Non-Contact Sensor System for Real-Time High-Accuracy Monitoring of Overhead Transmission Lines

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Acknowledgements


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Real-Time Transmission Line Monitor
(RT-TLM)

- High accuracy, purely electromagnetic, fully passive, real-time, autonomous field sensor system.

- Simultaneous determination, monitoring, and wireless communication of HV transmission conductor sag/clearance, phase current, ampacity, and maximum conductor temperature.

- Ground-based system is far less expensive (in terms of total installed/operational cost) than existing, commercial transmission line monitoring and rating products.

- Designed for simple, low-cost field deployment, installation, and calibration.

- Located in existing ROWs under overhead phase conductors.
RT-TLM: Features and Advantages

- Entirely non-contact, non-invasive installation, calibration, and operation.
- Fully secure, real-time communication of data.
- Solar powered with battery backup.
- Remote, autonomous, reliable field-and-forget operation.
- Does not require utility field crew for installation and calibration.
- Does not require outages for installation, calibration, & maintenance.
- Operation and accuracy not affected by rain, wind, fog, smoke, hail, snow and ice.
- Direct burial allows physically secure, subsurface operation.
# RT-TLM Prototype Performance

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Accuracy, 99% confidence</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>Clearance</td>
<td>+/- 0.12 meters</td>
<td>At ~18.5 meters.</td>
</tr>
<tr>
<td>Temperature</td>
<td>+/- 7 C</td>
<td>Using temperature-clearance calibration</td>
</tr>
<tr>
<td>Phase Currents</td>
<td>+/- 22 Amps</td>
<td>At 830 Amps</td>
</tr>
<tr>
<td>Update rate</td>
<td>Every 5 seconds</td>
<td></td>
</tr>
<tr>
<td>Data latency</td>
<td>&lt; 30 seconds</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feature</th>
<th></th>
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<tbody>
<tr>
<td>Measurement method</td>
<td>Non-contact AC magnetic field sensing.</td>
<td></td>
</tr>
<tr>
<td>Power supply</td>
<td>Solar with battery backup.</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>Wireless EVDO (cell-phone) network link.</td>
<td></td>
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RT-TLM Deployment: Duke Energy
Field Test Site:
Duke Energy Newport-Richmond 500 kV Tie
Fort Mill, SC.
Sensor Placement Cross-Section

- Sensors placed underground.
- Exact location not critical.
- Terrain, slope does not affect accuracy.
- System reports $h$, the conductor height above the sensors.
Prototype Sensor Installation

- Subsurface operation began August, 2007
- 4th Generation Sensor Assembly
5th Generation Sensor

- Watertight assembly
- Greatly reduced volume
- Simplified installation
- Reduced installation time.
RT-TLM Electronics Package: Duke Energy, Newport-Richmond 500 kV.

Solar panel and prototype electronics package
Displays: real-time clearance, conductor temperature, phase currents & ampacity
Installation and Calibration

1. Identify transmission line span; critical span preferred.
2. Place sensors and electronics in prepared subsurface locations; lay cables.
3. Laser survey as-installed sensor locations and overhead spans.
4. Connect electronics, solar panel; take calibration data with laser range finder, and I.R. camera cable temperature data.
5. Cover sensors and electronics with dirt.
6. Analyze calibration data, apply results to base-station software.
7. System functional.
8. Laser range-finder and I.R. camera will certify long-term accuracy.
Measurement Principle: *monitor amplitudes and phases of conductor AC magnetic fields.*

- Each phase generates individual magnetic field
- Fields combine in unique amplitude and phase combinations at each sensor
- Software determines cable heights, currents from sensor data
Conductor Clearance Validation: 9/2007

Conductor clearance measured by:

- Promethean RT-TLM
- Laser range finder.
- Data has been smoothed with a 5 minute window.

Overhead Phase Conductor Clearance: RTTL-Monitor and Laser Rangefinder Data
Field Test of September 7th, 2007
500 kV path; 1 pt./5 sec. over 10 hrs.

RMS Error = 2.0 cm
Average Clearance = 17.88 m

Promethean Devices Non-contact Real-Time Transmission Line Monitor
EPRI/EDM International Conference on Overhead Lines 3/31-4/3/2008
Phase Current Validation: 9/2007

Current, average of three phases, as determined by:

- Promethean RT-TLM
- CT data provided by Duke Energy
- No smoothing

Average Overhead Phase Current Comparison:
Promethean RT-TLM compared vs. Utility CT Raw Data
Field Test of September 7th, 2007
500 kV path; 1 pt./5 sec. over 10 hrs.

Average current = 830 Amps
RMS Error = 8.4 Amps
Clearance-Temperature Calibration

- Plot shows:
  - Laser range-finder measured height
  - I.R. camera measured conductor temperature
  - Linear fit serves as a height-to-temperature conversion and calibration.

![Graph showing clearance-temperature calibration.](attachment:plot.png)

**Phase B Conductor Height vs. Temperature**
Duke Energy Newport-Richmond 500 kV Tie
2515 kcml Joree ACSR Conductor (E = .91; 1968)

Phase B Conductor $T = -31.58 \times \text{Height} + 579.75$
RMS error = 1.75 C
Present status

- Prototype system running for seven months, in subsurface implementation.
- RT-TLM vs laser range finder height comparisons stable to ~3 cm, or ~1 degree C over this time period.
- DOE funding lasts through Summer 2008
Additional Measurement Capabilities

- Ice detection and loading
- Wind driven conductor motion; mechanical loading
- Galloping
- Detection of mechanical anomalies
Present Efforts & Near-Term Goals: Summer 2008

- Replace 1st generation fully autonomous RT-TLM prototype with 2nd generation, low-power, small footprint, “pre-production” system.

- Install several 2nd generation systems under heavily loaded, or dynamically/persistently congested, transmission paths to:
  - Monitor and report in real-time on critical operating parameters during the 2008 Summer Peak.
  - Demonstrate long-term system reliability and accuracy.
  - Expand conductor temperature & ampacity estimation data sets; improve and validate ampacity estimation algorithm.
  - Allow dynamic real-time rating and operation during the 2008 Summer Peak.

Promethean Devices is now looking for qualified test/evaluation sites.
• Thank you!

• Questions?