SPECIAL REPORT FOR SC B2
(Overhead Lines)

Bertie JACOBS
(South Africa)

Kjell HALSAN
(Norway)

Cécile ROZÉ for B2
(France)
Warren Funston for C3
(South Africa)

Special Reporters

Introduction

Study Committee B2 covers the design, construction and operation of overhead lines. This includes the mechanical and electrical design and experimental validation of new line components (conductors, ground wires, insulators, accessories, structures and their foundations), the study of in-service line performance and assessment of aged line components, line maintenance, the refurbishment and life extension as well as upgrading and uprating of existing overhead lines.

SC B2 comprises members from 24 countries plus observers from 17 countries. Seven Advisory Groups help to coordinate 21 working groups and two joint working groups with 385 members from 43 countries.

SC B2 has selected three preferential subjects for the CIGRE Session 2018. PS3 is a joint PS with SC C3.

PS 1: Overhead Lines and Information Technology

- Recent developments in Geographic Information Systems for line routing, environment mapping, data collection and analysis
- Transmission Lines as a communication network: monitoring and operation, Internet of things, Fiber optics and antennas
- Dynamic line rating and forecasting

PS 2: Experiences leading to Improvements of Overhead Lines

- Failures – excessive climatic conditions, line and hardware defects, component ageing
- Reliability – condition assessment and monitoring, residual life criterion, life extension methods
- Availability – corridor encroachments; maintenance access limitations; solutions for inspection, repair and construction

Joint PS 3 B2 with C3: Technical and environmental aspects of OHL

- Advantages and challenges of reducing environmental impacts
- Public acceptance (including psychological elements)
- Innovative design
- Multi-material structures
- Compact lines
- Mitigation and design for external impacts

bertie.jacobs@eskom.co.za; kjell.halsan@statnett.no; cecile.roze@rte-france.com

PS 1: Overhead Lines and Information Technology
Special Reporter Bertie Jacobs (South Africa)

Due to the high capital costs and the difficulty in acquiring new rights of way (servitudes) for transmission lines, utilities across the globe are exploring new and innovative ways to optimize their existing transmission systems. They are investigating methods of measuring prevailing weather conditions to improve line performance while some utilities are introducing novel ways of using current technology to monitor the physical integrity of their infrastructure.

Seven papers have been selected as contributions towards preferential subject one. Paper 108 has been cancelled. The selected papers have been divided into the following two groups:

- PS1/1 Dynamic Line Rating: forecasting and operational experiences
- PS1/2 Innovations to improve line performance and safety

PS1/1 Dynamic Line Rating: forecasting and operational experiences

Paper **B2-102** describes a Forecasted Dynamic Line Rating (FDLR) that has the ability to provide reliability-based transmission capacity forecasts 24 or 48 hours in the future to optimise economic dispatch as well as increasing grid flexibility for dynamic response power transfers.

Paper **B2-104** covers the results and use of historic line operational experiences in order to analyse potential dynamic rating optimisation. Two lines in particular, one in flat terrain and the other in mountainous terrain were analysed, compared in detail and results presented.

Paper **B2-105** explains the use of a fuzzy-based model and methods to address uncertainties in Dynamic Thermal Line Rating (DTLR) estimation. Specific focus was put on weather data uncertainties and this was addressed by assigning a range of values for the ampacity of the line at various desired levels of confidence.

Question 1.1: What are the main advantages and cost implications of using direct measurements like conductor temperature, sag etc. instead of indirect measurements like ambient temperature, wind speed etc. for line rating calculations?

Question 1.2: Experts are welcome to share their experiences, latest developments and/or challenges in the area of forecasted dynamic line ratings. Have new technologies such as continuous GPS receivers positioned on the conductor, low cost LiDAR sensors, Raspberry_Pi and other open source platforms been used? If so, please share the details of how these technologies have been used.

Question 1.3: The authors can comment on the impact that weather measurement location has on dynamic line rating predictions.

PS1/2 Innovations to improve line performance and safety

Paper **B2-101** describes a method of using an optical phase conductor (OPPC) to determine the integrity and failure along the length of an overhead line phase conductor. In places where public safety is at stake due to conductor failure, the system is integrated with the substation protection system to for example not activate the automatic reclose system in event of such conductor failure.

Question 1.4: Experts are invited to comment on the use of the fibre in the OPPC conductor to measure other parameters, such as conductor temperature.

Paper **B2-103** discusses the investigation of a particular long span (4.6 km) fjord crossing in Norway to determine whether the frequency of weak winds, below 0.6 m/s, is higher than for an average span in normal terrain. This was required as the single conductor long span could create a bottleneck in terms of capacity of the line and to ensure marine traffic under the crossing is not affected from a clearance point of view.

Question 1.5: Results are shown for simulated wind speed and frequencies predicted along the span, but how does that compare with actual wind conditions?

Paper **B2-106** describes the study on a double circuit line and a new approach for dimensioning electrical clearances for 380 kV overhead lines on the principle that fast front overvoltage surges, typical from lighting strikes, differ significantly from standard weather conditions.

Question 1.6: Will this new approach be considered to become the standard practice in the future?

Paper **B2-107** explains how maintenance optimisation tools are used to increase the efficiency and effectiveness of vegetation felling and pruning maintenance plans and operations by a Spanish Distribution System Operator (DSO). These tools included GIS, detailed vegetation maps, LiDAR scanning, dedicated software programs etc.

PS 2: Experiences leading to Improvements of OHL
Special Reporter Kjell Halsan (Norway)

New and advanced technologies are rapidly developing and used more often in the OHL business. Software tools and new products make it possible to optimize the design of new OHL and improve reliability of existing ones. In addition, a number of new inspection methods is now available for evaluating OHL condition and maintenance planning. Mentioned technologies and methods will lead to increased reliability and extended lifetime of OHL.

Eleven papers have been selected for PS2. Papers 202 and 205 have been cancelled. The contributions are divided into three main groups:

- PS2/1 Studies and research to define electrical and mechanical parameters for OHL design
- PS2/2 New methods and tools for design and inspection of overhead lines
- PS2/3 Methods for increasing reliability of overhead lines

PS2/1 Studies and research to define electrical and mechanical parameters for OHL design

Paper **B2-201** describes test results performed by EPRI, to confirm minimum vegetation clearance distance standards. The report describes the switching impulse tests that were performed on the representative tree shapes, and includes a description of the test set-ups, the procedure used and test results.

Paper **B2-203** describes modeling and verification of flowing air discharge in transmission lines in windy conditions. The paper present models to extend Townend's discharge model from static gases to flowing gases, which can be applied to a wider range of gas discharge situations.

Paper **B2-204** gives a comparative study of long-term reliability of HTLS conductor systems. The paper describes the approach and the results of an international research project assessing the long-term reliability of a wide range of commercial available high temperature conductor systems.

Question 2.1: What is the practice in other countries regarding specifying electrical clearances to trees, and is there a tendency to construct transmission lines in a way that would reduce tree cutting? What is the experience from other countries regarding extreme wind influence on minimum electrical clearances?

Question 2.2: Have utilities experienced any types of problems with adapting compression type fittings for use with HTLS conductors?

PS2/2 New methods and tools for design and inspection of overhead lines

Paper **B2-209** describes the problem with overheating of ground wire clamps of transmission lines in Czech Republic. The paper deals with possible root cause analysis of the overheating phenomena, use of a mathematical model for induced currents and a suggestion for solution of the problem.

Paper **B2-210** describes how the optimum maintenance frequency was determined for corroded towers along the Peruvian coastline. With use of a new software it was possible to estimate optimum tower maintenance frequency according to the corrosion level in the area where the structures are placed.

Paper **B2-211** describes inspection method developed in Russia to check the underground part of guyed towers for corrosion. Developed method is based on measuring corrosion currents by means of specially developed precision instruments. Report describes the application experience for both the developed method and conventional methods used.

Paper **B2-212** presents a method for estimating conductor tension by vibration and strain measurement in tower legs of transmission lines. With use of this indirect measuring method it is possible to record changes in conductor tension.

Paper **B2-213** presents methods used to optimize the design of high towers used for Scheldt river crossing in Belgium. To study the loads on the tower, techniques like 3D printing, wind tunnel testing and CFD modelling were used.

Question 2.3: Experts are invited to share their experience in use of new software tools, models and new technologies for optimized transmission line design, monitoring and maintenance.

Question 2.4: What is the experience with coatings or alternative materials that could reduce corrosion, and what methods are available for corrosion assessment? Experts are invited to present methods available to measure and predict pollution levels.

PS2/3 Methods for increasing reliability of existing lines

Paper **B2-206** presents the improvement of the performance of the overhead lines in Chile with the use of new technology. The paper describes a variety of challenges while operating and maintaining overhead lines. An Asset Management model was developed and implemented in order to improve the condition assessment of overhead line components.

Paper **B2-207** gives the RTE approach for mechanical reinforcement of OHL. The paper present the mechanical reinforcement program of overhead lines for a targeted and progressive implementation of works and the costs and benefit of the program.

Paper **B2-208** present recent disaster experience and countermeasures technology for overhead transmission lines in Japan. The paper introduces the damage situations caused by earthquake, conductor galloping and lightning, and countermeasures to improve the reliability in the future.

Question 2.5: Forecast for climatic change predict increased frequency of extreme weather events. Is there a need to revise the maximum design climatic loads and what mitigating measures can be implemented on existing transmission lines?

Question 2.6: What is the experience among utilities with innovative inspection methods of transmission line components, like for example use of drones?

Joint PS3 B2&C3 Technical and Environmental Aspects of Overhead Lines
Special Reporter for B2: Cécile Rozé (France) and for C3: Warren Funston (South Africa)

The scope of the Study Committee C3 covers the identification, assessment and management of the interactions between the natural and social environments, and the end-to-end electric power system, recognising the importance and influence of a wide range of stakeholders and communities. (Scope of SC B2 see at the introduction page 1)

Environmental management cannot be dealt with only by Environmental Managers. Study Committee C3 and B2 have initiated opportunity to work together since OHL management has a role to play in the protection of the world's different habitats, biodiversity and natural environment as well as regarding Life Cycle Assessment (LCA). The 2018 Paris session will see the joint hosting of preferential subject PS3 between the two Study Committees B2 and C3 to further explore areas of synergy and collaboration.

Environmental issues regarding OHL are more and more known, evaluated, sensitive and taken into account. Such aspects are: visual impact and social acceptance (tower, painting, procedures…), EMF, noise, insulation coordination, specific designs of towers, conductor configurations, and also development of methods, tools to assess impacts (Life Cycle Assessment, specific studies, etc.) and to simulate, test in laboratory or in the field. All efforts of innovation are addressed to get better knowledge (modelisation, simulation, sensors device or system) in order to reduce and limit impacts.

This preferential subject has a large number of papers 17 (12 for B2 and 5 for C3). Paper C3-304 has been withdrawn. There is a degree of overlap between papers and thus, in the Annex, we present a table (non-exhaustive list concerning subject matter found in the papers) where a reader can easily see which subjects are covered in the paper together with the summary of the paper.

The papers have been divided up as follows:

- PS3/1 Vegetation and right-of-way ROW
- PS3/2 Public acceptance and Tower design
- PS3/3 EMF, corona noise and insulation coordination
- PS3/4 Life Cycle Assessment (LCA)

CIGRE Global Junior Program

In support of CIGRE's Global Junior Program, the Joint B2-C3 session will include a 2-5 minute presentation by a young CIGRE candidate. The presentation will introduce a safety training program using virtual reality.

PS3/1 Vegetation and right-of-way (ROW)

Paper **C3-306** introduces an algorithmic model to assist a utility to plan optimally and prioritize where vegetation maintenance should be completed on their servitude networks. The model uses information pertaining to vegetation species, possible operational threats to the line, and costs to accurately identify the priority areas on the networks required to be cleared in the short, medium and long term.

Paper **B2-311:** the aim is to provide better conductor aerodynamic response understanding under high turbulent wind so as to improve ROW. Computational modelling with methodology explained is used on 3 ACSR round wires shaped and concludes on a reduction of ROW depending on conditions and hypothesis.

Question 3.1: How would it be possible to reduce the ROW without modifying the support? What is the comparison between field measurements and modelling techniques?

Question 3.2: When designing a line, are costs around environmental maintenance considered? What examples are there (preservation of natural habitats, social issues) where the OHL leads to environmental benefits? How have maintenance techniques been adapted for the benefit of the environment?

PS3/2 Public Acceptance and Tower Design

Paper **C3-301** describes a public survey that was conducted in Japan to evaluate whether there were any quantifiable differences in visual impact of towers dependent on what color they were painted. Towers were painted in 3 different colors (see hue, saturation and brightness) and evaluated by way of surveys across two different climatic seasons, whether there were differences in visual impact. The study concludes that there are significant differences and explainations why towers painted in different colors have different effects on visual impact.

Paper **C3-305** describes an independent post project assessment of the public participation process completed for an expansion of Belgium's network. The paper highlight the key learning points identified by a Non-Governmental Organization (NGO) conducted survey and provides recommendations on how to complete a successful public participation process.

Paper **B2-304** describes a project in Belgium where an existing 70kV lattice line is replaced with a double circuit 110kV concrete pole line. The paper compares the construction and maintenance aspects of the two towers.

Paper **B2-305** describes how in Italy, they have designed and built lattice towers and fittings for anti-torsional crossarms with the same dimensions of a steel monopole. Design affords adding steel plates on the tower for visual considerations.

Paper **B2-308** describes the design of a tower using only composite material to replace a lattice tower considering lightning performance, clearances, EMF, corona, electrical and mechanical tests. The tower design is tested and/or simulated against an array of technical criteria.

Paper **B2-312** describes how towers and foundations can be adapted, designed to be assembled by helicopter in order to reduce duration of works and tracks – this takes away the need for cranes and heavy concrete equipment which may cause environmental damage. Towers are cut into light-weight sections with guiding components whereas concrete in foundations is reduced to a minimum by reduced dimensions of metal lattice with stack, decking and berms.

Question 3.3: Experts are invited to submit their experiences relating to how the design of towers, (new tower designs, bird collision, bird electrocution, fittings, insulation, fiber optical components) can be maximized for environmental benefits. What are the consequences concerning new fittings (tests to ensure performance and ageing)?

Question 3.4: What are the best balances for environmental impacts? During maintenance, is there a difference in environmental impacts (displacements) depending on whether vehicles or helicopters are used - (what is the threshold?) What is the most relevant balance between concrete, lattice and composite towers? What are the consequences of new design on maintenance and updating data bases?

Question 3.5: Experts are requested to share experiences of how to deal with situations where the OHL is required to be visible for a certain reason? OHLs near airfields are painted red and white – are there other techniques that have been employed to make OHLs more visible, and for what reason? How does the painting of the towers effect the detection of ageing, wear and tear and corrosion? Does the painting of the tower lead to increased environmental impact through increased maintenance if repainting is required?

Question 3.6: Experts are invited to share what techniques have been used to elicit comment from the public, government authorities and interest groups on how they view the performance of a TSO or DSO? Have different techniques been designed to accommodate demographic bias or cultural sensitivity? How do we promote acceptance of OHL?

PS3/3 EMF, corona noise and insulation coordination

Paper **B2-301** presents studies and realisation in 2015 of uprating 69 kV to 138 kV existing line with reduced phase to phase distance: additional wire to reduce fault current to the ground, studies and tests on corona, audible noise, radio interference, EMF, air gap strength for lightning impulse and switching surge, surge impedance and grounding impedance, lightning surge performances, adaptation of concrete poles, replacement of insulators. The study concludes on feasibility for very short lines (around 4 km).

Paper **B2-203** describes the development of an optical microphone based on interferometry and laser to measure audible noise on a conductor. A specific suspension has been developed to position the device directly below the conductor. Laboratory tests have been done around audible noise with 2 different type of conductors.

Paper **B2-306** is a broad description of the efforts of the TSO of implementing passive loops (additional wires + compensating capacitances) as a solution for EMC compliances. It proposes an approach of design of the passive loop, alongside with an example of implementation and test over a real transmission line. The article goes beyond, and briefly explain a set of numerical simulations to evaluate the impact of the installation of the passive loops in the Back Flashover Rate and the distance protection functioning. The work can be easily divided into two detailed articles, one concerning the field tests, and other the evaluation of the impact of the passive loop on the transmission line performance through numerical simulations.

Paper **B2-307** presents numerical modelling of electric and magnetic fields generated by OHL as well as busbars in substations. A simple methodology based on analytical formulae and assumptions is adapted to case studies to provide fast numerical modelling. A particular software has been developed for substations communicating with AutoCAD to get the data input.

Paper **B2-309** highlights a corona testing cage used to decipher the difference in characteristics (frequency) between corona noise and background environmental noise. HVDC studies and tests on HVDC OHL are explained about positive conductor, negative conductor and bipolar conductor.

Paper **B2-310** is about a procedure implemented in order to validate an innovative HVDC OHL design. Insulation coordination of the line has been evaluated with simulations and measurements. A test platform of several OHL was constructed and detail is provided for the measurements and simulations of noise, and electromagnetic fields with interesting comparison between prediction and measure.

Paper **C3-303** conducts a trial which shows that GIC currents absorbed by the Transmission system in mountainous country can be simulated with a simple method. Currents are simulated and then compared to measurements with a good correlation. Underground train systems close to the grid are also considered.

Question 3.7: Noise, How does one extrapolate noise studies and results to other conductors (change in diameter, wires shapes, materials)? Can increase in noise levels be expected linked to the different regulations. How can the needs of the landowner be accommodated? How is the Feedback and field measurements on HVDC installation?

Question 3.8: EMF, Can passive loops be implemented on existing OHL? Besides, for EMF, what are the other environmental impacts of passive loops? Feedback and field measurements on HVDC installation?

Question 3.9: Insulation coordination, What about a model of soil (resistivity) and its use for OHL considerations? How to use models to aid the design of works and electric components?

Question 3.10: Other environmental considerations, How to consider impacts on birds when designing a new solution (towers, electrocutions and collisions)? How to identify OHL problems linked with GIC and deal with them (design)?

PS3/4 Life Cycle Assessment (LCA)

Paper **C3-302** is the only paper in the joint preferential subject dealing directly with LCA and although it is not dealing with OHLs, the principles for LCA evaluation are relevant. It sets out a Lifecycle Analysis comparison for a 145kV substation using SF6 gas and non SF6 gas. The paper evaluates the difference in environmental impact of SF6 gas technology and none SF6 technology across the life cycle of plant from production, use and final disposal.

Question 3.11: How should LCA studies for OHL be promoted? What about LCA for composite towers? For comparable components, are we sure that companies will use comparable methodologies that will come to the same conclusions for OHL?

==========

Information about
SC B2 Group Discussion Meeting (Session), Preview Meeting, Poster Session, B2 Tutorial

B2 Group Discussion Meeting and Preview Meeting

The B2 Group Discussion Meeting (former called « B2 Session ») will be held on **Friday August 31st, at the "Grande Amphitheatre" from 08:45h to 18:00h** (PS1 and PS2 in the morning, Joint PS3 B2&C3 in the afternoon).

Authors of session papers and other delegates wishing to present contributions to the questions raised by the Special Reporters in this Special Report are asked to **send their intended contributions in advance preferably not later than Monday, July 23rd** to the respective Special Reporter

for PS1: Bertie Jacobs, bertie.jacobs@eskom.co.za,

for PS2: Kjell Halsan, kjell.halsan@statnett.no

for JPS3 Cécile Rozé, cecile.roze@rte-france.com

and cc to B2 Chairman Herbert Lugschitz Herbert.Lugschitz@apg.at and to B2 Secretary Wolfgang Troppauer Wolfgang.Troppauer@mosdorfer.com

The related documents, i.e. guide, template and sample page, can be found under www.cigre.org in time and have to be strictly observed.

The Special Reporters together with the B2 Chairman and Secretary will **meet with the contributors on Thursday, August 30th,** in order to discuss their proposals and to allocate the period of time for their presentation. The rooms for this meetings with contributors will be one of the rooms 233, 234, 235 and 237 on level 2 mezzanine (the room for B2 will be announced by the CO in time). The timeframe is:

JPS3: Thursday morning 9:30h to 12:00h meeting of Special Reporter (Cécile Rozé) with prepared contributors for JPS 3.

PS1 and PS2: Thursday afternoon 13:30h to 16:00h meeting of Special Reporters (Bertie Jacobs and Kjell Halsan) with prepared contributors for PS1 and PS2

Poster Session

It is expected that authors of B2 Session Papers present their papers at the **B2 Poster Session** which is on **Thursday 30th August 14 :30h – 18 :00h** at Halles Ternes. The presentation will be on A0 video screens (no paper print out necessary!). The presentations shall be sent at least 3 weeks in advance, for a prior check by e-mail to the Poster coordinator of SC B2 Dale Douglass da.douglass@gmail.com .He will review the draft posters. If the author(s) cannot attend the Poster Session the National Committee is requested to send a substitute. Details can be found: http://www.cigre.org/Events/Session/Session-2018

B2 Tutorial

Please note that the **B2 tutorial** "Experience with the mechanical performance of non-conventional conductors" will be held on **Thursday 30th August from 8:30 to 10:20h**.

Annex
to the Special Report of SC B2, regarding joint PS3 B2 & C3

ARTICLES	substations	concrete pole	lattice tower	composite tower	helicopter	foundations	ROW	vegetation	OHL project	insulator	insulation coordination	EMF	corona noise	GIC	HVDC	sensors	monitoring	tests	numerical calculations
B2-301		x							x		x	x						x	x
B2-302												x	x		x				
B2-303										(x)			x			x	x	x	
B2-304		x							x	x									
B2-305			x				x		x	x		x							
B2-306							x				x	x						x	x
B2-307	x (and											x							x
B2-308				x					x		x		x					x	x
B2-309													x		x	x			x
B2-310										x	x		x		x	x	x	x	
B2-311							x	x											x
B2-312			x		x	x												x	x
C3-301			x																
C3-302	x																		
C3-303	x (and												x	x		x		x	x
C3-305									x										
C3-306								x								x			x