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Condition monitoring of Pump-turbines

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I. Introduction

At present, new renewables like wind, solar and marine energy are having a strong development. The generation of energy by renewables has the disadvantage that it depends on atmospheric conditions. It means that they can generate energy at any moment independently if this energy is required or not by the consumers.
For the stability of the electrical grid, supply and demand of energy has to be matched. The surplus of energy produced when consumption is low has to be stored and delivered again when consumption is high. Therefore, the future of renewables is tied directly to the future of energy storage.
At present, the only system to store huge amounts of energy is pumped storage (Pump-turbine machines). In these plants the surplus of energy in the grid is used for pumping water to a higher reservoir (pump operation). At peak hours or in case of emergency this water goes down generating energy (turbine operation). To guarantee this operation these machines have to be available at any time.
Pump-turbines (PT) are high performance machines that have to change operation from pump to turbine mode (reversing runner rotation and flow direction) in a short time. Due to their design characteristics (large power concentration) and operating conditions, they generate large pressure pulsations and forces when in operation. The PT structure has to resist all these forces and keep stresses below fatigue limit, for a lifespan of several decades.
With the increasing production of new renewables and the market regulations, new scenarios are appearing with:
- a large increase in the number of start and stop cycles
- a longer time of off-design operation at very low loads

Due to these facts the machines suffer from large hydraulic forces generating strong vibrations and stresses especially in the runner. Improved (and affordable) monitoring techniques are necessary.

II. Installation

Several pumped storage hydropower plants with PT are currently monitored remotely (Figure 1). Since 1998 remote on-line monitoring systems were installed in pump-turbine units. Several sensors were located in different positions depending on the type of machine. Overall levels, spectral bands and spectra are trended for monitoring (Figure 2). If an alarm is triggered other techniques are used for diagnostics.

Typical types of damage have been easily detected but a few of them, especially the ones occurring in the runner, were hardly detectable (Figure 3).

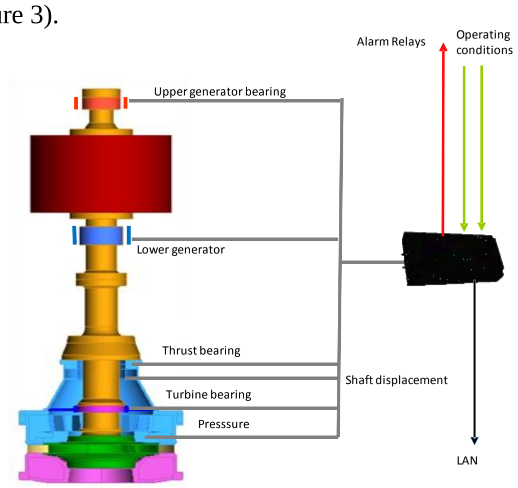

Figure 1. Sketch of the units monitored remotely

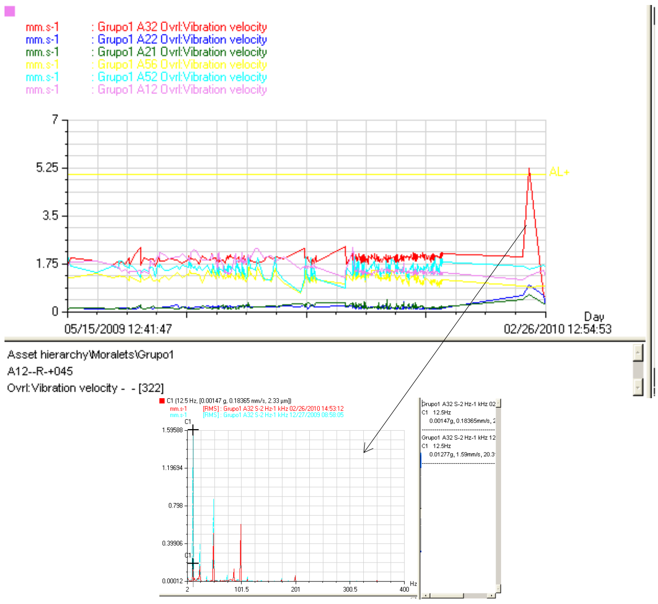

Figure 2. Trend and spectra

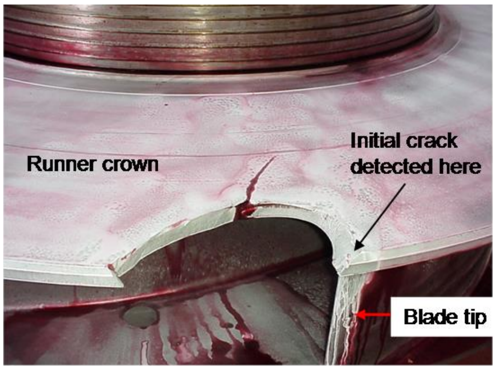

Figure 3. Damage in a machine runner

III. Procedure

PT are not standard machines. They are tailored made (each one is different) and the operating conditions can change continually to regulate power delivered to the electrical grid. Depending on the head and on the discharge, different phenomena can occur with significant changes in the vibration signatures. To improve the monitoring efficiency the following strategy has been followed:

- Analysis of the dynamic behaviour of the machine [1][2]
- Analysis of the symptoms before and after repair.
- Failure analysis of damage.

A. Dynamic behaviour

After installation of equipment the dynamic behaviour of the unit is analysed carefully. The excitation forces and the structural response are modelled [3].

To tackle with flow phenomena advanced 3 dimensional Fluid Dynamic Computation (CFD simulation) is

available but is too much time-consuming. Moreover even with a large computational power some phenomena have to be investigated experimentally in models at reduced scale.
To analyse machine response to the main excitation forces, advanced Finite Element Models (FEM) which include the surrounding mass of water and complex boundaries were performed (Figure 4). However the response of a submerged and confined rotating structure is very complex. Experimental measurements in prototypes are used to calibrate the numerical models.

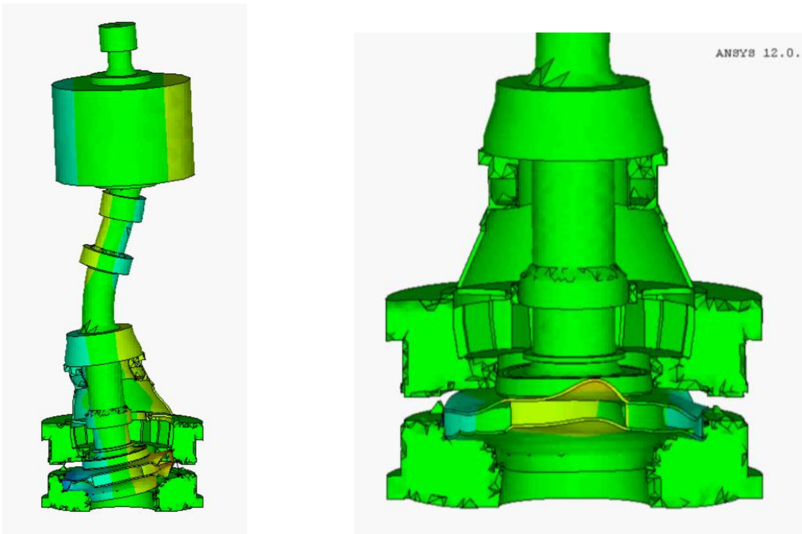

Figure 4. Dynamic behaviour

B. Analysis of vibrations in overhauls

The analysis of vibration signals before and after a repair is a good way to calibrate the symptoms and the alarm limits.

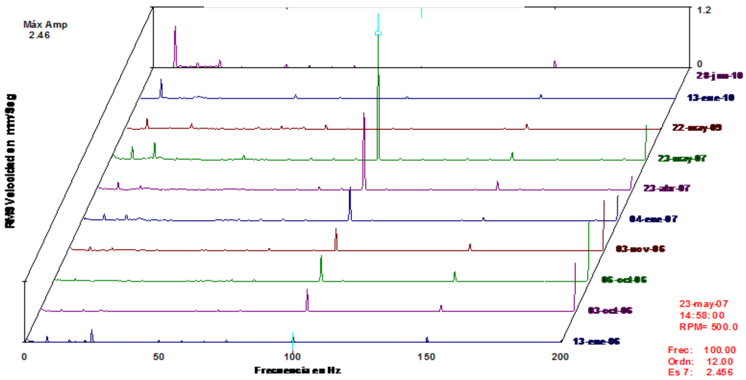

Figure 5. Example

IV. Conclusions

Pump-turbine units have been monitored on-line remotely for more than 15 years. Several types of damage have been detected during that time. One of the main components to suffer from damage is the runner which has been analysed in detail.
Because each unit is different, for the understanding of the vibration behaviour the dynamic analysis has been performed. The main excitations expected during the operation of the machine has been analysed and simulated as well as the structural response. The most important excitations are due to hydraulic phenomena especially the

periodic pressure pulsation generated by runner-stator interaction and cavitation. One of the main difficulties is the modelling of the runner response inside the casing full of water.
Different signals analysis techniques can be used depending on the type of damage. [4][5]

References

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