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# VIBRATION MONITORING SYSTEM OF HYDRO ELECTRIC TURBINE-GENERATOR SETS

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**Abstract**

Vibration monitoring system is designed to optimize operations and maintenance of hydro generating units. For this purpose the following actions had been done

- we have defined the functions of the measuring and monitoring system
- we have analysed the most important parameters influencing the reliability from generator to turbine
- we have defined the parameters to monitor, the nature of signals and the sensors for this, where they are embedded for vibration monitoring in whole process

**Keywords:** vibration, hydro generating unit, stator-bar, guide bearing, air gap

## 1.Introduction

After the analysis of the turbine-generator set, for monitoring the functional parameters, the automatic system was designed to prevent failures and forced outages, the maintenance and the operation in good conditions. The typical measuring points on a hydroelectric generating unit and the available parameters are presented in the fig. 1.

One of the most important parameter influencing the reliability of the hydroelectric generator is the electrical insulation. If the insulation fails to maintain its integrity during operation, the equipment will fail. In practice, insulation does not fail at once. Multiple stress acting on the insulation: voltage stress, mechanical forces, thermal effects, all combine to induce a slow but steady change in its nature over years. This problem is associated with the movement of the stator bar due to shrinkage, slackness or loosening. This is the reason why the monitoring system include measurements as in-slot vibration of stator windings, the differential shaft expansion and the height of magnetic levitation trains.

## 2. The problem of hydro generator vibrations

a) Stator bar vibrations

Statistics show that the main cause of hydro generator shutdown is related to stator winding problems.

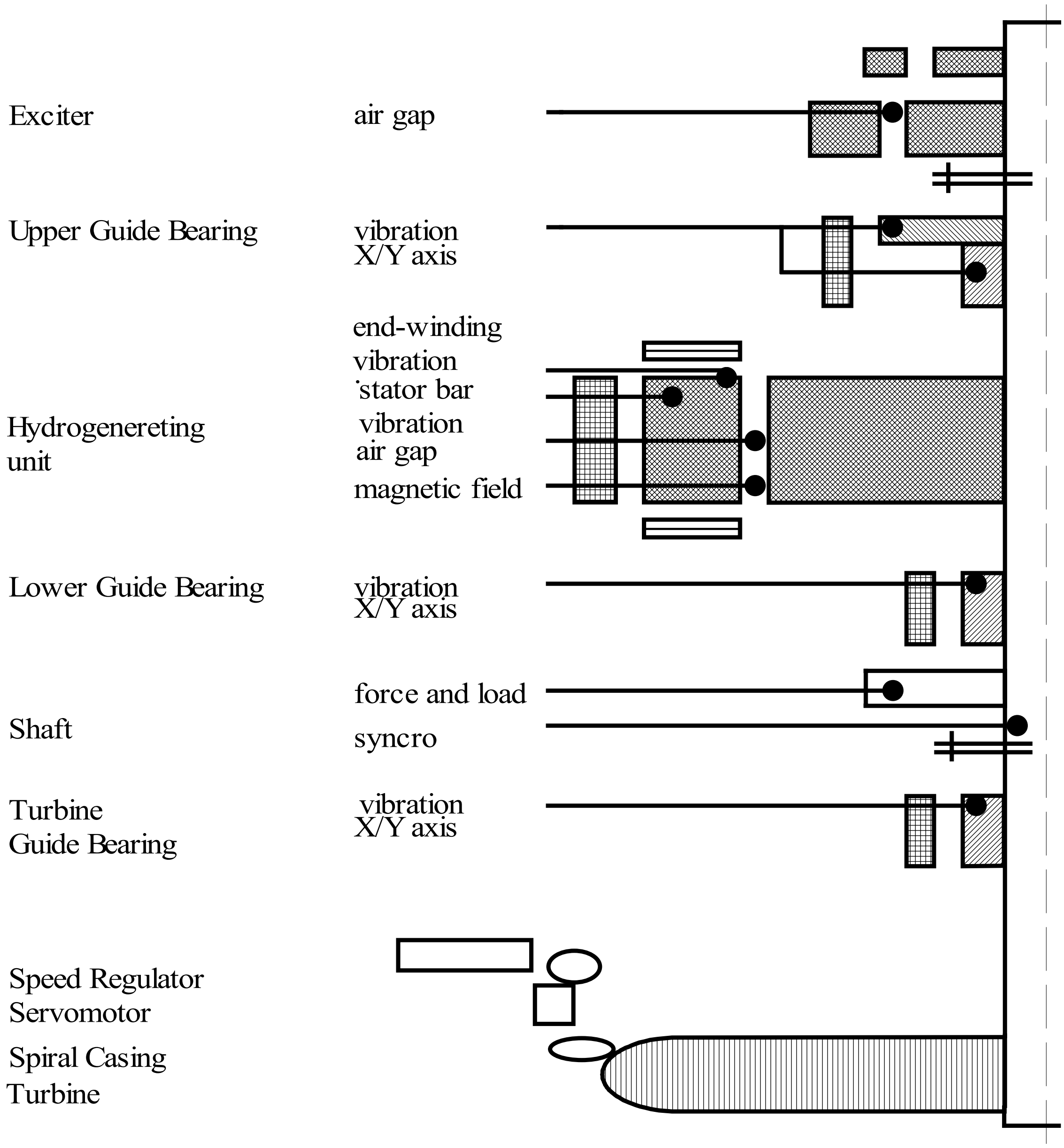


**Fig 1. TYPICAL MEASURING POINTS**

The monitoring and inspecting stator windings methods are based on detection of destructive effects, due to vibration of stator bar when machine is operating. The solution allows defining both wedging system tightness and level of bar insulation. One can obtain dynamical data, the detection before any destructive effect.

The system consist of a number of sensors embedded in specific stator slots (highest potential bar for each phase) linked to acquisition units. The system is designed to prevent long term destructive effects by trending bar vibration overtime respect the operating and temperature conditions. A complement of the system may be the device, which verifies the tightness of stator wedging system. This device is a flat probe that slides into the air gap and a mini camera to visually inspect the stator.

b) Air gap measurement

Many of machine problems can be seen through the air gap (machine vibration, mechanical or magnetic imbalance, out of roundness, misalignment, etc.). The system consists of a set of flat sensors glued on the upper plane of the stator wall. The number of sensors may be between 4 and 16 according to machine dimension. The measurement taken over one or multiple machine rotations can be visualized rectangular, polar or spectral.

c) Magnetic field measurement

The system is designed to detect and diagnose magnetic field imbalances, which contribute to machine vibration, rotor overheating and excessive stress on rotor and stator structure. It monitors the magnetic field by measuring the flux emanating for each pole. The flat sensors is glued onto the stator wall and connected

d) End-winding vibration measurement

End-winding vibration measurement is provided with optical accelerometers, which comprise a sensing head made of non-conducting materials, a fiber optic cable and an optical-electronic adapter. The solution is ideal for electrical hostile environment.

e) Guide bearing vibration measurement

The system is designed with proximity probes that provides immunity to electrical run-out, types of material, surface imperfection. The probe connects directly to the multi-channel, multi-tasking, on-line programmable, digital processing unit.

**3. Vibration monitoring system of hydroelectric turbine-generator**

a) Stator bar vibration monitoring system

The number of outages caused by deteriorated stator bars has increased since the introduction of thermosetting resin insulation. Deterioration of stator winding insulation is caused by wedge loosening, short-circuits and breakdowns. A good way to assess wedging stiffness is to measure bar vibration in the slot while the generator is operating. Dynamic measurement is much more reliable than periodic static stiffness test done manually.

The stator winding insulation system of a generator is exposed to harsh operating conditions. When the wedging system no longer holds the bar in place, vibration sets in. As stator bar retention within the slot gradually weakens, discharges slowly increase in intensity, and insulation is undermined. The action progress, electro-erosion activity intensifies and the vibration amplitude increases exponentially. If this harmful activity is not detected from the beginning and corrective action is not taken, rapid insulation deterioration may lead to irreversible damages.

Up to 12 DCS-400 capacitive sensors are embedded in stator slots on the upper part of the stator bore. Facing the bar, each sensor measures the gap between itself and the stator bar. The sensor's high accuracy makes it capable of measuring bar displacements as small as 1um. Each sensor is linked to a DCC-800 signal conditioner, which provide an analog output signal compatible with standards. Since excessive vibration is more apparent at the end of the stator iron, sensors are embedded in place of the second wedge from the top.

The DCS-400 proximity capacitive sensor is a non-contact passive measuring device, which generates the necessary electric field to measure the distance between its surface and the Faraday shield of the bar.

The DCC-800 signal conditioner supplies a HF driving signal to the sensor to generate necessary electric field used in the measurement process. The DCC-800 provides a 4-20 mA or 0-10 V output.

b) Air gap monitoring system

The system is designed to monitor the dynamic behavior of both rotor and stator structures. The system provides direct access to air gap value. The sensors can be mounted on the upper end or lower end of the stator wall. The capacitive sensor VM3.1 is a flat, non-contact type, which generates the necessary electric field to measure the distance between its surface and the target. The VM3.1 is a passive sensor, with no moving parts or active electronic elements and is compatible with most types of conductive and semi-conductive target material. The measured signal is sent trough a cable to the DCC-631 signal conditioner, which generate a standard signal 4-20 mA, or 0-10 V.

c) Magnetic field monitoring system

The system monitors online the generator magnetic field by sensing magnetic fluxes emanating from rotor poles. It is designed to detect field imbalance that contribute to machine vibration, overheating and excessive stress on rotor and stator structures. The system is an inductive measuring tool. It is composed of the MFP-100 probe, flat mounted on the stator next to an air gap sensor. The measured signal is transmitted to a MFC-100 signal conditioner which provide a 0-10 V linear output.

For effective diagnoses, the results are correlated with air gap measurement, to determine whether the Imbalance is caused by an electrical fault or induced by an uneven air gap.

d) End-winding vibration monitoring system

The optical accelerometer is nonconductive and immune to electromagnetic interferences. Its optical link ensures an electrical insulation between the sensor and the instrumentation. The optical sensor body is made of ceramic with no metallic elements. The system is composed of a FOA-100 optical accelerometer an optical fiber, embedded and protected, and the AGM-P21 signal conditioning module which provide a linear output signal 4-20 mA or 0-10 V.

e) Guide bearing vibration monitoring system

The system is designed for data acquisition from the upper and lower guide bearing of the electric generator and the turbine guide bearing. 8 proximity sensors are positioned on the X-Y axis of each guide bearing. The PCS-102, universal proximity probe dynamically monitors the distance between the probe tip and the target surface. Due to its insensitivity to electrical runout (material characteristics, minor surface irregularities) and the magnetic field, the PCS-102 provides an accurate and reliable measurement of target displacement than any eddy-current proximity probe. The PCS-102 probes are connected with LIN-102 linearization module to interface the probe signal output with other systems. The LIN-102 provides a linear output signal 0-10 V.

f) Programmable unit for monitoring system

The unit is designed with a PLC and his extension modules. The modular design offering mix and match capability:

- Fully programmable, multi-tasking
- Continuous high-speed sampling and processing rate
- Protection relays
- Communication link to machine monitoring system
- Change any settings on-line using fronts panel and display
- Password protection to prevent unauthorized access

## 4.Conclusions

The vibration monitoring system is useful, and offer a lot advantages such:

- Reduces inspection outage frequency. Many utilities schedule periodic inspection outages for observation can be reduced or eliminated.
- Reduces maintenance outage frequency. The monitoring system has the potential to reduce the time scheduled by helping to ensure that maintenance work is necessary when performed.
- Reduces maintenance outage repair time by utilizing the system to determine the actual condition of equipment.
- Reduces forced outage frequency by using the information from monitoring system to trend and predict potential problems. Many corrective actions can be taken before the problem becomes severe.

- Increases generating unit operating efficiency. The information provided by monitoring system could allow operation personnel that maximize the operating efficiency of generating equipment.
- Improves equipment safety. The prediction of potential degraded equipment condition will allow operating the equipment for longer intervals without jeopardizing the health or safety of the equipment.
- Increases plant life expectancy. Many of the benefits mentioned before lead toward this goal.

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