NUCLEAR NEW HORIZONS:
Fueling our Future
October 21-25, 2019 | Mendes Convention Center | Santos, SP, Brazil

AGING MANAGEMENT PROGRAM - THE SERVICE CONDITION INFLUENCE IN NUCLEAR CABLES DURING LONG TERM OPERATION

Giovanna C. C. Giovanardi[1], Helio Ricardo V. de Oliveira[2] and Matheus Almeida dos Santos[1,3]

[1]Eletrobrás Termonuclear S.A. - ELETRONUCLEAR
Departamento DO/NT LTO
Central Nuclear Almirante Álvaro Alberto
Rodovia Procurador Haroldo Fernandes Duarte BR101/RJ, S/N km 521,56 - Itaorna
23948-000 Angra dos Reis, RJ, Brazil
gicarol@eletronuclear.gov.br

[2]Eletrobrás Termonuclear S.A. - ELETRONUCLEAR
Departamento DO
Central Nuclear Almirante Álvaro Alberto
Rodovia Procurador Haroldo Fernandes Duarte BR101/RJ, S/N km 521,56 - Itaorna
23948-000 Angra dos Reis, RJ, Brazil
helio@eletronuclear.gov.br

[3]Centro Federal de Educação Tecnológica Celso Suckow da Fonseca (CEFET/RJ)
Rua do Areal,522, Parque Mambucaba
23953-030 Angra dos Reis, RJ, Brazil
matheus.santos.1@aluno.cefet-rj.br

Eletrobras
Eletronuclear

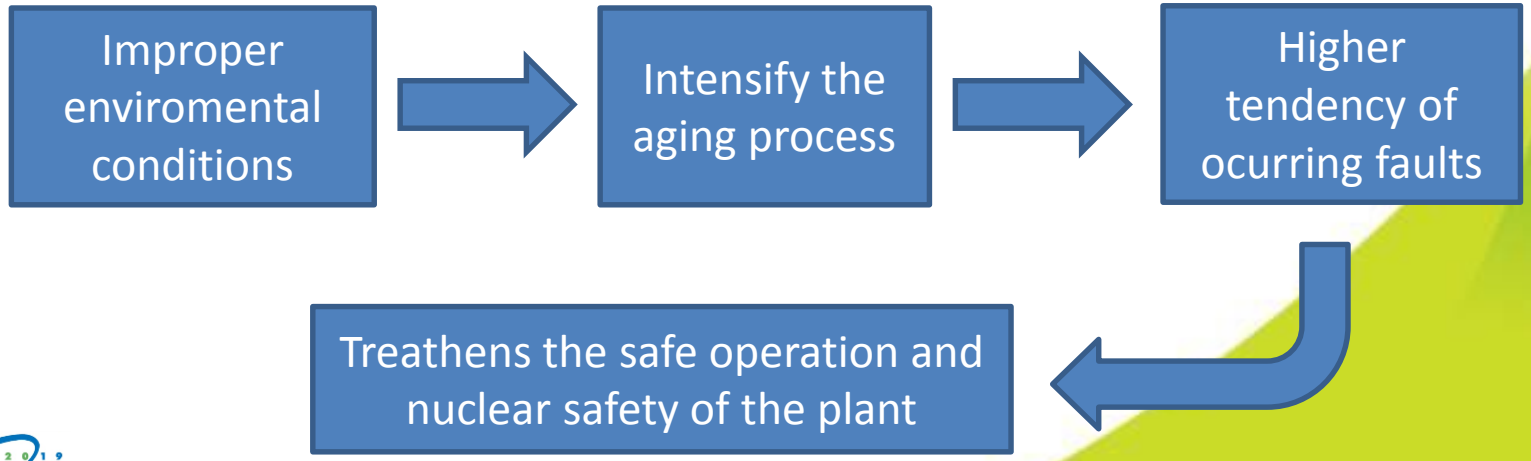
Introduction

Electrical cables are important for:

- correct functioning of electrical equipment;
- operational process of the Plant, assuring safe operation and nuclear safety.

They have a lifespan superior to the first period of intended operation of a Nuclear Power Plant (more than 40 years).

Even with this long lifespan, environmental conditions can intensify the process of aging what reduces their lives, causing degradation, known as aging effect, to the cable insulation.

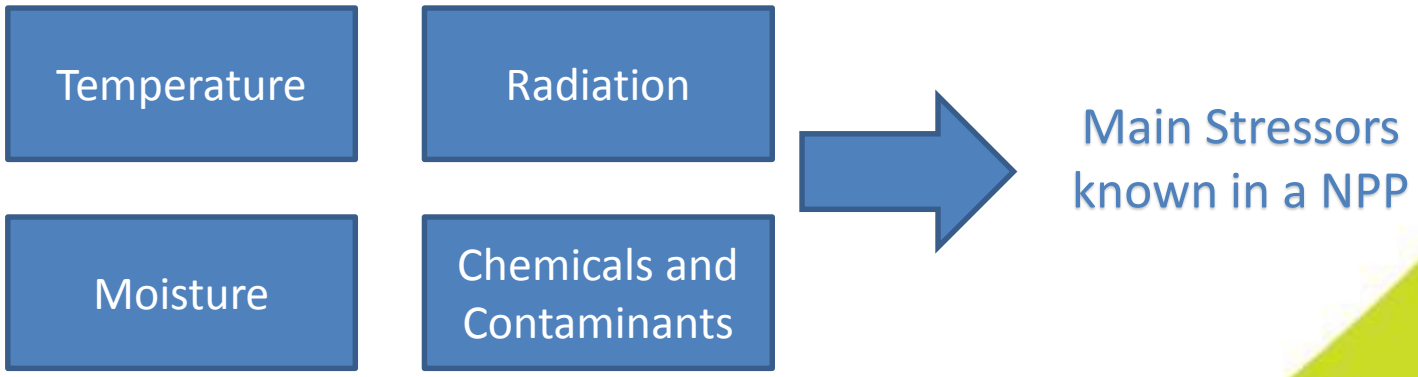


Adverse Environments for Cables in Service

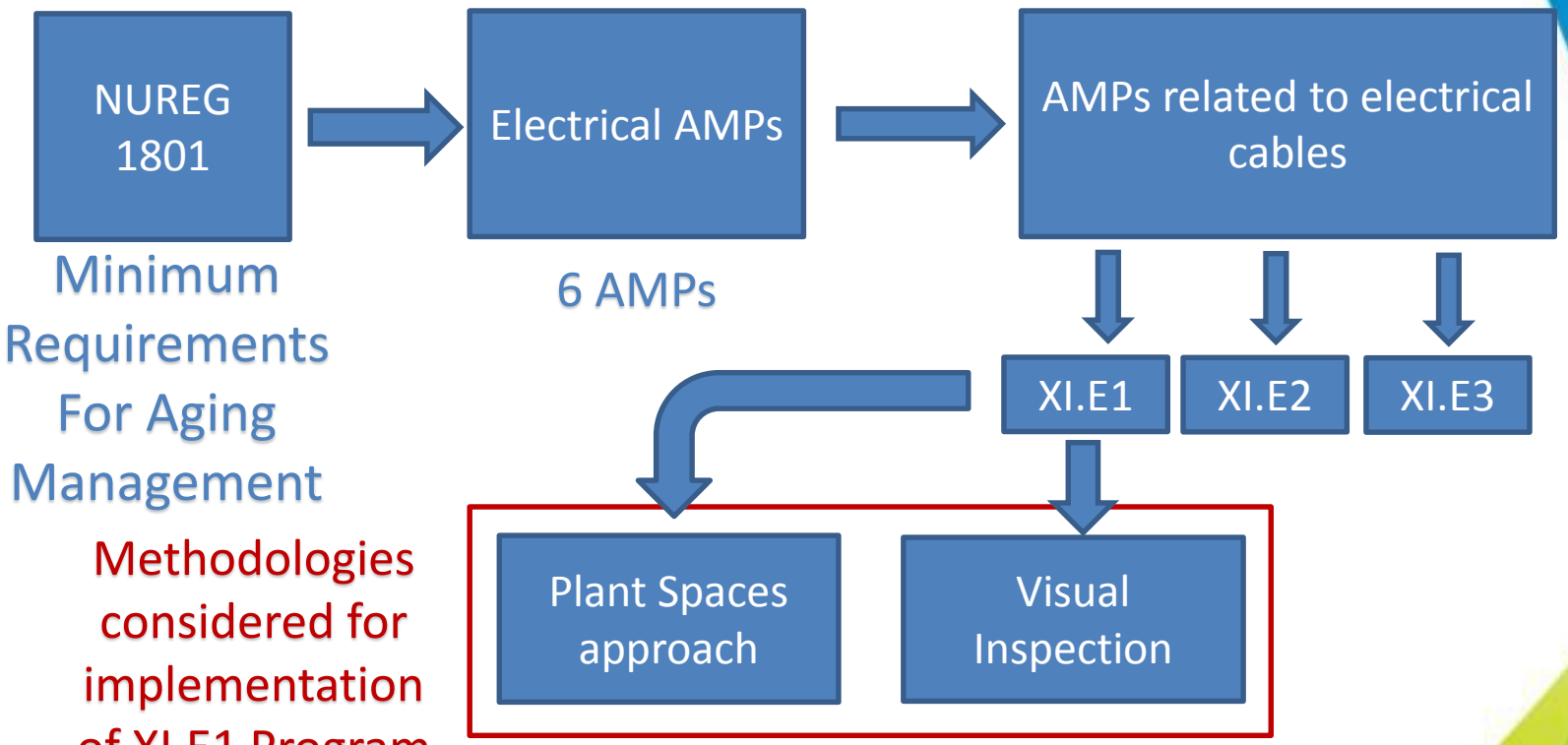
Sections of cables may run throughout different locations and rooms with various environmental conditions.

Once the conditions presented in some of these locations can be more extreme than the designed one, it can intensify the process of aging and degradation in this part of cable.

Adverse Environment – Location with stressors (aging agents):



Cable Aging Management Program (AMP)



Minimum Requirements For Aging Management

6 AMPs

Methodologies considered for implementation of XI.E1 Program

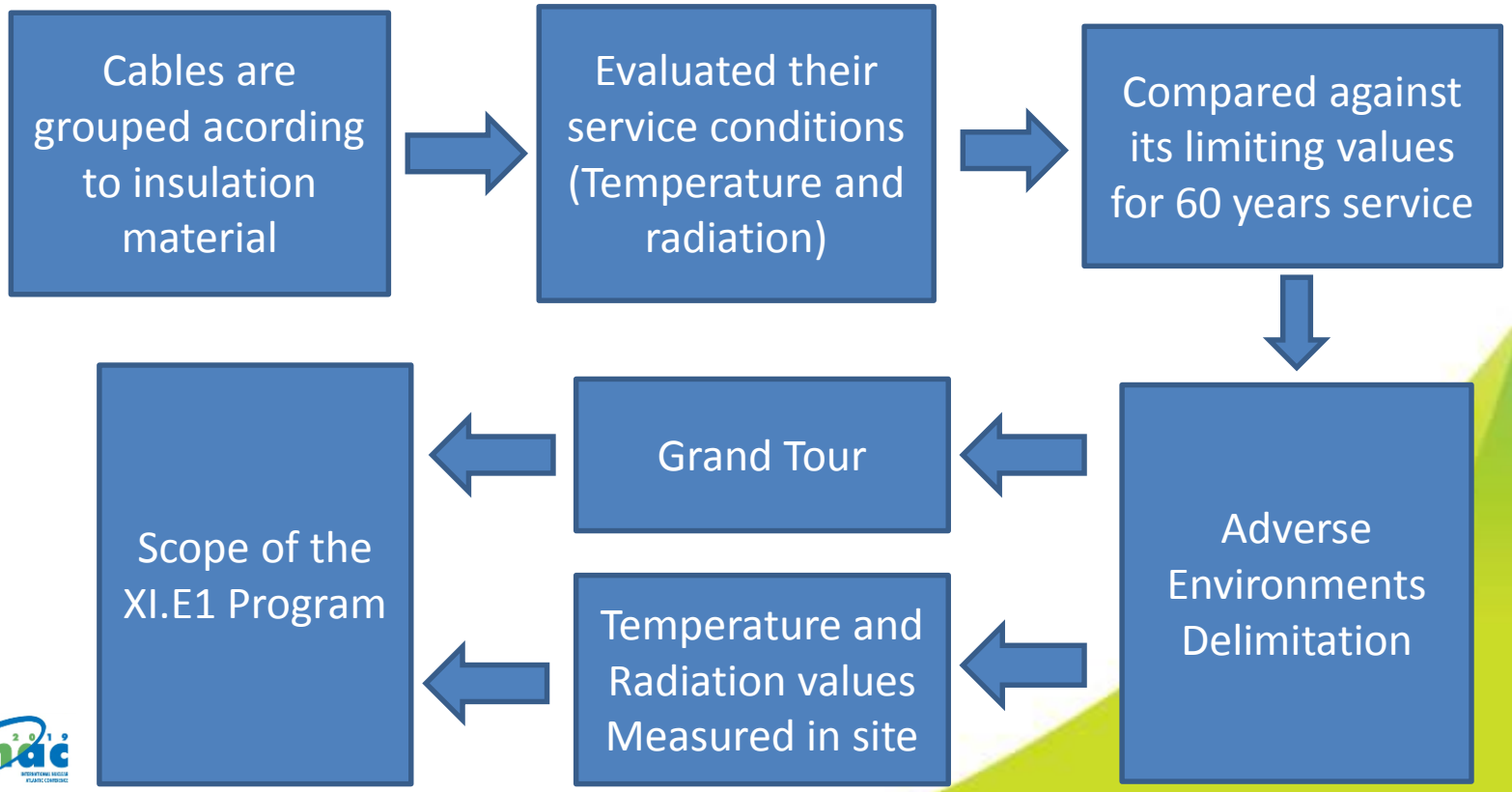
Defines the scope of the program

Condition monitoring of electrical cables

Scope Definition - Plant Spaces Approach

- Methodology accepted by NRC (Nuclear Regulatory Commission) to perform the scope and screening of the XI.E1 Aging Management Program (AMP).

- Used to define the Adverse Environments by the operating limits of the cables' insulation material.



Scope Definition - Plant Spaces Approach

Insulation material	Cables		Connections		Limiting environment for a 60 years' service project	
	Power	I&C	Power	I&C	Temperature	Radiation Dose
Butyl Rubber, BR		√			125°F (51.8°C)	5 x 10^6rads
Chloroprene, Neoprene	√		√		107°F (41.7°C)	2 x 10^6rads
CSPE (Hypalon)	√	√			167°F (75.0°C)	2 x 10^6rads
Cross-linked Polyethylene, XLPE, XLP	√	√			188°F (86.6°C)	1 x 10^8rads
Epoxy, XR5126 (WEC)			√		150°F (65.7°C)	1 x 10^7rads
EPDM	√	√		√	189°F (87.2°C)	5 x 10^7rads
EP, EPR	√	√	√	√	167°F (75.0°C)	5 x 10^7 rads
Halar, ECTFE	√				306°F (152.0°C)	1 x 10^8 rads
Hypalon (CSPE)	√	√			167°F (75.0°C)	2 x 10^6 rads
HTK (Kerite)	√				185°F (85.2°C)	1 x 10^8 rads
Kerite FR, FR (HC-711)	√	√			129°F(54.1°C)	5 x 10^7 rads
Kerite FR, FR (HI-70)	√	√			141°F (60.8°C)	5 x 10^7 rads
Kerite FR2, FR2			√		193°F (89.2°C)	5 x 10^7 rads
Kerite FR3, FR3			√		167°F (75.0°C)	5 x 10^7 rads
Melamine			√	√	205°F (96.2°C)	5 x 10^7 rads
Nylon				√	119°F (48.5°C)	2 x 10^6 rads
PE, HDPE, HMPE	√	√			112°F (44.4°C)	2 x 10^7 rads
Phenolic			√	√	231°F (110.6°C)	4 x 10^7 rads
Polyalkene	√				190°F (87.5°C)	1 x 10^7 rads
Polyimide (Kapton), Thermosets				√	266°F (130.2°C)	2 x 10^8 rads

√- Identifies the service applications of the insulation material.

Table 1 - Insulating materials, applications and environmental limits for 60 years' service of cables and connections. Font: EPRI, License Renewal Electrical Handbook.

Condition Monitoring - Visual Inspection

- Fundamental Tool for identifying aging effects because first, aging effects causes changes to mechanical properties of the material before its electrical characteristics;

- Applicable to accessible cables Located in Adverse Environments;

  → Do not require assembly of support structures

- Anomalies identified in electrical cables subject to aging effects:

Anomalies	
Bubbling	Red and sticky substance in junctions
Burnt	Verdigris
Cracking	Brightning
Formation of cristals	viscous
Discoloring	stiffening
Opacity	Sticky or humid
Softning	Blisters
Oiliness	White powder

Table 2 – Anomalies caused by aging effects

Figure 1: Discoloring proccess on cable insulation.

Condition Monitoring - Additional Monitoring Techniques

Other inspection techniques can be used complementing or in place of, in case of impossibility to access the cables, the visual inspection during the cable insulation condition monitoring.

These methods can be separated in two groups according the parameter monitored:

Mechanical Characteristic Monitoring

Alternative methods in place of visual inspection, evaluating the condition monitoring by the mechanical/physical insulation characteristic:

- Compressive Modulus (Indenter) – In situ;
- Elongation-at-Break – At laboratory;
- Oxidation Induction Time and Temperature – At laboratory.

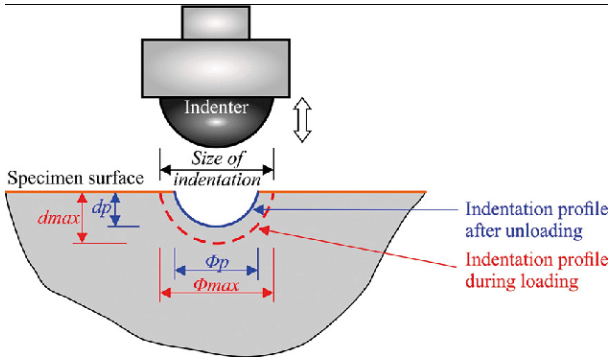


Figure 1: Indenter Test

Figure 2: Elongation at Break test

Aditional Monitoring Techniques

Electrical Characteristic Monitoring

- Dissipation Factor/ Power Factor (tan δ) – In situ;
- Insulation Resistance – In situ;
- Polarization Index – In situ;
- AC Voltage Withstand Test – In situ;
- Partial Discharge Test – In situ;
- Time Domain Reflectometry – In situ;
- Line Resonance Analysis (LIRA) – In situ;
- Fourier Transform Infrared Spectroscopy – At Laboratory

Figure 5: Time Domain Reflectometer

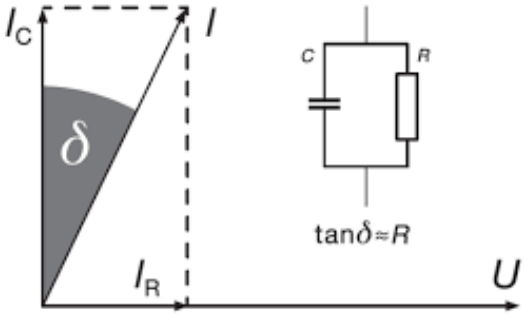


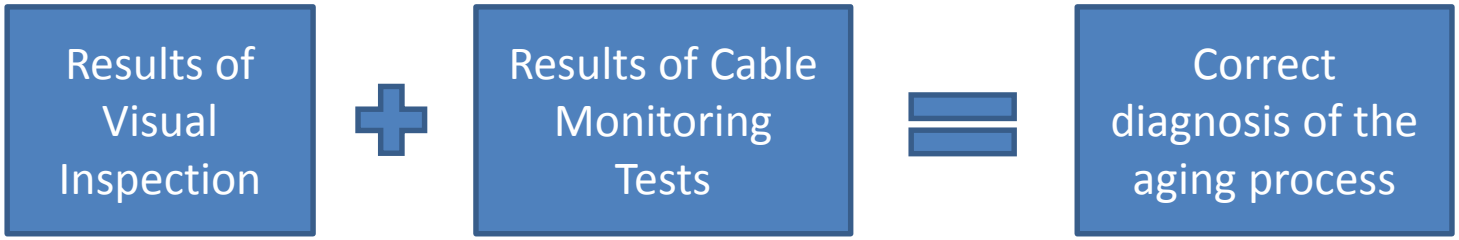
Figure 3: Dissipation fator (tan δ)

Figure 4: Equipment for LIRA test

Result Analysis of Condition Monitoring Techniques

- Visual inspection produces more trustful results about the cables aging assessment;

- The decision to take out of order a group of cables considering cannot be based only in Visual Inspection results:



Main tool for aging monitoring

Complementary tool

- Does not exist an “all in one” test or technique, all of them have positives and negatives points;

- A correct diagnosis may only be achieved by analyzing results of more than one condition monitoring technique.

Conclusion

- Importance of an AMP to manage the aging effects that may occur in systems, structures and components (SSCs), mainly during Long Term Operation;
- Presented the methodology for implementing the XI.E1 program on Angra 1 Power Plant;
- Correct management of Adverse Areas – forecast of unadvised failures;
- The major difficulty in managing the aging of cables is the application of monitoring techniques and consequently analyzing the results.

References

[1] Electric Power Research Institute, EPRI report TR-109619,“Guideline For the Management of Adverse Localized Equipment Environments”, June 1999.

[2] Electric Power Research Institute, EPRI report NP-7485s, "Power Plant Practices to Ensure Cable Operability", July 1992.

[3] Electric Power Research Institute, EPRI report 1003663, "Integrated Cable System Aging Management Guide: Low Voltage Cables", January 2003.

[4] Sandia National Laboratories, SAND 96-0344, "Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations", September 1996.

[5] United States Nuclear Regulatory Commission, "Elective Policy Issue # 2: Long-term Operation and Aging Management of Nuclear Facilities".

References

[6] International Atomic Energy Agency, IAEA Safety Report Series No. 57, "Safe Long Term Operation of Nuclear Power Plants", October 2008.

[7] Electric Power Research Institute, EPRI report 1013475, "Plant Support Engineering: License Renewal Electrical Handbook", February 2007.

[8] United States Nuclear Regulatory Commission, NUREG-1801, "Generic Aging Lessons Learned (GALL) Report", December 2010.

[9] United States Nuclear Regulatory Commission, NUREG/CR-7000, "Essential Elements for an Electric Cable Condition Monitoring Program", January 2010.

Acknowledgements

We would like to thank Eletrobras Termonuclear S.A. – ELETRONUCLEAR for giving us the opportunity and for providing us with a workspace and access to all the resources necessary to conduct this work.

Thank You All!