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Effective procedure for turbomachinery field balance

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Authors

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His main responsibilities are projects execution, integrated train rotor-dynamic analysis, vibration analysis, troubleshooting and RCA, support to test bench and NPI programs.

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Abstract

When unbalance induced vibrations exceed allowable limits, a more accurate system balance is required. If performed at site on assembled machines, it is commonly called field balance.
Key point of the activity is the determination of the unbalance amount and position, to be added or removed, in order to minimize the trial and error attempts: it can be challenging due to the quality of available data and due to a lot of variable factors to be considered, both during analysis and activity execution.
The present case study shows how a field balance, performed on a gas turbine compressor train, composed by five rotating equipment, can be effective and resolutive at first attempt.

Summary

Presentation summary:

- Introduction.
- Problem statement.
- Analysis of likely causes.
- Field balance procedure:
  - Determination of amount and position of mass to be installed.
  - Step by step procedure for site.
- Vibration after trim balance.
- Conclusions.

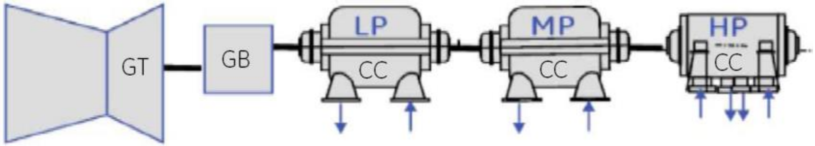
Introduction

Subject

- High synchronous vibration on parallel offset gearbox low speed shaft, up to alarm/trip limits

Train composition:

- Low/high speeds: 3600/6100 rpm
- Max driver power ≈ 37 MW
- Same design for 4 units



Problem statement

- During commissioning, 1 unit showed high vibration on gearbox low speed shaft, above alarm with speed above nominal speed.

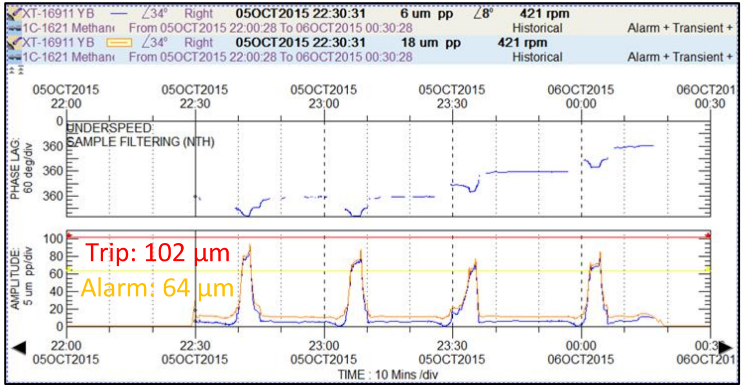
- No issues on other 3 units.

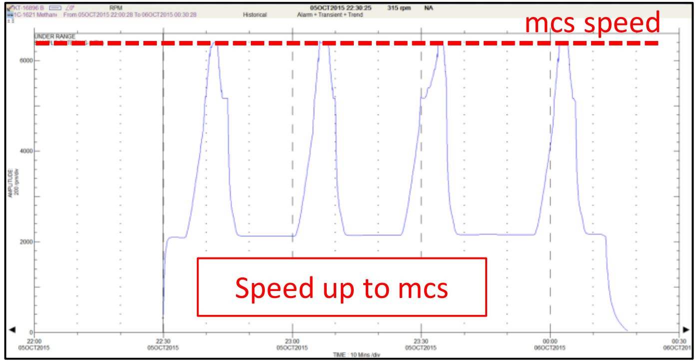
- Vibration main component: 1xRev.

- Max amplitude ~ 90 µm.

- Acceleration similar to other 3 units.

Gearbox low speed shaft radial vibration





Analysis of likely causes

Summary of RCA carried out:

Possible causes	Probability	
Shaft bow	unlikely	Gearset previously replaced. Similar behavior observed on previous gearset.
Gearbox residual unbalance		
Damaged gearset (cracks, damaged teeth)		
High GB clearances (shaft/bearing/housing)	unlikely	Assembly records checked
Critical speed	unlikely	Rotordynamic checked. No issues on other 3 units (same design).
Casing foundation bolts, shims and baseplate	unlikely	Site installation records checked
Coupling residual unbalance	possible	
Damaged, missing, incorrect coupling parts	possible	Point put as “to be checked” at next opportunity

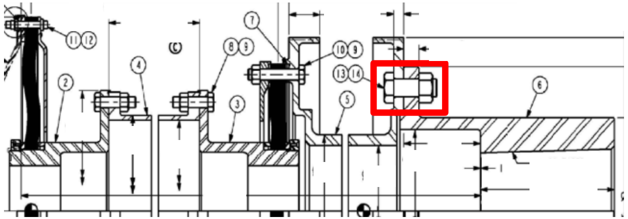
→ Proceed with field balance at first opportunity, at the same time checking load coupling.

Field balance procedure

(Determination of amount and position of mass to be installed)

- Balancing weight to be added as close as possible to gearbox DE → load coupling flange (20 holes available, radius 180 mm “r_u”).

Gas turbine



Gearbox

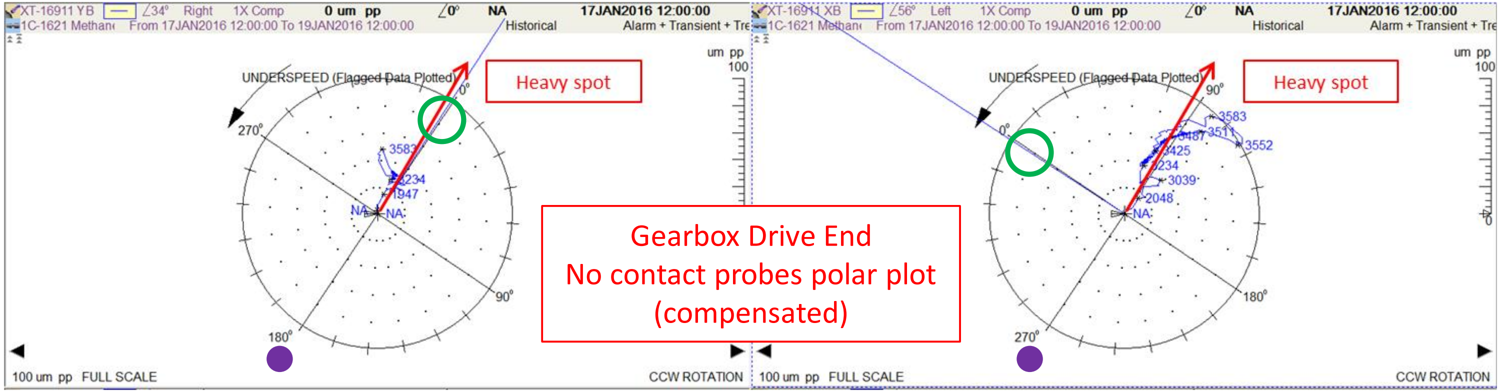
- Quantity of unbalance:
  - Influence vector was not available.
  - From literature: for a slow ramp-up machine, add a weight that will produce (at speed of interest “ω”) an unbalance force equal to 10% of rotor static weight. Considering above radius → 170 g “m_u”.

$$0{,}1 \cdot Rotor\ static\ weight = m_u \cdot \omega^2 \cdot r_u$$

Field balance procedure

(Determination of amount and position of mass to be installed)

- Phase of unbalance: polar plot shall be analyzed to detect the direction of the heavy spot. Weight to be added in the opposite direction.



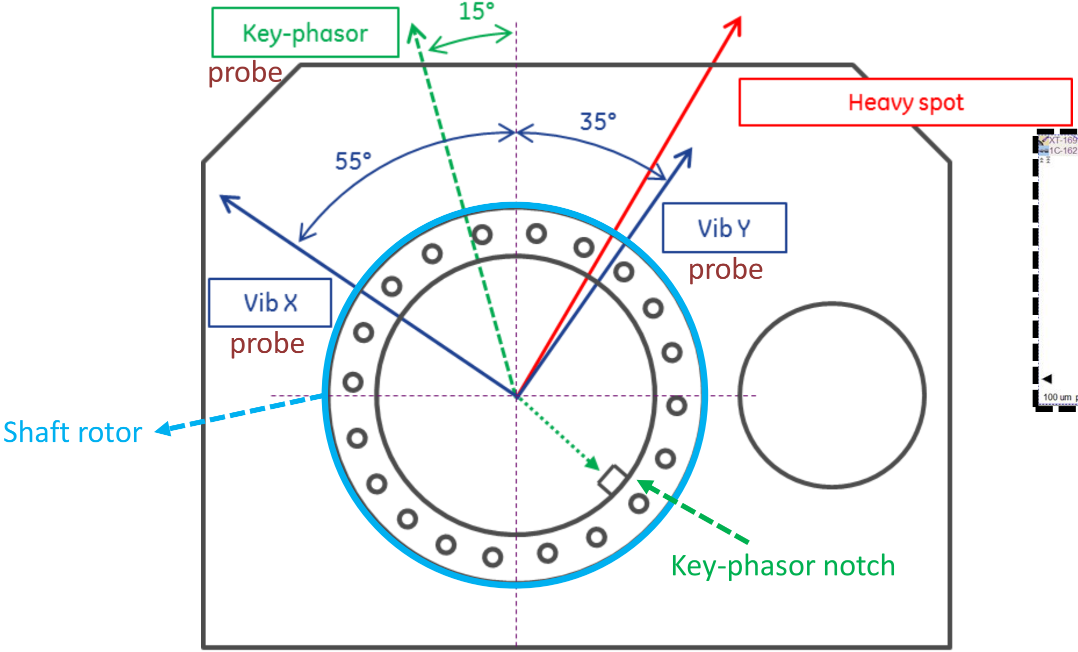
Position of the probe (X and Y) | Vibration at slow roll speed | Unbalance position

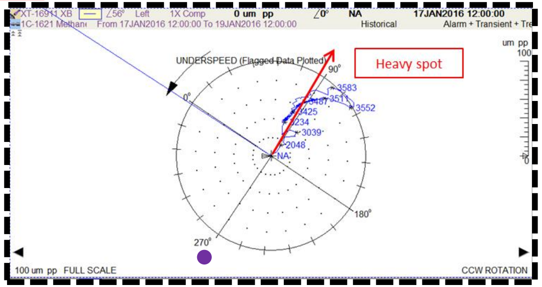
→ Position and amount of unbalance done

Field balance procedure

(Step by step procedure for site)

1. Stop the machine (key-phasor notch in random position) + low speed coupling inspection





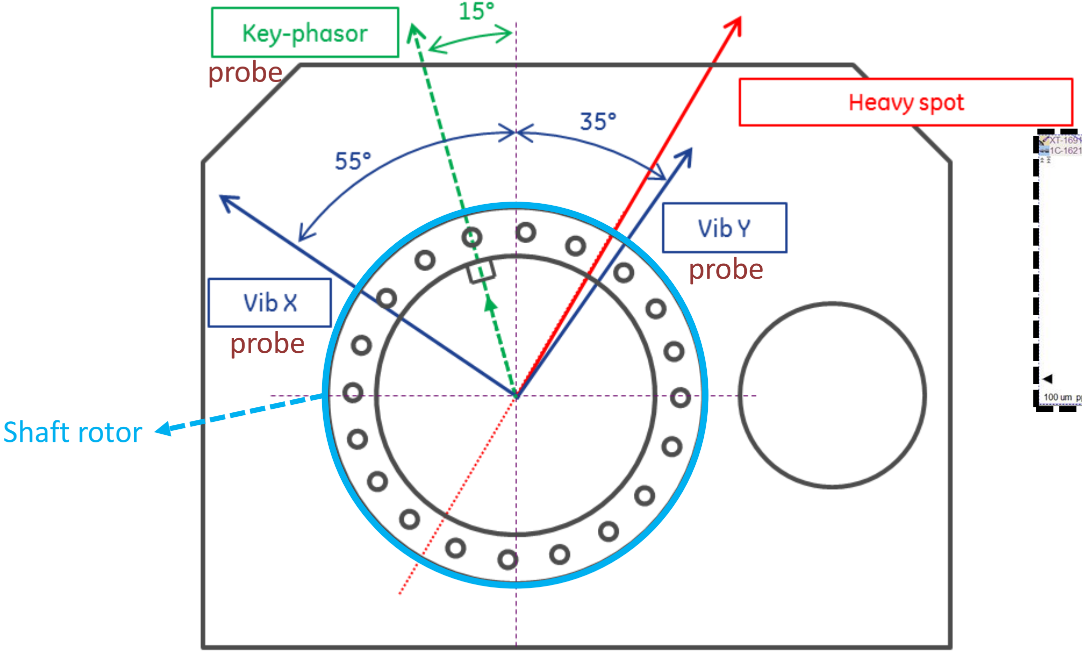
Schematic view: key-phasor notch and balancing holes highlighed

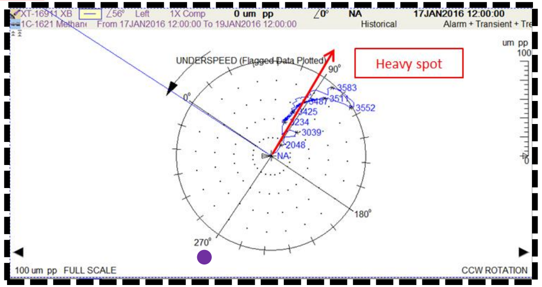
View from GT

Field balance procedure

(Step by step procedure for site)

2. Turn the shaft to align key-phasor notch with key-phasor probe





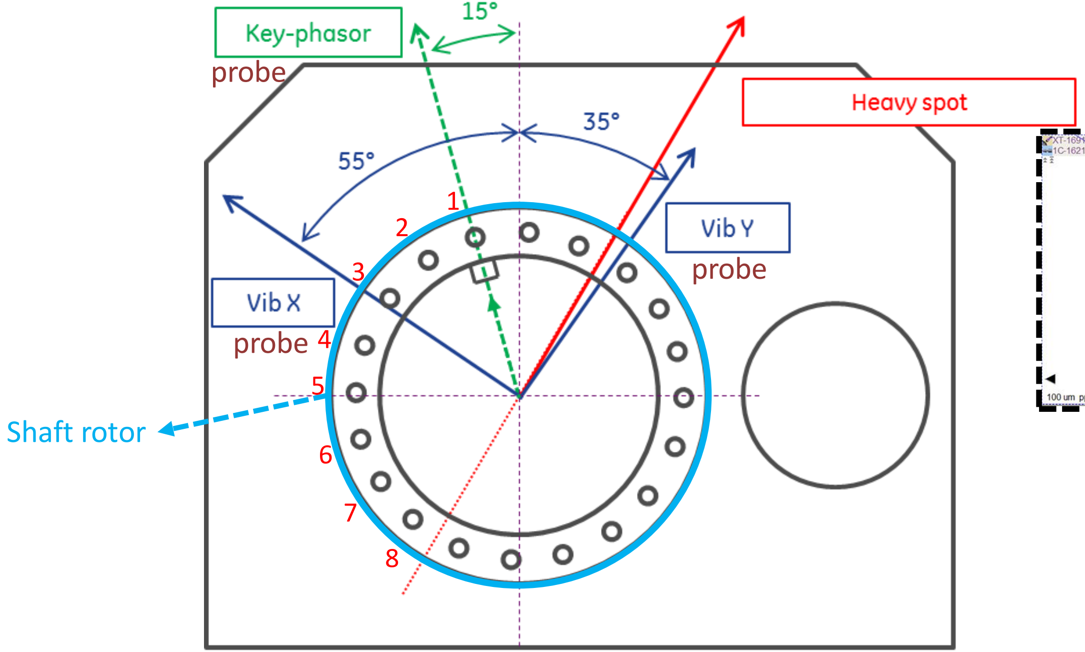
Schematic view: key-phasor notch and balancing holes highlighted

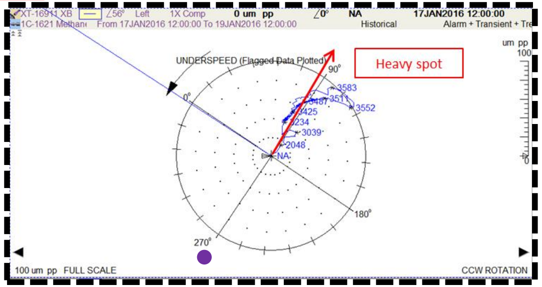
View from GT

Field balance procedure

(Step by step procedure for site)

3. Mark bolts/holes on shaft to have reference on machine





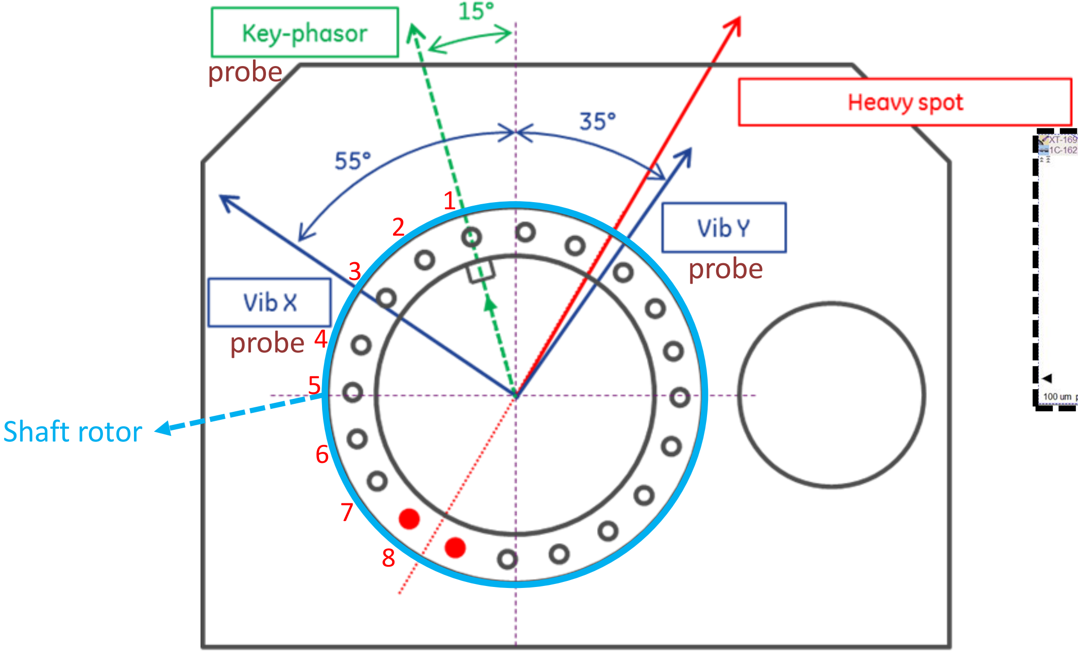
Schematic view: key-phasor notch and balancing holes highlighed

View from GT

Field balance procedure

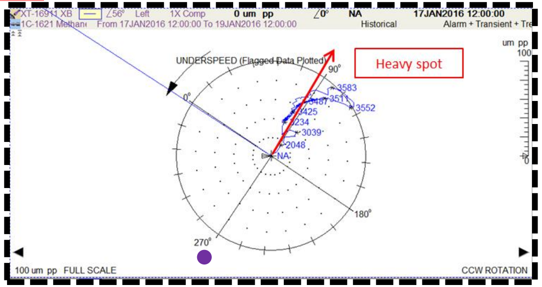
(Step by step procedure for site)

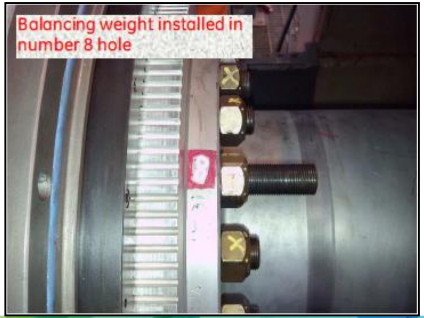
4. Add weight opposite to heavy spot vector



Schematic view: key-phasor notch and balancing holes highlighted

View from GT





Field balance procedure

(Step by step procedure for site)

5. Run the unit:
   - Keep the unit to MOS until gas turbine thermal stabilization.
   - Increase speed gradually from MOS to MCS.
   - Alarm/trip values temporarily increased for the duration of the test (checked with gearbox manufacturer).

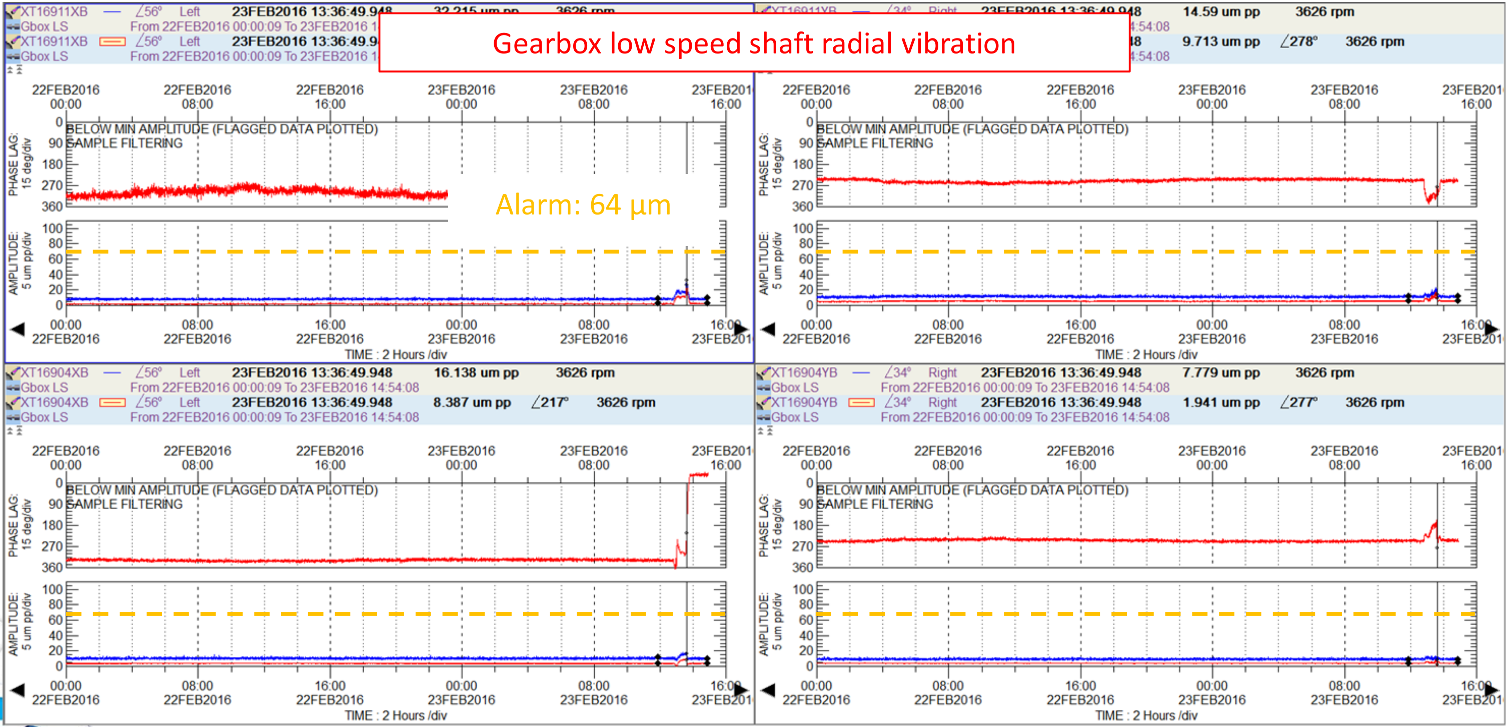
6. Optional: based on first run results, additional run for unbalance mass/position optimization.

NOTE: if specific needs lead to disassembly some components modifying their relative position (e.g. coupling dismounting), heavy spot and unbalance could be affected.

→ Match mark relative position

Vibration after trim balance

All operative speed range explored: at MCS max amplitude ~ 32 µm (vs previous ~ 90 µm).



Conclusions

- If RCA addresses to unbalance the cause of 1x vibration, field balance can be a powerful tool to decrease vibration.

- Data analysis: polar plot provides indication about phase of heavy spot whereas unbalance mass should be calculated based on previous run data availability. Otherwise, calculated by literature.

- Procedure for site activity shall be clear in such way to install the desired mass at the right position and angle. Make references on shaft can help for future activities.

- After reached machine thermal stabilization, test run shall cover all the speed range. It can be evaluated to increase temporarily alarm/trip threshold for the duration of the test (to be checked with gearbox manufacturer).