Southern Alberta Section
IAS-PES Chapter

Introduction to Transmission Line Design Workshop

Carl Orde, P.Eng, Member IEEE
Utilitech Consulting Inc.

The IEEE Southern Alberta PES/IAS Chapter is pleased to announce a two-day, hands-on transmission line design workshop on February 17 and 18, presented by Carl Orde, P.Eng.

A detailed agenda of the workshop can be found below.

Location: The Carriage House Inn
Victoria Room

9030 Macleod Trail South
Calgary, Alberta

Date: Tuesday, February 17, 2015 to Wednesday, February 18, 2015

Time: 7:30AM to 4:30PM — All times are: Canada/Mountain

Breakfast and Lunch are included.

Register at: https://meetings.vtools.ieee.org/m/31395

Speaker:

Carl Orde

Carl has almost 45 years of experience in the transmission and distribution areas of electric utility operations, with investor (TransAlta) and government owned (Ontario Hydro) organizations. He has held positions having both management and technical expert roles in the areas of design, operation and maintenance of transmission facilities. Carl has been very successful in completing large projects and bringing innovative solutions to complex and difficult problems.

Carl is currently operating a successful consulting company, which he established in 1998, offering T&D design, project management and specialized services to clients in the electric power industry. A significant part of his current activities is related to formal training and informal mentoring for engineers working in transmission and distribution line design.

Carl is a member of IEEE and CIGRE and is also a member of the CSA Overhead Systems Committee (C22.3 No.1 and C22.3 No.60826). He is a registered Professional Engineer in Alberta.

Please contact Rasheek Rifaat [rasheek.rifaat@ieee.org] if you have any problems registering for the workshop, or if you have any questions.

Detailed Workshop Agenda:

Day 1

- Preamble:
  - Introductions
  - Objectives and format of the workshop
  - Key aspects of line design process (loadings, strength, key components, etc.) and relevant definitions
  - Introduction to AESO Rules Section 502.2 – background, scope, ID document

- Basic approaches to transmission line design
  - Deterministic design
    - Requirements, AEUC, CSA C22.3 No. 1-10, load factors
    - Ultimate load design
    - Description of method, advantages and disadvantages, typical overload factors
  - Reliability based design
    - Description of method, load and strength factors, sequence of failure, advantages and disadvantages
    - Groups involved and publications
    - C22.3 No.1-01 – 12 drafts and 20 years
    - CSA C22.3 No. 60826
    - AESO Rules – reliability based design for Alberta
    - Relationship between load and strength
    - Probability functions
    - Basic load and strength equation

- Loadings
  - Weather loadings
  - Types of loadings – wind alone, wind and ice combined, ice alone
  - Two general approaches – wild generalization with large FS or ultimate load approach
  - CSA deterministic loadings & Alberta Code; loading areas in Alberta
  - Reliability based design (CSA C22.3 No.60826, AESO Rules for Alberta)
  - Wind loading – refer to AESO wind maps – variation by location and reasons, how return period loads are calculated, effects of terrain and height, drag coefficients, gust duration, gust front width, importance of wind loadings
  - Wind loadings – AESO Rules approach
  - Combined loadings - wet snow/ ice and wind, difficulty of calculating, work done to date by various parties, types of combined loadings found in Alberta, variation by location, AESO loading map
  - Vertical loading alone (AESO requirements)

- Failure containment loadings (deterministic)
  - Longitudinal loadings (define longitudinal)
    - Purpose - cascade prevention; describe phenomenon, give examples, include types of events that trigger cascades e.g, broken wires, hardware failure, different tensions (unequal ice or snow), broken subconductors (limited effect)

        - Methods of providing longitudinal strength – strong structures at intervals, provision for broken wire loads, flexible structures
        - Examples of strong structures (CSA, etc)
        - Typical (and non typical) examples of broken wire loadings (O-H Pickering lines); effect on line cost
        - Effect of structure and foundation stiffness – single pole and H-frame vs. lattice towers, effects of insulator swing
        - Use of computer programs to simulate broken wire or unbalanced tension events (SAPS, SAGSEC)
        - AESO Rules requirements – broken wire & unbalanced ice, failure containment structures
        - Sequence of failure – general guidelines, preferred sequence of failure, AESO Rules
    - Construction and maintenance loadings (deterministic)
        - Involves safety to people
        - Higher factor of safety than for other loadings
        - Typical operations covered – structure erection; wire stringing and sagging; maintenance operations such as insulator and hardware replacement; live line maintenance
        - Example of loads imposed by lowering conductor with two part line
        - Typical values of construction and maintenance loads
    - Calculation of weather loads on wires and structures
        - Simplified approach and basic equations (define span as distance between structures only)
        - Basic equation for wind force on wires
        - Wind force as per ASCE 74
        - Basic equation for wind force on structures – drag coefficient
        - Basic equation – vertical load
        - Equations for combined loading – ice/ snow density
        - Weather loads – using equations from AESO Rules for wind loads
        - Span factor
        - Effect of line angles is covered in Day 2 – Line Design

- Loading Calculation Exercises
        - Give simple wood pole span, 266 conductor data and wind loading (give area and refer to wind isotachs from AESO map) – calculate vertical and transverse loads for span. (Give different conductor sizes and loading areas to different people – compare results)
        - Repeat for typical 240 kV (large single conductor) – same loading areas – compare results
        - Compare loadings for different parts of province and different types of loads (wind alone and combined wet snow and wind)

- Structure strength
    - General considerations for deterministic, ultimate load and reliability based design
    - Statistical variation of strength (reliability based design)
    - Strength factors for sequence of failure
    - Strength of wood poles
    - Common values of wood strength – IEEE, CSA, variation of strength, common species of wood poles and arms, use of fir poles

        - Effect of age; use of wood preservatives; pole retreatment; methods of testing
        - Lifetime of wood poles
        - Pole sizes and classes
        - Strength of steel poles and lattice towers
        - Common types of steel, galvanized, weathering steel, painted structures
        - Variation of material and structure strength
        - Structure failures – practical examples – with pictures.

- Conductor basics
- Conductor construction and basic types:
    - ACSR, SDC, compact conductor, aluminum alloy, ACSS
    - Advantages and disadvantages – cost, construction and maintenance, high temperature operation
    - Recent / emerging developments in conductor technology

- Basic terminology
    - Span terminology (weight span, wind span, ruling span)
    - Rated strength, stranding terminology (26/7)
    - Sag, arc length (stressed and unstressed)

- Tension limits
    - Vibration control and reasons for this
    - Vibration tension limits (values specified by AESO Rules)
    - Mechanical loading limit (combined loading) – concern for mechanical integrity
    - CIGRE Bulletin 273 on tension limits (with and without dampers)

- Basics of sag tension calculation (level span)
    - Parabolic equations – give basic equations
    - Catenary equations – give basic equations
    - Use of computer programs (STESS, PLS-CADD, SAG10)

- Sag tension calculation exercise
    - Calculation exercise for different span lengths and conductor types – each person does different example – compare results
    - Use sag or tension limits from above
    - Include effect of external loads

- Other aspects of conductor behavior
    - Conductor behavior with time
        - Aluminum creep – function of time and mechanical loading, effect on tension
        - Stress strain charts
        - Behavior of aluminum and steel
    - Effects of temperature and tension
        - Load sharing of aluminum and steel, thermal coefficients of expansion
        - Effects of external load (ice, wind); resultant load (conductor doesn't care about direction)

    - Sag-tension performance (strength to weight ratios) – give examples in reference info
    - Thermal limits
        - normally 100 C

      - annealing of aluminum (loss of life) (graph)
      - load sharing of steel and aluminum at high temperatures
      - thermal time constant
  - Conductor motion
      - aeolian vibration – causes, characteristics, effects and control, AESO Rules requirements
      - galloping – causes of galloping, characteristics, effects and control

- Conductor basics – AESO Rules
- Conductor type
- Optimization study requirements
- Tension limits
- Aeolian vibration control
- Overhead shield wire
- Thermal rating methodology
- Galloping

- Day 1 - General discussion, Q&A

<u>Day 2</u>

- Insulators
    - Different types - porcelain, synthetic (EPDM, silicone rubber, matrix)
    - Requirements from AESO Rules
    - Show pictures and design characteristics (reference info)
    - Application of silicone rubber and performance (examples)
    - Manufacturers
    - Performance problems (corona cutting, torsional failure, brittle fracture, cement growth)
    - Ratings – electrical and mechanical – reference to CSA for polymer and porcelain (reference material)
    - Insulation levels from AESO Rules
    - Criteria for loading and strength of insulators (AESO Rules and other sources)

- Hardware
    - Conductor hardware – effect of splices on conductor strength (90%)
    - Types of hardware – compression, implosives
    - Spacers and spacer dampers, conductor clamps
    - AESO Rules requirements
    - Line hardware – guy hardware, anchors, bolts
    - Problem areas – problems with galvanizing, cold temperature impact problems, aluminum castings (yoke plates)
    - Loading and strength of hardware
    - Hardware requirements from AESO Rules

- Electrical Clearances
  - Basics
      - 60 Hz
      - Switching surge

        - CSA C22.3 No. 1 – including derivation of clearances
        - Voltage values as per AESO Rules
    - AEUC requirements
        - Clearances to ground (AESO Rules modifications)
        - Tree trimming
    - Clearance margins, or buffers
    - Ground clearance – AESO Rules
    - Clearance to underbuild
        - TAU criteria
        - Reasons for this requirement
        - Vertical circuit to circuit clearances (CSA)
    - Clearances under differential loading
        - AESO Rules requirements
    - Wind swing
        - Clearances to structures (various values and discussion, AESO Rules requirements)
        - ROW width – AESO Rules requirements and others
        - Insulator swing (equations)

- Other electrical considerations
    - RI – CSA limits mandated by Federal Govt
    - Induction (electrostatic and electromagnetic),
        - effects on pipelines, fences, etc.
        - mitigation
    - Use of bundled conductor

- Line design
    - Key aspects of the process (O-H list)
    - Considerations of structure type e.g. poles vs H-frame vs. lattice towers (Self Supporting and guyed)
        - Single poles on road allowance – steel poles allow longer spans & double circuit, loading on tangent and guyed structures.(moment vs column loading)
        - H frame – longer span but requires ROW
        - Steel towers – still longer spans
            - performance of single vs double cct
            - guyed vs self supporting
            - AESO tower families
        - Slide show – various structure types
    - Soils and foundations
        - Soil properties
        - Foundations – loads from various structure types, foundation types for wood poles, H-frames and lattice towers
        - Foundation alternatives for poor soils
        - guy anchors
    - Conductor ampacity determination
        - Effect of ambient temperature and wind
        - Summer and winter (Alberta definitions)
        - CSA definition of rated ampacity
        - AESO Rules criteria for thermal ratings
        - Economics (net present value of capital cost and losses)
        - AESO Rules requirements for conductor and line optimization studies

- Conductor choice
  - Conventional ACSR – good track record, easy to get
  - SDC – allows longer spans or shorter structures, problems in rough terrain or where there are a lot of angles, stringing and maintenance problems.
  - AESO Rules requirements for conductor types
- Overhead shield wires
  - Purpose, AESO Rules requirements
- Provisions for maintenance
  - Requirements of AESO Rules
- Loadings and overload factors
  - Brief overview of concepts
- Manual and automated line layout
  - Use of templates – hot curve and uplift curve
  - Automated programs – design for least cost
- Reliability considerations
  - Uncertainty of loading and strength
  - Can adjust relative reliability by adjusting return period

- Line uprating
  - Definition of line uprating
  - Increase capacity with existing conductor
    - Problems with operation at higher temperatures (clearances, etc)
    - Maximum temperature for ACSR
    - Dynamic line rating
      - CAT system (tension monitoring)
      - Use of weather stations for ambient temperature and wind speed
      - Risks associated with wind corrections
  - Reconductoring
    - Single conductor or bundle
    - Use of non-standard conductors (example of ACSS)
    - Check of structure capacity (wood and steel)
    - Angle and deadend structures may have to be replaced
    - Methods of increasing capacity of foundations for various structure types
  - Increasing the voltage
    - Need to check ground clearances
    - Check for suitable RI performance
    - Structure capacity
  - Examples from O-H (including live line tower raising)

- General discussion, Q&A

Reference Material: (will be listed at a later time)