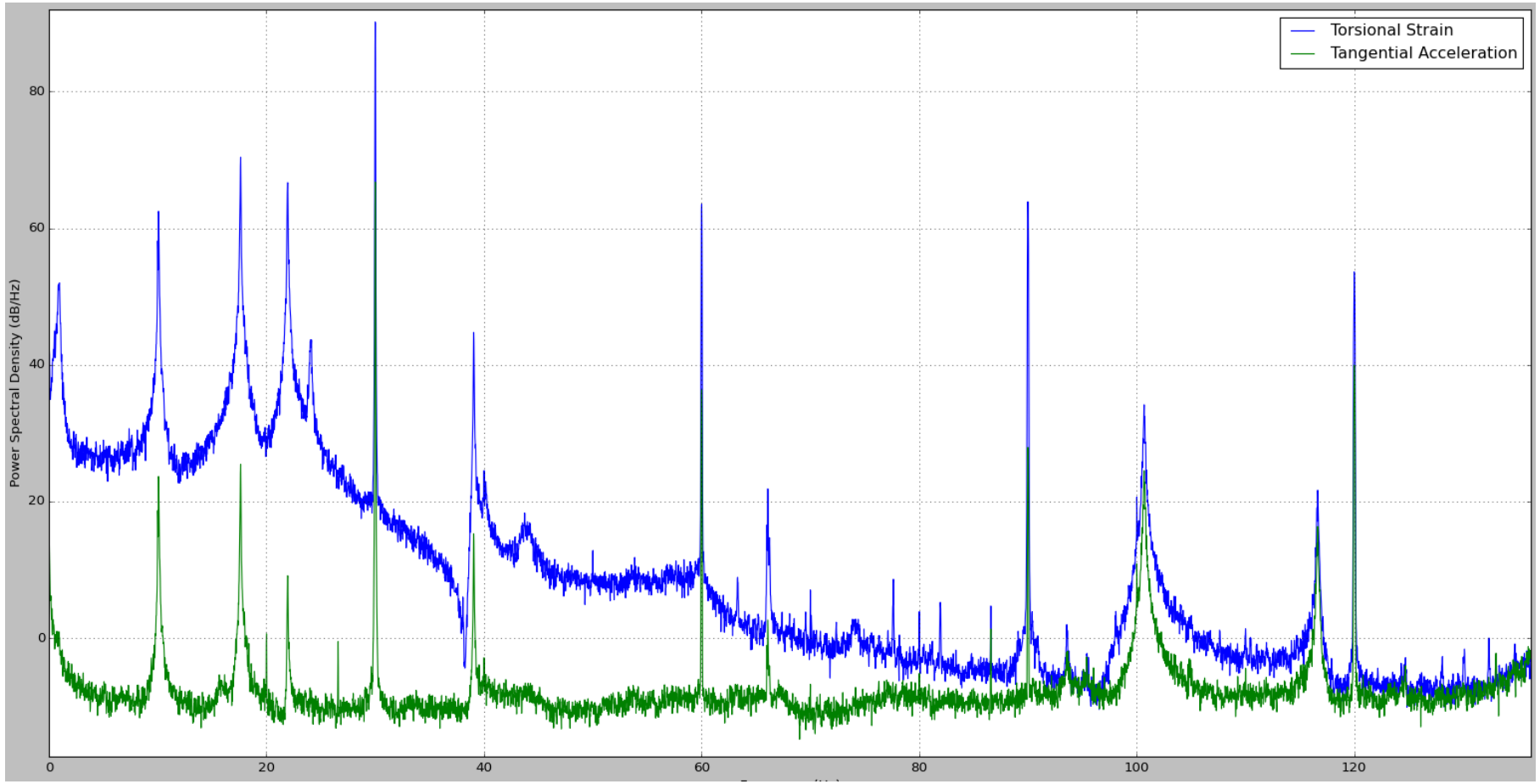
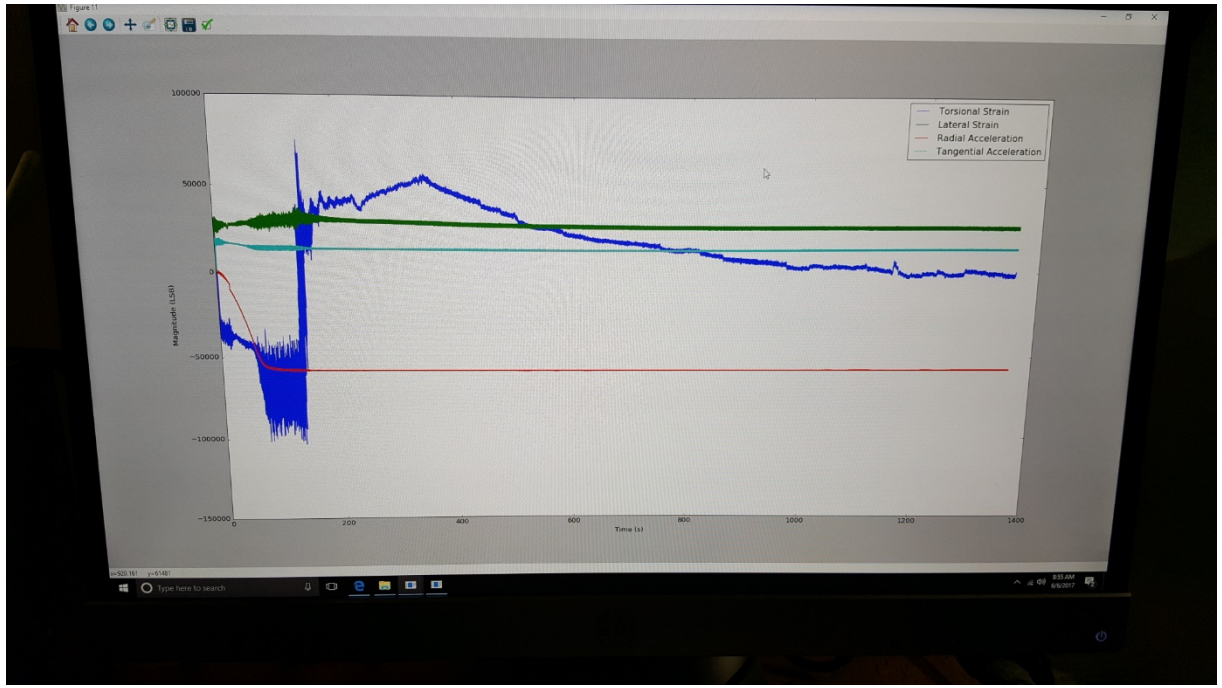
1200MW/1800RPM steam turbine-generator

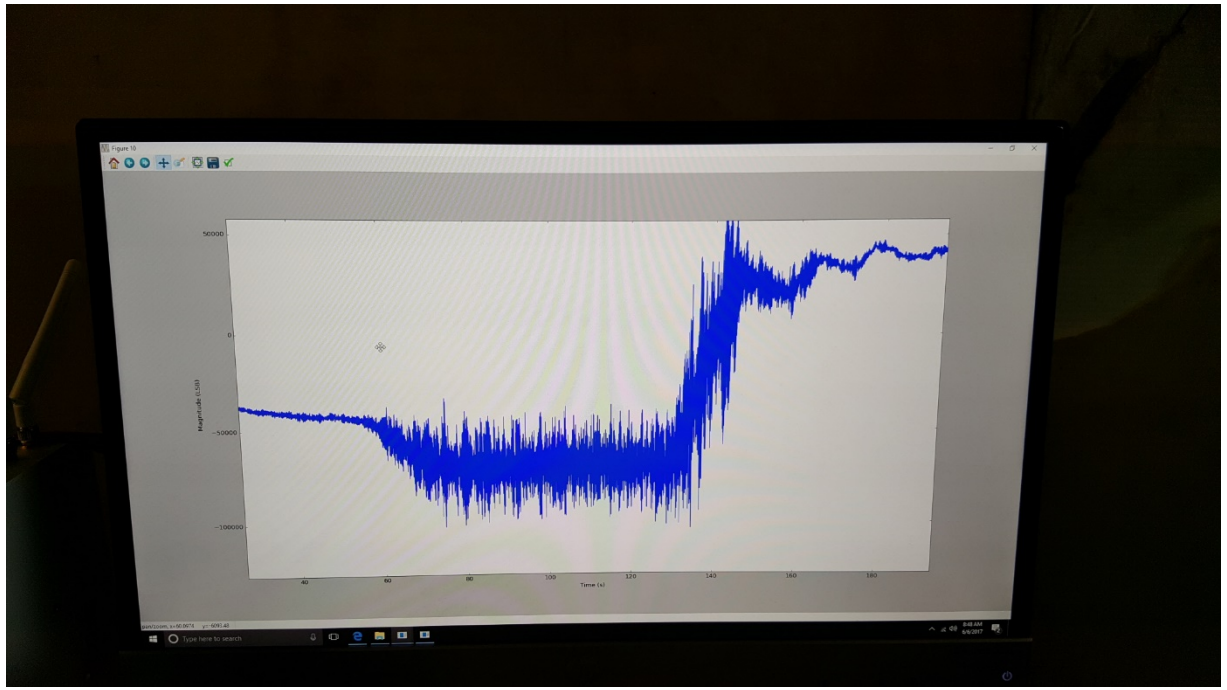
- Performed after complete turbine retrofit project.
- Goals to ensure compliance with NEIL specified avoidance bands.



275MW/300RPM hydroelectric Francis turbine-generator

- New applications developing for long term monitoring.
- Thus far detecting torsional vibration from bearing failure and turbine rope cavitation.
- Apologies for the screen shot (data transfer restriction)



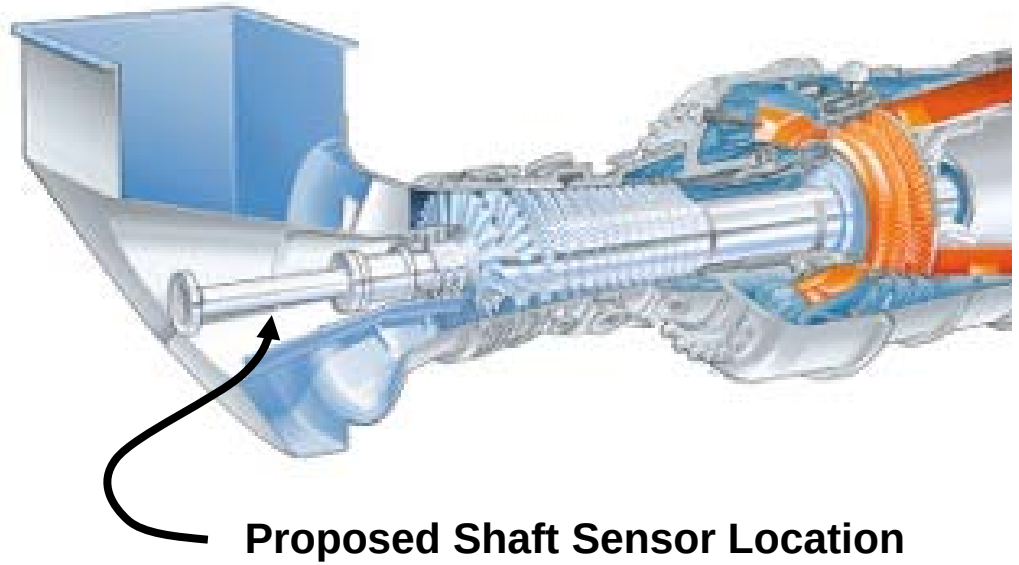


Ongoing and future applications of TDMS

- EPRI research exploring additional applications to power generation equipment:
  - Hydroelectric turbine-generator sets
  - Combustion turbine-generator sets
  - Turbine/compressor blade vibration detection
  - Continuous shaft health monitoring
  - Health/tuning of generator controls

Future Applications of Shaft Vibration Sensing

- Combustion Turbine Applications
  - Various operational anomalies can produce unique shaft torque oscillation signatures
  - R0 stage flutter, surge, tip rubs/contact
  - TDMS deployed for continuous operation with data “feature extraction” capabilities

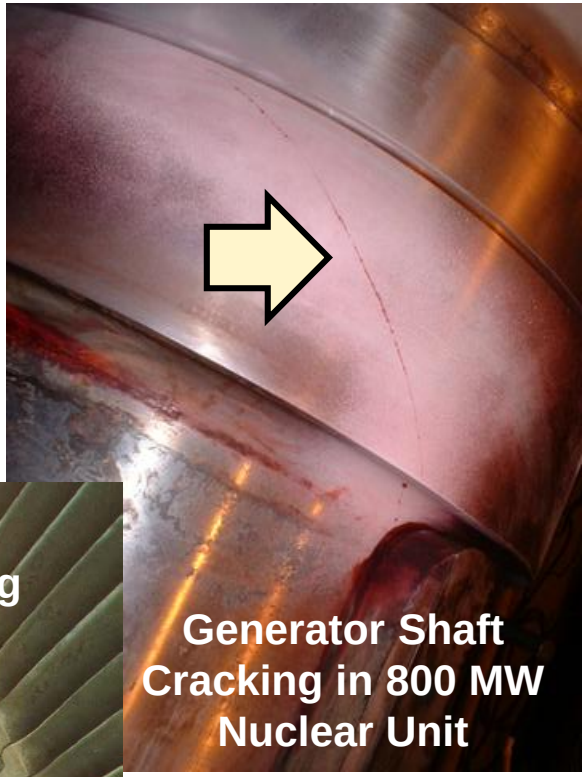


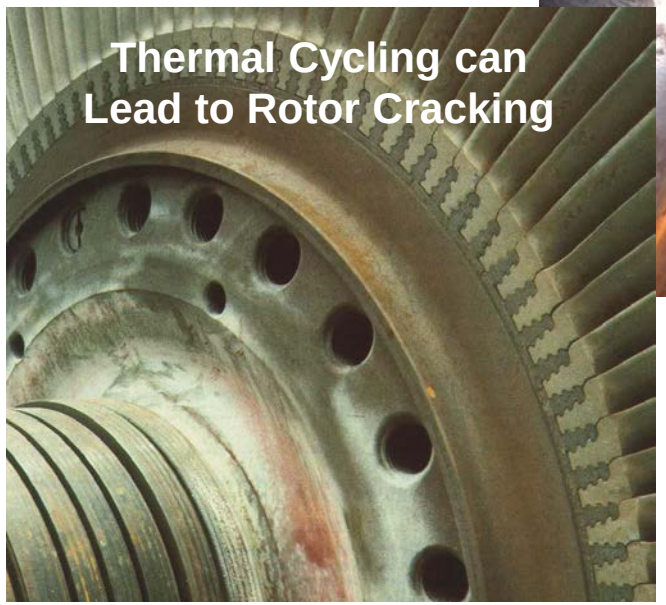
Proposed Shaft Sensor Location

Failure of R0 Compressor Blade

Future Applications of Shaft Vibration Sensing

- Turbine-Generator shaft health degradation monitoring
  - Turbine-generator rotor/shaft cracking is infrequent, but has high consequences if undetected
  - Proposed concept for TDMS application:
    - Monitor/trend shaft natural frequencies (torsional and lateral)
    - Use feature extraction; apply *Advanced Pattern Recognition* (APR) to highlight anomalous trends
    - Companion FEA necessary…provides basis for action levels





Questions and Discussion….

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