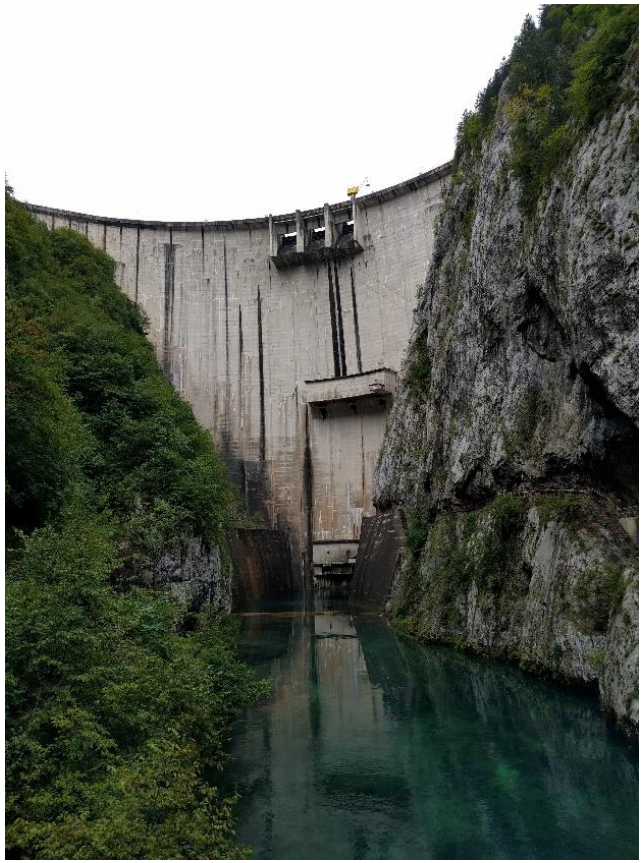
Magnetic unbalance problem on 60 year old hydrogenator – analysis and solution

Jun 22nd 2021



Ozren Husnjak, **Veski Ltd (Croatia)**

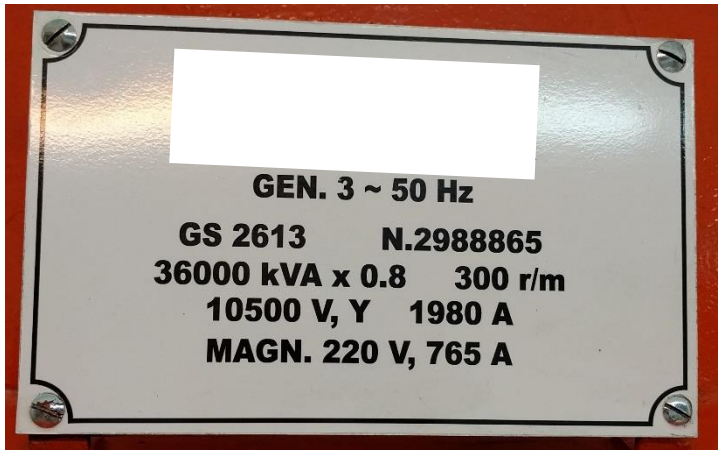
www.veski.hr

VESKi

History

- the plant was commissioned in 1957.
- two units, ~30 MW each (Francis)
- three-phase synchronous generator (10.5 kV, 36000 kVA)
- nominal rotational speed 300 rpm (20 pole unit, 50 Hz)
- suspended design (thrust bearing above the generator)

- both units had similar issues



Is hydro-energy ‘clean’?

History of a problem (problems)

Unit 1 vs Unit 2:

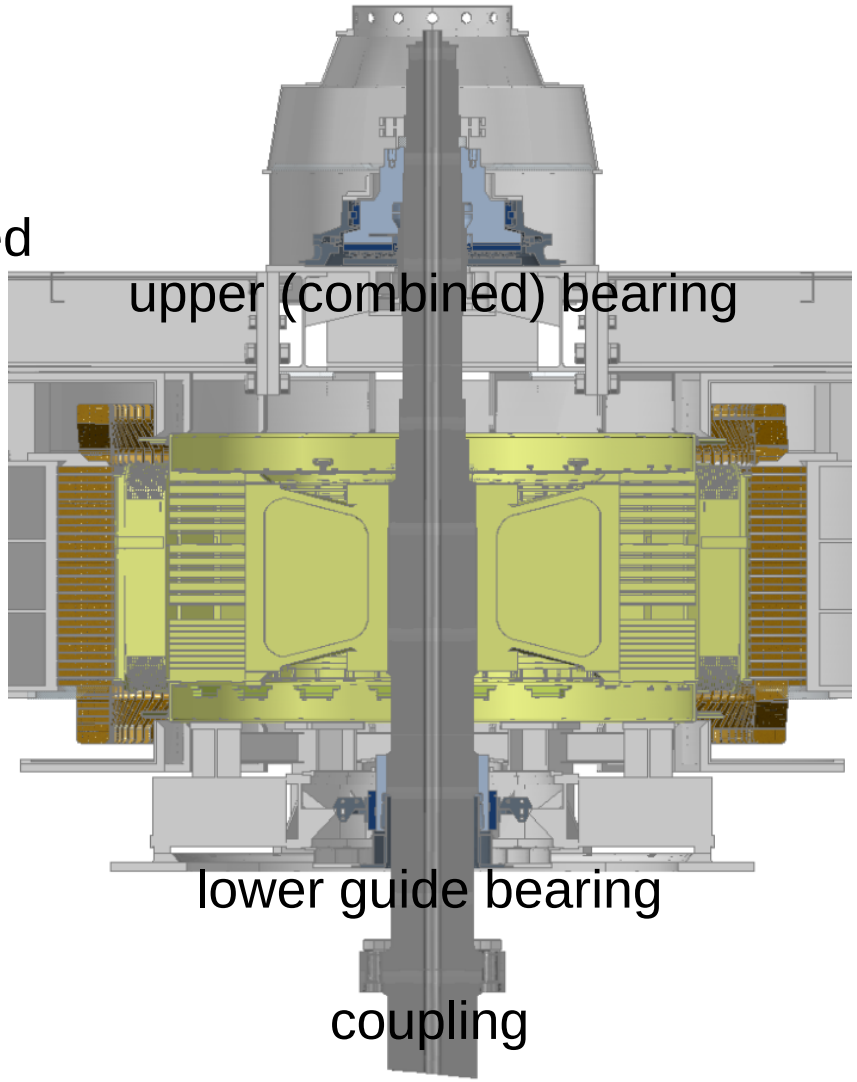
- both units had similar issues
- on Unit 1 increased vibrations after operation at run-away speed

Unbalances detected:

- mechanical (+ run-out)
- electromagnetic (magnetic) – large (~300 µm difference from mechanical)
- thermal

Additional issues:

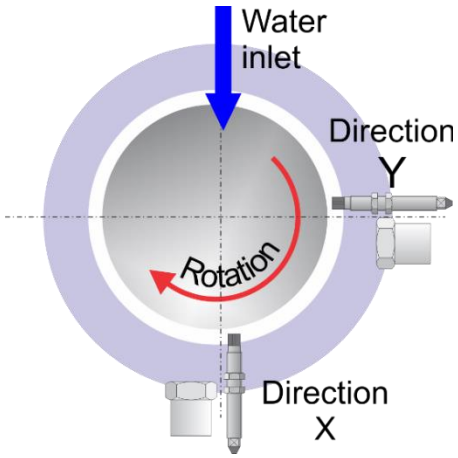
- misaligned rotor and bearing axes
- loose connection between thrust collar and shaft

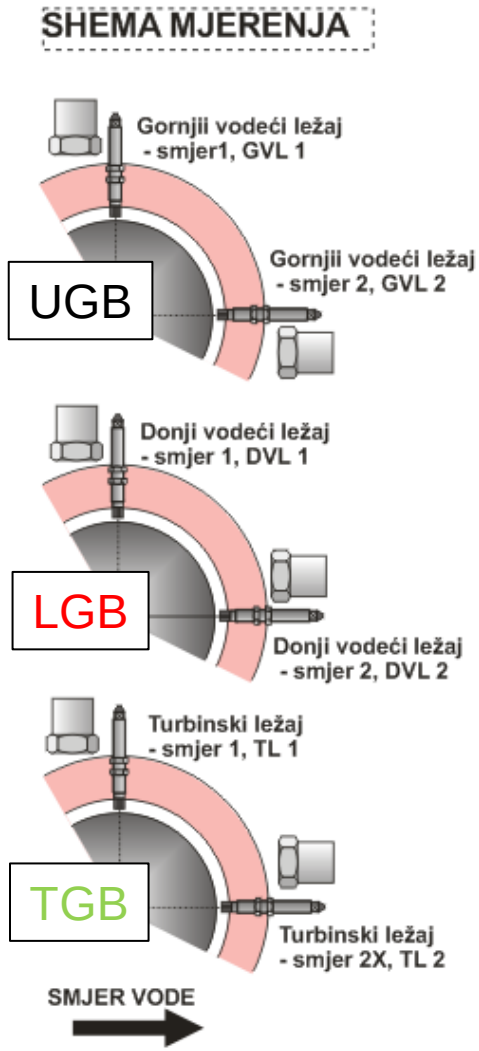


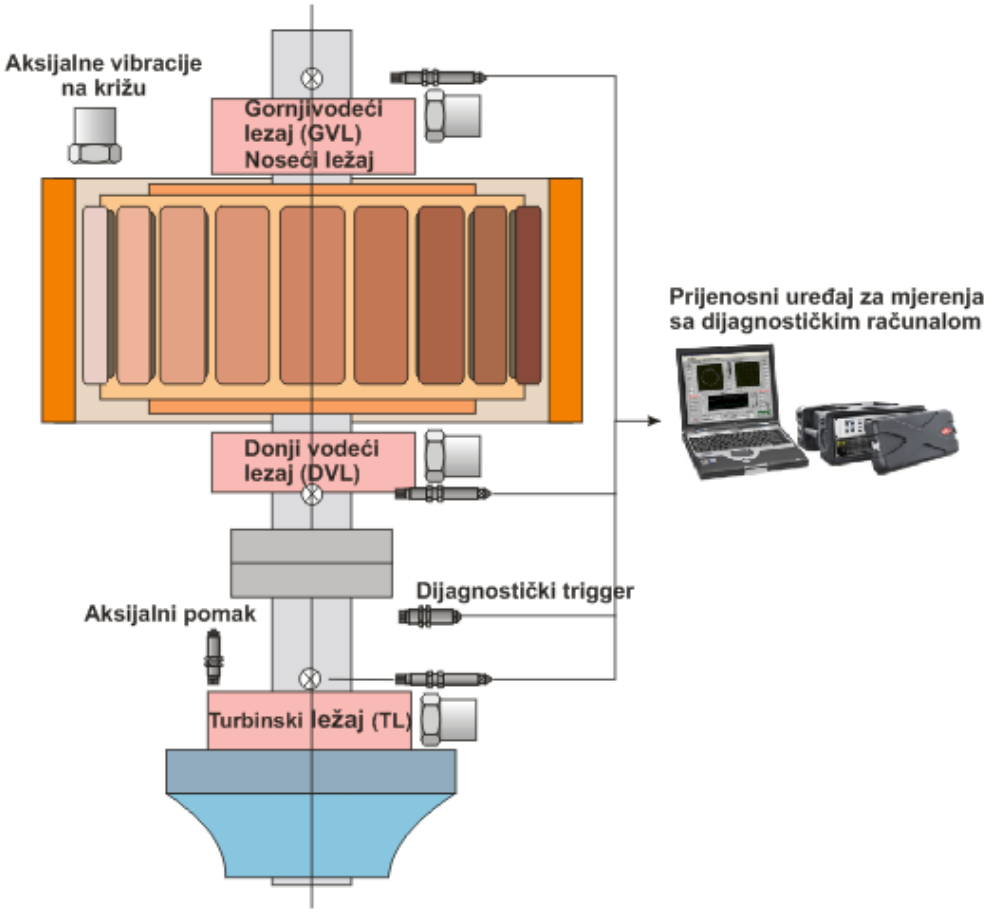
presented at HydroVision INTERNATIONAL 2016.

Measurement layout (typical)

- 18 channel portable instrument used
- typically relative and absolute vibrations measured
- 4 sensors per measurement plane
- additional measurements included air gap and magnetic flux measurements





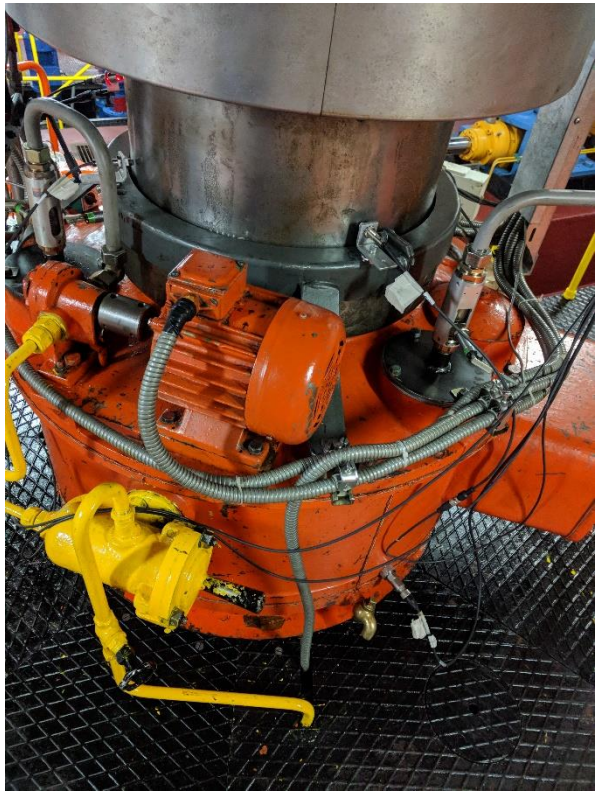


Sensors used

below slip-rings, above thrust collar

below LGB

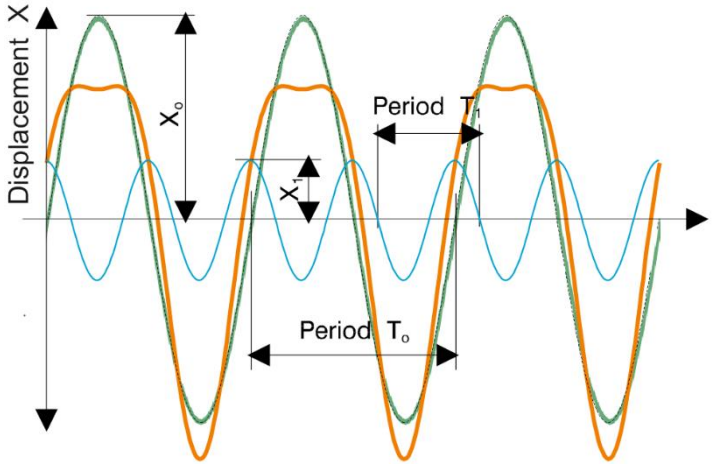
turbine level

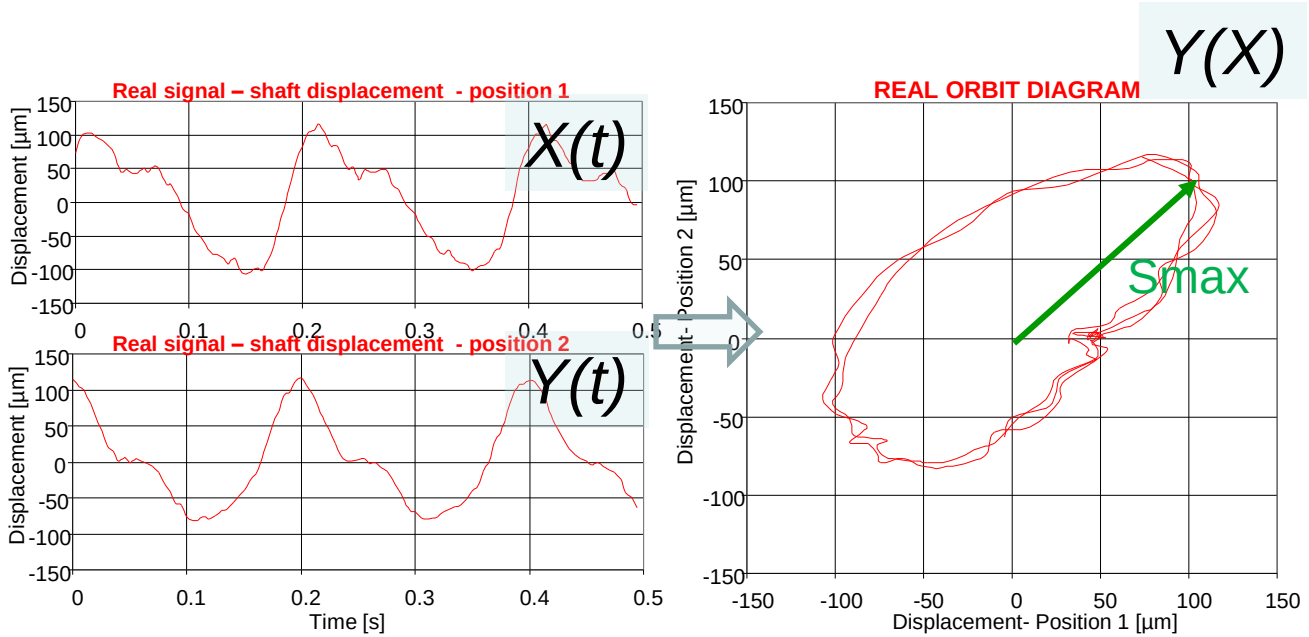


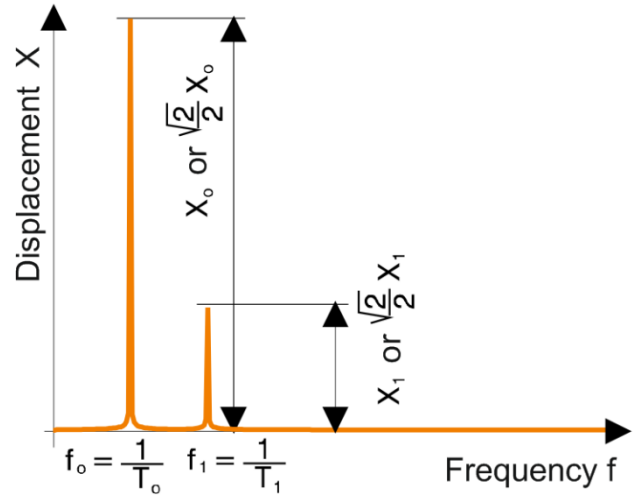
4 sensors per measurement plane (2x relative vibration, 2x absolute vibration)

Calculations performed (descriptors) / Vibrations

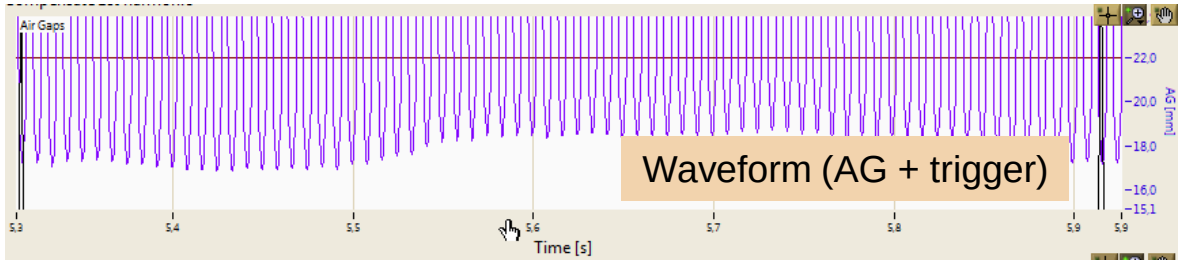
- Smax (obsolete as of 2018, when ISO 20816-5 was published)
- 1x, 2x, 3x rotational frequency harmonic(s) – amplitudes and phases
- peak-to-peak, EqPeak, Rest, DC
- rotational speed
- RMS (for absolute vibrations)

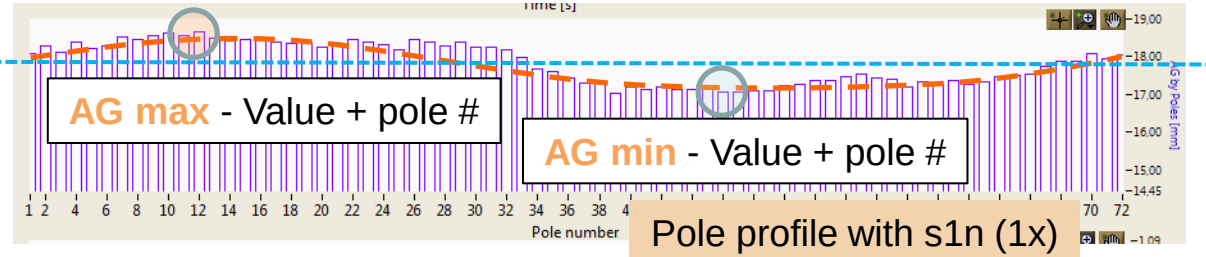


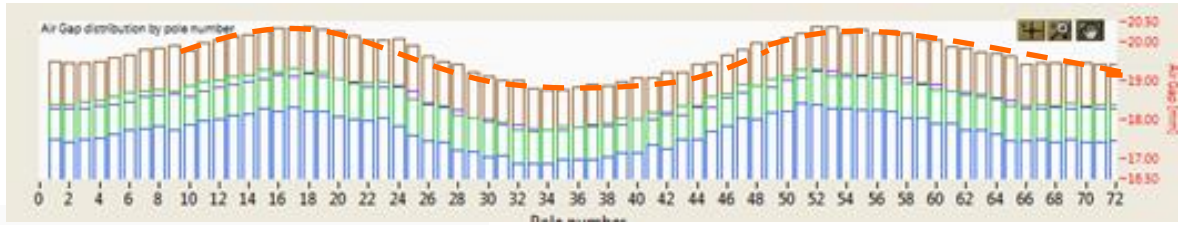


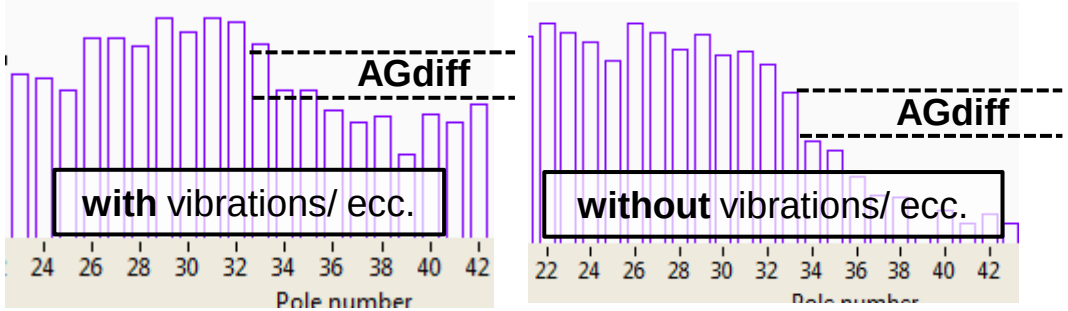


Calculations performed (descriptors) / Air-gap









- Air-gap by pole number
- average (DC) value of all poles
- minimum and maximum values of all poles
- 1x, 2x within the air-gap

Average (DC) gap
STATOR AND
ROTOR SHAPE (*) (*) multiple sensors needed

1x Amplitude
1x Phase
DYNAMIC ECC.

2x Amplitude
2x Phase
LOOSE RIM

AG min – Value + pole #
AG max – Value + pole #
RUB DETECTION

(AG max – AG min)
LOOSE RIM

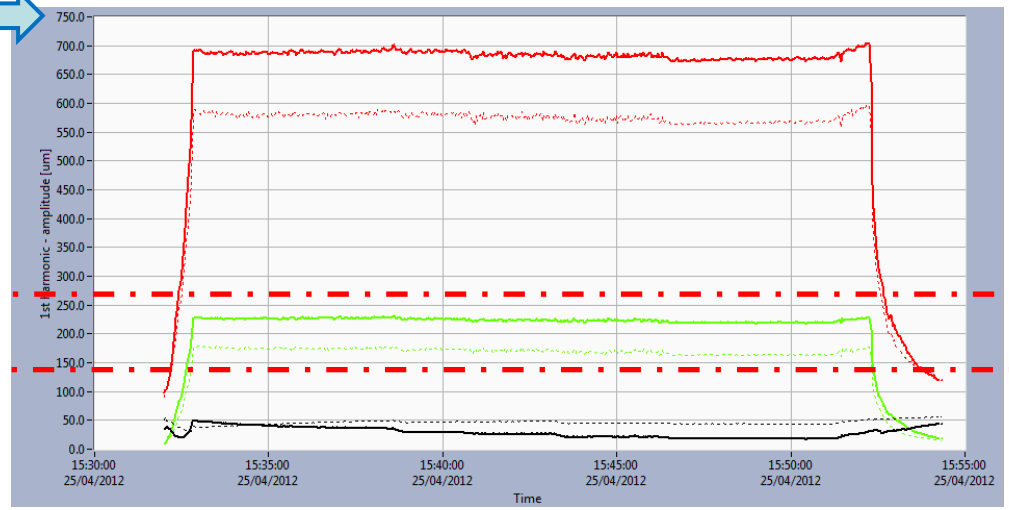
AGdiff Value + pole # **LOOSE POLE**
Adjacent pole difference / pole
Loosenes detection over long time

Year 2012. / Unit 1 / 1x harmonic

UGB (X, Y) / LGB (X, Y) / TGB (X, Y)

- extreme vibrations noticed (over 700 µm on LGB) – bearing clearance set to ~230 µm
- on UGB relative vibrations low, absolute vibrations high

750 µm



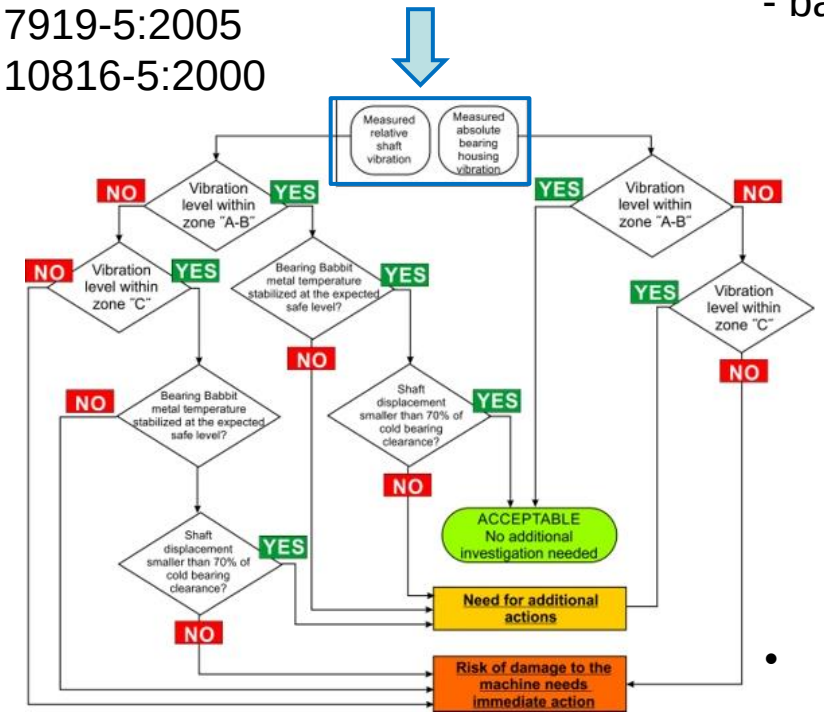
270 µm C/D zone (ISO 7919-5)

140 µm C/D zone (ISO 20816-5)
- based on peak-to-peak

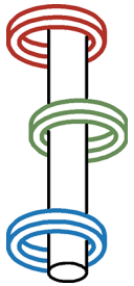
relative vibrations

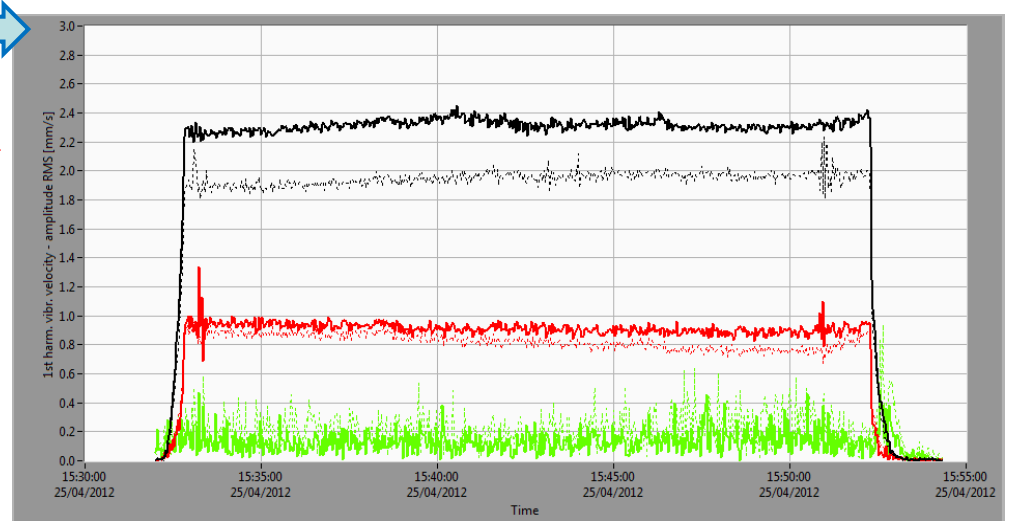
OLD STANDARDS (withdrawn):

- ISO 7919-5:2005
- ISO 10816-5:2000



3 mm/s





absolute vibrations

NEW STANDARD:

- ISO 20816-5:2018

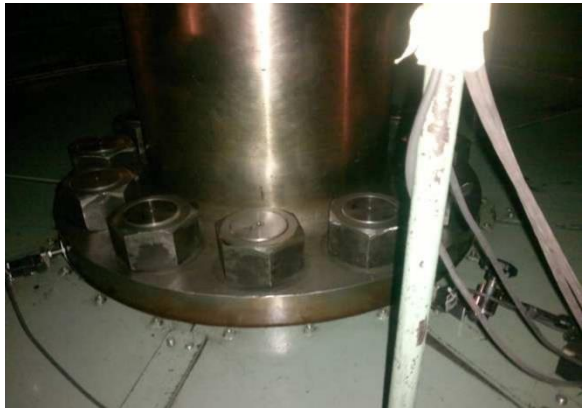
Year 2013. / Unit 1. / Dynamical rotor line prior to overhaul

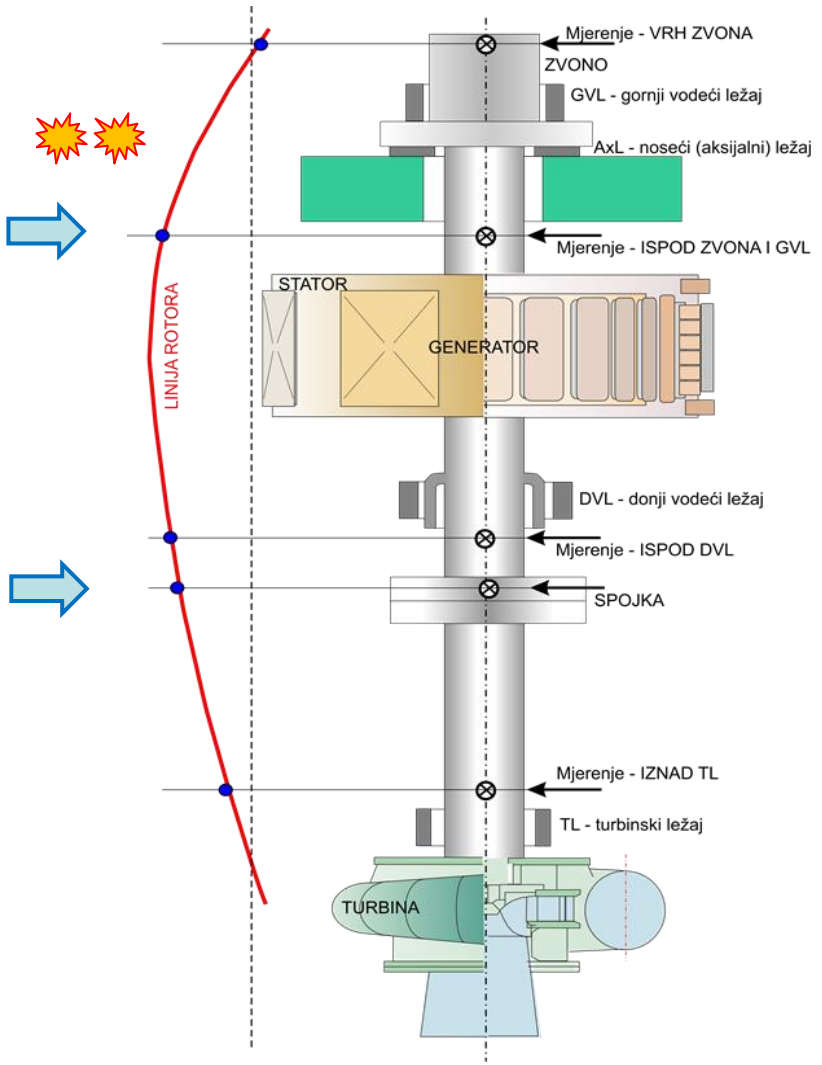
Dynamical rotor line measurements just prior to the overhaul

- dynamical rotor line is, basically, rotor ODS at the 1x (which is dominant)
- multiple measurement planes (5)
- indicated on the figure

The dynamical rotor line indicates:

- there is no solid connection (shrink fit is lost) between thrust collar and shaft
- additional proof is out-of-phase movement when comparing vibrations above and below thrust collar





dynamical rotor line

ODS = Operating Deflection Shape

Prior to and during the overhaul on Unit 1

Vibration caused damaged pads (used to set bearing clearance) on LGB

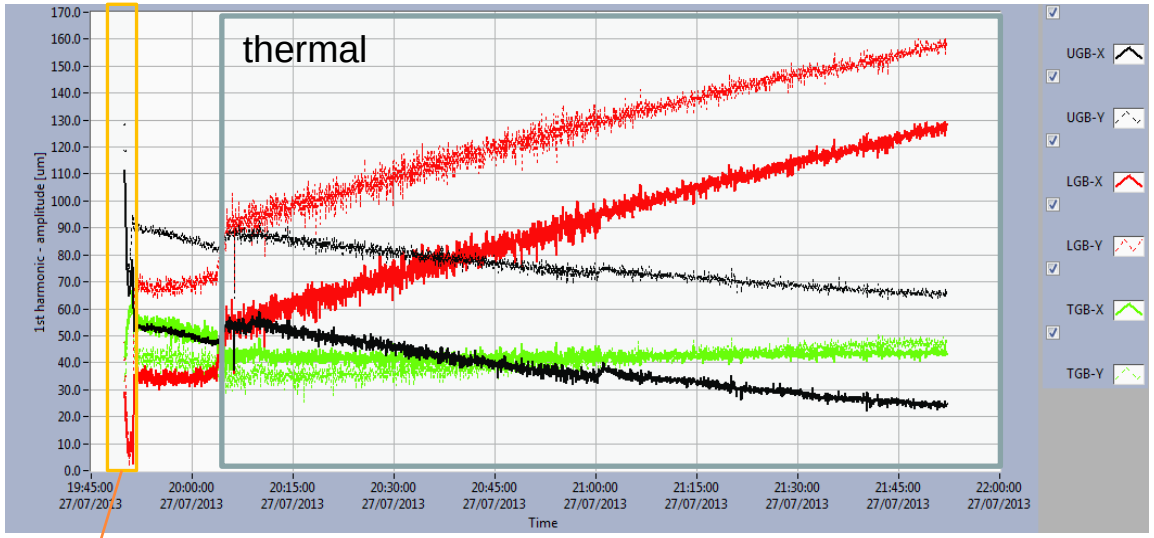
UGB clearance setup during the overhaul

Prior to and during the overhaul on Unit 1

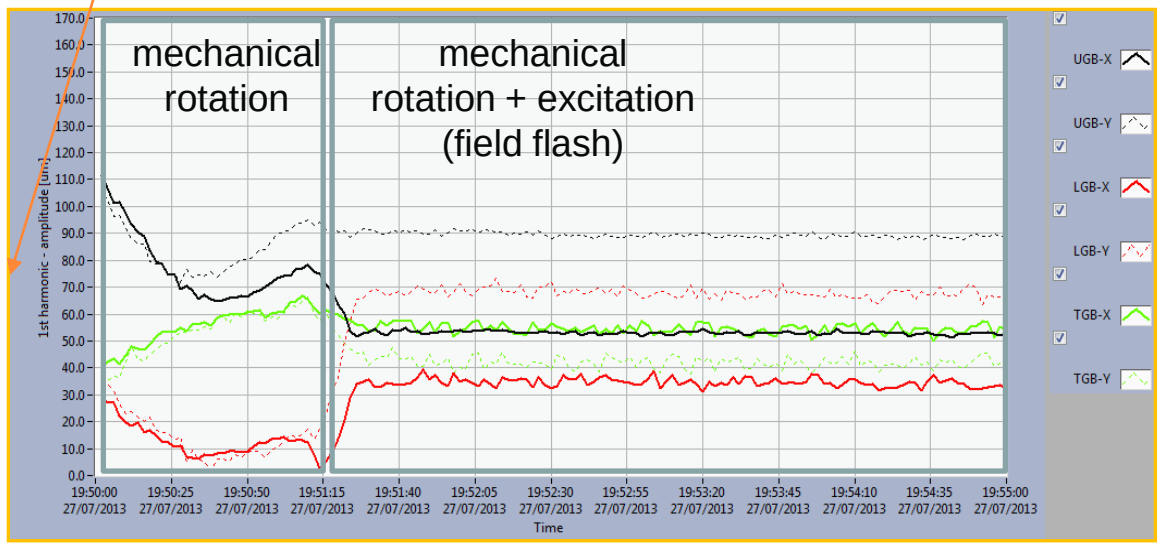
Rotor lowering

Balancing weights below the generator
(two-plane balancing performed)

Year – 2013. / After the overhaul prior to balancing



relative vibrations



UGB (X, Y) / LGB (X, Y) / TGB (X, Y)

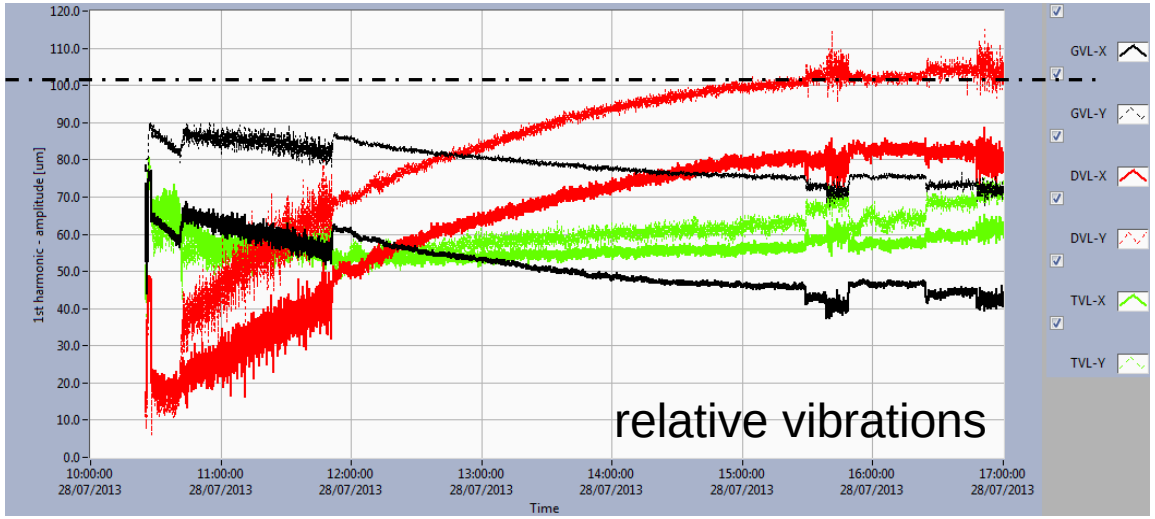
- at **LGB** the vibrations increase due to electromagnetic and (later) thermal reasons
- similar changes (bet decreasing) visible at **UGB** vibrations

- zoomed in portion of the graph for mechanical rotation and excited state
- it is neccessary to balance the unit so that there are no more than 100 µm in all operating regimes

- (absolute vibration criteria was set to 0.5 mm/s)

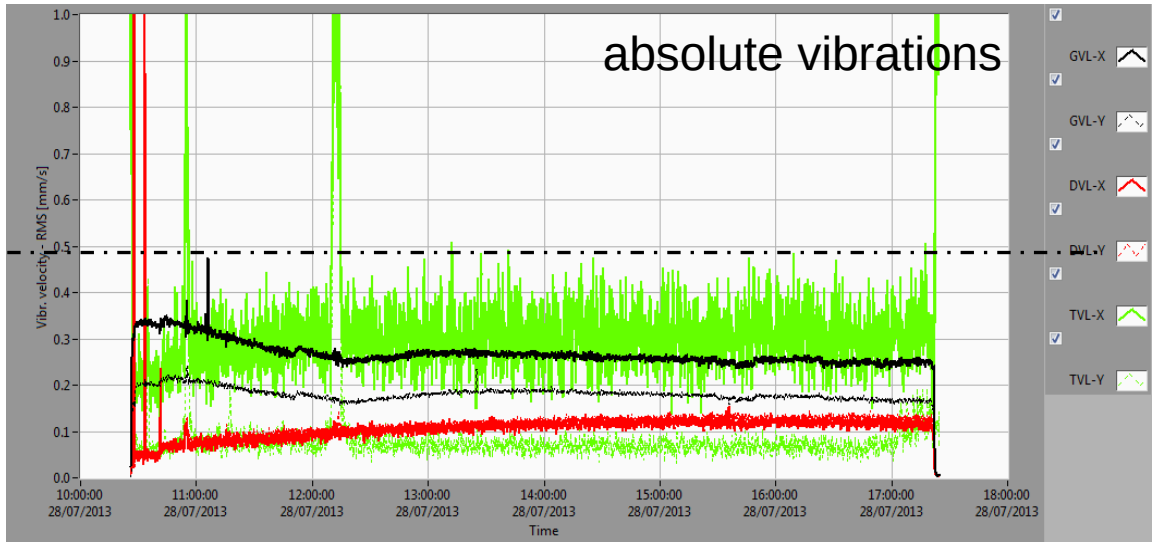
ZOOM in

Year – 2013. / after the overhaul and after the balancing



← **100 µm!**

- thermal effect for relative vibrations after balancing



- absolute bearing housing vibrations (RMS) after balancing

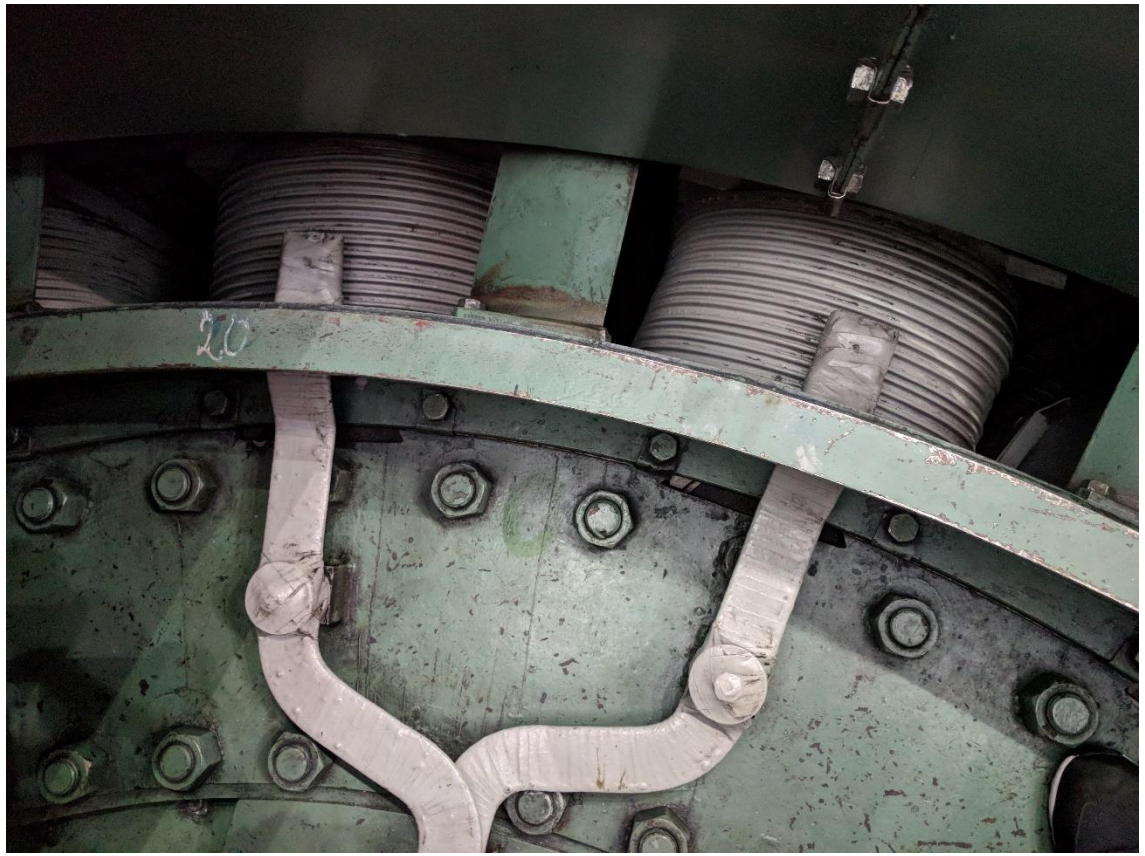
← **0.5 mm/s!**

Control measurements during the next year showed that **permanently stable state** was achieved!

Although**, a better** approach would be to minimize electromagnetic unbalance!

Air-gap & Magnetic flux measurements to the rescue!

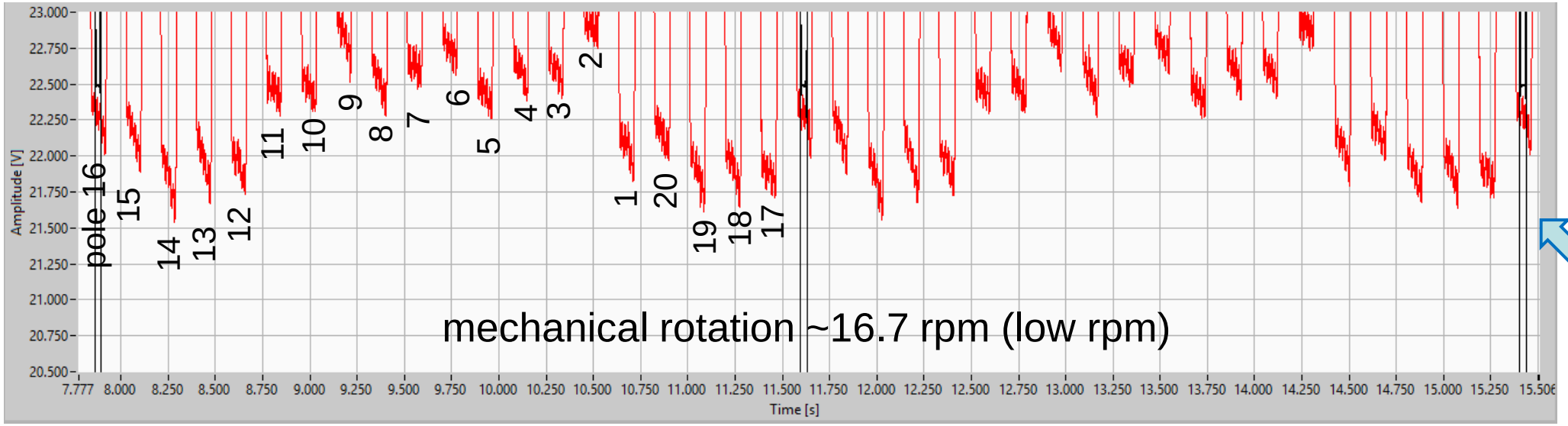
- balancing can only be done to reduce vibrations to certain extent

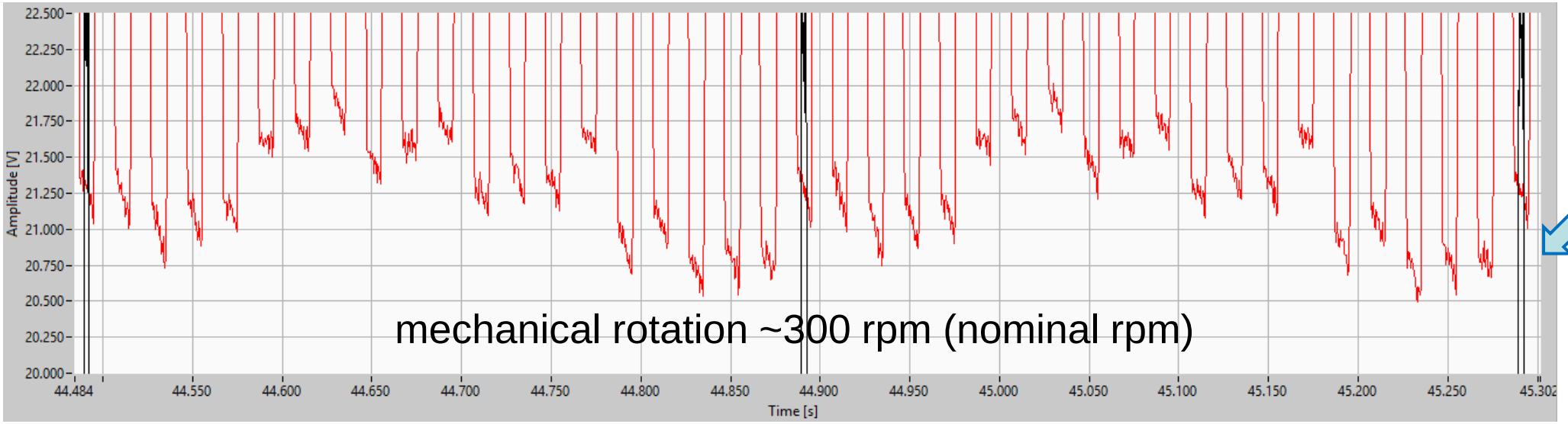


Rotor poles and excitation leads

Air-gap and Magnetic Flux sensors

Air-gap measurements / Unit 2

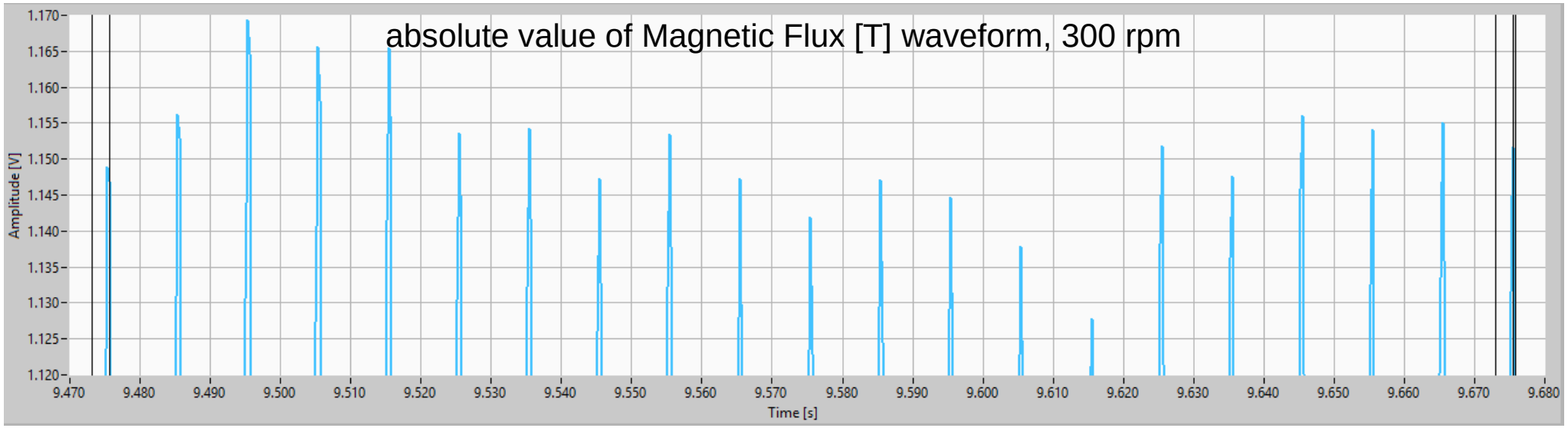


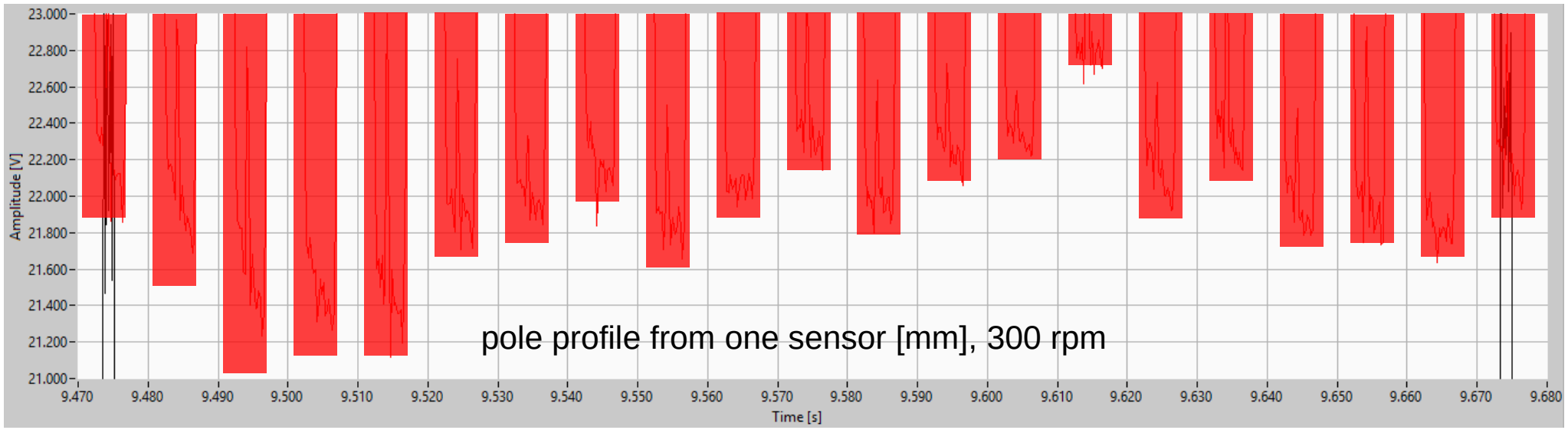


Similar or different?

(data from unit 2 – larger electromagnetic unbalance)

Air-gap + Magnetic Flux measurements (unit 2)





~30 MW

(data from unit 2 – larger electromagnetic unbalance)

Overhaul suggestions / Suggestion 1 (better)

- equalize air gap by the poles (by re-wedging them)
- for Unit 2 this means move poles 2-11 closer to stator for 0.8 mm (slide)
- this would equalize by ±0.2 mm

Dovetail connection pole to rim

... but problems during disassembly are to be expected + problems with spare parts

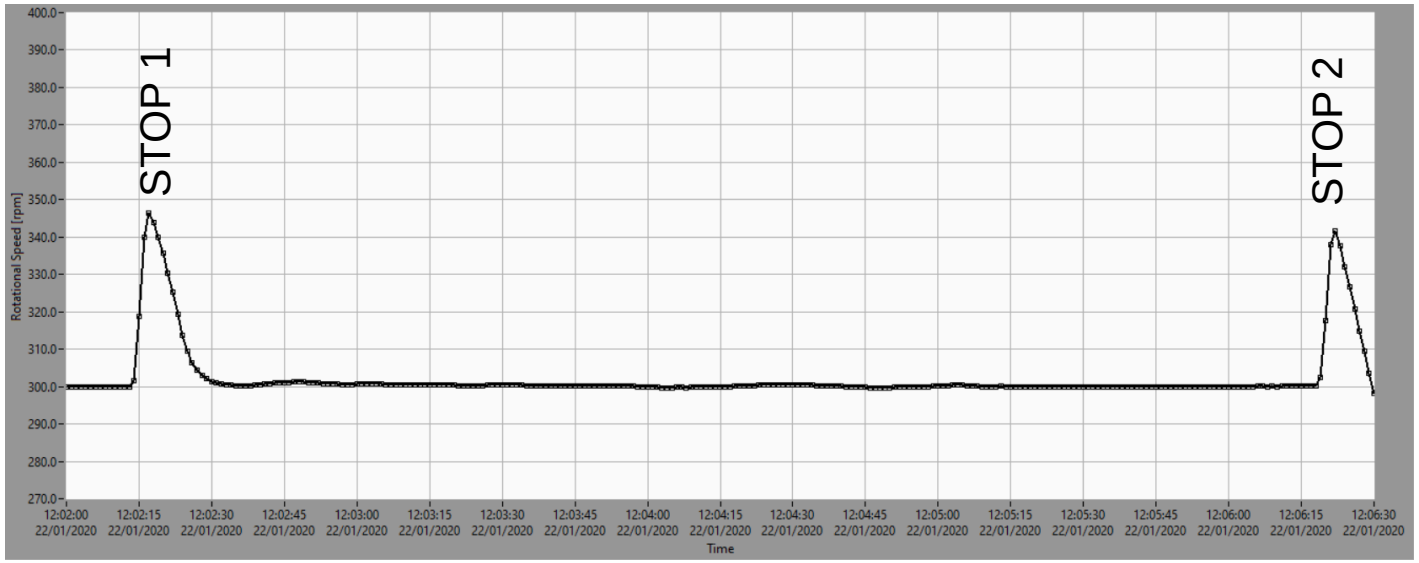
Overhaul suggestions / Suggestion 2

- if the pole re-wedging is not possible, regimes with extreme vibrations should be avoided
- if unit balancing is done in such a way as to minimize vibration amplitudes after the excitation is turned on (field flash) there will be large vibrations in mechanical rotation
- operation in mechanical rotation can be avoided (or reduced significantly) by turning on excitation automatically above 85% nominal speed regardless of the operating regime
- in this way large vibrations will be present only during run-up and run-downs for rotational speeds below 250 rpm
- these conditions are to be maintained in all operating regimes except when the generator protection system is turned on (for example, on stator short-circuits) but these events are rare

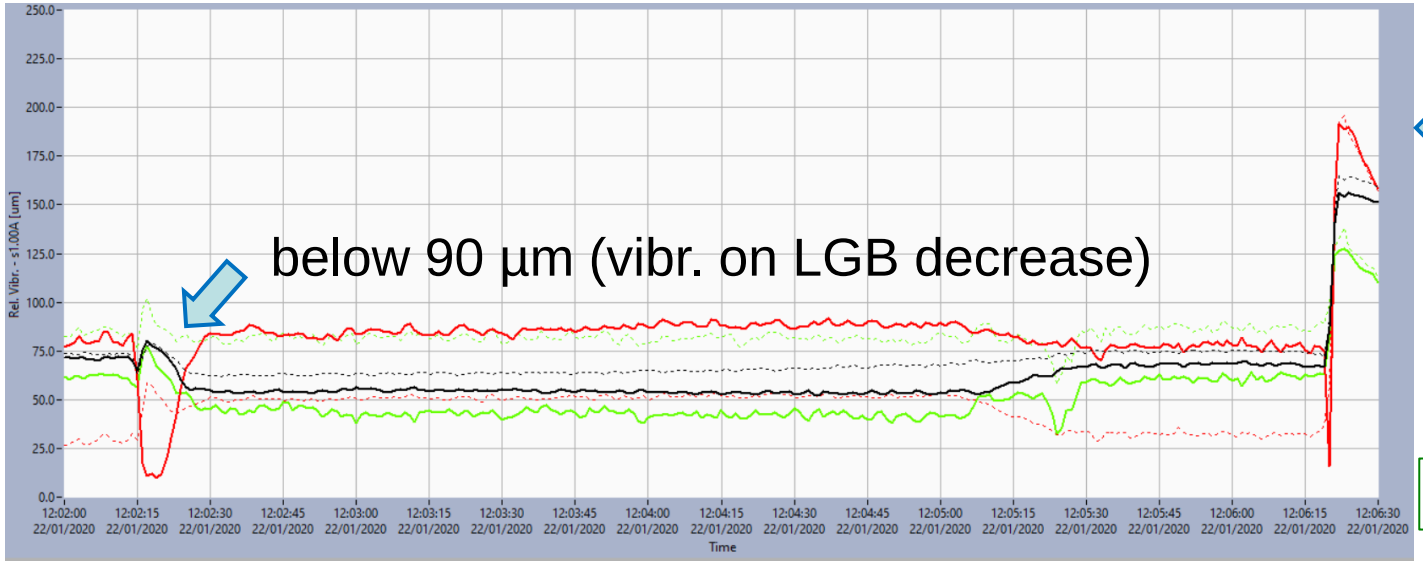
... decision was made to go with this

Load rejection from 20 MW / Unit 2

STOP 1 = excitation ON
STOP 2 = excitation OFF



Rotational speed [rpm]

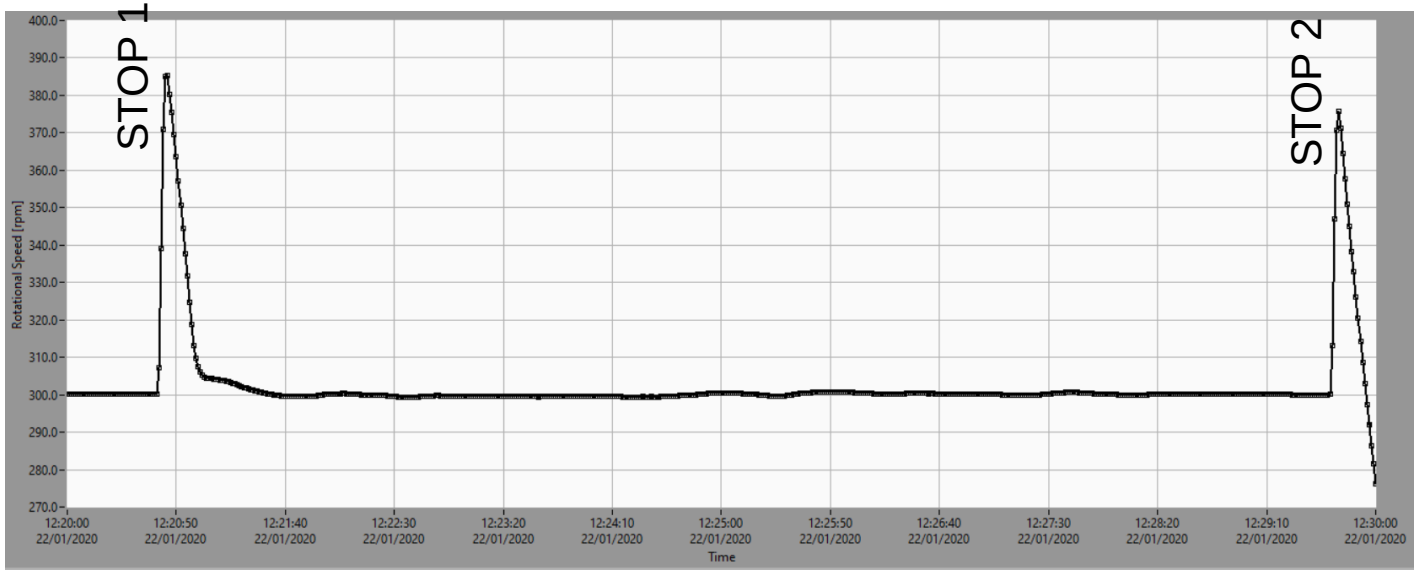


⇦ up to 195 µm

Relative vibrations – 1x [µm]

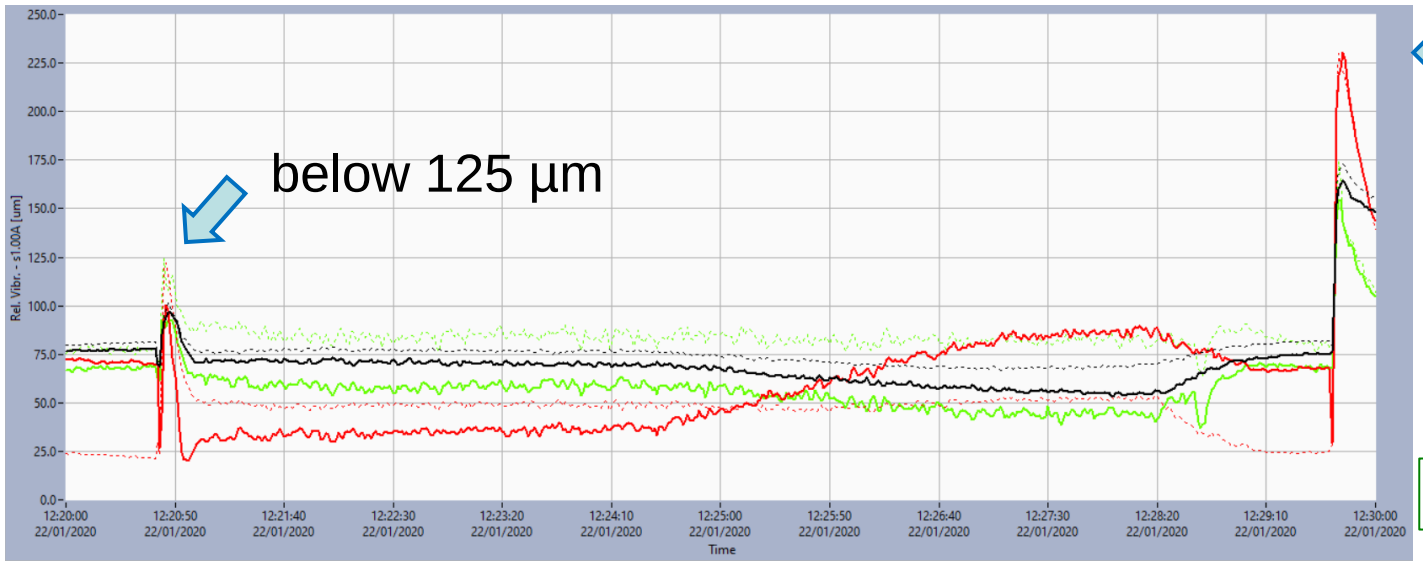
UGB (X, Y) / LGB (X, Y) / TGB (X, Y)

Load rejection from 30 MW / Unit 2



STOP 1 = excitation ON
STOP 2 = excitation OFF

Rotational speed [rpm]



⇦ up to 230 µm

Relative vibrations – 1x [µm]

UGB (X, Y) / LGB (X, Y) / TGB (X, Y)

Thank you for your attention!