Underwater automated system for grid and structure inspection

Underwater crack inspection

Among the inspection tasks prescribed for civil engineering structures and oil and gas infrastructures, underwater crack detection belongs to the most challenging. This application note aims at demonstrating that the eddy current (EC) technique can be applied to these tasks reliably and efficiently, in particular with automated systems. Our case study documents an application where the most advanced condition based maintenance procedures have been applied to a hydro power plant. The developed system matches the demand for limiting the exposure of divers to hazardous conditions and for a minimal or no impact on the plant operation. The results provided by the inspection system was key to condition based replacement of cracked grid components.

Case study: Hydro power plant in Geneva

The run-of-the-river power plant of Seujet in Geneva consists of 3 turbines producing 25 GW/h per year. It is located at the place where the Lake of Geneva ends and the Rhone river continues its westward flow. The same dam is used to control the level of the Lake of Geneva. Underwater grids, 16 m high and 30 m long in total, prevent debris larger than about 10 cm to flow into the turbine.

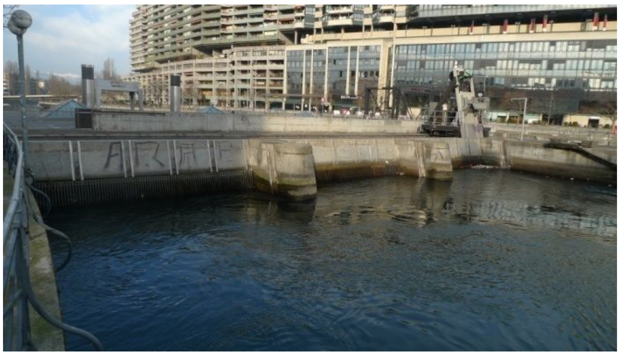

Figure 1: photograph of the dam of the Seujet hydro power plan

Inspection specification

Following the failure of few elements of the grids, the owner decided a systematic inspection of the grids to plan their replacement. Analysis of the failed samples pointed to the embrittlement of vertical bars (rectangular section) at the location where the horizontal bars (circular section) have been welded (see Figure 4). Cyclic displacement of the bars caused by the flow resulted in fatigue crack propagation from the weld to the bar edge and, at few occasions, to the failure of the vertical bars. Project specification therefore consisted in a systematic inspection of the 7'300 welded intersections, with a crack detection threshold of 2 cm. Based on the crack distribution provided by the inspection, the owner could prioritise the replacement of the most damaged panels and spread its investment over a longer period of time while keeping the risk of failure low. Additionally, the inspection should have no impact on the operation of the plant, which together with the volume of the inspected tasks, excluded the use of a diver.

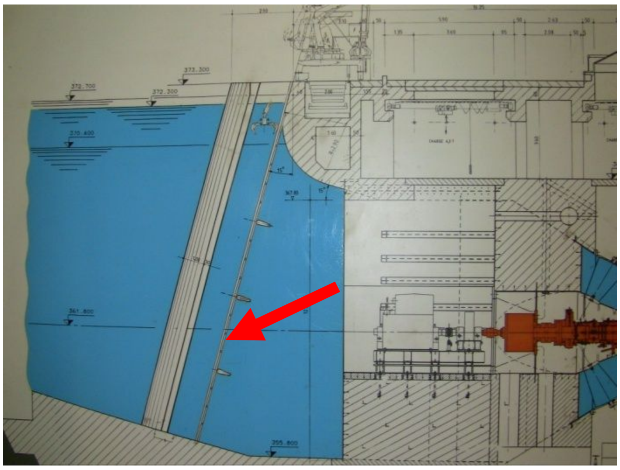

Figure 2: Cross section view of the dam and the turbine. The grid is marked by a red arrow.

Multichannel eddy current crack detection system

The system proposed by the consortium of Sensima Inspection and Hydro Exploitation consisted of 8 eddy current sensors: Each sensor was made out of 2 coils connected in series and located on each leg of "U" shaped holder positioned around a vertical bar, therefore ensuring a good cancelation of the lift off signal. The "comb like" sensor array with 8 "U" probes was attached to the crane used to clean the grid (see Figure 3) and used to inspect a portion of 8 bars per scan performed at 0.3m/s. The crane was moved along the dam to inspect the full grid.

Key to the project was the possibility to attach a very compact, water proofed and ruggedised multichannel EC electronic unit next to the probes, therefore minimising the effects of spurious signals caused by long analog cables.

Figure 3: Bucket of the crane used to clean the grid with the inspection system attached inside it. The red arrow points to one of the 8 "U" shaped EC sensors. At the bottom of the grid, at about 15m underwater, the bucket is closed and the EC sensors are positioned on the bar to be inspected. Inspection is performed while the bucket is pulled up.

The coils where driven at 150 kHz and the voltage measured in absolute configuration was demodulated at the interrogating frequency. A map of 44 bars is presented in Figure 5 with the bar number as horizontal axis and the position in m as vertical axis. The colour code is the amplitude of the component of the demodulated signal projected along the panel gap direction. This has been determined from a calibration sample produced from the same carbon steel as that of the grid. In addition, the direction of the cracks in the impedance plane has been determined from WEDM notches performed on the same sample.

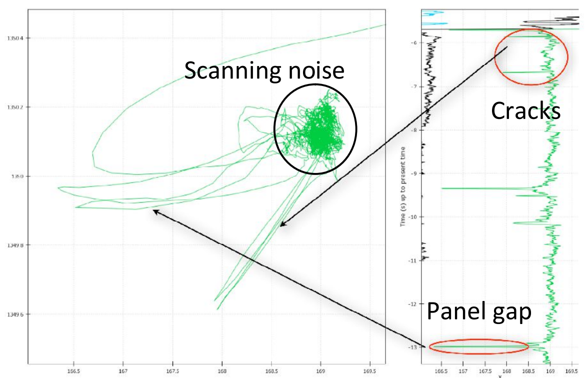

Figure 4: Impedance plane (left) and time series of the horizontal component of one probe passing over the gap between the panel (bottom) and 2 defects (top). Note the remarkable low scanning noise compared to the crack indications.

Analysis of defects

Identification of indications has been performed using a standard NDT EC methodology based on the selection of data corresponding to trajectories deviating from the scanning noise and from the expected panel gap or edge trajectories.

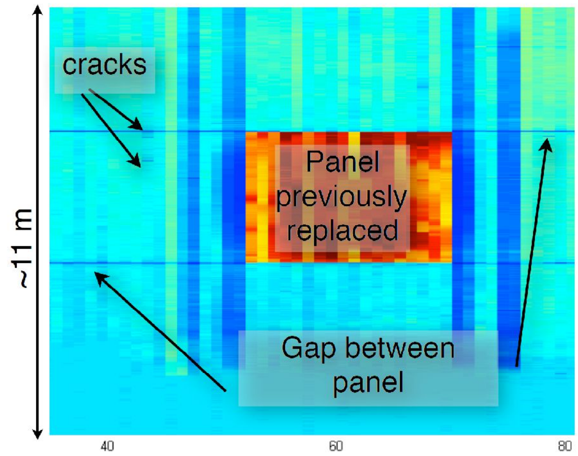

Figure 5: C-scan of a about 11x4m² part of the grid with the horizontal component of the impedance in color code. The vertical axis is the vertical length of the bars and the horizontal axis the bar number. The cracks of Figure 4 appear as 2 short dark blue lines ("cracks") located on one bar while the gap between the panels is seen as dark blue lines crossing horizontally the grid. These features show distinct phase response. A panel, previously replaced, appears as a different color because different materials have been used.

Moment of Truth

Panels showing the "cracks" indications presented in the previous section have been taken out of the grid and replaced with new ones. Although the cracks were not visible on the raw panels, grinding of the rust demonstrated the presence of long cracks, extending as expected, from the weld to the bar edge. An example of such a crack is given in Figure 6.

Figure 6: Grinded intersection of a panel showing a crack extending from the weld to the bar surface.