2019 MINNESOTA POWER SYSTEMS CONFERENCE

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

IEEE Standard 738-2012

Calculating the Current-Temperature Relationship of Bare Overhead Conductors

Conductor temperatures are a function of:

- Conductor material properties
- Conductor diameter
- Conductor surface conditions
- Weather conditions
- Conductor electrical current

IEEE Standard 738-2012

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

CIGRE Technical Brochure 299

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/m^2 (~92–119 W/ft^2)
- 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

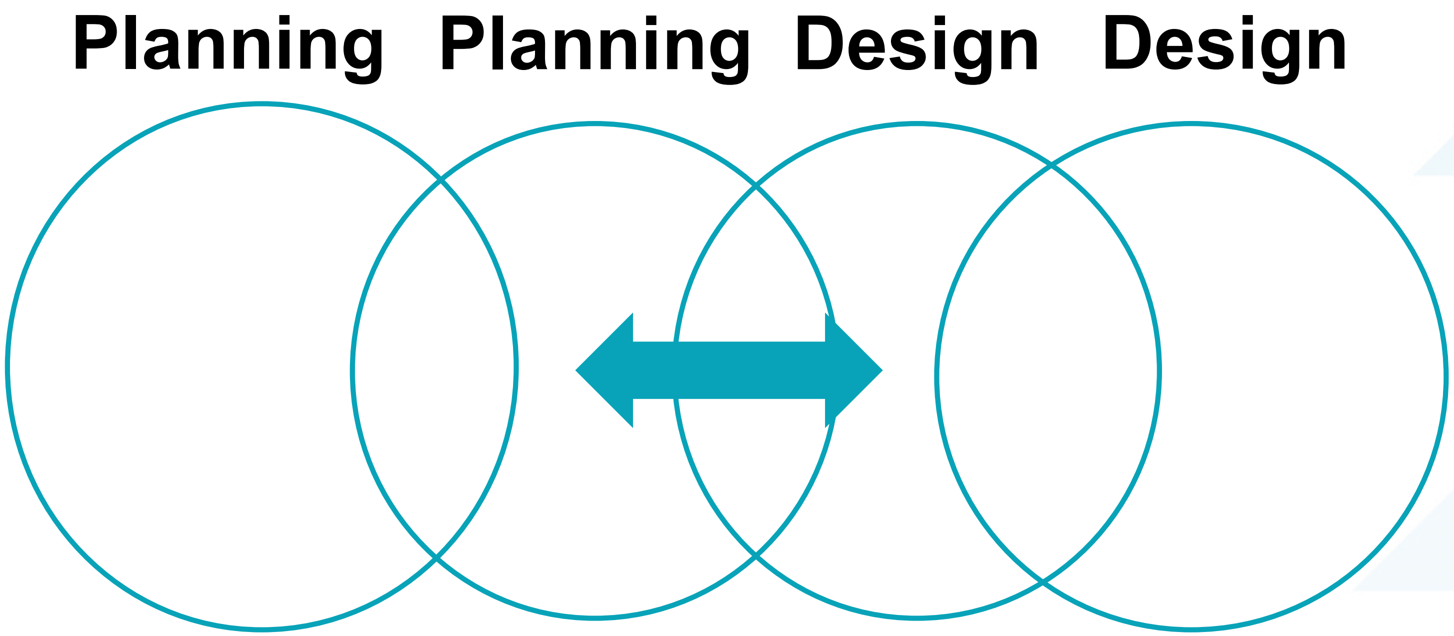
Temperature Input: 100° C
Steady State Current Rating: **983 Amperes**

Example – Effects of Changing Variables

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

Summary

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



Questions