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Nuclear power plants – Instrumentation and control important to safety – Methods for assessing the performance of safety system instrument channels

Centrales nucléaires de puissance – Instrumentation et contrôle-commande importants pour la sûreté – Méthodes d'évaluation des performances des chaînes d'instrumentation des systèmes de sûreté

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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NUCLEAR POWER PLANTS – INSTRUMENTATION AND CONTROL IMPORTANT TO SAFETY – METHODS FOR ASSESSING THE PERFORMANCE OF SAFETY SYSTEM INSTRUMENT CHANNELS

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International Standard IEC 62385 has been prepared by subcommittee 45A: Instrumentation and control of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation.

The text of this standard is based on the following documents:

FDIS	Report on voting
45A/653/FDIS	45A/661/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

a) Technical background, main issues and organisation of the Standard

This International Standard describes test methods for ensuring that safety system instrument channels in nuclear power plants comply with specifications for accuracy, response time and other performance characteristics. This Standard applies to those instruments whose primary sensors measure temperature, pressure, differential pressure, liquid level, flow and neutron flux. The focus of this Standard is on test methods that can be used remotely while the plant is on-line without a need to enter the reactor containment or physically access the instruments.

b) Situation of the current Standard in the structure of the SC 45A standard series

IEC 62385 is the third level SC 45A document tackling the issue of assessing methods of performance of safety systems instrument channels.

For more details on the structure of the SC 45A standard series, see item d) of this introduction.

c) Recommendations and limitations regarding the application of this Standard

The main interests to benefit from this international Standard are nuclear utilities that use on-line performance testing, suppliers who develop and install such systems, and regulatory authorities seeking documented industry consensus on successful practices. These users will benefit from the awareness of methods and practices considered appropriate by IEC experts and from the cost savings associated with the standardization of methods and practices.

d) Description of the structure of the IEC SC 45A standard series and relationships with other IEC documents and other bodies documents (IAEA, ISO)

The top-level document of the IEC SC 45A standard series is IEC 61513. It provides general requirements for I&C systems and equipment that are used to perform functions important to safety in NPPs. IEC 61513 structures the IEC SC 45A standard series.

IEC 61513 refers directly to other IEC SC 45A standards for general topics related to categorization of functions and classification of systems, qualification, separation of systems, defence against common cause failure, software aspects of computer-based systems, hardware aspects of computer-based systems, and control room design. The standards referenced directly at this second level should be considered together with IEC 61513 as a consistent document set.

At a third level, IEC SC 45A standards not directly referenced by IEC 61513 are standards related to specific equipment, technical methods, or specific activities. Usually these documents, which make reference to second-level documents for general topics, can be used on their own.

A fourth level extending the IEC SC 45A standard series, corresponds to the Technical Reports which are not normative.

IEC 61513 has adopted a presentation format similar to the basic safety publication IEC 61508 with an overall safety life-cycle framework and a system life-cycle framework and provides an interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector. Compliance with IEC 61513 will facilitate consistency with the requirements of IEC 61508 as they have been interpreted for the nuclear industry. In this framework IEC 60880 and IEC 62138 correspond to IEC 61508-3 for the nuclear application sector.

IEC 61513 refers to ISO as well as to IAEA 50-C-QA (now replaced by IAEA 50-C/SG-Q) for topics related to quality assurance (QA).

The IEC SC 45A standards series consistently implements and details the principles and basic safety aspects provided in the IAEA code on the safety of NPPs and in the IAEA safety series, in particular the Requirements NS-R-1, establishing safety requirements related to the design of Nuclear Power Plants, and the Safety Guide NS-G-1.3 dealing with instrumentation and control systems important to safety in Nuclear Power Plants. The terminology and definitions used by SC 45A standards are consistent with those used by the IAEA.

NUCLEAR POWER PLANTS – INSTRUMENTATION AND CONTROL IMPORTANT TO SAFETY – METHODS FOR ASSESSING THE PERFORMANCE OF SAFETY SYSTEM INSTRUMENT CHANNELS

1 Scope

The purpose of this International Standard is to define the requirements for demonstrating acceptable performance of safety system instrument channels through response time testing, calibration verification, and other means. The same requirements may be adopted for demonstrating the acceptable performance of non-safety systems and other instrument channels. This Standard contains the main topics in its body and includes annexes to provide further information. The annexes are for information only and contain a selection of the available methods.

The methods described in this Standard are used to check instrument calibration for accuracy and time response. It covers direct methods used to set calibration within required tolerances and indirect methods to indicate a need for a direct calibration. The use of the indirect methods allows for longer periods between the routine direct calibrations.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61224:1993, *Nuclear reactors – Response time in resistance temperature detectors (RTD) – In-situ measurements*

IEC 62397, *Nuclear power plants – Instrumentation and control important for safety – Resistance Temperature Detectors*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
accuracy of measurement
closeness of the agreement between the result of a measurement and the conventionally true value of the measurand

[IEV 394-40-35]

3.2
blockage
narrowing of a tube (e.g., pressure sensing line) due to accumulation of contaminants in the reactor water, solidification of boron, valves that are left partially open, etc. A blockage can cause a delay in measurement of dynamic pressure information.

3.3
calibration
set of operations that establish, under specified conditions, the relationship between values of quantities indicated by measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards

[IEV 394-40-43]

3.4
channel
an arrangement of interconnected components within a system that initiates a single output. A channel loses its identity where the single-output signals are combined with signals from another channels (e.g. from a monitoring channel or a safety actuation channel).

[IAEA Safety Glossary, Version 2.0, 2006]

3.5
channel check
process by which a plant operator compares the reading of redundant instrument channels on a regular basis to verify that these are in good agreement according to predefined criteria

3.6
cross-calibration (cross-validation)
a procedure of intercomparing the indications of redundant instruments (e.g., temperature sensors) to identify outlier sensors as a means of verifying calibration or identifying calibration changes. A more appropriate term for this definition is "cross-validation," but, cross-calibration is more commonly used.

3.7
drift
variation in sensor or instrument channel output that may occur between calibrations that cannot be related to changes in the process variable or environmental conditions

3.8
impulse line (sensing line)
piping or tubing connecting the process to the sensor; impulse lines/sensing lines are usually used to connect pressure, level, and flow transmitters to the process. They vary in length from a few metres to a few hundred metres. Sensing lines may also include isolation and root valves and other piping hardware along their length.

3.9
in-situ test
test of a sensor or a transmitter that is performed without removing the sensor or transmitter from its normal installed position in the system

3.10
noise analysis technique
method for in-situ response time testing of sensors, detectors, and transmitters and for on-line detection of blockages, voids, and leaks in pressure sensing lines

3.11
on-line monitoring
continuous or periodic measurement and recording of output of installed instrumentation

3.12
outlier
a sensor such as an RTD that has exceeded a prespecified deviation

3.13
performance monitoring (performance verification)
process of demonstrating that an installed instrument channel continues to perform its intended function of monitoring the process variable with the expected accuracy, response time, and stability

3.14
pressure transmitters
pressure, level, and flow transmitters that are based on the principle of pressure or differential pressure measurement, and are collectively referred to in this Standard as pressure transmitters, pressure sensors, or just transmitters

3.15
redundancy
provision of alternative (identical or diverse) structures, systems or components, so that any one can perform the required function regardless of the state of operation or failure of any other

[IAEA Safety Glossary, Version 2.0, 2006]

3.16
Resistance Temperature Detector (RTD)
detector generally made up of a stainless steel cylindrical barrel protecting a platinum resistor whose resistance varies with temperature. This detector is placed in the piping containing the fluid whose temperature is measured in this way. It can be directly immersed in the fluid or protected by an intermediate casing called the thermowell.

[IEC 62397]

3.17
response time
the period of time necessary for a component to achieve a specified output state from the time that it receives a signal requiring it to assume that output state

[IAEA Safety Glossary, Version 2.0, 2006]

3.18
test interval
the elapsed time between the initiation of identical tests on the same sensor and signal processing device, logic assembly or final actuation device

[IEC 60671]

3.19
thermowell
protective jacket for RTDs, thermocouples, and other temperature sensors. The thermowell is also used to facilitate replacement of the temperature sensor.

3.20
time constant
in the case of a first order system, the time required for the output signal of a system to reach 63,2 % of its final variation after a step change of its input signal.

If the system is not first order system, the term "time constant" is not appropriate. For a system of a higher order, the term "response time" should be used.

[IEC 62397]

4 Requirements for performance verification of process instruments

4.1 Background

The control and safety systems of nuclear power plants depend on process instrumentation which must provide reliable information to ensure plant safety and efficiency. Therefore, the performance of this instrumentation should be verified at predefined intervals during the plant life time. For this purpose, test methods have been developed, validated, and used in nuclear power plants. These methods include means to perform the tests in-situ and while the plant is operating (on-line testing).

This clause gives the requirements for in-situ and on-line testing to verify that process instrumentation provides accurate and timely data and to identify faulty instruments. The focus of the Standard is on the process sensors that measure temperature, pressure, liquid level, flow, and neutron flux.

4.2 General requirements

Performance monitoring shall be conducted to verify that the safety system instrument channels in nuclear power plants are functioning within their performance specification limits. The tests that verify performance characteristics shall be conducted in accordance with written procedures, and the test results shall be documented. The instrument channel should be tested in a single test. When the total channel is not tested in a single test, separate tests on groups of components or on single components encompassing the total instrument channel shall be combined to verify total channel performance. Performance monitoring encompasses the instrument channel portion of the overall safety system. Test boundaries shall include sensors and transmitters, sensing lines (impulse lines), thermowells, cables, and all other active and passive components that affect the overall instrument channel performance.

If a performance index such as response cannot be identified exactly, a conservative estimate of the index shall be made by measurement and analysis and compared against the pertinent performance requirements to ensure that the performance is acceptable.

4.3 Testing environment

In general, abnormal environmental conditions such as seismic events, radiation fields, extreme pressures, temperatures, and moisture conditions are covered by design qualification tests. As such, testing of equipment for such environments is not within the scope of this Standard. However, the performance testing described in this Standard should be carried out within the bounds of the instrument's environmental conditions (e.g., temperature, pressure, humidity, flow, etc.) If the test conditions vary widely, appropriate corrections shall be made for comparison or trending of data to compensate for performance due to variation in the environmental conditions or the effect of the environmental conditions on performance.

In some cases, such as response time testing of temperature sensors, process operating conditions can have a strong influence on the result. In these cases, the tests shall be performed at or near normal operating conditions to provide the actual "in-service" performance of the sensors. Extrapolation from laboratory conditions to plant conditions should not be performed in cases where the extrapolation results can have large and unquantifiable uncertainties.

4.4 Test interval

The test intervals shall be established to detect unacceptable performance. The following factors should be considered in determining the test interval:

a) technical specification requirements;

b) regulatory requirements;

c) manufacturer's recommendation and industry standards;

d) margin between measured performance characteristics and allowable performance limits;

e) rate-of-change of performance characteristics with time; and

f) component failure rates and target reliability.

4.5 Test location

Testing should be performed in-situ to the extent practicable. Instrument removal for testing is acceptable only if such removal does not affect test results. In most cases of concern in this Standard, in-situ tests are performed remotely from the instrument cabinet in the control room area. Procedures shall be implemented to confirm that equipment status is restored after testing.

4.6 Calibration of measurement and test equipment

The calibration of measurement and test equipment used in verifying equipment performance characteristics shall be traceable to national standards and/or accepted values of natural physical phenomena. Written procedures shall be used to perform the calibration and the results of the calibration shall be documented.

4.7 Test results

The test results shall be compared to the allowable performance limits. Allowances for uncertainties associated with the performance monitoring test shall be included in the test results or the establishment of performance limits. If the results are found to exceed the limit, or the rate of change in the performance characteristics are such that the allowable performance limits may be exceeded prior to the next test, predetermined action should be taken to correct the problem.

The accuracy of test results should be stated in terms of a percentage of the reported value or a ± band around the reported value. This accuracy should be determined from not only the equipment uncertainties, but also from the uncertainties of the test and analysis techniques involved. If uncertainties cannot be identified objectively, it should be demonstrated that the test results are conservative.

4.8 Validation of test methods

All performance monitoring test methods shall be validated. This validation shall be documented and should address the following considerations:

a) Comparison of the test method with suitable laboratory tests, in-situ tests, or both tests to establish the validity of the method and quantify the accuracy of its results. The accuracy of the test method and results should be established by theoretical or experimental means, or both. The accuracy determination should consider all sources of error in the test method.

b) Theoretical justification for the test method.

c) That the assumptions and conditions to ensure validity of the test method are satisfied. Furthermore, if the test assumptions are not fully satisfied, it should be demonstrated that the results that are obtained will nevertheless be conservative.

d) Any software used for data acquisition, data qualification, or data analysis should be designed and developed using a systematic approach according to accepted industry standards for software development for nuclear power plants. All software packages should go through comprehensive verification and validation (V&V) testing. The basis for the V&V tests and the results of the V&V work should be documented. The V&V tests should be designed to reveal any problem that can produce invalid or non-conservative results.

4.9 Qualifications of test personnel

Testing to verify the performance of nuclear power plant instruments shall be performed by test personnel who have been properly trained by experienced experts with documented qualification to perform the training. The training of the test personnel shall be documented and updated periodically. Examples of training topics to qualify the test personnel are:

a) principles of performance verification tests;

b) review of performance test procedures;

c) equipment preparation for data acquisition;

d) training on data acquisition and data analysis software; and

e) interpretation and documentation of results.

5 Acceptable means for instrument performance verification

5.1 Introduction

This clause gives the requirements for calibration, channel checks, functional tests, and response time testing of process instruments. It is followed by descriptions of methods to perform instrument calibration and response time testing.

The performance of instruments in nuclear power plants may be established in a laboratory or by bench testing. The means for laboratory or bench calibration of instruments are well established and are not addressed in this Standard. Rather, the means for in-situ/on-line calibration verification of sensors and transmitters are described. Regarding response time performance of sensors and transmitters, both laboratory/bench testing methods as well as in-situ/on-line testing methods are described in this Standard.

5.2 Calibration

Instrument calibration utilizes known precision inputs to verify that the instrument produces the required outputs over the required operational range within specified limits. When calibration is used for instrument performance verification, the calibration shall be accomplished or verified through individual application or combination of the following taking into account previous experience: