Metallurgy Training – Transmission Lines

Module Objective

To provide specialist knowledge to early career engineers within the Utility networks focusing on the properties of the possible conductor fleet from concept to end of life. The course utilises the technical knowledge contained in CIGRE Technical Brochures, session papers and the broader community.

Course participants will develop their knowledge of the properties and applications of the various conductors available. Topics covered over the ten-week course (3 hours per week online Team meeting, and 1 hour per week private review/ reading/ assignment preparation):

- Conductors and strength members available
- Conductor physical properties – breaking load, creep, thermal expansion, fatigue
- Line losses and Dynamic Line Rating: sun, wind and rain
- Corrosion and other degradation over time
- Asset management and design considerations; Life cycle analysis
- Vibration, ice, and bushfires: how conductors behave

The development of individual technical libraries and engineering community networking are also integral to the course. The course participants are drawn from a range of Utilities, consultancies and suppliers.

Course Outline – Metallurgy 101

Week	Module	Presentation/ Reading/ Questions to consider/ Teleconference/ Assignments/ Quizzes	Allocated time (min)
1	Introduction	Roundtable introductions Course Aims Course Structure Readings Assignments Industry Overview Preparation for next week	11x5min 15 15 15 15 *55* 10

Course Coordinator notes: Assignments include discussions with mentors and colleagues (via phone and discussion board). Presentations are provided in recorded Teams meeting format and summary pages are available via the Drop Box account to assist with note taking.

Reading material is a mixture of trade magazines and technical journal articles – some may be read in depth while others skim read. All are quite recent publications and will form a sound basis for a student's library (occasionally an older paper is presented highlighting the original theory and or how things have not change too much). Teleconferences will focus on the presentations, readings and assignments as well as being a forum for discussion of course difficulties.

The initial teleconferences will need to focus on how to use the internet and teleconferencing facilities as well as addressing issues associated with getting back to study and distance education.

Reading

Australian/ New Zealand Standard AS/NZS 7000: Overhead line design detailed procedures.

Utility annual reports: TransGrid, Electra Net, AusNet, Powerlink, Transpower NZ, Powerlink etc.

Paper: Overhead conductors in Australia: 1986

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2	Metallurgy – Transmission	Review of previous week Metallurgy 101 – Conductors and strength members Aluminium – purity and alloys • 1350, 1120, 6201, Al-Zr • Cold work, heat treated, annealed. Steels • Galvanized, Aluminium clad, Galfin… Composite cores, epoxy, carbon, MMC Australian/ New Zealand Standards Conductor construction Supplier catalogues Assignment – "Conductor fleet"	15 30 30 30 15 15 15 15 15

Course Coordinator notes: The range of conductors available to transmission engineers has developed with the availability of metals and materials – from copper to steel reinforced aluminium, all aluminium alloys and with composite core strength members. The assignment this week is to review the conductor fleet currently in use and how it has developed over the years with different Utilities.

Reading

CIGRE TB 818: Transmission line structures with fibre reinforced (FRP) composite.

Australian/ New Zealand Standard: ASNZS 1531: Conductors – bare overhead – aluminium and aluminium alloy

Australian/ New Zealand Standard: AS/NZS 1222 (1,2): SC GZ, SC AC conductors

Australian/ New Zealand Standard: AS 2848: Aluminium and aluminium alloys – compositions and designations – part 1 wrought products

Australian/ New Zealand Standard AS 3607: ACSR conductors

Australian/ New Zealand Standards AS3822: Test methods for bare conductors

ASTM B 803: Misch metal

ASTM B 941: Heat resistant Al-Zr alloy wire for electrical purposes.

Catalogues: Olex, Prysmian, Midal, ZTT…

Fittings catalogues: PLP, Sicame, Dulmison/ Maclean…

Code words for overhead aluminium electrical conductors: Aluminum Association (not AAAC 1120)

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3	Metallurgy – Properties	Review of conductor fleet Australian/ New Zealand Standards - testing • Breaking, stress strain • Creep • Thermal Expansion • Fatigue and Other Typical conductors – old and new (team discussions) • kN v resistivity • ACSR v AAAC v ACCC Assignment – spans for ACSR and AAAC1120 Preparation for next week – line losses	15 15 15 15 15 15 15 15 15 15 30 15

Course Coordinator notes: Balancing safety, reliability, environmental footprint, and affordability. Looking at minimum specifications and actual production numbers: in built safety factor or variations? The balancing of properties is highlighted with the assignment to compare an ACSR and AAAC and considering the quantity of steel and foundations required.

Reading

CIGRE TB 695: Experience with the mechanical performance of non-conventional conductors

CIGRE TB 643: Guide to operation of conventional conductor systems above 100C

CIGRE paper 22-204 1990: Mechanical fatigue of components of overhead lines with special attention to composite insulators

CIGRE paper 22-102: Predicting galloping fatigue cycles in quad bundles.

CIGRE paper 22-14 1976: The possibilities and advantages offered by A-GS/L aluminium alloy in the construction of overhead lines (6201 history)

Creep papers: Harvey and Larson, Barber and Callaghan, Lee

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4	Line ratings – Dynamic Line Rating	Review previous week Line length and connections – who pays for losses Dynamic Line Rating Weather – wind speed and "rating window" Assignment – Solar radiation (Mildura v Melbourne) Review to date and preparation for next week	15 15 90 30 15 15

Course Coordinator notes: What aspects of a conductor remain constant over time and how is the performance impacted by the things that vary? Dynamic lien rating focuses on the tension of the conductor in the presentation, a combination of monitoring the temperature and tension is ideal. The variability of wind speed and the importance at low wind speed is highlighted. The assignment focuses on quality weather data and the observed variability.

Reading

CIGRE TB 645: Meteorological data for assessing climatic loads on overhead lines.

CIGRE paper C2-143 2020: Use of dynamic line rating system in system operation and planning

CIGRE paper B2-224 2020: Case of dynamic line rating (DLR) for overhead transmission in context of tropical countries like India

CIGRE paper B2-105 2018: Quantifying the risk in dynamic thermal line rating.

CIGRE paper B2-105 2016: Operational aspects of dynamic line rating. Application to a real case grid integration of wind farms

CIGRE paper C2-112 2014: Thermo-mechanical dynamic rating of OHTL: applications to Italian lines

CIGRE paper C2-103 2014: Operational experience with dynamic line rating forecast-based solutions to increase usable network transfer capacity.

Solar files Mildura and Melbourne airports

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5	Metallurgy – Corrosion	Review of previous week Simplistic corrosion Case studies (conductors) • Surface – emissivity/ adsorption • Internal – strength degradation • Conductivity degradation Australian New Zealand Standards – AS7000 corrosion zones Ice, desert Grease – to grease or not to grease. Individual case studies – discussion and initial preparation	15 30 3 x 20 15 15 30 15

Course Coordinator notes: Corrosion concepts covered and examples of samples from the field presented. The lack of information and examples is lamentable, and participants should be encouraged to make their own observations and dig into their Utilities experience. The importance of moisture with respect to corrosion cannot be underestimated. The debate over grease excluding moisture or capturing moisture and dust is to be had.

Reading

CIGRE TB 838: Coatings for protecting overhead power networks against icing, corona noise, corrosion and reducing their visual impact.

CIGRE TB 837: Coating for improvement of electrical performance of outdoor insulators under pollution conditions

CIGRE TB631: Coatings for protecting overhead power network equipment in winter conditions.

CIGRE paper B2-213 2012: Corrosion characteristics based on an investigation of sampled OHTL conductors and a probabilistic lifetime estimation method.

Sample reports (mjl): Tasmania, NSW, New Zealand

CIGRE paper B2-309 2010: Assessment of OHL availability and residual lifetime by using on destructive instrumental control for conductors, steel wires and guys.

CIGRE paper B2-306 2010: the life extension policy of overhead lines

CIGRE paper B2-212 2008: Extending the service life of aged overhead line towers.

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6	Emergencies, Asset management and Projects	Review of previous week Critical spares – conductor, fittings, emergency structures Catering for old and new – wear and tear (example) Design methodology for new lines v reconductoring Group discussion – Lindsay structures v wood pole emergency Quality control of conductors in storage Published tenders/ recent projects. Preparation for next week	15 15 15 45 15 30 30 15

Course Coordinator notes: Reflect back on record keeping and how design standards have changed…weather conditions altered, line ratings also. Focus on data collection and test reports – suppliers, academia, CIGRE and individual Utilities.

Reading

CUGRE TB 865: Inspection and testing tools, equipment and training for live line work on overhead lines

CIGRE TB 767: Vegetation fire characteristics and the potential impacts on overhead line performance

CIGRE TB731: The use of robotics in assessment and maintenance of overhead liens

CIGRE TB 708: Guide on repair of conductors and conductor fitting systems

CIGRE TB 561: Live work a management perspective

Paper: practical approaches and experiences in the installation of overhead conductors

IEEE Standard 524 (1980): Guide to the installation of overhead transmission line conductors

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7	Life Cycle Cost	Review of previous week Line losses – life rating/ loading profile Carbon footprint • Materials of construction • Access construction • Ongoing maintenance • Design life • Recycle end of life Asset life – mine site, wind farm, transmission backbone… Bushfires – covered conductors Micro grids and other structural changes Building up your library – CIGRE Technical Brochures, textbooks…	15 15 30 30 45 15 30

Course Coordinator notes: Carbon footprint of materials and the ongoing line losses impact. Total life cycle cost to be examined for different materials and the implications of using different conductors.

Reading

CIGRE TB 748: Environmental issues of high voltage transmission lines in urban and rural areas

CIGRE paper 22-302 1992: Investigation on the ageing of old ACSR cables in transmission lines: microstructural evolution and loss of strength

World GHG emission flow chart

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8	Guest Vibration	Review of previous week Vibration – aeolian and galloping Theory and practice Preparation and discussion of current problem to present.	15 150 15

Course Coordinator notes: Utilising guest lecturer Jack Roughan.

Reading

CIGRE TB 828: Vibration modelling of high temperature low sag conductors and self-damping characterization

CIGRE paper 22-08 1974: Vibration in multiple conductor bundles

CIGRE paper B2-118 2020: Limits of vibration amplitude measurement-based conductor fatigue design

CIGRE paper B2-212 2018: Estimation of tensile force in conductor by vibration and strain measurement in pillar's legs of transmission line

CIGRE paper B2-3-3 2010: Impact of turbulence on vortex induced vibrations and fatigue of conductors: modelling and real span experimentation.

CIGRE paper B2-214 2008: Aeolian vibrations on high voltage lines comparative self-damping as evaluated on the field.

CIGRE paper 22-202: Two years vibration measurements and their evaluation for an optical ground wire (OPGW) installed on a 400kV transmission line.

White Paper: PLP Vibration

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9	Line Design & Review	Review of previous week Line design process Cyclonic conditions example: Cx values • Compact designs Evaluating new materials – NZ example Library update Preparation for presentations	15 30 30 30 45 15 15

Course Coordinator notes: Reflection on weather conditions, corrosion, grease, line losses. Example of design process in South Africa. Wind load safety factor and the lack of laboratory data, how should this be included in standards and approved?

Reading

CIGRE TB 809: Dynamic loading effects on overhead lines – impact of structures

CIGRE TB 788: Dynamic loading effects on overhead liens – impact of foundations

CIGRE TB 763: Conductors for the uprating of existing overhead lines, physical modification, reconductoring with conventional and high temperature conductors

CIGRE TB 638: Guide to overall line design

CIGRE paper B2-10976 2022: Development of aluminium tower for 420kV AC line to reduce environmental impact and safety risks under construction.

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10	Presentations	Individual presentations Review Questionnaire	10 x 20min 20 20

Course Coordinator notes: Summary slide reflecting how the individual presentations link to the conductor theory presented in the previous 9 weeks.