RESISTANCE TEMPERATURE SENSOR AGING DEGRADATION IDENTIFICATION USING LCSR TEST

Roberto Carlos dos Santos and Iraci Martinez Pereira Gonçalves,
Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242, 05508-000 São Paulo, SP
rcsantos@ipen.br, martinez@ipen.br

Keywords. Loop Current Step Response, Time Response, Sensor Aging, Nuclear Power Plant.

1. INTRODUCTION

Most critical process temperatures in nuclear power plants are measured using RTD (Resistance Temperature Detector) and thermocouples. In a PWR (Pressure Water Reactor) plant, the primary coolant temperature and feedwater temperature are measured using RTDs, and the temperature of the water that exits the reactor core is measured using thermocouples. These thermocouples are mainly used for temperature monitoring purposes and are therefore not generally subject to very stringent requirements for accuracy and response-time performance. In contrast, primary coolant RTDs typically feed the plant's control and safety systems and must, therefore, be very accurate and have good dynamic performance.

The response time of RTDs and thermocouples has been characterized by a single parameter called the Plunge Time Constant [1]. This is defined as the time it takes the sensor output to achieve 63.2 percent of its final value after a step change in temperature is impressed on its surface. This step change is typically achieved by suddenly immersing the sensor in a rotating tank of water, called Plunge Test. In nuclear reactors, however, plunge testing is inconvenient because the sensor must be removed from the reactor coolant piping and taken to a laboratory for testing. Nuclear reactor service conditions of 150 bar and 300°C are difficult to reproduce in the laboratory. Therefore, all laboratory tests are performed at much milder conditions, and the results are extrapolated to service conditions. This leads to significant errors in the measurement of sensor response times and an in-situ test method called LCSR - Loop Current Step Response test was developed in the mid-1970s to measure remotely the response time of RTDs. In the LCSR method, the sensing element is heated by an electric current; the current causes Joule heating in the sensor and results in a temperature transient inside the sensor. The temperature transient in the element is recorded, and from this transient, the response time of the sensor to changes in external temperature is identified by means of the LCSR transformation.

Since the response time is controlled by heat diffusion, response time could degrade either because of changes in the overall heat-transfer resistance and/or effective heat capacity of the sensor material. Response time generally degrades due to the following possible causes: changes in the properties of the filler or bonding material, material on sensor surface, and changes in contact pressure or contact area [2].

Therefore, the LCSR test results can either give information about the time constant value and the level of RTD response-time degradation. In order to identify the time response degradation causes, LCSR laboratory tests were performed using normal and artificially degraded RTDs. This work presents the results of time response time degradation identification obtained from LCSR test.

2. PLUNGE TEST

Plunge Test is a laboratory test that simulates a temperature step change in the fluid temperature where the sensor is immersed. The test consists in a sensor that is suddenly immersed in a fluid maintained in a constant temperature and to monitor its output until it reaches the steady state temperature. In such a way, the sensor quickly passes from a room temperature T_a to a fluid temperature T_1, that is, it suffers a temperature step change. The Time constant value is obtained directly from the Plunge Test and consists in the time necessary to the sensor reach 63.2% of its final value. Figure 1 shows a Plunge Test and Figure 2 shows a plot of the temperature step change and the corresponding RTD output.

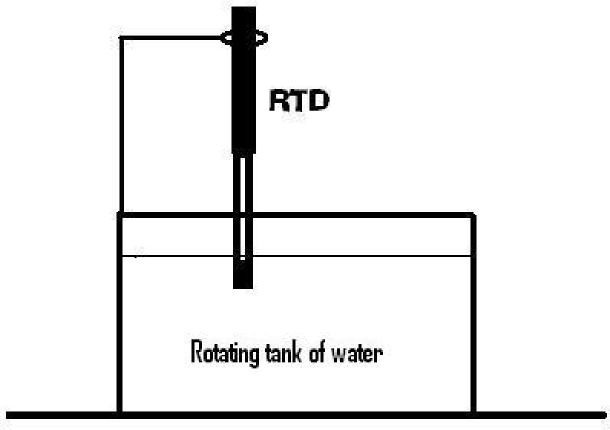

Figure 1. Plunge Test.

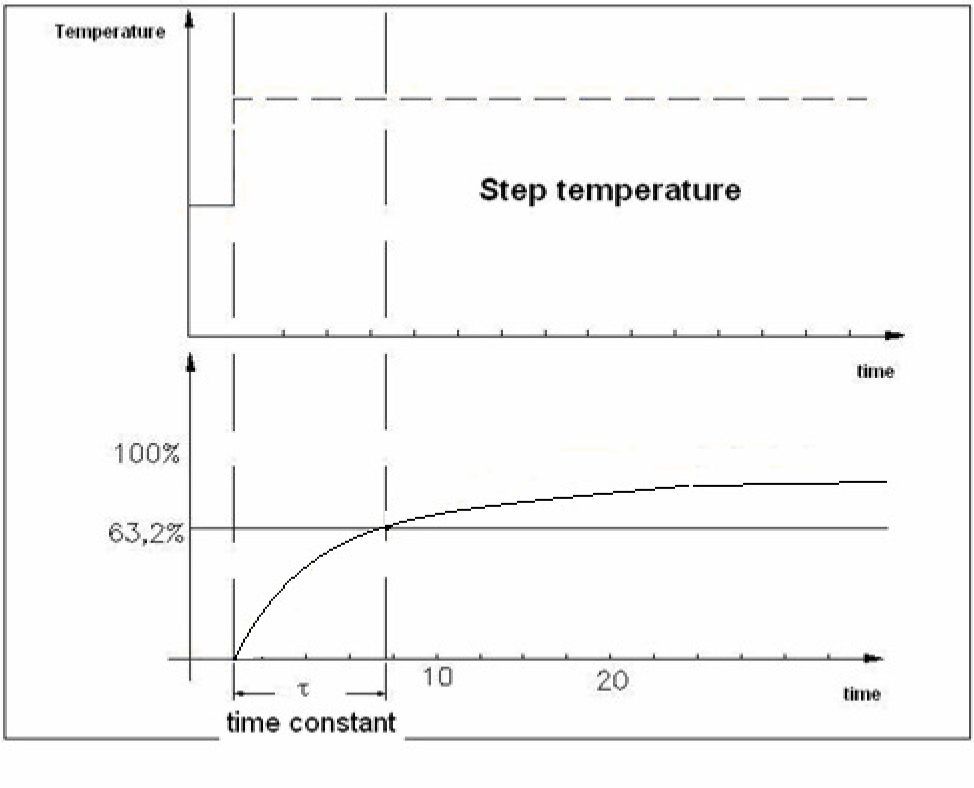

Figure 2. Temperature step change

3. LOOP CURRENT STEP RESPONSE TEST

The Loop Current Step Response methodology was developed to remotely measure RTDs time response while the sensor is installed in the process. The test consists in applying a small current to the RTD leads that heats the sensor filament and the temperature transient due to a step change is analysed to determine the response time that would have followed a fluid temperature change. The LCSR data gives the sensor response of an internal heating perturbation, but the response of interest is the one that results from a fluid temperature perturbation. The time plot, of either the heating while the current is applied, or the cooling after the current is discontinued, is recorded during the LCSR test. From this plot, the sensor response time is obtained by means of the LCSR transformation [1]. The LCSR test accounts for all the effects of installation and process conditions on response time and thereby provides a sensor's actual "in-service" response time.

The LCSR test equipment consists in a Wheatstone bridge with current switching capability (Figure 3). The switch can be opened or closed to decrease or increase the current. The LCSR test is made by connecting a test instrument at the point where the sensor leads are normally connected to their in-plant transmitter.

First, the bridge is balanced with 1 to 2 mA of DC current running through the RTD (switch open). Then, the current is switched "high" to about 30 to 50 mA (switch closed). This causes the RTD sensing element to heat up gradually and settle a few degrees above the ambient temperature. The amount by which the temperature rises in the RTD depends on the magnitude of the heating current used and on the rate of heat transfer between the RTD and its surrounding medium. Typically, the RTD heats up about 5 to 15 ºC during the LCSR test. Figure 4 shows a typical LCSR test performed in the laboratory also using a 40 mA heat current.

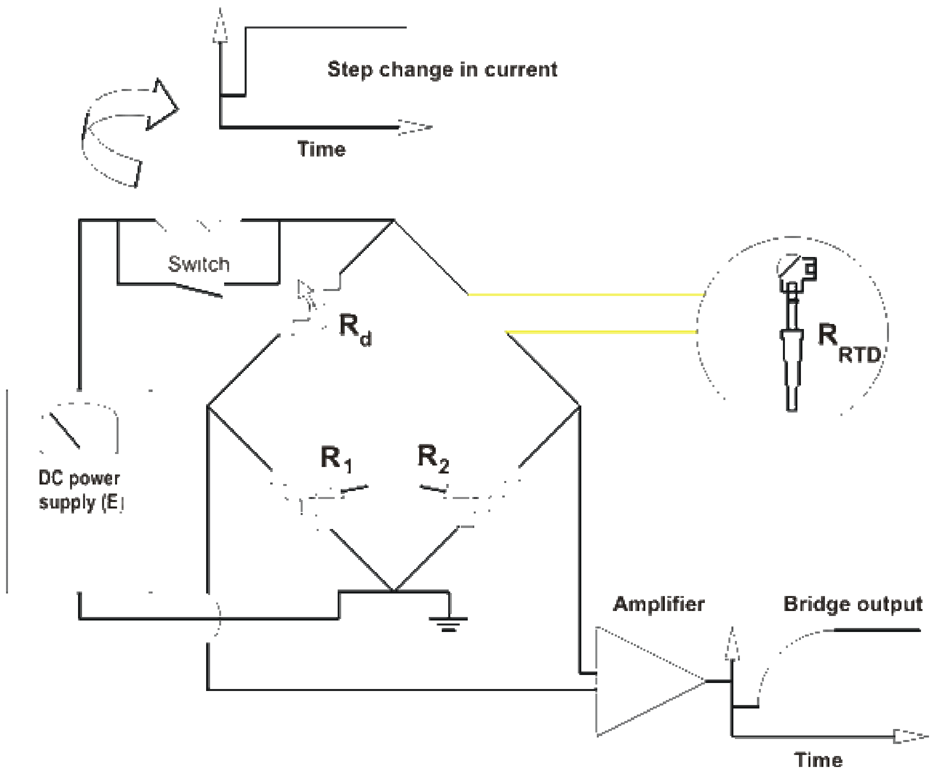

Figure 3 - Wheatstone bridge used in RTDs LCSR tests.

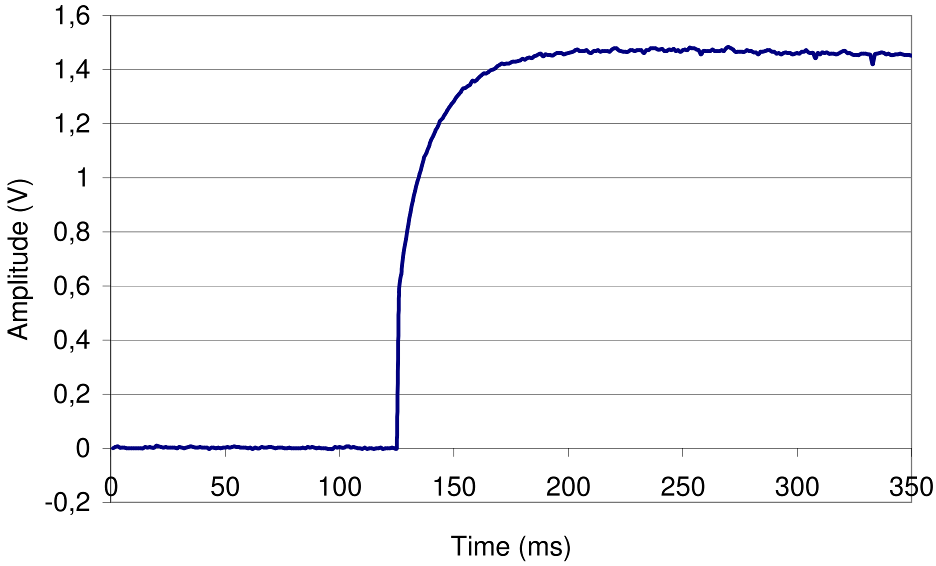

Figure 4. A typical LCSR data.

4. EXPERIMENTAL SETUP

The experimental setup consists in [3], [4]:

- RTD temperature sensors;
- Thermal Bath and plunge test drop assembly;
- LCSR Eletronic Measuring System;
- Data Acquisition System.

RTD. General purpose, high accuracy, 900° F maximum construction temperature, 4-wire, ¼" diameter. (Figure 5)
Model 101-01A-C-012.00-00-Z059
Ultra Electronics Nuclear Sensors & Process Instrumentation
Resistance Temperature Detectors (RTDs)

Thermal Bath and plunge test drop assembly. The Plunge tests experimental setup consists in a Thermal Bath from Gebrüder Haake , model FT with maximum temperature of 350°C and constant flow. The sensor is fixed on a rod that can move up and down, performing the plunge test.

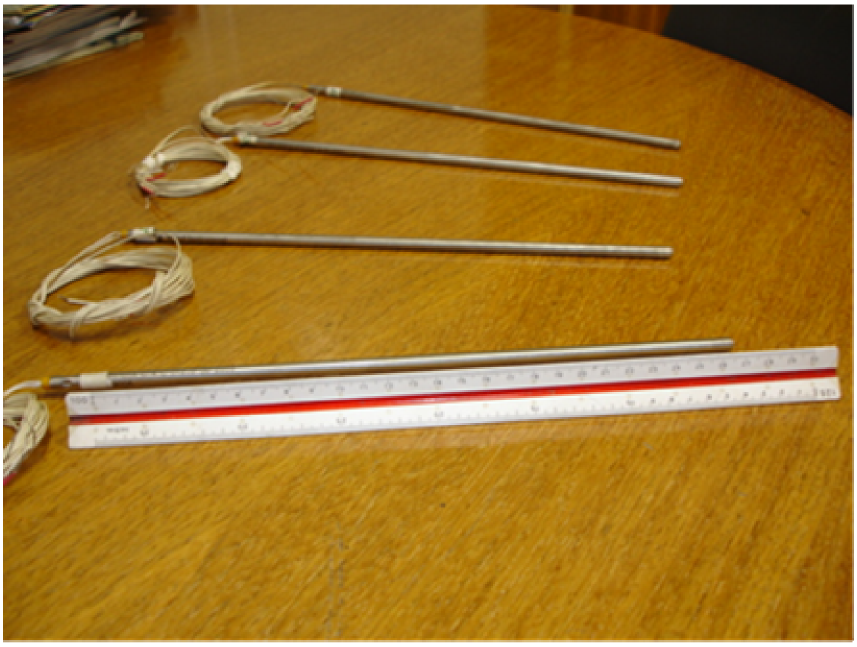

Figure 5. RTD temperature sensors.

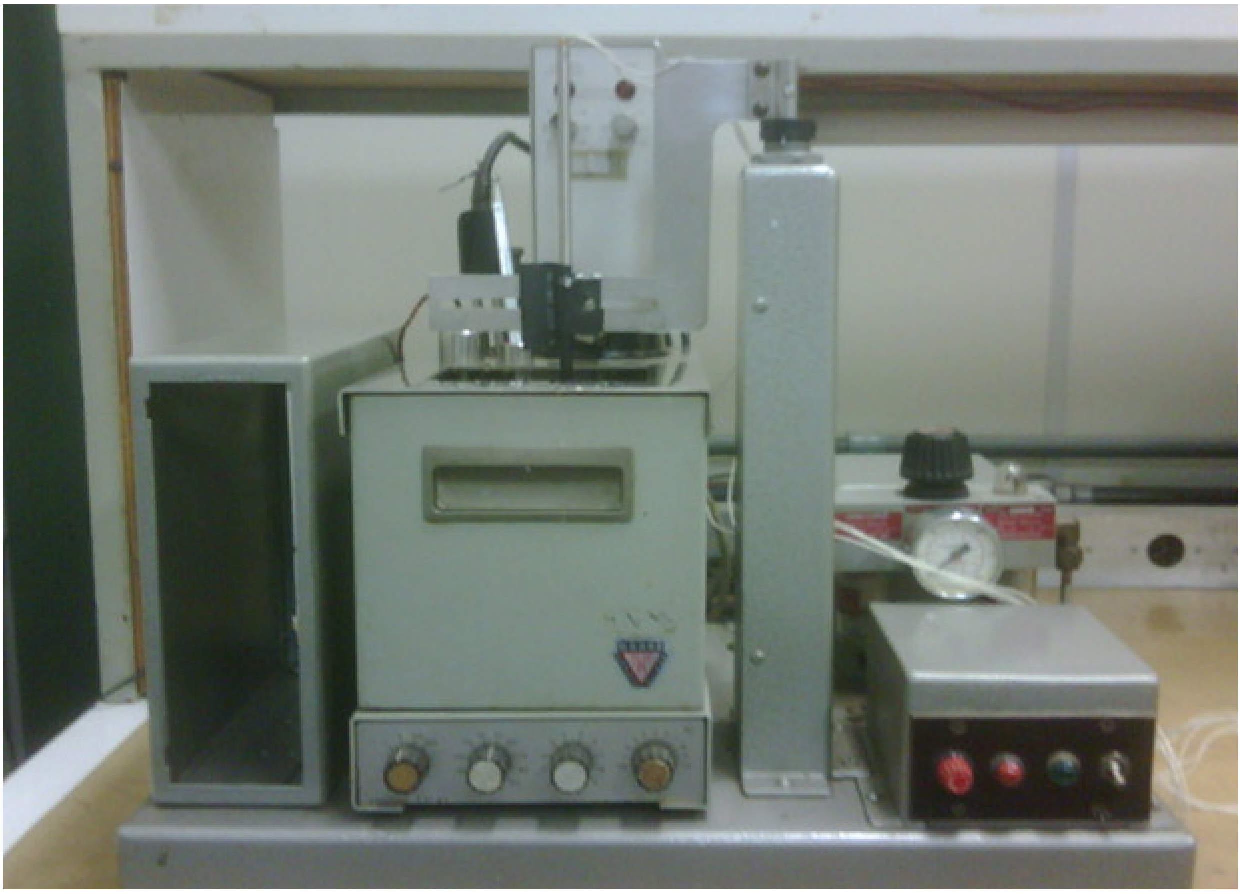

Figure 6. Plunge test experimental setup

LCSR Electronic Measuring System. The electronic circuit with a Wheatstone Bridge is used to perform both plunge and LCSR tests. An amplifier has X3, X5, X10, X40, and X60 gain adjust and a connection for a resistor decade is also provided.

Figure 7. Loop current step response test equipment.

Data Acquisition System. Consists in a Pentium IV notebook, Windows XP, acquisition software LabView, acquisition card from National Instruments DAQCaed-6024E and a connection box also from National Instruments SC-68.

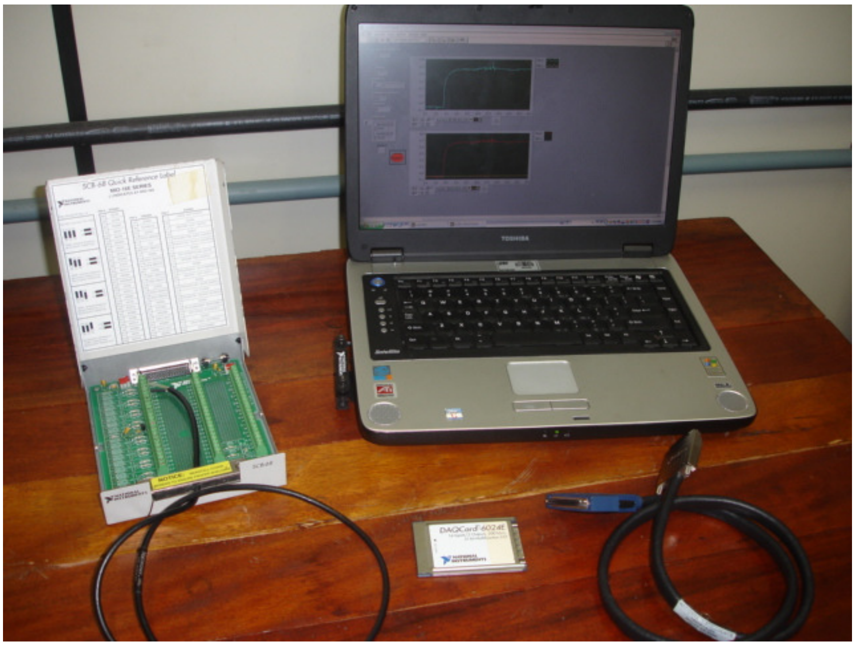

Figure 8. Data Acquisition System.

5. PRELIMINARY RESULTS

Nuclear grade RTDs, like their commercial-grade counterparts, can suffer from calibration drift, response-time degradation, reduced insulation resistance, erratic output, wiring problems, and the like. As mentioned earlier, response time generally degrades due to the following possible causes: changes in the properties of the filler or bonding material, material on sensor surface, and changes in contact pressure or contact area. In order to simulate one of these possible faults, it was made a little hole in the cover sheath of the RTD, leading to a seeping of water into the RTD sensing element.

The RTD time response was calculated using both Plunge and LCSR tests. The results are shown in Figures 9 and 10.

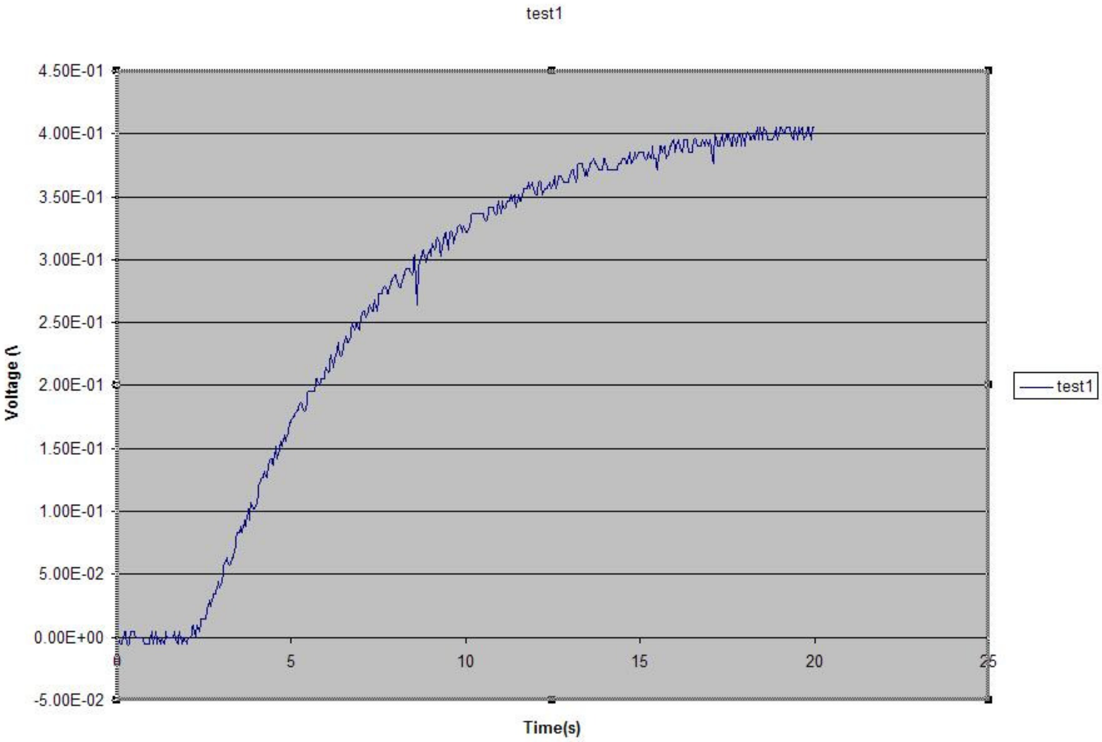

Figure 9. Plunge tests result.

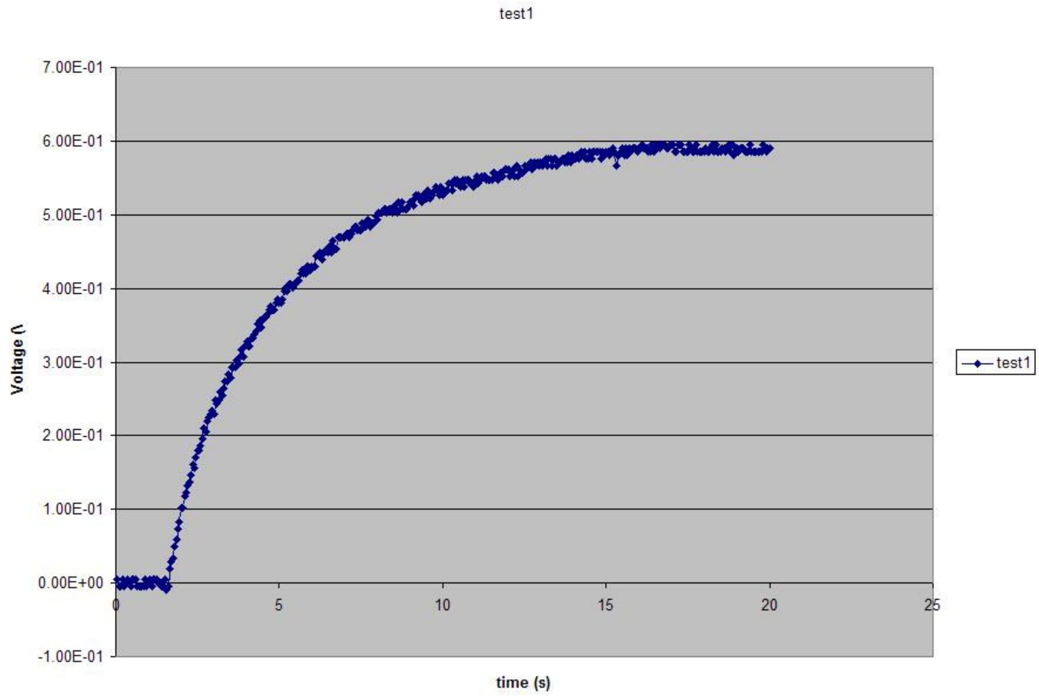

Figure 10. LCSR result.

Plunge tests and LCSR tests were then performed in this damage sensor, and the results were shown in Figures 11 and 12.

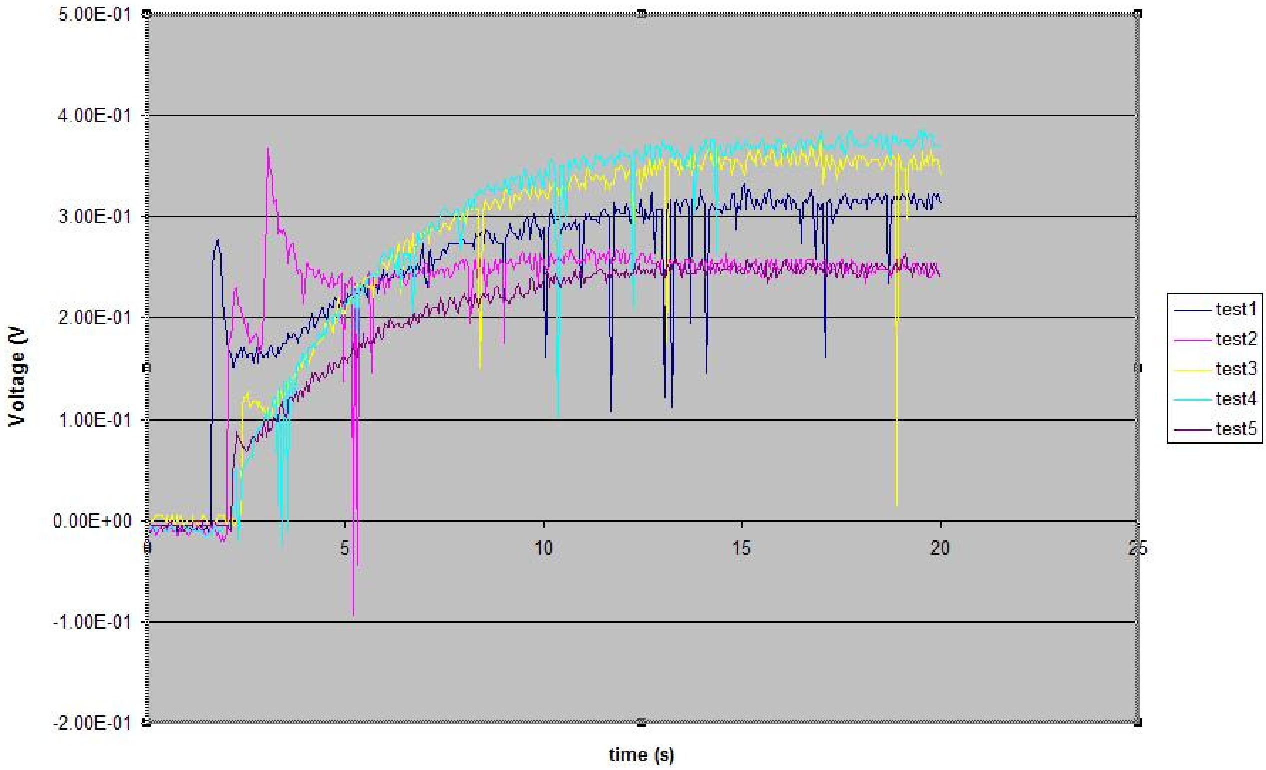

Figure 11. Plunge tests results.

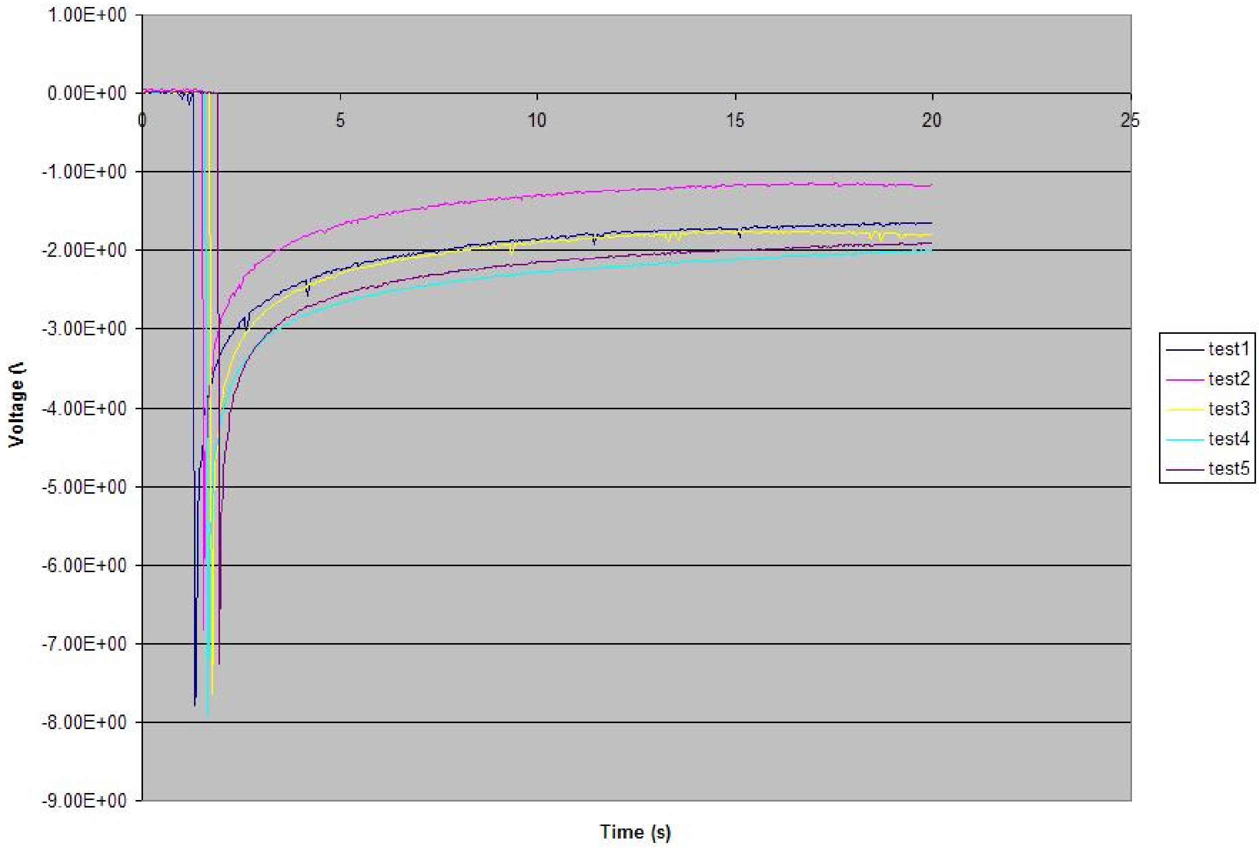

Figure 12. LCSR results.

From the experiments analyzed so far, significant signal changes were successfully obtained which suggests that RTD temperature sensor faults can effectively be detected based on LCSR tests. The RTD time constant value will be determined and compared with the original value.

REFERENCES

1. B. R., Upadhyaya, T. W., Kerlin, "In Situ Response Time of Platinum Resistance Thermometers". **Vol. 2**, .Palo Alto, *Electric Power Research Institute EPRI* NP-834, July 1978.
2. H. M. Hashemian, *Maintenance of Process Instrumentation in Nuclear Power Plants*, Springer, Knoxville, TN, USA (2006).
3. Gonçalves, I. M. P., Determinação do Tempo de Resposta de Sensores de Temperatura do Tipo RTD através de medidas in situ, MSc Dissertation , IPEN, São Paulo (1985).
4. Santos, R. C., Utilização de Redes Neurais Artificiais para Determinar o Tempo de Resposta de Sensores de Temperatura do Tipo RTD, MSc Dissertation , IPEN, São Paulo (2010).