



GTEN 2021 Virtual Symposium

October 18th & 19th, 2021

Training – Gas Turbine Vibration Protection System Basics

Brett Butler, TC Energy

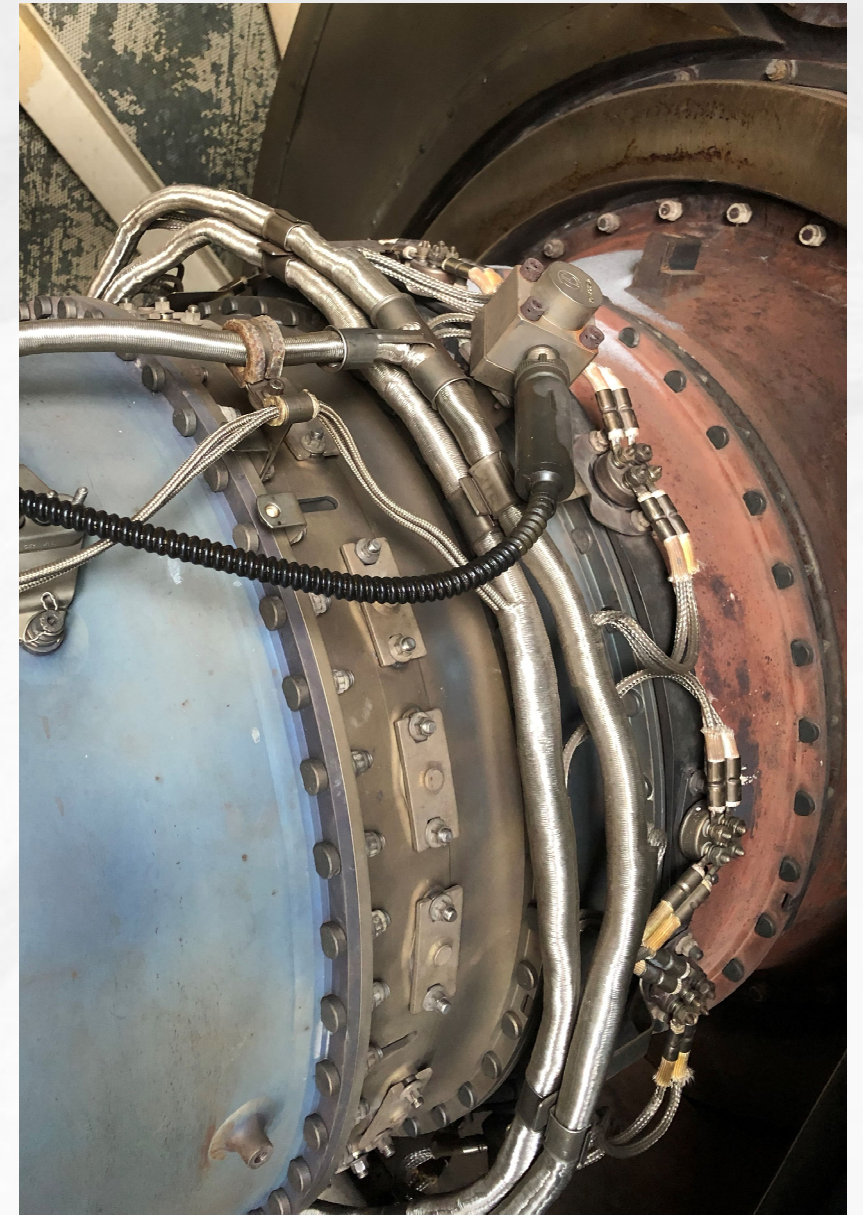
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Session Outline

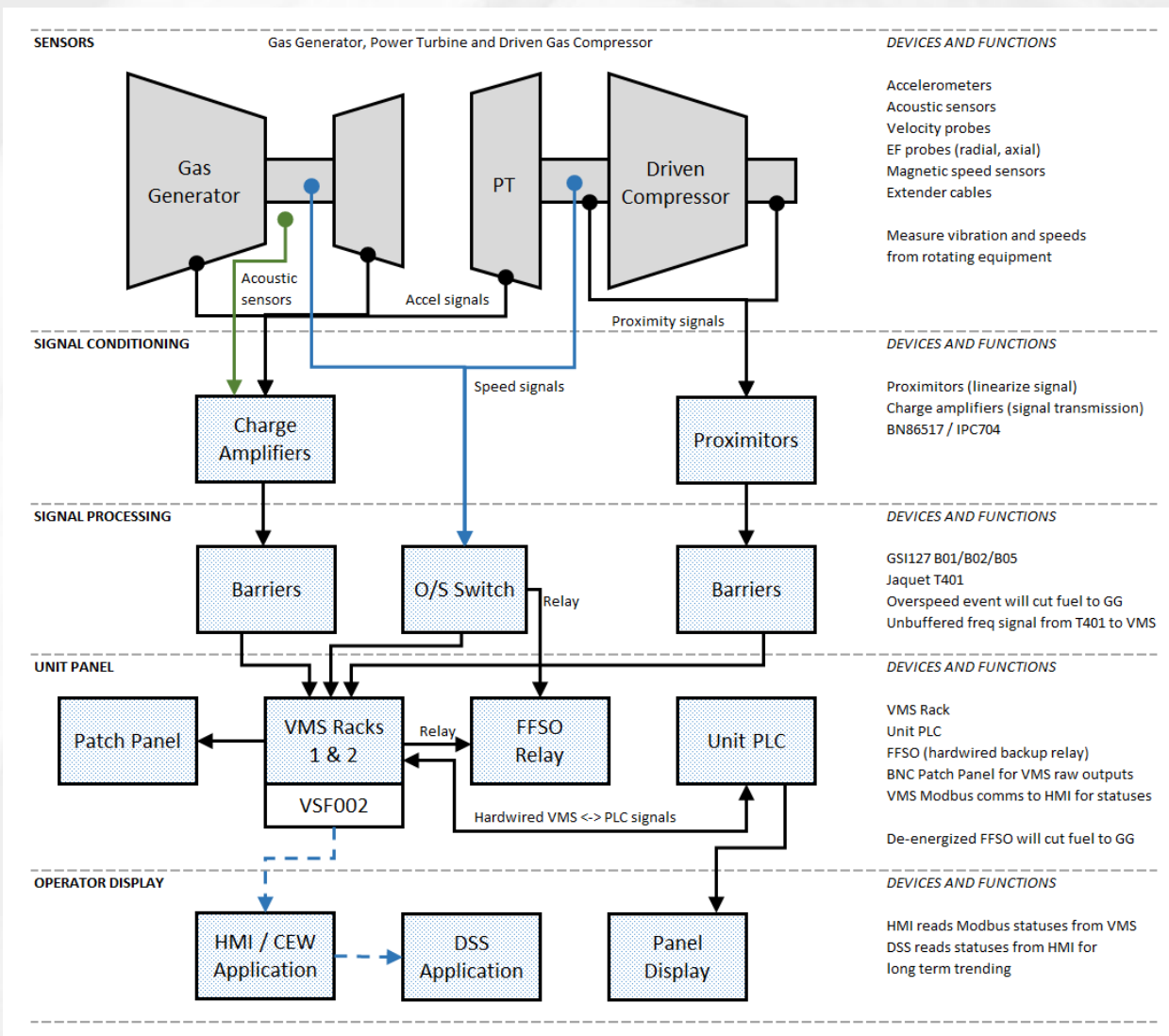
- Vibration protection system overview
 - Why we need them and basic layout of the VMS design
- Instrumentation types and locations
 - Accelerometers, proximity sensors and probes, thrust probes, key phasors and speed probes (MPUs) and their locations.
 - Signal conditioning and filtering
- Rotating equipment diagnostics and some typical vibration issues
- TCE vibration system upgrades and latest technology
 - Protective functions and operational diagnostics for long-term trending, together with remote diagnostic capabilities of hi-res trending

Why Monitor GT Vibration?

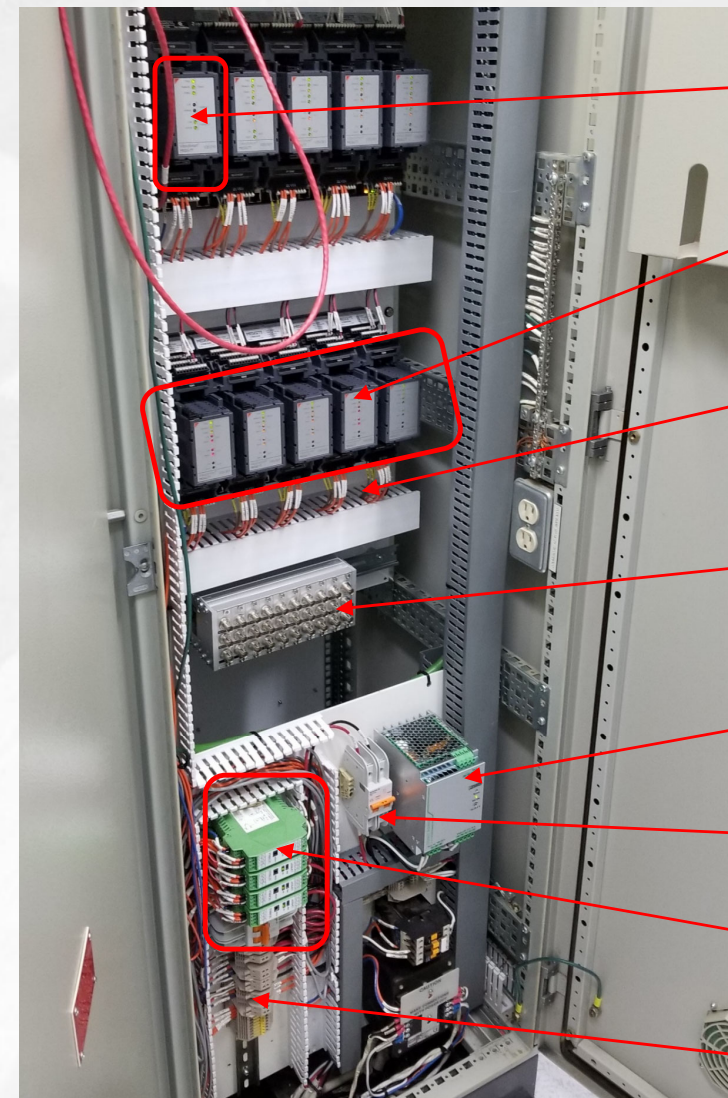
1. Excessive vibration levels will eventually cause equipment damage
 - Protect by safely shutting down before lost production / accidents occur
2. Monitoring and analysis provides additional troubleshooting information
 - Every rotating machine exhibits own vibration characteristics
 - Vibration changes can be caught early, and any actions/maintenance planned prior to any failure
 - Reduction of unscheduled down time, turnaround time, any major equipment damage



Vibration System Overview



TC Energy Typical VMS Panel



Communication module

Monitoring modules

Hardwires to PLC and relays

BNC patch panel

Isolated power supply

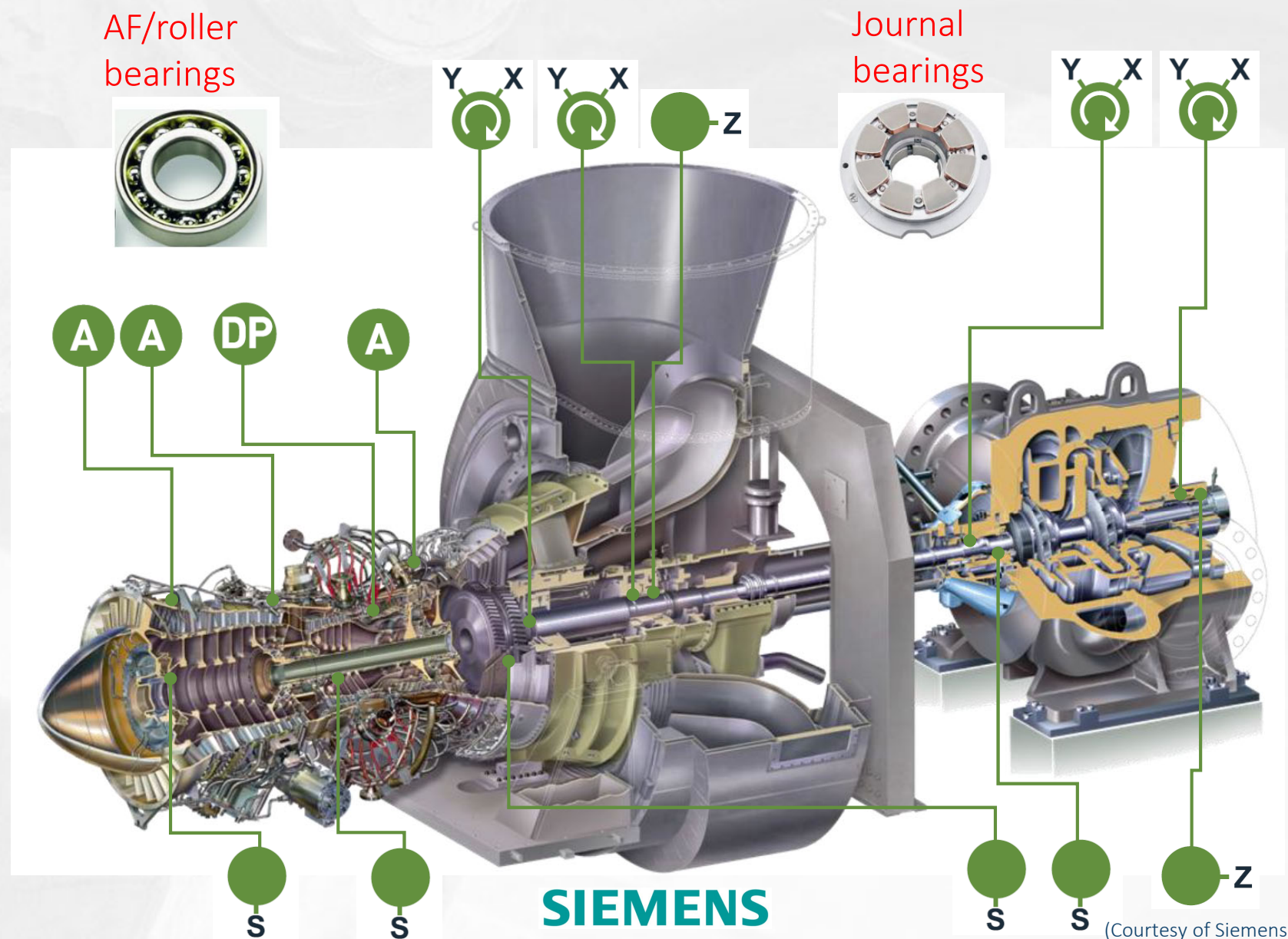
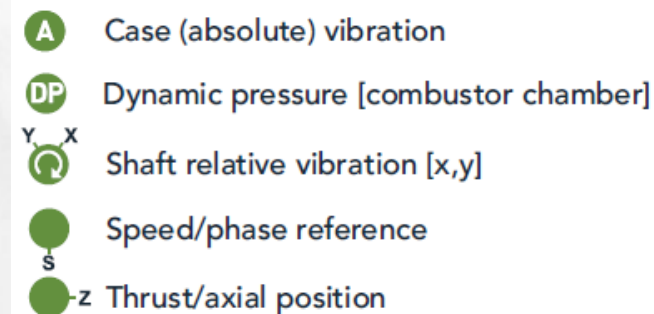
Relays

Overspeed cards

Field terminals

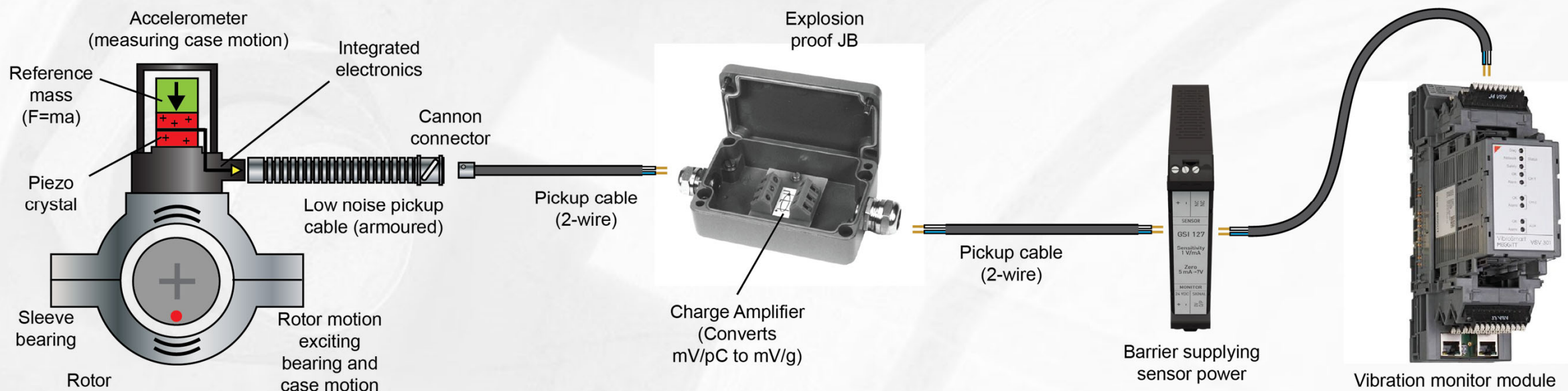
Typical VMS Monitored GT Components

- Aero-derivative GG's fitted with anti-friction/roller bearings
- PTs supported by hydrodynamic journal and thrust bearings
- Driven compressors supported by journal and thrust bearings
- Some applications monitor combustion chambers and/or gearboxes



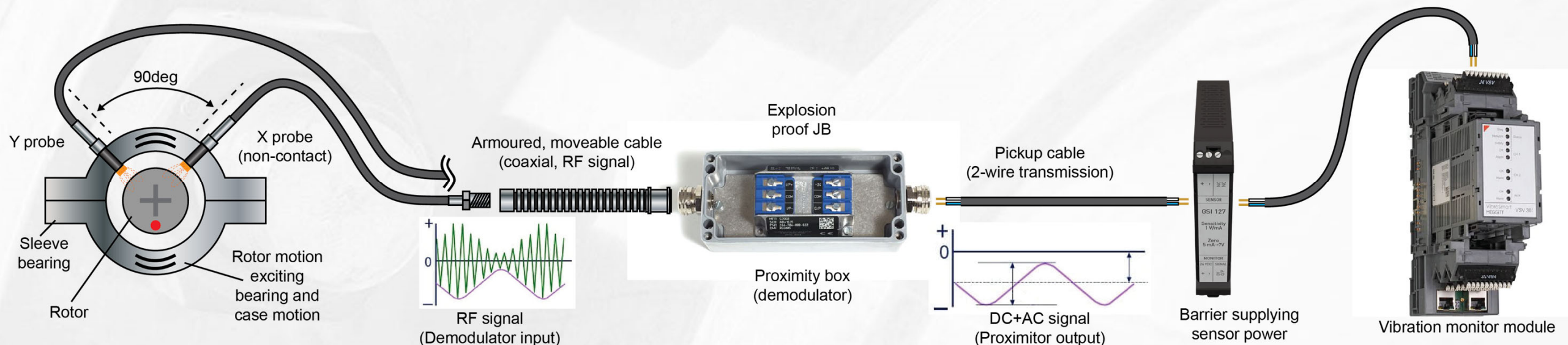
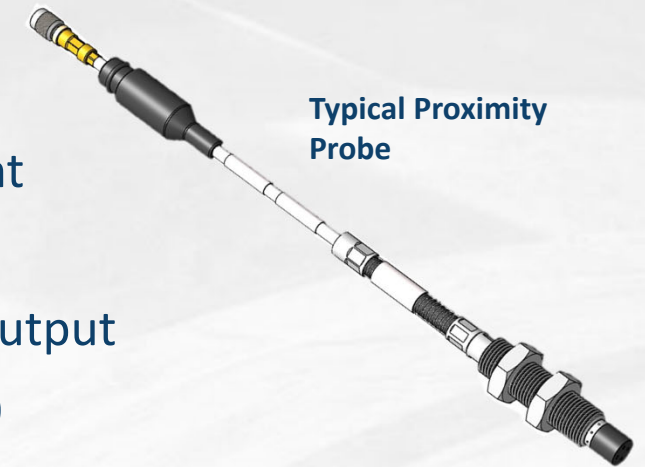
Sensors – Accelerometers

- Seismic sensor measures absolute acceleration or velocity
- Mounted externally on GG/PT cases
- Signal can be integrated to velocity, velocity to displacement
- Consists of case probe, pickup cable, charge amplifier
- Charge amp generates mVAC signal (no DC offset)
- High dynamic measurement range, can withstand high temps
- Sensitive to mounting method, cable movement, EM signal noise



Sensors – Proximity Probes (Radial, Axial)

- Measures the distance between tip of probe and target (shaft)
- Non-contact eddy current sensors, outputs relative displacement measurement
- For axial monitoring, probe provides static displacement output
- For radial monitoring, X-Y probe (90deg) pair, provide dynamic displacement output
- Consists of probe (inserted on machine), extension cable and proximator (in JB)
- Measure both AC (dynamic) and DC (static)
- With a key phasor, the phase (degrees) for the X-Y signals can be calculated

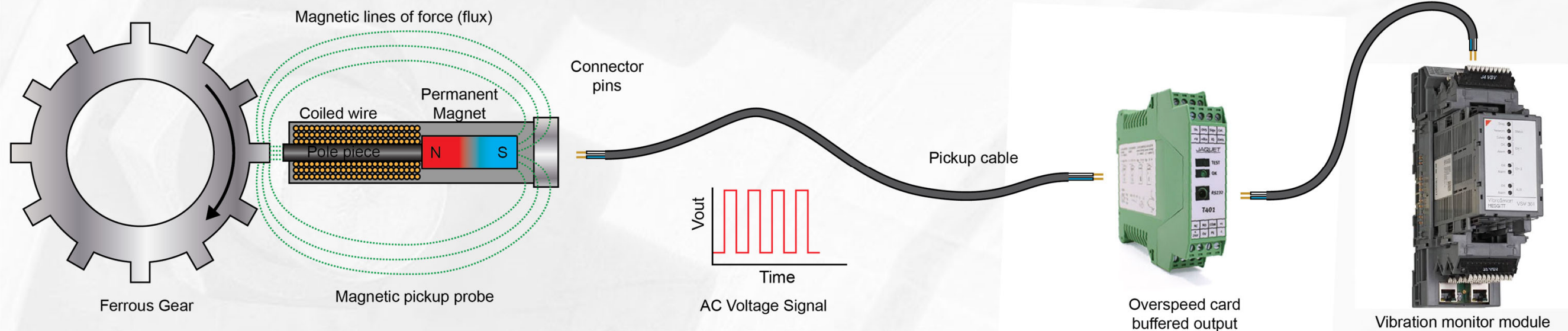


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Vibration Protection System Basics

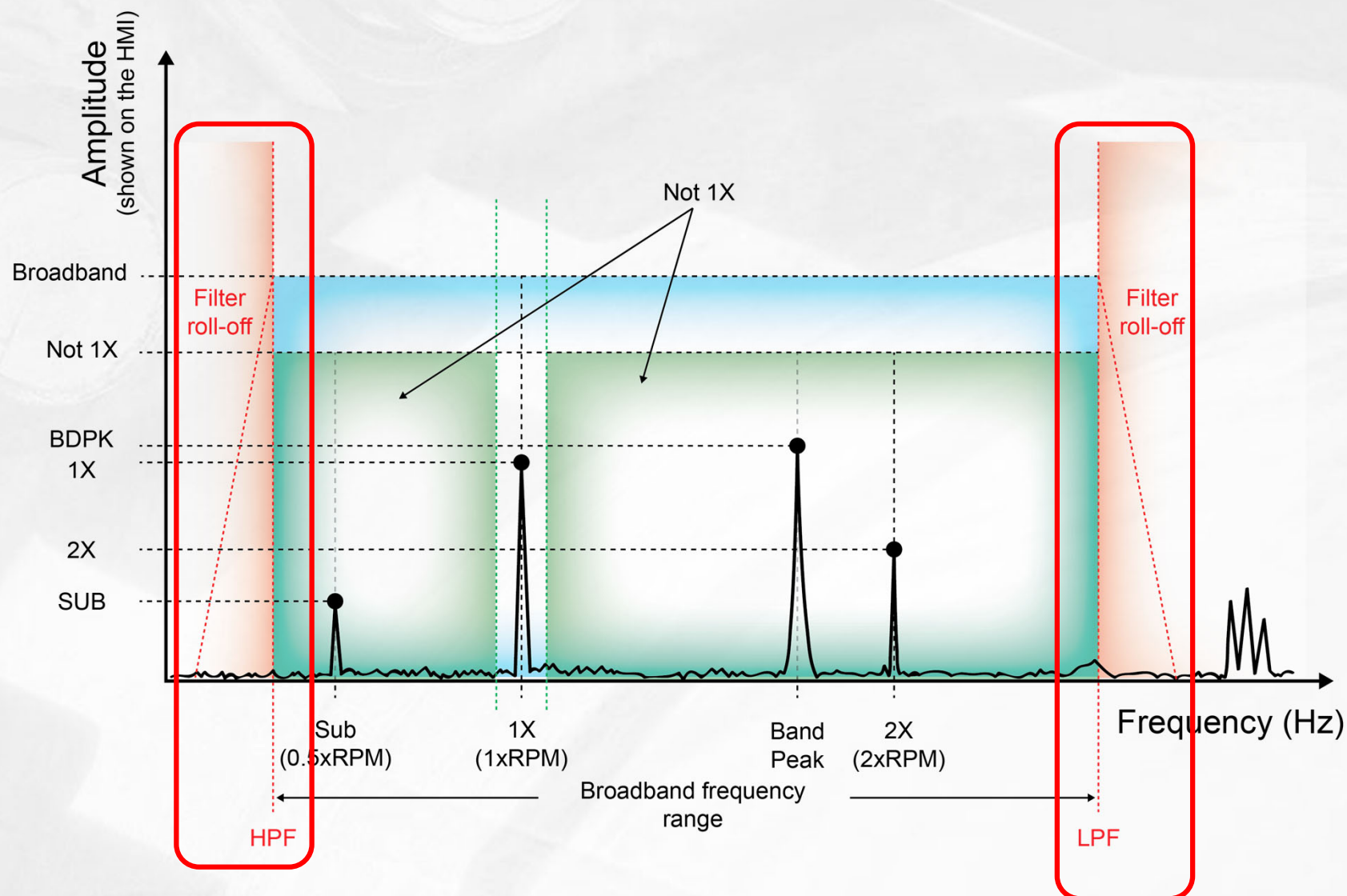
Speed and Key Phasor Probes

- Magnetic pickup used to sense the speed of the rotating shaft
- Main control parameter for GT fuel control system
- Basically, MPU is a single pole, AC electric generator
- Used in VMS for tracking filters (1X, 2X etc)
- Also used in protective backup O/S system
- Keyphasor is a proximity probe, sensing a single notch



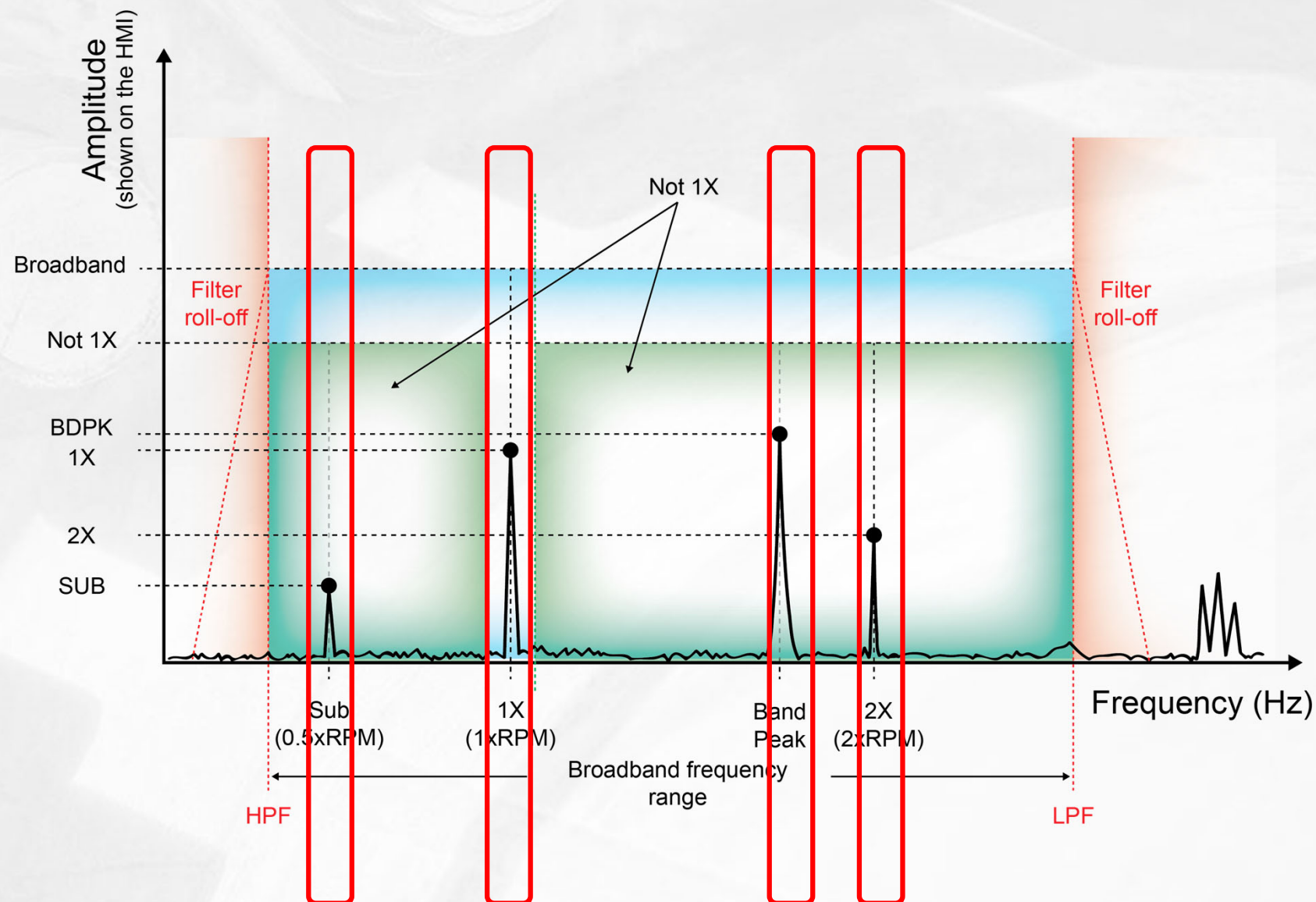
Vibration Signal Filtering

- The vibration probe will add up all energy peaks within the sensitivity range and present as one amplitude
- With no filters, this makes it difficult to diagnose issues
- 2 filters applied to remove frequencies that are of no interest
 - Low pass (LPF) removes high frequencies
 - High pass filter (HPF) removes low frequencies



Vibration Diagnostic Filtering

- The VMS has diagnostic filters to output the various amplitudes
- 1X amplitude related to the frequency of the rotating shaft (1 x rpm)
- If key-phaser present, then can output 1X-phase value
- 2X amplitude related to twice the frequency of the rotating shaft (2 x rpm)
- Sub-harmonic amplitude related to half the frequency of the rotating shaft (0.5 x rpm)
- Not 1X amplitude is all 1X related frequencies removed
- Band Peak/ /Freq provides the dominant amplitude and its associated frequency



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Vibration Protection System Basics



Unit H1 Vibration

AMB PRESS
93.3 kPaa

N1 SPEED 9360 RPM
N3 SPEED 5348 RPM
EGT AVG 794 °C

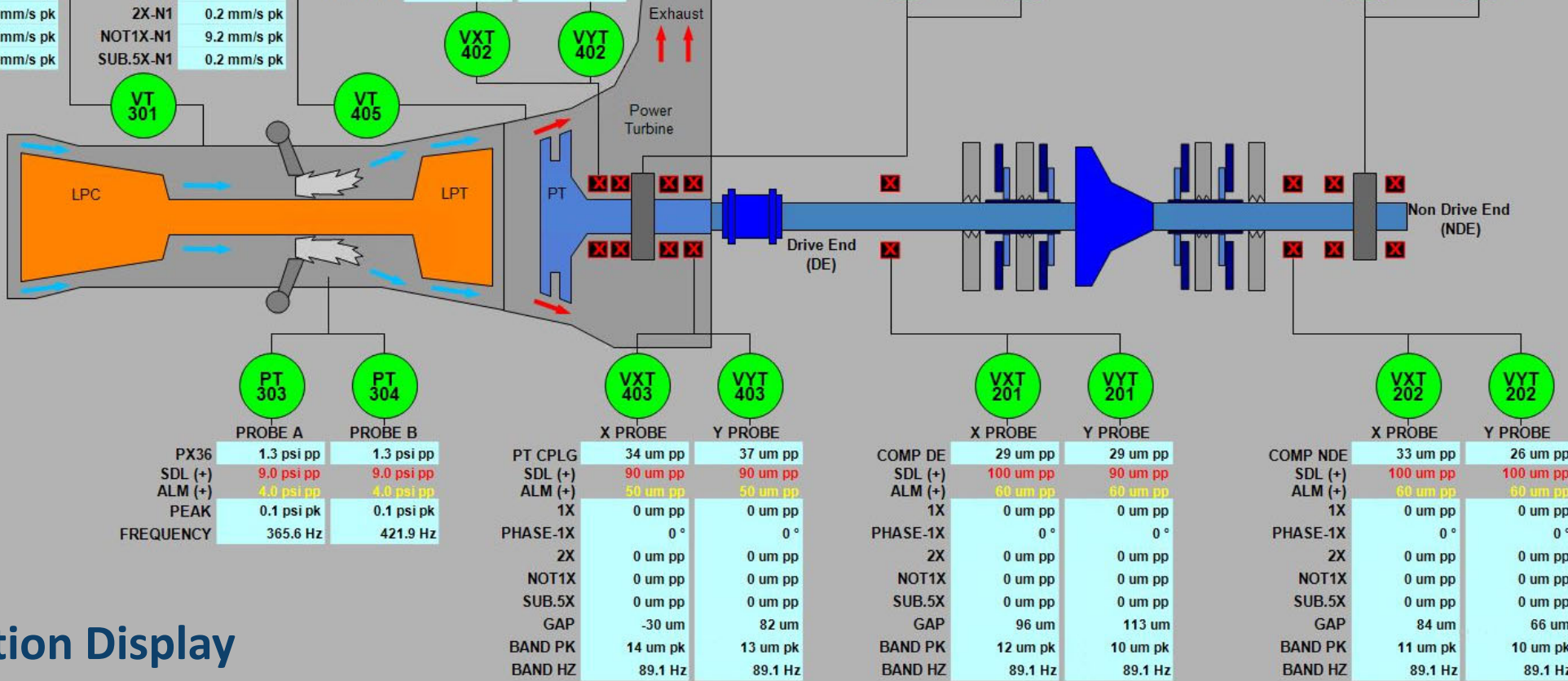
GG CASE BB	26.2 mm/s pk	PT CASE BB	10.6 mm/s pk
SDL (+)	91.4 mm/s pk	SDL (+)	25.4 mm/s pk
ALM (+)	53.3 mm/s pk	ALM (+)	15.3 mm/s pk
GG 1X-N1	23.9 mm/s pk	PT 1X-N3	9.1 mm/s pk
SDL (+)	76.2 mm/s pk	SDL (+)	25.4 mm/s pk
ALM (+)	44.5 mm/s pk	ALM (+)	12.7 mm/s pk
2X-N1	2.6 mm/s pk	2X-N3	0.1 mm/s pk
NOT1X-N1	12.5 mm/s pk	NOT1X-N3	2.3 mm/s pk
SUB.5X-N1	0.4 mm/s pk	SUB.5X-N3	0.1 mm/s pk
BAND PK	23.1 mm/s pk	BAND PK	9.1 mm/s pk
BAND HZ	156.3 Hz	BAND HZ	89.1 Hz
1X-N3	2.3 mm/s pk	1X-N1	1.1 mm/s pk
2X-N3	0.2 mm/s pk	2X-N1	0.2 mm/s pk
NOT1X-N3	23.9 mm/s pk	NOT1X-N1	9.2 mm/s pk
SUB.5X-N3	0.8 mm/s pk	SUB.5X-N1	0.2 mm/s pk

	X PROBE	Y PROBE
PT DISC	30 um pp	15 um pp
SDL (+)	90 um pp	90 um pp
ALM (+)	50 um pp	50 um pp
1X	0 um pp	0 um pp
PHASE-1X	0 °	0 °
2X	0 um pp	0 um pp
NOT1X	0 um pp	0 um pp
SUB.5X	0 um pp	0 um pp
GAP	-3 um	113 um
BAND PK	10 um pk	6 um pk
BAND HZ	89.1 Hz	89.1 Hz

	PROBE A	PROBE B
PT AXIAL	-466 um	-473 um
SDL (+)	405 um	405 um
ALM (+)	365 um	365 um
ALM (-)	-630 um	-630 um
SDL (-)	-675 um	-675 um

	PROBE A	PROBE B
CMP AXIAL	138 um	102 um
SDL (+)	375 um	375 um
ALM (+)	325 um	325 um
ALM (-)	-325 um	-325 um
SDL (-)	-375 um	-375 um

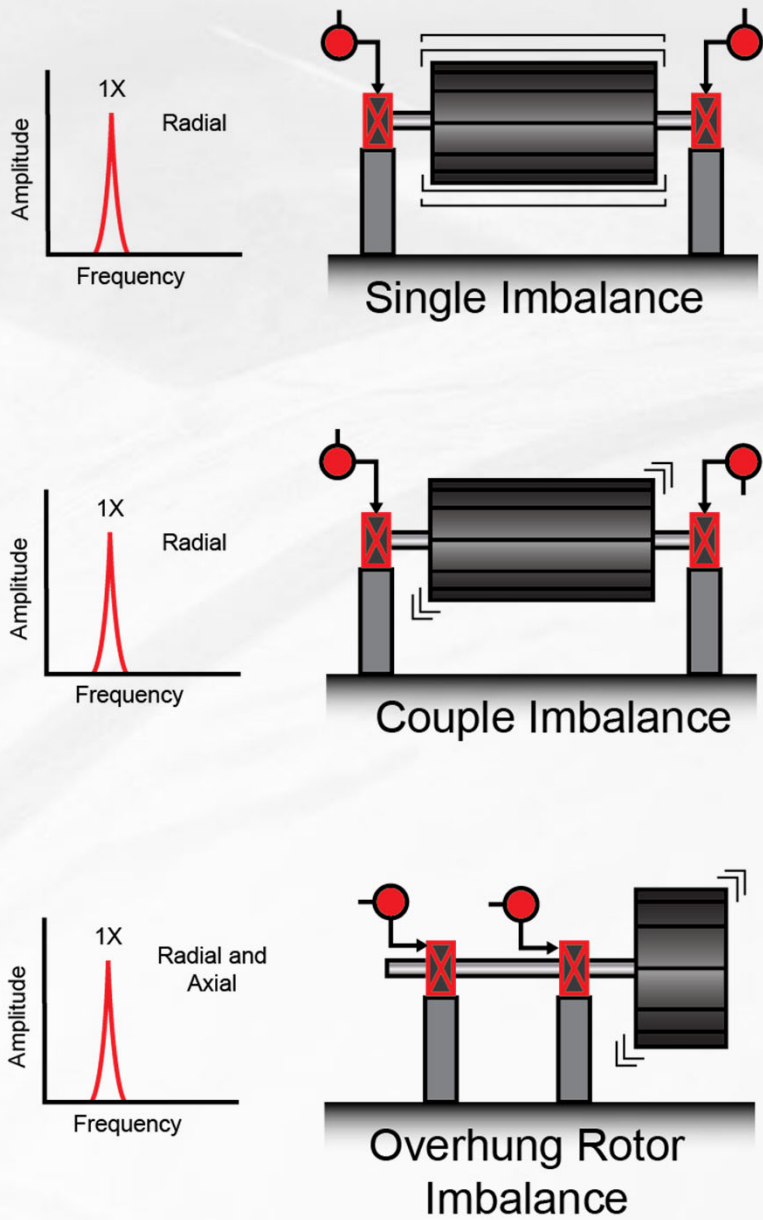
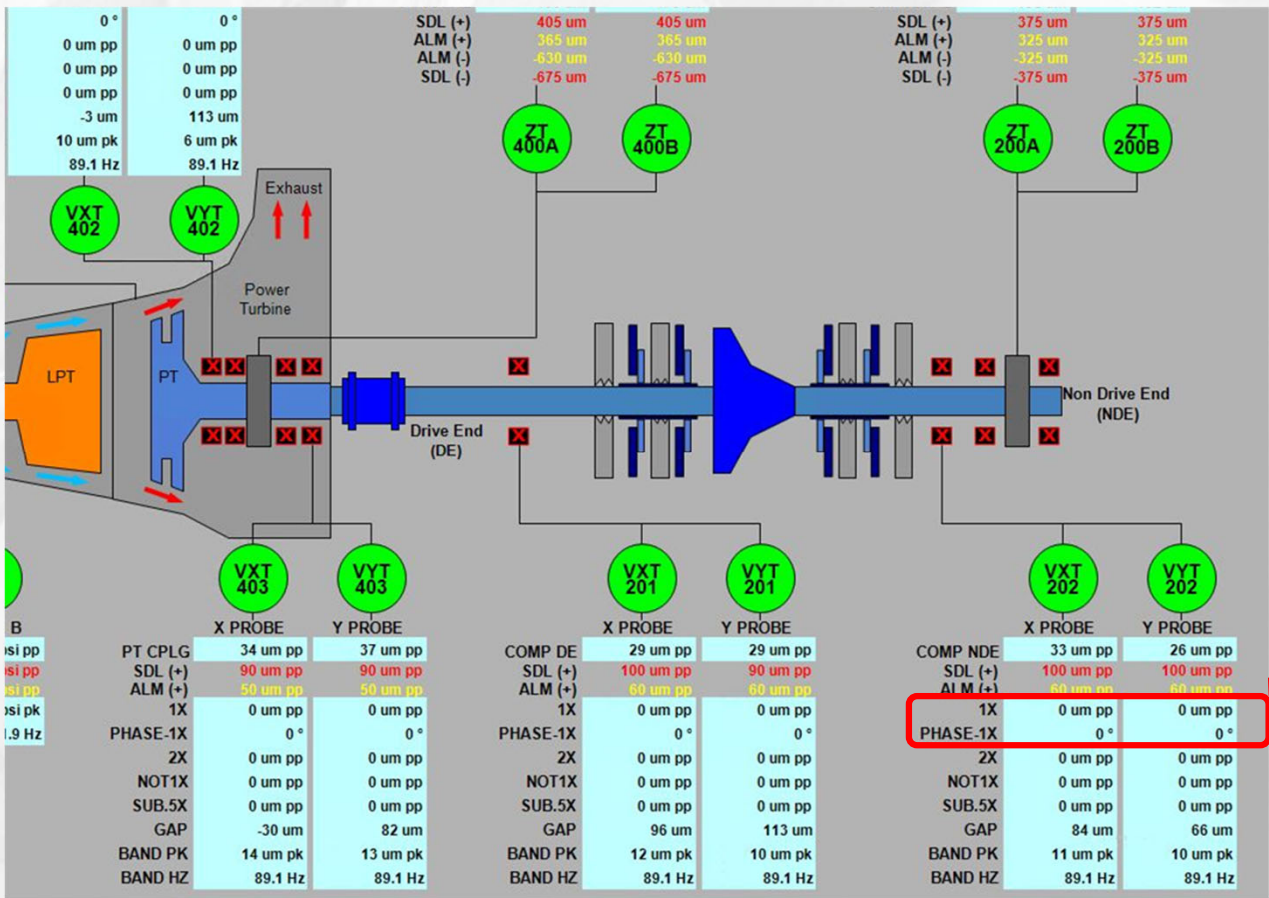
VIB RACK STATUS	
SIGN OF LIFE	-4183
TRACKING N1 SPEED	9356 RPM
TRACKING N3 SPEED	5343 RPM
KEYPHASOR	0 RPM
TRIP MULTIPLY OFF	
VIB COMMON FAULT (PLC)	
VIB COMMON ALARM (PLC)	
VIB COMMON CSL (PLC)	
VIB COMMON SDL (PLC)	
V1M1 OK	SENSOR OK
V1M2 OK	SENSOR OK
V1M3 OK	SENSOR OK
V1M4 OK	SENSOR OK
V2M1 OK	SENSOR OK
V2M2 OK	SENSOR OK
V2M3 OK	SENSOR OK
V2M4 OK	SENSOR OK
V2M5 OK	SENSOR OK



Typical HMI Vibration Display

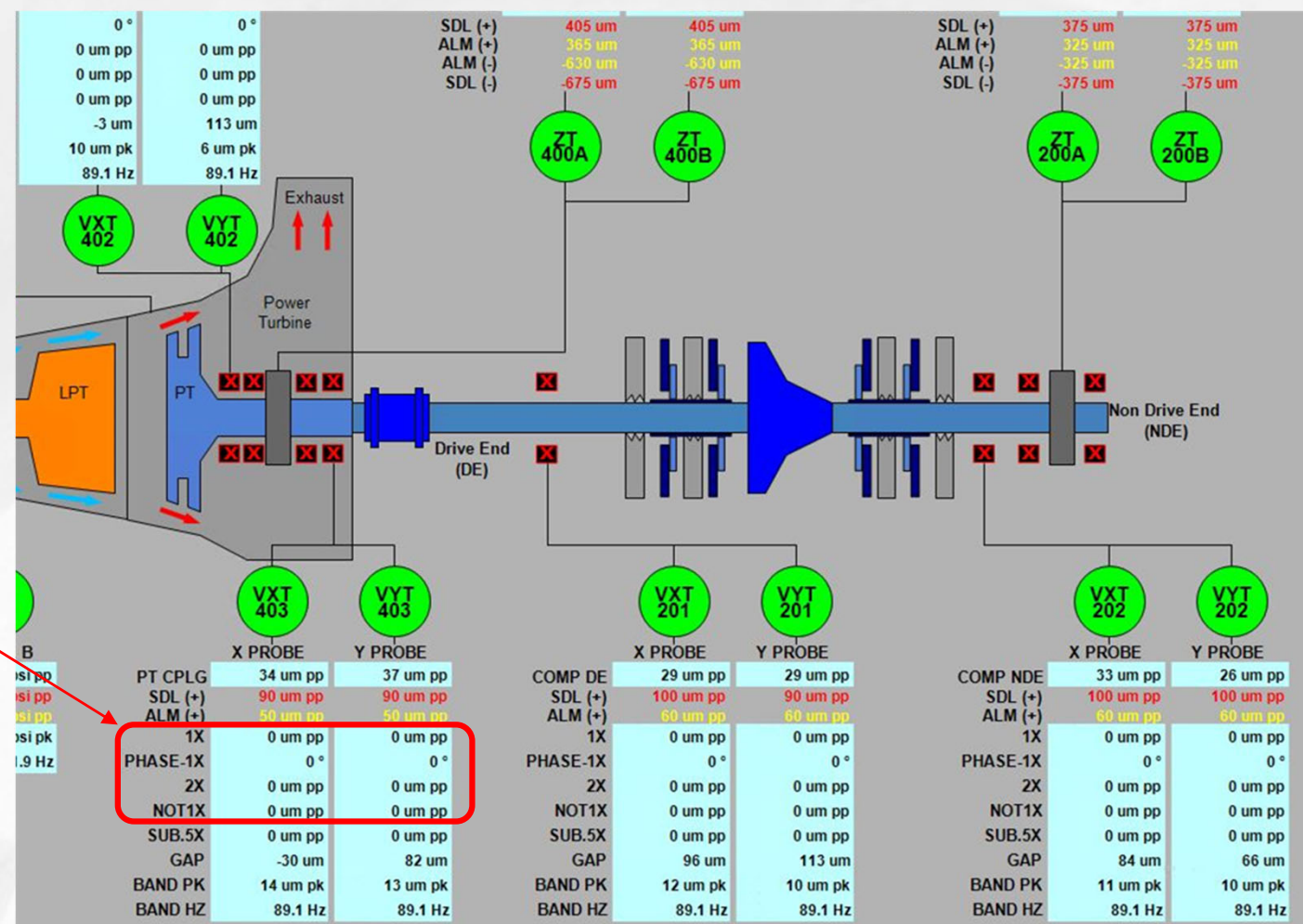
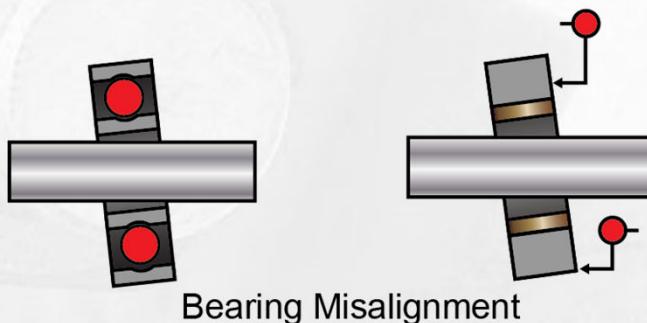
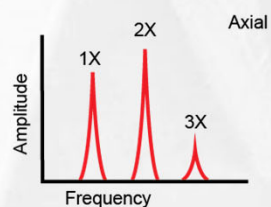
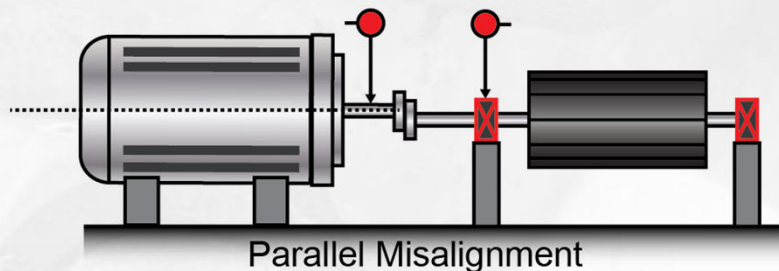
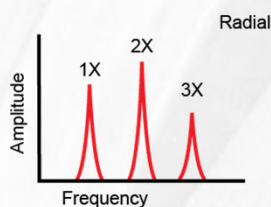
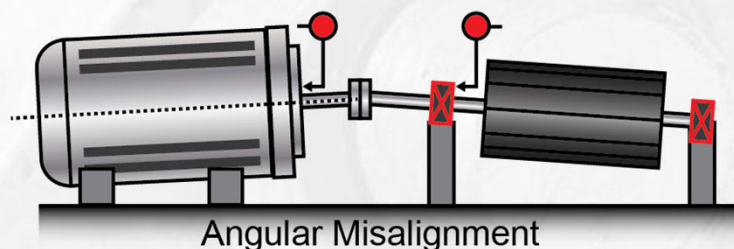
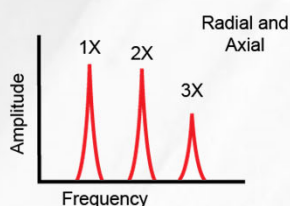
Vibration Problems – Imbalance

- Imbalance occurs when mass and rotational centers do not align
- Exhibit 1X amplitudes, phase can help with problem differentiation



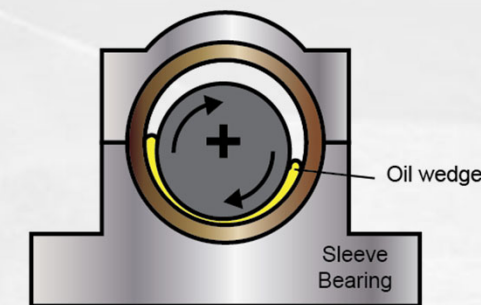
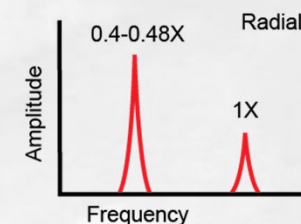
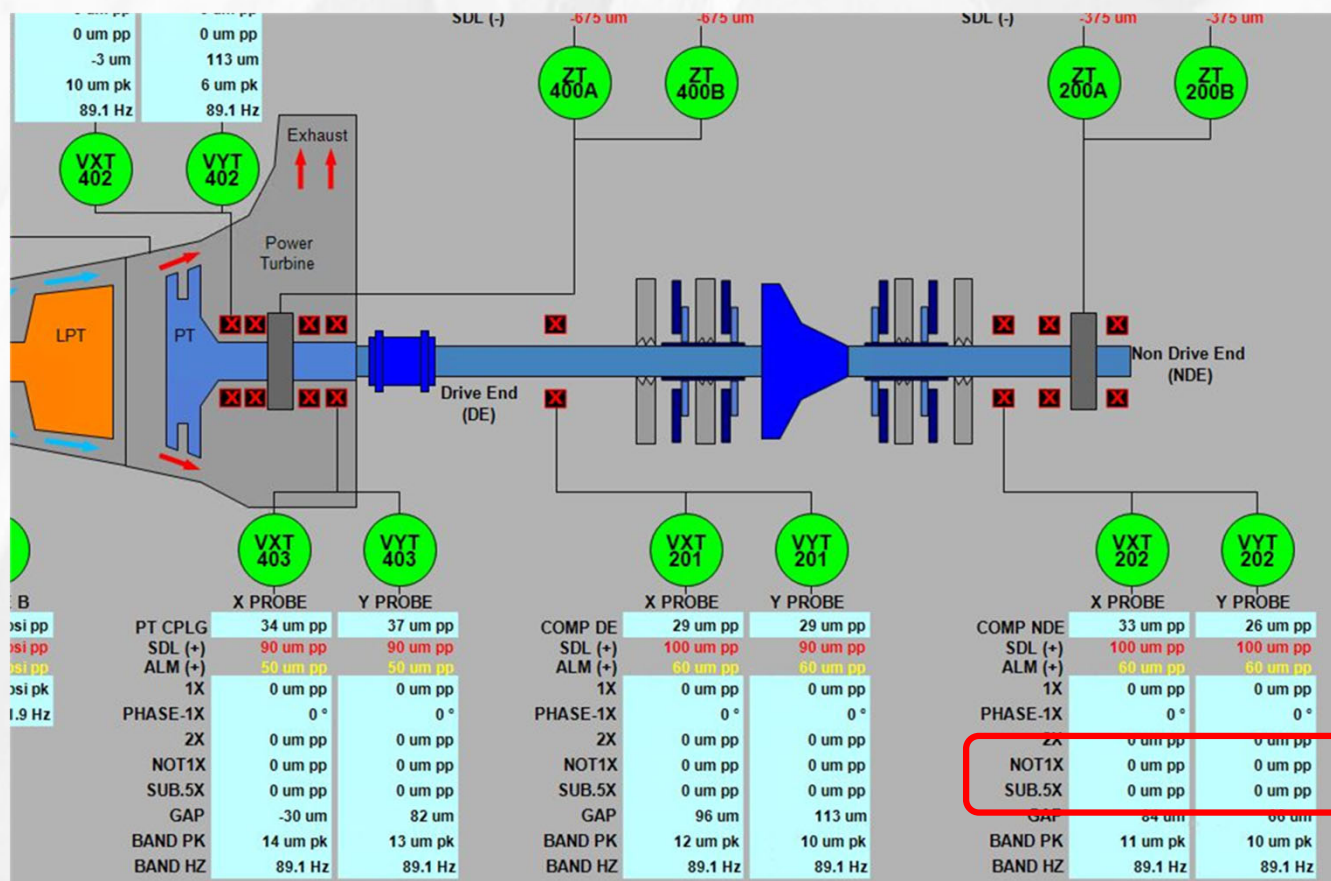
Vibration Problems – Misalignment

- Misalignment occurs when inaccuracy in alignment between couplings, bearings and shafts

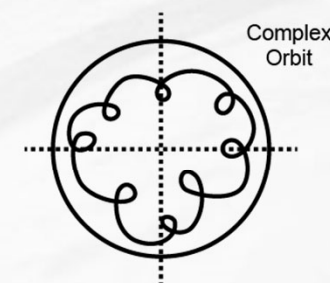
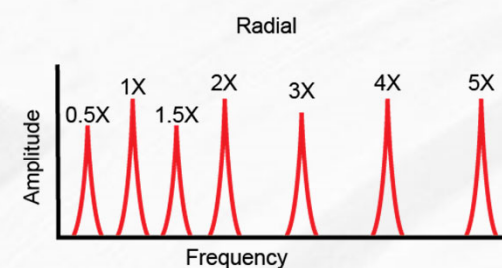


Vibration Problems – Rubs, Oil whirl, Looseness

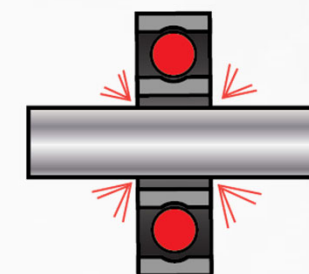
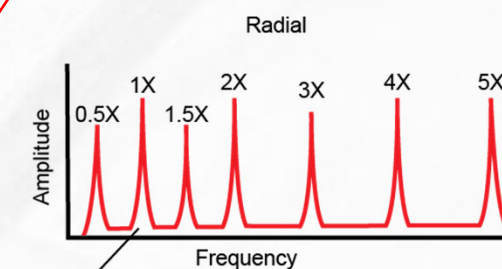
- Sub-harmonic vibration can be caused by phenomena such as rubs and oil whirl, where oil wedge forms in journal bearings or oil trapped in rotor



Oil Whirl



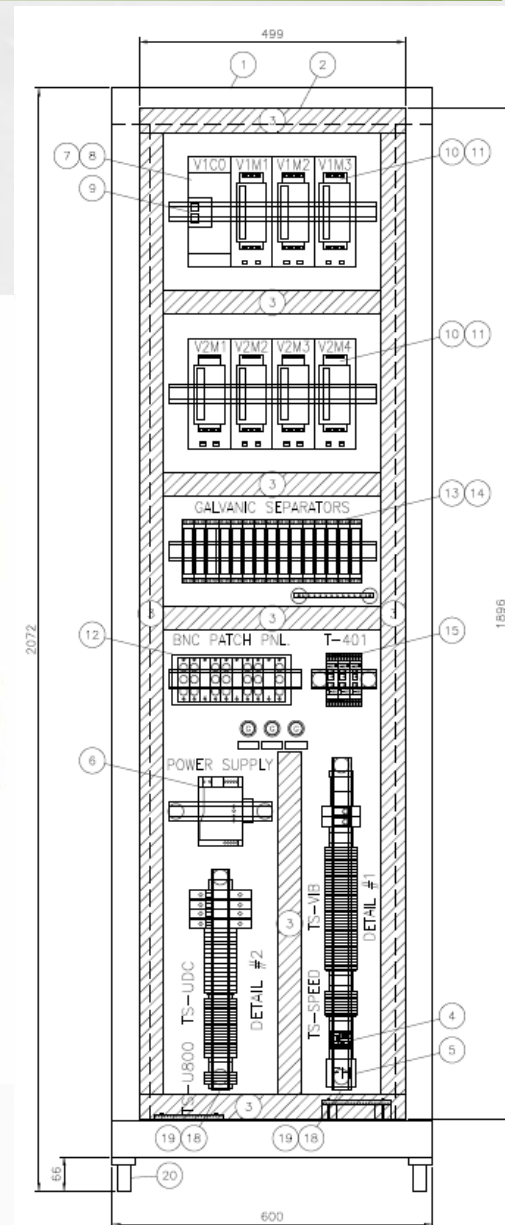
Rubs



Looseness, wear/clearance

TC Energy Vibration System Upgrades

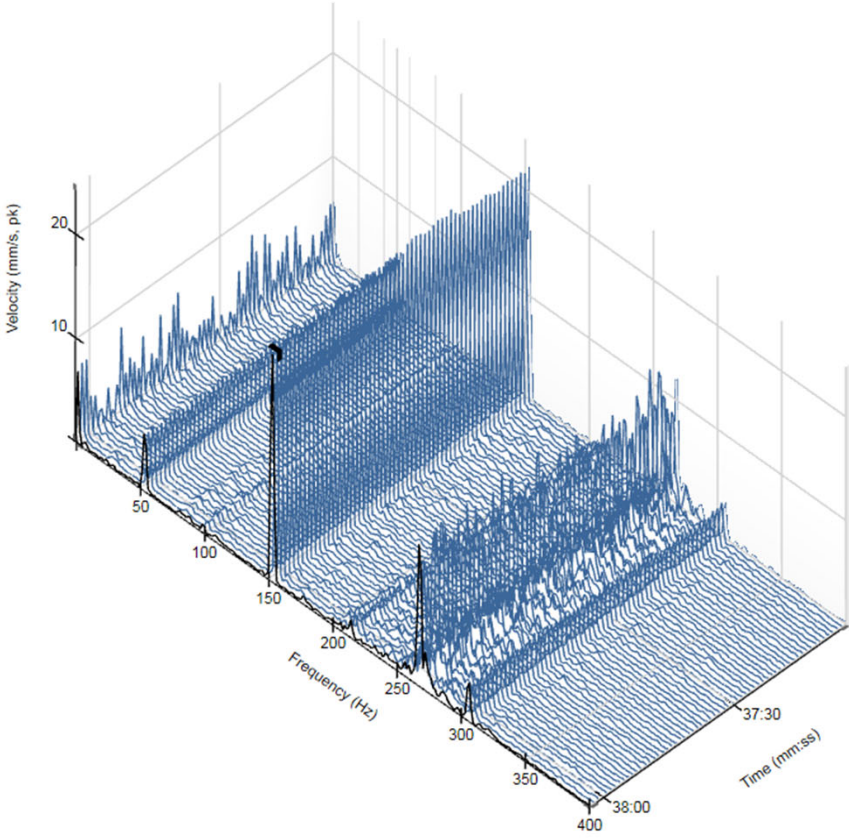
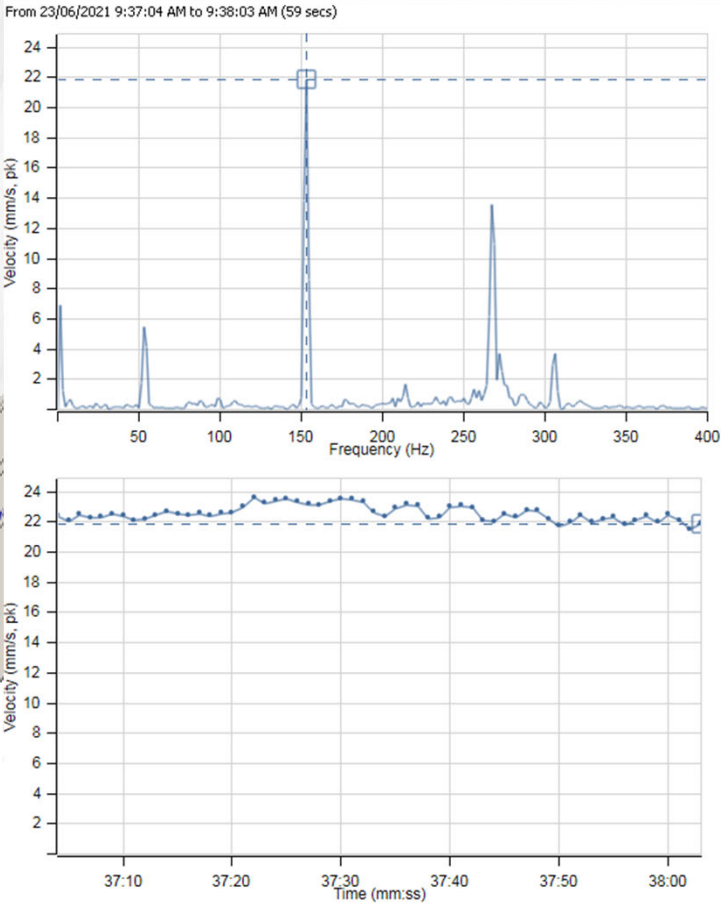
- Current TCE upgrades replacing obsolete VMS hardware with new
 - Inhouse upgrades 2016 to present
 - Typically keeping instrumentation
 - 40+ sites upgraded
- Standardized design
 - Using the Meggitt VibroSmart platform
 - Software configuration for equipment type
 - I&C drawing based on instrumentation type
 - Standardized data mapping
 - HMI object-orientated code for import
- Improved capabilities



VMS Improved Capabilities

Data Storage view

- Configuration
 - UA1
 - UB1
 - SP & Orbits
 - Data Entities
 - 10 sec when Transient/Overspeed OR Alarm OR Danger
 - 12 hours when running
 - Trends
 - Data Entities
 - 10 minutes when running
 - 1sec when Transient/Overspeed Or Alarm OR Danger
 - 30sec Transient/Overspeed Or Alarm OR Danger after 30mi
 - Events Storage Group 1
 - Event Entities
 - Conditional Events Logging Rule 1



Legend | Measurement Block 1 > V1M2 PT CASE > PT Case

Curve	Visible	Timestamp	Speed	State	Main cursor	Resolution	Location
Spectrum	<input checked="" type="checkbox"/>	23/06/2021 9:38:03 AM	9175 rpm		21.9 mm/s s_pk @ 153 Hz	1.56 Hz	0° EU

Frequency Time 1 x 1 Projections