

## **SPECIAL REPORT FOR SC B2 OVERHEAD LINES**

### **Special Reporters**

**PS 1: J. TOTH (CA), H. VALENTE (PT)**

**PS 2: S. LANGLOIS (CA), N. FULK (US)**

**PS 3: R. MENEZES (GB), C. KANT (IN)**

### **Poster Session Convenors**

**PS1: S. TAKAHASHI (JP)**

**PS2 & PS3: I.L. DE PAULA SOUZA (BR)**

**SC B2 Chair: P. VAN DYKE (CA) and SC B2 Secretary: V.T. CHARI (IN)**

### **A few words about Session Papers**

Session Papers focussed on a number of Subjects – referred to as ‘Preferential Subjects’ – selected in advance by the 16 Study Committees of CIGRE and available in the [Call for Papers](#).

Session Papers are selected through a two-phase review process – abstracts and full Papers.

Have a look at the [Technical Programme](#) - the list of selected Papers for the Session, and so have an overview of subjects that will be discussed. It is updated as Full Papers review proceeds.

### **And specificity of CIGRE Sessions**

At CIGRE Sessions authors are given the opportunity to present their Paper during half-day specific meetings – the Poster Sessions.

Four days are also dedicated to ‘Group Discussion Meetings’ organised by Study Committees. Four meetings run simultaneously each day from Tuesday to Friday, under the presidency of the Study Committee Chairs. The purpose of these meetings is the discussion of the Session Papers on the basis of “Special Reports” which incorporate the gist of the Session Papers and raise a number of questions for discussion.

The Special Reports are available to all on free access – at the end of May - on the CIGRE website, on the [Session page](#).

For fruitful discussions delegates are strongly encouraged to read the Papers before the Session.

The set of Session Papers is made available for downloading to all duly registered delegates before the Session through their private account on the [registrations](#) portal. Papers are also readable on the Session smartphones application on site in Paris.

Follow our Session latest news and General Programme - by regularly visiting our [website](#) !

## CIGRE Study Committee B2

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

Overhead lines play a key role in the electricity system of the future and the activities of SC B2 are fully aligned with this important aspect of CIGRE's mission.

The technical guidelines of SC B2 are:

- Increase the ampacity of existing lines
- Ensure or improve line reliability
- Ensure environmentally compatible lines
- Develop working methods and new tools

To encourage the sharing and promotion of knowledge in these important fields, SC B2 has selected the following three preferential subjects for the 2026 CIGRE Session:

- PS1 - OHL modernization and emerging technologies
- PS2 - Health assessment and refurbishment of OHL
- PS3 - Sustainability and climate change impacts

A total of 118 SC B2 papers has been selected including four NGN papers.

### SC B2 NGN papers

Paper Number	NC Country	Name of the candidates	Preferential Subject	Title of the papers
12611	Japan	Shohei Takahashi	PS1	Characteristics and Application of Multi-Function Conductors
12619	UK	Odemadighi Oye Igenewari	PS1	Feasibility of Horizontal-Vee Insulator Configurations for Application in Undulating Terrain
12606	South Africa	Thingahangwi T Ludere	PS2	Non-Destructive Testing Techniques for Condition Assessment of Reinforced Concrete Overhead Transmission Foundations
12599	Brazil	Iago Souza	PS3	Evaluation of Downburst Impact in the Electric Reliability of Transmission Line Spans Through Numerical Analysis

### Group Discussion Meeting

The B2 Group Discussion Meeting (GDM) will be held on **Tuesday August 25**, at the “Grand Amphitheatre” from 08:45 to 18:00.

Special Reporters have prepared 25 questions from common issues and trends identified in the accepted SC B2 papers. We encourage you to share your views or experiences by sending us your answers to these specific questions. During the Group Discussion Meeting, each prepared contribution will be allocated a time slot of three to four minutes for a presentation.

Spontaneous oral contributions will also be possible during the GDM.

With your participation, we expect lively discussions during the GDM which will provide the best opportunities to share knowledge among participants.

#### **Procedure for contributions.**

1. Contributors should upload their contributions on the [registrations](#) portal – “Contributions to Group Discussion Meetings” section - using your existing account and own credentials before 7th August 2024, for a prior screening and a good organization of the Group Discussion Meeting.
2. Access to contribution uploading is given only to duly registered delegates.
  - As a consequence, registration to CIGRE Session should be finalized before uploading contribution(s) online.
  - Register now for the Session registrations.
  - Contributions uploading will open at the beginning of June.
3. Special Reporters will review the prepared contributions (Power point presentation with max **3** slides and a written word file with max 1000 words per contribution). Each file must be named as follows: **SC\_PS\*\_Question Number\_CONTRIBUTOR’S NAME (in capital letters) Country (official abbreviation)**, for example B2\_PS3\_Q3.5\_WANG\_CN. A guide for contributors as well as templates and sample pages are available on the [Paris Session](#) webpage. Important notice: No commercial names are to be included in presentation or the written summary (even TSO/DSO names).
4. Any recommendations or changes to the contributions will be provided to the contributors by the Special reporters directly on the Registration platform between 7th of August and 14th of August 2026. Contributors are encouraged to visit their account on the registrations portal to see the result of this review.
5. All contributors with accepted/finalised contributions will be contacted by the Special reporters between 7th of August and 14th of August 2026, to finalize the presentation and receive the instructions regarding the session.
6. Important note:
  - All contributions must be uploaded prior to the Conference in Paris.
  - Last minute changes to the contributions will not be granted.
7. During the GDM the Study Committee Chair may call for spontaneous contributions, which will only be verbal with no slides. All attendees are eligible to make such a contribution. Attendees who provide a spontaneous contribution are allowed to deliver a written contribution which will be included in the Session Proceedings. This text is required to be forwarded within a maximum delay of two weeks after the Study Committee GDM Session (i.e. by September 8, 2026) to the SC Secretary ([vivek@tagcorporation.net](mailto:vivek@tagcorporation.net)).
8. It is expected that the questions relevant to the Preferential Subjects will attract many prepared contributions. The number of contributions for each Preferential Subject (PS1, PS2 and PS3) may need to be limited. The selection will be based on relevance, quality and time of submission of the contribution.
9. Please note that accepted contributors will be required to attend a short pre-session virtual meeting with the Special Reporters, SC Chair and SC Secretary on Friday August 15, 14h00 (CET). You can also meet them on Monday August 24, 14:00-18:00 in **location** at the Palais des Congrès to finalise presentation arrangements. The purpose of this short meeting is to review the final details of their contribution and to receive the latest instructions (such as schedule).

## Poster session

Authors of SC B2 session papers are required to present their papers during the SC B2 Poster Session, scheduled for Monday, 2026-08-24, in Halle Ternes (Level 1, Room 2). Templates and instructions for poster preparation are available on the CIGRE 2026 Session website. Posters will be displayed on digital screens.

Poster presentations must be uploaded to the ConfTool platform from 18 May and no later than 29 June for review by the poster session conveners. The conveners may request revisions; a final version incorporating any requested changes must be uploaded by 14 August.

Please note that authors will not have the opportunity to upload their files on the day of the Poster Session. If the author(s) cannot attend the session, he or she—or the relevant National Committee—is requested to arrange for a substitute.

## Tutorial

Please note that the B2 **Tutorial** ‘Emergency Restoration Systems for Overhead Lines - Guide for Design, Planning and Installation (WG B2.85)’ will be held on **Wednesday morning** from 10:40 to 12:30 in room Bordeaux.

## Summary of key dates

Date	Time (UTC+2)	Location	Description
Friday 2026-08-07		Registration platform	Deadline for submission of prepared contributions via the registration portal
Wednesday 2026-08-13			Deadline for notifying contributors of the review outcome
Friday 2026-08-15	14:00	Teams meeting	Virtual contributors’ meeting with the SC Chairman, Secretary and Special Reporters
Monday 2026-08-24	14:00-16:00	Hall Ternes, level 1, Room 2	<b>SC B2 Poster session – Group 1: PS1 papers</b>
Monday 2026-08-24	16:00-18:00	Hall Ternes, level 1, Room 2	<b>SC B2 Poster session – Group 2: PS2 and PS3 papers</b>
Monday 2026-08-24	14:00-18:00	Hall Ternes, level 1, Room 2 Meeting room near the entrance	Final contributors’ meeting with the SC Chairman, Secretary and Special Reporters
Tuesday 2026-08-25	8:45-18:00	Grand Amphitheatre	<b>SC B2 Group Discussion meeting:</b> Prepared contributions and the Special Report will be presented and discussed
Wednesday 2026-08-26	10:40-12:30	Room Bordeaux	<b>SC B2 Tutorial</b> WG B2.85 Emergency Restoration Systems for Overhead Lines - Guide for Design, Planning and Installation
Thursday 2026-08-27	8:30-18:00	Room 353	<b>SC B2 Study Committee Meeting</b>
Tuesday 2026-09-08		To be sent to the SC Secretary at vivek@tagcorporation.net	Deadline for submission of written spontaneous contributions

## Preferential Subject 1 OHL Modernization and Emerging Technologies

Preferential Subject 1 focused on the modernization and optimization of overhead line (OHL) infrastructure to address the dual challenges of the energy transition: integrating renewable energy sources and meeting increasing electricity demand within constrained environments. This primary theme is characterized by a shift from traditional, conservative design methods toward data-driven, resilient, and capacity-maximizing strategies.

PS1 accepted a total of 50 papers, of which 2 were accounted as NGN.

The Preferential Subject was divided into 3 main themes:

- Theme 1.1 - Uprating or upgrading existing lines including conductors' replacement and associated towers modifications and foundations reinforcement and other line components and technologies.
- Theme 1.2 - Accelerating the design and construction of new lines, reducing the cost and the manpower required in view of scarcity of skilled workforce and expertise.
- Theme 1.3 - Preassembled overhead line components, man less installation of overhead line components.

**Theme 1.1 - Uprating or upgrading existing lines including conductors' replacement and associated towers modifications and foundations reinforcement and other line components and technologies.**

The papers received can be grouped into five major topics:

### Advanced Conductors

Papers 10118, 10135, 10703, 10832, 11362, 11615, 12157, 12232 and 12611 explore emerging technologies for upgrading overhead transmission lines, including HTLS (High Temperature Low Sag) and PMC (Polymer Matrix Composite) conductors, advanced steel-core ACSS designs, improved epoxy resin systems, and embedded optical-fibre monitoring. They highlight how innovations in materials, thermal performance, corrosion resistance, dielectric assessment, and real-time sensing can increase grid capacity, reliability, and resilience without major structural reinforcements.

***Q1.01 In the case of HTLS conductors with new core material, how are the utilities preparing their asset management strategies, particularly with regard to inspection practices?***

### Dynamic Line Rating (DLR)

Papers 10184, 10286, 10289, 11620, 12338 and 12490 present advanced methods for improving overhead line capacity and reliability, including CFD-enhanced wind forecasting for Dynamic Line Rating, LiDAR-integrated clearance assessment, long-term weather-based rating curves, and hybrid uprating strategies such as Static Line Uprating combined with DLR. They show how localized meteorological modelling, terrain-aware ampacity calculations, and sensor-driven forecasting can unlock significant additional transmission capacity, often 8–40%, while maintaining safety margins.

***Q1.02 Dynamic Line Rating (DLR) unlocks capacity during favourable weather but offers no gain during low-wind, high-temperature periods. To what extent can "passive" technologies, such as spectrally selective coatings (Static Line Uprating), be combined with DLR to raise the OHL ampacity baseline?***

### Voltage and Structural Upgrades

Papers 10371, 10727, 11152 and 12044 examine strategies for increasing transmission capacity when there are relevant constraints on building new lines. These include voltage uprating of existing corridors in India, alternative underpass structures for South Africa's 400 kV network, and hybrid HVDC–HVAC corridors in Colombia. Each case study demonstrates how engineering redesign, structural adaptation, and mixed-technology corridors can overcome spatial, environmental, and regulatory limitations while meeting rising electricity demand.

***Q1.03 As utilities turn to upgrading, structural redesign, and hybrid AC–DC corridor configurations to expand capacity within constrained rights-of-way, how should engineers assess the trade-offs between technical feasibility, long-term structural and electrical performance, and environmental or societal limitations when determining the most appropriate upgrade strategy?***

#### **Clearance Enhancement**

Papers 10288 and 11313 present two approaches for improving safety and reliability in overhead transmission lines: the use of Interphase Spacers to increase vertical clearances in existing spans and a revision of EN 50341-1 proposing more consistent deterministic and statistical approaches for defining electrical clearances.

#### **Compacting Lines**

Papers 10119, 10871 and 12619 present advanced structural innovations for overhead transmission lines, including a next-generation hinge-mounted insulating cross-arm for Belgium's 380 kV network, a lightweight and low-load tower design, and stability-optimized Horizontal-Vee insulators for varied terrain. Each study uses detailed mechanical or numerical modelling to improve reliability, reduce structural forces, and enable safer, more adaptable tower configurations.

***Q1.04 The push for reduced visual impact has led to innovations such as insulated cross-arms (ICA) and pivoting horizontal-vee insulators. However, these introduce complex stability issues (e.g., snap-through instability) in undulating terrain. How can design codes be updated to better integrate these elements not merely as insulators but as structural components, similar to angle members?***

**Theme 1.2 - Accelerating the design and construction of new lines, reducing the cost and the manpower required in view of scarcity of skilled workforce and expertise.**

The papers received can be grouped into five major topics:

#### **Generative Design**

Papers 10672, 11762, 12037 and 12229 explore how transmission line design is being transformed through both strategic planning methods and AI-driven engineering tools. They show that tower spotting strategies must adapt to terrain conditions to balance cost and construction speed, while AI-augmented design frameworks, using generative models, machine-learning surrogates, and robotic optimization, can dramatically reduce design time and improve technical-economic decision making.

***Q1.05 With the "silver tsunami" of retiring engineers threatening to deplete institutional knowledge, can AI-augmented design frameworks effectively digitize and preserve empirical "rule-of-thumb" intuition to act as a mentor for the next generation of engineers?***

#### **Building Information Modelling (BIM)**

Paper 10110 details a pilot project by the Slovenian combined transmission and distribution system operator to integrate Building Information Modeling (BIM) into their overhead transmission line reconstruction process. The project focuses on developing an open BIM-based 3D model of the Brestanica–Hudo transmission line, testing workflows within a common data environment, and demonstrating BIM's practical application during construction and handover phases.

***Q1.06 While Building Information Modelling (BIM) offers significant advantages during the design and construction phases, utilities often revert to fragmented, manual processes during the operational phase. How can utilities establish a unified, machine-readable data schema (similar to IFC (Industry Foundation Classes) in construction) to ensure that the "digital thread" remains unbroken from design through to more than 60 years of asset management?***

#### **Novel Tower Designs**

Papers 11067 and 11069 present two innovative multi-phase transmission line technologies, designed to increase power transfer capability while reducing environmental and electromagnetic impacts. By comparing these configurations with traditional double-circuit lines, the studies show how multi-phase

geometries, tower-over-tower reconstruction, and optimized electromagnetic performance can support renewable integration and minimize visual intrusion.

***Q1.07 Novel tower geometries are being proposed to increase power density and reduce magnetic fields in urban corridors. What are the long-term operational implications of these non-standard phasing arrangements regarding maintenance procedures, system reliability (N-1 contingency) and protection relay coordination?***

### **Smart Inspection and Monitoring**

Papers 10829, 11901, 12042 and 12503 highlight how digital and automated technologies, such as AR-based inspection tools, drone-thermal imaging frameworks, predictive vegetation analytics, and advanced lightning monitoring, are transforming transmission line maintenance and reliability. These systems reduce human risk, improve diagnostic accuracy, and enable proactive asset management by combining sensors, AI, geospatial data, and real-time monitoring.

***Q1.08 While UAVs and thermal cameras are reducing the need for manual patrols, the sheer volume of data remains a bottleneck. How can unsupervised learning techniques (such as PCA-based anomaly detection) be reliably integrated into maintenance workflows to identify novel or evolving thermal faults that pre-trained supervised models might miss?***

### **Foundation Optimization**

Papers 10737, 10830 and 11019 examine how advanced geotechnical modelling and high-quality subsurface investigations are essential for ensuring the safety and reliability of transmission tower foundations. They show that while simplified beam-element models are fast, refined shell and solid models combined with 3D bearing-capacity analysis and liquefaction-mitigation strategies provide far more accurate predictions of soil–structure behaviour. These studies emphasize that rigorous geotechnical data and sophisticated modelling are critical to avoiding costly design errors and ensuring long-term foundation performance.

***Q1.09 As foundation design increasingly relies on detailed soil-structure interaction models and high-resolution geotechnical data, how should utilities balance the cost and time of advanced investigations with the need to minimize structural risk, prevent failures, and ensure long-term asset resilience?***

## **Theme 1.3 - Preassembled overhead line components, manless installation of overhead line components.**

Several of the papers received for PS1 fall within the scope of theme 1.3, and can be grouped into three major topics:

### **Remote and Automated Technologies**

Papers 11070 and 11788 describe how digitalization and equipment innovation are reshaping overhead line construction, from IoT-enabled job-site coordination systems that automate stringing operations to compact modular tensioning equipment that improves safety, reduces environmental impact, and enhances construction efficiency.

### **Safety Devices**

Papers 10324 and 12444 introduce two innovations to improve safety and efficiency during transmission line construction: A system which allows lattice tower sections to be aligned and secured without workers standing beneath suspended loads, and a redesigned catenary system that enhances control, reduces disruption, and improves safety when stringing lines across sensitive areas. Together, they highlight a growing emphasis on engineering solutions that eliminate high-hazard tasks while improving construction productivity.

***Q1.10 As construction methods increasingly incorporate solutions that remove workers from high-risk zones, how should utilities and contractors redesign their construction practices, training programs, and project planning to fully leverage these innovations while ensuring consistent safety gains across diverse project environments?***



### **Specialized Methods:**

Papers 10285, 10361, 10373, 10828, 11439, 12203 and 12426 highlight major advances in transmission tower design, validation, and construction, ranging from a push for standardized 380 kV tower families to meet rapid grid-expansion needs, to new methods for validating tower behaviour through strain-gauged prototype testing and high-fidelity finite-element simulations. They also showcase innovative construction and structural solutions, including helicopter-assisted dismantling, node-and-bolt tubular tower systems, lightweight tubular designs for large spans, and modular temporary towers, each with the purpose of improving efficiency, reducing environmental impact, and enhancing structural performance.

***Q1.11 To address the scarcity of specialized OHL labour, is it more effective to invest in tower standardization or in simplified and “automate-ready” design, for example by involving product design specialists?***

PS1 also received the paper 11904, which presents a frequency-domain approach for calculating induced current duties in high-speed earthing switches used in extra-high-voltage (EHV) AC systems. The method accurately models electromagnetic and electrostatic coupling effects, soil influence, and distributed earthing paths, providing more precise results than conventional EMTP simulation tools. The study highlights that conductor phasing and sequence significantly influence induced current levels, while earthing parameters have a negligible effect on phase coupling.

### **Preferential Subject 2 Health Assessment and Refurbishment of OHL**

Utilities face major challenges and a high level of pressure to extend the life of existing overhead transmission lines. Many technologies are becoming available for the monitoring, maintenance and refurbishment of lines. However, extensive research and development works are needed to adapt these technologies to the practical reality of overhead lines.

Forty papers were accepted including one NGN paper. They were regrouped under three subtopics as follows:

- 2.1 Remaining life of assets, increasing the life of assets, and refurbishment of OHL.
- 2.2 Reducing maintenance and operation costs, evaluating durability and maintenance costs.
- 2.3 Monitoring, predictive maintenance and digital twins.

#### **Theme 2.1 Remaining life of assets, increasing the life of assets, and refurbishment of OHL**

Fourteen papers covering remaining life of assets are covered in this section. These papers include works related to the refurbishment or life assessment of different overhead line components.

##### **Conductors**

Paper 10229 present ageing tests that can help validate and harmonize the Arrhenius model proposed in IEC TS62818, which predicts the expected lifetime of the conductors, for carbon fibre composite core conductors.

Paper 10711 describes a probabilistic model for assessing potential conductor fatigue damage. The procedure can be used to predict residual life to failure and take account of varying loading histories.

Paper 12368 refines in-cloud icing models using experiments and field data, showing higher-than-expected collision efficiency and weak sensitivity to inflow angle (45°–90°). It also finds that conductor temperature mainly controls icing initiation but has limited impact on later ice growth.

***Q2.01: Knowledge of the remaining life of conductors is key to proper planning of investments in overhead lines. What efforts are utilities making to develop a detailed knowledge of the remaining life of existing conductors? Can some of these efforts be incorporated into IEC standards, for example regarding composite cores, for which a new standard is currently under development?***



## **Insulators**

Paper 12030 assesses acoustic resonance as a non-destructive test for porcelain insulators, showing good repeatability but no reliable link to mechanical strength.

Paper 12276 proposes a comprehensive, holistic approach for evaluating composite insulators, including new test methods and a traffic-light classification system for condition and maintenance decisions.

Paper 12348 shows that composite insulators can withstand higher dynamic loads than static ones and supports using simplified component-level tests instead of full-scale testing.

***Q2.02: Insulators are made of composite, porcelain or glass materials through a complex fabrication process and are subjected to both mechanical and electrical stresses from conductors. What measures have been taken to ensure that testing and assessment methods accurately reflect real-world performance and maintain safe operating limits?***

## **Towers and poles**

Paper 10120 presents the design, cost calculation and return of experience from the field for the reinforcement of aged concrete pole using carbon fiber fabrics glued with epoxy resin.

Paper 12558 evaluates ultrasound non-destructive testing (NDT) for wood pole condition assessment, showing it can detect early and incipient decay that traditional methods miss, enabling earlier treatment and extended asset life.

## **Foundations**

Paper 10379 describes the approach of using condition assessment of corrosion on tower components located just above the concrete foundations to determine the associated corrosion risk.

Paper 10704 presents the general results of a wide-ranging program for inventorying foundation damages and the factors affecting their degradation identified in France. Preliminary results of analyses and proposals for further inventory and repair work are presented.

Paper 12606 presents a multi-method non-destructive testing framework for assessing buried transmission line foundations, showing that combining techniques (e.g., UPV, rebound hammer, and GPR) improves reliability while minimizing excavation.

***Q2.03: In extensive maintenance program for towers and foundations, how to define technical criteria for deciding between reuse, reinforcement or replacement? How can those be applied to multiple materials and geometries of components?***

## **Grounding and electrical performance;**

Paper 11628 shows that high footing resistance is a key driver of lightning-related failures in MV lines and demonstrates that a performance-based grounding design approach can significantly reduce flashover risk and improve reliability.

Paper 12125 analyses the performance of 500 kV transmission lines under lightning, showing that terrain, lightning characteristics, and tower configuration significantly affect outage rates, and emphasizing the need for site-specific modelling and design solutions.

Paper 12324 investigates corrosion of tower earthing systems in inundated areas and shows that material substitution and protective encasing significantly improve lifespan and reliability, with copper-based and stainless-steel materials providing the best long-term performance.

***Q2.04: TSOs are striving for “perfect power” to improve customer experience. How can we standardize grounding, shielding, and protection design—while still accounting for site-specific conditions—to set practical performance targets (e.g., footing resistance) and prioritize mitigation across large transmission networks for maximum reliability?***

## **Theme 2.2 Reduced maintenance and operation costs, evaluate durability and maintenance costs**

Thirteen papers presented research and development works regarding the maintenance and control of operation costs.

Paper 10136 describes an innovation that uses LiDAR and the analysis of LiDAR-derived data to obtain a reliable assessment of the risks posed by vegetation located beneath and near overhead power lines.

Paper 10809 presents an inspection method of distribution poles with a vehicle-based video system and AI defect detections.

Paper 10831: The paper describes the use of drones for the inspection of bolts and nuts connections on OHL towers. AI is used to assess the data provided by the drones.

Paper 11096 shows that using more detailed annotations (marking exact parts of defects instead of just labelling whole images) significantly improves defect detection on insulators using AI. This approach leads to faster model training, better results, and less need for large datasets.

Paper 12504 presents an AI-driven monitoring approach combining satellite, UAV, and camera data to improve transmission line inspection. It uses cross-scale image matching to detect threats and has been applied to over 15,000 km of lines, significantly enhancing efficiency and reducing O&M workload.

***Q2.05: AI technologies evolve fast. What are the current challenges and limitations associated with automated line inspections and data processing using AI tools? On the other hand, what are the potential cost and reliability benefits of using these methods?***

Paper 10383 presents a reliability-centered maintenance framework applied to the scheduling of line inspections and the planning of maintenance activities. The model relies on scoring the probability of failure and the impact of failures at the tower level. It uses a weighted-parameter scoring method which is then applied to determine inspection priorities and inspection schedules.

Paper 12312 presents an automated AFA system that integrates fault, lightning, and asset data to accurately locate and diagnose transmission line faults. It improves accuracy—especially for high-resistance faults—while reducing analysis time and manual effort, enabling faster restoration and more efficient reliability management.

Paper 11020 investigates a case of slippage of performed splices mounted on overhead conductors in Brazil with the role of joints. The results suggested that slippages were due to a combination of inappropriate design and assembly errors.

Paper 10376 illustrates an innovative method to string short sections with machines placed at ground level, thus eliminating the need for extra space as well reducing work at heights.

Paper 11371 outlines the findings of a condition assessment of composite insulators and the subsequent investigation and testing. Their investigation and testing led to the author's recommendations that electric field testing should be elevated in importance in IEC standards for composite insulators.

Paper 11552 develops condition-based maintenance strategies for composite insulators using service data, diagnostics, and testing. It identifies IR, UV, and visual methods as most effective and links failures to material defects and high electric field stress. The resulting guide defines standardized actions—replace, monitor, or continue service—based on condition.

Paper 12477 compares AC and DC dielectric performance of polluted composite insulators using a rapid flashover method. It shows differences in flashover behaviour—especially in pre-arcing—highlighting the need to consider voltage type. The method enables repeatable single-insulator testing and supports improved asset health assessment.

Paper 12186 presents a circular approach that reuses transmission towers for rerouting to cut costs and emissions. It shows that evaluating and adapting existing towers reduces material use and construction time while maintaining reliability. Overall, reuse delivers both economic and sustainability benefits.

***Q2.06: Condition assessment of overhead line components in service is typically very challenging. What are the best strategies to perform effective maintenance and identify problems before they appear while maximizing the service life of the various components? What is the return of experience of utilities regarding these strategies?***

### **Theme 2.3 Monitoring, predictive maintenance and digital twins**

Thirteen papers cover monitoring and digital twin application for overhead lines.

Paper 10290 presents the potential use of wind information derived from Distributed Acoustic Sensing (DAS) measurements on OPGW to support DLR applications. It also includes results obtained during a pilot project conducted in the Netherlands. In the conclusion the paper proposes a hybrid solution combining DAS ratings with direct sag monitoring on selected spans.

Paper 11214 presents a novel approach to evaluate clearance based static current carrying capacity utilising long-term DLR data.

Paper 11583 presents an acoustic emission method for detecting strain clamp damage. It shows that key signal features can identify defects using a neural network, enabling accurate, real-time non-destructive monitoring.

Paper 11586 optimizes UAV infrared inspection of composite insulators, showing that detection accuracy decreases with distance. It recommends limits of  $\leq 10$  m or  $\leq 20$  m depending on resolution and provides practical guidelines for reliable defect detection.

Paper 12075 uses leakage current monitoring to support condition-based insulator maintenance. It shows that current and harmonic indicators track humidity and contamination, enabling detection of critical conditions and more efficient maintenance.

Paper 11071 presents an embedded optical fibre within the carbon core to enable real-time monitoring of temperature and strain in the conductor throughout its lifetime. This data can then be used to develop predictive maintenance strategies and determine the end-of-life of the conductor.

Paper 11872 shows that aeolian vibration on long-span crossings can differ significantly between phases despite identical setups. It attributes this to wind, terrain, and aerodynamic effects, emphasizing the need for full-phase monitoring for long-span crossings.

Paper 12370 presents a large-scale, data-driven approach to tower earthing diagnostics. It shows a strong link between soil resistivity and footing resistance and uses statistical indicators to identify problematic towers, supporting risk-based maintenance and improved reliability.

***Q2.07: New technologies are now available for continuous monitoring or periodic inspection of lines across various applications, such as dynamic line rating, vibration monitoring and tower earthing. What are the future developments in this field and how can they be adapted to the wide range of environments and configurations found in the network, including complex terrain and wind conditions, different conductor and span configurations, and various type of structures and foundations?***

Paper 10382 proposes an asset management framework using AI. It includes asset inspection and condition monitoring. It details the advantages of predictive maintenance and analysis of large data.

Paper 10708 presents how a utility integrates AI into its inspection process, starting with an R&D project and gradually moving toward a global solution for the TSO.

Paper 11440 applies a machine learning technique to identify a mathematically validated correlation between the insulator leakage current and a combination of meteorological parameters, rather than individual variables. The approach presented offers a comprehensive evaluation based on a large dataset.

Paper 11017 presents the integration of digital line and tower modelling used from design to construction. Those tools are used by all partners for planning, manufacturing, transportation and construction of a project. Gains in safety and productivity are mentioned as the main advantages.

Paper 12505 presents a LiDAR-based 3D modelling and inspection approach for transmission lines. It uses deep learning to accurately classify components and build digital models, enabling efficient large-scale monitoring and asset management.

***Q2.08: What level of investment is required to implement AI based monitoring and digital twin systems? What are the main obstacles to their practical implementation? What challenges arise when extending these methods to other lines or networks where data may be less extensive or of lower quality?***

### **Preferential Subject 3 Sustainability and Climate change impacts (with C3)**

Climate change is increasingly stressing overhead transmission lines, as more frequent and intense events such as heatwaves, high winds, icing, and flooding reveal the limits of traditional design standards and cause infrastructure failures. In response, engineers are adopting forward-looking approaches that integrate advanced climate projections to ensure reliability through mid-century and beyond, while also accounting for the compounding effects of multiple interacting hazards through improved risk modelling. At the same time, sustainability has become a key priority across the entire lifecycle of transmission systems, with efforts focused on reducing carbon emissions through better material choices, higher efficiency, and innovations like high-temperature low-sag conductors. Life Cycle Assessments are widely used to balance embodied and operational emissions, while broader environmental and social considerations—such as land use, biodiversity, and noise impacts—are also addressed. Overall, the field is shifting toward data-driven, risk-based, and lifecycle-optimised practices to support a more resilient and environmentally responsible power grid.

A total of 28 papers has been accepted and grouped into the following themes.

#### **Climate Loads, Extreme Events, and Adaptive Design in Power Systems**

Papers 10291, 10292, 10773, 12009, and 12599 show that traditional design assumptions for overhead lines are increasingly inadequate under changing climate conditions. While some criteria, such as ice load zoning, may be overly conservative, shifting icing patterns can still intensify risks in certain regions. Emerging hazards like downbursts introduce localized extreme wind loads not captured in current standards, increasing failure risks. Evidence of wind-related failures further highlights these gaps, indicating that climate change is redistributing risks, with wind becoming a key concern for future design.

Papers 10405, 10833, 10872, 11757, 11588, and 11590 emphasize the growing importance of hazard interactions and compound effects on transmission system reliability. They show how combined impacts of wind, lightning, flooding, volcanic ash and temperature significantly increase infrastructure stress. Findings indicate that the interaction of operational loading with climate factors—such as heat and wind—can be more critical than individual hazards, while the combination of icing and wind heightens galloping risks and mechanical instability. Overall, these studies highlight the need to move beyond single-load design toward multi-hazard modelling and resilience-based planning.

Advanced tools are becoming essential to manage uncertainty in transmission systems. Papers 10413, 11754, 11810, 11873, and 12124 show that combining real-time monitoring with modelling improves icing detection, while calibrated climate datasets support better decision-making. GIS tools help identify assets at risk, and digital methods optimize routing and environmental trade-offs. Overall, these studies highlight a shift toward predictive, data-driven asset management.

Climate change is impacting transmission system operation and capacity, with studies showing a 5–10% reduction in ampacity and greater variability requiring more regionalized ratings. Dynamic solutions such as dynamic line rating are key adaptations, while operational conditions often have a stronger effect than temperature alone. Overall, papers 12230 and 11810 highlights a shift toward more flexible and adaptive operation strategies.

***Q3.01 How should transmission design standards evolve to address emerging hazards like downbursts and compound climate events rather than relying on historical weather data?***

***Q3.02 How can engineers balance simplification and conservatism in design criteria as some risks decrease (e.g., icing) while others increase (e.g., extreme winds)?***

***Q3.03 What is the optimal balance between structural strengthening and operational or digital solutions to improve grid resilience? What role should emerging technologies (AI, GIS, digital twins, advanced sensing) play in transforming transmission planning from reactive to predictive and adaptive systems?***

### **Sustainability and Lifecycle Carbon Reduction**

The session highlights the importance of reducing environmental impacts across the lifecycle of transmission systems. Papers 10346, 10406, 11363, 12246, 12327, and 12424 show that operational losses are a major contributor to emissions, with improved conductors capable of significantly reducing total impact. They also emphasize the role of low-carbon materials, such as green steel and recycled components, in achieving substantial emission reductions, while material production itself accounts for a large share of lifecycle emissions. Although advanced conductors may have higher upfront impacts, they offer lower overall emissions through improved efficiency. Overall, the key message is that decarbonization requires a lifecycle optimization approach rather than focusing solely on initial design.

***Q3.04 How should lifecycle emissions, including operational losses and upfront embodied carbon, influence the selection of materials and technologies for transmission systems (e.g. ACSR vs AAAC vs HTLS conductors)?***

***Q3.05 What are the most effective approaches to reducing the overall carbon footprint of transmission systems, considering conductor types, system design (e.g., bundling), recycling potential, and operational optimisation?***

### **Environmental and Social Considerations**

Papers 10412, 10406, 10929, 12364 and 12491 highlight that sustainability in transmission systems extends beyond carbon emissions to include environmental and social factors. They demonstrate integrated approaches that balance engineering design with land use, biodiversity protection, and social acceptance, including impacts on wildlife such as avian electrocution. Attention is also given to noise mitigation, reflecting stricter regulations and community expectations. Overall, the studies emphasize the need for comprehensive, holistic sustainability frameworks.

***Q3.06 How can transmission expansion balance urgent energy transition needs with increasing environmental and social constraints, particularly in biodiversity-sensitive or densely populated areas?***

## Paper Summaries

### Preferential Subject 1 OHL Modernization and Emerging Technologies

**10110 OTL BIM in Practice: From Design and Construction Towards Future Integration into Operation and Maintenance Processes** This paper details a pilot project by the Slovenian combined transmission and distribution system operator to integrate Building Information Modeling (BIM) into their overhead transmission line reconstruction process. The project focuses on developing an openBIM-based 3D model of the Brestanica–Hudo transmission line, testing workflows within a common data environment, and demonstrating BIM's practical application during construction and handover phases. The ultimate goal is to validate BIM requirements in practice and support the ongoing digital transformation strategy of the Slovenian system operator.

**10118 High tensile steel wire cores for High Temperature Low Sag conductors: a case study with Elia Belgium** This paper presents a case study conducted with the Belgian transmission system operator Elia to demonstrate that High Temperature Low Sag (HTLS) conductors with high tensile steel wire cores can successfully upgrade conventional power lines to increase grid capacity. The proposed solution features an Aluminum Conductor Steel Supported (ACSS) design utilizing an advanced S8A steel core and a specialized zinc-aluminum coating (Zn95Al5) to provide superior corrosion resistance and thermal stability up to 300°C. Through the use of controlled on-site pre-stressing during installation, this configuration successfully meets all ampacity, sag, and horizontal tower force requirements without requiring costly structural reinforcements to the existing infrastructure.

**10119 Next generation of hinge-mounted insulating cross-arms** This paper presents a next-generation design for hinge-mounted insulating cross-arms used in Belgium's 380 kV transmission network. The new design addresses concerns about stability and clearance under extreme loading conditions, while incorporating features like maintenance accessibility and conductor stringing capabilities. This optimized design aims to minimize visual impact, enhance reliability, and facilitate retrofitting on existing towers.

**10135 An Industry Summary of Batch versus Bobbin Annealed Conductors** This paper examines the performance differences between batch and bobbin annealed ACSS conductors, a type of conductor gaining popularity for its higher ampacity compared to traditional ACSR. The author analyzes industry data on stress-strain properties and conductivity from three different vendors utilizing varying annealing methods. Ultimately, the findings suggest that the annealing method alone may not be the most significant factor influencing sag-tension and conductor conductivity.

**10184 Hyperlocal forecasting with sensor feedback for reduced uncertainty in dynamic line rating** This paper presents a novel approach to dynamic line rating (DLR) by utilizing computational fluid dynamics (CFD) to improve wind speed forecasting accuracy. Traditional weather models often fail to accurately predict wind speeds at localized levels due to their coarse resolution and inability to account for terrain effects, which significantly impact DLR calculations. By incorporating sensor data from utility right-of-ways, the authors' CFD model achieves a 50.4% reduction in mean absolute error (MAE) for wind speed predictions, leading to a corresponding improvement in DLR accuracy.

**10285 Standard 380kV lattice steel tower within the Netherlands** This paper examines the challenges faced by TenneT TSO B.V. in expanding the Netherlands' high-voltage grid to meet the demands of the European Green Deal and national climate goals. The authors highlight the need for standardization in 380kV tower design due to increasing demand, limited resources, and evolving environmental concerns. The paper uses the Zuid-West 380kV Oost (ZWO 380) project as a case study to illustrate these challenges and propose a standardized approach to streamline procurement, construction, and spatial planning.

**10286 Refined Clearance Assessment of Overhead Lines Combining LiDAR, Climate Data, and Finite Element Analysis** This paper presents a refined methodology for assessing clearances in overhead lines by integrating LiDAR data, climate information, and finite element modeling. The combined approach allows for more accurate conductor temperature calculations and a detailed analysis of clearance margins across individual spans, leading to improved identification of potential

risks. This methodology is demonstrated using a real-world example in the Netherlands, highlighting its effectiveness in supporting efficient network operation and asset management.

**10288 Improved calculations for external clearances on overhead lines** This paper critiques the current EN 50341-1 standard for calculating external clearances on overhead transmission lines, identifying inconsistencies and limitations, particularly for the Netherlands' use of long insulators due to high contamination levels. The authors propose a new deterministic approach based on IEC and CIGRE guidelines that addresses these issues and provides a consistent method for determining both internal and external clearances. Furthermore, they introduce a statistical approach allowing users to calculate external clearances based on desired flashover risk levels, supported by an example case and summarized recommendations for standardization purposes.

**10289 Development and application of hourly values for the static rating of high-voltage overhead lines** To address severe grid congestion in the Netherlands, this paper introduces the "Year Rating Curve" (YRC), an advanced method designed to safely increase overhead power line ratings beyond conservative traditional seasonal assumptions. The methodology utilizes the CIGRE 601 heat balance equation paired with over 40 years of localized hourly weather data from the ERA5 reanalysis dataset, applying a modified Hourly Rolling Window method and Kernel Density Estimation to establish consistent, low-risk capacity percentiles. Preliminary findings show that the YRC maintains a uniform risk level across the year while unlocking an additional 8% to 15% in transmission capacity, proving highly beneficial for long-term grid planning, system operations, and as an operational fallback for Dynamic Line Rating systems.

**10324 Aim-Guide-Lock self-alignment system for tower erection avoids work under suspended load** This paper presents a novel "Aim-Guide-Lock" system designed to eliminate the safety hazard of working under suspended loads during lattice tower erection. The system uses a coupling and guiding device that allows tower sections to be aligned and locked mechanically without workers being positioned beneath a suspended load, as verified through mechanical design, FEA, and prototype testing. The Aim-Guide-Lock system is currently being trialled on a 500 kV double circuit line in Australia and has the potential to improve safety and efficiency in transmission line construction projects.

**10361 Strain Gauge-Based Quantitative Monitoring During Prototype Testing of Transmission Towers** This paper presents a novel methodology for full-scale prototype transmission tower testing that integrates real-time strain gauge instrumentation to provide quantitative data on member behavior. Five towers were instrumented and tested, with strain data compared to analytical predictions from PLS-Tower to validate structural response and detect overstressed members. The authors conclude that incorporating strain gauge monitoring significantly enhances the depth, safety, and reliability of prototype tower testing, contributing to a more robust design validation process.

**10371 Smart Greener Grid Expansion: Re-Engineering 66 kV Infrastructure for 220 kV Operation – BBMB Case Study** This paper presents a case study from the Bhakra Beas Management Board (BBMB) in India, where an existing 66 kV transmission line was upgraded to operate at 220 kV. The upgrade was necessary due to increasing energy demands and limitations in constructing new transmission lines due to topographical, environmental, and safety concerns. The authors detail the challenges faced during the project and highlight the successful implementation of this smart grid expansion strategy, providing valuable insights for similar upgrades elsewhere.

**10373 Advanced Finite Element Simulation of Transmission Towers** This paper presents a finite element (FE) simulation methodology for replicating full-scale load tests on lattice transmission towers, aiming to reduce reliance on costly and time-consuming physical testing. The developed FE framework incorporates 3D solid modeling, nonlinear material definitions, and bolt-slip behavior representation to accurately simulate tower response under various loading conditions. Validation through comparison with physical prototype tests demonstrates promising consistency in member behavior and failure trends, highlighting the potential of this simulation approach for enhancing design validation and reducing testing dependence.

**10672 Designing for delivery: tower spotting strategies to accelerate transmission line design and construction under South Africa's TDP2024** This paper examines the impact of different



transmission line tower spotting strategies on project delivery speed, manpower requirements, and total cost in South Africa's context. The study analyzes three strategies: fully standardized towers, fully site-specific optimization, and a hybrid approach, using digital corridor modeling to simulate various terrain conditions. Results demonstrate that terrain variability significantly influences the optimal strategy, with standardization being most effective in flat terrain while full optimization is crucial for undulating terrain, highlighting the need for tailored approaches based on project specifics.

**10703 Dielectric assessment of composite core conductors: impact and return of experience from a field deployment** This paper examines the use of dielectric assessment technology to monitor the integrity of HTLS (High Temperature Low Sag) composite core conductors in overhead lines. The authors detail their experience adapting laboratory testing methods for field application, highlighting the challenges and complexities involved in transitioning from a controlled factory environment to a real-world worksite. The paper also presents system performance indicators, including detectability and analysis of flaws, as well as a detailed procedure for implementing this technology during overhead line installation.

**10727 Addressing Audible Noise Challenges in the Integration of the 6 x IEC 315 Conductor on South Africa's 765 kV Transmission Network** This paper investigates the feasibility of using a smaller-diameter IEC 315 conductor on South Africa's 765 kV transmission lines compared to the traditional Tern conductor. While both options meet electrical performance criteria, the IEC 315 conductor presents a challenge due to increased audible noise levels caused by higher corona activity. The study proposes mitigation strategies such as optimized conductor spacing and tower height adjustments to manage noise and ensure compliance with regulatory limits.

**10737 Comparative Analysis of Grillage Foundation Modeling for Lattice Transmission Towers: A Detailed Assessment of Beam Element, Shell Element, and Solid Element Approaches Incorporating Soil-Structure Interaction** This paper compares three modeling approaches for analyzing grillage foundations used in lattice transmission towers: beam elements, shell elements, and solid elements. All models incorporate soil-structure interaction (SSI) to account for the complex interplay between the foundation and the surrounding soil. The study finds that while beam element models are quick to implement, shell and solid element models provide significantly more accurate predictions of stress distribution and deflection, highlighting the importance of refined modeling techniques for ensuring structural safety in transmission tower foundations.

**10828 Development of a Helicopter-assisted Method for Dismantling Steel Pipe Towers** This paper presents a novel helicopter-assisted method for dismantling steel pipe transmission towers, addressing the challenges posed by traditional methods that require extensive temporary facilities. The authors developed new jigs specifically designed for steel pipe towers, enabling safe and efficient dismantling using helicopters. This innovative approach has been successfully implemented in seven projects as of December 2025, demonstrating its effectiveness and labor-saving potential compared to conventional methods.

**10829 Development of AR-Based Inspection Technology for Transmission Line Construction** This paper presents an Augmented Reality (AR) based inspection technology for transmission line construction that aims to improve safety and efficiency. The system utilizes smartphones, commercial fixtures, and AR to enable workers to perform sag measurements and compression sleeve inspections without requiring multiple personnel at high altitudes. By overlaying target lines on live camera feeds and using AI-based shape recognition, the AR system standardizes inspection quality, reduces workload, and facilitates real-time monitoring and adjustments.

**10830 Modernising OHL Foundation Design: 3D Bearing Capacity Evaluation and Cost-Effective Liquefaction Protection** This paper investigates two key aspects of overhead line (OHL) foundation design: three-dimensional bearing capacity and liquefaction protection. Through centrifuge model tests and finite element analysis, the authors demonstrate that 3D effects can increase bearing capacity compared to traditional 2D design methods. Additionally, shaking table tests reveal that using top-shaped concrete blocks with a gravel base effectively mitigates liquefaction-induced deformation in OHL foundations.

**10832 Verification for expanding the application of PMC conductor** This paper investigates the application of polymer matrix composite (PMC) conductors in Japan by examining their heat resistance, vibration characteristics, and suitability as overhead ground wires. The study found that PMC conductors exhibit high current-carrying capacity due to compatibility with ZTAL outer layers and maintain sufficient vertical phase-to-phase clearance even under severe ice shedding conditions. Furthermore, the DC arc test results demonstrate the robustness of PMC conductors, withstanding higher electric charges compared to conventional ground wires while preserving the core integrity.

**10871 Structural analysis of the CICA Cross-Rope tower** This paper examines the structural design of the CICA Cross-Rope (CICA-CR) tower, which utilizes polymeric insulators for phase suspension and positions guy wires and cables below the internal tie cable. A non-linear static numerical model was used to compare traditional Cross-Rope towers with CICA-CR towers in four 500 kV transmission lines, revealing significant advantages in terms of reduced mast compression forces, lower structural weight, and decreased foundation loads. These findings demonstrate the potential for cost-effective and efficient transmission line designs using the CICA-CR tower.

**11019 Poorly executed surveys: hidden risks in energy transmission projects** This paper examines the critical role of geotechnical investigations in energy transmission line projects, emphasizing the importance of accurate subsurface data for foundation design. The authors illustrate how poorly executed surveys can lead to significant consequences, including increased project costs, schedule delays, and operational risks due to undersized foundations. Ultimately, the paper highlights the benefits of adhering to standards and best practices in geotechnical investigations to ensure project success and asset durability.

**11067 Loadability and Magnetic Field Characteristics of Advanced 7-Phase Overhead Conductors** This paper examines the "7-Phases" overhead line, a new technology designed to increase power transmission capacity while minimizing environmental impact. The authors compare the performance of "7-Phases" towers with traditional double-circuit towers, focusing on primary constants, magnetic field emissions, and loadability. The goal is to demonstrate how "7-Phases" lines can effectively address the challenges of integrating renewable energy sources into the Italian power grid while adhering to strict electromagnetic field emission regulations.

**11069 The '5 Phases' OHL Towers for Refurbishing Existing Lines: First Installations and Experiences on 150 kV and 230 kV Backbones in Italy** This paper presents the "5 Phases" overhead transmission line technology developed by Terna, the Italian Transmission System Operator. This innovative approach utilizes a tower-over-tower reconstruction technique to upgrade existing lines, increasing capacity while minimizing environmental impact and visual intrusion. The paper details several ongoing projects implementing this technology, highlighting its benefits in reducing electromagnetic field emissions, mitigating corona effects, and enhancing grid reliability.

**11070 A Digital Architecture Toward an Integrated Job-Site Ecosystem for Overhead Lines Stringing** This paper presents a digital architecture designed to transform overhead line stringing job sites into more efficient and automated environments. The system utilizes IoT principles to connect machines, equipment, and operators in real-time, enabling improved coordination, reduced reliance on manual labor, and enhanced safety. Successfully tested in both simulated and real-world scenarios, this technology has reached TRL 8, signifying its readiness for full industrial implementation and paving the way for further advancements in intelligent automation within the energy sector.

**11152 Underpass options for 400 kV Overhead Lines in South Africa** This paper explores the need for alternative underpass structures in South Africa's 400 kV transmission lines due to limitations of existing substation gantries. The authors investigated steel pole underpasses and modified lattice terminal towers as potential solutions, considering cost-effectiveness and load capacity requirements. The paper presents case studies and lessons learned from implementing these alternative underpass designs.

**11313 The Investigation and Modelling of Vertically Installed Inter-Phase Spacers for the Enhancement of Clearance in Overhead Transmission Lines** This paper investigates the use of Inter-Phase Spacers (IPs) as a novel method to enhance vertical clearance in overhead transmission lines (OHTLs), particularly those with a vertical phase configuration. The authors propose installing

IPSS at predetermined intervals within spans to increase the distance between lower-phase conductors and the ground level, addressing clearance issues that may arise after construction or due to design errors. The study focuses on double-circuit OHTLs and utilizes theoretical analysis and international software modeling to evaluate the effectiveness of this method.

**11362 Overhead conductor with stranded multiwire composite core in aluminium sheath – IEC TS 62818 Arrhenius testing of resins** This paper investigates the thermal aging performance of two epoxy resin systems (Type A and Type B) used in carbon fiber composite conductors for overhead transmission lines. The study, conducted using Arrhenius testing, reveals that Type B resin exhibits superior durability at elevated temperatures compared to Type A, with delayed onset and slower progression of strength degradation. These findings suggest that Type B epoxy resin systems offer enhanced long-term thermal performance and reliability for high-temperature, low-sag overhead line applications.

**11439 Mechanical testing of a new “node-and-bolt-based” assembly system using a full-scale tubular lattice tower module** This paper investigates a novel "node-and-bolt-based" assembly system for tubular lattice towers, aiming to address the challenges of conventional angle-based designs in overhead line (OHL) infrastructure. A full-scale module was experimentally tested under simulated wind loads, demonstrating the structural feasibility of the proposed connection system and its ability to withstand demanding conditions. The results highlight the potential of this innovative approach for creating more cost-effective, compact, and visually integrated OHL structures.

**11615 Monitoring of Overhead Lines Using Embedded Optical Fibers for Capacity Optimization, Line Awareness, and Determining Maintenance Schedules** This paper presents a novel system for monitoring overhead power lines using embedded optical fibers within the conductor. The system utilizes BOTDR and DAS to provide continuous, meter-scale measurements of temperature, strain, and vibration, enabling real-time insights into line condition and performance. By integrating these measurements with AI forecasting and cloud-native analytics, the system supports proactive asset management, capacity optimization, and wildfire risk mitigation.

**11620 Static Line Uprating: In-situ Modification of Overhead Conductor Properties for Continuous Capacity Enhancements and Synergy with Dynamic Line Ratings** This paper introduces Static Line Uprating (SLU) as a technology to enhance the capacity of overhead power lines by applying coatings that reduce solar absorption and increase thermal emissivity. SLU, combined with Dynamic Line Ratings (DLR), provides a hybrid approach to increase grid reliability and accommodate growing renewable energy integration. The authors demonstrate through a California Independent System Operator model that this combination significantly increases average line capacity and reduces instances where DLR falls below Static Line Ratings.

**11762 Artificial Intelligence Augmented Design for Electrical Transmission Line Towers** This paper proposes an AI-augmented design framework for electrical transmission line towers to address the challenges of grid modernization and workforce attrition. The framework utilizes generative design, machine learning surrogates, and reinforcement learning to optimize tower structures while reducing costs and design time. This AI-driven approach aims to enhance efficiency, knowledge retention, and ultimately contribute to a more sustainable and resilient electrical grid.

**11788 Study on New Compact Modular New Tensioning Equipment for Overhead Transmission Lines** This paper presents a new compact modular tensioning equipment developed by Korea Electric Power Corporation (KEPCO) for overhead transmission lines. The innovative design addresses the limitations of traditional engine pullers by reducing weight, enabling remote operation, and incorporating automatic tension control features. This new equipment enhances safety, construction quality, environmental sustainability, and economic efficiency in overhead transmission line construction.

**11901 Autonomous UAV-Based Thermal Inspection and AI-Powered Fault Detection for Overhead Power Lines** This paper presents a simulation framework for inspecting overhead power lines using a drone equipped with a thermal camera. The framework integrates drone flight control, thermal imaging, and path planning to enable autonomous inspection of power lines, considering factors like sensor noise and wind interference. The simulation results demonstrate the effectiveness of

the framework in accurately tracking the planned route and detecting abnormal temperature areas on power line components, highlighting the potential of drones for safer and more efficient maintenance compared to traditional methods.

**11904 EHV AC Earth Switch Induced Current Capability Using Frequency Domain Approach**

This paper presents a frequency-domain approach for calculating induced current duties in high-speed earthing switches used in extra-high-voltage (EHV) AC systems. The method accurately models electromagnetic and electrostatic coupling effects, soil influence, and distributed earthing paths, providing more precise results than conventional EMTP simulation tools. The study highlights that conductor phasing and sequence significantly impact induced current levels, while earthing parameters have a negligible effect on phase coupling.

**12037 Joint Optimization of Overhead Conductors and Structures Using Artificial Intelligence, Genetic Algorithms, and Robotic Automation**

This paper presents a novel methodology for optimizing overhead conductors in power transmission systems by integrating artificial intelligence (AI), genetic algorithms, and robotic automation. The proposed approach overcomes the computational challenges of traditional joint optimization methods by using AI to predict tower weight and catenary behavior based on conductor and structure parameters. This hybrid methodology significantly reduces design time while enabling a more refined technical-economic choice for planners.

**12042 Predictive Analytics for Vegetation Management within Power Derived from Data Collected during Pruning Activities: A Strategy Approach to Enhancing Sustainability and Operational Efficiency in the Energy Sector**

This paper presents a predictive analytics tool designed to optimize vegetation management in electricity distribution networks. The tool utilizes geospatial data, species-specific growth rates, and historical pruning records to forecast vegetation encroachment and prioritize maintenance activities. By enabling proactive intervention and efficient resource allocation, the system aims to reduce service interruptions, enhance operational efficiency, and improve sustainability in the energy sector.

**12044 HVDC–HVAC Hybrid Transmission Corridors: A Feasible Option for Transmission Expansion in Colombia**

This paper investigates the feasibility of using hybrid HVDC-HVAC transmission corridors to address Colombia's growing electricity demand and limitations on expanding traditional transmission infrastructure. The study focuses on quantifying and mitigating electromagnetic coupling phenomena that arise from coexisting AC and DC conductors within a shared right-of-way. The authors conclude that hybridization is technically feasible and potentially cost-effective, offering a sustainable solution for increasing transmission capacity in Colombia while minimizing environmental impact.

**12157 Solution to OPGW Cable Breakage Due to Lightning Strikes in Transmission Lines: Technical and Economic Evaluation of Alternatives**

This paper presents a solution to mitigate OPGW cable breakage caused by lightning strikes on two newly commissioned 500 kV transmission lines in Colombia. Due to high costs associated with traditional replacement methods, an innovative approach was implemented involving shielding the existing OPGW cable with an additional Alumoweld wire acting as a sacrificial element against lightning strikes. This cost-effective solution minimizes service interruptions and enhances both telecommunications reliability and electricity supply stability.

**12203 Load Transfer and Weight Analysis of Angular and Tubular Profile Towers in Transmission Lines for Large-Span Crossings**

This paper investigates the structural performance and weight efficiency of angular and tubular profile towers used in 500 kV double-circuit transmission lines, particularly for large-span crossings common in challenging Colombian terrains. The study utilizes advanced modeling software and adheres to international standards to compare both tower types under identical design conditions, revealing that tubular towers significantly reduce overall weight (38.69%) and foundation loads while maintaining structural integrity. Despite the advantages, the paper also highlights challenges for implementing tubular towers in Colombia due to limited manufacturing capacity, standardized methods, and local experience.

**12229 Artificial Intelligence Augmented Transmission Line Design** This paper explores how Artificial Intelligence (AI) can revolutionize the design of high-voltage transmission lines, moving from traditional Computer-Aided Design (CAD) to AI-Augmented Design (AAD). The authors examine AI applications in various stages of transmission line design, including routing, micrositeing, structural design, and conductor selection, highlighting the potential for increased efficiency and resilience. The paper also discusses challenges such as data quality and model interpretability while emphasizing AI's role in bridging workforce skills gaps and enabling a "Generative Grid" optimized for both cost and resilience.

**12232 Modernization of Overhead Lines in Kosovo: Challenges, Technologies and Future Directions** This paper examines the modernization of overhead distribution lines in Kosovo, highlighting the need to address aging infrastructure and enhance reliability. The authors discuss various modernization strategies, including the use of advanced conductors and digital technologies like SCADA and IoT sensors for real-time monitoring. The paper concludes by emphasizing the importance of investment prioritization, regulatory frameworks, and workforce training to ensure successful implementation and long-term sustainability of these modernization efforts.

**12338 Validation of a Dynamic Line Rating Methodology across Different Topographies with Integration of a Global Radiation Profile** This paper investigates the impact of topography on Dynamic Line Rating (DLR) methodology by analyzing two representative transmission lines in Germany – one in mountainous terrain and another in flat terrain. The study found that incorporating a global radiation profile into the DLR calculation significantly increases ampacity, especially during nighttime and winter periods, while maintaining conductor temperature within safe limits. Although this enhanced approach carries a higher risk of overestimating ampacity, the analysis suggests it can be safely implemented with ongoing verification measures.

**12426 FlexiBL A new temporary tower solution for use in the 110-kV grid of Deutsche Bahn** This paper presents the "FlexiBL" project, a new temporary tower system designed by DB Energie GmbH to address the challenges of maintaining and modernizing their 110-kV power grid. The FlexiBL system is modular, standardized, and installation-friendly, aiming to be flexible, rapidly deployable, safe, and minimize environmental impact. This innovative solution was developed to meet the increasing demand for temporary overhead line tower systems in DB's complex and extensive railway power network.

**12444 A new catenary system for safe and efficient crossing protection** This paper presents a novel catenary system designed to enhance safety and efficiency during overhead power line stringing operations, particularly when crossing sensitive infrastructure. The authors address shortcomings in existing systems by focusing on improved roller block design, suspension rope characteristics, and field-proven operational behavior. This innovative catenary system aims to reduce costs, save time, and minimize disruption while ensuring the safety of workers and surrounding structures during construction and maintenance activities.

**12490 Enhancing Grid Performance: Implementing Dynamic Line Rating on Transmission Systems** This paper presents a Dynamic Line Rating (DLR) system designed to increase the transmission capacity of overhead lines in real-time and during planning processes. The DLR architecture utilizes meteorological data from on-tower sensors, orographic buffers, and thermal conductor models to determine safe current ratings, while also incorporating neural networks trained on historical weather data for improved forecasting accuracy. The authors demonstrate the effectiveness of their system through an example 380 kV circuit, achieving a potential ampacity increase of approximately 40% in real-time operation and 30% in planning processes.

**12503 Application of Lightning Monitoring System in Beijing Distribution Network** This paper presents a new-generation lightning monitoring system implemented in Beijing's distribution network to address the significant impact of lightning-caused faults. The system utilizes digital lightning detection technology to accurately analyze and locate lightning-induced faults, enabling rapid diagnosis and targeted preventive measures. Furthermore, the system generates ground flash density maps that guide operational units in implementing differentiated lightning protection strategies based on regional lightning activity patterns.

**12611 Characteristics and Application of Multi-Function Conductors** This paper presents a new type of multi-function conductor designed to mitigate snow accretion on overhead transmission lines, a common problem in Japan. The conductor features a unique combination of uneven and smooth wire strands that reduce both snow accumulation and wind pressure compared to standard conductors. Field testing is currently underway to evaluate the performance of this innovative conductor in real-world conditions.

**12619 Feasibility of Horizontal-Vee Insulator Configurations for Overhead Lines in Undulating Terrain** This paper investigates the stability of Horizontal-Vee (H-Vee) insulators mounted on steel poles in undulating terrain using a two-stage modeling approach. The study found that the Axis of Rotation (AoR) inclination significantly affects H-Vee stability, with inclinations of 15° or less leading to snap-through and inclinations of 25–30° providing self-restoration capacity. The research identifies practical stability thresholds for H-Vees in flat terrain and undulating landscapes, contributing valuable insights for the design of overhead lines incorporating this insulator configuration.

## Paper Summaries

### Preferential Subject 2 Health Assessment and Refurbishment of OHL

**10120 Use of Fiber Reinforced Polymer (FRP) membranes for reinforcement and structural restoration of 70kV concrete poles** evaluates the use of advanced composite systems (ACS) to rehabilitate aging 70 kV concrete transmission poles as a cost-effective alternative to traditional replacement. It demonstrates that ACS can restore structural capacity, improve durability, and extend service life without requiring outages, based on combined structural modeling, laboratory testing, and field applications. The study also highlights practical installation considerations and confirms that ACS can be deployed efficiently under live-line conditions. Economic analysis shows significant cost savings and reduced environmental impact compared to replacement, supporting ACS as a practical, sustainable solution for enhancing grid reliability and optimizing asset management.

**10136 AI-Powered 3D Data Fusion System for Vegetation Risk Assessment in Distribution Networks** presents an AI-driven framework for managing vegetation-related outage risk using LiDAR data, replacing traditional manual inspections and fixed trimming cycles. It uses deep learning to classify objects and extract tree-level attributes, then applies a risk-scoring method to prioritize mitigation based on proximity to power lines and other factors. The approach integrates with existing utility workflows and provides a scalable, data-driven solution for improving reliability in distribution networks.

**10229 Evaluation, Analysis, and Recommendation of Acceptance Criteria to Determine Ageing on Composite Core Conductors Utilizing the Arrhenius Method** evaluates the long-term thermal durability of carbon fiber composite (CFC) conductor cores using Arrhenius-based testing per IEC standards. Results from up to 12,000 hours of exposure show that at 180°C, CFC cores can achieve a service life of roughly 80 years, depending on strength-retention criteria. The study recommends using the conservative 90% original tensile strength threshold for reliability and demonstrates that the Arrhenius approach can also estimate safe durations under emergency operating temperatures, supporting better asset management decisions.

**10290 Monitoring of overhead lines using the optical fiber in OPGW** presents the use of Distributed Acoustic Sensing (DAS) on Optical Ground Wire (OPGW) to support Dynamic Line Rating (DLR) by estimating wind speed from measured mechanical strain. The study shows that combining DAS-derived wind data with wind profile modeling and terrain information can produce reliable inputs for DLR calculations. Despite challenges from terrain and modeling assumptions, results align well with conventional sensor measurements, demonstrating that DAS is a feasible distributed solution for wind monitoring in transmission systems.

**10376 Innovative Mechanized Stringing Method for Manual Sections in Transmission Lines Reducing Manpower, Enhancing Safety, and Improving Efficiency** presents a ground-based mechanized stringing method for challenging “manual sections” of 765 kV double-circuit transmission

lines, where conventional tension stringing is not feasible due to terrain and access constraints. The approach shifts key operations—such as tensioning, sagging, and bundle assembly—from tower tops to ground level, using controlled lifting systems to minimize work at height. Feasibility analysis confirms that loads and tensions remain within equipment and structural limits, while field comparisons show significant improvements, including ~60% reduction in manpower, faster execution, and enhanced safety. Overall, the method provides a practical, efficient, and scalable alternative for modern high-voltage line construction.

**10379 Risk Mitigation and Condition Assessment of Corrosion in Tower Structures of High Voltage Transmission Lines** proposes a ground-based mechanized stringing method for challenging sections of 765 kV double-circuit transmission lines where conventional equipment cannot be used. By moving key activities—such as sagging, tensioning, and bundle assembly—to ground level and using controlled lifting systems, the method minimizes tower-top work. Technical analysis confirms feasibility within equipment limits, while comparisons show major benefits, including ~60% manpower reduction, faster construction, and improved safety. The approach is scalable and adaptable, offering a practical and efficient solution for stringing in complex terrains.

**10382 Enabling Proactive Overhead Line Management Through Monitoring, Predictive Maintenance, and Digital Twins** introduces a hybrid Digital Twin approach for transmission line asset management that integrates real-time sensor data, AI-based predictive maintenance, and a virtual 3D replica. The system enables continuous monitoring, early fault detection, and optimized maintenance planning, validated through an interactive dashboard. Overall, it enhances grid reliability, operational efficiency, and supports digitalization goals.

**10383 Reliability-Centred Maintenance in POWERGRID: A Strategic Approach for Enhancing Transmission Line Performance and Grid Reliability** presents a Reliability-Centred Maintenance (RCM) framework for large-scale transmission line networks, designed to replace traditional time-based inspections with a risk-based approach. By evaluating the probability and impact of failure, the framework prioritizes inspection and maintenance across over 278,000 towers using a severity index and risk matrix classification. It also incorporates seasonal and environmental factors to ensure adequate coverage. The results show improved inspection efficiency, better resource allocation, reduced outages, and enhanced overall grid reliability and resilience.

**10704 Range of studies – asset management for aged foundations** examines how the French TSO is evaluating whether to reuse, reinforce, or replace aging transmission line foundations as many assets approach 85 years of service. Studies show that foundation failures are relatively rare (0.2–1%), but about 10% of sampled foundations exhibit weaker-than-expected strength due to environmental degradation. The research also identifies high-risk conditions and develops three reinforcement solutions to extend foundation life. Overall, the findings support a risk-based approach, indicating that foundations are generally not the primary failure mode and can often be safely reused or strengthened.

**10708 Optimizing surveillance activities with AI solutions** examines how AI, machine learning, and computer vision can improve transmission line inspection and maintenance. It shows that techniques such as CNNs enable automated asset identification and anomaly detection, increasing inspection accuracy and efficiency. The study outlines a structured strategy—from defining business needs and validating prototypes to scaling solutions through partnerships and cloud infrastructure—demonstrating that AI-driven inspections can support more reliable, data-driven asset management.

**10711 Estimating reliability functions of overhead conductors based on experimental fatigue data** introduces a stochastic model for fatigue behavior of overhead conductors using a combination of the Negative Binomial Distribution and Markov chains. The approach captures variability in experimental data through just two parameters, allowing the prediction of probabilistic survival laws under both constant and variable loading conditions. Validated with aluminum conductor data, the method provides a practical tool for asset management and risk analysis, especially when field data is limited.

**10809 Leveraging AI, Video, and GPS for Distribution Inspections** presents an AI-assisted, vehicle-based inspection method for distribution networks that replaces labor-intensive manual patrols. By using cameras and GPS on standard vehicles, the system automatically detects poles,



estimates their locations, and identifies defects through AI models, with a human-in-the-loop review for validation. The approach improves safety, reduces costs, and enables faster, scalable inspections compared to traditional methods.

**10831 Developing Drone-Based AI for Defect Detection in Transmission Tower Bolts-and-Nuts**

describes the use of drone-based inspections combined with AI to detect defects such as missing or loose bolts on transmission towers in Japan. The AI analyzes high-resolution images taken from multiple angles and achieves about 90% detection accuracy, significantly reducing the need for manual inspection. By automating image verification, the approach can save several hours per tower, lower costs, and improve efficiency, while ongoing improvements focus on handling image-quality limitations and automating report generation.

**11017 Digital Twin Implementation for Data-Driven Planning and Assembly of 525 kV**

**Transmission Towers in Brazil** presents the use of a Digital Twin (DT) and BIM-based approach to improve planning and execution of a complex 525 kV transmission line project. By creating a detailed 3D digital replica, the system enables efficient component management, automated bill of materials generation, and improved logistics and assembly planning. Real-time data integration across construction stages enhances traceability, reduces errors, and supports safer operations. Overall, the approach increases productivity, reduces rework, and shortens project timelines, demonstrating the value of digitalization in transmission line construction.

**11020 Evaluation of Failures Due to Slippage of Preformed Splices** investigates the causes of splice slippage in AAAC 838 conductors used in 500 kV lines, based on multiple failure incidents in Brazil. The study identifies that the issue resulted from a combination of factors, including inadequate splice design (leading to a “tube effect” that reduces gripping force), improper installation practices such as passing splices through tensioners, and incorrect field assembly. Overall, the findings highlight the importance of proper design selection, installation procedures, and quality control to prevent such failures.

**11071 Monitoring of Advanced Composite Core HTLS Conductors with distributed sensing** investigates an advanced HTLS conductor with integrated distributed sensing to monitor real operating conditions. Using embedded optical fibers and Brillouin-based temperature sensing, the study demonstrates accurate, continuous measurement of core temperatures during operation. The results confirm that this approach provides valuable insight into thermal behavior, supporting improved maintenance planning and better assessment of long-term performance of composite-core conductors.

**11096 Automating electrical grid asset inspections: improving insulators health assessment with Region-Level annotations** evaluates the use of region-level annotations to improve AI-based visual inspection of transmission assets. It shows that richer, more detailed labeling of defects enables deep learning models to achieve better accuracy, reduced data requirements, and faster training compared to conventional annotations. The results highlight that enhanced annotation strategies can significantly improve automated inspection efficiency, while also introducing some practical challenges.

**11214 DLR-Based Reassessment of Continuous Current-Carrying Capacity for Improved RES Integration in Legacy HV Networks** proposes a clearance-based static line rating (CB-SLR) method that uses long-term Dynamic Line Rating (DLR) data and clearance limits instead of fixed temperature assumptions. By incorporating weather conditions, conductor behavior, and a risk-based framework, the approach provides more realistic ampacity limits. Validation on Polish 110 kV lines shows that traditional ratings can be overly conservative or insufficient, while CB-SLR better utilizes existing capacity and supports renewable integration while maintaining safety margins.

**11371 Service experience with composite insulators in Danish OHL** examines failures of composite insulators identified through field inspections and testing, revealing a gap between updated IEC standards and actual service performance. It highlights common quality issues leading to hotspots and failures, and recommends improvements in insulator specifications, manufacturing quality control, and standards to better align with real-world conditions and prevent similar issues.

**11440 Condition Monitoring of Composite Insulators: A Machine Learning Based Investigation at Martigues Test Station** investigates leakage current behavior of composite insulators under polluted conditions using long-term field data and machine learning. It shows that electrical activity is driven by specific combinations of environmental factors—such as wetting and pollution transport—rather than single parameters. The study demonstrates that data-driven analysis provides a more accurate and physically meaningful approach to condition monitoring and performance assessment of insulators in real service conditions.

**11552 Corrective maintenance of OHL equipped by composite insulators** summarizes a large European R&D project developing condition-based maintenance guidelines for composite insulators. It establishes standardized methods for collecting service data, identifies key diagnostic tools (IR, UV, and visual inspection), and correlates long-term field performance with laboratory testing of aged insulators. The result is a practical maintenance guide to support optimized corrective actions and improved asset reliability.

**11583 Experimental Study and Signal Analysis of Acoustic Emission from Typical Damages of Strain Clamps for Transmission Lines** presents an acoustic emission (AE)–based method for detecting damage in strain clamps used in transmission lines. By analyzing signal characteristics such as frequency, energy, and RMS values, the study distinguishes between under-crimping, over-crimping, and cracked states. A neural network model is developed for automated damage identification, achieving good overall accuracy (~83%), demonstrating the feasibility of AE techniques for condition monitoring and fault detection in critical line components.

**11586 On-Site Infrared Detection Methodology for Abnormal Temperature Rise in Composite Insulators of High-Voltage Transmission Lines** analyzes how measurement distance and spatial resolution affect drone-based infrared inspection of composite insulators. It shows that greater distances reduce image quality and temperature accuracy, while different defect types require varying stabilization times for reliable detection. The paper provides recommended distance limits based on camera resolution and introduces a practical method to control inspection distance, offering guidance to optimize and standardize UAV infrared inspection practices.

**11628 Footing Resistance Design for Reliable OHL Lightning and Fault Protection** presents a performance-based methodology for optimizing footing resistance in medium-voltage overhead lines to improve lightning resilience. By combining probabilistic lightning analysis with electromagnetic transient simulations, it shows that poor grounding—especially high footing resistance—can drive repeated failures even when traditional protection is correctly designed. Treating footing resistance as a key design parameter, rather than a fixed requirement, is shown to reduce misdiagnosis, improve reliability, and enhance overall system performance.

**11872 Vibration monitoring of all phases on Hjørundfjorden fjord crossing – measured differences between phases** investigates aeolian vibration on a long fjord crossing and shows that vibration behavior can differ significantly between phases, even with identical conductor and damping designs. Field monitoring revealed that wind direction and terrain effects strongly influence high-energy events, and that adding dampers does not fully eliminate phase differences. The study highlights the need for full-phase monitoring to better understand complex vibration mechanisms and improve mitigation strategies.

**12030 Aging and Reliability of Porcelain Longrod Insulators: Insights from Statistical Modeling and Acoustic Analysis**

**12075 Field Monitoring of Leakage Currents in Overhead Transmission Lines for Condition-Based Insulator Maintenance** evaluates impulse-excited acoustic resonance testing as a non-destructive method for assessing the strength of porcelain insulators. While the technique is fast, repeatable, and effective for detecting material variations, the study finds no reliable correlation between acoustic measurements and actual mechanical strength. This limitation arises because resonance reflects bulk properties, not microscopic defects that govern failure. The paper concludes that although useful for quality screening, acoustic testing alone cannot predict residual strength, and more advanced techniques are needed.

**12125 Performance Analysis of 500 kV Transmission Lines Under Lightning Strokes Considering the Influence of Various Environmental Conditions and the Effect of Terrain Slopes in Colombia** evaluates the performance of high-voltage transmission lines in Colombia under extreme lightning and environmental conditions, which differ significantly from standard assumptions. Using site-specific data and sensitivity analyses, it shows that high lightning density, complex terrain, and long spans strongly influence line reliability. The study recommends tailored modeling and design approaches, including improved shielding strategies, to enhance resilience and support reliable integration of renewable energy.

**12186 Circular Economy Applied to Power Grid Rerouting Projects: Maximizing Financial and Environmental Value at ISA INTERCOLOMBIA** presents a circular economy approach for transmission line rerouting by reusing existing steel towers instead of procuring new ones. Through structural evaluation and redesign, the method proved technically viable and delivered significant benefits, including 60% reduction in new tower purchases, cost savings, lower carbon emissions, and faster project execution. Overall, the approach demonstrates a sustainable and efficient strategy to enhance infrastructure resilience while supporting economic and environmental goals.

**12276 Modern Approach to Condition Evaluation of Composite Insulator in Service** reviews current methods for evaluating the condition of composite insulators and identifies gaps between existing CIGRE guidelines and newer diagnostic techniques. It proposes additional tests—such as leakage current, hydrophobicity measurement, interface integrity, and sealing evaluation—to enable a more comprehensive, condition-based assessment. The study introduces a holistic classification system with six condition levels, supported by reference material “fingerprints,” and emphasizes the need for continuous monitoring. A case study demonstrates the approach on insulators after long-term service, highlighting its practical application for improved asset management.

**12312 In-House Developed Automated Fault Analysis with Multi-Collaboration of Asset Information System** presents the Automated Fault Analysis (AFA) system developed by TNB to improve transmission line fault diagnostics. By integrating real-time grid data and using two-ended fault location methods, AFA significantly enhances accuracy compared to traditional manual approaches. The system provides automated outputs such as fault location, lightning validation, phase identification, and equipment performance analysis, enabling faster and more informed decision-making. Overall, AFA reduces diagnostic time, improves operational efficiency, and supports modern, data-driven grid management.

**12324 Improved Technical Requirements for Potential Refurbishment on Tower Earthing Systems for Inundated-prone Areas** investigates corrosion and degradation of tower earthing systems in flood-prone areas and evaluates mitigation strategies to improve reliability. Laboratory testing of different earthing materials shows varying corrosion rates and lifespans depending on soil conditions. The study finds that enhanced solutions—such as improved galvanization, use of copper-based materials, and protective encapsulation—can significantly extend service life. Overall, it provides practical recommendations to reduce maintenance costs, improve durability, and strengthen grounding system performance in challenging environments.

**12348 New Experiences with Load Transposition Tests on Composite Long Rod Insulators in Multiple Insulator Sets** reviews failures of porcelain long rod insulators caused by load transposition effects in multi-string configurations. It analyzes the failure mechanisms, influencing factors, and supporting field and laboratory evidence, and proposes design measures to mitigate uneven load distribution. The findings highlight the importance of proper mechanical design to prevent unintended stress and improve the reliability of insulator strings.

**12368 Effects of Conductor Temperature and Conductor Angle on Icing of Overhead Power Line Conductors During Atmospheric Icing Events** improves the probabilistic modeling of ice accretion on transmission lines by refining key parameters such as collision efficiency, inflow angle, and conductor temperature. Field and laboratory results show that existing models underestimate ice accumulation, that accretion is less sensitive to wind angle than assumed, and that icing only begins below 0°C before becoming thermally independent. Overall, the updated approach enables more

accurate ice-load predictions, supporting better design decisions and improved reliability of transmission infrastructure.

**12370 Systematic Comprehensive Diagnostics of Transmission Line Tower Earthing in Czech Republic** presents a large-scale monitoring program of tower grounding performance across more than 13,000 transmission towers to support reliability and safety. By regularly measuring parameters such as footing resistance and soil resistivity, and applying statistical analysis, the study identifies key correlations—especially between soil conditions and grounding behavior—and creates characteristic “fingerprints” for each line. The results enable improved condition assessment, maintenance planning, and lifetime estimation of transmission line grounding systems.

**12477 Comparison of the dielectric performance of polluted composite insulators under AC and DC stress using the rapid flash over method** investigates the use of rapid flashover testing to compare AC and DC pollution performance of composite insulators for asset management purposes. It shows that traditional testing methods are limited, and the IEC rapid flashover approach enables consistent evaluation using a single test object under controlled pollution conditions. Experimental results reveal differences in flashover behavior between AC and DC stresses, highlighting the need to adapt assessment methods and support a unified asset classification for insulators in mixed AC/DC systems.

**12504 Satellite-Based Transmission Line Operation and Maintenance Method: A Novel Practice in China** presents a multi-technology corridor management system that integrates satellite imagery, UAV inspections, and tower-mounted cameras to monitor transmission lines. Using AI techniques such as Vision Transformers and cross-scale image matching, the system overcomes differences in data sources to enable accurate asset detection and tracking. Applied over more than 15,000 km of lines, the approach significantly improves inspection efficiency and reduces maintenance effort.

**12505 Research on 3D point cloud modeling and evaluation technology for transmission lines and corridor environments** presents a LiDAR-based approach for intelligent inspection and digital management of transmission lines using high-resolution point cloud data. An improved PointTransformer model is developed to classify assets with high accuracy, achieving over 90% overall accuracy and 99% for conductors. The study also enables 3D reconstruction and digital representation of key components, supporting scalable, data-driven monitoring across various voltage levels.

**12558 Non-destructive condition assessment of utility wood pole assets, with severity of decay measurement capability, a more reliable enabler for life extension and refurbishment optimisation** compares traditional inspection methods with an ultrasound-based non-destructive evaluation (NDE) approach for detecting decay in wooden utility poles. It shows that conventional methods cannot reliably detect early or incipient decay, while ultrasound technology can identify all stages without damaging the pole. Early detection enables timely treatment, extended service life, and improved asset management, making the NDE method a more effective and data-driven solution.

**12606 Non-Destructive Testing Techniques for Condition Assessment of Reinforced Concrete Overhead Transmission Foundations** presents a non-destructive testing (NDT) framework for assessing the condition of buried transmission line foundations, which are difficult to inspect directly. By combining methods such as visual inspection, rebound hammer, ultrasonic testing, ground-penetrating radar, and SONREB analysis, the approach enables a more reliable evaluation of structural integrity under varying soil and environmental conditions. A case study demonstrates how the framework reduces uncertainty in refurbishment decisions and supports safer, more effective life extension of overhead line foundations.

## Paper Summaries

### Preferential Subject 3 Sustainability and Climate change impacts (with C3)

**10291 Changing Ice and Wet Snow Loads on Conductors of Overhead Lines (OHLs) in the Netherlands in relation to climate change** reassesses ice and wet snow loads on Dutch overhead

lines using updated KNMI data, finding current standards, based on older empirical methods and regional zoning, are conservative and outdated. Analysis of 30–50 years of weather data shows limited regional variation, supporting a single nationwide ice load lower than existing design values, while climate change may further reduce icing frequency. Wet snow can cause rare but significant loads (~20 N/m) and should be treated as an accidental load case, with continued consideration due to uncertainty in extreme events.

**10292 Study Impact Downburst Events on Overhead Lines (OHLs) in the Netherlands in Relation to Climate Change** shows that downbursts are an emerging climate-driven threat to Dutch overhead lines, producing localized extreme winds beyond current EN 50341 design assumptions and increasingly causing failures, especially in older 110–150 kV assets. Climate models indicate warming of +1.5–2°C could raise downburst intensity by 10–15% and frequency by 3–5×, highlighting the need to update design standards, include extreme wind cases, and improve resilience and response planning.

**10346 Environmental life cycle analysis of overhead transmission lines: Metallurgical considerations and sustainability impacts** assesses the life cycle impacts of overhead transmission lines, showing aluminium dominates embodied carbon and that AAAC conductors can reduce steel use despite similar upfront emissions, with regional energy sources strongly affecting results. It finds operational losses are the largest lifetime impact, with AAAC reducing losses by ~9% compared to ACSR, delivering significant CO<sub>2</sub> and cost savings. Overall, optimising conductor choice, using low-carbon materials, and applying lifecycle design can cut emissions by 5–20% and support more sustainable transmission systems.

**10405 Impact and Strategies in Response to Climate Change and Extreme Weather Events on EHV Transmission Lines** highlights how climate change is intensifying extreme weather impacts on EHV transmission systems, threatening structural integrity and grid reliability, particularly in diverse climates like India. It shows that conventional design methods based on historical data are no longer sufficient, requiring a shift toward climate-resilient planning. The study proposes enhanced engineering designs, advanced monitoring tools, and proactive strategies to build a more reliable and future-ready transmission network.

**10406 From Poles to Planet: Life Cycle and Carbon Footprint of OHL Infrastructure with Environmental and Social Compliance** assesses the environmental, social, and carbon impacts of overhead transmission lines in India, identifying material production as the dominant source of emissions (65–80%), with 2,000–3,200 tCO<sub>2</sub>e/km. It highlights key challenges such as deforestation, biodiversity loss, and land-use conflicts, addressed through a structured mitigation hierarchy and advanced route optimisation. The study shows that engineering innovations and sustainability measures can reduce lifecycle emissions by 35–45% while enabling reliable and environmentally responsible grid expansion.

**10412 Sustainable Transmission Expansion in India: Innovative Approaches to Environmental and Social Compliance in Overhead Infrastructure Development** promotes a shift from compliance-driven development to sustainable, integrated planning for India's grid expansion toward 500 GW non-fossil capacity by 2030. It highlights GIS-based routing, corridor planning, and engineering innovations (e.g., monopoles, undergrounding, drones) to minimise environmental impact, land use, and project risks. The study shows transmission growth can align with biodiversity protection and fair land compensation through proactive planning, technology, and equitable policies.

**10413 Spatial Model for Prediction of the Vulnerable Towers Affected by River Meandering** presents a GIS-based model by POWERGRID (India) to identify transmission towers at risk from river meandering using multi-temporal satellite data. It maps tower locations against historical river movement and applies buffer zones to classify vulnerability and enable early risk detection. The approach improves asset management and grid reliability, offering a cost-effective, scalable solution with potential for future AI-driven enhancements.

**10773 Extreme weather incident experienced on 765 kV line in South Africa** examines the collapse of three 765 kV towers in South Africa after a severe October 2023 storm, ruling out corrosion, material defects, and installation issues. Field data and testing showed failures in guy wire fittings, while modelling indicated wind speeds (~36–37 m/s) exceeded the design limit (~32 m/s),

causing overload. The study concludes an extreme localized wind event led to collapse, highlighting the need to reassess design standards under changing climate conditions.

**10833 Preventive measures and post-event responses for volcanic ash deposition on transmission line insulators** assesses the impact of Mt. Fuji volcanic ash on transmission line insulators, showing that ash, especially when wet, significantly reduces flashover voltage before reaching a saturation point. It recommends designing insulation using worst-case degraded performance assumptions, with conservative inputs based on highly conductive ash characteristics. A combined strategy of targeted upgrades and effective post-event cleaning is proposed to maintain system reliability during volcanic ash events.

**10872 Climate Challenges in Power Transmission: A case study of the 500 kV Line in Brazil** analyses how climate change is increasing vulnerability of Brazilian transmission systems, with extreme weather causing outages, damage, and operational challenges on a 500 kV case study line. Key risks include lightning, strong winds, wildfires, and soil instability, driving the need for improved design and resilience measures. The study highlights solutions such as reinforced structures, better grounding, wildfire management, and advanced monitoring to ensure reliable future transmission networks.

**10929 Quantifying the Probability of Avian Electrocutation on Overhead Transmission and Distribution Structures** presents a probabilistic framework using Monte Carlo simulation to assess avian electrocution risk on transmission structures based on bird interaction geometry and design parameters. It shows that increasing conductor spacing can significantly reduce risk, with effectiveness varying by scenario, supporting targeted and cost-effective mitigation. The model aids utility decision-making but requires further refinement to include ecological and behavioural factors for full risk assessment.

**11363 Sustainable End-of-life for Advanced Composite Core Conductors** evaluates advanced conductors with CFRP cores, showing higher manufacturing impacts but improved performance through lower losses and greater capacity over their lifespan. Life cycle results indicate these operational benefits offset initial emissions, making them favourable for grid decarbonisation. Effective end-of-life recycling, especially mechanical and chemical methods, is key to maximising sustainability and supporting a circular economy.

**11588 Galloping Mechanism and Anti-Galloping Design of UHV Transmission Lines in Extreme Meteorological Environments** studies conductor galloping in UHV lines under extreme weather, using a nonlinear model to show how wind, icing, and span length drive severe vibrations and damage risks. It proposes optimised inter-phase spacer designs that significantly reduce galloping amplitudes and improve system stability. The findings demonstrate that tailored spacer configurations enhance reliability and resilience of UHV transmission under climate-driven conditions.

**11590 Research on susceptibility risk assessment and application of geological hazards in power grid** assesses geological hazard susceptibility across five southern Chinese provinces using a Random Forest model and over 50,000 hazard records. Results show strong spatial variability, with high-risk areas linked to elevation, steep terrain, river proximity, and human activity, with elevation as the most influential factor. High- and medium-risk zones contain most hazard sites, demonstrating accurate predictions and supporting targeted infrastructure planning and risk mitigation.

**11630 Naturally Aged RTV Sir Coatings in Harsh Desert Environment: Technical Approach & Estimation Procedure** reviews long-term ageing of RTV silicone rubber coatings on 400 kV insulators in harsh desert-marine environments, showing creepage-based design alone is inadequate. Field data (17+ years) demonstrates that insulator profile, coating strategy, and self-cleaning are critical, with open profiles and selective coating outperforming full coatings. Tan  $\delta$  diagnostics reveal strong correlation with ageing and performance, proving it a reliable non-destructive tool for condition-based maintenance and asset management.

**11754 A Novel Approach to Ice Detection on Power Lines Using Distributed Strain and Temperature Sensing (DSTS) with Field Test Validation** introduces a cost-effective method to detect ice on transmission lines using DSTS with BOTDR, comparing Brillouin Frequency Shift

(BFS) signals along OPGW cables. Field tests show BFS variability clearly indicates icing phases, distinguishing active icing, stable accumulation, and melting conditions. The approach enables long-distance, single-ended, and reliable real-time monitoring, offering a scalable solution for harsh environments.

**11757 Failure modelling of overhead lines exposed to worsening gradual and instantaneous weather hazards due to climate change** introduces a probabilistic SMCS (Sequential Monte Carlo Simulation) framework to model combined climate hazards on overhead conductors, linking thermal ageing and wind loading. Using UKCP18 data, it shows heat-driven annealing weakens conductors, increasing vulnerability during wind events. Results indicate electrical loading drives risk more than climate alone, though further model refinement is needed.

**11810 Climate Data for Overhead Line Resilience to extreme Events** explores how climate data can enhance the resilience of GB electricity overhead lines to climate change, stressing accurate projections and sector-specific temperature metrics. It shows that while extreme heat will increase, impacts on conductor degradation remain limited due to already high operating temperatures, and highlights the need for calibrated datasets like ERA5 and UKCP18. The study emphasises accounting for uncertainty and spatial variability using ensemble modelling and provides tools to support better infrastructure planning and climate resilience.

**11873 A novel approach to the assessment of extreme weather events related to icing** presents a method combining real-time measurements and atmospheric modelling to assess extreme icing loads on high-voltage transmission lines, demonstrated on a 420 kV line in Norway. By integrating field sensor data with weather and ice accretion models, it enables continuous monitoring, validation of design loads, and analysis of dynamic effects like galloping. Results show improved accuracy in load estimation and forecasts, highlighting the value of integrated approaches for enhancing resilience and reliability of power infrastructure.

**12009 Investigation of the future Development of Icing Events in relation to Climate Change in the Alpine Region of Austria** examines how climate change will affect ice loading on overhead lines in Austria's Alpine region using monitoring data and EURO-CORDEX climate scenarios. Results suggest icing frequency may not rise overall, but alpine areas will remain highly exposed, with longer events, higher loads, and a shift toward spring and autumn icing. The study highlights the need to combine climate modelling with real-time monitoring to improve grid resilience, design, and maintenance strategies.

**12124 Implementation of Digital Tools for the Application of the Technical-Environmental Methodology for Sustainability in Transmission Line Projects** introduces TASLT, a digital-supported methodology to optimise transmission line design by balancing technical, environmental, and economic factors, particularly in biodiversity-rich regions. It uses data such as vegetation growth, land cover, costs, and emissions to optimise tower placement and reduce environmental impact while improving lifecycle efficiency. Applied in projects in Colombia and Peru, it delivered reduced forest clearing, lower costs, and better coordination through automated, data-driven decision-making tools.

**12230 Climate-Driven Ampacity Analysis of High-Voltage Power Lines** examines how climate change is reducing ampacity and reliability of high-voltage lines in Central Europe, focusing on Hungary. Rising temperatures, changing wind, and solar radiation are projected to lower line ratings by ~5–10% by 2050, with increased variability and regional differences. It recommends regional rating zones and adopting dynamic line rating (DLR) to improve grid reliability and optimize performance under changing climate conditions.

**12246 Live cycle assessment of 110 kV power lines equipment** evaluates the life cycle environmental and GHG impacts of 110 kV overhead lines vs underground cables using a cradle-to-grave LCA per km. About 70% of emissions come from manufacturing and construction, while remaining impacts differ: operational losses dominate for overhead lines and end-of-life processes for underground cables. Key mitigation includes low-carbon materials, higher voltage, improved recycling, and optimized design, reducing emissions by up to ~50% (overhead) and ~30–37% (cables).



**12327 Experience in Assessing HTLS Carbon Composite Core Conductor on Field Trial While Adhering to Sustainability and Strategies to Response Climate Change Issues in Malaysia** highlights HTLS carbon composite conductors as a solution to upgrade existing transmission lines in Malaysia, increasing capacity, reducing losses, and supporting renewable integration without new corridors. They offer superior thermal performance, lighter weight, and lower sag compared to ACSR, improving efficiency and reducing emissions while enhancing reliability. Field trials confirm reliable performance in local conditions, with manageable challenges, making HTLS a strong option for a resilient, low-carbon grid.

**12364 Advances in Acoustic Modelling of Overhead Transmission Lines** presents a method to model and predict corona noise from high-voltage transmission lines, integrating traditional semi-empirical models with CNOSSOS-EU and ISO standards for realistic environmental noise mapping. The approach treats conductors as acoustic line sources and enables full spatial analysis, including mitigation assessment and both broadband and tonal noise components. Validation shows good accuracy, and case studies demonstrate that measures like larger conductor bundles can reduce noise by about 10 dB, supporting better planning and compliance.

**12424 Sustainable lattice towers for 380kV transmission lines** explores improving sustainability of 380 kV transmission towers by using higher-strength S460 steel and low-carbon “green steel.” S460 reduces tower weight and emissions by up to ~17%, though gains are limited by structural constraints like buckling. Green steel offers far greater CO<sub>2</sub> cuts (~70%), and combining both approaches provides the best long-term sustainability strategy.

**12491 The Effect of Ageing on Corona Discharge induced Audible Noise of Overhead Line Conductors** shows that corona-induced audible noise from HVAC conductors decreases with age, especially in early years, based on field and lab data (2013–2025). It introduces an “acoustic ageing function” and finds high variability between similar-aged conductors, driven largely by surface condition. Surface chemistry and contamination dominate noise behaviour, with treatments (e.g., plasma/flame cleaning) reducing noise by up to ~5 dB, highlighting the need for contamination control.

**12599 Evaluation of Downburst Impact in the Electric Reliability of Transmission Line Spans Through Numerical Analysis** analyses downbursts as localized wind events causing non-uniform, transient loads that challenge conventional transmission line design assumptions. It compares a fast semi-analytical method and a CFD–FEA approach, showing good agreement while significantly reducing computation time. Results indicate large conductor swings (~40°), clearance reductions (up to 65%), and significant longitudinal forces, highlighting the need for 3D analysis and improved design criteria.