IEC/IEEE 62582-6

Edition 1.0 2019-10

INTERNATIONAL STANDARD

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Nuclear power plants – Instrumentation and control important to safety – Electrical equipment condition monitoring methods – Part 6: Insulation resistance

Centrales nucléaires de puissance – Instrumentation et contrôle-commande importants pour la sûreté – Méthodes de surveillance de l'état des matériels électriques – Partie 6: Résistance d'isolement

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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation.

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International Standard IEC/IEEE 62582-6 has been prepared by subcommittee 45A: Instrumentation, control and electrical power systems of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation, in cooperation with the Nuclear Power Engineering Committee of the Power & Energy Society of the IEEE][1], under the IEC/IEEE Dual Logo Agreement.

It is published as an IEC/IEEE dual logo standard.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
45A/1267/FDIS	45A/1277/RVD

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

A list of all parts in the IEC/IEEE 62582 series, published under the general title *Nuclear power plants – Instrumentation and control important to safety – Electrical equipment condition monitoring methods*, can be found on the IEC website.

International standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this publication will remain unchanged until the stability 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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

[1] A list of IEEE participants can be found at the following URL: https://ieee-sa.imeetcentral.com/p/eAAAAAAAQbmGAAAAACt2TZA

INTRODUCTION

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

This IEC/IEEE standard specifically focuses on insulation resistance measurement methods for monitoring of the dielectric condition of instrumentation and control cables during simulation of design basis events.

This IEC/IEEE standard is the sixth part of the IEC/IEEE 62582-series. It contains detailed descriptions of condition monitoring based on insulation resistance measurements.

The IEC/IEEE 62582-series of standards is issued with a joint logo which makes it applicable to management of ageing of electrical equipment qualified to IEEE as well as IEC Standards.

For aged cables and accessories, the dielectric behaviour during simulated accident conditions generally indicates the condition of the cable during the simulated accident condition.

Significant research has been performed on condition monitoring techniques and the use of these techniques in equipment qualification as noted in NUREG/CR-6704, vol.2 (BNL-NUREG-52610) and JNES-SS-0903, 2009.

It is intended that this Standard be used by test laboratories, operators of nuclear power plants, systems evaluators and licensors.

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

IEC/IEEE 62582-6 is the third level IEC SC 45A document tackling the specific issue of application and performance of insulation resistance measurements during simulated accident conditions in nuclear power plants.

IEC/IEEE 62582-6 is to be read in association with IEC/IEEE 62582-1. IEC/IEEE 62582-1 provides requirements for application of methods for condition monitoring of electrical equipment important to safety of nuclear power plants.

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

c) Recommendations and limitations regarding the application of the Standard

It is important to note that this Standard establishes no additional functional requirements for safety systems.

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 documents of the IEC SC 45A standard series are IEC 61513 and IEC 63046. IEC 61513 provides general requirements for I&C systems and equipment that are used to perform functions important to safety in NPPs. IEC 63046 provides general requirements for electrical power systems of NPPs; it covers power supply systems including the supply systems of the I&C systems. IEC 61513 and IEC 63046 are to be considered in conjunction and at the same level. IEC 61513 and IEC 63046 structure the IEC SC 45A standard series and shape a complete framework establishing general requirements for instrumentation, control and electrical systems for nuclear power plants.

IEC 61513 and IEC 63046 refer directly to other IEC SC 45A standards for general topics related to categorization of functions and classification of systems, qualification, separation, defence against common cause failure, control room design, electromagnetic compatibility, cybersecurity, software and hardware aspects for programmable digital systems, coordination of safety and security requirements and management of ageing. The standards referenced directly at this second level should be considered together with IEC 61513 and IEC 63046 as a consistent document set.

At a third level, IEC SC 45A standards not directly referenced by IEC 61513 or by IEC 63046 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 45 standard series, corresponds to the Technical Reports which are not normative.

The IEC SC 45A standards series consistently implements and details the safety and security principles and basic aspects provided in the relevant IAEA safety standards and in the relevant documents of the IAEA nuclear security series (NSS). In particular this includes the IAEA requirements SSR-2/1, establishing safety requirements related to the design of nuclear power plants (NPPs), the IAEA safety guide SSG-30 dealing with the safety classification of structures, systems and components in NPPs, the IAEA safety guide SSG-39 dealing with the design of instrumentation and control systems for NPPs, the IAEA safety guide SSG-34 dealing with the design of electrical power systems for NPPs and the implementing guide NSS17 for computer security at nuclear facilities. The safety and security terminology and definitions used by SC 45A standards are consistent with those used by the IAEA.

IEC 61513 and IEC 63046 have adopted a presentation format similar to the basic safety publication IEC 61508 with an overall life-cycle framework and a system life-cycle framework. Regarding nuclear safety, IEC 61513 and IEC 63046 provide the interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector. In this framework IEC 60880, IEC 62138 and IEC 62566 correspond to IEC 61508-3 for the nuclear application sector. IEC 61513 and IEC 63046 refer to ISO as well as to IAEA GS-R part 2 and IAEA GS-G-3.1 and IAEA GS-G-3.5 for topics related to quality assurance (QA). At level 2, regarding nuclear security, IEC 62645 is the entry document for the IEC/SC 45A security standards. It builds upon the valid high level principles and main concepts of the generic security standards, in particular ISO/IEC 27001 and ISO/IEC 27002; it adapts them and completes them to fit the nuclear context and coordinates with the IEC 62443 series. At level 2, IEC 60964 is the entry document for the IEC/SC 45A control rooms standards and IEC 62342 is the entry document for the ageing management standards.

NOTE 1 It is assumed that for the design of I&C systems in NPPs that implement conventional safety functions (e.g. to address worker safety, asset protection, chemical hazards, process energy hazards) international or national standards would be applied.

NOTE 2 IEC/SC 45A domain was extended in 2013 to cover electrical systems. In 2014 and 2015 discussions were held in IEC/SC 45A to decide how and where general requirements for the design of electrical systems were to be considered. IEC/SC 45A experts recommended that an independent standard be developed at the same level as IEC 61513 to establish general requirements for electrical systems. Project IEC 63046 is now launched to cover this objective. When IEC 63046 is published, this NOTE 2 of the introduction of IEC/SC 45A standards will be suppressed.

NUCLEAR POWER PLANTS – INSTRUMENTATION AND CONTROL IMPORTANT TO SAFETY – ELECTRICAL EQUIPMENT CONDITION MONITORING METHODS –

Part 6: Insulation resistance

1 Scope

This part of IEC/IEEE 62582 contains methods for condition monitoring of organic and polymeric materials in instrumentation and control cables using insulation resistance measurements in the detail necessary to produce accurate and reproducible results during simulated accident conditions. It includes the requirements for the measurement system and measurement procedure, and the reporting of the measurement results.

NOTE Measurement of insulation resistance during simulated accident conditions with the aim of determining the lowest value during the accident in order to assess cable performance involves special requirements given in this document. Methods for measurement under stable (non-accident) conditions are available in other international standards, e.g. IEC 62631-3-3.

The different parts of the IEC/IEEE 62582 series are measurement standards, primarily for use in the management of ageing in initial qualification and after installation. IEC/IEEE 62582-1 includes requirements for the application of the other parts of the IEC/IEEE 62582 series and some elements which are common to all methods. Information on the role of condition monitoring in qualification of equipment important to safety is found in IEC/IEEE 60780-323.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

JCGM 100:2008, *Evaluation of measurement data – Guide to the expression of uncertainty in measurement. First edition 2008. Corrected version 2010*

3 Terms and definitions

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

For definitions not specifically called out in this standard, the following references could be useful:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp
- IEEE Standards Online Dictionary: available at http://dictionary.ieee.org

3.1
capacitive charging current
current that charges the capacitor formed by the tested insulation between the conducting parts connected to the measuring instrument inputs

Note 1 to entry: At the beginning the capacitor is not charged and high current is flowing. The current drops as the capacitor is being charged.

3.2
conductor
material that allows the flow of an electric current

Note 1 to entry: The term conductor used in this document is synonymous with the term wire.

3.3
insulation leakage current
current that flows through insulation

3.4
insulation resistance
resistance between two conducting parts separated by electric insulation

Note 1 to entry: The value of the measured insulation resistance shall be reported as Ωm.

3.5
polarization absorption current
component of a dielectric current that is proportional to the rate of accumulation of electric charges within the dielectric

3.6
surface leakage current
current that flows on the surface of insulation between connection points of applied voltage

Note 1 to entry: The surface leakage current is constant with time.

4 Abbreviated terms and acronyms

AC	Alternating current
DAQ	Data acquisition
DC	Direct current
DMM	Digital multimeter
GUM	Guide to the expression of uncertainty in measurement
JCGM	Joint committee for guides in metrology
IR	Insulation resistance
I_s	Surface leakage current
I_i	Insulation leakage current
I_p	Polarization absorption current
I_c	Capacitive charging current
LOCA	Loss of coolant accident
R_{meas}	Resistance of the resistor intended for measuring the total leakage current
U_{meas}	Voltage across the resistor R_{meas}
U_{source}	Supply voltage

5 General description

Insulation resistance measurement is one commonly applied method for indication of the condition of insulating components, primarily cable insulation, during simulated accident conditions. A minimum value of the insulation resistance of a cable may be prescribed to be exceeded throughout the simulated accident conditions. The minimum insulation resistance value may be prescribed to ensure a margin to dielectric conditions at which the safety function of the circuit will not be affected. This is generally for instrumentation cables. The insulation value prescribed is related to the length of the cable and should be given in Ωm, i.e. in Ω for one m of cable length.

For measurement of IR as a measure of the condition of a cable, DC voltage is recommended. AC voltage is primarily used for measurement of the functionality of the cable in its intended application. An example of a set up for measurement of IR using DC voltage is shown in Annex A. Some guidelines for leakage current measurement using AC voltage are given in Annex B. The set up in Annex B is recommended for functional testing only, and not as a substitute for IR measurement using DC voltage.

The total current measured after a DC voltage is applied is composed of I_s, I_i, I_p, and I_c. The I_s causes an error in insulation resistance measurement if the ground plane is not in contact with the surface of the isolation and can be eliminated by use of a guard terminal. For values of IR which can be expected during simulated accident conditions, the influence of I_p is small.I_c is significant for most common insulation materials during a short time after the application of voltage and the stabilization of the total current value has to be awaited. For all common insulation materials, I_c may be considered as insignificant after less than 3 s when the IR is measured under simulated accident conditions. Figure 1 shows an example of the time to stabilization from measurement of IR before and during LOCA.

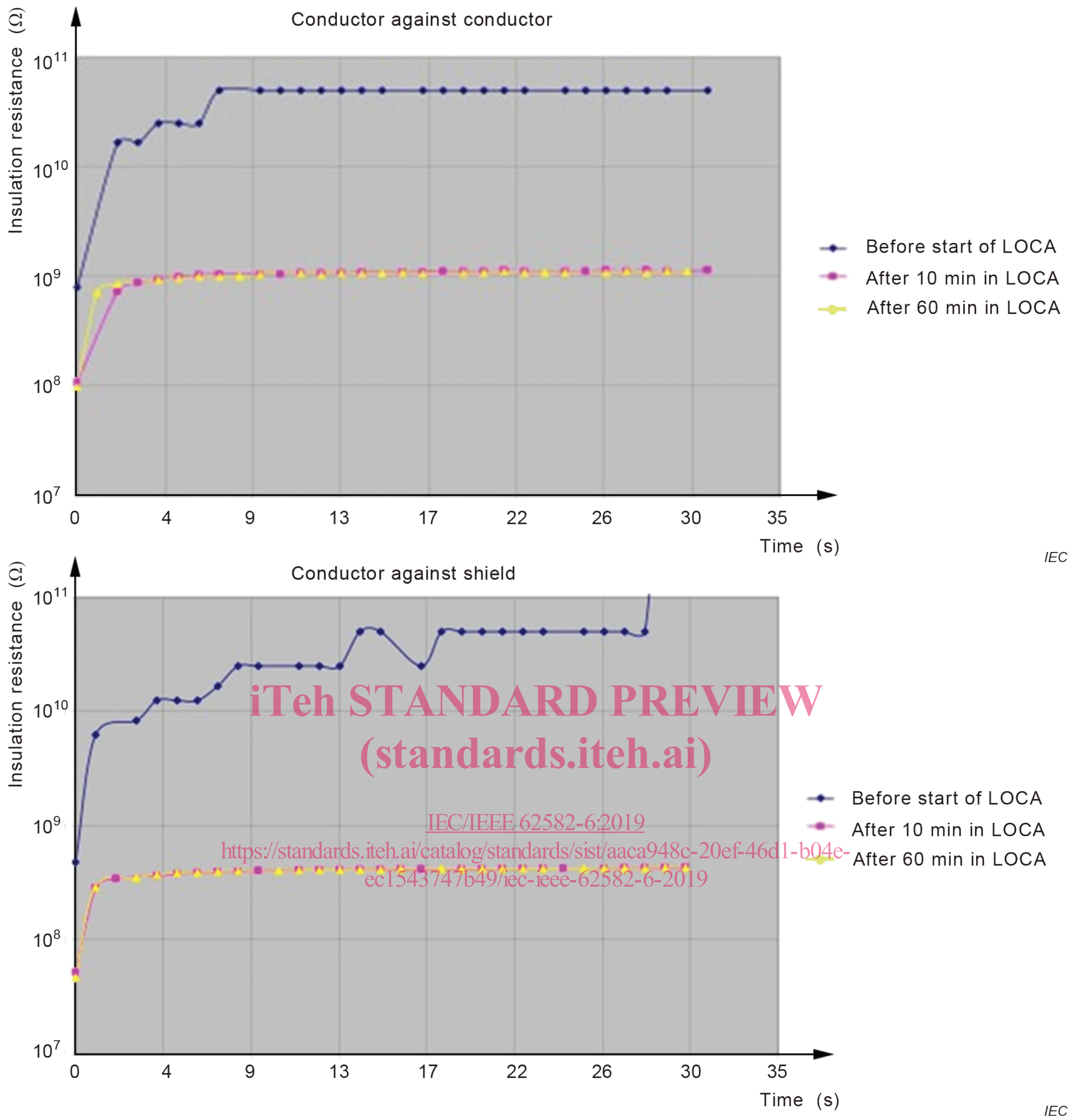

Figure 1 – Time to stabilization of IR measured before LOCA, after 10 min in LOCA and after 60 min in LOCA

The diagrams show that stabilization of the measurements during LOCA is reached well within 3 s also in a case where the IR value is well above 100 MΩ.

6 Applicability and reproducibility

This document is limited to the use of insulation resistance measurement for monitoring the condition of cables during simulated accident conditions. The temperature of the insulator has a very significant influence on the values measured – an approximation that is used sometimes is that of the IR decrease by a factor of two for each increase of temperature of 10 K. In addition, the high humidity and pressure involved in the simulated accident conditions, resulting in moisture condensed on the insulator and penetration of moisture into the insulator, affect the measured values. The dependence of IR on temperature and steam is discussed in Annex C. In the simulation of accident conditions, temperature, moisture condensed and penetration of moisture into the insulator vary with time. The result of an insulation resistance measurement during simulated accident conditions varies significantly depending on the initial condition of the cable and at what time during the simulated accident conditions the measurement is taken. Annex D shows some results of IR measurement on aged cables during a simulated LOCA.

As illustrated by Annex D, Figures D.1 through D.3, limited time is available for each measurement to allow detection of the lowest IR value during a simulated accident condition when a multiconductor cable is measured. Figure D.1 also illustrates the importance of measuring IR on each conductor in order to find the conductor with the lowest value.

The elimination of voltage stress may yield a better condition, or lesser level of degradation than if it is applied during the test. Some cable qualification standards, such as IEEE Std 383, require that the cable is loaded with rated voltage and current during the test. The measurement technique then needs to combine measurement and load. If there is a non-continuous measurement the interval between measurements needs to be defined to find the lowest value with a required uncertainty.

The purpose of the IR measurement according to this document is to detect values in the range up to 100 MΩm, i.e. IR values above which no significant effects during simulated accident conditions will be expected on functionality of typical low voltage cables.

NOTE The acceptable level of IR depends on the application. For most applications, the required insulation is well below 100 MΩm.

Per IEEE Std 383-2015 the qualification type tests for coaxial, triaxial, twinaxial and data/communication cables should include sufficient testing of cables critical electrical performance characteristics to permit an adequate analysis of the compatibility of the cables for the specific application, as appropriate. This may include insulation resistance testing for some applications but the IR may need to be higher than 100 MΩm.

7 Instrumentation

7.1 Measurement voltage level

Measurement equipment shall be capable to supply enough voltage to be able to keep the specified measurement voltage level constant over the whole measurement range, including the lowest acceptable IR value.

7.2 Uncertainty

The measuring device shall be calibrated to an overall uncertainty within ±10 %.

NOTE This can be achieved in a standard set up with a 10 kΩ shunt resistor when a 6 ½ digit digital multi-meter is used. The uncertainty limit occurs at 100 MΩ and IR in the 10 kΩ range can still be traced.

The uncertainty shall be calculated according to JCGM 100:2008 (GUM methodology).

7.3 Calibration

The IR measurement device shall be calibrated in the range of the quantities measured to ensure accuracy. These quantities can be either voltage and the current or the resistance.

8 IR measurement procedure

8.1 General

The measurement procedure described allows determination of the lowest IR of individual conductors of a multiconductor cable. In the case only one conductor or group of connected conductors per measurement instrument is measured, the measuring period can be equal to the test time in case of measurement on non-energized specimens. If this is not the case and one instrument is used for measurement of more than one conductor or group of conductors, the measurement procedure has to include switching. For the case of measurement on energized specimens, see 8.6.5.

8.2 Requirements on tracking of changes of IR during the simulated accident conditions

To catch the maximum influence on the resistance of the rapidly varying temperature/moisture/pressure at the initial part of the accident condition simulation the switching time, the stabilizing time and the measuring time shall be limited to enable tracking of the changes in insulation resistance. The procedure shall allow consecutive readings of the IR value at least every 7,5 min during the accident condition simulation. The lowest value detected during the accident condition simulation shall be reported. In addition to reporting the lowest IR value, a diagram shall be included, showing the IR time history during the accident condition simulation.

8.3 Test specimen

The test specimen (complete cable or single conductor under test) shall have a minimum length of 3 m. The conductors shall be sealed at the ends. When a complete cable, including jacket, is tested, there shall be no sealing between the conductors and the jacket, unless the test is intended purely for a certain application where it is sealed.

The ground plane shall be in contact with all parts of the surface of the isolator of the test specimen. No guard is then needed. This is achieved by using a metallic braid around the specimen as ground plane. The metallic braid shall be of a construction that does not influence absorption of moisture into the insulation material or penetration of moisture through cracks in the insulation material.

NOTE 1 The position of the ground plane in contact with the isolator results in a conservative (low) value of IR, similar to what can be expected in the field if the cable is installed in a metallic conduit or at the bottom of a solid metallic cable tray. If the cable in the field is installed on a cable ladder the connection to ground is point-wise, resulting in higher values of IR.

NOTE 2 In case of testing of specimen submerged in water, the water may be used as ground plane.

8.4 Interference

Other specimens in the chamber that are AC loaded or energized shall be shut off during the IR measurement in order to avoid cross-talk.

8.5 Conditioning

Before start of the accident simulation, the specimen shall be stabilized to a condition corresponding to normal operation in the field.