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Challenges for LTO beyond 60 years on I&C systems including cables

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- Cable ageing management
  - Requalification of cables originally qualified for 40 years

PHYSICAL AGEING OF ELECTRICAL, ELECTRONIC I&C SYSTEMS AND COMPONENTS

- Physical ageing is typically managed by:

- Ageing degradation for active electrical and I&C systems is addressed by:
  - **Maintenance programmes**. Examples include various electrical, electronic components: sensors, -limit switches/position indicators, relay, circuit breakers, transformers, capacitators, resistors, diodes, transistors integrated circuits, digital electronics cards, different types of batteries for electronic cabinets, various types of displays at the control rooms (main control room, supplementary control room) and local control stations (e.g. I&C and electrical cabinets

- Ageing degradation of passive electrical and I&C components are managed by:
  - **Ageing management programmes**. Examples include various cables and connection interfaces, electrical penetrations not subject to environmental qualification

  - **Equipment qualification programme**. Examples include active and passive electrical, electronic I&C components subject to environmental qualification

TYPICAL ‘AGEING’ ISSUES FOR ELECTRICAL AND I&C SYSTEMS

- Electrolytic capacitators
  - Elevated ambient temperatures that cause increase rate at which electrolytic capacitors lose their liquid electrolyte as a result of degraded end cap seals (e.g. through evaporation)

- Circuit boards and components
  - Thermal cycling can cause circuit boards and components to expand or contract at different rates, which can place solder joints under mechanical stress.

- Whiskers formation on circuit boards
  - Inadvertent electrically conductive connections can be formed through growing whiskers which can lead to malfunctions or short circuits on the affected components

TYPICAL ‘AGEING’ ISSUES FOR ELECTRICAL AND I&C COMPONENTS

- Electrical, I&C cables
  - Exposing cables to high temperatures can cause their insulation polymers to degrade, which can lead to the cables failing and causing a short circuit.
  - Chemicals, such as grease, oil, acids and cleaning fluids, can degrade the integrity of cable insulation polymers, which can lead to cable failure and short circuits

- Fiber optic cables
  - Ionizing radiation can cause fiber optic cables to darken

ACTIVITIES FOR LTO BEYOND 60 (1)

- Approach is basically the same as for LTO beyond 40
- Maintenance programme is subject to review whether it can be credited for the LTO period (scope, periodicity, techniques)
- Aging management review for equipment not subject to environmental qualification need to be performed in order to:
  - Perform ageing management review (AMR) of In-scope equipment
  - Review existing AMPs against 9 attributes of an effective AMP (e.g. SSG-48)
  - Develop new AMPs, as necessary (e.g. SRS-82 Rev.1. IGALL)

ACTIVITIES FOR LTO BEYOND 60 (2)

- Equipment subject to environmental qualification (EQ)
  - EQ is a TLAA - need to be reviewed updated, modified as necessary (plant EQ zones, confirm or modify initial assumptions, environmental monitoring
  - Special focus on qualified equipment for which **qualified life** is established
    - Replacement on time specified intervals
    - Requalification

- Environmentally qualified cables
  - Qualified equipment with established qualified life (typically in harsh environment, or with significant ageing degradation mechanism in mild environment):
    - Requalification, re-assessment of initial conservativism (T, Ra doses)
    - Additional type testing may be necessary to confirm safe functions beyond 60 years

CHALLENGES FOR LTO BEYOND 60?

- **Extension** of the qualified life for cables originally qualified for 40 years **beyond 60 years**
  - Evaluation of in-service ageing
  - Diagnostic methods
  - Credibility of methods used (analytical, testing)
  - Additional type testing may be necessary

- **Replacement** of electrical and I&C cables (feasibility, time duration, costs)

CHALLENGES FOR LTO BEYOND 60?

- **Obsolescence** of electrical and I&C system and components seems a bigger issue than physical ageing

- **Modernization** of electrical and I&C systems is necessary for LTO in almost all existing NPPs
  - Maintenance and reliability concerns
  - Availability of the original vendors and spare parts
  - Analogue spare parts nowadays almost impossible to get

CHALLENGES FOR LTO BEYOND 60?

- **Digital upgrades**
  - Large scale vs small grade upgrades
  - Availability of ‘nuclear grade’ digital devices
  - Extensive use of industrial digital devices (qualification, CCF consideration in I&C architecture, cyber security)
  - New safety concerns related to programmable reactor protection systems (e.g. SW reliability, consideration of CCF, diverse actuation)
  - Considerations of new failure modes (e.g. multiple spurious actuation due to SW errors)
  - Need for significant modifications of human system interface (HIS), personnel training, procedures

- **Costs and licensing** uncertainties appear to be legitimate challenges

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Evaluation of electrical and I&C cables beyond 60 years

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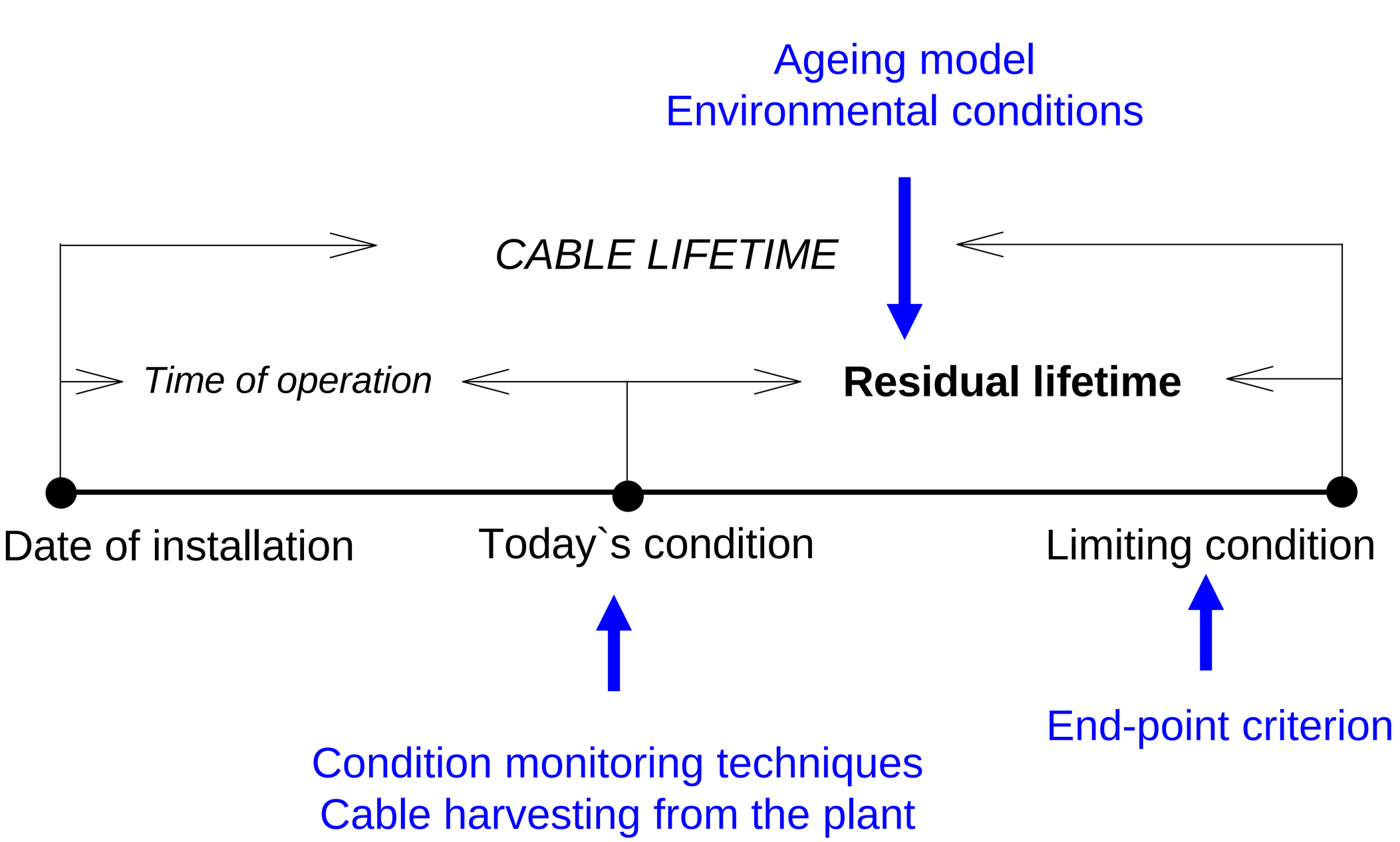
WHAT IS NEEDED

- Information about the cables, routing
- Cable operating environments
- Methods to determine actual cable condition
- Ageing model for life time calculation
- End-point value for assessing residual lifetime


Ageing model
Environmental conditions
CABLE LIFETIME
Time of operation
Residual lifetime
Date of installation
Today`s condition
Limiting condition
End-point criterion
Condition monitoring techniques
Cable harvesting from the plant

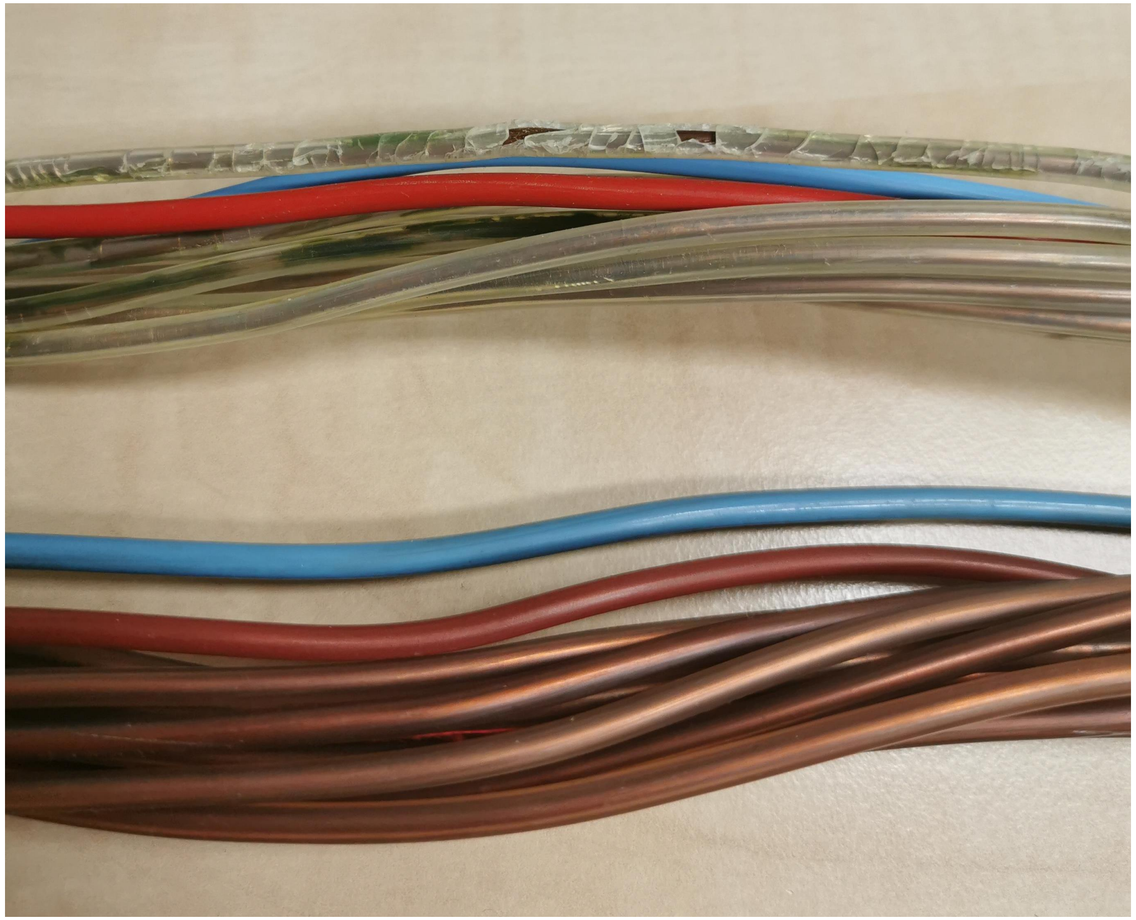
SPECIFIC ISSUES INFLUENCING LTO BEYOND 60 YEARS DECISION

- LTO beyond 60 years concerns NPPs built in 70‘ and 80‘.
- At that time, cables were not as critical issue as now.
- Wasn’t put the such accent on manufacturing quality as now
- Different batches of the same type, material changes, qualified vs. installed
- Qualification done according to actual knowledge, sometime very fast
- Not all cables were tested. Delivered without information about life-time

SPECIFIC ISSUES INFLUENCING LTO BEYOND 60 YEARS DECISION

- Cables are spread everywhere throughout the plant
- Large amount of cables in scope, important for safety, important for production, other non-safety cables
- Many types, more producers
- Cables often go through different locations with different level of stressors
- Same degradation mechanisms may have different effect in different locations, within one cable route through more rooms
- Exact routing not always available.
- Old cables were later covered with additional fire-retardant layer

- **Cable ageing management programme (CAMP) helps to solve all these issues**



Problem with different batches.

Same type of cable. Same location.

Cable type with designation KPOSG (Cu conductor, PE insulation of conductors and lead sheathed PVC jacket).

We found several KPOSG cables with wire insulation cracking – see attached photos 1 and 2. At least 2 production batches exists, one with colorless wire insulation and another one with faint brown insulation. We know that loss of color is not due to degradation Only batch with colorless wires were found cracked.

Old cables covered with fire retardant layer

MODEL FOR LIFE-TIME CALCULATION

- **Main degradation factor is temperature!!**

- Old cables, missing information about composition (stabilizers, antiox. etc.). Difficult to apply new modern ageing models, that require such information

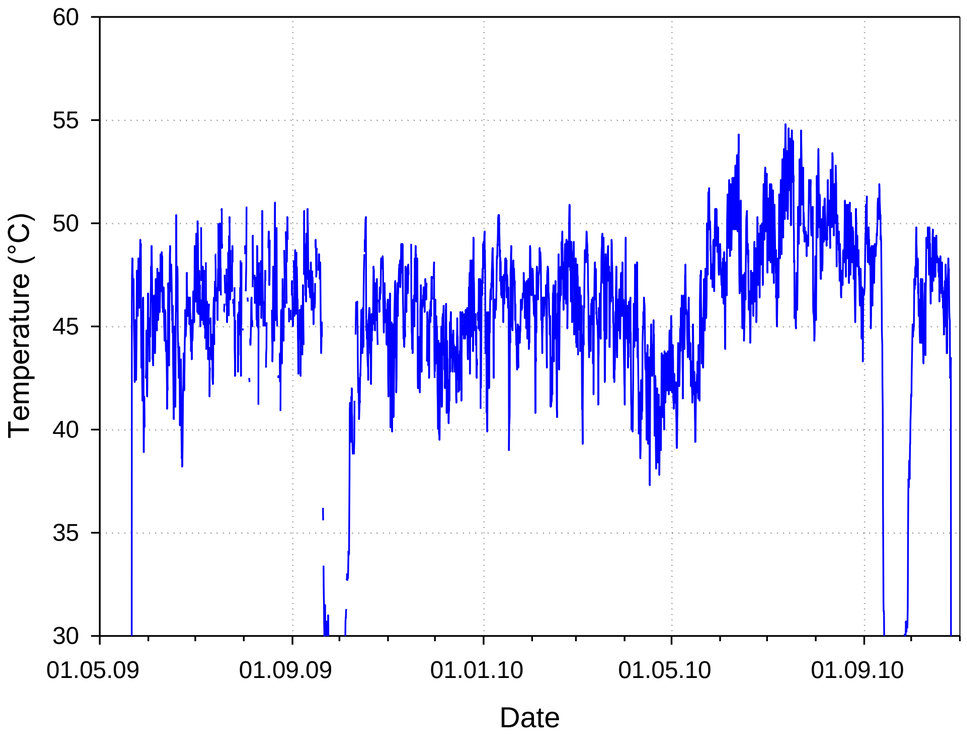
- **Environmental parameters monitoring**
- Provides very important knowledge

UNCERTAINTIES IN CALCULATION

- Properties measurement scattering
- Measurement method uncertainty
- Temperature not constant
- Equipment quality uncertainty (different batches, tested vs. installed)
- Arrhenius (or other) model uncertainty

- Calculated life-time (residual life-time) **only indicator**

- Data for the model are précised / compared with:
  - Samples form cable deposits
  - Samples harvested from the plant



HOW TO CONTINUE

- Cable harvesting as much as possible
- Visual inspection, inc. junction boxes
- Developing methods for conditions monitoring
- Precision of ageing model
- Close cooperation with maintenance staff
- Condition based qualification (e.g. IEC/IEEE 60780/323)
- Use cable deposits
  - Place in deposits also cable harvested in the plant for future tests

CABLE CONDITION, TODAY'S CONDITION, CABLE HARVESTING

- Reliable methods for determination of actual cable condition
- A lot of in-situ methods are proposed with different confidence level
  - small samples, cross-correlation with other method needed, not applicable for insulation, not clear trending with time/degradation etc.

- **The best method is cable harvesting at the plant**
  - Planned reconstructions
  - Timely identification of failed cables
  - Cable replacement if sample really needed

SITUATION IN THE CZECH REPUBLIC

Dukovany NPP (in operation since 1985)

- Approx. 70 000 cables important to safety (3 500 LOCA qualified)
- More than 300 000 cables in total (safety +non-safety)
- Goal is to withstand 60 years operation at least
- Final decision about operation (and cables) beyond 60 years not yet made
- It depends among other on the CAMP outputs

SITUATION IN THE CZECH REPUBLIC

Dukovany NPP LTO following 40 years in operation

- Life-time calculated for 60 years + 10 years decommissioning
- Cables approaching end point criterion are replaced
- A lot of old replaced cables are installed in cable deposits
- Cables that did not pass additional LOCA tests are replaced
- In total a really massive cable replacement is scheduled
- But successively, not all cables replaced in one huge/long step.
- Strategy and plans for cable replacement

Thank you for your attention

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