

TIME RESPONSE MEASUREMENT OF TEMPERATURE AND PRESSURE SENSORS OF ANGRA-I NUCLEAR POWER PLANT USING NOISE ANALYSIS TECHNIQUE

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ABSTRACT

The operation conditions and the limits, which the facility is subject to during a transient, are determined in the design period whether it is a nuclear facility or not. To monitor the dynamic variables and keep them under control in order to guarantee that they do not exceed the security limits, sensors are installed throughout the process. To guarantee that these sensors respond properly, the response time determination of temperature and pressure sensors from the Reactor Protection System (RPS) is necessary and is a requirement that must be satisfied. Furthermore it is an indicative of its degradation and its remaining working period. In this work we present the results of the time response of the RPS's sensors using an indirect method called Noise Analysis Technique and compare these results with those from the indirect method.

I. INTRODUCTION

Due to the hostile environment in which many sensors are installed, its components, whether mechanical or electrical can suffer alterations in time, which can alter significantly the sensor time response. In general the sensor answers slower and if the degradation is too significant the response time may reach values above the technical specifications of the facility.

To avoid that a degraded sensor might put a nuclear facility at risk, in 1997 the publication of the Nuclear Regulatory Guide 1.118 [1], the U.S. Nuclear Regulatory Commission (NRC) established important rules in order to determine the time response of the sensors. Therefore norm-based procedures has been adopted that explicitly requires the nuclear facilities to perform periodic tests to monitor the behavior of the sensors responsible for the protection system. Accordingly to the norms the tests must be carried out "in situ", i.e., with the sensor installed and when not possible, the laboratory conditions must be as close as possible of those found in the working spot.

Response Time Determination Methods. In general one can say that there are two basic methods to determine the

response time: direct and indirect methods. The direct method used to determine the response time of Resistance Temperature Detector (RTD) is the Loop Current Step Response (LCSR) (2, 3, 4), which consists in applying a small current to the RTD leads. The temperature transient due to a step change that heats the sensor filament is analyzed to determine the response time that would have followed a fluid temperature change. The test can be implemented in a plant by connecting a test instrument at the point where the sensor leads are normally connected to their in-plant transmitter. Laboratory results show that the time constant estimates by this method are within 10 to 20 per cent of their true values.

For pressure sensors, the direct method is the Pressure Ramp Test, which consists in simultaneously applying a pressure ramp to the sensor and to a fast reference sensor and compare both responses to determine the time delay between them (5). This method was developed in the 70's by the Nuclear Services Corporation.

As a result of a Master Degree thesis in 94 a pressure test unit was conceived (6), based on a previous work from Cain and Foster (7), but as it was considered only for academic purposes, the maximum allowed pressure is not enough to test all sensors of the Angra – I nuclear power

plant but only those who operates at low pressure ranges, so during the past 2 years we have been working on a new test unit, able to test the 15 MPa pressure sensors, and also in determination methods of response time of pressure sensors using whether “in-situ” methods or indirect methods.

Fig. 1 shows a pressure ramp test used to determine the sensor response time of a pressure sensor. The Validyne sensor is used to measure the time response of the Barton 746 sensor.

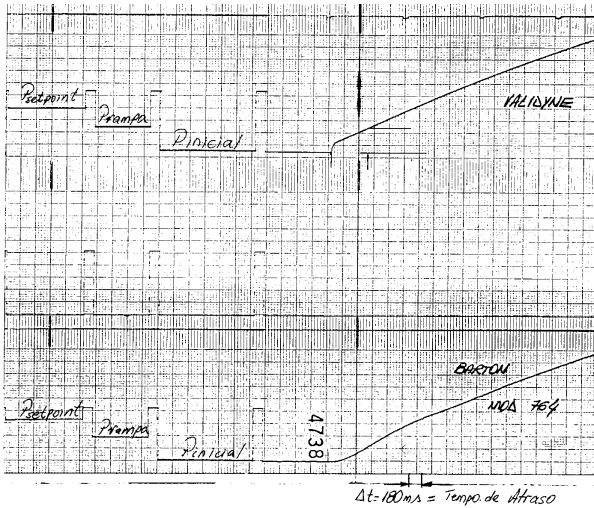


Figure 1. Pressure Ramp Test to Determine the Response Time of Pressure Transducers

Finally, the indirect method consists in doing the analysis of the noise from the sensors, where one can obtain the information about the dynamic behavior of the sensor, with a minimal interference during the normal operation of the nuclear power plant.

The methodology basically consists on using a noise analysis based in time-series. Auto-regressive models are adjusted to the data and the impulse and step responses are then calculated from the adjusted auto-regressive coefficients (8, 9).

To determine the response time of 20 RTD sensors and 36 pressure sensors from the Angra – I nuclear power plant, computer based programs were developed using Labview® and Matlab®. The response time results were then compared with those obtained using direct methods showing good accordance.

Once acquired, the data from the sensors were analyzed using a Matlab® program that:

- calculates the Power Spectral Power density (PSD) of the signal;
- calculates the auto-regressive (AR) coefficients;
- calculates the power spectral signal from the impulse and step response, using the coefficients from the auto-regressive model.
- from the step response one can calculate the time constant of the sensor.

The time constant is defined as the necessary time to the sensor output to reach 63.2% of its final value when applied to its input a step signal. So the time constant is determined from the PSD curve where one use the curve obtained from the auto-regressive coefficients. Fig. 2 shows a PSD from a temperature sensor. The blue line is the fitting using the Auto-Regressive model and the red line is the data test.

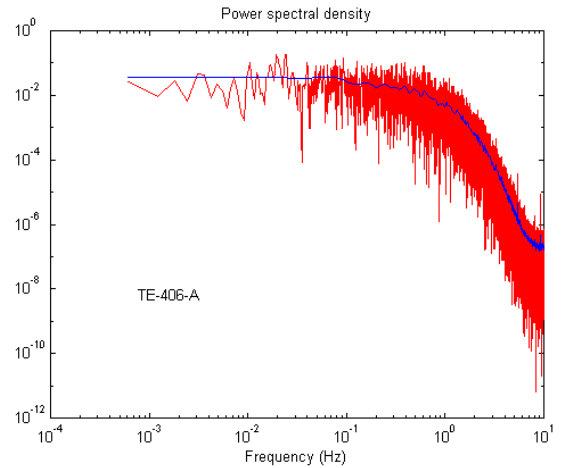


Figure 2. Power Spectral Density of a RTD Sensor.

Measurements. It was made the measurement of 20 temperature and 36 pressure sensors from the RPS. As it was not possible to directly access the terminals from each sensor, most of the measurements were taken in the computer room. It must be considered that the acquired signals carries several informations about the way between the impulse line and the computer room.

The connections of some of the temperature sensors were not in the computer room, but in the control room. So, for security reasons it was possible only to acquire the signal from two sensors at the same time, instead of seven at the same time as it was in the computer room.

Results. The obtained results using Noise Analysis were compared with previous results obtained using direct methods to determine the response time of the sensors. Table 1 shows some results of this comparison, remembering that for temperature sensors the method used was LCSR and for pressure sensors was Pressure Ramp Test.

Sensor	Direct Method (ms)	Noise Analysis (ms)
Temperature of the primary circuit	103	200
ΔT of the primary circuit	79	130
Steam Generator Flow-I	135	160
Steam Generator Flow-II	119	140
Pressurizer Level	426	230

Table 1. Comparison between Direct Methods Results and Indirect Methods

II. CONCLUDING REMARKS

For systems whose PSD shows a first order behavior, simple or not, the values of the time constant are easily determined, and the results are very coherent with the expected values. Even for quadratic systems, in cases where it was possible to identify the low frequencies asymptotes, the determination of the time constant was immediate and also showed coherent values.

But in cases where the low frequencies asymptotes were not accurately determined, the classification of the system was not possible, so the time constant associated to the break frequency has not shown a coherent value, but a much higher value than it would be expected as a true value for those sensors.

III. FUTURE WORKS

Although the methodology presented here is fully established, is interesting to extend the studies to use the results of the Auto-Regressive model in the determination of the response time using estimated values from the response to an impulse and a step test. This was made in this work, but only 17 of the 56 sensors supplied the time constant.

In April 2000, another set of measurements using both direct and indirect techniques was made in Angra-I Nuclear Power Plant and the data tests are being analyzed.

IV. ACKNOWLEDGEMENTS

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V. REFERENCES

- [1] **Periodic Testing of Electric Power and Protection Systems**. New York, N.Y, Nov. 1977. (NUREG 1.118), U.S Nuclear Regulatory Commission.
- [2] Upadhyaya, B. R., Kerlin, T. W. **"In Situ Response Time of Platinum Resistance Thermometers"**. Vol. 2. Palo Alto, Electric Power Research Institute EPRI NP-834, July 1978.
- [3] Gonçalves, I. M. P. **"Determinação do Tempo de Resposta de Sensores de Temperatura do Tipo RTD Através de Medidas "in situ"**. São Paulo, 1985. (Dissertação de Mestrado em Tecnologia Nuclear, Instituto de Pesquisas Energéticas e Nucleares).
- [4] **"Review of Resistance Temperature Detector Time Response Characteristics"** (NUREG-0809). Safety Evaluation Report. U.S. Nuclear Regulatory Commission. August 1981.
- [5] **"Effect of Aging on Response Time of Nuclear Plant Pressure Sensors"** (NUREG/CR-5383). June 1989. . U.S. Nuclear Regulatory Commission.
- [6] Perillo, S.R.P.. **"Determinação do tempo de resposta de transdutores de pressão utilizando o método de medida direta"**. São Paulo, 1994. (Dissertação de mestrado, Instituto de Pesquisas Energéticas e Nucleares).
- [7] Cain, D. G. and Foster, G. C. **"A Practical Means for Pressure Transducer Response Verification"**. Nuclear Technology, Vol. 36, Mid-December 1977.
- [8] Lopes, P.R.L. **"Estudo da Metodologia de Análise de Séries Temporais Aplicada à Monitoração do Tempo de Resposta dos Instrumentos Ligados ao Sistema de Proteção de Reatores Nucleares"**. Dissertação de Mestrado, 1995.
- [9] Upadhyaya, B. R., Kerlin, T. W. ISA Transactions – Vol. 17, No. 4.