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PREVENTIVE MAINTENANCE INSTRUMENTATION RESULTS IN SPANISH NUCLEAR POWER PLANTS

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ABSTRACT

This paper is a recompilation of the most significant results in relation to the researching in Preventive and Predictive Maintenance in critical nuclear instrumentation for power plant operation, which it is being developed by Logística y Acondicionamientos Industriales and The Isirym Institute of the Polytechnic University of Valencia. Instrumentation verification and test, it is a priority of the Power Plants Control and Instrumentation Department' technicians. These procedures are necessary information for the daily power plant work. It is performed according to different procedures and in different moments of the fuel cycle depending on the instrumentation critical state and the monitoring process. Normally, this study is developed taking into account the instantaneous values of the instrumentation measures and, after their conversion to physical magnitude, they are analyzed according to the power plant operation point. Moreover, redundant sensors measurements are taken into consideration to the equipment and/or power plant monitoring. This work goes forward and it is in advanced to the instrument analysis as it is, independently of the operation point, using specific signal analysis techniques for preventive and predictive maintenance, with the aim to obtain not only information about possible malfunctions, but the degradation scale presented in the instrument or in the system measured. We present seven real case studies of Spanish Nuclear Power Plants each of them shall give a significant contribution to problem resolution and power plant performance: Fluctuations in sensor lines (case 1), Air presence in feed water lines (case 2), Root valve partially closed (case 3), Sensor malfunctions (case 4), Electrical source malfunctions (case 5), RTD malfunctions (case 6) and LPRM malfunctions (case 7).

1. INTRODUCTION

Today, more and more work is being done in setting up *Management Systems for the Life and Monitoring of Nuclear Power Plant Component Conditions*. To do so, it is necessary to have information about the plant systems and components monitored, including the information provided by the manufacturer and by the power plant's instrumentation.

The Life Management Systems take for granted that the measurement given by the instrumentation is correct. This is why it is important to monitor the instrumentation performance, and not only the ones that are essential for the correct functioning of the plant but also all instrumentation involved in the condition monitoring processes. This is where preventive maintenance of this instrumentation plays a key role.

The work of checking the instrumentation is part of the daily work of the Nuclear Plant Instrument and Control Technicians. Their work follows procedures and is a source of information on the day to day operating of the plant. This is carried out according to distinct procedures and at different moments in the fuel cycle depending on how critical the information is and the process being monitored.

Normally this study is carried out taking into account the instantaneous values from the instruments' measurements and converting these to a physical magnitude depending on the point of operation of the plant. Redundant sensors' measurements are also relied upon to monitor the apparatus and/or the plant.

Our experience and preventive maintenance of the nuclear instruments goes further and looks into the analysis of the instrument itself, independently of the point where it operates. It is here that specific signal analysis techniques for preventive and predictive maintenance come into play in order to obtain information not only about possible malfunctions but also about the degree of deterioration in the instruments and the system that is carrying out the measurement.

In this paper, we present seven real case studies of Spanish Nuclear Power Plants each of them shall give a significant contribution to problem resolution and power plant performance:

Case 1: Fluctuations in sensor lines.
Case 2: Air presence in feed water lines.
Case 3: Root valve partially closed.
Case 4: Sensor malfunctions.
Case 5: Electrical source malfunctions.
Case 6: RTD (Resistance Temperature Detector) malfunctions.
Case 7: LPRM (Local Power Range Monitor) malfunctions.

2. CASE STUDIES OF SPANISH NUCLEAR POWER PLANTS

2.1. Case 1: Fluctuations in Sensor Lines

All mechanical systems that are rotary or subject to external vibrations have their own frequencies characteristic of the system. When these frequencies vary in range or change their amplitude abruptly during normal plant operation, this is symptomatic of deterioration or malfunction in the system itself or other systems that are interdependent with it.

In order to monitor systems, different instruments are used for measuring level, flow rate, pressure, temperature, impedance, etc. As has already been mentioned, information on the electrical magnitude is acquired and the system is monitored, but except for the plant's critical instruments there is no preventive or predictive maintenance for this instrumentation.

This means that deterioration or malfunctions in the apparatus may go undetected until the damage is such that only corrective maintenance can be carried out.

In the case of Nuclear Power Plants, we also have redundant measurements available to try to locate and/or distinguish where the problem is. Even so, as the information being used is usually provided by the processes' computer, the data available has been numerically converted to obtain its physical magnitude and in the process relevant information for preventive and predictive maintenance has been lost.

Figure1 illustrates this case. The situation shown corresponds to a problem with a PWR reactor's pressurizer. When the instruments that measure this feature's behaviour were analysed, it was seen that there was an oscillation in the signal that did not correspond to the behaviour of the previous measurements made. The instrumentation was measured downstream in the apparatus and it was seen that said oscillation was also present. The possibility of it being a problem in the measuring instrument was thus discarded. Even so, it was necessary to analyse the behaviour of this instrumentation and provide a technical report about the Response Time in order to calculate the Loop Time.

The oscillation was so strong (see Figure 1) that it altered the signal's behaviour such that it was necessary to use advanced signal analysis techniques in order to be able to separate the information into two signals. This procedure was necessary because the measured signal is composed of these two independent signals:

- One signal with the information of the oscillation, that was provided to the plant technicians so they could locate the problem in the system.
- One signal with information regarding to the transmitter, with which the preventive analysis was carried out.

In order to separate the two signals we resorted to the Singular System Analysis (SSA). This technique is a powerful tool to remove the contribution of the unwanted oscillations (induced by some components of the plant) without impact on the information stored in the signal [1-2].

Specifically, in our case, SSA technique was used to remove both unwanted oscillation components and the contribution of high frequencies of the signal, due to the malfunction of some plant components. Furthermore it was possible to eliminate the noise.

Figure 1 shows a sample of the original signal acquired from the sensor and its analysis in terms of frequency.

Figure 2 shows the signal without the oscillation, after the application of SSA technique. This signal was used to carry out the preventive and predictive maintenance.

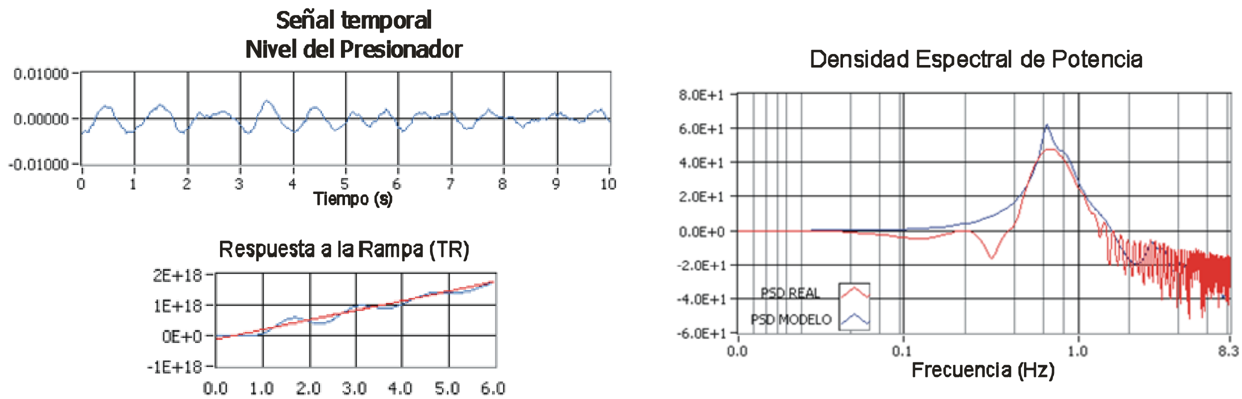

Figure 1. Fluctuations in sensor lines

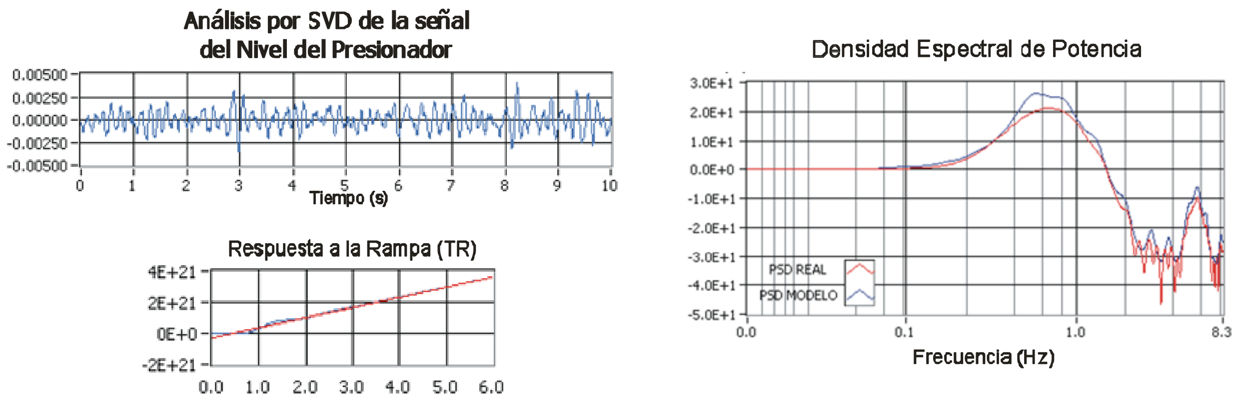

Figure 2. Signal without the oscillation after the application of SSA technique

2.2. Case 2: Air Presence in Feed Water Lines

While acquiring the data in a Nuclear Power Station, it was seen that the measurements in the three Feed Lines did not behave in the same way. All the redundant sensors were analysed for each one of the lines and these were compared with different measurements carried out in previous cycles, and the conclusion was reached that something was happening in Line 1.

Analysing the acquired signal in detail, it was seen that a non-Gaussian amplitude distribution was present (see Figure 3). It was also seen that the signal had too many low values that could make the transmitter raise the alarm due to low level.

Furthermore a frequency analysis was carried out with the technique known as Power Spectral Density (PSD), in order to compare the redundant sensors. It was seen that the spectral behaviour was similar in the frequencies corresponding to the instruments mechanical characteristics, but there was strange behaviour at very slow frequencies (1-10 Hz), see Figure 3.

The analysis of one redundant sensor (line 2) can be seen in figure 4. Histogram and PSD are different from ones showed in Figure 3.

After making a bibliographical study [3-4] and reviewing the information with technicians from the Plant, the conclusion was reached that this alteration was due to the presence of air in the sensors' line and that action should be taken to correct this.

The statistical analysis and the frequency analysis were enough to detect the problem. In this case it was not necessary to resort to advanced analysis tools.

In this case there was no malfunction or deterioration, but an improvement in the running of the system was achieved, which is another step forward in the plant’s preventive maintenance.

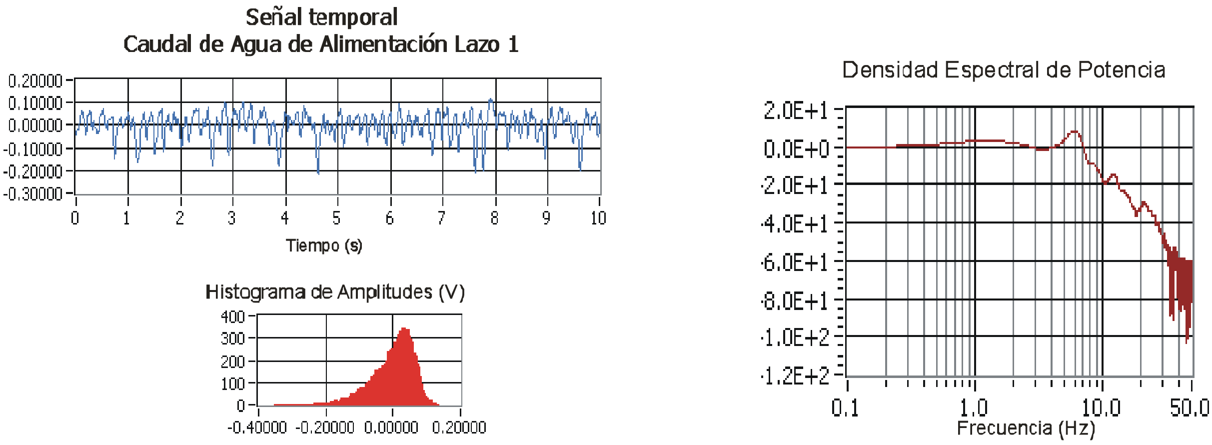

Figure 3. Air presence in feed water lines.

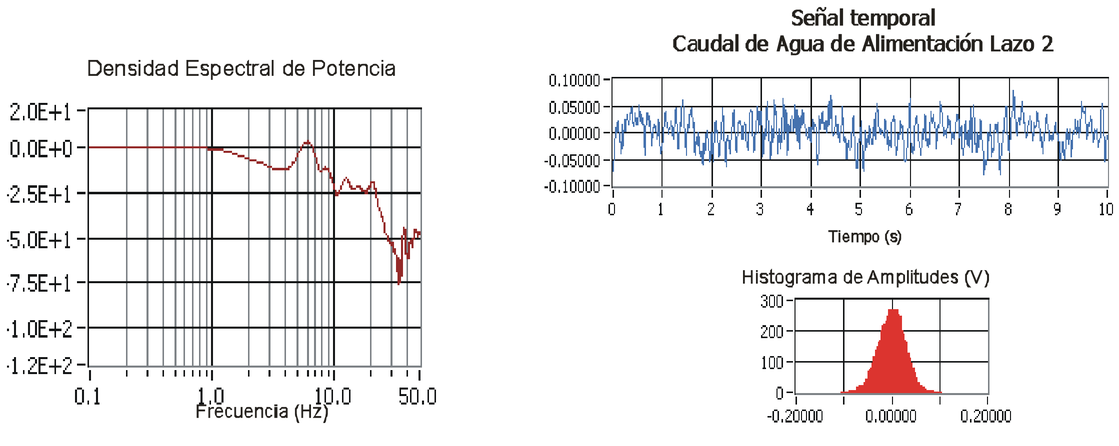

Figure 4. Analysis of a redundant sensor.

2.3. Case 3: Root Valve partially Closed

This case follows on from the previous one. On acquiring signals from the plant and taking into account the redundant instrumentation, it was seen that one of the transmitters had much lower amplitude than its redundant ones and the measurements carried out in previous cycles.

When a detailed analysis was carried out, it was seen that there was anomalous behaviour as if it were being dampened. The temporary magnitudes were compared, and the frequency analysis and the differences were even more significant: there was a double distribution of amplitudes, and the frequency analysis behaved completely differently. Analysing the case with technicians from the plant, the conclusion was drawn that the dampening of the transmitter's signal was due to partial closing of the transmitter's root valve. This caused the dampening seen in the signal's amplitude, the deformation of the histogram of amplitudes (a double density is seen) and a considerable increase in the Response Time.

This incidence led to action being taken in the plant, as this situation could mean that if there were an incident, one of the three transmitters would not respond and therefore the plant's safety would be affected. Once action was taken and the root valve was positioned correctly, a new measurement was made after a period for settling and levelling out, and it was possible for the transmitter's real response to be analysed.

Figure 5 shows the instrument analysis before (up) and after (down) correcting the transmitter.

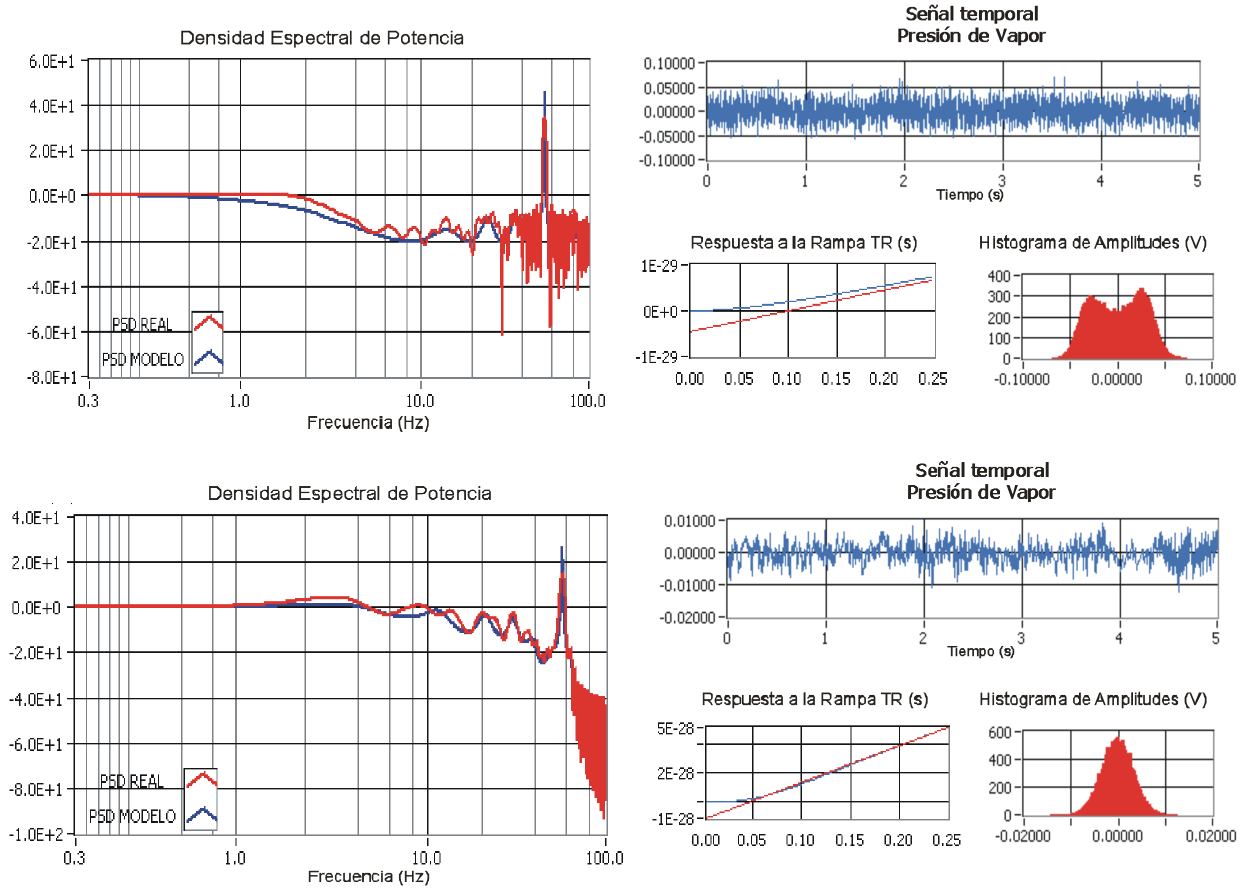

Figure 5. Root valve partially closed

2.4. Case 4: Sensor Malfunctions

This case does fall within preventive and predictive maintenance of the instruments, since a high level of deterioration was clearly detected in the measuring instrument.

To come to this conclusion, the aforementioned tools were used: analysis of redundant instrumentation signals (Sensors A and B) from the cycle in which measurements were taken (Figure 6), and from a previous cycle (Figure 7).

In Figure 6, it is shown the frequency analysis (PSD) of redundant sensors A and B, with very different behaviours. A comparison with their values in the previous cycle was made (Figure 7). The malfunction in the sensor B can be seen by comparing the frequency responses of its both cycles.

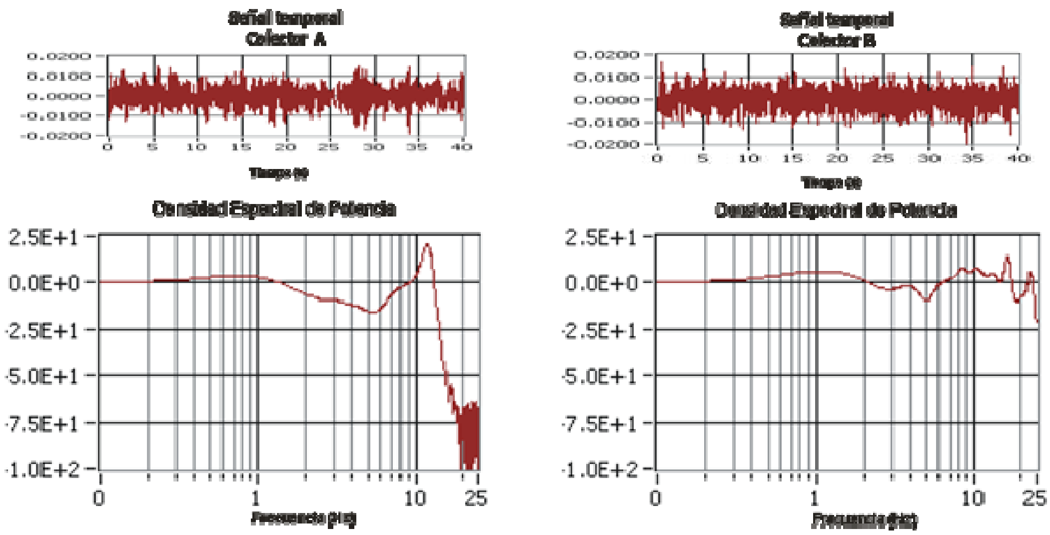

Figure 6. Analysis of redundant instrumentation signals (Sensors A and B)

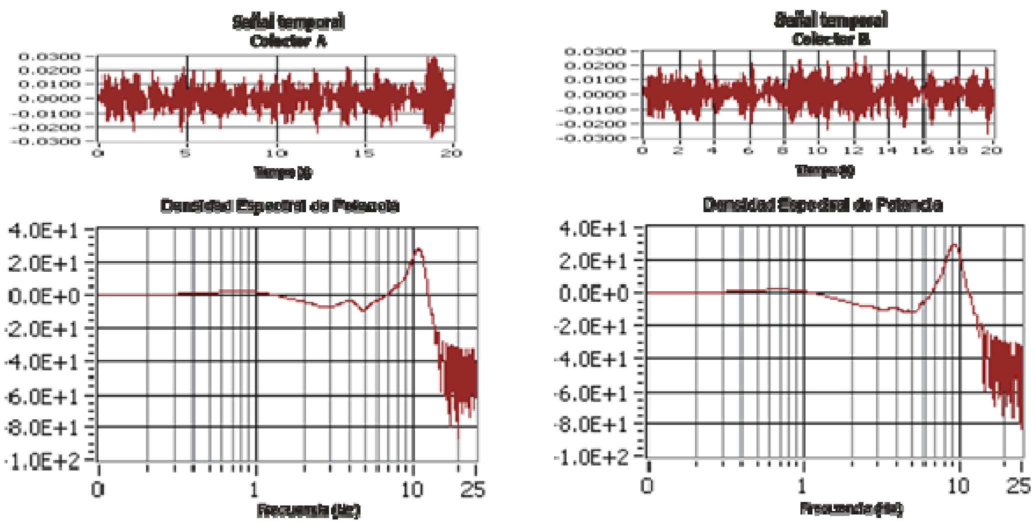

Figure 7. Analysis of redundant instrumentation signals (Sensors A and B) from the previous cycle.

During the next recharge of the Plant, the transmitter was replaced. In the following measurements carried out with the transmitter in operation the two redundant transmitters behave similarly in both time and frequency, and that the transmitter's behaviour is similar to what it had been in the previous cycle.

The transmitter's fault was confirmed by the manufacturer, who agreed with the diagnosis.

2.5. Case 5: Electrical Source Malfunctions

Figure 8 shows the case of electrical source malfunctions. On analysing two redundant sensors, it was seen that one of the signals had different ranges and behaviour.

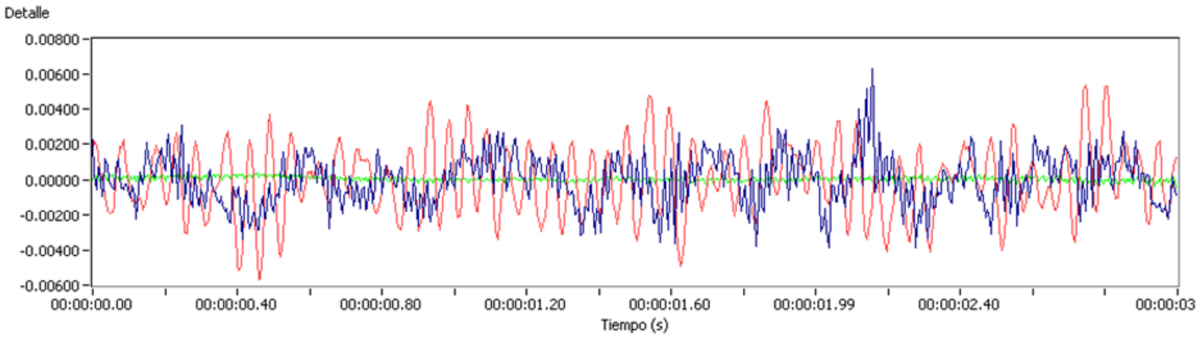

Figure 8. Electrical source malfunctions

A detailed analysis of the frequency response showed there was a dominant frequency that did not appear in the other redundant ones or in other sensors in the sensors' line. The conclusion was that this anomaly could only be coming from either the transmitter itself or its power supply source.

The transmitter was behaving correctly in terms of magnitude and frequency, but on magnifying the data graph it was seen that periodically there was a very fleeting effect. This was commented to the plant's technicians and it was requested that the power card should be measured.

After acquiring and analysing the electrical signal from the power source, a ripple was seen that was transmitted to the signal provided by the transmitter, thereby altering its behaviour. However, this power source had passed the calibration verification according to the parameters provided by the manufacturer.

The power card was replaced and the instruments were measured and analysed again. The transmitter's signal behaved normally in operation.

2.6. Case 6: RTD Malfunctions

Following a request by a Nuclear Plant's Instrumentation and Control Department, a detailed analysis was carried out on an RTD or temperature measuring sensor that was behaving anomalously.

After measuring and analysing the RTD and its redundant instrumentation, it was seen that one of them showed a dominant frequency of 50Hz and its frequency response changed completely as if the instrumentation were not capable of “seeing” the system it was measuring. The incident was commented to the Instrumentation and Control Department’s Technicians, and after inspecting it when the plant was stopped it was found that it had a completely deteriorated electric circuit.

Figure 9 shows the analysis graphs corresponding to this case. In these, one can clearly see the instrumentation’s different behaviour.

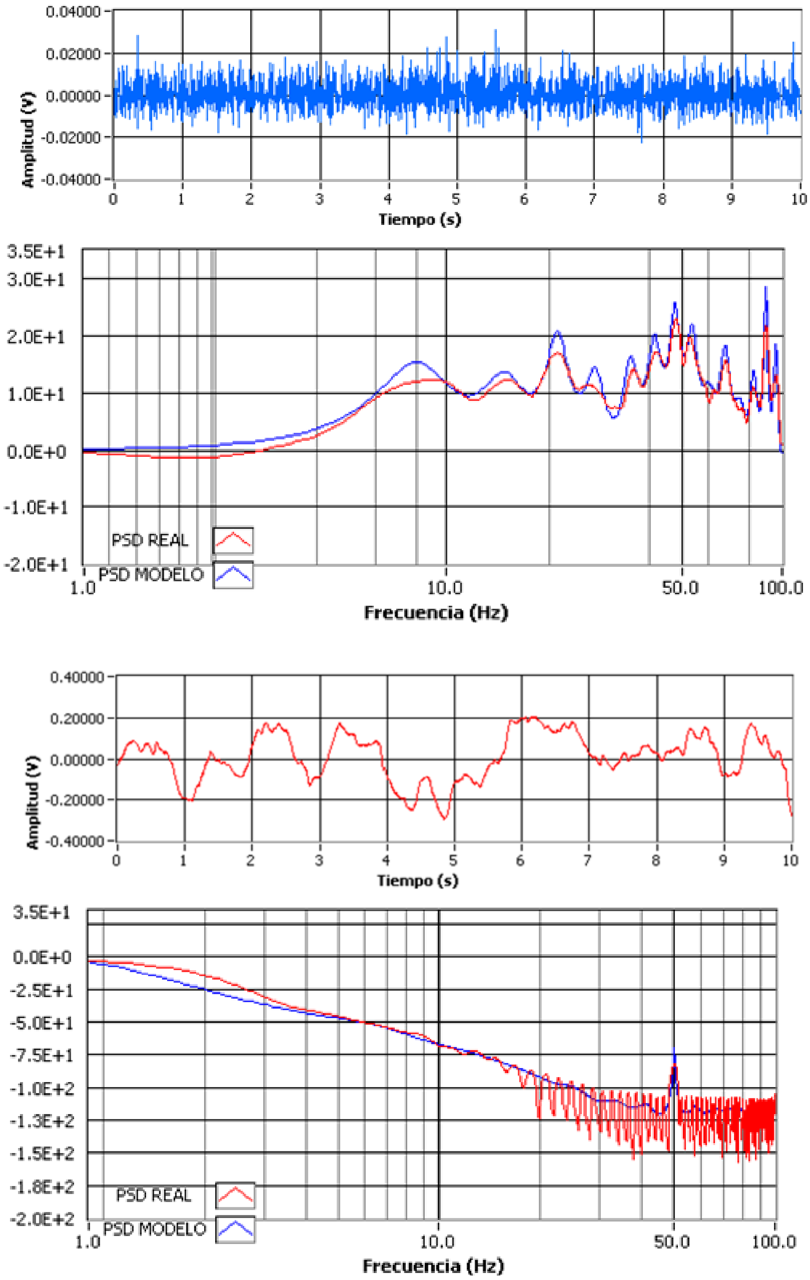

Figure 9. RTD malfunctions

2.7. Case 7: LPRM Malfunctions

LPRMs (Local Power Range Monitors) are inspected using a computer tool designed by this company that automatically carries out the necessary tests according to criteria defined by the manufacturer and the plant itself. The neutron detector is subjected to a voltage ramp (from 0 to 300 volts) and its response is measured in terms of intensity in order to know if it is operational. This inspection is carried out with the instrumentation in operation in order to analyse the amount of burn-out and check the LPRM detectors that have to be changed on reloading. Figure 10 shows the voltage ramp response for a correct LPRM. When a detector has a different response shape, like in Figure 11, we can conclude that the LPRM has a malfunction and it has to be changed.

In this case, instead of carrying out a preventive and predictive maintenance service, a computer tool has been developed to carry out tests and deliver a report according to the accepted criteria defined.

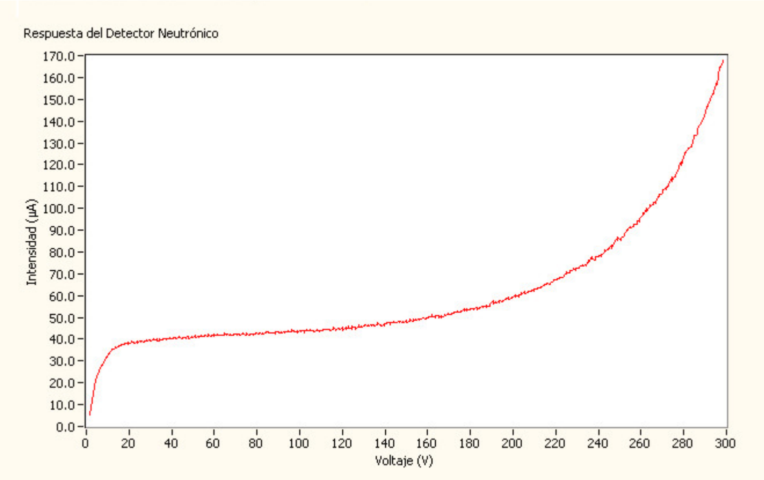

Figure 10: LPRM response reference in operation.

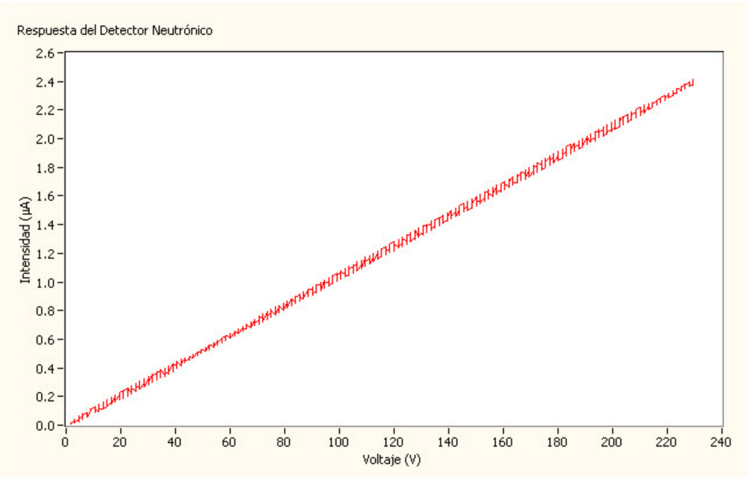

Figure 11: LPRM response in operation with a malfunction.

In addition, it is necessary to inspect the LPRM in storage to check they are in perfect condition before installing them. If an LPRM is replaced when a plant is stopped, one last inspection is carried out before starting up the plant in order to check it has been installed correctly and that there have been no problems in setting it up.

3. CONCLUSIONS

As has been seen throughout this article, there are no predictable rules or behaviour for preventive and predictive maintenance when it comes to malfunctions or deterioration. Each plant, each system analysed, each instrument and at all times during operation, the instrumentation's response has its own rules.

In order to carry out this work, it is necessary for the staffs that do the testing to have experience and information available, whether the latter be from other operation cycles or other NPPs, as well as interdisciplinary knowledge (analyses of vibrations, knowledge of how machines behave, electronic behaviour, etc.). In addition, even when dealing with a technical branch of knowledge, it is essential for them to be intuitive and know how to coordinate knowledge and communicate with the plant's Instrumentation and Control technicians to find the correct solution.

Complete plant maintenance is becoming more and more important in itself. On top of this, the introduction of management systems for the life and monitoring of conditions of the plant presupposes that the instrumentation is working correctly, which makes it even more important to extend preventive and predictive maintenance for instrumentation beyond the plant's critical systems, and include instrumentation that is involved in the systems monitored.

REFERENCES

1. M. Palomo et al., 2003. *Analysis of pressure signals using a singular system analysis (SSA) methodology, Progress in Nuclear Energy*, Vol. **43**, p. 329-336.
2. G. Verdú et al., 2001. *Neutronic Signal Conditioning using a Singular System Analysis, Annals of Nuclear Energy*, Vol **28**, p.568-583.
3. *ARMA. Sensor Response Time Analysis*. EPRI. NP-116. Research Project 503-2. Final Report May 1980.
4. *Effect of Aging on Response Time of Nuclear Plant Pressure Sensor*. NUREG/CR-5383. U.S. Nuclear Regulatory Comission. June 1989.