INTEGRETY ASSESMENT OF UNDERGROUND POWER DISTRIBUTION CABLES

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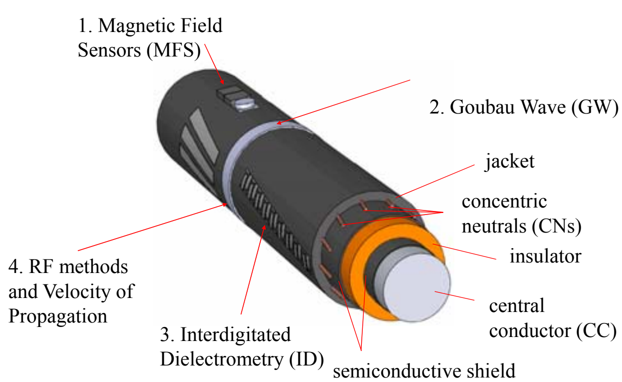
Vision

- Develop an Intelligent Infrastructure to monitor and evaluate the degradation of underground AC power distribution cables.
- Identify novel means for on-line discovery and evaluation of deterioration of concentric neutrals, water-tree growth in the insulator, and other causes of failure in underground power distribution cables
- Develop and fabricate MEMS sensors that can be embedded into underground cables to enable remote monitoring of cable operation

Research Questions

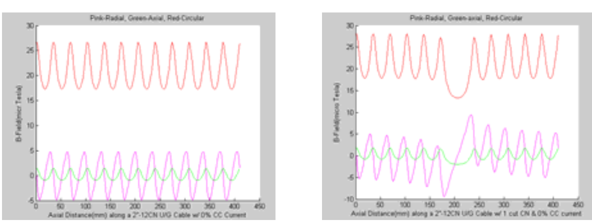
- What cable characteristics change as the cable goes from a healthy to an unhealthy state?
- What type of sensors can be used to detect these changes while the cable is in-power?
- How will information be communicated from the installed sensors to the power utility companies?

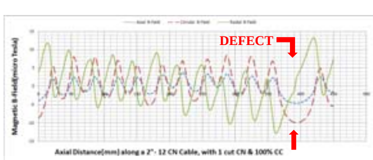
We propose four methods to assess the integrity of underground power distribution cables:



1. Magnetic Field Sensors (MFS)

We use magnetic sensors (AMR-sensors) to detect current asymmetries in the concentric neutrals, which are indicative of the CN failure.

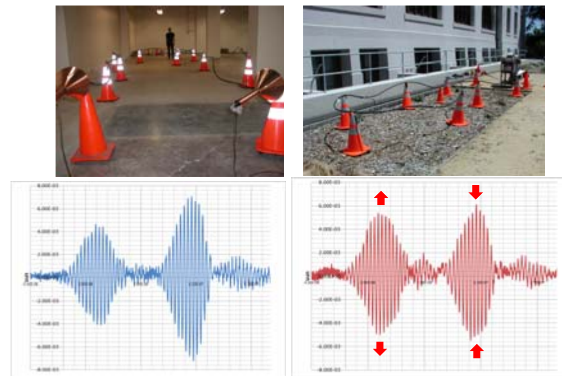




Simulated differences in AMR scans from a healthy (top-left) and damaged (top-right) cable. (bottom-right) An AMR scan of a damaged cable, clearly showing the defect CN, obtained using a device similar to the handheld scanner (bottom-left).

2. Goubau Wave (GW)

We couple a surface-guided RF wave (Goubau Wave - GW) to the CNs of an underground power distribution cable. Breaks in the CNs cause the signal to radiate, and changes the signature of the transmitted GW.

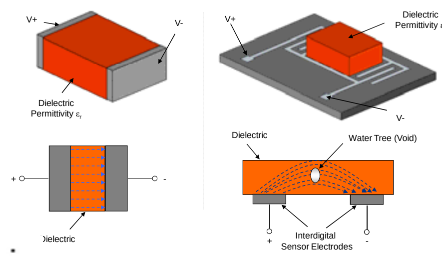


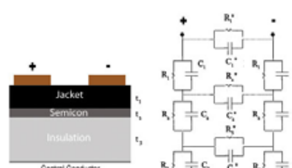
Launching the GW indoors (**top-left**) and outdoors (**top-right**). The signature of the transmitted signal is clearly different before (**bottom-left**) and after (**bottom-right**) the break in all the CNs (red arrows indicate relative change).

3. Interdigitated Dielectrometry (ID)

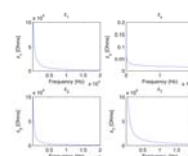
An interdigitated fringe-field capacitor is used to probe the complex permittivity of the insulating materials. Nonlinear response to the instantaneous applied voltage may indicate degradation of the insulator. Conformal mapping is used to design the sensor analytically.

Several prototypes of the ID sensors fabricated using dispensing printing and transfer toner methods





Simulation of semicon effect on sensor measurements



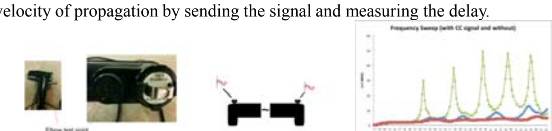
Total Impedance and impedance of the different layers as a function of frequency

The impedance of the semicon layer and of the total circuit are really low compared to the insulation impedance. This "shorts" the path of the current for the ID sensor [the majority of the current goes through the semicon instead of the XLPE] and the measured values are irrelevant of the characteristics of the XLPE. This limits the ability to create a valid comparison between healthy and damaged cables using ID sensors.

4. RF Signals and Velocity of Propagation (VOP)

The idea is to use RF signals to measure the change of permittivity of cable's insulation as the 60Hz voltage of the CC/CN changes. We would connect capacitively to the Central Conductor via the commercial Test Points to send a high frequency signal from one end of the cable to the other. We can calculate the velocity of propagation by sending the signal and measuring the delay.

$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{\sqrt{\varepsilon_r \mu_r}}$$



Initial experiments on a stand-alone open-circuit cable show that a si test points at frequencies in the 3-10 MHz range and possibly higher. The graph above shows a frequency sweep for three different scenarios: A signal is sent through the commercial test point without terminating the cable - this created standing waves at specific frequencies. A signal sent through the commercial TP but with a 52 Ohm load terminating the cable reducing the magnitude of the standing waves. The same signal with a 52 Ohm load terminating the cable and a 60 Hz voltage applied to the Central Conductor showing a 60 dB loss when measured via the Test Point at the end of the cable.