Instrumentation and Control

Neutron Flux, Radiation and Activity

Nuclear Instrumentation System Based on TELEPERM XS
AREVA has designed, developed and manufactured nuclear instrumentation systems for nuclear installations, research and power reactors for more than 30 years. Our extensive experience gained during these years is at your service.

From SINUPERM to TELEPERM XS

With the SINUPERM nuclear instrumentation System AREVA can refer to more than 30 years of successful operation in nuclear plants.

Now, TELEPERM XS is taking over the task. New components for neutron flux instrumentation, and for radiation and activity monitoring complete the system platform for safety-related instrumentation and control systems and make its advantages available to these fields of application.

No Measurement Without a Detector

The AREVA product portfolio also includes the design and manufacturing of detectors and detector arrangements for both, pressurized and boiling water reactors.

**Detectors and detector arrangements for neutron flux instrumentation**

- Incore instrumentation:
  - Power distribution detectors and local power range monitors (PWR, BWR)
  - Aeroball measurement system (PWR)
  - Traversing incore probe system (PWR, BWR)

- Excore instrumentation:
  - Source range (PWR)
  - Intermediate range (PWR)
  - Power range (PWR)
  - Wide range (PWR)
Neutron flux instrumentation systems measure the power generated in the reactor core by means of fission. They are used from the shutdown, cold, subcritical condition through to rated power and beyond.

The source range channels monitor the subcritical condition and the approach to criticality of the reactor.

During plant startup and shutdown, and in the event of abnormal conditions and accidents, the source and intermediate range channels are used to monitor controlled startup of the reactor, as well as reactor shutdown and reduction of reactor power. In power operation, the intent is to observe the reactor power for compliance with limit values and to promptly detect possible overpower, power tilt and power oscillations. Power range channels and instrumentation channels with power distribution detectors (PDDs) and local power range monitors (LPRMs) are the main types of instrumentation for this application.

Wide range channels combine the monitoring function of source, intermediate and power range channels in a single assembly with only one detector. Three-dimensional power distribution maps of the reactor core are acquired using the traversing incore probe system and aeroball measurement system (AMS). These systems also supply calibration data for the power and power distribution channels.

Neutron Flux Instrumentation System Arrangements

Neutron flux instrumentation systems can be implemented in the form of excore or incore instrumentation.

Incore instrumentation directly supplies a three-dimensional map of power distribution in the reactor core.

Since excore instrumentation systems are installed outside the reactor pressure vessel, they are protected from thermal-hydraulics transients in the reactor core.

However, by virtue of their nature they supply a simplified, indirect map of power distribution.

Schematic diagram
Nuclear Instrumentation Systems
with TELEPERM XS

**Signal conditioning; control and monitoring of detectors**

<table>
<thead>
<tr>
<th>Component</th>
<th>Module(s)</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC amplifier</td>
<td>SCV1P</td>
<td>30 nA to 10 mA</td>
</tr>
<tr>
<td>DC amplifier</td>
<td>SCV1B</td>
<td>30 nA to 10 mA (with auxiliary voltage 200 V / 5 mA)</td>
</tr>
<tr>
<td>DC amplifier</td>
<td>SCV2</td>
<td>1 pA to 1 mA</td>
</tr>
<tr>
<td>Source range amplifier</td>
<td>SPSR1</td>
<td>Pulses from preamplifier, e.g., SPSR1</td>
</tr>
<tr>
<td>Wide range amplifier</td>
<td>SWR1</td>
<td>Pulses, AC from preamplifier SPWR1, DC</td>
</tr>
<tr>
<td>Test signal generator</td>
<td>STG1</td>
<td>Test signals for pulse, DC and AC inputs</td>
</tr>
</tbody>
</table>

**Preamplification of sensitive detector signals**

<table>
<thead>
<tr>
<th>Component</th>
<th>Module(s)</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source range preamplifier</td>
<td>SPSR1</td>
<td>1 MHz pulses</td>
</tr>
<tr>
<td>Wide range preamplifier</td>
<td>SPWR1</td>
<td>1 MHz pulses, AC 5 μA</td>
</tr>
</tbody>
</table>

**High-voltage supply for detectors**

<table>
<thead>
<tr>
<th>Component</th>
<th>Module(s)</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-voltage generator</td>
<td>SHV1-P</td>
<td>+1500 V / 20 mA</td>
</tr>
<tr>
<td>High-voltage generator</td>
<td>SHV1-N</td>
<td>-1500 V / 20 mA</td>
</tr>
<tr>
<td>High-voltage generator</td>
<td>SHV2</td>
<td>+4250 V / 0.5 mA</td>
</tr>
</tbody>
</table>

**Neutron Flux Measurement**

TELEPERM XS features components for signal conditioning and auxiliary power supply for all standard types of detectors used in neutron flux monitoring systems. The conditioned detector signals are acquired using standard TELEPERM XS input/output modules.

Subsequent processing takes place in TELEPERM XS computers using algorithms specified in function diagrams. The function scope ranges from simple signal logic operations to complex adaptive digital filters.

**Signal Conditioning Functions**

TELEPERM XS neutron flux and computer modules together are the basis for individual measuring system applications.

“Individual” means that replacement of existing instrumentation equipment – including equipment from other suppliers – by equipment with identical functions is just as possible as the implementation of progressive new instrumentation concepts.

**Automated Tests**

The test signal generator STG1 is also implemented in the I&C cabinet. It is controlled by the TELEPERM XS computer and can be used for implementing test routines with a high level of automation. This configuration significantly reduces the time and effort associated with periodic testing. The test signal generator is not required during normal operation and can be switched off and disconnected following testing, e.g. for calibration.
The same fundamental measuring principles are applied for radiation and activity monitoring as for neutron flux measurement. For this reason, the TELEPERM XS components are ideally suited for safety-related activity measuring points, such as N16 measurements on the main steam lines of pressurized water reactors. This is especially the case when these signals are used in the reactor protection system. They can also be used for local dose rate measuring points or emission measurements. Modernization based on TELEPERM XS is especially attractive in this area in cases where large sections of the safety I&C are to be implemented using TELEPERM XS.

This approach eliminates any additional costs and effort required for stocking dedicated spare parts inventories and acquiring specific expertise for specialized monitoring systems from other suppliers to be avoided.

Radiation and Activity Monitoring

The typical applications of ex-core and in-core instrumentation in PWRs

Source range
HP & LF BF3 counters

Intermediate range
Compensated ionization chamber

Power range
Detectors in the top and bottom core halves

Power distribution detectors 6 detectors

The typical applications of in-core instrumentation in BWRs

Local power range monitoring
Fission-chamber, 4 detectors

Wide range
Fission chamber

The typical applications of radiation and activity monitoring

Source channel
Fission detectors with external or integrates preamplifier

Current channel
Ionization chamber

Radiation and Activity Monitoring

Interaction between signal acquisition modules, auxiliary power supply modules and standard TELEPERM XS computers
Testing and Parameterization – Using the Diagnostics Interface

TELEPERM XS components feature long service life and minimum failure rates.

The application will be designed in a way that the system tolerates components faults or failures. The faulty component can quickly be located using the TELEPERM XS service unit with its graphical service monitor and dynamic function diagrams.

While the scope of the dynamic function diagrams is limited to the function scope implemented in the computers through to the connector of the input/output modules, a special diagnostics interface (TDI1) supplies similar functions for testing of signal conditioning and preprocessing.

The modules for neutron flux monitoring feature a diagnostic socket for the connection of a TDI1. All of the module input and output signals relevant for function testing and fault diagnostics can be displayed on a PC or notebook.

Module parameters are also set via the diagnostics interface by adjusting digital potentiometers. The software is created using LabView® and can be adapted to suit the requirements of the individual application.

The diagnostics interface provides the maintenance staff with a perfect tool for troubleshooting and periodic testing.
In addition to the static measurement of temperature coefficients, control assembly and boron worths, etc., (dynamic) reactivity measurement can be used as a diverse measuring method for the verification of core design data. Instead of the traditional approach of using external devices for reactivity measurements, AREVA offers an integrated digital solution.

The TELEPERM XS reactimeter function – implemented with the aid of some few function diagrams – permits the measurement of current reactivity, e.g., of an H₂O-moderated pressurized water reactor.

The reactivity is continuously calculated based on the signals of the neutron flux monitoring system (e.g., intermediate range for PWR plants), knowledge of the composition of the fissile material in the fuel and point kinetics equations.

Thanks to their accuracy and time response, the TELEPERM XS signal conditioning modules are suitable for supplying input data for the reactimeter function even in the case of extremely low-level detector signals.

The digital reactimeter outputs are then available for processing in other computers.

Automatic evaluations of measurements and test data can also be implemented; e.g., during plant startup following refueling. External reactimeters are superfluous for neutron flux monitoring systems based on TELEPERM XS.

This principle of an “integrated reactimeter” was implemented as early as 1994 in the SINUPERM N nuclear radiation measuring system and has been in use ever since.

A reactimeter can be implemented by seven function diagrams using the TELEPERM XS function block library. An external reactimeter is not required.
AREVA supplies solutions for carbon-free power generation. Its expertise and know-how in this field are setting the standard, and its responsible development is anchored in a process of continuous improvement.

As the global nuclear industry leader, AREVA’s unique integrated offer to utilities covers every stage of the fuel cycle, nuclear reactor design and construction, and related services. The group is also expanding considerably in renewable energies – wind, solar, bioenergies, hydrogen and storage – to be one of the top three in this sector worldwide in 2012.

Every day, AREVA’s 48,000 employees cultivate the synergies between these two major carbon-free offers, helping to supply safer, cleaner and more economical energy to the greatest number of people.

 Interested in further details or is there anything else that AREVA can do for you? Please contact your regional sales manager or

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