CASE STUDY – 05

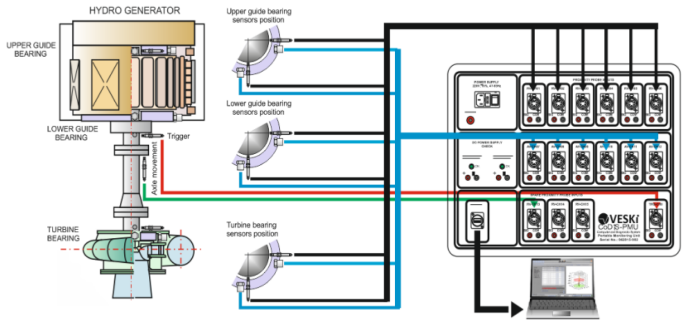
Hydrogenerator Hydraulic unbalance / Portable Diagnostic System

Machine data:

Vertical hydro unit with 3 guide bearings / Power: 145 MW; / Francis Turbine; Speed: 333,33 RPM

Measurement Configuration:

- 6 relative shaft vibrations
- 6 absolute bearing vibrations
- Axial displacement
- Phase reference (and RPM measurement)



Problem: Large turbine guide bearing vibrations which increase with load

The power plant staff noticed that the vibrations on turbine guide bearing increase significantly with load reaching dangerous values exceeding bearing clearance in some regimes.

This was realized on machine commissioning after major refurbishment that included the replacement of the turbines and generators and an overall increase of power by 25%.

Vibration amplitudes were very high, disabling the machine from operating at full power thus reducing its availability.

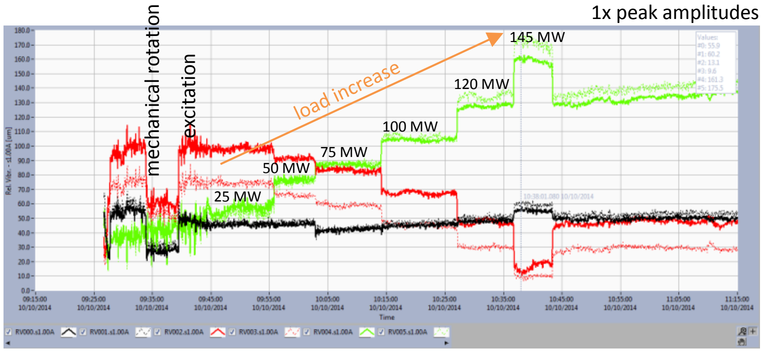
Data analysis and problem identification

Using CoDiS-PDS (Computerized Diagnostic System – Portable Diagnostic System)[1], relevant vibration data was captured and analysed. The data was correlated with different machine operating regimes.

The most important parameters that were analysed were the 1x harmonic amplitudes and phases since these proved to have the most significant contribution to the overall vibration levels. Additionally, the CoDiS-PDS system enables DC (shaft centerline), 2x, 3x, Rest (Non harmonic), process quantities, air gap dynamic and static eccentricity and real time flux data (shorted turn detection on rotor poles) analyses.

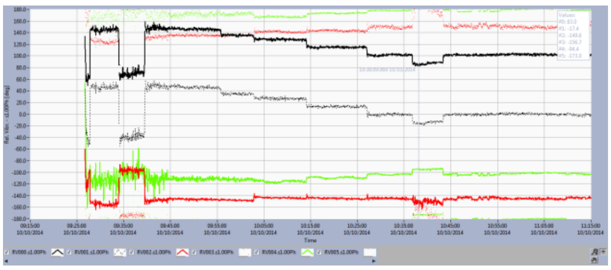
Relative and absolute vibrations analysis

1x peak amplitudes



From the vibration response it can be seen that on increasing load from 25 MW to maximum 145 MW (each regime lasts approximately 10 minutes) relative shaft vibrations on TGB – turbine guide bearing (green) increased in both perpendicular measurement directions from ~50 µm to ~175 µm (first harmonic peak amplitude). There is practically no influence of excitation on the vibrations on the TGB. It can also be seen that the vibrations decreased on LGB – lower guide bearing (red) from ~100 µm to ~10 µm. Vibrations on the UGB – upper guide bearing (black) appear to not change significantly (in amplitude). But when looking at the phases of the 1x harmonic, it can be clearly seen that there is a significant load dependence on the UGB. On the LGB and UGB, these

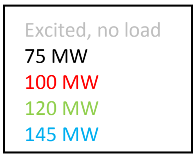
1x phases

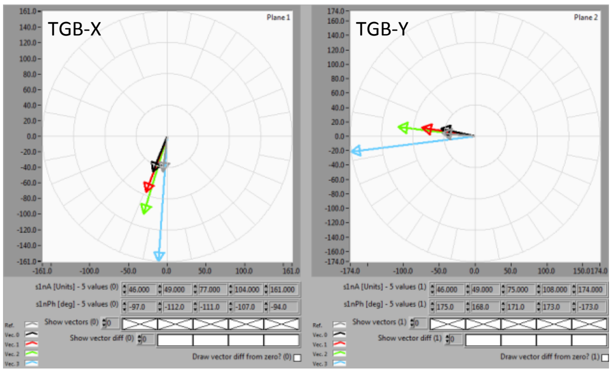


[1] Veski Ltd's product - a portable measurements system intended primarily for vibration measurements, but can be used for air gap, magnetic field, process parameters etc. analyses as well

changes are due to electromagnetic unbalance forces. Changes in vibration amplitudes indicate that the acting forces change during the load increase. The phases of the TGB measurements change very little during the load increase. The change from mechanical rotation to maximum load is up to 15°. Invariance of phase means that forces change in the same direction during the load increase.
Vibrational velocities of bearing housings on the UGB and LGB in steady state working conditions are considered low (0.5 mm/s on UGB and 0.2 mm/s on LGB). On the TGB, vibrations reach up to 1.5 mm/s and increase with load. The values are not too high, but they last continuously when operating at maximum load.

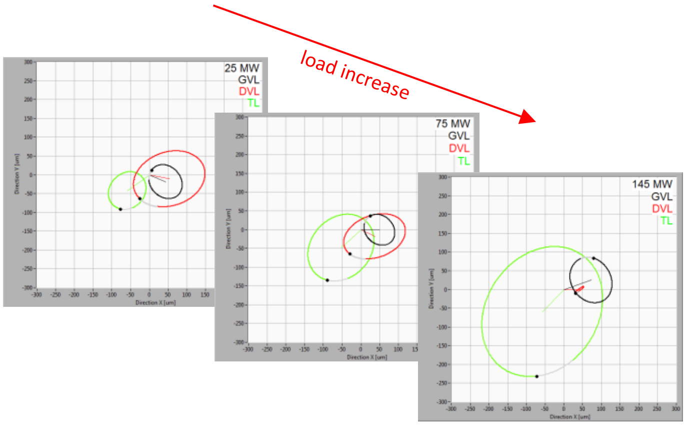
Vector analysis





Another way to visualize the effect of hydraulic unbalance is to draw vibration vectors for different operating regimes during load increases for the TGB using polar plots (in both X and Y measurement directions).
Gray color represents excited, no load regime, black represents vectors at 75 MW load, red at 100 MW load, green at 120 MW load and blue at 145 MW load.
It can be seen how the amplitudes of these vectors increase with load in practically the same direction (variations ~15°).

Orbit analysis



1x orbits (first harmonic only) are shown for different loads with statical position included (UGB – black, LGB – red, TGB – green). It can be clearly seen how the TGB orbit increases with load. LGB orbit decreases with load while the UGB orbits slightly increase.

Hydraulic unbalance

Since there is a very large change in vibration levels on the 1x harmonic on load increase we can conclude that the rotor blades do not produce symmetrical reactive forces, even though the forces from the water intake are symmetrical (as obtained from statical shaft positions which do not change significantly with water flow). This is evidence that large vibrations of turbine bearing are generated by asymmetry in the turbine rotor which is a typical example of hydraulic unbalance.

Conclusion

- Machine vibrational state is unacceptable due to the high radial shaft relative vibrations on turbine guide bearing.
- At maximum load the vibration amplitudes exceed 200 µm which is the nominal turbine bearing clearance.
- Due to such large vibration values the machine is limited to a maximum power of 120 MW.
- The cause of the unacceptable vibrational state is turbine rotor hydraulic unbalance due to the asymmetry in the turbine rotor.
- The turbine rotor should be changed as soon as possible to enable machine operation at full power (145 MW).