CIGRE 2014

# B2 - 00

## SPECIAL REPORT FOR SC B2
## (Overhead Lines)

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**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 has selected three preferential subjects for the CIGRE Session 2014. They are listed below:

**PS 1 – Minimizing the impact of new Overhead Lines**
- Design construction and operation
- Ecology, vegetation and wildlife management
- Routing and visual acceptance
- Design of, and experiences with, transition to underground

**PS 2 – Reliability and design optimization**
- Tools and methods
- Impact of different designs on initial and life cycle costs
- Cost effects of environment, regulatory and public influence

**PS 3 – Conductors: Installation and long term performance**
- Installation, maintenance and replacement methods including live line techniques
- Creep and fatigue issues on new conductor types
- Mechanical behaviour of new bundle configurations

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**Preferential Subject 1: Minimizing the impact of new Overhead Lines**
**Special Reporter Kresimir Bakic (Slovenia), email: kresimir.bakic@eles.si**

Impact of overhead lines (OHL) on environment is nowadays the topic of every new overhead line project. Public opposition against electric power lines is evident almost in the entire world. Thus, because of its high interest and actuality this subject was selected as a topic for discussion.

For the first preferential subject 15 papers have been chosen coming from 18 countries, from five continents, written by 69 authors. The papers have been divided in the following four groups:

1.1. *Design, construction and operation*
1.2. *Ecology, vegetation and wildlife management*
1.3. *Routing and visual acceptance*
1.4. *Experiences with transitions to underground sections.*

### 1.1. Design, construction and operation

Increasing capacity of Right-Of-Ways (ROW) is a great challenge for utilities, designers and innovative equipment manufacturers. How to transmit more power in less space? And what are the consequences of new approaches on other environmental parameters?

Paper **B2-104** highlights various examples of initiatives for application of new technology solutions to minimize the land use and impact of transmission lines. Besides increasing voltage levels, using UHVDC and UHVAC the authors explored the use of multi-circuit schemes and HTLS conductors and concluded that 765 kV double circuit UHVAC and 800 kV HVDC lines are the options with the most suitable ROW utilization rates.

**Question 1.1: Is there any similar analysis of new technology solutions (UHVAC/DC) to minimize land use in other large systems like China, Brazil, and Russia? The authors of paper B2-104 are invited to explain how they consider effects of EMF, audible noise and other environmental parameters in the optimization process and in particular what has been the public reaction after reconductoring the 400 kV lines from quad bundle to twin bundle HTLS due to audible noise?**

Conversion of AC multi-circuit lines to AC-DC hybrid lines is considered in many countries the last years. Paper **B2-105** presents some very interesting results related to the conversion of an existing 38 kV AC double circuit line to a ±400 kV AC-DC hybrid line dealing specifically with the dielectric behaviour and electric field issues.

**Question 1.2: The authors of paper B2-105 are asked to comment:**

a. **Possibility of conversion to DC for a higher pollution situation than in the paper (low-to-average values)?**
b. **What is the effect of power transfer capacity of a hybrid line at different altitudes and what is the influence of the number of sub-conductors?**
c. **What is the public opinion of this kind of transmission projects?**

**All experts are asked to comment on needs for standards for DC overhead lines and hybrid AC-DC lines.**

Paper **B2-106** summarizes briefly the state of the art of line compacting and describes the development steps of a horizontal Vee arrangement for 765 kV. Presenting compact tower of double circuit 765 kV line with insulated cross arms could reduce land use for almost 40%. Development of rod diameters with suitable performances is crucial for this horizontal Vee concept for voltages above 420 kV. Paper **B2-107** is also describing the mechanical design and laboratory testing of insulating cross arms for compacting HV lattice towers. The motivation of this development is to develop compact towers, to provide ground clearance solution for existing lines and to allow increases in voltage on existing lines.

**Qestion1.3: Initial physical and electrical material tests of such large rod diameter have proven the suitability of the material, stated the authors in paper B2-106 and announced soon the results of full scale testing of horizontal Vee configuration and are invited to explain newest results while authors of paper B2-107 are invited to present experiences after one year operation of these composite cross-arms in Scotland. Are there similar experiences in other transmission systems with use of insulating cross arms for compacting HV towers?**

Paper **B2-109 is** dealing with possible solutions to increase transmission capacity with uprating a 220 kV OHL to 400 kV by redesigning the tower head. Paper is focused on evaluation of the merit of two designs (using lattice steel tower design with composite insulator strings or novel design replacing existing tower cross arms with composite cross-arms).

**Question 1.4: What are experiences in other TSO's with upgrading 220 kV to 400 kV lines? Is the new concept of insulating composite cross-arms a promising solution for future uprating 220 kV OHLs? What obstacles can be expected?**

Paper **B2-112** describes a comprehensive research work involving detail measuring of corona and audible noise by investigating the number of conductors in bundle and composite insulator strings for new 400 kV OHL.

**Question1.5: The authors of paper B2-112 are asked to comment what was experience with reducing audible noise using hydrophobic treatment in the newest 400 kV line in Slovenia? What was the result of corona considering trapezoidal wires conductors vs. round wires conductors? What experience exists regarding the surface treatment of conductors to reduce corona in other TSOs? Is there any new innovative approach? How utilities manage to minimize audible noise of OHLs in urban areas?**

Possibility to minimize impact to environment during construction of new OHL was presented in paper **B2-115**. This paper describes an innovative approach with extensive use of helicopter for tower erection and conductor stringing. This approach needs special helicopters and novel tower design.

**Question 1.6: Using helicopters for OHL construction can significantly reduce the environmental impact and time savings. The author of paper B2-115 is invited to explain overall cost effectiveness of this approach in construction works and possible obstacles for use. Other experts are invited to share their experiences with construction of OHLs using helicopters considering to mitigate environ-mental impact.**

Paper **B2-103** describes a method of calculation and results of evaluating the capacitive and inductive induced voltages on a pipeline running parallel to AC OHLs. The induced voltage is evaluated for pipelines in air underneath an OHL (500 kV, 380 kV and 66 kV) as well as in the ground underneath a 220 kV line.

**Question 1.7: What mitigation techniques for control of induced voltages on a pipeline in the same ROW are in use in other utilities? Is there any new approach in avoiding and/or reducing electro-magnetic coupling between OHLs and pipelines? Is it an issue from safety point of view for TSOs, regarding to increasing number of gas pipelines?**

### 1.2. Ecology, vegetation and wildlife management,

Only two papers appertained to this group. One dealt with planning new OHLs in heavy industrial environment and one with wildlife management. Unfortunately, no papers have been submitted on vegetation management in spite of the importance of this topic. Many blackouts in past occurred due to unsuccessful implementation of vegetation management.

**Question 1.8: What is the experience in utilities with implementing new tools of information technology or GIS technology in the vegetation management issue?  Do utilities consider the risks of vegetation growing in ROW and impact of wind and ice storms in the procedure of selecting corridors for new OHLs?**

Paper **B2-102** investigates and presents an added value for the TSOs intending to build a new OHL in a heavy industrial environment and concludes that building of an important overhead line in heavy industrial area (Seveso classified) implies a lot of safety measures, which can have financial impact on the project and even make it unrealistic.

**Question 1.9: Authors of paper B2-102 are asked to explain whether they have compared the OHL project with an Underground Cable one? Is there any general risk assessment approach in the planning procedure for new OHLs in other utilities?**

In paper **B2-113** the authors presented very comprehensive approach how to manage the accommodation of birdlife effects. Using automatic signal processing and data management, they show that cohabitation of birds across all stages in the life of OHL is feasible.

**Question 1.10: What is the experience of other TSOs with ecology ROW management and protection of birds? The authors of paper B2-113 are asked to explain what was the main motivation for the multi-discipline methodology employed? What have been the evaluated costs and benefits from project?**

### 1.3. Routing and visual acceptance

Paper **B2-108** presented the routing and visual acceptance approaches in Japan for OHL. Some methods as preserving scenery by taking advantage of mountain ridges, preserving plants and animals by selecting routes with carefully evaluated habitat assessment and reducing noise through different types of equipment have been described.

Paper **B2-110** describes an improved wind model to verify the stability of Wintrack, a recently developed design of OHL (the first Wintrack OHL has been commissioned and taken in operation one year ago) aiming to reduce magnetic fields and to improve visual acceptance of a new 400 kV line. Using braced post-insulators with vertical hinges, which may become unstable as result of unbalanced loading, the paper presents a wind model for unbalanced wind loads in line with the new European Standard EN 50341 (part 3-Dutch NNA).

Paper **B2-111** presents an innovative solution to increase visual acceptance and minimize the environmental impact of overhead lines. Taking in consideration multi criteria approach and some adapting on locl circumstances a new OHL tower, similar as Wintrack, has been developed.

**Question 1.11: The authors of paper B2-108 are invited to explain the method of minimizing scenic impact. What is the experience of the first year operation of the Wintrack OHL in the Netherlands? The authors of paper B2-111 are asked to explain the new TWINNI model used in the steep slope (mountains) in Austria? All experts are invited to present news in reducing visual impact?**

### 1.4. Design of and experiences with transition to underground cables

Paper **B2-114** dealing with increasing the availability of OHL aided by reducing grounding impedances as the most efficient way to prevent the occurrences of back flashovers, which play an important role of outages of OHLs. The conclusion was to use a specific grounding system (Type A) for transmission towers, regarding their impulse response performances, which enables significant improvements in reduction of the grounding resistance.

Paper **B2-101** describes the impact of transition points to underground cables on the OHL earthing system performance. It emphasizes the high importance of such transition points for the earthing system design and concludes, that when lines are designed in ignorance of these effects the risk level can quickly increase 10 fold!

**Question 1.12: What is the experience of utilities, designers and manufacturers with OHLs with under-ground cable section? What are the experiences with grounding system design in the case of sectional undergrounding? What is the experience with comparison of OHL and underground cables at different voltage levels?**

## Preferential Subject 2: Reliability and design optimization
## Special Reporter: Rob Stephen (South Africa), email: rob.stephen@eskom.co.za

This topic resulted in 10 papers being submitted. The papers were in four main categories:

2.1 *line optimisation*
*2.2 dynamic rating*
*2.3 insulator maintenance*
*2.4 conductor-sag determination.*

Each sub topic will be dealt with in turn.

### 2.1 Line Optimisation

Paper **B2-201** deals with the optimisation of the conductor and tower types for a double circuit 400kV line in India. The crossings are in the region of 1500m to 2300m. Tower heights of around 250m with weights of around 1300 metric tonnes were considered. High strength alloy conductors with high percentage steel core were favoured for the crossing. Due to manufacturing limitations and non-standard designs, the compact conductors were not considered.

Paper **B2-203** describes a research project whereby the 500kV line is designed for a high surge impedance loading as a result of expanded bundles. An inverted delta phase configuration is used with interphase insulators on a cross rope suspension tower. The bundles are asymmetrical and are smaller at the tower than at mid span. The interim results are very promising.

Paper **B2-205** describes use of High Temperature Low Sag Conductors including ACCR and a Russian developed ACCC conductor. The paper describes the benefit of using HTLS conductors for large crossings. A large saving in tower height was realised with the use of the HTLS conductors. It is estimated for the crossing across the Kama reservoir (2000m) that the use of TACSR/ACS conductor (lighter than the conventional ACSR), reduced the height of the tower from 154 to 106m. A saving in construction cost of 17% was realised. The other large crossing projects mentioned indicate a saving of between 15% and 40% with the use of high temperature low sag conductors.

**Question 2.1: Paper B2-201 does not indicate consideration of use of HTLS conductors in the crossing, was this considered?**

**Question 2.2: Have other utilities such experience with HTLS conductors (for crossings), expanded bundles or inverted delta designs?**

### 2.2 Dynamic rating

Paper **B2-207** describes a line in Spain where an optical conductor (OPPC) was used to determine the temperature of the conductor. A series of 6 weather stations along the line were used in conjunction with the temperature to determine the line ratings in real time. An average of 15% increase above the static ratings was achieved. On certain days the rating obtained was 100% above the static rating due to high wind speed. The real time rating system was installed to monitor and optimise the operation of the network to cater for the wind generators in the area.

Paper **B2-208** describes the use of a dynamic line rating system which transforms the conductor temperature to a perpendicular equivalent wind speed based on the current weather conditions. A dynamic rating forecast is then determined. In addition the DLR system is enhanced by integrating the line rating into the SCADA and state estimator systems. This iDLR (integrated DLR) system does not require operator intervention and automatically incorporates the real time ratings into the network analysis. It was found to work very successfully. The paper also indicates the difference in rating between the ambient adjusted, static and dynamic ratings. This indicates that the DLR permits higher line loading compared to the other methods.

**Question 2.3: Paper B2-207 indicates the possibility of using the OPPC conductor for line rating determination. The temperature determination of a conductor is one step in obtaining the line rating. Can the authors elaborate how the sag-temperature relationship was determined for OPPC and then used to determine the rating of conventional conductors?**

**Question 2.4: Are other system operators using the dynamic line rating system either by direct or indirect methods? If so is it integrated as described in paper B2-208? Please describe the advantages or disadvantages of such a system.**

**2.3 Insulator maintenance**

Paper **B2-206** describes the insulator maintenance programme in Spain by Red Electrica. It describes the different inspection and replacement practices for both glass and composite insulators. Composites are used near the coastal areas which has higher pollution. Glass insulators are inspected using live line techniques whereas composite are inspected with the line out of service. Laboratory tests are also carried out on composite insulators. It was also mentioned that silicon coated glass has been used with great success. A comprehensive data base on insulator installations (type, location, expected life) has been established.

Paper **B2-209** describes additional tests required for glass insulators. This is because of the apparent reduction in manufacturing quality that will cause the insulator to fail even though it passed the IEC specifications. RIV, Impulse and mechanical load tests among others are described. A risk factor can be determined from a relatively small sample of around 10 insulators. This makes using the tests relatively low cost and can determine if the batch received is suitable for use or not.

**Question 2.5: What inspection methods are used by other companies with respect to composite insulators? Are they conducted under dead conditions or using live line techniques?**

**Question 2.6: Have other countries experienced quality issues with respect to glass insulator manufacturers? If so have the tests been expanded as described in paper B2-209? Please describe any additional tests or inspection methods used.**

**2.3 Disaster Mitigation**

Paper **B2-204** describes the activities relating to mitigation techniques with regard to icing. These included a correlation study linking sun spots to icing events, an ice detection system that can detect the thickness of the ice on a conductor and composite insulators that have shed designs to prevent bridging. In addition there is a description of a DC current injection system for de-icing on conductors. These techniques have all been used on the Chinese grid with success.

Paper **B2-210** describes the strengthening of foundations to prevent damage to towers in the event of rivers changing their course during high water situations. In both the cases mentioned the lowest cost and most rapid to complete option was the strengthening of the foundations. In the first case study the tower foundations were encased with a cuboid of cavity walls that surrounded the entire tower base. In the second case study the foundations were individually strengthened by four piles per foundation and then capped.

**Question 2.7: Please describe other methods of ice detection and prediction used in other utilities. Is there experience of the insulator described in other parts of the world?**

**Question 2.8: It was found in paper B2-210 that the best option to prevent tower collapse in the case of river flooding is to strengthen the foundations as opposed to strengthening the river bank or rerouting the line. Is this the case in other countries?**

### 2.4 Conductor sag

Paper **B2-202** describes a method whereby the sag on inclined spans can be determined from the sag in level spans for any point in the span. In addition there are methods proposed to increase the accuracy of parabolic estimate on inclined spans by using the angle of inclination as a modifier. Differences between the simple parabola, hyperbolic function and modified parabola is given.

**Question 2.9: What experiences are there relating to the use of these equations in relation to special conductors such as Gapped, ACCC where the catenary constants may not be in the same range as the conventional ACSR conductors?**

## Preferential subject 3: Conductors: Installation and long term performance

**Special Reporter: Pierre Van Dyke (Canada), email: van_dyke.pierre@ireq.ca**

The conductor is considered to be the most important component of an overhead line since its function is to transfer electric power and its contribution towards the total cost of the line is significant. The most widely used conductors are made of layers of aluminium round wires stranded around each other over a core made of aluminium or steel. However, for more than thirty years now, other types of conductors have been designed using trapezoidal or Z-shaped wires and/or using other material to increase their ampacity and/or strength.

Those so-called non-standard conductors address the need of very long spans for river or valley crossings. Moreover, in recent years, the power flow through transmission lines has increased due to the opening of the production market, integration of renewable energy and increasing demand for energy. Many existing lines cannot meet the demand and thus have been upgraded using non-standard conductors having a higher ampacity while having similar diameter and mass per unit length as the initial conductors.

Since it is increasingly difficult to build new overhead transmission lines due to environmental and visual impact, protected areas, and to the reluctance of the population to have new lines in their backyard, it is extremely important to maintain the existing lines in good health to avoid replacing them. Moreover, the cost of replacement of those lines would be prohibitive and there are already many transmission lines that have reached or are beyond their intended useful life. Therefore, their long term performance must be known to make sure that ground clearances will be respected in the long term and that there won’t be fatigue issues due to wind-induced vibrations.

Data is already available mainly for ACSR and also for AAAC, Alumoweld, and steel conductors. Since creep and fatigue data require very long tests and thus are costly, few data is available for non-standard conductors.

A total of six interesting papers cover this preferential subject and are divided n the following sub-topics:

*3.1 Installation, maintenance and replacement methods including live line techniques*
*3.2 Creep and fatigue issues on new conductor types*

*3.3 Mechanical behavior of new bundle configurations*

**3.1 Installation, maintenance and replacement methods including live line techniques**

Paper **B2-304** on video based defect detection of ground wire of transmission lines describes a software developed to detect arc marks, cut wires, bird cage or kinks on ground wires. Their software discards the images where there are no defects and thus the images to be checked by the inspectors are dramatically reduced and they save a lot of time.

**Question 3.1: Can the authors expand on the applicability of this method to conductors and bundles? Do they plan to use only robot cameras since the efficiency is better than with cameras from a helicopter? Does the software miss defects and what type of defects would it be? Does their technique require full sunshine or does it work on cloudy days? Did they compare this method with a visual inspection from the ground? Can experts inform on other techniques used?**

Paper **B2-303** on phase displacement as a prospective means for right-of-way upgrading presents three different methods to upgrade a transmission line while maintaining service continuity. In these conceptual approaches, one AC phase position at a time is removed from service while the remaining two continue carrying power providing either (1) the opportunity to pull in new replacement conductor one phase at a time or (2) create the clearance necessary for erection of new structures capable of supporting greater MW transfer.

**Question 3.2: Using the figures provided in the paper, can any expert report on existing projects or future projects where the suggested technology would be advantageous? What would be the issues including the ones mentioned by the authors such as safety concerns and how could they be addressed?**

**3.2 Creep and fatigue issues on new conductor types**

Paper **B2-301** on a 220-kV field study of different high temperature low sag conductors presents results on the influence of wind velocity, air temperature and load current on conductor temperature. The conductor creep has been evaluated by monitoring the conductor tension as a function of time for an ACCR (aluminium conductor composite reinforced), ACCC (aluminium conductor composite core) and ZTAL/HACIN (super-thermal-resistant-aluminium high strength aluminium-clad invar reinforced).

**Question 3.3: Did the authors observe the same trends regarding conductor tension over time (creep) with the additional data available since the paper was written? If so, how do they explain the tension increase of the ACCC? Can they provide for each conductor the detailed equations used to obtain the tension corrected to correspond to 10˚C? Can they explain the data scatter for the ACCR above 10˚C in Figure 7 b Tension Vs conductor temperature? Can other experts provide additional data from other sites?**

Paper **B2-302** on creep behaviour of high temperature low sag conductors presents detailed data on conductor creep as a function of pre-stress. It appears that a permanent deformation does not depend on the load sequence, but only on the starting permanent elongation of the conductive materials; therefore the final elongation of a conductor for any load history can be studied from a case of a conductor subjected to the design overload and, afterwards, to several creep stages (with different values of time, temperature and load).

**Question 3.4: What would be the recommendations of the authors regarding the pre-stressing required to minimize conductor creep taking into account the towers and tower arms strength? What is the opinion of other experts on the findings presented in the paper?**

Paper **B2-305** on limits of allowed ampacity of EHV/UHV overhead lines with ACSR and ACCC conductors in the specific climatic conditions of the Slovak Republic compares the two conductor types regarding ampacity and sag clearance of the lower phase.

**Question 3.5: The authors compared the losses of an ACCC with an ACSR. What is the expected cost of losses with the new conductors and how does it compare with the cost of more conventional solutions. Conductor pre-stressing at 50 and 70% of UTS is mentioned as a way to remove most of the initial creep. Would it be easily applicable on their line considering the strength of their towers and tower arms? The authors provide sag information at different temperatures and lifetime for three ACSRs. Is this information available for ACCCs and how does it compare with an equivalent ACSR? Experts are encouraged to provide similar comparisons if they have data available.**

Paper **B2-306** on creep and fatigue into copper micro alloys for overhead transmission lines presents a material with an electrical and thermal conductivity greater than 95% IACS and 350 Wm which does not have significant creep up to temperatures of 250˚C. They also claim that it has an excellent fatigue resistance.

**Question 3.6: To complete the interesting comparison made in figure 7 between a micro-alloyed conductor and an ACSR conductor, could the authors provide more details for each conductor such as diameter, ultimate tensile strength, mass per unit length, equivalent modulus of elasticity, stranding, coefficient of linear expansion, area of each material plus mechanical tension and temperature during the test (same as in figure 6?)? Could the authors also present the main mechanical properties (modulus of elasticity, density, coefficient of linear expansion, etc.) of the copper micro alloy presented in this paper as well as results on conductor fretting fatigue with this material since this is the main fatigue mechanism on conductors?**

**Question 3.7: In order to make better use of new (or non-standard) conductors, it is extremely important to diffuse the data available on their creep as well as fatigue behaviour and endurance limits, among other properties. Could experts and cable manufacturers provide this data whenever it is available in order to include it in the work done within CIGRE B2 TAG06. Any other field or lab results would also be welcomed.**

### 3.3 Mechanical behavior of new bundle configurations

There was no paper presented on this sub-section, however many papers have already been presented within CIGRE on expanded bundles. Moreover, a recent visit of Bina 1200 kV UHV test station during the CIGRE International colloquium on UHV showed bundles of eight conductors tested with different sub-conductor spacing to compare their performance regarding corona and RIV.

**Question 3.8: Is there among experts other information available regarding mechanical behaviour of new bundle configurations?**

## Main session and preview meeting

The main session of Study Committee B2 will be held on Tuesday, August 26th, in the "Grand Amphithéâtre". Authors of the session papers and other delegates wishing to present contributions to the questions raised by the Special Reporters are requested to send in advance, i.e. by August 10th, their intended contributions to the respective Special Reporter and SC Chairman Konstantin O. Papailiou (konstantin@papailiou.ch) and Secretary Herbert Lugschitz (herbert.lugschitz@apg.at). The related documents, i.e. guide, template and sample page, can be found under www.cigre.org and have to be strictly observed. Study Committee Chairman and Secretary together with the Special Reporters will meet with the contributors on Monday, August 25th, from 14:00 -17:00 in either room 361, 362, 363 or 364 in order to discuss their proposals and to allocate the period of time for their presentation.