NUGENIA position paper

# Ageing of Low Voltage Cable in Nuclear Environment

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POSITION PAPER

NUGENIA is an international non-profit association under Belgian law established in 2011. Dedicated to the research and development of nuclear fission technologies, with a focus on Generation II & III nuclear plants, it provides scientific and technical basis to the community by initiating and supporting international R&D projects and programmes. The Association gathers member organisations from industry, research, safety organisations and academia.

The activities of NUGENIA cover plant safety & risk assessment, severe accidents, reactor operation, integrity assessment and ageing of systems, structures & components, development of fuel, waste & spent fuel management & reactor decommissioning, innovative light water reactor design & technologies, harmonisation and in-service inspection & their qualification.

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# INTRODUCTION

*Safety of power plants is totally dependent on the smooth running of the measure and control equipments. Without instrumentation, operators are blind and without power and control systems, they can't pilot anything. Furthermore, in the context of Nuclear Power Plant (NPP) operation beyond 40 years, electrical cables are critical components due to their highly complicated replacement. These cables have to maintain required electrical and mechanical properties during their entire life (much longer than for other industries) including, for some of them, in accident conditions. It is therefore very important to be able to replace these equipments right on time.*

*Concerns regarding cable lifetime prediction and evaluation of ageing are considered critical by other international actors. Among others, IAEA has launched a Coordinated Research Programme to address these issues; OECD-NEA continues to follow the topic through the CADAK project; China has recently started the ANTIAGE project.*

*Because I&C and power cables are made of polymers, they degrade when exposed to temperature and radiations. Such equipment is often considered as being a chain which very likely breaks at its weakest link. The detection and evaluation of defects is therefore of utmost importance for predictive maintenance programme which needs to have non-destructive testing systems. In order to support such programme, the understanding of material ageing and improvement of present condition monitoring techniques are important.*

*Determining appropriate end-of-life acceptance criteria (criteria beyond which the cable cannot perform its function) is a crucial issue not yet solved, especially for non-destructive condition monitoring techniques. If these criteria are not properly set, large safety margins are needed or the lifetime can be overestimated.*

*Better ageing management of cables is very important to keep high safety standards for Gen-II fission reactors and research centres dealing with high energy particles. Optimisation of cable replacement and planning activities can also help to reduce exploitation costs of nuclear facilities, spare workforce and reduce collective irradiation dose linked to cable replacement.*

# POSITION OF INTERNATIONAL COMMITTEES

FP7 – ADVANCE (2011-2013)

*Ageing diagnostics and prognostics of low-voltage I&C cables*

*The ADVANCE overall objective was to adapt, optimise and assess electrical Condition Monitoring (CM) techniques that could allow nuclear utilities to assess in-situ the degradation state of the installed safety-related cables and to get information about their remaining useful life.*

*This project addressed open issues regarding the assessment of safety-related cables, like in the case of the Loss Of Coolant Accident (LOCA).*

*Results*

- *For some cables, the ageing was to mild to approach the end of their life.*
- *Some materials have shown an inverse temperature effect behaviour.*
- *In general mechanical tests are good condition indicators.*
- *Among electrical techniques, dielectric spectroscopy shows promising results.*
- *Reflectometry could be interesting to detect hotspots.*

*Gaps*

- *The effect of ageing on material performance is not fully understood.*
- *Confidence in the test results has to be improved to be able to draw conclusions.*
- *Link between the laboratory analyses and on-site cable evaluation has to be made.*

*Perspectives*

- *To track the degradation at all stages, it is recommended to use a combination of techniques.*
- *The best monitoring method has to be defined for each cable.*
- *Synergistic effects should be considered with care in future test protocols.*
- *Further work should be considered on test protocols in order to decrease the uncertainty.*

IAEA CRP (2012-2015)

*Qualification, Condition Monitoring, and Management of Aging of Low Voltage Cables in Nuclear Power Plants*

*The goal of the CRP is to provide the current and next generation of nuclear facilities with information and guidelines on how to qualify new cables, monitor the performance of existing cables, and establish a programme of cable ageing management.*

*Results*

- *More accurate test procedures are very important to increase confidence in results.*
- *Mechanical indentation techniques showed very interesting results.*

*Gaps*

- *No unanimity was reached for the acceptance criteria definition.*

*Perspectives*

- *Further work on test procedure improvement should be considered.*
- *Validation of local mechanical non-destructive test methods are important.*
- *Definition of functionality requirements for the different cable types could help to define acceptance criteria.*

OECD/NEA – CADAK (2011-2014)

Cable Ageing Data And Knowledge

*This project aims to establish the technical basis for assessing the qualified life of electrical cables in light of the uncertainties identified following the initial (early) qualification testing. This research investigates the adequacy of the margins and their ability to address the uncertainties. The following four topics are considered as very important by the group experts:*

- *Completion of cable data and maintenance*
- *Performance of condition monitoring methods*
- *Commendable practices*
- *Extension of cable knowledge to other technical items*

ANTIAGE (China, 2013-2015)

*Ageing Diagnostic and life Assessment of Nuclear Low-voltage cable*

*Based on the research content of the EU project ADVANCE, China has defined a related research project ANTIAGE. The project proposal was officially launched in 2013. According to the up-to-date proposal, the research on NPP Cable ageing management will end by 2015.*

*China side participant organisations are:*

- *RINPO (Coordinator, Research Institute of China Nuclear Power Operation)*
- *CIAE (Participant, China Institute of Atomic Energy)*

*The overall objective of the project is to assess, optimise and develop non-destructive condition monitoring techniques for nuclear cables that would allow utilities to perform a full-length cable evaluation from its terminals in order to detect local and bulk insulation degradation, to verify the cable qualified state and to estimate its residual lifetime.*

## GAPS

- Understanding of ageing – Life time prediction
  *Long-term polymer ageing in nuclear environment is a relatively new concern (in comparison with piping and reactor pressurised vessels) which is only partially understood. The historic lack of research adds difficulties to evaluation of cable performance.*
- Performance of representative accelerated ageing and its use for the qualification process
  *Representativity of the accelerated ageing performed in the framework of the cable qualification process is an important question. Indeed, making prediction for long period of time (typical 60 years) is very tricky. Moreover, examples of non accurate lifetime predictions are reported.*
- Use of electrical reflectometry-based techniques - Defect detection
  *Full cable techniques need to be developed to be able to detect hot spots in the cable length.*
- Use of non-destrictive condition monitoring techniques and related acceptance criteria – Defect Evaluation
  *No single condition monitoring (CM) technique or acceptance criterion is internationally adopted to assess the ageing condition of cables. However, such techniques are essential to support predictive maintenance programmes which are recognised as the most reliable, and therefore the safest.*

## CAST PROJECT

Based on the evaluation of current gaps in the knowledge of cable ageing and testing, a new consortium of European experts proposed a project for the Horizon 2020 research programme (2015-2019).

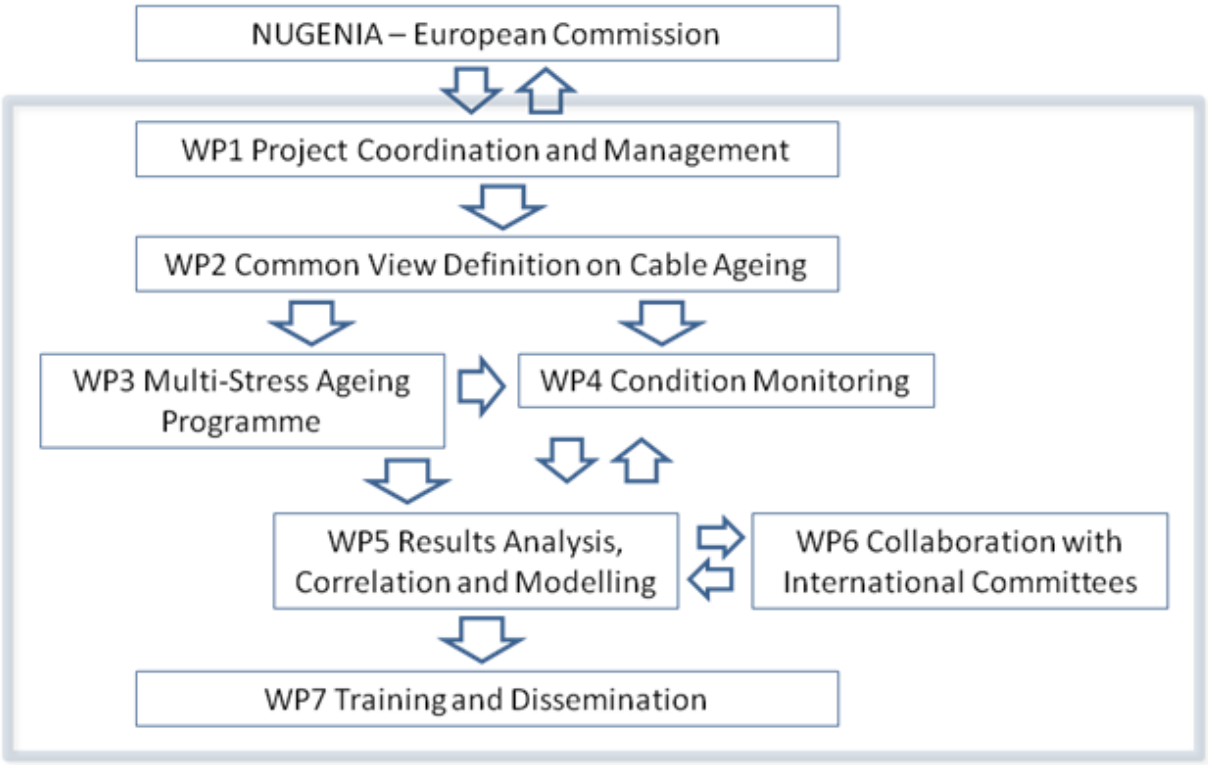
*The CAST project has two main research directions.*

*The first aims to evaluate the effect of the nuclear environment on cables during their entire life; i.e. 40+ normal operation, including potential LOCA and post LOCA phases and/or severe accident. This will include study of the different radiation effects (β, γ, and neutrons), the role of polymer additives and representative accelerated ageing conditions.*

*The second will study condition monitoring (CM) techniques that can be used to assess the state of cables. Traditional techniques (chemical, electrical and mechanical) will be evaluated as well as innovative non-destructive solutions like the indenter for local assessment of the jacket or electrical reflectometry for detection of weak points in cable insulation.*

*To support these objectives, the research programme will focus on only 2-3 cable types which will be aged in different conditions in order to evaluate the sensitivity of the materials to ageing parameters and to identify synergistic effects. This limited amount of studied samples will allow their in-depth characterisation that supports the CAST mission of providing excellent results. Selected tasks for validation, standardisation and coordination of measurement procedures between different laboratories will ensure quality and validity in data.*

*Based on this strong framework, three workshops will be organised to present the conclusions to the scientific community. This will promote harmonisation of cable assessment practices and enhance the project impact on scientists as well as on the nuclear industry. The database developed by the former ADVANCE project will also be studied and extended for this purpose.*




*Perspectives*

- Understanding of beyond design basis accident influence on safety cables
  *CAST will study the impact of beyond design basis accident on safety cables. The results are expected to help end-users to understand related degradation as well as to improve current formulation of cables or plant design.*
- Common view on cable evaluation
  *There are currently different views on cable evaluation or discussions about relevant parameters for evaluation of their functionality. Definition of a common approach is an important step forward towards harmonisation and standardisation of working practice.*
- New accepted testing reference

*Currently, no technique or acceptance criteria are fully accepted by the scientific community. The lack of a common reference impedes stake holders (TSO's, competency centres or plant operators) from agreeing on when cables have to be replaced. Proposing and justifying a testing reference is, in that view, an important breakthrough in current knowledge.*

- Validation of non-destructive methods
  *Some electrical (e.g. broadband dielectric spectroscopy and reflectometry) or mechanical techniques (indenter) showed preliminary but promising results to be used as non-destructive methods for both bulk aging and local degradation evaluation. The ambition of this project is:*
  - *to validate these techniques by correlating the results with those obtained by traditional destructive methods (like e.g. elongation at break or oxidation quantities);*
  - *to adapt these techniques so that they could be used on-field for the assessment of health state of nuclear cable insulation.*