

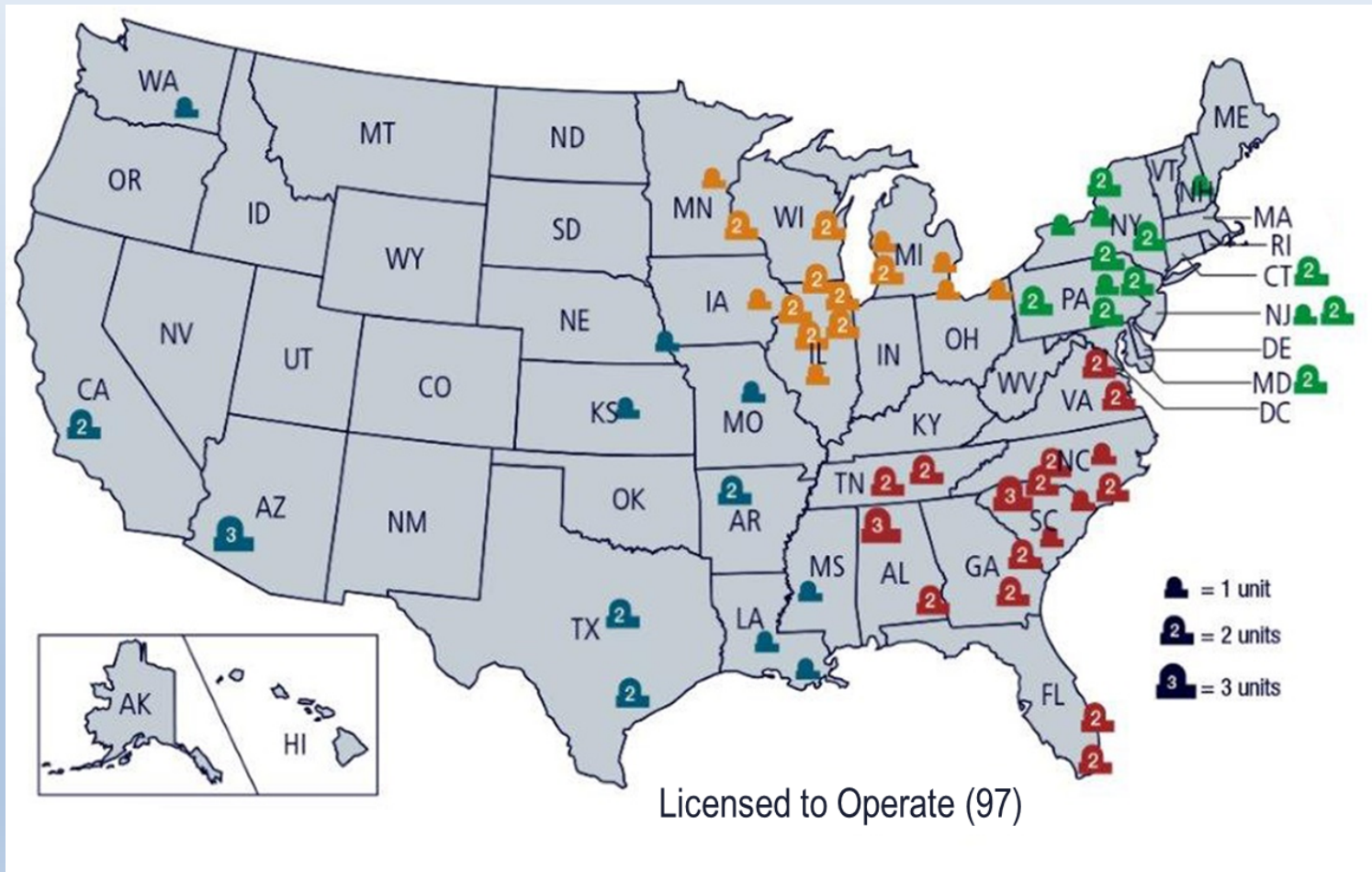
# Regulatory Perspectives on Electrical Cables for Long Term Operation in Nuclear Power Plants



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*Mohammad Sadollah*  
Electrical Engineering New Reactor and License Renewal Branch  
Division of Design Engineering  
Office of Nuclear Reactor Regulation  
U.S. Nuclear Regulatory Commission

# Operating Nuclear Power Reactors



# Background

- There are 96 operating nuclear power reactors in U.S. regulated by the NRC, with a combined output of approximately 92,000 MW\*
- 89 reactors have received renewed licenses to operate beyond the initial 40 year license term to extend to 60 years
- Six reactors are currently under review for additional 20 year licenses (80 years total) under a new process called subsequent license renewal (SLR)
- U.S. Code of Federal Regulations, 10 CFR Part 54, governs license renewal
- NUREG-1801, “Generic Aging Lessons Learned (GALL) Report,” provides recommendations for aging management programs for passive, long-lived components including electrical cables
- NUREG-2191, “Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report,” provides recommendations for aging management of components for SLR, including Environmental Qualification.
- One of the top four technical issues for SLR is cable performance during long term operations and lack of operating experience (in nuclear plants) as well as some knowledge gaps in this area

\* (2018)

# Cable construction and aging

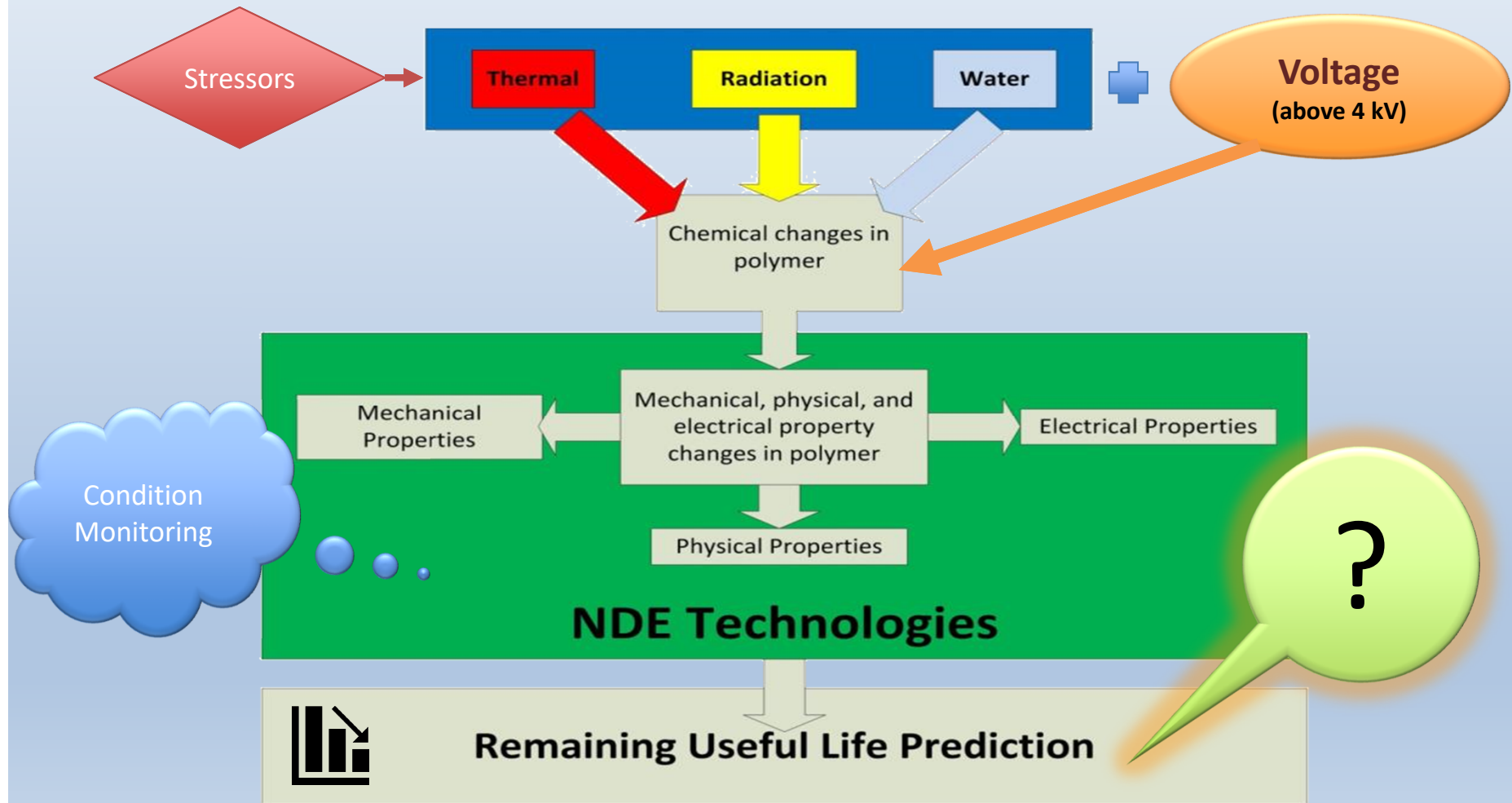
- Cables are typically composed of copper core conductor, shielding, insulation and jacket made of various polymers and organic material additives
- Aging primarily impacts the insulation and jacket material by depleting and degrading additives and antioxidants
- Secondary aging effects can break polymer chains and diminish insulation properties





## How Do Cables Degrad?

### How is degradation detected?



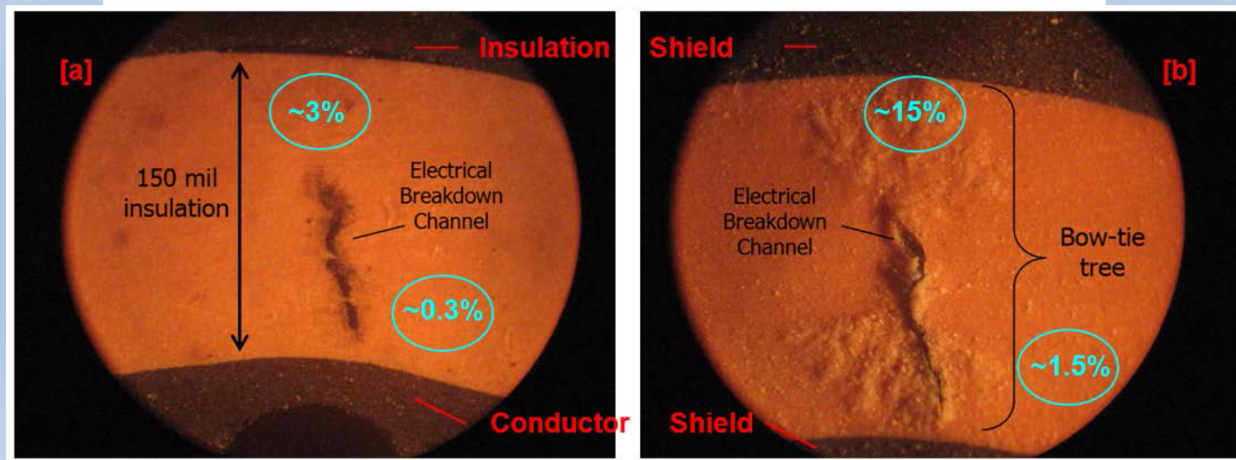
# What are some of the major concerns?



## Installation and Maintenance Issues

# Submergence resulting in Water Trees

(Medium voltage cables)





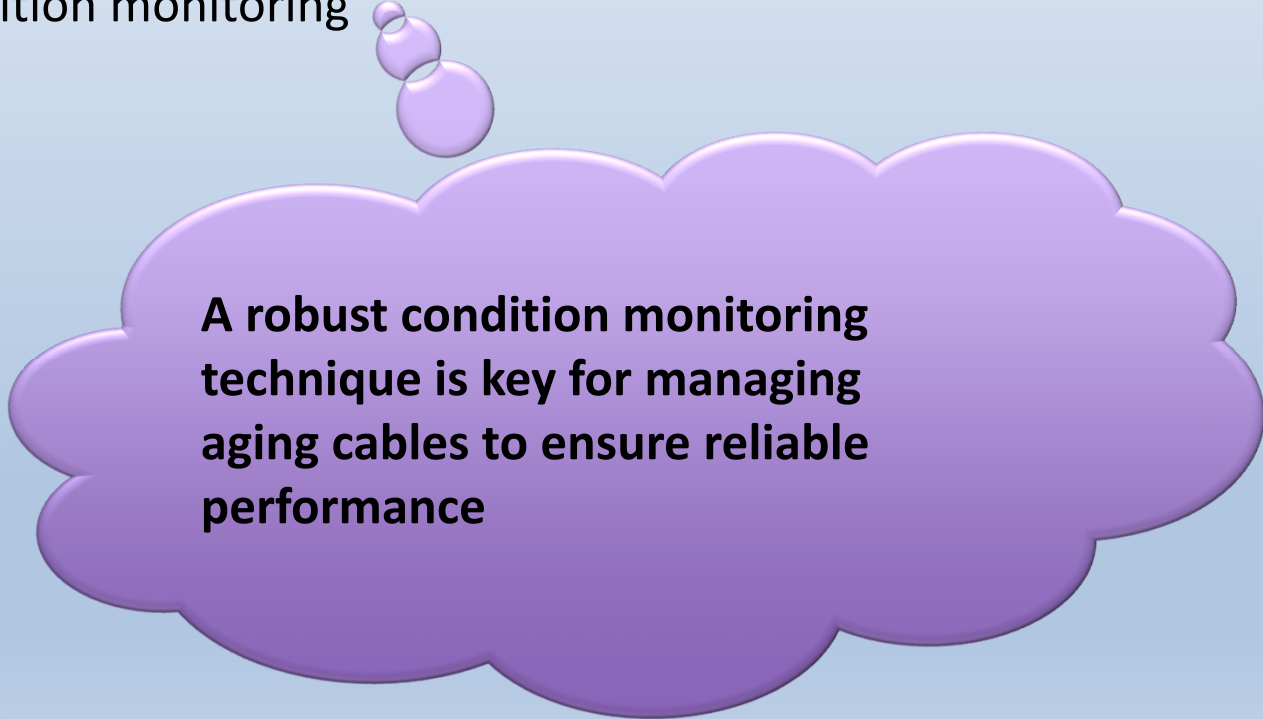
# Adverse Localized Environments



Cables being subjected to the environment for which they were not designed

# How are these problems dealt with?

- Maintenance Programs (10 CFR 50.65)
- Environmental Qualification Programs (10 CFR 50.49)
- License Renewal Aging Management Programs (10 CFR 54)
  - Cable aging management programs rely on inspection and condition monitoring



**A robust condition monitoring technique is key for managing aging cables to ensure reliable performance**



# Recent Regulatory History

- Generic Letter 2007-01, “Inaccessible or Underground Power Cable Failures that Disable Accident Mitigation Systems or Cause Plant Transients,” was issued to inform licensees of cable failures, obtain industry history and request inspection, testing and monitoring program descriptions
- NUREG/CR-7000, “Essential Elements of an Electrical Cable Condition Monitoring Program,” issued in 2010
- Regulatory Guide 1.211, “Qualification of Safety-Related Cables and Field Splices for Nuclear Power Plants,” issued 2009. NRC endorsed IEEE 383-2003 with some exceptions
- Regulatory Guide 1.218, “Condition-monitoring Techniques For Electric Cables Used In Nuclear Power Plants,” issued in 2012
- Information Notice (IN) 2010-26, “Submerged Electrical Cables,” issued
- NUREG/CR-7153, Vol. 5, “Expanded Material Degradation Assessment (EMDA),” issued in 2014, which identified knowledge gaps in cable aging, testing, monitoring and recommended future areas of research

# Expanded Material Degradation Assessment

- EMDA identified knowledge gaps that include:
  - ☐ Activation Energy
  - ☐ Diffusion-Limited Oxidation
  - ☐ Low Dose Rate Effects
  - ☐ Synergistic effects of aging
  - ☐ Inverse Temperature Effects
  - ☐ Moisture Effects
  - ☐ Actual Environments
- Various research activities have been initiated to address these knowledge gaps by the Electric Power Research Institute (EPRI), the Department of Energy (DOE) and the NRC

# NRC Currently Conducting Two Research Projects

- Evaluation of Cable Degradation in a Submerged Environment
- Assessment of Condition Monitoring Techniques for Electrical Cables

## Overview of SLR Process With Respect to Cables

- EQ cables continue to maintain qualifications under existing 10CFR 50.49 programs
- NUREG 2101 (GALL-SLR) provided recommendations for cable aging management programs (AMP):
  - AMP XI.E1 (Accessible cables in adverse localized environments)
  - AMP XI.E2 (Sensitive instrumentation cables in high radiation areas)
  - AMP XI.E3A (Inaccessible medium voltage cables)
  - AMP XI.E3B (Inaccessible instrumentation cables)
  - AMP XI.E3C (Inaccessible low voltage power cables)
- SLR applicants can opt to follow GALL-SLR AMPs, take exceptions, make enhancements, or develop site-specific programs
- NRC reviews proposed AMPs for consistency with GALL-SLR, or evaluates the technical bases for proposed site-specific AMPs

# What are the contents of the recommended AMPs?

**GALL\_SLR recommends each AMP to have the following ten elements:**

- 1. Scope of the Program**
- 2. Preventive Actions**
- 3. Parameters Monitored or Inspected**
- 4. Detection of Aging Effects**
- 5. Monitoring and Trending**
- 6. Acceptance Criteria**
- 7. Corrective Actions**
- 8. Confirmation Process**
- 9. Administrative Controls**
- 10. Operating Experience**



# Summary

- Cable aging and related failures have been an NRC focus since 2007
- Regulatory framework has been developed and will be informed and updated as more research and operating experience results are available
- A number of technical challenges and gaps have been identified and communicated
- Several collaborative efforts are underway (EPRI/DOE/Industry/NRC) to address gaps
- SLR applications will be evaluated considering the latest available research results and endorsed industry standards