framatome

PULSE

To monitor the health of safety I&C critical components

About PULSE

PULSE is a comprehensive range of services dedicated to monitor the health of nuclear safety I&C critical components.

Because instrumentation & control (I&C) systems are critical equipment for the safety and the availability of nuclear reactors, you need to ensure that these systems and the associated components work properly.

Because these systems and components are also operated over very long periods, you need to monitor their aging status and its evolution.

In order to provide an adapted answer, Framatome has developed the PULSE offer, made of a range of services to perform the health monitoring of safety critical I&C components.

Pulse detects and anticipates potential failures and issues to precisely locate and identify the cause of the problem and address it efficiently.

Thanks to PULSE, risks and costs of the associated maintenance programs are optimized.

To monitor the health and aging of critical I&C components

Scope of PULSE

PULSE, how does it work?

Services performed as part of the PULSE offer have been developed to be simple and efficient. All of them are using the same model.

The PULSE model

For each of the components monitored as part of the PULSE offer, we apply a single model.

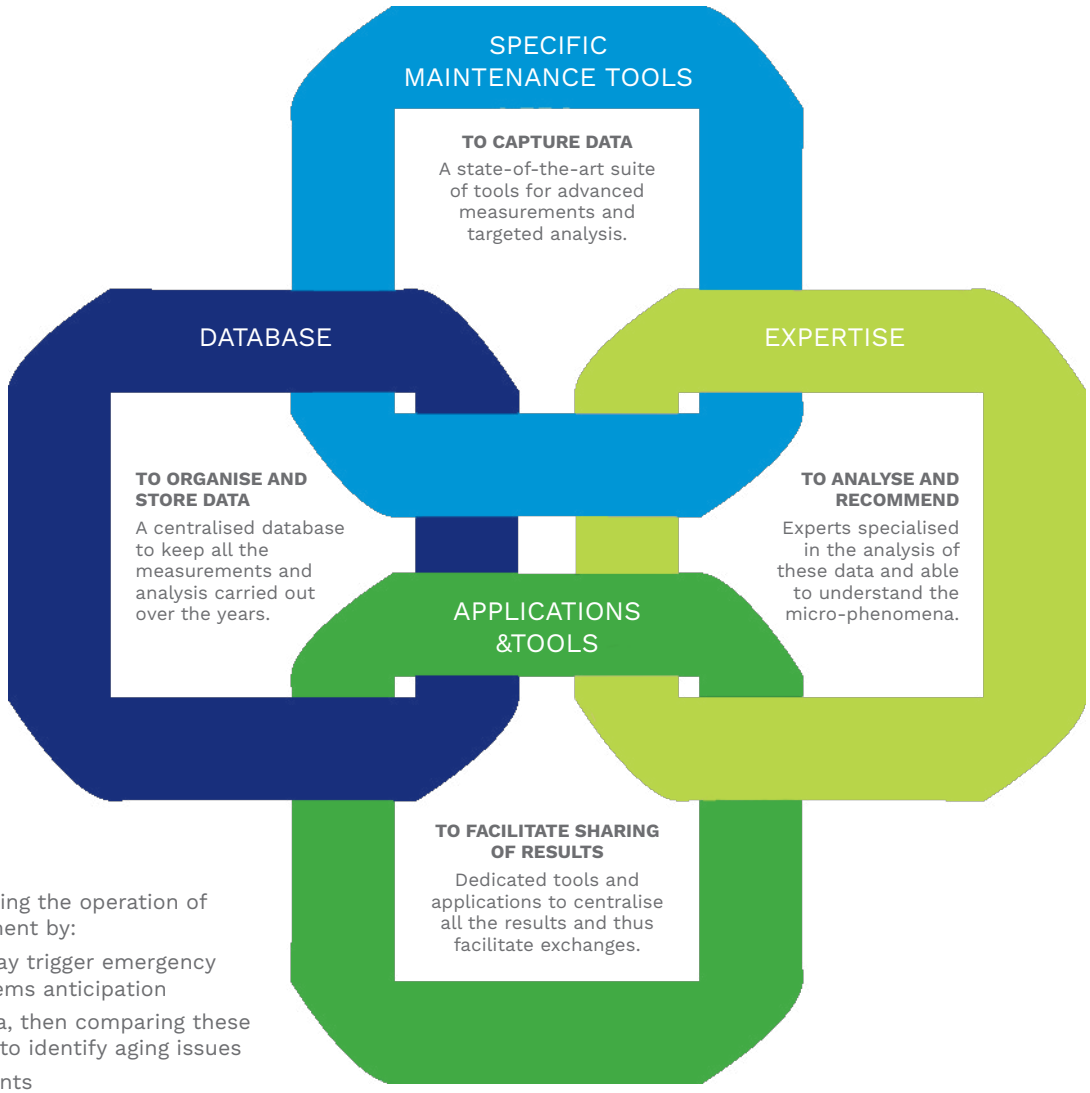
We use state-of-the-art testing tools able to perform advanced tests and capable of collecting a large amount of data from units in operation or during outages.

We save this data in a centralized, safe and cyber-secure database.

Our experts analyze this data and establish trends by comparing data collected over the years.

We finally share our recommendations with our customers through the use of dedicated tools and applications.

A simple and efficient model



Added value

The PULSE offer allows optimizing the operation of monitored systems and equipment by:

- Reducing incidents that may trigger emergency shutdowns, through problems anticipation
- Establishing reference data, then comparing these data on a long-term basis to identify aging issues
- Reducing unscheduled events
- Allowing identification of the location of issues so they can be quickly repaired
- Reducing duration of maintenance activities, saving time on critical path
- Planning and anticipating maintenance actions, in order to limit delay impacts on plant start-ups

PULSE [Electromagnetic Interferences - EMI]

Monitoring the external EMI and checking the EMI robustness of neutron instrumentation channels, from detector to cabinet.

Principle

As a Neutron Instrumentation System (NIS) has to process low and accurate signals, EMI is an essential characteristic to control in order to ensure a reliable and safe operation of this safety critical system.

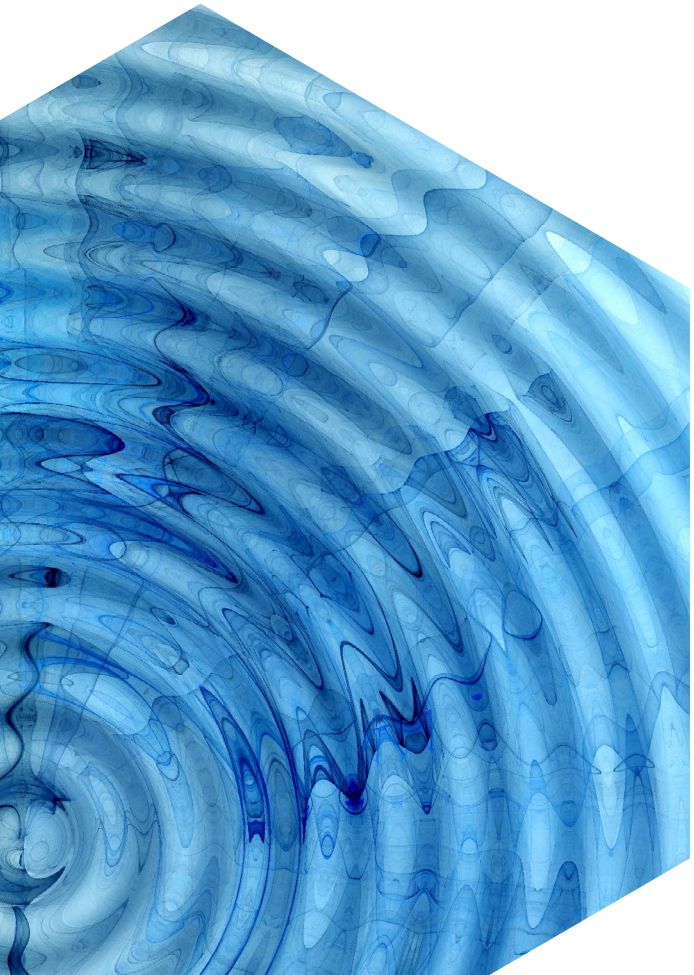
The electromagnetic disturbances circulating on the NIS cables and the quality of the immunity of the system line can lead to disrupting the counting rate and thus cause in certain conditions an automatic reactor shutdown.

Leveraging its 50-year experience in the field of Neutron Instrumentation, Framatome developed a set of three innovative tools called Wave. The tools allow the complete diagnostics of the EMI activity.

Objectives

Through the use of the Wave range of tools, PULSE [EMI] allows nuclear operators to:

- Have a clear diagnostic of external EMI activity
- Have an accurate knowledge of the NIS lines immunity
- Check the EMI compliance of the NIS after each maintenance operation (detector or connector replacement, disconnection, etc.)
- Detect failures on the lines, including failure on the penetration, connector mounted unproperly, abnormal grounding



Tools

The Wave tools family is made of three independent and complementary tools: Wave-B, Wave-S and Wave-IP.

Wave-B:

- To monitor external EMI activity that could impact the system and then check the ability of the installation to mitigate environment electromagnetics disturbances, from the detector to the cabinet.
- Recording of disturbances can run in operation, without influence on the NIS operability and during several days or more.

Wave-S:

- To check the EMI robustness of the Source Range Channel by measuring and quantifying their immunity
- Recording is performed with intrusion into the NIS (cables must be disconnected from the cabinet)
- This service guarantees the quality of the line, the quality of the interfaces, the tightening quality and the operability of the line.

Wave-IP:

- To check the EMI robustness of the Intermediate/Power Range Channels
- Recording is performed with intrusion into the NIS (cables must be disconnected from the cabinet)

Customer benefits

- Increase the reliability of the NIS
- Avoid spurious shutdowns caused by EMC problems related to poor line quality
- Allow the reactor to be started with the guarantee of the operability of the line
- Anticipate maintenance by comparative analysis of recorded data, cycle after cycle

Wave-B tool

PULSE
[Cables and connections]

Health monitoring of cables and connections.

Principle

All I&C systems depend on reliable plant wiring. Most of these cables are installed at the start of the plant's operation. They have been subjected to strong constraints for many years.

Tests that are done to check these cables are often basic (continuity, isolation) and do not identify weaknesses and aging, usually at the interface level.

Although individual cables can be replaced, wholesale replacement is neither a prudent nor a practical aging management strategy.

As part of PULSE, Framatome proposes electrical testing of cables, including a comprehensive set of tests performed with the CHAR tool (Cable Condition Monitoring System):

- DC Resistance (R) Measurements
- Insulation Resistance (IR) Tests
- Inductance-Capacitance- Resistance (LCR) Measurements
- Time Domain Reflectometry (TDR)
- Reverse Time Domain Reflectometry (RTDR)
- Frequency Domain Reflectometry (FDR)
- Current-Voltage or I-V Measurements

Objectives

Collectively, all the measurements performed with the CHAR tool help to identify, locate and determine the nature of the problem and guide the plant as to whether the problem is in the sensor itself or along its cables or in its connectors.

By comparing the tests performed over time, trends can be determined and aging issues can be identified in advance.

The tests performed with the CHAR tools allow operators to identify issues such as common cable problems, degraded connectors, moisture intrusion into cracked cable insulation, intermittent connections, noise coupling from damaged or degraded shielding, open-circuit faults, conductor to ground, etc.

Tool

The CHAR tool is a solution mixing a measurement device and a multiplexer, enabling a complete set of tests, in optimized conditions.

It measures the health and integrity of a cable by performing a series of non-destructive electrical tests that can be administered from the measurement end of the cable circuit.

This allows testing of most cable circuits, and end devices while saving test personnel exposure to potentially harsh environments.

The data collection is managed by user-friendly proprietary software that automatically trends recent measurements with historical baseline data and aging discrepancies and outliers.

Applications

The CHAR tool can be used for different types of I&C cables, including:

- Rod Control System cables
- Rod Position Indication System cables
- Instrumentation cables
- Pressurizer Heater controller cables

Customer benefits

- Identify and locate previously undetectable problems on a complete line, in terms of cabling, connectors and sensors
- Characterize a complete line at a given moment and follow its evolution over time to anticipate potential problems
- Optimize the duration of the interventions, notably thanks to the localization of the problems

Thanks to PULSE [Cables and Connections], you are thus assured before the restart of the reactor that the lines are perfectly operational and that they will not generate any spurious shutdown.

CHAR tool used on Rod Control System of Framatome

PULSE [Neutron detectors]

Monitoring the aging status across the years, and make replacement decisions at the right moment.

Principle

Neutron detectors are critical equipment for safety and nuclear reactors availability. They are complex equipment working under extreme conditions.

A detector issue may trigger an emergency shutdown. Therefore neutron detectors' aging condition must be carefully monitored.

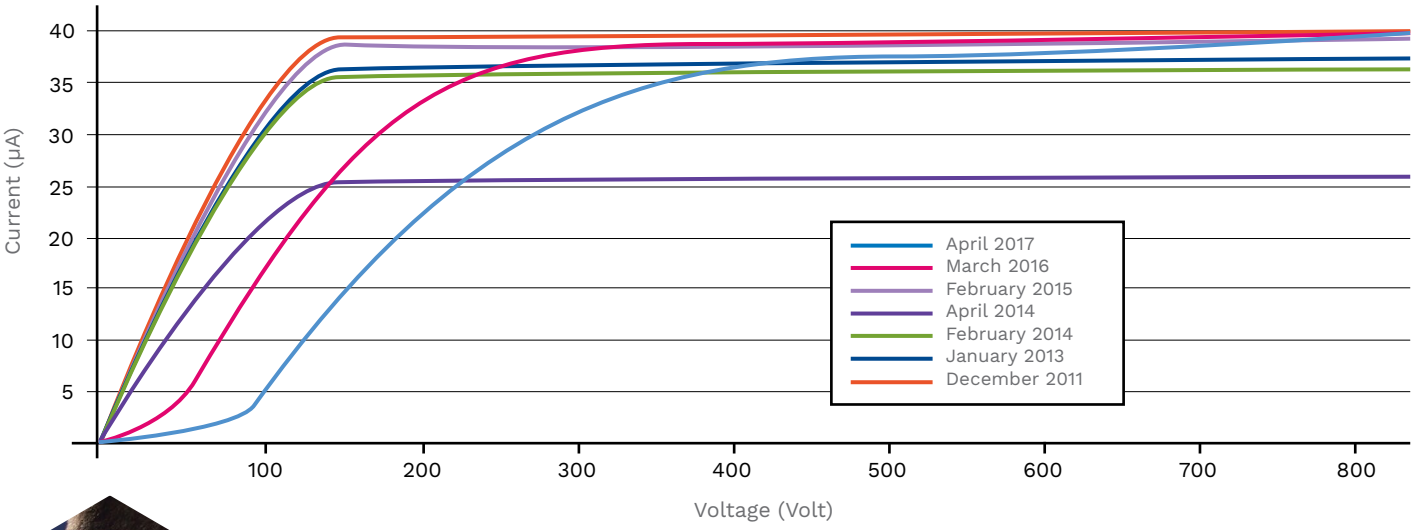
Based on its 50-year experience in neutron detectors, Framatome has developed a solution to support nuclear operators in the decision making of replacing a detector.

Methodology

The solution proposed by Framatome is based on a specific methodology:

- The collection of curve plotting data
- A specific database enabling to store data and analyze the aging status of each detector
- Technical expertise and recommendations

Through the support of a pool of experts and the close monitoring of neutron detectors curve plotting across the years, we give our customers visibility on the aging status of their neutron detectors fleet.



Customer benefits

With the PULSE [Neutron detectors] solution, nuclear operators can:

- Better schedule detector replacements
- Avoid unscheduled shutdowns
- Improve detector replacement activity budgeting thanks to early detection of aging issues

PULSE [Pressure transmitters]

Health monitoring of pressure transmitters and associated sensing lines.

Principle

The response time of pressure, level and flow transmitters in nuclear power plants (NPPs) can be verified passively and remotely using the “noise analysis” technique. The noise analysis technique uses the output of an I&C channel, sampled at 1000 Hz or more, to provide its dynamic response. More specifically, the noise analysis technique is based on monitoring the natural fluctuations that exist at the output of sensors while the plant is operating.

These fluctuations are due to turbulence induced by the flow of water in the system, random heat transfer in the core, and other naturally occurring phenomena.

The noise is extracted from the sensor output by removing the DC component of the signal and amplifying the AC component, and is then analyzed to provide the dynamic performance of the sensor.

Tool

The online testing for response time of pressure transmitters in NPPs is performed with the OLM tool, consisting of a data acquisition system and a computer.

The tool is connected to the output signals of the transmitter, on the instrumentation cabinets.

Tests performed with the OLM tool are normally done while the plant is at normal operating conditions.

The OLM tool is compatible with any type of pressure transmitters and is already used in more than 120 nuclear units across the USA, UK, Spain and China.

Objectives

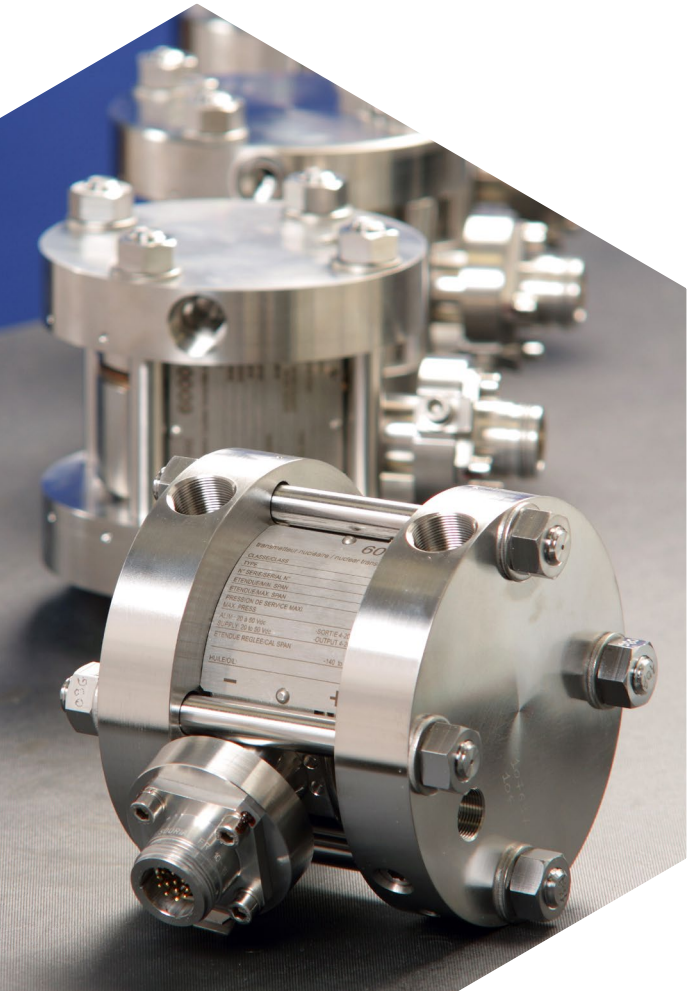
The analysis of the frequency curves generated by the OLM tool, in term of magnitude, natural frequencies, slopes and shape, allows performing a complete diagnostic of the pressure transmitters and of its associated sensing line.

Main objectives are to:

- Make passive measurement that can be used to verify response time of pressure, level and flow transmitters, unit in operation
- Provide diagnostic information about the health of transmitter sensing lines (blockages, voids and leaks), unit in operation
- Identify the aging of the transmitters and sensing lines by comparative analysis of the recorded data, cycle after cycle

Customer benefits

- Perform measurement unit in operation, without any impact on the availability of the nuclear reactor, and avoiding any radiation exposure to maintenance personnel
- Perform measurement simultaneously on several sensors at a time
- Have recommendations from Framatome on the maintenance activities to be performed on the transmitters and/or on sensing lines
- Anticipate before the outage the potential maintenance activities to be performed on transmitters and/or on sensing lines



OLM tool

PULSE [Temperature probes]

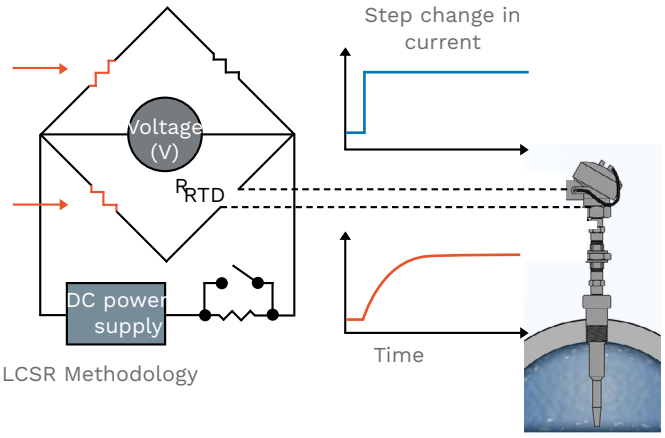
To monitor the health of nuclear RTDs and measure their response time by keeping them connected to the process.

Principle

Loop Current Step Response (LCSR) tests allow operators to determine the response time of a temperature probe sensor installed in NPP by keeping it connected to the process.

This test, which can be carried out remotely from the electrical cabinets or the control room, is based on the heating of the sensitive element (RTD) of the temperature probe by the injection of an electric current. The injected current causes a temperature transition in the probe that can be analyzed through its current to determine its response time.

This test is usually performed during hot shutdown.

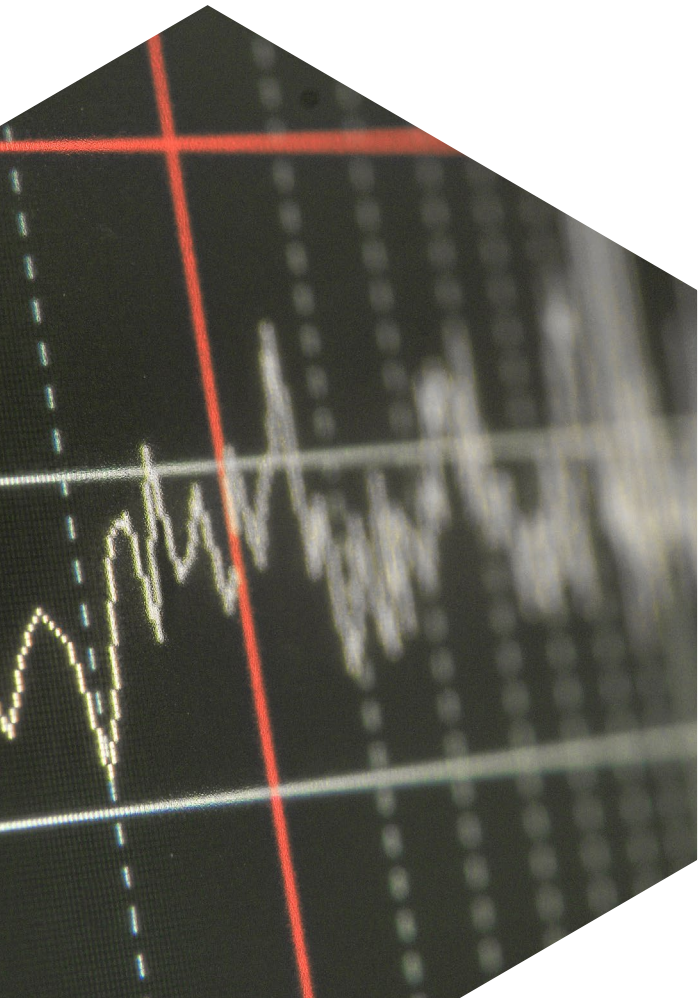


LCSR Methodology

Objectives

The LCSR test allows the operators to:

- Measure the response time of the temperature sensor and check its conformity with the technical specifications or regulatory requirements, keeping it connected to the process
- Identify, by comparison, probes that may have a default or probes that are not properly installed in their thermowells, especially for newly installed probes
- Monitor the health of temperature probes by comparing the response time measurements performed cycle after cycle, so as to anticipate any temperature probe replacement
- Have the guarantee before each restart that all the probes are working correctly



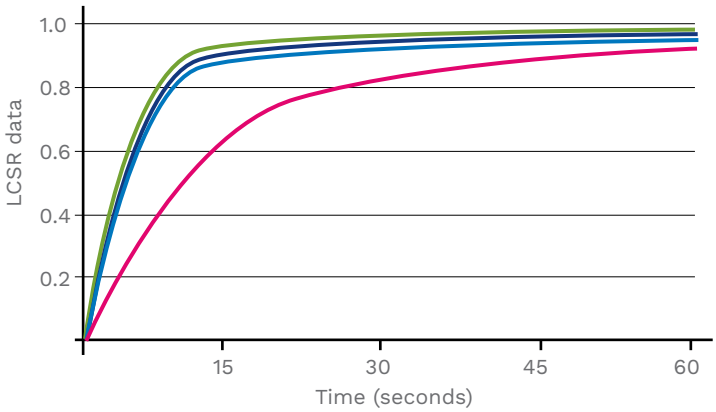
Tool

The ERT-3 tool, a PC-based system using a proprietary software, allows in-situ response time testing of RTDs using the LCSR technique.

In relation to the particular parameters of each probe, the tool samples the data, analyzes them and thus makes it possible to deduce their response time, by keeping them connected to the process.

The ERT-3 tool is able to measure the response time of five temperature probes simultaneously, reducing the duration of the tests and the efficiency of the measurements.

The ERT-3 tool is the result of 30 years of experience in response time analysis. This tool has already made more than 50,000 measurements of response time in nearly 100 nuclear reactors worldwide.



Example of LCSR test enabling to identify by comparison RTDs installation problems

Customer benefits

- The LCSR technique and the ERT-3 tool make it possible to measure the response time of the temperature probes by keeping them connected to the process
- The test time is significantly reduced, as tests can be performed on up to five probes simultaneously
- The tests are performed during hot shutdown
- The results of the tests are available a few minutes after the end of the tests. With these data, a first analysis can be done on site

PULSE [Thermography]

Monitoring the health and aging status of the equipment through infrared thermography and making replacement or maintenance decisions at the right moment.

Principle

In order to monitor the health and aging status of nuclear safety classed systems and their components, we use a specific methodology based on infrared thermography. This methodology can detect faulty components, crimping or clamping problems and identify components that lose their initial characteristics, leading to overheating.

The comparison of infrared thermography pictures performed over time also makes it possible to establish trends and anticipate problems that may appear on some components.

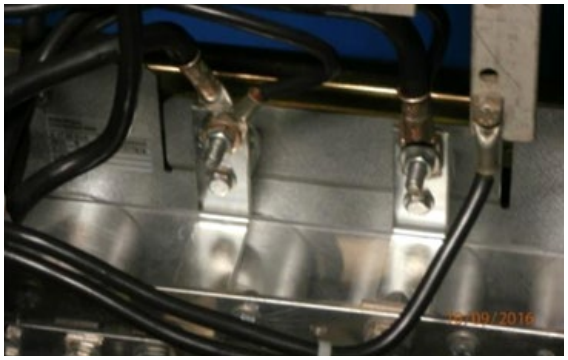
Tool

In order to perform this specific monitoring, Framatome uses dedicated tool sets equipped with thermal cameras that are able to make a complete scanning of equipment.

All pictures collected are then analyzed by experts who will issue their conclusions and recommendations.

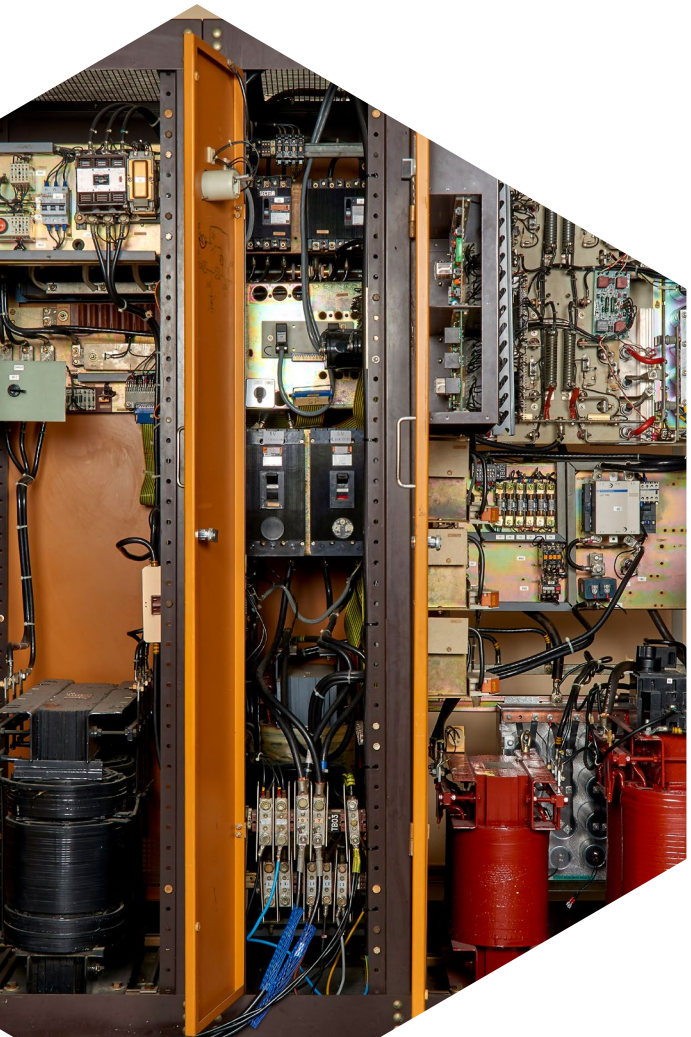
Objectives

Thanks to infrared thermography operations added to the classical maintenance operations performed on inverters, Framatome offers to nuclear operators more visibility on the health status of their equipment by detecting technical or aging problems at an earlier stage and before failure occurrence.



68.3 °C

Example of Infrared thermography analysis, performed on a safey inverter



Experience and references

PULSE is the result of 60 years of experience in nuclear I&C.

Long-term field experience

For more than 60 years, Framatome's team have been involved in designing nuclear power plants, supplying nuclear steam supply systems, designing and manufacturing components and fuel assemblies, integrating instrumentation and control systems, and servicing all types of nuclear reactors, to deliver the highest levels of operational safety for our customers.

Our safety-critical systems and solutions ensure today the safety and sustainability of more than 380 nuclear reactors worldwide.

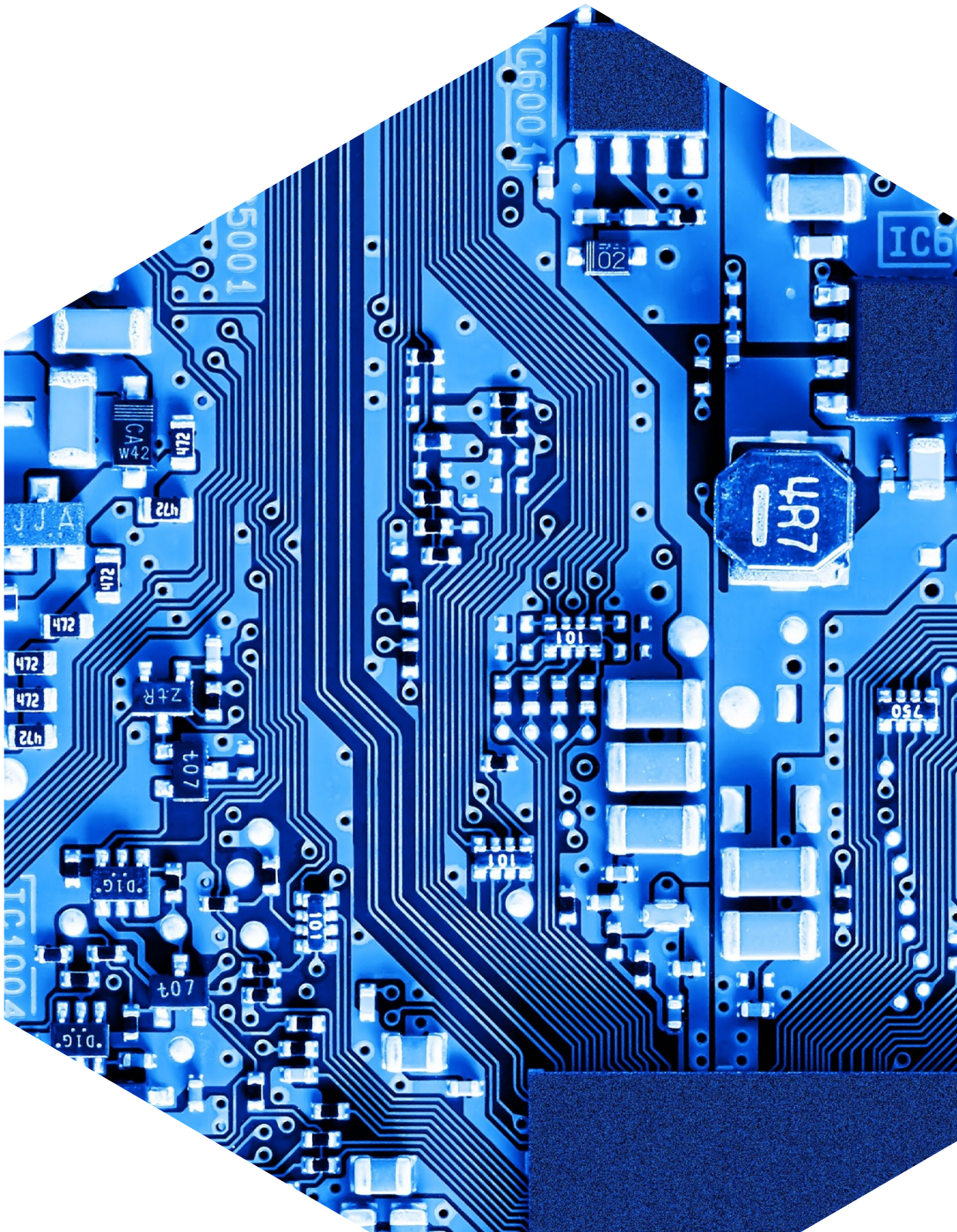
Our highly skilled employees have successfully addressed many challenges to develop innovative, robust and reliable technologies to ensure the highest level of safety and operational performance.

Extensive expertise, proven tools

Over the years, our employees have developed solutions to ensure the operational maintenance of these technologies over the long term for our customers, helping them achieve safe, reliable and cost-effective electricity generation throughout the entire lifetime of their plant.

PULSE is the result of this long experience and expertise in the nuclear I&C domain.

Our tools are today used by almost 200 nuclear reactors worldwide, including all the NPPs in the USA, most of the reactors in France, China, Spain and UK.



Framatome is an international leader in nuclear energy recognized for its innovative, digital and value added solutions for the global nuclear fleet. With worldwide expertise and a proven track record for reliability and performance, the company designs, services and installs components, fuel, and instrumentation and control systems for nuclear power plants. Its more than 16,000 employees work every day to help Framatome's customers supply ever cleaner, safer and more economical low-carbon energy.

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