How to detect Electrostatic discharge (ESD) using proximity probes on rotating machines

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Nicolas Peton

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a Baker Hughes business

Presenter/Author Bios

Guillaume Christin is Machinery Diagnostic Services (MDS) Technical Leader for Southern Europe for BHGE Bently Nevada , located near Lyon in France.. He began his career with GE Power at the heavy gas turbine engineering department in Belfort, France, as mechanical engineer. In 2010, Guillaume joined Bently Nevada as MDS engineer where he developed tremendous knowledge in condition monitoring and machinery diagnostics on various machines. He has twelve years of expertise with vibration analysis, balancing, predictive maintenance/monitoring and mechanical system design and analysis. Guillaume holds a degree diplôme d'ingénieur in mechanical engineering with a major in vibration and acoustics from the University of Technology of Compiègne, France.

Nicolas Péton joined GE in 2006 in the Machinery Diagnostic Services (MDS) group. He has spent the last 13 years with the MDS team progressing to the Global Director position. Previously he worked for two different manufacturers (Alstom Steam turbine and Cryostar expander/compressor) where he was in charge of onsite startup activities worldwide.

He also worked as an operation and maintenance engineer in the chemical industry (PPG industry, USA) and as Free Lance for startup activities worldwide. He has been also a mechanical/acoustical research engineer in research institutes (Technion, Haifa and TU Berlin). He has a « Diplôme d'ingénieur » from the Université de Technologie de Compiègne (1997), France and is a European Professional Engineer (Eur-Ing).

Abstract

In this session, a brief introduction about electrostatic discharge phenomena will be done. Then three historical cases with Electrostatic Discharge (ESD) issue will be analyzed in order to explain how to detect Electrostatic Discharge using proximity probes. It will point out that the vibration behavior in case of ESD is not always the same.

Source of ESD ?

Some rotating machines, because of electrical or mechanical characteristics, induce an **electrical potential (voltage) on** their rotating shafts. If this voltage is not managed, or if the voltage mitigation system (often a shaft-grounding brush) is not maintained and fails, the voltage seeks an alternate path to ground.

In an operating steam turbine generator (STG), there are at least four possible sources of voltage between the shaft and ground:

1. Electromagnetic loop voltage due to asymmetries in the generator magnetic paths may create an electric potential between opposite ends of the generator shaft.
2. Static charges may build up from droplets of water being thrown off blades in wet stages of the turbine.
3. A capacitive voltage due to a ripple on the DC field voltage may result in a voltage from shaft to ground.
4. Residual magnetism in parts

How to detect ESD ?

Proximity probe measurements

- Noisy direct signals
- Timebase waveform with random peaks
- Significative shaft centreline displacement (GAP)

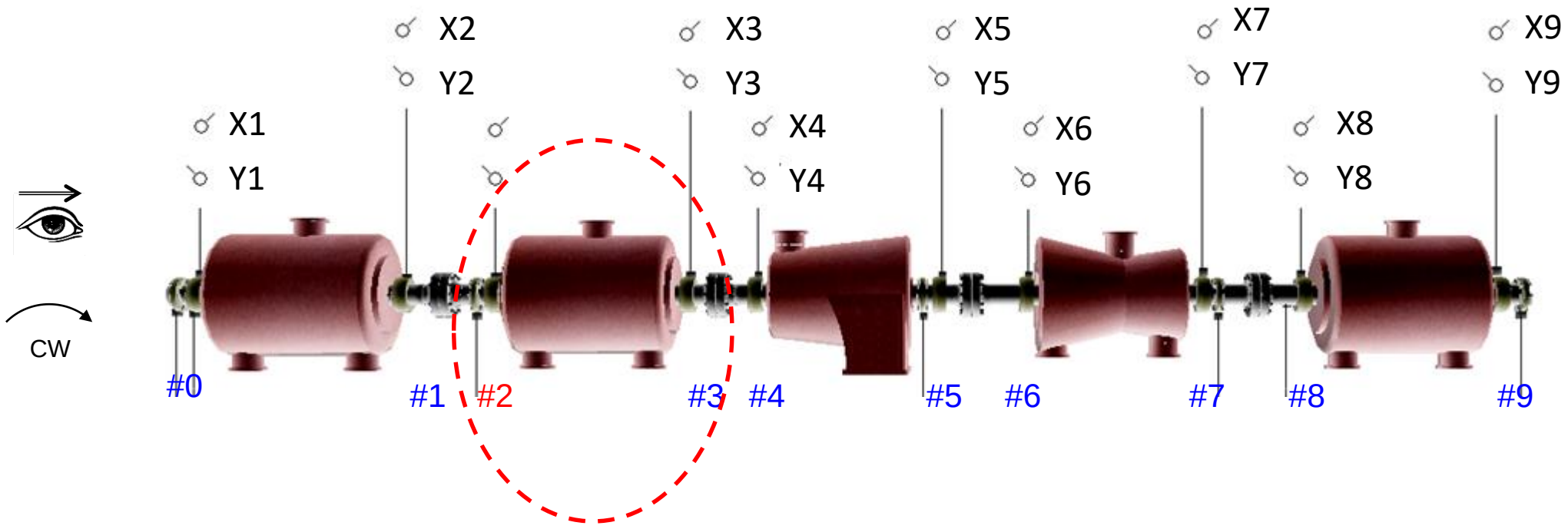
Bearing temperature ?

Shaft voltage monitoring ?

Shaft voltage monitoring system that alarms or tracks shaft voltages that may become a problem or may indicate the grounding system isn’t working as needed.

Historical CASE 1 : Machine train diagram

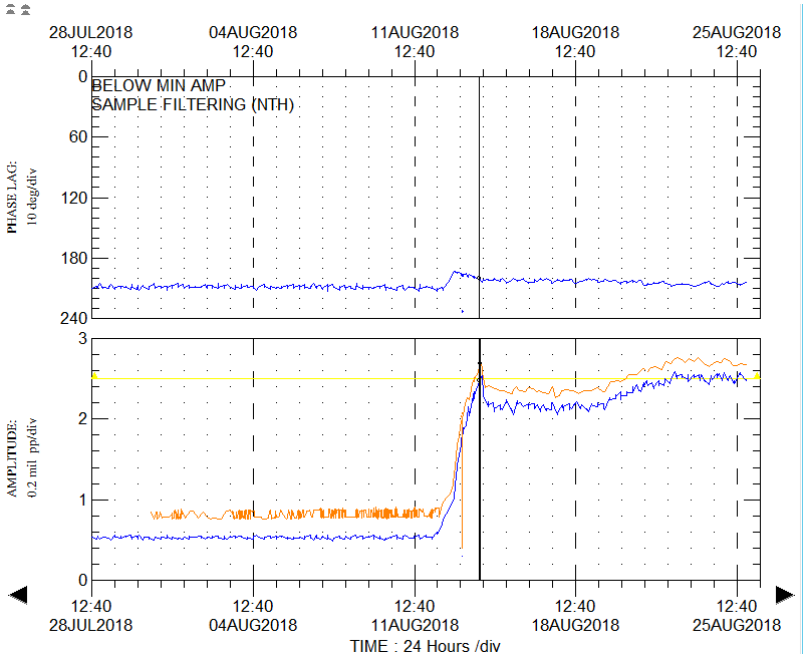
Syngas compressor

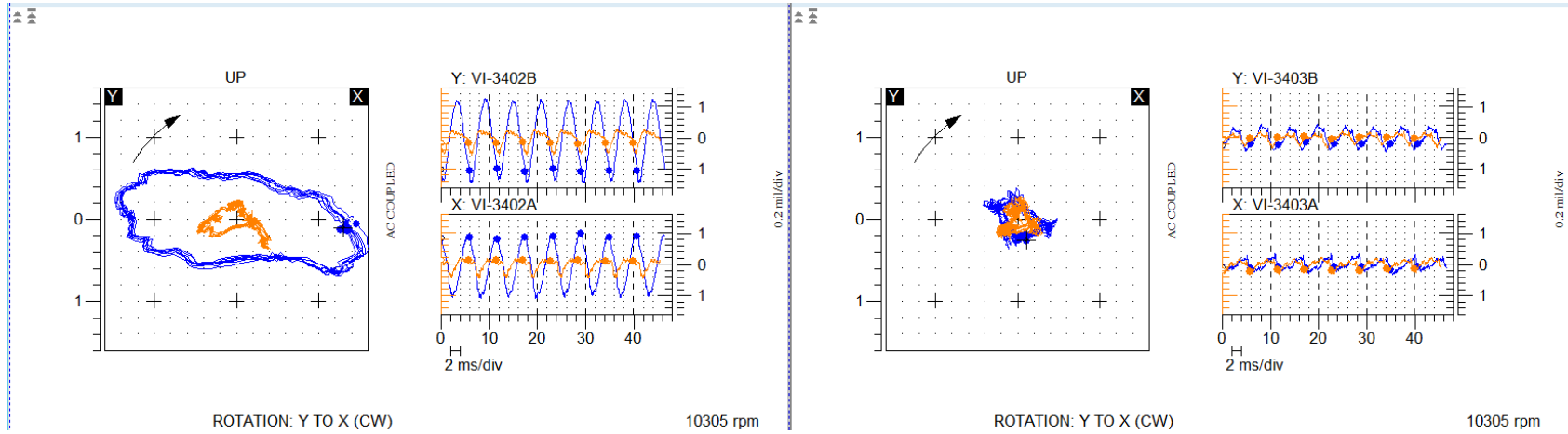


All bearings are equipped with XY proximity probes. All these data are connected to a condition monitoring platform that saves static and dynamic data.

Vibration data

- Only steady state data are available.
- During 2 days the level of vibration increases from 0.5mils pp to 2.5mils pp (from 13µm pp to 64µm pp)
- Vibration are mainly 1X / Forward precession / Elliptical orbits



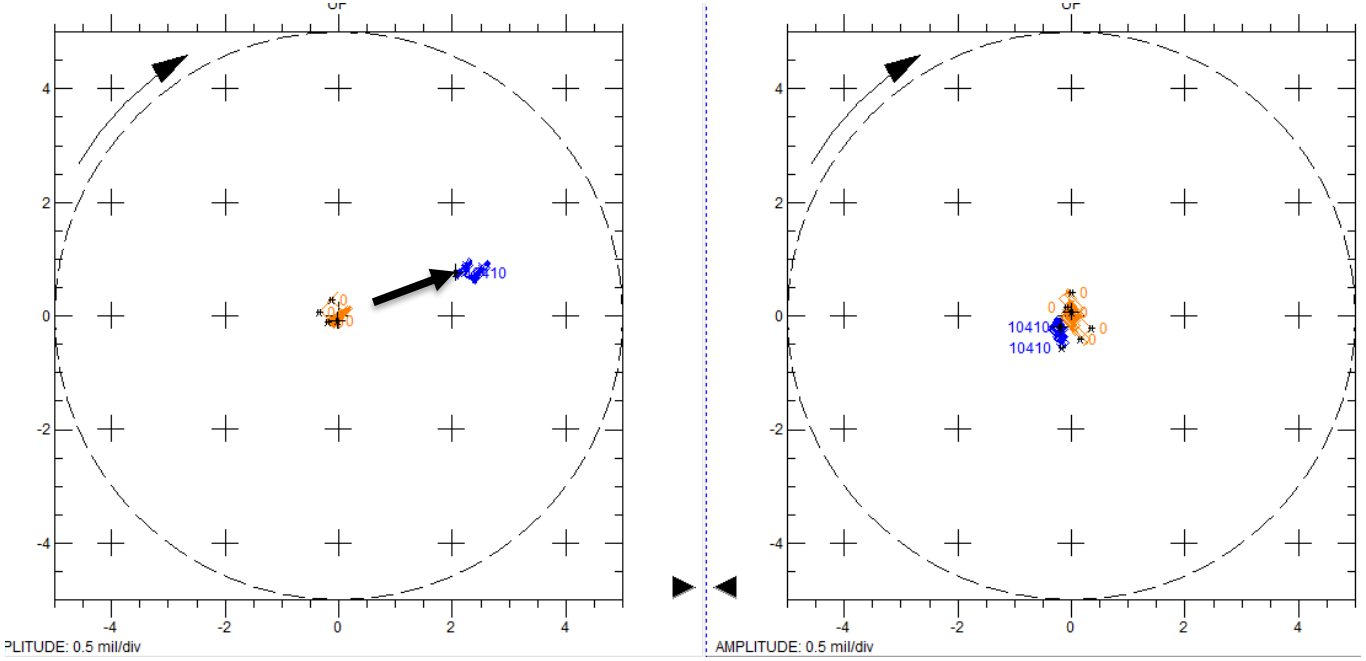


Unbalance or not ?

$$\overrightarrow{d_{Synch}} = \frac{\overrightarrow{F_{Unbalance}}}{Synchronous\ Dynamic\ Stiffness}$$

Vibration data

Position of the shaft moves from left to right and the 1X level of vibration increases.



It means that the shaft operates in a position where the dynamic stiffness is lower than before

Is this movement real ?

Metal bearing temperature dropped by 20°C when the shaft moved from one position to another one

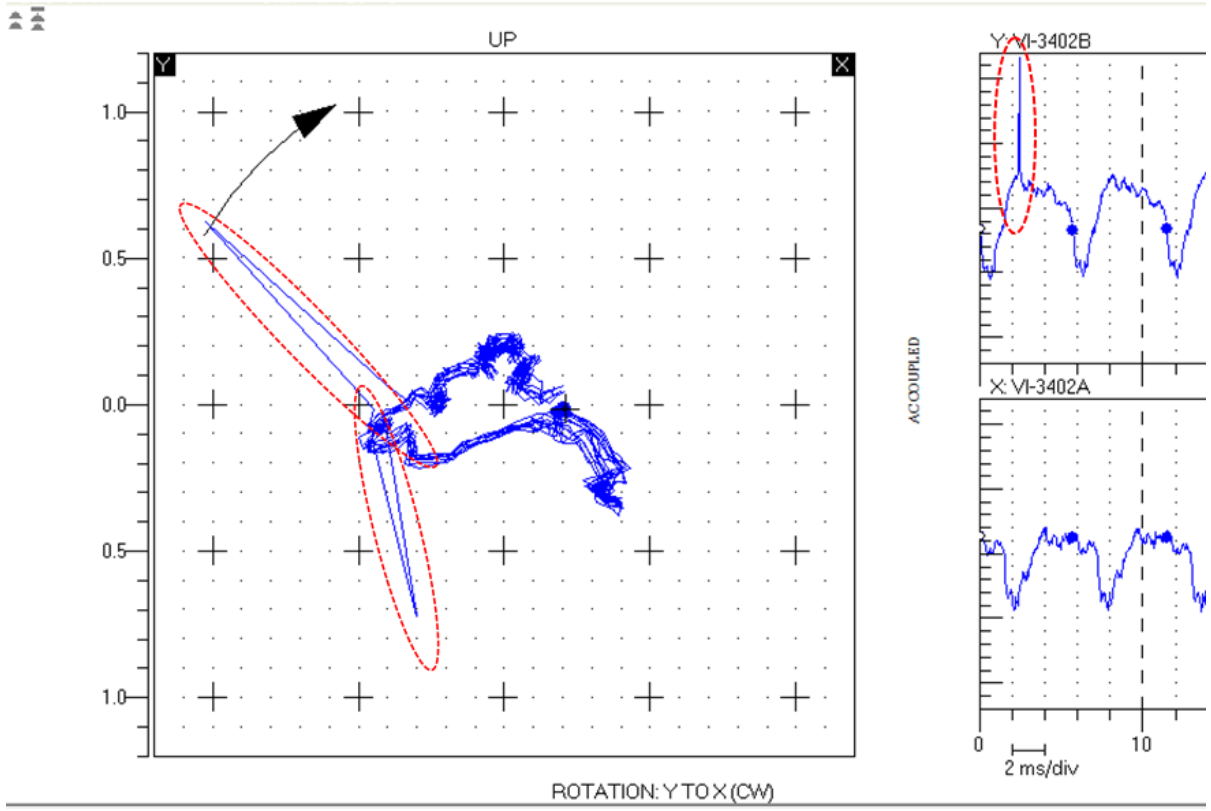
It confirms that the movement of the shaft is real

Vibration data

Two main possible root causes :

- Preload
- Increase of clearances

??



Erratic peaks on waveform confirms Electrostatic Discharge (ESD).

Bearing clearances Increased !

What were the characteristics for this case ?

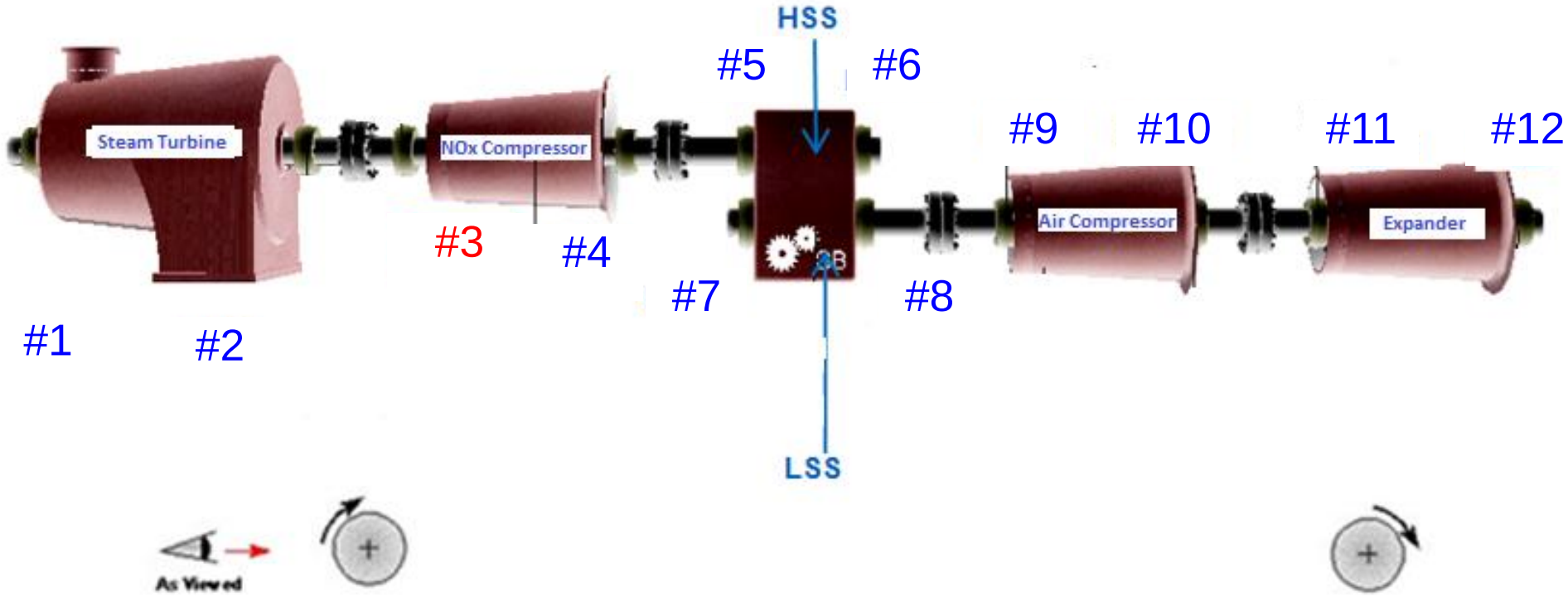
- Direct level of vibration was increasing (due to 1X increase) in **2 days**
- 1X vibration increased due to shaft centerline movement
- Bearing temperature decreased
- High random peaks on waveforms but not all

RCA : Two main options
1- Static charges may build up from droplets of water being thrown off blades in wet stages of the turbine
2- Residual magnetism in parts

However customer solves the issue by installing grounding brushes

Historical CASE 2 : Machine train diagram

Nox compressor



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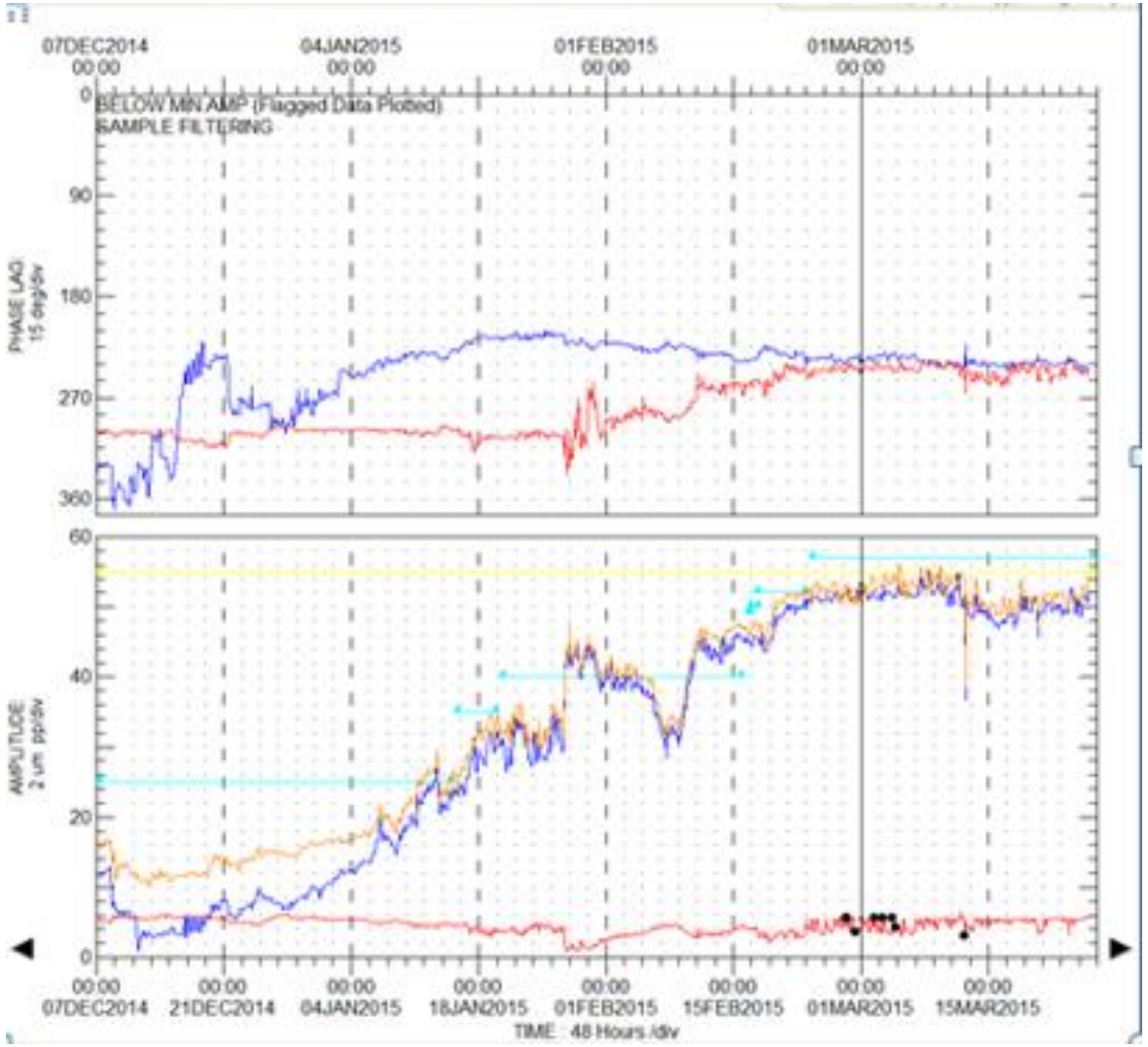
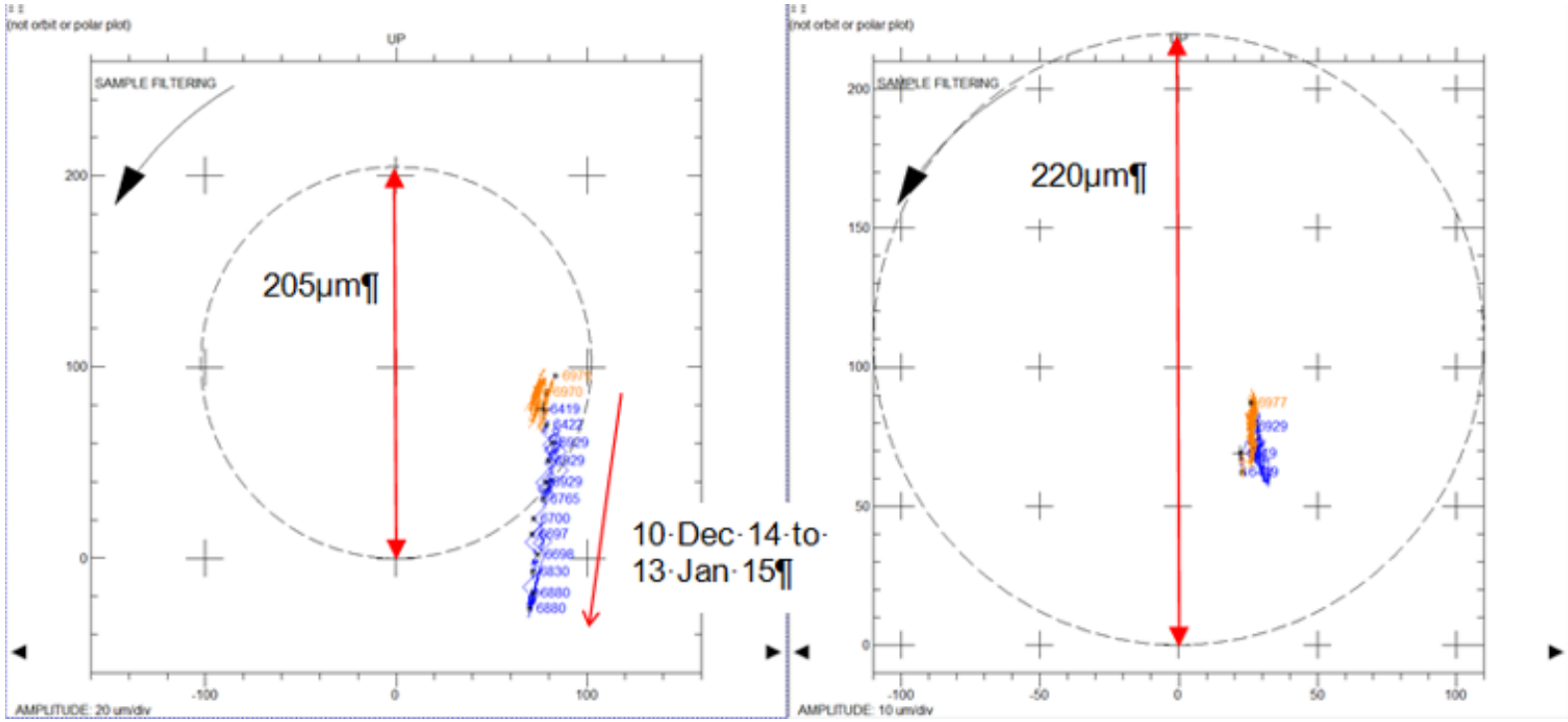
Vibration data



- Only steady state data are available.
- During **several months** the level of vibration increases from 0.6mils pp to 2.4mils pp (from 15µm pp to 60 µm pp)
- Vibration are mainly 1X

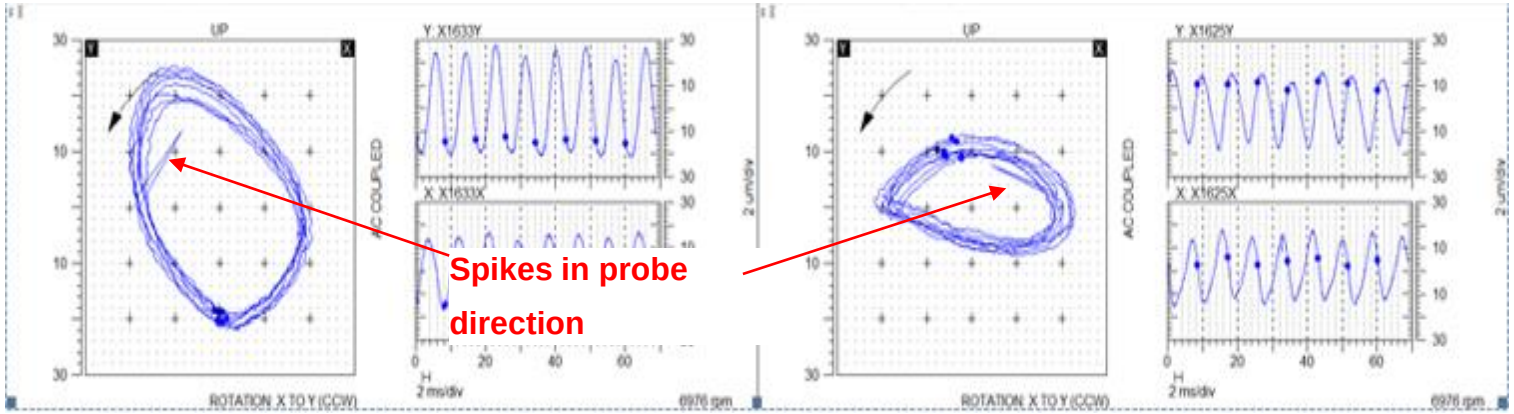
The vibration levels on NOx Compressor started to increase, triggering at one moment the management/SW alarm (Direct, 1X, 2X)

Vibration data



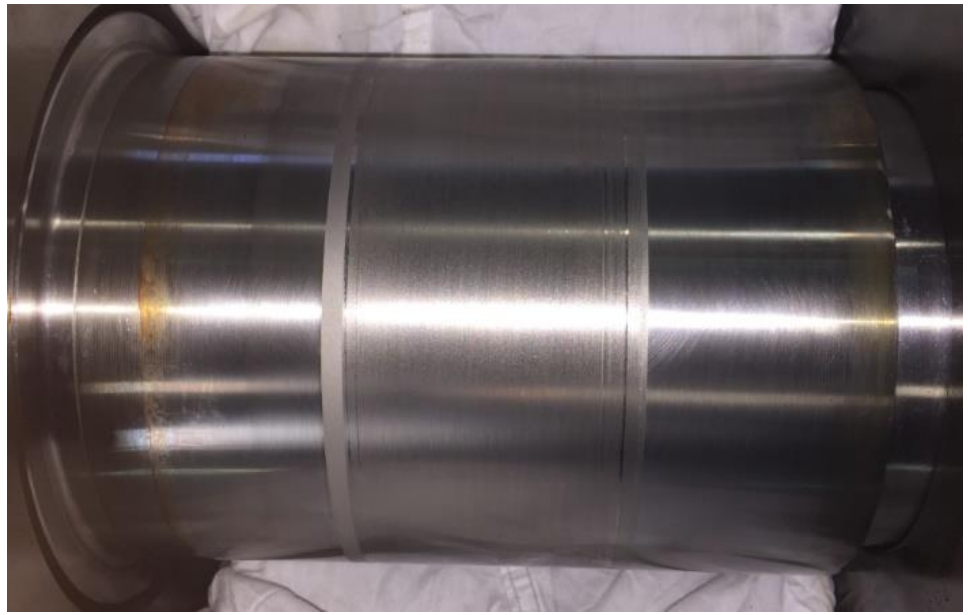
Position of the shaft moved down and the 1X level of vibration increased.

It means that the shaft operates in a position where the dynamic stiffness is lower than before

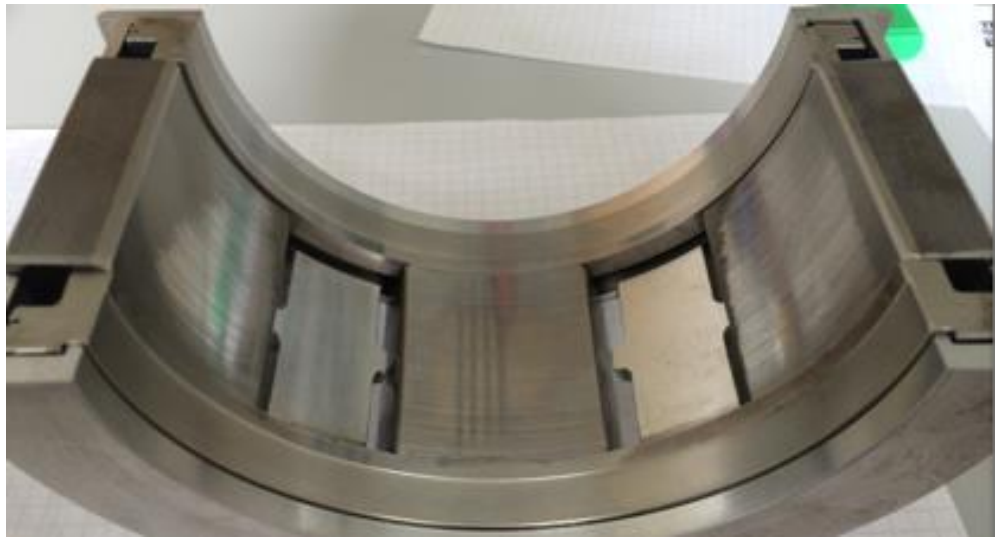


Erratic peaks on waveform confirms Electrostatic Discharge (ESD).

Findings



Journal area of the NOx compressor drive-end bearing, showing “frosting” in the area of the oil deflectors



Bearing diametric clearance was found 0.48mm, double then allowed (0.2mm-0.26mm) !

What were the characteristics for this case ?

- Direct level of vibration was increasing (due to 1X increase) during **almost 4 month**
- 1X vibration increased due to shaft centerline movement
- Small random peaks on waveforms

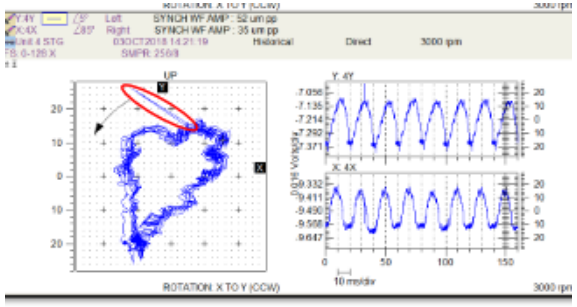
RCA results was found to be a damaged grounding brush

Historical CASE 3

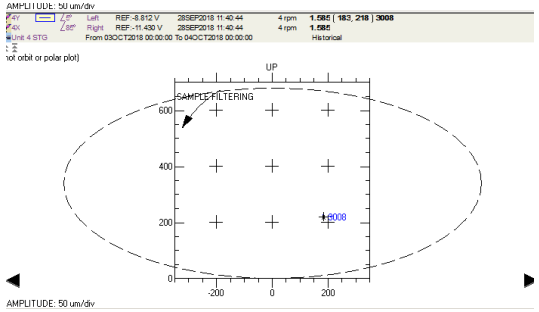
Machine train : Steam turbine and generator unit

Historical background : Customer reported vibration spikes at bearing 1 and 2 displacement probes at Steam Turbine Generator unit 4 (240 MW).

Customer concerned vibration spikes will cause trip on the unit.



Direct Orbit Plots of shaft displacement showed vibration spikes at all bearings



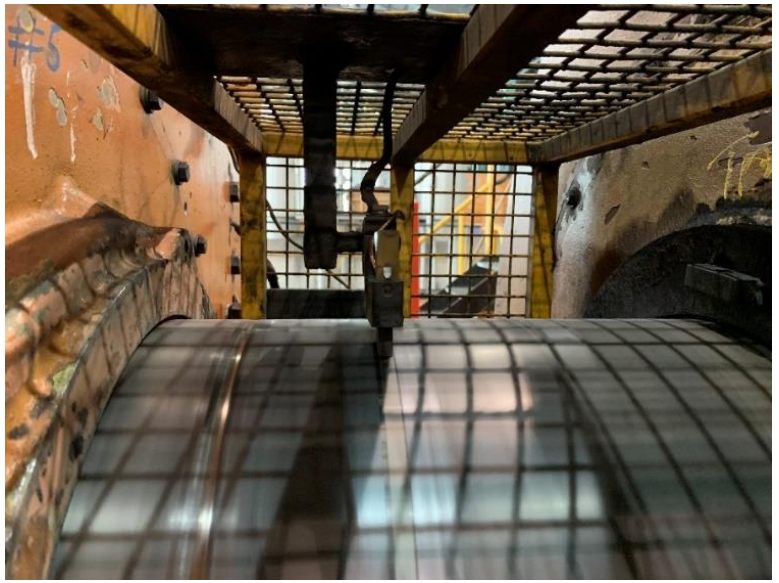
Shaft centerline plots indicated no change in shaft position

The ESD phenomena detection was confirmed at an early stage of development

What were the characteristics for this case ?

- Random spikes on the direct level of vibration
- 1X vibration did not increase and no shaft centerline movement were observed
- High random peaks on waveforms

RCA : loose grounding brush



How to prevent re-occurrence ?

1 - Brushes should be maintained in working condition

But what if the problem happened in spite of brushes working ?
high magnetism of the shaft ?

What about magnetism of the stationary part also?

2 - Demagnetization of the rotating and stationary parts is advised.

Conclusion

- Electrostatic Discharge is a well known issue but it is often detected at a late stage.
- An increase of 1X is not necessary a modification of unbalance or a rub issue.
- The Shaft Center Line should be always monitored to allow early detection of Electrostatic Discharge or other malfunctions
- Always analyzed the waveforms to detect Electrostatic Discharge spikes which can be more or less random or fairly constant.
- With analytics and online condition monitoring system, the static and dynamic data can be automatically analyzed to point out a potential Electrostatic Discharge issue as soon as possible.
- Grounding and brushed condition are almost always the root cause