Transmission Line Conductor Size Selection

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Planning Change Drivers

- Regional markets and planning
- Rise of intermittent generation resources
- Changes happening at the grid edge
- Competitive considerations
  - FERC Order 1000
  - Alternative technologies (e.g. Non-wires alternatives/NWA)
- Justification challenges
  - Benefit-Cost ratio
  - Policy goals
New Planning Outlook

- More coordinated, regional approach with multiple entities involved in process
- More cases to be studied to capture changes in resources/load profile
- More alternatives to be considered
- More non-traditional solutions
- More iterations to maximize Benefit-Cost ratio
Transmission Line Solution

Maximize Benefit-Cost Ratio

- Benefit: rating and impedance
- Cost: route, conductor and structure

Study Process

1. Identify area need
2. Investigate minimum area requirements
3. Develop potential solutions
4. Perform analysis to evaluate benefit
5. Refine/optimize solutions

Example
Transmission Design Considerations

- Reconductor vs. new construction
- Galloping
- Bundling
- Mechanical requirements
- Electrical requirements
- Structure design
- Foundation design
- Ruling span
- Terrain
- Contractor equipment
Utility Standards

- Using consistent conductor types reduces overall maintenance and inventory costs.
- Not always competitive under FERC Order 1000 or against non-wires alternatives.
- Rating methodology established minimum conductor needed based on the atmospheric conditions.
Conductor temperatures are a function of:

<table>
<thead>
<tr>
<th>Conductor material properties</th>
<th>Conductor diameter</th>
<th>Conductor surface conditions</th>
<th>Weather conditions</th>
<th>Conductor electrical current</th>
</tr>
</thead>
</table>

Calculating the Current-Temperature Relationship of Bare Overhead Conductors
Calculate conductor temperature when electrical current is known

Calculate the current (thermal rating) that gives the maximum allowable conductor temperature

Steady-State vs. Transient vs. Dynamic Cases

Calculator Tools
Guide for Selection of Weather Parameters for Bare Overhead Conductor Ratings

Provides recommendations for inputs

Details impact of major variables
Conductor Rating Inputs

Wind Speed & Direction

• The most important variables
• Default = 0.6 m/s (2 ft/s)
• Sheltering affect
• Consider 45° net effect per CIGRE
Conductor Rating Inputs

Ambient Temperature

- 1-to-1 relationship with conductor temperature
- Can significantly affect lower thermally rated conductors
- Summer vs. Winter
Conductor Rating Inputs

Solar Radiation

- Commonly between 1000 and 1280 W/m² (~92–119 W/ft²)
- Temperature increases proportionately to absorptivity of the conductor
- Ambient temperature + solar radiation = net radiation temperature
- Typically assume solar temperature is 7-9°C (~44-48°F) higher than ambient
- Solar temperature is lower when ambient temperature is high
Conductor Rating Inputs

Emissivity & Absorptivity

- **Emissivity**: the relative power of a surface to emit heat by radiation
- **Absorptivity**: the fraction of incident radiation absorbed by the body
- Highly correlated
- 0.2 – 0.3 after conductor installation, can be closer to 0.8 within 2 years
- CIGRE recommends 0.9 for absorptivity and 0.8 for emissivity, though many utilities use 0.5–0.6
Consequences of Insufficient Line Ratings

**Clearance violations**
- Reliability
- Public Safety

**Annealing**
- Limited long-term emergency rating
- ACSR conductors with >7% steel are more tolerant

**Elevated temperature creep**
- Creep may restart or accelerate
- ACSR conductors are relatively immune to high temperature creep
Example – Base Inputs

- Conductor: 795 ACSR Drake 26/7
- Absorptivity & Emissivity: 0.5
- Wind Speed: 2 ft/s
- Wind Angle: 90°
- Ambient: 40°C
- Frequency: 60 Hz
- Atmosphere: Clear
- Altitude: 1000 ft
- N. Latitude: 46°
- Line Azimuth: 90°
- Local time: 12 Noon
- Solar Day: June 30th

Temperature Input: 100°C
Steady State Current Rating: 983 Amperes
### Example – Effects of Changing Variables

<table>
<thead>
<tr>
<th>Modification</th>
<th>Rating Change</th>
<th>Cost Change</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase wind speed from 2 ft/s to 4 ft/s</td>
<td>17% increase</td>
<td>Positive</td>
<td>Ability to use a smaller conductor</td>
</tr>
<tr>
<td>Changing wind direction from 90° to 45°</td>
<td>7% decrease</td>
<td>Negative</td>
<td>May be more accurate but ultimately needs to be consider with wind speed</td>
</tr>
<tr>
<td>Increasing conductor diameter (954 ACSR 54/7)</td>
<td>10% increase</td>
<td>Negative</td>
<td>Additional rating capacity, but at a higher cost</td>
</tr>
<tr>
<td>Decreasing ambient temperature by 5°C</td>
<td>4% increase</td>
<td>Positive</td>
<td>Ability to use a smaller conductor</td>
</tr>
<tr>
<td>Increase percent of steel (795 ACSR 30/19)</td>
<td>1% increase</td>
<td>Neutral</td>
<td>Conductor can accommodate larger mechanical loads</td>
</tr>
<tr>
<td>Increasing emissivity and absorptivity (0.7 &amp; 0.9)</td>
<td>1% decrease</td>
<td>Neutral</td>
<td>Accurately reflects field conditions</td>
</tr>
</tbody>
</table>
Summary

- Customer demands increasing
- Technology/competition changing selection outcomes
- Early identification of design considerations that improve project benefits can create a competitive advantage