Advancements in Overhead Conductor technology: Engineered Emissivity
Conductor Temperature/Line Ratings

Ratings can be increased with higher emisivity and lower absorptivity
The *Infrared Emissivity* coefficient represents the ratio of radiant energy emitted by the conductor surface to the infrared radiant energy emitted by a blackbody at the same temperature, and can vary between about 0.2 to about 0.9. As a conductor ages, the infrared emissivity, or ability of the conductor to radiate heat energy to its surroundings increases, which increases the MVA rating of the conductor.

The *Solar Absorptivity* coefficient represents the fraction of incident solar radiant energy that is absorbed by the conductor surface. The solar absorptivity coefficient varies between about 0.2 to about 0.9, with higher values indicating that more solar energy is being absorbed by the conductor. As a conductor ages, the solar absorptivity, or the amount of solar energy absorbed by the conductor increases, which decreases the MVA rating of the conductor.

*E3X changes these variables to fixed values, eliminating uncertainty*
New vs. Aged Conductors

How many years will it take for conductor to “darken” to assumed value? Will today’s conductors ever reach this level?
Atmospheric Pollution Reduction 1970-2010

Conductors from existing studies were installed pre-1970

Limited number of more recent conductors tested show lower emissivity
What value of Emissivity is used today? (For standard lines not using E3X conductors)

A sample of emissivity values used for line rating by EEI members: 0.4, 0.5, 0.7, 0.8, 0.9

Which value is Correct?

<table>
<thead>
<tr>
<th>Location</th>
<th>Years in service</th>
<th>approx. year installed</th>
<th>Reference</th>
<th>Emissivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washington, DC</td>
<td>0.8</td>
<td>1971</td>
<td>PJM/NASA</td>
<td>0.46</td>
</tr>
<tr>
<td>Washington, DC</td>
<td>8</td>
<td>1964</td>
<td>PJM/NASA</td>
<td>0.74</td>
</tr>
<tr>
<td>Washington, DC</td>
<td>36</td>
<td>1936</td>
<td>PJM/NASA</td>
<td>0.85</td>
</tr>
<tr>
<td>San Francisco</td>
<td>40</td>
<td>1916</td>
<td>Taylor, House</td>
<td>0.91</td>
</tr>
<tr>
<td>Philadelphia</td>
<td>21</td>
<td>1935</td>
<td>Taylor, House</td>
<td>0.89</td>
</tr>
<tr>
<td>Chicago</td>
<td>25</td>
<td>1931</td>
<td>Taylor, House</td>
<td>0.89</td>
</tr>
<tr>
<td>San Francisco</td>
<td>43</td>
<td>1913</td>
<td>Taylor, House</td>
<td>0.88</td>
</tr>
<tr>
<td>New York</td>
<td>23</td>
<td>1933</td>
<td>Taylor, House</td>
<td>0.80</td>
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<tr>
<td>Tennessee</td>
<td>38</td>
<td>1918</td>
<td>Taylor, House</td>
<td>0.77</td>
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<tr>
<td>New Jersey</td>
<td>15</td>
<td>1993</td>
<td>EPRI</td>
<td>0.63</td>
</tr>
<tr>
<td>Austin, TX</td>
<td>32</td>
<td>1982</td>
<td>EPRI</td>
<td>0.45</td>
</tr>
<tr>
<td>San Bernadino</td>
<td>32</td>
<td>1924</td>
<td>Taylor, House</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Values derived by Aluminum Company of America in study cited in IEEE 738 and by EPRI using their Emissivity Testing Instrument and by NASA in for 1973 PJM conductor rating task force. Shape of aging curves are estimates for illustration purposes only.
Surface Modified Overhead Conductor Temperature Rise Test
Impact of different surface conditions on ratings

1590 kcmil Lapwing ACSS @200°C ratings
2ft/sec crosswind, 40°C ambient, 200ft elevation, 0.5 W/ft² solar

Assumption that time and environment will change conductor surface before full loading

What if full “0.9” load put on new conductor? 2309 amps = 320°C

What if 2309 amps put onto E3X Conductor? 195°C
Introducing

Surface Coating

High Emissivity (0.9), Low Absorptivity (0.2)

Results in cooler operating conductor for given load

Applied in the factory to the outside of the conductor

Thin (½ mil) coating

Environmentally stable

Hard, Durable, Abrasion and Heat Resistant, Flexible

Can only be removed by removing underlying aluminum
Commonly Used ERCOT conductors

<table>
<thead>
<tr>
<th>Frequency:</th>
<th>60 Hz</th>
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</thead>
<tbody>
<tr>
<td>Ambient Temperature:</td>
<td>40 °C</td>
</tr>
<tr>
<td>Crosswind Velocity:</td>
<td>2.00 ft/s</td>
</tr>
<tr>
<td>Wind Angle:</td>
<td>90 °</td>
</tr>
<tr>
<td>Total Solar Radiated Heat:</td>
<td>95.4 W/ft²</td>
</tr>
<tr>
<td>Northern Latitude:</td>
<td>32 °</td>
</tr>
<tr>
<td>Elevation:</td>
<td>600 ft</td>
</tr>
<tr>
<td>Month and Day of Year:</td>
<td>July 1</td>
</tr>
<tr>
<td>Time of Day:</td>
<td>2:00 PM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temp</th>
<th>Resistance</th>
<th>Ampacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Ω/kft</td>
<td>New (shiny) E=0.5/A=0.5 E3X</td>
</tr>
<tr>
<td>200</td>
<td>0.03622</td>
<td>1415</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temp</th>
<th>Resistance</th>
<th>Ampacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Ω/kft</td>
<td>New (shiny) E=0.5/A=0.5 E3X</td>
</tr>
<tr>
<td>200</td>
<td>0.01955</td>
<td>2125</td>
</tr>
</tbody>
</table>
E3X Technology improves any aluminum conductor

Added Capability
• E3X adds capacity to standard bare aluminum conductors such as ACSR and ACSS, increasing operational flexibility and reducing the need for one-off solutions

More Ratings Certainty
• E3X lowers risk of clearance violations and damage to lines from overheating by converting uncertain ratings variables to fixed values
  – Changes assumed emissivity values to fixed emissivity values
  – Changes assumed absorptivity values to fixed absorptivity values
E3X Testing: from the lab to field trials to utility deployment

Performance
- Temperature Reduction (vs. New, Non-Specular, and Aged)
- Ampacity
- Oak Ridge National Laboratory
- Temperature Reduction vs. Coating Coverage

Physical Durability
- Adhesion
- Thermal Stability
- Sheave Roller
- Galloping
- Aeolian Vibration
- Tension Cycling

Environmental Durability
- Weatherometer
- 85/85 Heat/Humidity
- Water Immersion
- Low pH
- High pH
- Salt Water

Electrical Performance
- Corona / Wet Corona

Field Testing
- Utility Installations
Sample of testing performed: Oak Ridge National Laboratory

- Conductor was installed at Oak Ridge National Laboratory’s PCAT (Powerline Conductor Accelerated Test Facility) in October 2014
Sample Test Results at Oak Ridge National Laboratory

Conductor Temperature (°C)

Day

Day End
Coated
Uncoated
Sample Test Results at Oak Ridge National Laboratory

<table>
<thead>
<tr>
<th>Ambient Temp (°C)</th>
<th>Wind Velocity (ft/s)</th>
<th>Drake ACSS/MA2 (°C)</th>
<th>Drake ACSS/MA2/E3X (°C)</th>
<th>Temperature Reduction (°C)</th>
<th>Sag Differential (ft)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>1.1 - 3.6</td>
<td>90</td>
<td>72</td>
<td>18</td>
<td>0.5</td>
</tr>
<tr>
<td>8</td>
<td>0 - 4.7</td>
<td>119</td>
<td>90</td>
<td>29</td>
<td>0.7</td>
</tr>
<tr>
<td>8</td>
<td>4.4 - 5.7</td>
<td>125</td>
<td>94</td>
<td>31</td>
<td>0.9</td>
</tr>
<tr>
<td>6</td>
<td>0.2 - 3.2</td>
<td>166</td>
<td>125</td>
<td>41</td>
<td>1.5</td>
</tr>
<tr>
<td>6</td>
<td>0.4 - 4.8</td>
<td>200</td>
<td>150</td>
<td>50</td>
<td>1.6</td>
</tr>
<tr>
<td>4</td>
<td>N/A</td>
<td>240</td>
<td>174</td>
<td>66</td>
<td>2.25</td>
</tr>
<tr>
<td>2</td>
<td>2.1 - 2.2</td>
<td>275</td>
<td>190</td>
<td>85</td>
<td>2.85</td>
</tr>
</tbody>
</table>

* 600 ft span
E3X Technology: Increased Capacity, Lower Risk

Risk of Overloading Line
Risk of Unused Capacity
Risk of Unused Capacity
E3X E=0.9
Eliminated Risk with E3X

Additional Capacity with E3X

Example: E=0.7 estimate

21 year old conductor
E=0.89

32 year old conductor
E=0.37

Years in Operation
Summary

– Adds capacity and flexibility to accommodate uncertainty in a fast changing transmission landscape
– Reduces risk in transmission line ratings by changing assumed variables to fixed values
– Lowers project costs by enabling conductors to operate safely at higher rated ampacities
– Reduces O&M costs by increasing capabilities of products already used everyday.
– Proven in the lab, the field, and with utility installations
Thank You!

Joe Coffey
General Cable
Director Transmission
303 284 8025
jcoffey@generalcable.com