IEC/IEEE 62582-1

Edition 1.0 2011-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Nuclear power plants – Instrumentation and control important to safety – Electrical equipment condition monitoring methods – Part 1: General

Centrales nucléaires de puissance – Instrumentation et contrôle-commande importants pour la sûreté – Méthodes de surveillance de l'état des matériels électriques – Partie 1: Généralités

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

PRICE CODE
CODE PRIX

N

ICS 27.120.20

ISBN 978-2-88912-668-2

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 1: General

FOREWORD

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International Standard IEC/IEEE 62582-1 has been prepared by subcommittee 45A: Instrumentation and control 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 between IEC and IEEE.

This publication is published as an IEC/IEEE Dual Logo standard.

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

FDIS	Report on voting
45A/840/FDIS	45A/849/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.

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

A list of all parts of IEC/IEEE 62582 series, 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.

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- withdrawn,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.

[1] A list of IEEE participants can be found at the following URL: http://standards.ieee.org/downloads/62582-1/62582-1-2011/62582-1-2011_wg-participants.pdf.

INTRODUCTION

a) Technical background, main issues and organisation of this standard

This part of this IEC/IEEE standard specifically focuses on methods for condition monitoring for management of ageing of electrical equipment installed in nuclear power plants and for application of the concept of qualified condition.

This part of IEC/IEEE 62582 is the first part of the IEC/IEEE 62582 series of standards, containing background and guidelines for the application of methods for condition monitoring of electrical equipment important to safety of nuclear power plants. The detailed descriptions of the methods are given in the other parts, one part for each method. This part also includes some elements which are common to all methods.

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

Condition monitoring is a developing field and more methods will be added to the IEC/IEEE 62582 when they are considered widely applied and a good reproducibility of the condition monitoring method can be demonstrated.

Historically, IEEE Std 323-2003 introduced the concept and role that condition based qualification could be used in equipment qualification as an adjunct to qualified life. In equipment qualification, the condition of the equipment for which acceptable performance was demonstrated is the qualified condition. The qualified condition is the condition of equipment, prior to the start of a design basis event, for which the equipment was demonstrated to meet the design requirements for the specified service conditions.

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 IEC/IEEE Standard be used by operators of nuclear power plants, systems evaluators and by licensors.

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

Part 1 of IEC/IEEE 62582 is the third level IEC SC 45A document tackling the issue of application of condition monitoring in equipment qualification and management of ageing of electrical I&C equipments in nuclear power plants.

Part 1 of IEC/IEEE 62582 is to be read in association with IEC 60780 and IEEE 323, which provide general requirements for qualification of I&C systems and equipment that are used to perform functions important to safety in NPPs and nuclear facilities.

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 this standard

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

The Standard discusses the general measurement technique for current condition monitoring methods and is not meant to cover any specific technologies.

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 GS-R-3) 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 – ELECTRICAL EQUIPMENT CONDITION MONITORING METHODS –

Part 1: General

1 Scope and object

This part of IEC/IEEE 62582 contains requirements for application of the other parts of IEC/IEEE 62582 related to specific methods for condition monitoring in electrical equipment important to safety of nuclear power plants. It also includes requirements which are common to all methods.

IEC/IEEE 62582 specifies condition monitoring methods in sufficient detail to enhance the accuracy and repeatability, and provide standard formats for reporting the results. The methods specified are applicable to electrical equipment containing organic or polymeric materials. Some methods are especially designed for the measurement of condition of a limited range of equipment whilst others can be applied to all types of equipment for which the organic parts are accessible.

Although the scope of IEC/IEEE 62582 is limited to the application of instrumentation and control systems important to safety, the condition monitoring methods may be applicable also to other components which include organic or polymeric materials.

The different parts of IEC/IEEE 62582 are measurement standards, primarily for use in the management of ageing in initial qualification and after installation. For technical background of condition monitoring methods, reference is made to other IEC standards, e.g. IEC 60544-5. Information on the role of condition monitoring in qualification of equipment important to safety is found in IEEE Std 323. General information on management of ageing can be found in IEC 62342 and IEEE 1205.

NOTE The procedures defined in the IEC/IEEE 62582 are intended for detailed condition monitoring. A simplified version of the procedures may be appropriate for preliminary assessment of the need for detailed measurements.

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.

IEEE Std 323:2003, IEEE *Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*

3 Terms and definitions

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

3.1
condition indicator
characteristic of a structure, system or component that can be observed, measured or trended to infer or directly indicate the current and future ability of the structure, system or component to function within acceptance criteria

[IAEA Safety Glossary, 2007 Edition]

3.2
condition monitoring
continuous or periodic tests, inspections, measurement or trending of the performance or physical characteristics of structures, systems and components to indicate current or future performance and the potential for failure

[IAEA Safety Glossary, 2007 Edition]

3.3
equipment qualification
generation and maintenance of evidence to ensure that equipment will operate on demand, under specified service conditions, to meet system performance requirements

[IAEA Safety Glossary, 2007 Edition]

3.4
item important to safety
item that is part of a safety group and/or whose malfunction or failure could lead to radiation exposure of the site personnel or members of the public

[IAEA Safety Glossary, 2007 Edition]

3.5
qualified condition
condition of an equipment, prior to the start of a design basis event, for which the equipment was demonstrated to meet the design requirements for the specified service conditions

3.6
qualified life
period for which a structure, system or component has been demonstrated, through testing, analysis or experience, to be capable of functioning within acceptance criteria during specific operating conditions while retaining the ability to perform its safety functions in a design basis accident or earthquake

[IAEA Safety Glossary, 2007 Edition]

3.7
service life
period from initial operation to final withdrawal from service of a structure, system or component

[IAEA Safety Glossary, 2007 Edition]

4 Condition indicators

4.1 General

Condition monitoring should only be applied if there is a known relationship between the ageing degradation of the component monitored and the degradation of the equipment's safety function. This relationship should be established during equipment qualification. The relationship should take into account any diffusion limited rate effects that occur during accelerated ageing with high acceleration factors.

Condition monitoring programs rely on measurable indicators that provide insight into the overall degradation of the materials. To perform measurements of the condition of naturally aged components, a sample shall either be taken destructively or the measurements shall be made on the material in the field in a non-destructive way. The latter methods are preferred since they allow the material to be studied without interrupting operation; however, it is often

difficult to perform these types of measurements directly in the field with the required degree of repeatability and accuracy.

In organic materials, ageing occurs that may adversely impact the important safety function through a range of chemical reactions, including chain scission and cross-linking, which alter the polymeric structure. For condition monitoring programs, it becomes imperative to find methods that, either directly or indirectly, follow the progress of these reactions. A large number of methods exist to perform this task, which makes it difficult to provide an overview of each individual technique. Instead, this standard will focus on general groups of methods. The overall description of these groups is provided below.

4.2 Chemical indicators

As mentioned above, the degradation mechanism for organic materials follows from a series of chemical reactions in which the chemical structure of the polymer is altered. The progressive change in the chemistry of the material provides an opportunity to monitor the degradation throughout its ageing. Numerous techniques exist to perform this task, some which monitor the polymer chain degradation itself and others which monitor side reactions which are related to the degradation.

4.3 Physical indicators

Another key family of indicators includes techniques which monitor the material's physical properties. The degradation of organic materials manifests itself in changes to these physical properties (i.e. tensile strength, elongation, and hardness). By measuring these physical characteristics, it is possible to create a correlation with the aged condition of the material.

4.4 Electrical indicators

A third category of techniques involves measuring electrical properties of the materials. Many of these techniques were developed for polymeric materials used in electrical insulation. Within this family there are two basic subsets of methods. The first subset involves measuring the dielectric properties of the materials.

A second subset of methods monitors the electrical response of systems under normal operation. In these cases, a signal is passed through the electrical system and any changes from baseline are detected. These changes could be signs of degradation, whether through ageing or through physical damage.

4.5 Miscellaneous Indicators

As new technologies are developed and implemented, it becomes necessary to develop condition monitoring methods to keep pace. As such, some methods are developed specifically for certain types of materials.

5 Applicability of condition indicators to different types of organic materials

There is currently no single condition monitoring method which is suitable for all organic or polymeric materials. A basic requirement for inclusion in a part of IEC/IEEE 62582 is that the condition indicators are sensitive to the effects of ageing. An important characteristic of a useful condition indicator is that it shows a trend that changes monotonically with degradation and can be correlated with the safety related performance. An indicator that does not change for a long time and then suddenly undergoes drastic changes is not useful for prognostic applications. This can be the case with mechanical condition monitoring on semi-crystalline materials, e.g. cross-linked polyethylene and thermosetting resins, dependant on the formulation.

Information on the applicability of various condition indicators to different polymeric materials used in instrument and control equipments in nuclear power plants can be found in NUREG/CR-7000 and in IAEA-TECDOC-1188, see Bibliography.

6 Destructive and non-destructive condition monitoring

A condition monitoring method may be considered destructive or non-destructive, depending on whether the measurement or the sampling of material used for the measurement will affect operability or future ageing. Non-destructive use of condition monitoring is preferable in field measurements but with presently available methods it is limited to a few types of equipment, mainly cables, where the parts of the equipment of interest are accessible in the field. In other cases deposited samples or samples which can be replaced are needed to allow condition monitoring.

If deposited samples are available or where components can be replaced, a broader range of condition monitoring methods can be considered, including destructive methods. In this case, condition monitoring can be applied to all types of equipment where the ageing material – normally organic materials used for electrical insulation, sealing etc. – can be accessed.

7 Application of condition monitoring in equipment qualification and management of ageing

7.1 General

Condition monitoring as part of qualification and management of ageing of electrical equipment in nuclear power plants can have one or a combination of the following aims :

- determination of acceleration factors for the establishment of qualified life from artificial laboratory ageing;
- extension of qualified life;
- establishment of qualified condition;
- periodic assessment of equipment condition after installation for comparison with qualified condition.

Condition monitoring can also be used for determining whether the degradation of age sensitive materials in equipment is within specific limits. These limits are those for which it has been established that the effects on operability in specified service conditions and design basis events are negligible.

7.2 Use of condition monitoring in the establishment of qualified life

7.2.1 Establishment of qualified life

The qualified life of an equipment is generally established by accelerated ageing of samples in a laboratory, followed by verification of their capability to function within acceptance criteria during a simulated design basis event. The acceleration factor is the ratio between the rate of degradation under the laboratory simulation and in normal operating conditions in the field. Condition monitoring is used to establish activation energies for calculation of the acceleration factor in accelerated thermal ageing.

7.2.2 Determination of acceleration factor in accelerated thermal ageing

The acceleration factor F in accelerated thermal ageing is normally calculated by application of the Arrhenius equation as follows: