Application of Inductive "Eddy Current" Technology for Hydro-Electric Generator Rotor-Stator Gap Measurement

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ABSTRACT: The removal, repair and reinstallation of a rotor in hydroelectric generating stations is a costly endeavor. Added to the actual cost of the repair is the lost revenue during the downtime. After repair, reinstallation of the rotor includes an extensive alignment process. Rotor-stator gap measurements are taken, and computer programs provide the maintenance engineers with the appropriate adjustments to be made. The accuracy of these measurements directly affects the number of measurements and adjustment iterations required to bring the rotor-stator alignment into spec.

This paper presents an inductive displacement sensor technology to make rotor-stator gap measurements accurately and quickly, reducing the overall time to accomplish complete rotor-stator alignment.

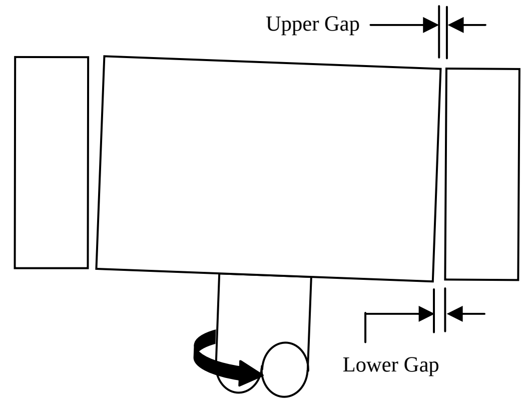

Figure 1

Introduction

Hydro power generation is no different than fossil fuel, nuclear, wind and solar when it comes to down time. Down time costs money, both in the cost of the maintenance and lost revenue during the shutdown. Maintenance shutdowns are tightly scheduled and controlled to ensure that the amount of work to be done is accomplished in the allotted time. Unscheduled shutdowns to repair failures or to prevent pending failures are costlier still.

There are many repair and maintenance issues that can require the removal of the generator rotor. Once reinstalled the rotor-stator alignment process must take place to ensure efficient generator operation and bearing life.

Typical Methodology

After reinstallation, the initial rotor alignment is accomplished by physically measuring the misalignment, feeding the measurements into a computer program which identifies where the correction is to be made and by what amount, to bring the rotor into coaxial alignment.

After the initial measurement and data processing, alignment corrections are made, the misalignment is again measured to verify the correction resulted in rotor-stator alignment within design specifications. If alignment is still out of specification, measurements are taken again, data processed and additional corrections are made. This is repeated until the alignment is within specification.

A Time Consuming Task

Hydro turbine electric generators can be 20 foot or more in diameter and consist of hundreds of pole pieces. As each pole piece can exert a force on the rotor, each pole piece gap is measured so the radial alignment of the rotor in the stator will even out these forces. Mechanical gages can be used to make the measurement, but their use is typically time consuming, and susceptible to variability between technicians.

Inductive Sensor for Gap Measurement

Inductive "eddy current" sensors are designed to output an analog voltage that is proportional to the distance between the sensor face and an electrically conductive 'target'. Figure 2 shows a typical inductive sensor arrangement

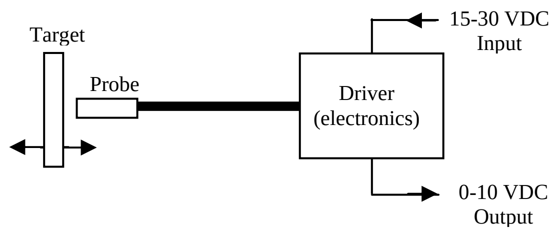

Figure 2

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In operation the driver excites a wire wound coil in the probe with an RF signal, typically 1MHz. The coil in the probe generates an oscillating electromagnetic field. Any electrically conductive material engaging the field will have “eddy current” induced in its surface. The eddy current produces its own electromagnetic field. The interaction between the coil field and eddy current field produces an impedance change in the coil, the magnitude which is based on the distance between the two fields, or between the probe and the target surface. The driver monitors the impedance of the coil and outputs a linear analog voltage proportional to the distance between the probe and the target surface.

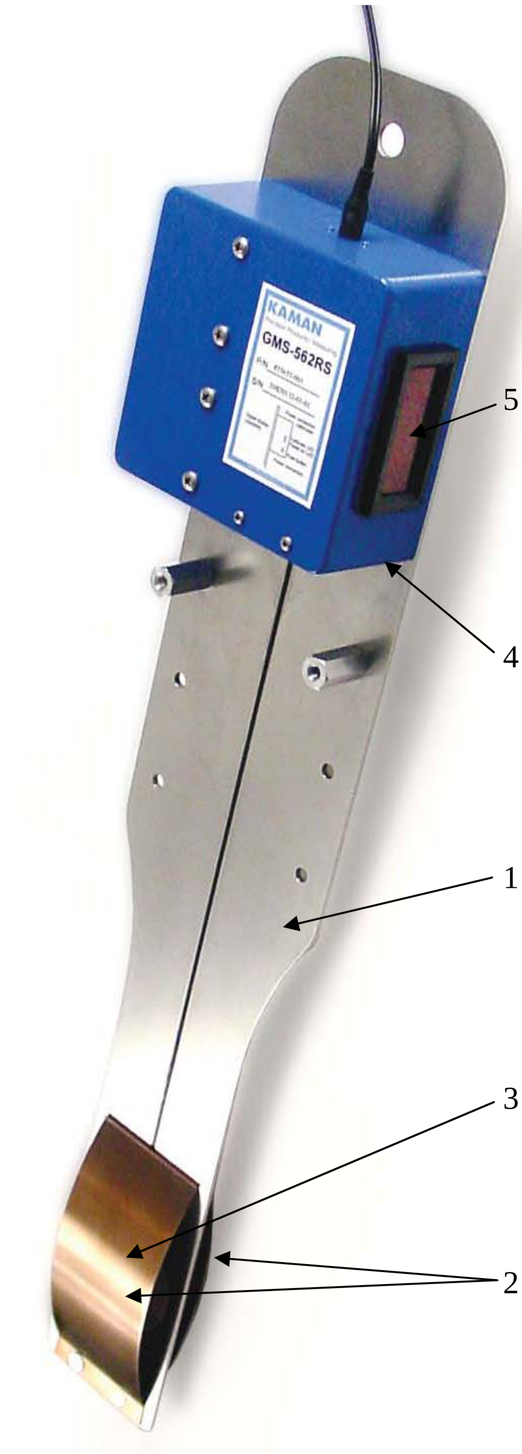

Figure 3

Limitations Preventing Direct Measurement
The ideal target for eddy current displacement sensors is electrically conductive and has a smooth flat surface equal to 2.5x to 3x the diameter of the sensor. Although there is plenty of electrically conductive material to sense in a rotor and stator, the design of each prevents accurate direct measurement. Variations in materials, laminated segments and changes in topography of the OD of the rotor and ID of the stator will cause variations in the sensor output.

The Design Solution
Sensing the OD and ID of the rotor and stator would involve too many error sources to make an accurate measurement. The solution that proved to be without error sources was to incorporate suitable targets as part of the instrument. Eddy current induced in a target surface is an RF skin effect. The current induced into the surface is only a few mils (1mil=0.001”) in steel. This allowed the use of thin steel curved springs for the target.

With the sensor coil mounted in a stainless steel flat bar, as each spring deflects towards the sensor when the flat bar is inserted into the rotor-stator gap, the springs form to the ID of the stator and OD of the rotor. The eddy current coil indicates the distance between the two springs. An offset added to the eddy current sensor output compensates for the thickness of the springs. The resulting output of the sensor indicates the rotor-stator gap, and is read out in inches on the LED display.

Figure 3 items:
1. Flat bar
2. Steel spring targets
3. Eddy current sensor coil
4. Eddy current sensor driver
5. LED digital display

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In Operation
As shown in figure 4, the steel spring targets are deflected by the rotor and stator when the instrument is inserted in the gap between them.

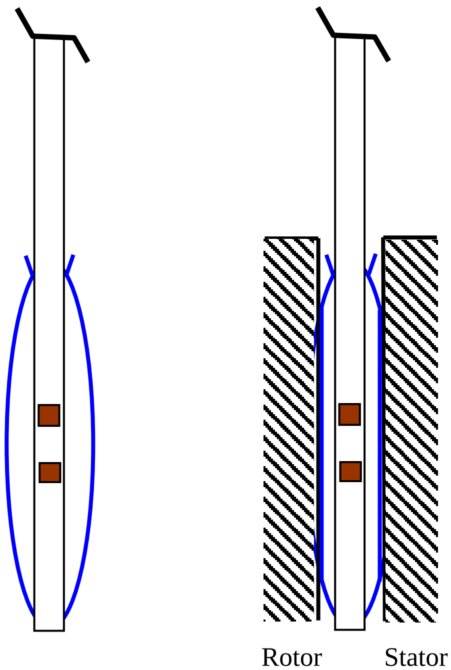

Figure 4

As the rotor stator gap varies, the sensor will detect a change in the distance between the two springs and vary the output on the digital display to indicate the rotor-stator gap.

Calibration
The electronics includes a multi-use push button interface, with a corresponding red/green LED. In normal operation the LED will glow red to indicate power is on and the unit is operational. Depressing and holding the pushbutton for 2 seconds puts the unit into calibration mode, a rapid flashing green LED indicates the unit is in calibration mode. Using a suitable fixture to depress the two springs to a 0.562” overall thickness and depressing the push button will set the full scale dimension. The flashing of the green LED will slow. Depressing the two springs to a 0.250” overall thickness and depressing the push button will set the minimum scale dimension. The LED will return to red indicating run.

Tare
Once calibration is complete, the push button servers to tare the output to a known gap. Simply insert the spring end into a gap equal to the tare distance, or depress the springs to the tare distance and momentarily depress the push button. The electronics will tare the output to reflect the tare distance.

Insertion Depth
Stops are provided for the user to set an insertion depth. This is important as the gap between misaligned rotor-stator assemblies can change with the depth that the measurement is made. See figure 5.

Simply position the stops into the holes provided to limit the maximum depth of the sensor and target springs.

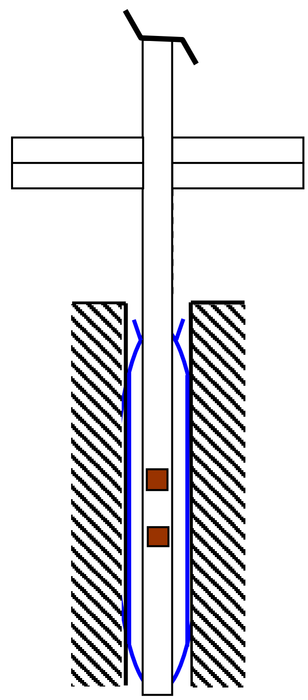

Figure 5

Benefits
The system provides accurate and repeatable gap measurements between 0.250” and 0.562”, with a 0.001” resolution. The simplicity of the design eliminates operator variables while dramatically reducing the overall time it takes to align the rotor to the stator.

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