# Wireless condition monitoring for de RA-6 research reactor

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## *Abstract*

The vibration laboratory at C.A.B. has a great experience with the analysis and diagnostic of symptoms of failures in the rotating equipment of the R-6 research reactor and in our longest NPP (CANDU 600 Mw), located in Embalse town, Córdoba city, Argentina.

**Objective**: The standard condition monitoring instrumentation system were designed for large equipment operating under different environmental conditions and sensitivities. The signal processing is not flexible and the diagnostic is an expensive method for the small poll type research reactors.

This papers describes the research and development which are related whit the new concept, cheaper and flexible condition monitoring instrumentation system.

Implementing a vibration analysis measurements technique with a sensor inside (in the pool) of the nuclear reactor RA-6, and mainly based on fft signal processing, an extensive program for vibration source identification was done.

Different nuclear power conditions were monitored as full power and in zero power, also.

This zero power shows the best acoustical environmental, because the cooling pumps are stop, and the core is cooling by natural convection.

Two sensors were mainly used as the detector´s subsystem. One of these detectors was an accelerometer attached to the top of the fine control rod and the other one was a water resistant omnidirectional microphone which was located underwater at different distances from the nuclear core.

All the signal measurement by this two sensors were recorded and then was processed.

Both signal was acquired at the same time for correlation analysis purposes. The analysis was composed by a "Spectral Dynamics SD380" connected to a P.C. with dedicated post processing software.

On the other hand, some calibration and sensitivity comparition was done using an SKFCM40, dual channel data collector & analyzer.

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## Introduction

Is well know the power of vibration signal analysis as a standard tool for mechanical condition monitoring.

Neutron noise analysis is another important tool , which is usually combined with vibration analysis methods for the detection and tracking of early failures in different reactor components such as : control rods, mechanisms, valves, pumps, in-pool structures and fuel elements.

This report describes the implementation of a multipoint basic measurement technique using two sensors installed : one on the fine control rod and the other, is an underwater microphone.

This sensors' distribution is quite knew and with a poor utilization in the in-service inspection for the pool type research reactors.

Vibration is directly related with the mechanical forced condition during different reactors'operating stages, and in all of them it is possible to discriminate the own frequency responses of each component, in a wide power range ( full, intermediate and zero).

## Experimental set-up

The measurements were done detecting pressure fluctuations and acceleration coming from two detectors, and calculating the autopower spectral densities of both electrical's signals separately.

The accelerometer is a piezoelectric type skfcm 797 with a magnetic base., and the pressure sensor is a capacitor microphone , general porpouse.

The rector is located 500 m far from the vibration laboratory. For that reason we decided to implement two different measurement system.

The first one is an old data tape recorder with its, associated conditioning electronics, where signals were recorded. Then this equipment was connected in the laboratory to a real time universal signal analyzer ( Spectral Dynamics SD380), which was controlled by a P.C. with an gpib interface and a general software platform for post processing.

The second one was a real time "spectrum" unit (data collector SKFCM40) where the sensors (microphone) in the reactor, were connected to a radio transmitter and the remote data collector (located in the vibration laboratory) was connected to the radio receiver (Figure 1). This way allows us upload the data base directly and with the possibility of fast diagnostics.

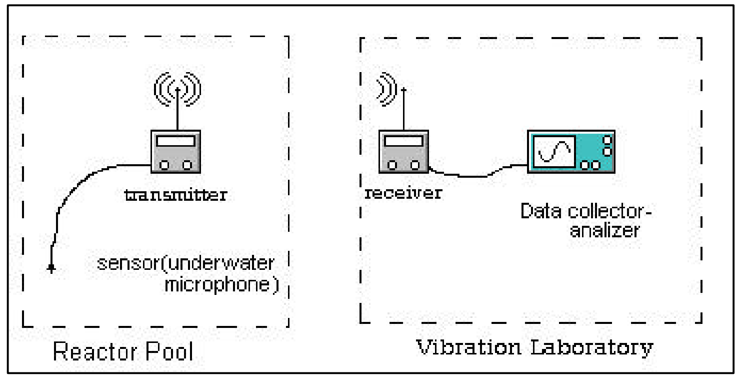


**Figure 1**. Basic experimental set-up of wireless communication for remote monitoring.

## Results

*Bump Tests*: This test was carry on for the detection of several vibration response frequencies of the different components. The results of this test can be observed in the data tables 1,2,3,4,5 and 6.

| Peak number | Frequency |
|---|---|
| 1 | 375 Hz |
| 2 | 725 Hz |
| 3 | 1000 Hz |
| 4 | 1350 Hz |
| 5 | 4525 Hz |
| 6 | 4675 Hz |
| 7 | 4825 Hz |

**Table 1**.Shows the characteristic response frequencies from the reactivity control mechanics bridge.

| Peak number | Frequency |
|---|---|
| 1 | 1200 Hz |
| 2 | 2400 Hz |
| 3 | 3600 Hz |
| 4 | 4675 Hz |

**Table 2**.Shows the characteristic response frequencies from the reactor pool.

| Peak number | Frequency |
|---|---|
| 1 | 1300 Hz |
| 2 | 2600 Hz |
| 3 | 3900 Hz |
| 4 | 4675 Hz |

**Table 3**.Shows the characteristic response frequencies from the fine control rod.

| Peak number | Frequency |
|---|---|
| 1 | 1325 Hz |
| 2 | 2750 Hz |
| 3 | 4675 Hz |

**Table 4**.Shows the characteristic response frequencies from the control rod 1.

| Peak number | Frequency |
|---|---|
| 1 | 30 Hz |
| 2 | 80 Hz |
| 3 | 165 Hz |
| 4 | 192 Hz |

**Table 5**.Shows the characteristic response frequencies from control rod 1, while it is moving.

| Peak number | Frequency |
|---|---|
| 1 | 375 Hz |
| 2 | 725 Hz |
| 3 | 1000 Hz |
| 4 | 1350 Hz |
| 5 | 4525 Hz |
| 6 | 4675 Hz |

**Table 6**.Shows the characteristic response frequencies from fine control rod, while it is moving.

*Reactor in "zero power condition "*

In the figure 2 is possible to see the frequency spectrum calculated from the accelerometer's signal. As it can be seen it shows the frequencies corresponding to the control mechanisms bridge ($A_1$=375 Hz, $A_2$=725 Hz, $A_3$=1000 Hz).

It is also shown the frequency response corresponding to the fine control rod.( $D_1$=1300 ).

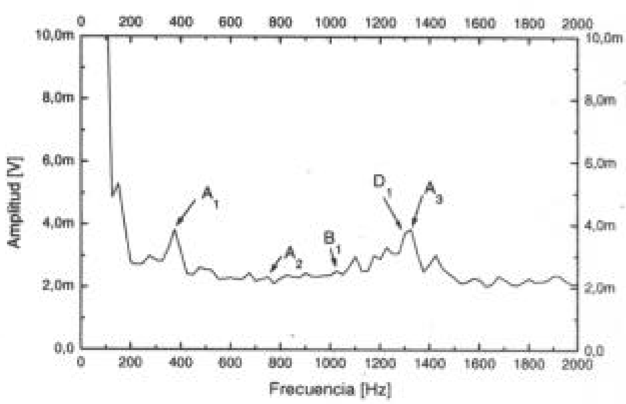


**Figure 2**. Shows the principal peaks which are tracked with the accelerometer in "zero power condition ".

In the figure 3 is possible to see the frequency spectrum calculated from the microphone's signal, this spectrum is similar to the figure 1, except that the peak at 1Khz is smaller.

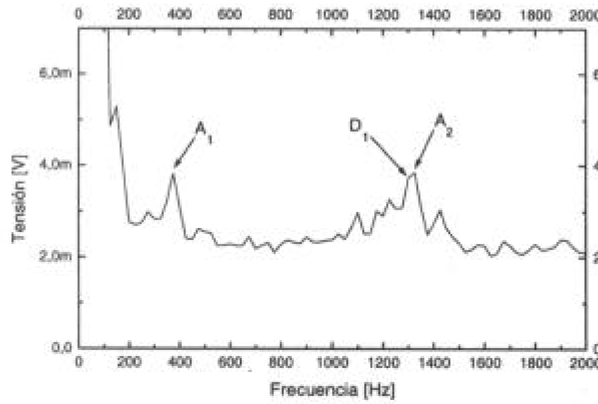


**Figure 3**. Shows the principal peaks which are tracked with the microphone in "zero power condition ".

*Reactor in critical condition with pumps in operation*

In this condition the calculated spectrum from the accelerometer's signal can be seen in the figure 4. This shows a high energy peak with frequency at 220 hz. which is a new response induced by water flow. Also, the same happens between 400 and 1000 Hz.

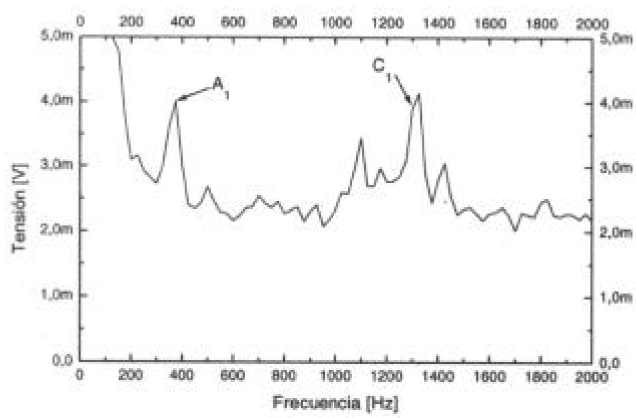


**Figure 4**. Shows the principal peaks which are tracked with the accelerometer when reactor is in critical condition with pumps are running.

In the figure 5 is possible to see the frequency spectrum calculated from the microphone's signal when reactor is in critical condition while pumps are in operation. A frequency at 375($A_1$) Hz is related to the blade pass frequency of the pump, and one natural frequency from the control mechanics bridge.

Another intensity can be seen at 1375 Hz ($C_1$) related to the control rod 1.

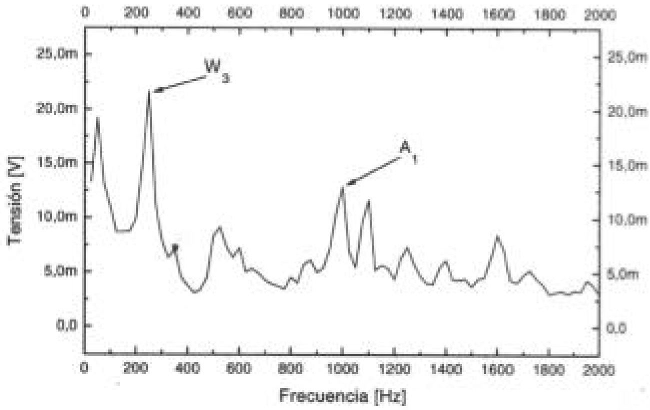


**Figure 5**. Shows the principal peaks which are tracked with the microphone when reactor is in critical condition with pumps running .

*Full Power condition*

The figure 6 shows the spectrum calculated with the accelerometer´s signal. In this figure it is observed activity near 250, 1000, Hz.

The first peak is related to the fine control rod mechanism ,movement, and the second cams from the control mechanism bridge.

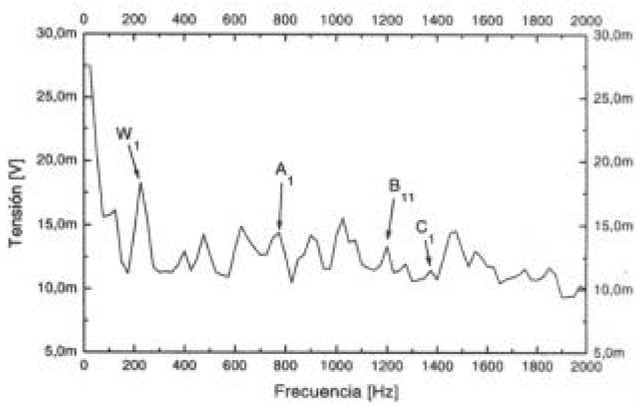


**Figure 6**. Shows the principal peaks which are tracked with the accelerometer in full power condition

The microphone plot (figure 7) shows the movement of the fine control rod (W4=95).It is also possible to see energies related to the control mechanics bridge(A1=375; A2=1350 Hz.), to fine control rod ($D_1$=1300 Hz) and control rod 1 ( $C_1$= 1375 Hz).

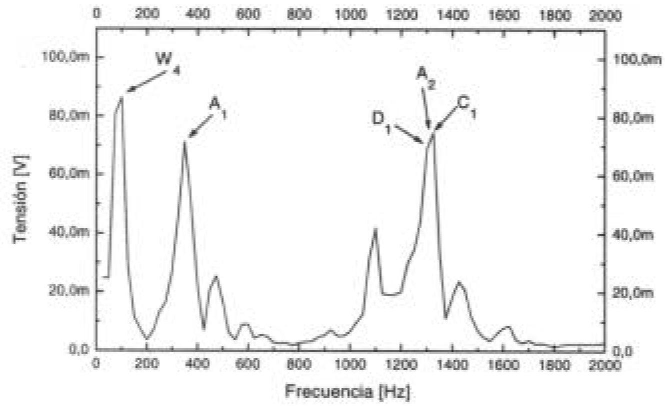


**Figure 7**. Shows the principal peaks which are tracked with the microphone in full power condition

**Conclusions**

This work demonstrates that different operating conditions could be distinguish from the calculate spectrums obtained from the vibration measurement and analysis.

For all the frequencies we had observed along the experiment, the level of them has been increased when the main cooling pumps were running.

The fact related to the possible identification of the control rods responses under movement, let us conclude that with technique we can recognized operative actions.

The low complexity and cheap instrumentation installed in the pool surface. Therefore, this method simplifies the reactor operators and engineers interactions.

The most important property of the experiment is the possibility of an immediate and really remote monitoring from every place in the world.

The systematic analysis of the signals allows to the analyst share the same level of information simultaneously with the operator ( in the reactor’s control room/field).

This configuration based on wireless communication makes possible the statistical information treatment in several other local operators’places than remote analyst action, sharing a simultaneous decision making.

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