Powerline Conductor Accelerated Testing (PCAT)

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Topics to Address

- Recap on what is PCAT and why is it here?
- Previous Capabilities & Challenges
- Status of Current Upgrades & Test Results
Recap - History: Powerline Conductor Accelerated Testing Facility – Why is it here?

2002 - National Transmission Grid Study
- One of the 51 Recommendations -

“DOE will develop national transmission-technology testing facilities that encourage partnering with industry to demonstrate advanced technologies in controlled environments.

Working with TVA, DOE will create an industry cost-shared transmission line testing center at DOE’s Oak Ridge National Laboratory (with at least a 50 percent industry cost share).”


Originally built for the 3M Composite Conductor development, now available for any manufacturer to validate their product.
Recap: Past Accomplishments

- PCAT has been in operation for over 10 years
- The PCAT facility has been used to test many different conductors and sensors:
  - 3M 477 kcmil ACCR
  - 3M 675 kcmil ACCR
  - Southwire 1113 kcmil ACSR FO
  - Power Donut2
  - 3M 1272 kcmil ACCR
  - 3M 795 kcmil ACCR
  - Southwire C7 Overhead Conductor
  - Others
Recap - Capabilities: Powerline Conductor Accelerated Testing Facility

- **Testing Capabilities**
  - Thermal / Mechanical Cycling
  - Current / Temperature Ramp
  - Current / Temperature Steps and Hold
  - Controlled current testing
  - Controlled temperature testing

- **Facility**
  - 2400 feet of conductor
    - two 600 foot spans
    - 3 towers
  - 0 to 400 Vdc
  - 0 to 5,000 Adc
  - Conductor and accessories
  - Tested up to 300°C
    - can go higher if needed
Recap: Driver of higher operating temperatures is higher current ratings

Need to test / verify new conductors over entire operating range

Over temperature causes annealing and loss of strength for Conventional Conductors (ACSR, ACAR, and AAC)
Recap: Benefit of a high temp/low sag conductor

More ampacity while still meeting the National Electric Safety Code (NESC) required minimum clearance
Recap: Existing Infrastructure
Recap: Conductors are installed by TVA using conventional industry practices.

Typical installation is ~ 3-4 days.

CERTS
Consortium for Electric Reliability Technology Solutions
Where PCAT fits?

- PCAT provides a unique transmission conductor testing facility to augment utility field tests and demonstrations
- Each conductor test undertaken in collaboration with industrial partner
How is PCAT Unique?

Who else does this in the US?

- **Other Facilities:**
  - KEMA – No Overhead testing in US
  - NEETRAC – Primarily indoor
  - EPRI – Charlotte is indoor, Lennox could add outdoor testing, but currently not present

*Only facility in North America where there are realistic spans, realistic environment, and realistic loads*
Historical Data Collection – Visual Basic

- Conductor/accessory temperature
  - Surface contact or conductor core
  - Upto 128 thermocouples
- Applied current and voltage
  - Measured by power supply
- Conductor sag
  - Laser at mid-span
- Conductor tension
  - Load cells on both circuits
- Weather
  - Ambient temperature, wind speed, wind direction
  - Conductor net radiation sensor
- PC-based data acquisition system
  - 10 second polling, 1 minute data archive

Note: combined at midnight, non real-time
Historical Challenges to Testing

- Lightning strikes have damaged many sensors
- System lacked flexibility to adapt test plans and analysis to meet specific vendor needs:
  - Legacy software was in Visual Basic, original programmer has since retired.
- Measurement resolution
  - Inability to investigate short duration phenomena
- Inability to detect bad data
  - Unable to validate measurements using multiple sources (diverse measurement technologies)
- Conductor Right-of-Way Encroachment
  - Tree limbs were in close proximity to conductor including touching at times
Current Activities

- Rehabilitating PCAT Data Acquisition, Controls, and Visualization:
  - Replaced broken, obsolete and inflexible parts
  - Transitioning control from Visual Basic to LabVIEW.
  - Integrate new sensors including thermal imaging of conductor
  - Integrate continuous CAT-1 data feed
  - Implement real-time remote monitoring and warning system

- Continue testing
  - Installed and currently testing General Cable ACSS Drake 795 Conductor
    - One side coated, One side non-coated
5 days of testing at different current levels
% Reduction between coated and non-coated
General Cable Test Results

Temperature profile at 1425A

Conductor Temperature (°C)

Time Of Day

- Red: Uncoated
- Blue: Coated
## General Cable Test Results

### Conductor: ACSS Drake 795kcmil

<table>
<thead>
<tr>
<th>Ambient Temp (°C)</th>
<th>Wind Velocity (ft/s)</th>
<th>Uncoated Conductor (°C)</th>
<th>Coated Conductor (°C)</th>
<th>% Reduction</th>
<th>Differential Sag (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>1.1 - 3.6</td>
<td>90</td>
<td>72</td>
<td>20%</td>
<td>0.5</td>
</tr>
<tr>
<td>8</td>
<td>0 - 4.7</td>
<td>119</td>
<td>90</td>
<td>24%</td>
<td>0.7</td>
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<tr>
<td>8</td>
<td>4.4 - 5.7</td>
<td>125</td>
<td>94</td>
<td>25%</td>
<td>0.9</td>
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<tr>
<td>6</td>
<td>0.2 - 3.2</td>
<td>166</td>
<td>125</td>
<td>25%</td>
<td>1.5</td>
</tr>
<tr>
<td>6</td>
<td>0.4 – 4.8</td>
<td>200</td>
<td>150</td>
<td>25%</td>
<td>1.6</td>
</tr>
<tr>
<td>4</td>
<td>NA</td>
<td>240</td>
<td>174</td>
<td>28%</td>
<td>2.25</td>
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<tr>
<td>2</td>
<td>2.1 - 2.2</td>
<td>275</td>
<td>190</td>
<td>31%</td>
<td>2.85</td>
</tr>
</tbody>
</table>

20-30% Reductions in Operating Temperature and Sag for Coated Conductor vs Uncoated Conductor
Right of Way Clearing

- Current Right of Way was encroaching on the conductor
- At times would have tree contact with conductor
- Cleared a large Right of Way (~15’) for the Conductor to ensure uninterrupted testing
Thermocouple Upgrade

- Thermocouple modules all updated to I-7018-R modules
- Every channel individually checked to ensure valid identification and labeling
- Added open circuit thermocouple detection to the module enabling identification of unused thermocouples
PCAT LabVIEW implementation using Actor Framework

Advantages
- Measurements, processing, and controls performed asynchronously and in parallel
- Allows adding new measurement or control capabilities without affecting current functionality
- Enables rapid development of additional measurements and new controls
Initial Thermal Investigation

- Roadside tracker with 2 FLIR Tau 2 Longwave Infrared (LWIR) cameras (640 by 512).
- 9 mm lens with focal length providing a 70 degree horizontal view angle.
Selected Thermal Camera

- Purchased A310f 15° FLIR Camera
- Currently integrating with LabVIEW front panel, followed by embedded image processing for sag and temperature analysis

Planned Installation Site, 2nd at other end once validated
Additional sensors

- Material Transfer Agreement has been executed with UC Synergetics to implement their ThermalRate System
  - Plans to expand into a CRADA
- Plans to install the system during June and incorporate into the LabVIEW data feed
- Will provide feedback on any beneficial features
Risk Factors

- Glitches during cutover to new control system.
  - Have minimized risk by paralleling the serial connection to keep it connected to both sets of controllers.

- Unfavorable weather conditions
  - Because sustained bad weather is not predicted, this is only a minor risk to the schedule.
Proposed FY16 Activities

- Continue conductor testing
- Finish integrating additional sensors
- Enhance Real-time controls

- Expand PCAT test capability to include alternating current
  - Add a DC to AC inverter stage to the current infrastructure
  - Conduct additional testing including:
    - Perform conductor testing of steady state and transient conditions at grid frequency accounting for all the effects of the AC EM field
    - Test and experiment with measurement devices and auxiliary equipment including:
      - Dynamic Line Rating Devices
      - PMUs
      - CTs
      - VTs
      - Other devices intended for ac powerline applications
    - Test and experiment with different power flow control devices
      - Smart Wire
      - Power Donut
      - ORNL’s Continuously Variable Series Reactor (CVSR)
      - Others
    - Investigate the impact of AC EM field on different devices/objects along the right-of-way