Application Note

Case study – Integrated vibration, process monitoring at HPP Momina Klisura

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ABSTRACT

The 35-year old generating units at the Momina Klisura hydropower station in Bulgaria are primarily used for peaking. Because of high maintenance costs and low availability of the ageing equipment, a major refurbishment was done a couple of years back. The installation of an advanced machine condition monitoring system was an important part of the modernization project.
A comprehensive vibration and process parameter monitoring system was installed on both units and included the following monitoring techniques:

- *Stator core absolute vibration monitoring*
- *Displacement and absolute vibration monitoring of the upper/lower generator and turbine bearings*
- *Axial displacement and vibration monitoring of the thrust bearings*
- *Cavitation monitoring at the runner*
- *Imported digital and process parameters for correlation and machine state definition (e.g. active power)*
- *Magnetic flux monitoring of rotor poles*
- *Air gap monitoring between rotor and stator*

This Application Note discusses the challenges of implementing an integrated monitoring system that includes diverse monitoring techniques, and monitors these parameters for different operational conditions. The monitoring system was commissioned only a half a year ago so there is little operational experience. But the results up to now, however, have been positive.

Figure 1. Momina Klisura 2 x 60MW generating units.

Operation and maintenance of the generating units

The Momina Klisura hydroelectric power station is the furthest down in elevation of a total of four hydropower stations on the Belmeken-Sestrimo-Chaira cascade on the Maritza river. The 2 x 60MW Francis turbines operate under a 251m head at 300 rpm. The penstock takes in 54.4 m3/s flow from a canal exiting the upstream Sestrimo hydropower station (2 x 130MW) and discharges it into the River. Momina Klisura produced 174 GWh in 2006[1].

Natsionalna Elektricheska Kompania EAD (NEK EAD) owns Momina Klisura together with 30 other hydropower stations, with a total installed capacity of 2563MW.

The Momina Klisura power generation, as with the other Bulgarian hydropower stations, is heavily influenced by the perennial climatic changes. Therefore during periods of low rainfall, machine availability is critical. Downtime due to machine faults simply cannot be tolerated during these demanding periods. In addition to this, the varying reservoir levels plus the irregular hours spent on stabilizing the grid results in varying loads on the generating units, thus making it difficult to effectively implement a time-based maintenance strategy. Machine maintenance cannot be accurately predicted under these conditions, as the components wear at different rates.

As a peaking station, the machines are more stressed compared to baseload applications and thus more prone to premature failure.

This is compounded by the fact that the machines have reached the end of their life cycle expectancy (Momina Klisura was commissioned in 1972). The severe operating conditions and ageing equipment resulted in high operation and maintenance costs, low availability due to high failure rate, and low overall efficiency.

A major refurbishment was done a couple of years back to increase availability, reliability and efficiency, while at the same time to ensure conformity to the Union for the Coordination of the Production and Transport of Electric Power (UCPTE). The rehabilitation work encompassed upgrading the turbine, generator, auxiliaries and the distributed control system (DCS). As a consequence of the demanding operating conditions at Momina Klisura, a condition-based maintenance strategy was adopted to replace the primarily time-based one. Therefore installation of an advanced machine condition monitoring system was also an important part of the rehabilitation project.

Implementation of the monitoring system

A comprehensive on-line vibration and process parameter monitoring system was installed in 2006. This was an important step in moving towards a conditioned-based maintenance strategy from the interval-based maintenance strategy. Selection of a condition monitoring system was based on a monitoring strategy, which draws from the operational and maintenance experience mentioned above.

Monitoring strategy

The basic overall requirements for the condition monitoring system were already determined by the power station operation and maintenance staff prior to the rehabilitation. The primary objective of the rehabilitation and implementation of a condition monitoring system was to improve machine uptime, reliability and efficiency, and reduce maintenance costs. Because of the demanding operational conditions at the plant and the maintenance experience acquired, it was decided that the primary machine components for monitoring would be the generator, turbine and shaft and bearings. The objectives for monitoring these components were focused on:

- Detecting and diagnosing faults at an early stage of development so maintenance can be planned ahead of time
- Optimizing part load operation to avoid cavitation

The monitoring system selected to accomplish these objectives is described in the sections that follow.

Site survey

After being selected, the monitoring system supplier conducted an on-site survey early in the year in the machine hall to facilitate installing the system. This is not always necessary for off-the-shelf portable monitoring systems, but it is imperative for plant-wide permanently installed systems like the one selected for this application. Some of the site-survey activities included:

- Determining the type of sensors needed to fulfil the requirements of the monitoring strategy, and determine their ideal location for optimal signal response. This also included determining how the machine monitoring surface should be prepared, and making specialized brackets to support the sensors
- Positioning the sensor conditioning units, signal wiring, junction boxes, and monitoring cabinet racks and properly grounding and wiring these
- Setting up the monitoring system network and any other system communications
- Determining how process data and digital signals are to be imported into the monitoring system from the distributed control system (DCS)
- Evaluating the ideal locations for the monitoring system servers, remote terminals and other computer peripherals such as printers
- Collecting machine data to help with setting up the database

Sensor inputs

The monitoring system sensors used are shown in Figure 2, and a typical installation of the air gap and magnetic flux sensors on the stator is shown in Figure 3.

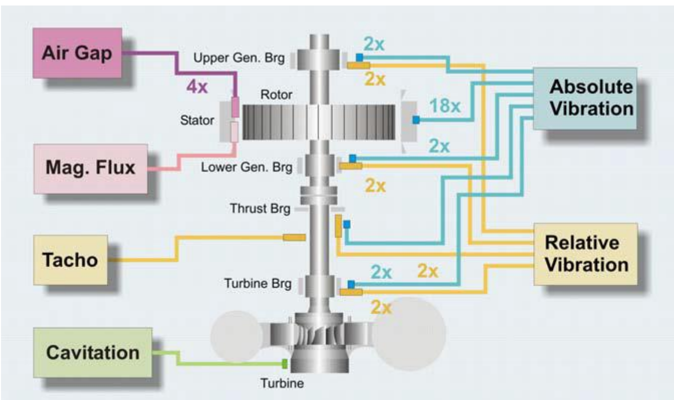

Figure 2. Sensors installed on the Momina Klisura generating units. Process parameters imported from the DCS are not shown here.

Figure 3. Mounting of the air gap sensor (green plate) and the magnetic flux sensor (right) between two poles on the stator laminates.

Machine component	Sensor	Measurement	Description and function
Stator frame/core, shafts and bearings	Radial accelerometer, displacement sensors	Vector	1st and 2nd order magnitude and phase for shaft fault detection and trending
		FFT spectrum	Diagnosis for faults that occur at different frequency ranges
		CPB spectrum	Constant percentage bandwidth for early fault detection and initial diagnosis of a wide range of faults
		Smax	Maximum magnitude from an X-Y measurement
		X-Y time signals	Displayed individually and combined in an orbit plot for diagnosis
		Bandpass	Detection of shaft/bearing faults at different frequencies
		DC	Shaft centreline monitoring
	Axial accelerometer, displacement sensors	FFT spectrum	Diagnosis of thrust bearing faults
		Bandpass	Continuous measurement to detect vibration changes
		DC	Continuous measurement to detect lube film thickness change
	Tacho	RPM	Speed and phase
Rotor/stator air gap	Air gap	Time signal	Overview of air gap for all poles during one revolution
		Min. air gap (DC)	Continuously monitored for safety
		Calculated values (DC)	Diagnostic values used to determine stator and rotor form
	Magnetic flux	Time signal	Overview of magnetic flux for all poles during one revolution
		Calculated values (DC)	Diagnostic values to identify shorted rotor turns
Runner	Cavitation	High frequency emissions (DC)	Indicate the onset of cavitation

Table 1. List of some of the measurements monitored and their function.

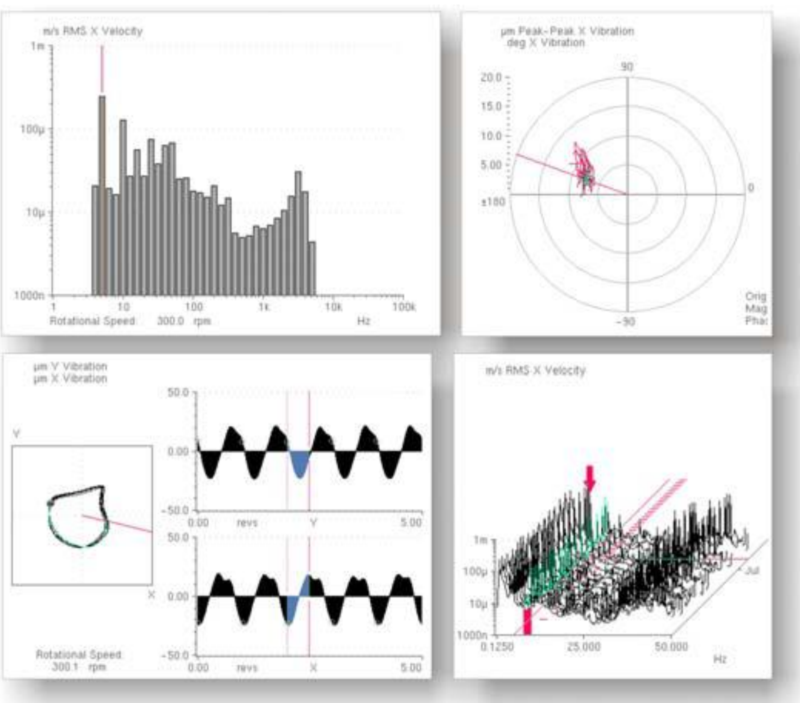

Figure 4. Example of plots for the upper generator bearing of unit 1. CPB spectrum at 23% bandwidth frequency (upper left), 2nd order vector history (upper right), orbit (lower left), and a waterfall FFT spectrum.

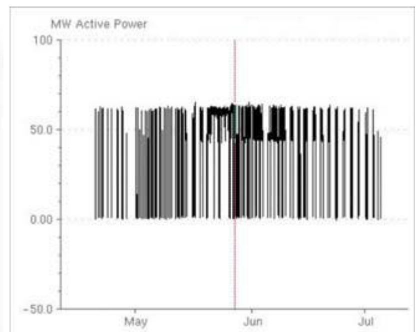

Figure 5. Active power plot showing the high number of starts and stops for unit 1during a 2.5-month period. Part load operation can also be seen here.

Measurements

A number of measurements are done on the vibration and process signals coming from the sensors, as summarized in Table 1. Typical measurement plots are shown in Figures 4 and 5.

Adaptive monitoring strategy

The generating units at Momina Klisura are frequently started up and shut down for peaking (often at part load), or used in a synchronized compensation operation to stabilize the grid. This places special demands on effective monitoring since the vibration signature for the same measurement is different for the different machine states. The monitoring system utilizes an adaptive monitoring strategy so a measurement is monitored to alarm limits specific for each respective machine state. “Tighter” alarm limits give earlier fault detection with less risk for false alarms. The measurements are saved in the database separate from the same measurement in other machine states, so it is easier to identify trends.

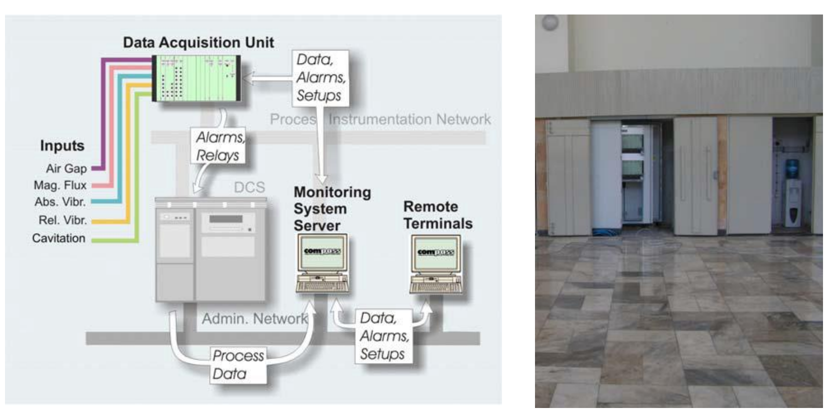

Figure 6. Monitoring system configuration (left), and the monitoring system cabinet in the machine hall (green acquisition units visible).

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Monitoring system configuration

The monitoring system is installed as a plant-wide system that includes sensors, data acquisition and conditioning units, a monitoring system server with a database, and remote access to operators and the distributed control system. See Figure 6.

Training

Training is very important for plant-wide monitoring systems, because of the wide range of measurement techniques used, and the comprehensive nature of the technology. The monitoring system operators, administration manager as well as the some of the control room operators were trained in running the system for one week. Momina Klisura has a support agreement with the local agent for the monitoring system.

Conclusion

Only a conditioned-based maintenance strategy can be used on a multiple role hydropower application such as Momina Klisura. The multiple starts and stops puts extra loading on the machine components and the varying duty cycles make machine component wear unpredictable. This kind of application requires an advanced machine condition monitoring system that is capable of detecting and diagnosing faults at an early stage of development using a number of vibration and process inputs from many machine components. The wide range of measurement parameters then have to be monitored to individual alarm limits and stored in the database with respect to a specific machine operating condition. Because of the risk of cavitation occurring at part load at Momina Klisura, the monitoring system is also used for optimizing which loads the hydro generating units can be safely operated. An advanced condition monitoring system is critical for peaking applications, since downtime cannot be tolerated. In fact, any downtime at the baseload thermal power stations has to be compensated for at Momina Klisura.

The complete process of installing, fine-tuning and commissioning of the system was successful, but was not without mishaps. Some sensors were incorrectly installed or wired, and some of the some of the measurements were incorrectly set up, but these are quickly identified during the commissioning. Proper project management is vital when installing a plant-wide comprehensive monitoring system.

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