Southern Alberta Section
IAS-PES Chapter

Introduction to Transmission Line Design Workshop

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

Attendees should bring a scientific calculator for the design exercises. Printed course notes and a PDF version of the same on a Memory Stick will be provided.

A detailed outline of the workshop can be found below.

Location: The Carriage House Inn

9030 Macleod Trail South
Calgary, Alberta, Canada

Date: Tue., May 1 to Wed., May 2, 2018

Time: 8:00AM to 5:00PM — All times are: Canada/Mountain

Lunch is included. Please indicate any food allergies or dietary restrictions when registering.

Register at: https://events.vtools.ieee.org/m/170713

Speaker: Carl Orde, P.Eng.

Carl Orde

Mr. Orde is past chairman and associate member of Canadian Standards Association (CSA) Overhead Lines Committee (Standard C22.3 No. 1). He is a Professional Engineer with over 45 years' experience in overhead line design.

Please contact Rod McNeil [rjmcneil@telus.net] 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. 1-15, 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 (PLS-CADD, 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

Day 2

- 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)
        - Clearances to buildings
    - 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

<u>Reference Material: (will be listed at a later time)</u>