Intelligent Infrastructures for Underground Power Distribution Cables

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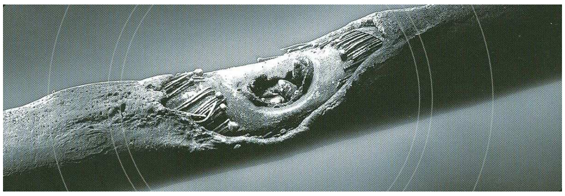
Vision

- Develop an Intelligent Infrastructure to monitor *in-situ* maintenance and to explore the degradation of underground AC power distribution cables
- Identify novel means for discovering and evaluating tree growth and other causes of deterioration in underground power distribution cables that might lead to failure
- Integrate model of sensor with mathematical model of cable work done by the material science research group



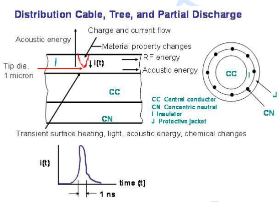
Research Questions

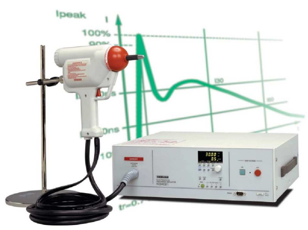
- What cable characteristics change as the cable goes from a healthy to an unhealthy state?
- What type of sensors can be used to detect these changes in its specified characteristics?
- How will information be communicated from the installed sensors to the power utility companies?

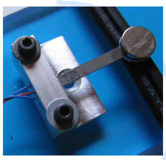
Methods & Findings

Using Concentric Neutrals

- Use concentric neutrals (CN) as transmission line to probe cable insulator. Launch test pulse by capacitive coupling of Electrostatic Discharge Simulator (gift from Kikusui Co.) to a CN wire beneath insulating jacket (J). Pulser produces up to 30 kV, 60 ns pulse. Use to sample cable for water trees.
- Near cable ends where concentric neutrals are all connected together and grounded, use MEMS-based current sensors to measure current in each concentric neutral (CN) wire. Detects open CNs (no CN current flowing). Asymmetric CN currents may indicate presence of potentially destructive water trees near those CNs.
- Failure Mechanism: Microvoids and channels form in insulator (I) due to electrical forces, water seeps in and fills them, forms tree-like conducting structure (in region outlined in red in side view of cable). Ultimately a high-powered brief arc occurs producing damage pictured below.



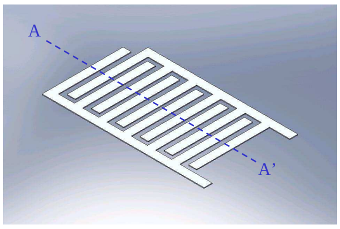




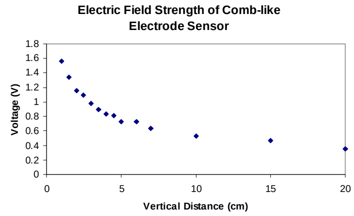
Eli Leland's macro-scale current sensor

Looking at Electric fields and Permittivity of Insulator (XLPE or others)

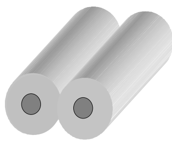
- The Voltage of the central conductors and concentric neutrals produce an electric field around the distribution cable
- The electric field can be detected using a comb-like electrode as a sensor (interdigital dielectrometry)
- A macro scale version of the electrode sensor has been designed. It's electric field has been measured as a function of vertical distance (*see figures below*)

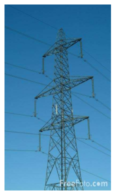


CAD version of electrode (SolidWorks)



ELECTRIC POWER INDUSTRY APPLICATIONS OF MEMS





Residential/Commercial 120 – 660 Vrms | Distribution Circuits 4 – 39 kVrms | Transmission Circuits 115 kVrms and up

MEMS — **Wireless passive proximity measurement of voltage, current, phase, power.**

"Suite" of MEMS-based sensors in different voltage ranges conceived

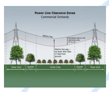
Energy scavenging from energized circuit via sensor + efficient rectifier

Sensors can also derive energy from nearby conductors; prototype 88% efficient synchronous rectifier developed at UCB (Seeman and Sanders)

Assessment of U/G cable aging

Conductor temperature measurement

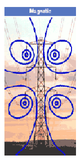
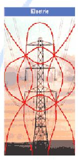
Can add temperature sensor.



MEMS accelerometer sag sensor described in literature; we're looking at using electric field. Vegetation growth → liability?

Line sag measurement

Vegetation growth detection

Can you determine voltages from remote E-fields? Analysis, hardware questions.

Remote (non-MEMS) field-based voltage measurement

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Future Work

- Model electrode sensor behavior with COMSOL® and compare with experiments
- Simulate sensor behavior along with cable simulation done by Material Science group
- Verify the results of the simulations with on field testing at UCB or PG&E San Ramon Research Center