Diagnostic Selection for Condition Assessment of Long MV Underground Feeder Circuits: --> Technical Challenges and Hydro-Quebec R&D Project Definition

Jean-François DRAPEAU

Research scientist
Expertise Équipement électriques
IREQ

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WETS D'15

Hydro Québec

Outline

- **Diagnostic Tests for Underground MV Cable Systems:**
  --> User Perspective for Tests Selection
- **Application Context:**
  Hydro-Quebec Distribution (HQD)
  MV Underground System Configuration
- **Actual R&D Project Carried Out at IREQ:**
  "Diagnostic Tests for Underground MV Lines"
- **Tentative Portfolio of Diagnostic Methods for HQD**

1. Diagnostic Tests for Underground MV Lines: --> User Perspective for Test Selection

- **Current situation:**
  - **Condition based maintenance is typically based on two testing strategies:**
    - ↪ **Withstand tests**
    - ↪ **Diagnostic tests**
  - **For each strategy, there is a wide range of methods & testing technologies**
    - ↪ **Voltage type: 60 Hz, VLF (0.1 Hz), DAC**
    - ↪ **Multiple diagnostic approaches**
      - **Diagnostic based on dielectric loss (e.g. VLF Tan δ)**
      - **Diagnostic based on PD assessment**
    - ↪ **Multiple systems & diagnostic providers**

      ... typically "fighting" each others in front of potential clients

1. Diagnostic Tests for Underground MV Lines: --> User Perspective for Test Selection

- **Challenge:**

  ==> How can we "choose" through such a wide variety of options ?

How to select the testing strategies &/or technologies that fit the best the need for condition based maintenance for each utility specific system configuration ?

1. Diagnostic Tests for Underground MV Lines: --> User Perspective for Test Selection

- **Current situation:**

  - **The current testing methods / strategies / technologies rarely provide the level of information that would be required to optimize the maintenance actions**

    - **Is there a problem ? YES / NO --> [Go] / [No Go] on whole segment**

    - **If there is a problem… YES**
      … we would like to be able to answer the following questions:

      - **Where ?**
      - **What ?**
      - **How bad is it ?**

1. Diagnostic Tests for Underground MV Lines: --> User Perspective for Test Selection

- **Challenge:**

==> How far can we go ?

Details regarding challenges

…in terms of enabling ourselves to answer these questions ?

==> Is it possible to develop some criteria that could help to overcome these types of issues ?

e.g. through

- **Combining results from various test methods ?**
- **Investigating new "diagnostic features" ?**

==> What do we know about component aging situation and specific problems to track ?

Details

--> These are some of the challenges which are addressed in the current R&D project at IREQ

2. Application Context: HQD MV Underground System Configuration

Overall picture: (2011)

For the most part:

- **3Φ radial feeder circuits (many times with branches), conduits & manholes**

- **Size: ~10 300 km (circuit length)** **i.e. up to 30 000 km of MV cable**
  ~32 000 manholes
  ~380 000 joints

- **Economic (complete replacement value):**
  MV cables & accessories
  --> ~ 1,8 G$

2. Application Context: HQD MV Underground System Configuration

Technical aspects:

- **Circuit lengths: Typical --> 1 to several km**
- **Cable segment lengths: ~20-50m (downtowns)**
  ~150-250m (suburbs)
- **Cable type:**
  - --> Triplex, mostly XLPE based insulation (>>90%)
  - --> Bare neutrals (unjacketed)
  - --> Mostly 25 kV (few remaining 12 kV)
- **Joint types:**
  - --> Premolded: straight (regular) & straight (disconnectable & taps)
  - --> Cold shrink: straight
- **Age: --> Up to 40 yrs**
  - --> Many cable & joints having been immersed in water for various time periods

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

Improve the efficiency of construction & network operation activities

Diagnostic Tests for Underground Distribution Lines

Context :

- The MV distribution underground system is aging. An increasing proportion of the equipment has cumulated up to 35 to 40 years of service operation.
- Without taking any preventive action, the aging of cable system component will eventually cause a substantial increase of the in-service failure rate.
- There is a need to constitute a "toolbox" of decision tools in order to help determine accurately and efficiently the remediation actions to be undertaken, based on the use of an appropriate set of diagnostics.

Technological Developments Required :

- Evaluate the efficiency and accuracy of existing diagnostic methods + those under development.
- Determine the diagnostics that are the most appropriate to help identify the degraded component that pose the most serious threath, following an optimized sequence.

Anticipated Benefits :

- Maintain the MV underground system reliability, despite the aging of an increasing number of component.
- Optimization of remediation actions deployment.

Project leader : J.-François Drapeau (IREQ)
Customer "Pilot" : Jacques Côté (Expertise souterraine)

	2011	2012	2013	2014	2015	2016	2017	2018
Project Schedule (Stage-gate)	1	2				3	4	5

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J.-F. Drapeau - "Diagnostic Selection for Condition Assessment of Long MV Underground Feeder Circuits: Technical Challenges & Hydro-Quebec R&D Project Definition"

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

- **PURPOSE: For Hydro-Québec Distribution**
  - **Prevent system failure rate to increase due to the aging of MV cable system components (Strategic benefit)**
  - **Optimization of maintenance actions (replacements) (Economic benefit)**
    - ➥ **Avoid unnecessary "wall-to-wall" replacements**

- **TECHNOLOGICAL DEVELOPMENT:**

  Develop the most proper portfolio of diagnostic procedures, in order to get:
  - **the best accuracy**
  - **the best efficiency**

  ... for the selection and planning of maintenance actions

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

Targetted Implementation Approach:

- **"Rehabilitation"**

  ↪ **Bring-up the reliability level of identified MV underground circuits (targetted as "vulnerables") to a level equivalent to that of circuits considered as in "good condition"**

  … or, at least, up to a level considered as "satisfactory".

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

Technological needs : (more specifics)

> Diagnostic methods: --> Develop a portfolio of

--> Diagnostic tools to be used to identify and/or locate the degraded components that present the highest probability of failure

--> Diagnostic and/or testing method to be used to confirm that the "refurbished" cable system is in a "back to normal" condition.

> Diagnostic criteria:

--> Diagnostic feature levels on which will be based the condition assessments "Normal" vs "Suspect", ideally according to the type of component concerned (cable, splice, …)

--> Diagnostic feature levels on which will be based the confirmation of the return to "back to normal" condition of the targeted circuit, once the needed replacements are performed.

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

IREQ "Innovation Process"

--> Stage Gate: Step 2 "Proof of concept"

For this step, two basic issues to address as "proof of concept:

--> Determine how much it is "operationally feasable" to:

1) **Detect and pinpoint "suspicious components" to be replaced ("rehabilitation" actions)**

2) **Confirm the "back to normal" condition of the "refurbished" circuits**

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

IREQ R&D Project Execution

Technical tasks: Step 2 "Proof of concept"

1) Get familiarized with the various diagnostic techniques (especially those involving PD measurements)

2) Perform various studies (lab & field) in order to determine the ability of the diagnostic techniques to detect and "hopefully" identify "suspect" components

--> Diagnostics for neutral condition assessment

--> Diagnostics based on dielectric loss (Tan δ) assessment

--> Diagnostics based on PD assessment (detection & localization)

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

IREQ R&D Project Execution

Based on:

- **Laboratory studies**
- **Tests performed in the field**
- **Partnership with other research facilities**

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

IREQ R&D Project Execution

Laboratory studies:

- **Perform comparative tests with various diagnostic systems on various types of samples:**
  - ***Samples with artificial defects***
  - ***Field aged samples: MV cables, MV joints***
  - ***...***

  Details of available test systems

- **Laboratory investigations :**
  --> regarding diagnostics based on:
  - ***Dielectric loss*** Details
  - ***PD*** Details

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

IREQ R&D Project Execution

Laboratory studies:

- **Laboratory investigations - Review & other examples :**
  - ***Monitor the effect of water content & aging degree on cable performance & diagnostic features (ICC S14 Sub F)***
  - ***Investigate the effect of voltage type & frequency on PD features (ongoing)***
  - ***Investigate the effect of bad accessories (e.g. joints) on the condition assessment based on dielectric loss (tg δ) (ICC F08 Sub F, ICC F08 F03D, ICC S10 Sub F, ICC S11 F10D, + ongoing)***
  - ***Investigate the potential of combining diagnostics methods for obtaining more informations on the type of problem present [e.g. cable vs joint] (ICC F12 Sub F)***
  - ***...***

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

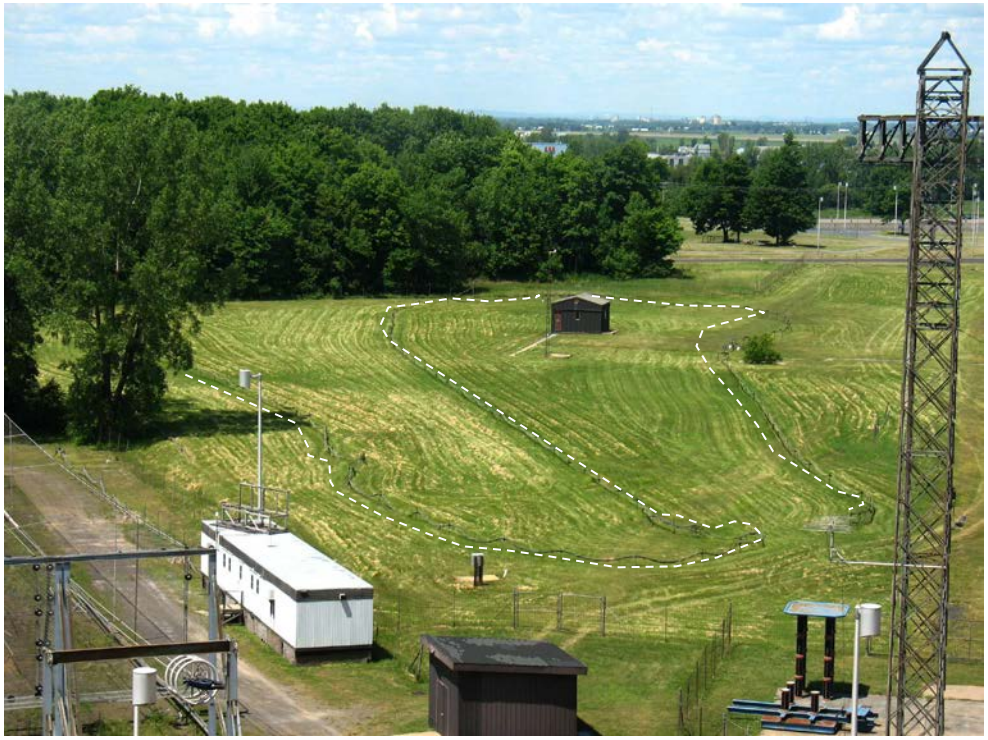
IREQ R&D Project Execution

Example of test sample

Diagnostics based on PD : **--> Tests on a sample equivalent to a real cable system**

--> Mini MV experimental cable system at IREQ HVL

(more than 1 km of cables with cable segments & joints)



3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

IREQ R&D Project Execution

Example of test sample

Diagnostics based on dielectric loss & PD :

--> Tests on an experimental underground cable system

--> New experimental underground cable system
(cable segments: 105 m & 165 m)

Details of all available test samples

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

IREQ R&D Project Execution

Tests performed in the field:

- **Concept: Get some "good" case studies in order to improve our skills with diagnostic interpretation**
  - ***--> Better find some cable systems with expected problems related to aging***

- **The "DEAL":**
  - ***Offer to perform a set a diagnostic test (IREQ team)***
  - ***Each party covers his own expenses (no charge from IREQ)***
  - ***No "official report", but we share our interpretation of the results .... "win-win"***

- **Utilities visited up to now:**
  - **Duke Energy (USA)**
  - **Georgia Power (USA)**
  - **Alabama Power (USA)**
  - **WE Energies (USA)**
  - **Snohomish PUD (USA)**
  - **Eidsiva (Norway)**

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

IREQ R&D Project Execution

Collaborations with other R&D entities:

- **NEETRAC: (U.S.A.)**
  - ***Project "CDFI" (Cable Diagnostic Focus Initiative)***
- **SINTEF: (Norway)**
  - **Team of Sverre Hvidsten**
- **EDF R&D: (France)**
  - **Team "LME" (T. Espilit, H. Digard)**
- **KINECTRICS: (Canada)**
  - **Team of Sarajit Banerjee**

3. Actual R&D Project Carried Out at IREQ Relating to Cable Diagnostics & Condition Assessm.

IREQ R&D Project Execution

Partnerships (informal) with diagnostic equipement suppliers:

- **Seba KMT / Megger (Germany)**
- **BAUR (Austria)**
- **TechIMP (Italy)**
- **Seitz (Switzerland)**
- **HV Diagnostics (U.S.A.) b2 HV (Europe)**
- ***Omicron***

4. Tentative Portfolio of Diagnostic Methods for HQD

Tentative portfolio of diagnostic methods for HQD:

	Diagnostic test method / system	Target components	Information revealed
1°	TDR	Neutral & splices	- Splice positions - Neutral condition (preliminary)
2°	Neutral resistance measurement	Neutral	- Neutral continuity
3°	Offline PD (60 Hz / OWTS / (diagnostic mode)	Cables and Splices Neutral	- Local defects detection - Local defects localization - Defaults severity assessment (prelim.) - Neutral assessment (prelim.)
4°	VLF Tan δ (diagnostic mode)	Cables …….. Splices ……..	- Cable global (& local) aging - "Strong" hot spots on splices
5°	TDS (diagnostic)	Splices ……. Neutral …… Very degraded cables	- Splices with dielectric hot spots - Degraded neutrals - Cable aging indication
6°	VLF Withstand with PD & tan δ monitoring	Cables …… Splices ……	- Cable global (& local) aging - "Strong" hot spots on splices - Confirmation to "back to normal" condition

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THANK YOU
for your attention !