SPECIAL REPORT FOR SC B1 – Insulated Cables

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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 !

PARTICIPATING IN THE 2026 PARIS SESSION

You are invited to participate in discussing this Special Report at the SC B1 session held on 28.08.2026 starting at 08:45 in Salle Bleue at the Palais de Congress de Paris.
The reporters have compiled 13 questions, these are not specifically aimed at the papers' authors, but are synthesised from common issues and trends identified in across the papers. This provides the opportunity for a broader response and participation in the discussion session.
We encourage you to share your views or experiences in response to the specific questions in this report. During the Group Discussion Meeting, each prepared contribution will be allocated a time slot of three to four minutes for a presentation.

Procedure for contributions.

1. Contributors should upload contributions on the registrations portal – "Contributions to Group Discussion Meetings" section - using your existing account and own credentials before 7th August 2026, for a prior screening and a good organization of the Group Discussion Meeting. Important points:
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 be open at start 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 pr contribution). A guide for contributors as well as templates and sample pages will be 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 date) to the SC Secretary (email address).
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. There will be a virtual meeting with for the contributors with SC Chairman, Secretary and Special Reporters on 18th or 20th August 2026. The purpose is to be given instructions and possibility to ask questions. Contributors will be sent invite to this online meeting.

KEY DATES FOR SC B1

Day	Date	Time	Room	Description
Monday	2026-06-29	EOB	N/A	Deadline for upload of Posters
Friday	2026-08-07	EOB	N/A	Deadline for submission of the prepared contributions
Friday	2026-08-14	EOB	N/A	Deadline for informing the contributors about the outcome of the review.
Tuesday or Thursday	2026-08-18 or 2026-08-20	15:30	N/A	Virtual contributors' meeting with SC Chairman, Secretary and Special Reporters
Friday	2026-08-21	EOB	N/A	Information regarding time slot for contribution for the GDM
Monday	2026-08-24	14:00– 15:50	TBD	Tutorial: TB 963 - Finite Element Analysis for Cable Rating Calculations
Thursday	2026-08-27	08:30 - 12:30	Halle Ternes	SC B1 Poster Session where all authors of the accepted papers are invited to present an e-poster. This is an opportunity to meet authors and discuss papers.
Friday	2026-08-28	08:45 – 12:30 & 14:00 – 18:00	Amphitheatre Bleue	SC B1 Group Discussion meeting. Prepared contributions and the Special Report will be presented and discussed.
Friday	2026-09-11	EOB	N/A	Deadline for submission of written spontaneous contributions.

Authors of SC B1 Session papers are required to present their papers during the **SC B1 Poster Session scheduled on 27th August** in Halle Ternes on level 1. Template and instructions on poster preparation are available on the CIGRE 2026 Session website. Posters will be displayed on digital screens. **Poster presentations must be uploaded on the ConfTool platform from 18th May by 29th June at the latest** for review by the poster session convener. Poster conveners may ask for a final version, incorporating any requested changes, must be uploaded by August **14th**. It should be noted that authors will **not** have the possibility to upload their own file on the day of the Poster Session. If the author(s) cannot attend the Poster Session he/she or the relevant National Committee is requested to send a substitute.

Thank you very much!

INTRODUCTION TO SC B1

Study Committee (SC) B1 is responsible for AC and DC insulated power cable systems for power transmission, distribution and generation connections on land and in submarine applications, as well as for power cable systems associated with micro-grids and the integration of distributed resources. Within its technical field of activity, Study Committee B1 addresses theory, design, application, manufacture, installation, testing, operation, maintenance and diagnostic techniques.

For the 2026 Group Discussion Meeting, three preferential subjects were proposed to stimulate discussion considering the strategic directions:

PS1 - Future cable systems and innovative cable applications
PS2 - Recent experience with AC and DC cables, both land and submarine
PS3 - Environmental impact and cable lifecycle

A total of 120 papers has been accepted and published.

PS1 - Future cable systems and innovative cable applications

- Cable systems challenges and solutions such as floating applications/deep water, meshed DC grids, overhead-line/substation interfaces.
- New developments on materials, design and construction challenges such as super-conducting solutions, hydrogen inclusion, high temperature / electric stress, very large conductors and cost effectiveness.
- Intelligence into cables. Integration of sensor technologies, real-time use of data, predictive maintenance, use of robotics, dynamic management of load demands, digital twins, data use for BIM implementation.

PS1 Paper summaries

10117	The Belgian TSO has developed a Universal Transition Joint (UTJ) to repair and modify its ageing and highly diverse fleet of 150 kV XLPE underground cables, more than half of which are now out of warranty. The UTJ provides a standardized solution compatible with cables from multiple manufacturers, conductor types, and screen designs, reducing dependence on numerous bespoke spare parts and suppliers. Its implementation cuts the number of unique repair components by a factor of ten and lowers strategic stock value by approximately 25%, significantly simplifying inventory and procurement management. The paper presents the operational need, tendering and qualification process, and the practical deployment of the UTJ as a strategic asset management innovation for high-voltage cable systems.
10281	The paper evaluates requirements for implementing superconducting (SC) cables in power grids. Compared with copper and aluminium, SC cables provide high current density, compact design, minimal magnetic fields, and narrow rights-of-way. They could reduce grid congestion, while MgB_2 cables additionally enable liquid hydrogen transport and energy storage.
10282	This study uses time-domain reflectometry to examine how temperature affects propagation speed in MVAC PILC cables. Experiments and field tests confirm a linear speed–temperature relationship, enabling accurate, non-intrusive real-time thermal monitoring of active networks with about 1°C resolution over extended periods.
10320	The paper presents a new 150 kV underground cable system using 4000 mm^2 aluminium Milliken conductors as a sustainable alternative to conventional copper cables. It evaluates technical performance, costs, environmental impact, and installation methods, showing the system is a scalable, reliable solution for expanding high-capacity transmission networks efficiently.

10325	This paper proposes an analytical method for accurately calculating current ratings of submarine power cables, including fully immersed and partially buried configurations. Unlike existing standards based on land cables, the method improves ampacity estimation, helping avoid cable oversizing and reducing offshore wind farm system costs.
10426	This 2026 CIGRE Reliability Advisory Group report analyzes service experience and failure data for AC/DC land and submarine cable systems above 36 kV from 2014–2023. Using ten years of operational data, including joints and terminations, it provides updated reliability estimates for high-voltage cable systems.
10678	This paper examines challenges of installing underground power cables in congested urban areas, where limited space and mutual cable heating reduce performance. It outlines collaborative civil and electrical engineering strategies, comparing construction methods and their impacts on cable ratings, permitting, costs, and infrastructure planning for growing urban energy demands.
10679	This paper describes and discusses the many challenges to XLPE retrofit applications for pipe-type cable and identifies a specific case study where a utility retrofit three existing 115kV pipe-type cable systems with XLPE-insulated cable.
10699	This paper presents the development of medium-voltage DC superconducting cables for offshore renewable energy transmission. Designed for up to 2 GW over 70 km, the system offers compact, low-loss, cost-effective alternatives to conventional HVDC, with industrial-scale manufacturing, validated accessories, and a planned 2026 demonstrator.
10701	This paper investigates distributed fibre optic sensing for monitoring dynamic offshore wind power cables. Experimental tests show that Distributed Acoustic Sensing detects dynamic motions effectively, while Distributed Strain Sensing captures slower loading changes. Together, they offer complementary capabilities for long-term condition monitoring of floating offshore wind cable systems.
10720	This paper analyzes high-temperature superconducting (HTS) power cables for data center interconnections using electromagnetic transient modelling (EMT). Simulations and experiments show HTS cables provide compact, low-impedance, high-capacity power delivery but experience short high-frequency transients, highlighting the importance of EMT analysis for reliable integration into data center infrastructure.
10728	To meet the scale and urgency of decarbonization, six European electricity Transmission System Operators gathered their knowledge and cable expertise to commonly write High Voltage technical reference documents, covering both HVAC and HVDC cable technologies. This paper presents the way of working, the main technical outcomes and compromises achieved to support more coordinated and efficient grid development across Europe.
10822	This paper presents 275 kV aluminum-conductor XLPE cables and connectors developed to replace oil-filled cables in Tokyo. The design reduces size and cost while maintaining performance. New compact connectors using cold spray technology demonstrated reliable operation, supporting planned practical deployment by 2030.
10823	This study develops a 500 kV DC submarine cable for 1500 m deep offshore wind applications in Japan. A prototype with double steel armour was tested for mechanical and electrical performance. Results confirm suitability for deepwater use and identify optimized flat-wire armour designs to improve safety and reduce costs.
10824	This paper demonstrates ultra-long-range monitoring of HVDC submarine cables using Distributed Acoustic Sensing (DAS) enhanced with remote optically pumped amplification (ROPA). The system enables continuous detection of external impacts like anchors and fishing gear over hundreds of kilometers, improving fault localization, vessel identification, and early warning capability.
10991	This paper presents a 245 kV HVAC dynamic submarine cable system for large-scale floating offshore wind. It addresses the need for higher-capacity transmission under complex mechanical loading conditions. The design includes advanced insulation, protective sheathing, and robust joints, validated through modelling and extensive mechanical, thermal, and electrical testing.

11146	This paper deals with theoretical analysis, development tests and official tests in accordance with IEC 62067, focused on the development and qualification of a 420 kV Dry-Type Outdoor Termination. Being the dry-type terminations not yet fully covered by the existing international and domestic standards, some additional special tests have been specifically defined and carried out to deep dive on the performance of such a new product.
11167	This article reviews design, manufacturing, and testing of a high-voltage transition joint connecting XLPE and oil-impregnated paper cables in high pressure fluid filled (HPFF) systems. It outlines technical requirements, CIGRE-based testing, design variants, and materials. A cable simulator was also developed to test early paper-wound stress cone prototypes.
11268	This paper studies the “zero-miss” phenomenon in offshore wind submarine cable energization with shunt reactors, where current zero crossings disappear, hindering breaker operation. Using electromagnetic transient simulations, it analyzes causes and proposes mitigation via controlled switching and sequential switching to improve protection reliability and system safety.
11341	This study examines recyclable polypropylene as a sustainable alternative to XLPE cable insulation. It investigates how catalyst residues affect AC dielectric performance. Results show that low-residue polypropylene reduces dielectric losses and improves breakdown strength and reliability, highlighting the importance of impurity control for eco-friendly, high-performance power cable insulation.
11366	This study evaluates subsea shunt reactors for reducing reactive power in offshore wind farm AC export cables. Simulations using PSCAD and PSS/E software show that distributing reactors along the cable improves transmission distance and power capacity more effectively than midpoint compensation, especially at higher voltages, while reducing offshore substation size and maintaining acceptable operating limits.
11368	This report investigates protecting buried HVDC cables from nearby lightning strikes using bare copper wires. Through 3D FEM simulations, electric field stresses on cable sheath insulation and crossing third-party cables were evaluated, concluding that the risk of damage, particularly to crossing cables, is low.
11380	This paper presents a passive optical-fibre-based system for online partial discharge monitoring in HV cables. The solution improves reliability by avoiding active field electronics, enabling long-distance signal transmission, AI-based defect detection and localization, and successful detection of PD signals as low as 10 pC in laboratory tests**.**
11407	This research develops a DC-optimized XLPE insulation material for HVDC cables with improved resistivity and reduced space charge accumulation. After optimizing polymer blends and crosslinking systems, the material successfully passed ±320 kV type testing as per CIGRE recommendations and showed potential for ±525 kV applications through predictive modelling.
11412	This paper presents the first deployment of an internal curvature sensor in a dynamic cable on a floating platform. Collected data on bending variations were compared with weather conditions, and statistical analysis was used to assess fatigue effects and support future cable lifetime predictions.
11513	This study developed a 110 kV torsion-resistant intelligent cable for deep-sea offshore wind power. The cable improves transmission capacity by over 60% compared to existing 66 kV cables, enhances fatigue life, integrates real-time monitoring, and withstands extreme torsion and thermal conditions, supporting reliable operation of high-capacity offshore wind turbines without booster platforms.
11705	This project modernized a UK transmission substation by replacing transformers and cables using a “Digital First” BIM-based design approach. Flexible cable systems reduced thermomechanical forces and steelwork requirements significantly, while reducing the amount of access required to the tunnel significantly.

11731	This study examines fatigue loads and insulation strain in dynamic HVDC cables for floating offshore platforms. Results from the developed tethered wave configurations show that the number of cycles deceases with increasing strain rrange, with maximum fatigue strain below 0.6%. The findings support ageing studies, operational design limits, and realistic full-scale testing of future dynamic HVDC cables.
11761	This paper presents the point-source method for calculating ampacity in complex underground cable systems. Compared with conventional approaches, the optimization-based method achieved the same results with significantly faster computation. Case studies confirmed accuracy and demonstrated the method's effectiveness for modelling crossings and multi-circuit installations.
11789	This paper proposes a simplified method to analyze arcing faults in cables, which are highly chaotic, dynamic and intermittent, and therefore difficult to model. By reducing arc voltage–current data into key scalar parameters, the approach enables clearer characterization of different arc stages, improving diagnosis and evaluation of breakdown behavior in cable components.
11812	This study combines distributed temperature sensing (DTS) and fibre Bragg grating (FBG) sensors to monitor a 66 kV subsea cable. Results show seasonal variations in hotspot locations, with terminations often hottest in summer. FBGs provide faster, more precise termination monitoring, enhancing real-time thermal rating and cable condition assessment.
11824	This paper reports successful type testing of a ±525 kV HVDC mass-impregnated cable system designed for installation at 3000 m water depth. The system is intended for the Great Sea Interconnector, a 1000 MW link between Crete and Cyprus, making it the world's deepest and one of the longest submarine cables.
11827	This paper proposes a J-tubeless submarine cable installation method for offshore wind farms to overcome biofouling and maintenance issues in conventional J-tubes. A polymer-based cable protection system replaces steel J-tubes. Fatigue and electrical tests confirm reliability, showing improved installation feasibility, reduced maintenance risk, and enhanced lifecycle performance.
11834	This study qualifies 132 kV wet-design XLPE submarine cables and factory joints for offshore applications. Test cables underwent long-term wet ageing and electrical stress testing under CIGRE TB 722 regimes. Results confirmed the suitability of the wet design XLPE cables and factory joints for dynamic and static high-voltage renewable energy cable systems.
11836	This paper presents a monitoring and predictive modelling framework for HV cable systems using fibre-optic sensing technologies including DTS, DAS, vibration, and PD detection. Applied in real HVDC/HVAC projects, the system enables real-time condition assessment. Results show that the integration of advanced sensor technologies combined with predictive modelling and secure edge infrastructure can improve reliability, lifetime prediction, and operational efficiency of XLPE cable networks.
11837	This paper presents a 3D scanning-based quality control method for HVDC cable installations, enabling high-resolution inspection of joint and termination surfaces. Analysis of approximately 100 site scans showed reliable differentiation between acceptable and defective work. The real-time feedback improves installation accuracy, traceability, and allows corrective actions before completion.
11838	Dynamic cable systems are critical for floating offshore wind farms but remain underdeveloped above 220 kV, with failures often linked to unanticipated dynamic loading. This paper highlights the need for robust technology qualification, favoring analysis-based approaches to assess mechanical reliability, especially in conductor components under complex dynamic conditions.
11844	This paper describes a hydrogen-cooled superconducting cable system under development in the EU SCARLET project. The system enables simultaneous transmission of electricity and liquid hydrogen, targeting 500 MW at 25 kV. Key components are being optimized and validated, with type testing planned for 2026 and field operation in 2027.

11845	This study investigates aluminium alloy conductors for wet-design HV cables in offshore applications, focusing on potential stress-induced electrochemical degradation (SIED). After up to 10 months of water exposure and thermal cycling or constant elevated temperated, corrosion was observed on strands, but no SIED occurred, supporting aluminium's suitability for cost-effective HV cable designs.
11846	This paper presents a real-time thermal rating (RTTR) method for HVAC submarine cables using distributed temperature sensing and a simplified thermal cable model. Applied to the Norwegian Fensfjorden cable, the model parameters are continuously adapted to environmental changes, resulting in ampacity improvements of 5–30% over static ratings, enabling more efficient use of existing infrastructure.
11848	This paper presents the development, qualification, and validation of a single-point bonding system for 3-core submarine cables to mitigate thermal constraints at offshore wind landfalls. The design employs a conductive PE sheath and electrode tape to suppress sheath losses. Results confirm reliable performance, model accuracy, and increased ampacity.
11849	This paper investigates the dielectric strength of HVDC cable-grade XLPE insulation under temporary overvoltages (TOVs) not covered by current testing standards. Experimental results show high withstand levels for defect-free samples, while contamination significantly reduces breakdown strength. No substantial dependence on TOV waveform characteristics was observed.
11902	This paper presents a 154 kV polypropylene-insulated cable system with higher thermal endurance and transmission capacity than conventional XLPE cables. The system successfully passed IEC 60840 qualification tests at 110 °C, enabling higher ampacity, reduced conductor size, and lower installation costs, demonstrating its suitability for future power transmission applications.
12007	This paper investigates the impact of polarity reversal on the dielectric strength and lifetime of HVDC cable insulation in LCC-based transmission systems.Experimental testing and Weibull analysis showed that high temperature and electric field are the most critical factors affecting insulation degradation. Slow polarity reversal caused slightly greater dielectric strength reduction than fast reversal under combined electro-thermal stress conditions.
12231	This paper investigates lightning-induced transient overvoltages in underground MV cable systems and their impact on cable sheath integrity and insulation lifetime. Simulation and laboratory results demonstrate that coordinated mitigation measures, including optimized cable design, conductive backfill, ducts, and shield wires, effectively reduce lightning-related risks in high-activity regions.
12398	This paper investigates transient behavior and operational challenges in 380 kV hybrid EHV transmission systems combining overhead lines and underground cables. Detailed simulations and field measurements were used to evaluate overvoltages, fault response, and switching effects under real operating conditions. The results support improved design, protection, and planning strategies for future hybrid transmission networks.
12401	This paper addresses quasi-stationary overvoltage conditions in VSC-based MTDC grids that exceed current HVDC cable qualification practices. A new operational voltage framework and 551 kV type test methodology are proposed to validate temporary operation above the rated 525 kV level without requiring insulation redesign. The results support alignment of HVDC cable qualification with future MTDC operational requirements.
12501	This paper presents the development and standardization of 750 kV XLPE insulated extra-high voltage cable systems for large-capacity power transmission applications. The study covers cable design, manufacturing, and qualification testing, including key advances in insulation extrusion and aluminum sheath technologies. Testing confirmed the system's electrical, mechanical, and long-term reliability for future smart grid deployment.
12570	This paper presents a fully coupled current rating model for dynamic offshore wind cables with corrugated metallic sheaths and double wire armouring. The approach combines electromagnetic, thermal, and CFD analysis to accurately assess losses and heat dissipation under operating conditions. The results identify design conditions enabling higher thermally compliant current ratings for optimized floating offshore wind cable systems.

12571	This paper investigates the thermoelectric performance of a novel 132 kV umbilical cable integrating power cores and stainless-steel hydrogen pipes for offshore wind applications. Coupled FEM and EMT analyses were used to evaluate electromagnetic, thermal, and fault performance under normal and contingency conditions. The results confirm a robust cable design enabled by high-quality semiconductive pipe coating materials.
12618	This paper investigates water tree initiation and propagation in 132 kV wet-design dynamic offshore wind cables under high electric stress and moisture exposure. Accelerated ageing tests on XLPE materials revealed strong material-dependent differences in water tree growth, morphology, and transition to electrical trees. Results show that insulation microstructure critically affects long-term reliability, with elevated stress accelerating degradation in wet operating conditions.

PS1 Discussion

The contributions under PS1 reflect a rapid evolution of high-voltage cable systems driven by the energy transition, particularly the expansion of offshore renewable energy, increasing urbanization, and the need for higher transmission capacity and improved system flexibility. Across the papers, several converging trends emerge, highlighting both technological innovation and growing system complexity.

A significant portion of the contributions focuses on **new cable system designs and materials** to meet increased capacity and environmental requirements. Developments such as large cross-section aluminium conductors, advanced XLPE materials, and alternative insulation solutions illustrate a shift towards more cost-effective and sustainable designs without compromising performance. At the same time, new insulation concepts, including polypropylene-based systems and DC-optimized XLPE, demonstrate ongoing efforts to improve dielectric performance under higher thermal and electrical stresses. These developments indicate a clear trend towards extending operational limits while maintaining long-term reliability.

In parallel, **superconducting cable technologies** are increasingly explored as a potential solution for future high-capacity corridors. Several contributions highlight their advantages in terms of compactness, high current density, and reduced losses, particularly for applications such as urban grids, offshore transmission, and data centre interconnections. However, the studies also underline that large-scale implementation will require further validation, standardization, and system integration considerations.

Another dominant theme is the growing importance of **dynamic cable systems for offshore wind applications**, particularly for floating installations. Several papers address the mechanical, thermal, and electrical challenges associated with dynamic loading, including fatigue behavior, torsional stresses, and deep-water installation requirements. New designs, qualification approaches, and installation concepts are proposed, reflecting the fact that dynamic cables are becoming critical components in future offshore grids, yet remain an area where experience and standardization are still developing.

A strong focus is also placed on **monitoring, diagnostics, and digitalization of cable systems**. Advanced sensing technologies, including distributed fibre optic sensing, acoustic monitoring, curvature sensors, and partial discharge detection systems, are presented as key enablers for real-time condition assessment. Several contributions demonstrate how combining monitoring with predictive modelling and digital frameworks can improve asset management, enhance reliability, and optimize operational margins, such as through dynamic rating approaches. This reflects a clear shift from traditional design-based operation towards data-driven system management.

In addition, multiple papers address **system integration and operational challenges**, including transient behaviour, overvoltages, hybrid AC/DC systems, and interactions with compensation

equipment. These studies highlight that increasing system complexity-particularly in offshore grids and multi-terminal HVDC systems—requires more advanced modelling, coordination, and protection strategies to ensure safe and reliable operation.

The challenges associated with **installation, retrofitting, and asset management** are also widely covered. Contributions describe urban installation constraints, retrofit of existing infrastructure such as pipe-type cables, and the need for standardized solutions such as universal joints and modular components. These approaches aim to reduce complexity, improve maintainability, and enable efficient renewal of ageing assets, which remains a critical issue in many transmission systems.

Finally, several contributions underline the importance of **system-level optimization**, including improved ampacity calculation methods, real-time thermal rating, and coordinated approaches among TSOs to standardize technical solutions. These efforts are essential to maximize the utilization of existing and future infrastructure while supporting the rapid expansion of transmission networks required for the energy transition.

Overall, the papers demonstrate a transition from conventional cable engineering towards **integrated, high-performance, and digitally enabled systems**, where materials, design, monitoring, and operation are increasingly interlinked. While significant progress is evident, the contributions also highlight the need for further validation, standardization, and operational experience to ensure that these innovations can be applied reliably at scale.

PS1 Questions

Q1.01. Standardization and Digitalization for Lifecycle Optimization:
How do standardisation approaches, such as a common specification for harmonisation of the qualification process across TSOs and Universal Transition Joints (UTJs), contribute to future repairs involving multiple vendors or users? Does the digitalisation of cable system design contribute to improved lifecycle management, reduced inventory complexity, and the more efficient modernisation of existing cable infrastructure?

Q1.02. Superconducting and Multi-functional Cable Technologies:
What are the main advantages and future potential of superconducting and hybrid cable systems, particularly in enabling high-capacity transmission, compact design, and integration with hydrogen transport in next-generation energy networks?

Q1.03. Smart Monitoring and Predictive Maintenance:
How can modern monitoring tools detect faults early and improve cable reliability? More specifically how do advanced sensing technologies such as distributed fibre optic sensing, time-domain reflectometry, and integrated predictive modelling frameworks enhance real-time monitoring, early fault detection, and reliability of modern cable systems?

Q1.04. Dynamic Offshore and Deepwater Cable Innovations:
What are engineering challenges and lessons learned associated with dynamic cables in offshore wind applications, and how do innovations such as deep-water HVDC cables, flexible but robust systems, and novel installation methods improve performance and reliability?

Q1.05. Sustainable Materials and High-Performance Design:
How can new materials improve cable performance while reducing cost and environmental impact - such as aluminium conductors and recyclable polypropylene insulation, lead free HV offshore cable - supporting the development of more sustainable, cost-effective, and high-capacity cable systems for future power transmission?

PS2 - Recent experience with AC and DC cables, both land and submarine

- Quality, monitoring, condition assessment, diagnostic testing, after installation testing, fault location, upgrading and uprating methodologies and relevant management.
- Lessons learned from permitting, consent, interface management cables to other equipment/device/substations and safety issues.
- Experiences with new test requirements and new tools for cable ratings calculation.

PS2 Paper summaries

10157	This paper presents a 3D FEM modeling framework to evaluate thermal pinch points affecting ampacity in congested urban underground transmission corridors. Analysis of 230 kV HPFF cable systems showed that conductor upsizing delivers the greatest ampacity improvement, while pumped dielectric fluid provides localized benefits in thermally saturated crossing areas. The study highlights the importance of 3D thermal assessment for complex cable installations.
10257	This paper presents an analytical method for calculating shielding factors in armoured three-core submarine cables across a wide frequency range. The approach incorporates circulating and eddy current effects, improving accuracy for current distribution and loss calculations, particularly in cables with magnetic armour. Validation against 3D FEM simulations demonstrated strong agreement and highlighted areas for further refinement in reactance modelling.
10283	This paper presents an empirical criterion for assessing thermal runaway in EHVDC cables using only intrinsic insulation properties, cable design parameters, and operating conditions. Derived from comprehensive cable modelling, the approach enables practical verification of runaway margins and conductor temperature rise, demonstrating safe operation for a 525 kV XLPE cable design.
10315	This paper presents a comprehensive end-of-warranty assessment of the Borssele offshore export cable system, integrating thermal, electrical, and mechanical performance data. A multi-disciplinary, data-driven approach combining DTS, TDR, and subsea inspections enables predictive integrity evaluation. Results confirm that the system operates within design limits and establish a robust framework for future asset management.
10319	This paper investigates a failure in a 380 kV outdoor cable termination and subsequent damage in a cross-bonding joint associated with the same system. Field measurements and diagnostic testing identify transient overvoltages as a probable root cause of the electrical activity observed. The study validates this hypothesis through on-site measurements and supports improved EMT modelling of transient phenomena in cable systems.
10322	This paper proposes a component-aware planning framework based on dynamic cable rating for medium-voltage distribution networks with high renewable integration. By combining thermal headroom assessment with explicit thermal ageing analysis, the method quantifies both capacity potential and associated reliability impacts. The results demonstrate that dynamic operation can increase cable utilisation, support renewable integration, and help defer reinforcement investments.
10323	This paper presents lessons learned from a major flooding incident in a 132 kV cable tunnel, which resulted in significant water ingress into cable joints. Investigations confirmed penetration through joint sealing systems and highlighted challenges in water removal and repair. The study provides recommendations for improved tunnel design, flood risk management, and recovery strategies to maintain cable integrity.
10332	This paper presents the design and implementation of a 220 kV underground XLPE cable system in the Zojila Pass to improve reliability in a critical high-altitude transmission corridor. The study addresses severe environmental and accessibility challenges associated with overhead lines. Results demonstrate a robust hybrid OHL–UGC solution ensuring reliable power supply under extreme conditions.

10355	This paper examines the interaction between a ±320 kV HVDC cable system and adjacent cathodically protected metallic pipelines at multiple crossing points. It evaluates corrosion risks and stray current effects through measurements, simulations, and fault analyses. The results support effective mitigation design and highlight the impact of HVDC operation on pipeline integrity.
10357	The paper emphasizes maximizing current carrying capacity using Fluidized Thermal Backfill to lower thermal resistivity around cables. It provides guidance for power engineers on designing underground transmission networks in densely populated old cities of developing countries, focusing on specialized FTB material compositions. The paper includes a case study of a +320 kV VSC HVDC cable project between Adani Kudus and Aarey substations (symmetrical monopole, ±320 kV, 1000 MW), comprising 30 km overhead and 50 km cable.
10992	The study designs a hang off method for submarine cables without armour wires. Armour wires contribute weight, cost, and carbon footprint; replacing them with a plastic mesh aims to improve sustainability. A temporary hang-off is presented as well as a permanent hang-off which anchors the cable by molding a resin cone around the cores inside a metallic mould, relying on adhesion to transfer axial loads. Prototypes were validated, with the hang-off withstanding axial forces beyond operational demands; the paper discusses design steps, validation, and optimization for offshore installations
11021	Bentonite is widely used as a filling material in underground ducts for high-voltage cables due to its high thermal conductivity, which enhances heat dissipation and enables optimization of conductor sizing. However, even localized application failures may create hot spots that reduce the system current-carrying capacity and accelerate insulation aging. This paper proposes a noninvasive method to assess bentonite filling quality during the project execution phase. The method is validated through simulated filling failures. Thermal profile analysis allowed accurate detection and localization of anomalies, which were eliminated after corrective actions. The proposed approach enables early detection and correction of installation defects prior to system energization.
11022	This paper presents the first application of an insulated cable system at 525kV in Brazil. The conventional air insulated bus solution remains economically attractive due to lower implementation costs, supplier availability, and standardized maintenance practices. However, insulated cable systems offer advantages in terms of operational safety, reliability, and mitigation of risks associated with environmental interferences and insulation failures. The project applies the conventional solution in the 440 kV yard and an XLPE insulated cable solution in the 525 kV yard, including the integration of an existing backup unit commissioned in 2004.
11025	This paper presents a comparative assessment of overhead transmission lines and insulated underground cable systems, focusing on recent Brazilian experience. Technical performance, operational aspects, environmental and social impacts, economic considerations, and regulatory milestones are discussed, with explicit reference to projects at 138 kV, 230 kV, 345 and 525 kV. Particular attention is given to hybrid high voltage lines combining overhead and underground sections, which have emerged as a pragmatic solution within the Brazilian planning framework for distribution and transmission as it represents an attractive cost x benefit solution.
11060	Comparative analyses between medium voltage (MV) and low voltage (LV) networks are rarely found in the literature, and it remains unclear whether these networks share common features or diverge entirely. This paper focuses on the MV and LV grids of Milan, operated by the distribution system operator (DSO) Unareti, from which the analyzed data are sourced. The comparative analysis reveals that the LV network maintains a stable daily interruption pattern, closely linked to user consumption habits and unaffected by seasonal changes, while the MV network exhibits evolving interruption profiles, with increased events during early mornings and evenings, especially in summer, indicating latent insulation degradation rather than load-driven faults.

11061	Growing use of high-voltage underground cables due to environmental and land-use constraints is changing how planners assess network performance. Traditional IEC-based methods use fixed assumptions (steady temperature, uniform soil) and can be overly conservative or fail to prevent overloads. The paper presents an advanced EMTP-based multi-domain framework to evaluate cable ratings under both steady-state and dynamic conditions. The model combines an electrical EMTP core with a custom thermal-electrical network, accounting for ambient temperature, soil conductivity, mutual heating, cyclic/peak loads, and seasonal variations.
11062	The shift to trenchless underground HV cables in urban/infrastructure settings increases unfilled duct installations, making accurate thermal design essential. The traditional IEC 60287 method may be inaccurate for complex installations with casing ducts. This paper compares IEC-based ampacity estimates with Finite Element Method (FEM) simulations grounded in CIGRE Technical Brochure 963, and extends FEM to a real micro-tunnel case with a steel-cased duct. The aim is to assist design engineers in planning and rating cables in non-homogeneous environments with internal heat sources.
11064	The study demonstrates non-invasive active capacitive sensors that detect and localize PD over several kilometers by coupling to the electric field and capturing high-frequency components without galvanic contact. A field test on a 35 kV, 3 km solar-farm cable with suspected splice defects validated sensor performance. A distributed parameter transmission line model was developed to simulate PD pulse propagation, matching time- and frequency-domain data and predicting detection limits and optimal sensor spacing. The paper concludes that combining non-invasive sensing with simulation provides a robust framework for condition-based cable monitoring and defect localization over long distances and in complex layouts.
11065	This study aims to assess the ability of HVDC MIND cable to a larger number of polarity reversal per year. A specific test protocol has been used. A 500 kV HVDC MIND cable loop with joints and terminations from two suppliers has been tested in laboratory. Test results are very encouraging highlighting that HVDC MIND cables have an excellent ability to withstand polarity reversals and are able to cope with the more stringent requirements of the evolving electricity market.
11066	This paper introduces a novel monitoring architecture comprising three integrated modules: (1) real-time estimation of temperature and electric field distribution, (2) DC-specific partial discharge (PD) detection, and (3) ageing assessment via dielectric loss analysis. Overall, the proposed monitoring system offers a comprehensive solution for predictive maintenance and asset management of HVDC cables, supporting the development of an HVDC-specific Health Index.
11265	The development of digital twins for high-voltage (HV) and extra-high-voltage (EHV) cable systems requires accurate electromagnetic modelling, particularly for predicting overvoltages and electrical stresses arising during transient events. A key parameter in these simulations is the impedance of bonding leads, whose evaluation becomes non-trivial when single-core cables are buried and arranged in irregular loop geometries. This paper investigates the frequency-dependent input impedance of buried single-core bonding leads through a combined analytical, numerical, and experimental approach. Results show that simplified analytical models and magnetostatic FEM accurately describe the impedance up to approximately 500 kHz, while MoM simulations exhibit very good agreement with measurements across the entire frequency range up to 10 MHz
11278	The present and future of energy is impossible without the mass use of medium-voltage power cables (6-35 kV). Despite the high quality of modern cables, owners of electrical networks suffer significant economic damage as a result of incorrect selection of type and cross-section of cables, as well as not optimal choice of the mutual arrangement of three phases. Such damage is especially noticeable for long cables, that is, for example, in cases where cables are used to connect wind generators to the electrical network. The article is related to some of these issues.

11308	The paper proposes a Health Index (HI) framework for cable terminations to consolidate diverse condition evidence into a single, decision-ready indicator for planning and risk management. The HI covers all termination types: outdoor and GIS (oil-filled), outdoor wet/dry-type, and GIS wet/dry-type (XLPE cables). It integrates eight condition parameters spanning observed condition, diagnostic test outcomes, operating duty, and service environment, with expert-agreed weights. Case studies show HI outcomes align with field observations: higher scores indicate issues and informed interventions; lower scores reflect good condition
11381	This paper presents an integrated approach to safety from the Spanish TSO - technology, procedures, and safety culture - which has proven effective in mitigating risks and improving resilience and asset availability. A range of advanced inspection techniques are presented (including drones in confined spaces, submarine ROVs) and predictive real-time monitoring (PD, DTS, vibration, current in cable screens) is deployed to support early warnings and maintenance.
11382	The Spanish TSO emphasizes standardized forensic root cause analysis for underground cable incidents to prevent recurrence and minimize impacts. A rigorous methodology covers evidence collection, component disassembly, failure mode analysis, and correlation with operating conditions, documented in an official procedure. The Underground Cable Campus in Getafe provides training, simulations, and controlled environments to develop specialized competencies. The Cable Intervention Group (GIC) conducts field and laboratory forensic investigations, informing corrective and preventive measures that improve reliability and foster innovation. This paper gives an overview of the approaches taken.
11384	Early PD detection in HV underground/submarine cables is crucial, but optimal sensor placement remains challenging. The study compares PD sensors (HFCT, VHF, HF, and UHF) on sensitivity, frequency response, installation, and compatibility; each type has strengths depending on defect origin and attenuation. Tests cover Spanish TSO cable types with lab and field measurements supported by detailed cable modelling. A mathematical optimization model was used to determined the minimum number and best placement of sensors, guiding deployment to improve reliability and reduce maintenance costs.
11389	CIGRÉ Technical Brochures 852 and 853 define several TOV wave shapes, with the long-front same-polarity waveform (LTOV-SP) being the primary reference. Using electric-field calculations for a 525 kV, 3000 mm² cable, the paper compares LTOV-SP with other waveforms such as opposite-polarity LTOV-OP and zero-crossing damped TOVs (ZCD-TOV). Across materials and temperatures, LTOV-SP consistently produces the highest electric-field stress, while LTOV-OP and ZCD-TOV remain equal or lower. Standard tests such as AC power-frequency and lightning impulse (LI) often create higher peak stresses than ZCD-TOV. The paper calls for targeted research to better understand breakdown mechanisms and for caution before standardizing costly new test requirements.
11408	The paper assesses Na-based SAP tape for moisture sealing in submarine cables and its impact on water treeing under long-term conditions. Using a modified sand-paper test (ASTM D6097), SAP-attached insulation developed microscopic water trees in DI water, while the bare insulation did not. In 1 M NaCl, many longer water trees formed (up to ~400 μm), showing that ionic concentration accelerates growth. Although SAP doesn't directly touch the insulation, potential indirect transport pathways could allow Na+ and moisture to reach the insulation vicinity. The paper concludes that Na-based SAP can improve moisture sealing but may pose long-term insulation reliability risks; a Na-free/low-ionic SAP and optimized design are recommended.
11429	The paper tackles the lack of a standard, frequency-dependent impedance model for HVDC submarine cables and cable pairs (including different polarity arrangements). It proposes fully analytical impedance formulae that incorporate skin effect, screening, armour magnetics, and ground effects, with both low- and high-frequency limits. For a single cable, the results align with classical analyses (Schelkunoff, Wedepohl & Wilcox, Ametani) within about 10%, and match the low/high-frequency behavior exactly. Validation against 2D FEM over 0.01 Hz to 1 MHz shows ~10% agreement for various armour permeabilities (Grade 34, Grade 65 galvanized steel) and non-magnetic armour, with larger permeability reducing the discrepancy. The work builds on and extends prior CIGRE TB 531/908 and related studies to provide a standardized analytical approach for HVDC cable impedance.

11514	This paper studies XLPE-insulated HVDC cables for high and extra-high voltage applications, proposing a non-destructive diagnostic method. Using extra-low-frequency dielectric spectroscopy, it correlates dielectric relaxation characteristics with crosslinking byproduct content, enabling effective evaluation of insulation condition and degassing performance, thereby supporting reliability assessment of HVDC cable systems.
11515	This paper examines HVAC cable systems (66 kV–220 kV, mainly single-core cables) and their metal sheath grounding. It proposes a live loop-resistance detection method using DC and frequency coupling. Application to 17,000 tests identified ~5% defects, proving effective for detecting poor connections and improving cable reliability.
11516	This paper addresses SCFF submarine cables used in high-voltage HVAC/HVDC transmission systems. It develops a UV fluorescence method for precise oil-leakage detection and an in-situ sealing repair technique. Field application shows rapid leak localization and over 80% cost reduction, while maintaining insulation integrity and improving reliability
11517	This paper presents a ±500 kV XLPE-insulated EHVDC submarine cable system for a 2 GW offshore wind project. It details design, manufacturing, and installation challenges. The project successfully achieved full qualification and testing, demonstrating reliable large-capacity long-distance transmission and validating EHVDC XLPE cables for future high-power applications.
11613	This paper investigates 132kV XLPE HVAC transmission corridors combining overhead lines and underground cables. It proposes a single-ended fault location method using a dynamic impedance factor. Results show near-zero error in simulations and significantly improved accuracy versus conventional methods, enabling reliable identification of cable faults.
11671	This paper presents a 400 kV XLPE underground HVAC cable system (1×2500 mm² Cu) installed in an urban corridor. It highlights installation challenges and solutions. Results show successful commissioning using optimized routing, cross-bonding, and DTS-based monitoring, enabling reliable operation and real-time thermal performance validation.
11698	This paper introduces case study thermal modelling of underground cables installed by HDD (1600 mm² class). It compares 2D, full 3D, and simplified 3D thermal models. Results show 2D methods are overly conservative, while the proposed simplified 3D method provides accurate yet efficient predictions, improving ampacity estimation and reducing required cable spacing.
11709	This paper reviews HVAC/HVDC subsea cables used in offshore wind farms, focusing on thermal rating. It shows that post-installation soil effects can significantly improve heat dissipation and ampacity. A proposed equivalent thermal resistivity method accurately captures these effects, enabling less conservative and more efficient cable rating.
11712	This paper analyzes HVAC three-core submarine cables (e.g., 220 kV export and 66 kV array cables), focusing on sequence impedance calculation. It finds that advanced analytical methods closely match 3D FEA results with good accuracy, enabling reliable and efficient impedance evaluation for offshore wind cable system design.
11728	This paper analyzes a 70 kV HVAC dynamic inter-array submarine cable, comparing round and flat armour wires using FEM. Results show flat-wire armour improves compactness, stiffness, and pressure resistance, but exhibits higher local stress and ~2× fatigue damage, indicating the need for geometry optimization despite strong mechanical advantages
11729	This paper investigates EHV underground HVAC and HVDC cable systems installed in ducts in South Korea. It finds that external forces and thermal expansion cause cable creepage and displacement, risking joint stress. Field results confirm that stopper systems and pull-back devices effectively restore offsets and improve mechanical stability.
11737	This paper analyzes HVAC (e.g., 220 kV AC) and HVDC (e.g., 525 kV DC) cables installed in unfilled ducts, comparing IEC 60287 with FEM modelling. It finds IEC methods generally conservative for plastic ducts, but inaccurate for trefoil, metal, and water-filled ducts, where correction factors and improved constants enhance rating accuracy.
11787	This paper investigates EHV submarine power cables (HVAC/HVDC) focusing on the lead sheath water barrier. It shows that low-cycle fatigue data enables accurate prediction of bending fatigue life under large deformation. Results confirm strong agreement between material and full-scale tests, improving reliability assessment of submarine cable systems.

11866	This paper studies heat transfer of single-core 12 kV XLPE AC power cables installed in a concrete trough. It evaluates IEC 60287-2-3 ampacity calculations against experiments. The standard is accurate without ventilation (≤7% deviation), but under forced ventilation it misrepresents convective cooling—underestimating laminar heat transfer and overestimating turbulent effects—leading to up to ~33% temperature error and overly optimistic ratings.
11868	This paper studies HVAC power cables (72 kV, 800 mm² Al) installed in unfilled troughs. It shows standard IEC methods underestimate ampacity by up to ~11%. A validated FEM-based approach accurately predicts temperatures, with <3% deviation, enabling improved cable rating and more efficient utilization
11869	This paper examines HVAC offshore wind farm array cables (e.g., 3-core 800 mm² subsea cables) near turbine J-tube terminations. It shows phase separation creates circulating screen currents and localized losses not covered by IEC methods, reducing ampacity by ~5%, highlighting the need to include termination effects in rating.
11923	This paper examines offshore windfarm export cables (220kV HVAC and HVDC 320 kV-class). It finds low initial loading delays detection of infant-mortality failures. Applying ~85% load cycles during commissioning enables thermomechanical conditioning, DTS validation, and earlier fault identification, improving reliability and ensuring performance verification
12003	This paper investigates urban underground HVAC and EHV cable systems (110 kV & 380 kV), focusing on third-party damage prevention. Field trials show DAS-based TPID monitoring can significantly improve detection of excavation activities, reducing outages, though performance varies widely and requires tailored configuration and evaluation procedures.
12005	This paper analyzes medium-voltage (MV) HVAC cables using VLF testing with integrated Arc Pre-Location (APL). It shows the combined workflow enables immediate fault pre-location during testing, achieving accuracy comparable to conventional methods while reducing maintenance time and improving detection of intermittent and high-resistance faults.
12058	This paper assesses 230 kV HVAC XLPE submarine and underground transmission cables. It finds electromagnetic coupling to nearby infrastructure is negligible, with induced voltages, currents, and magnetic fields remaining well within safety limits under both normal and fault conditions, confirming safe integration alongside cables and pipelines.
12092	The paper is intended to raise awareness of an easily overlooked issue concerning calculating and designing for circulating sheath currents at the terminations of offshore high voltage cable systems. This experience relates to 3 core armoured submarine cables with semiconducting sheath designs. The paper highlights an end-effect which is not well described in standards, but one that can still be readily calculated.
12234	The paper presents a review of the recent retrofitting of legacy External Gas Pressure (EGP) cable systems with modern XLPE cables on the 132kV transmission network in Aberdeen, Scotland. Originally installed over 60 years ago, the existing EGP assets comprised two 4.8 km, steel pipe systems between Redmoss and Clayhills substations. As urban constraints made full cable route replacement undesirable.
12266	Offshore power cables are typically buried in the seabed for their protection against human activities. Post-installation, the depth of cover (DoC) can vary significantly leading to potential exposure or over-burial of the cable. Beginning with the cable as built information including cross-section, material, nominal depth of burial and seabed parameters, together with the DTS data and the load data, a real time thermal rating (RTTR) based finite element modelling simulation has been developed to calculate conductor temperature Tc. A second computational step calculates the temperature distribution in the cable and the seabed, for a range of DoC's, as a function of load, time, and distance.
12268	Optical methods like Distributed Acoustic Sensing (DAS) are finding their way as a fast and efficient means of localising fault position in near real time with distance accuracy along a submarine power cable within a few tens of meters. Multiple examples from recent field measurements are reported here to illustrate the speed and the accuracy with which DAS helps localising faults.

12352	The paper presents an illustrative case study highlighting variations in the continuous operating voltage (Uc) and rated voltage (Ur) of sheath voltage limiters (SVLs), based on differing criteria outlined in relevant technical documents. Furthermore, The paper presents a comparison of criteria for selecting SVL in accordance with the IEC, CIGRE and ENA standards and recommendations.
12377	The paper confirms the need to use statistical methods for calculating lightning processes in the cross-bonding nodes, to share operational experience that suggests the need for broader consideration of switching processes, and to propose a new rule for selecting operating voltage of sheath voltage limiters (SVL). The article calculates the switching processes on one of the lines, and shows why there are risks of damage to the joints located closest to the circuit breaker supplying voltage to the line.
12404	The paper presents a new automated method that identifies the characteristic V-shaped wavefront pattern generated by fault-induced bidirectional wave propagation. The detector operates on optical-phase distributed acoustic sensing data using spectral filtering and geometric feature extraction. The system is validated on nine real HVAC and HVDC cable faults and it accurately identified eight, with no false positives observed.
12436	Power line communication (PLC), which is often used for smart metering and automation, provides a sensor less basis for condition assessment, as its signals reflect the electrical environment. However, the metadata obtained from PLC is high dimensional, unsynchronised and operationally variable, which makes conventional analysis difficult. This paper explores unsupervised machine learning (ML) methods for detecting anomalies in PLC data.
12445	Distributed acoustic sensing (DAS) enables continuous monitoring by capturing vibrations along the cable route. In this work, we analyze signal characteristics for activities that can lead to cable damage, including excavator digging, jackhammering, auger drilling, and diver interference. Based on this analysis, we present a detection framework that combines deep learning and signal processing to enhance adaptability and robustness.
12569	In the paper, a computationally efficient three-dimensional finite-element method (3D FEM), based on an extension of the short-twisted periodicity concept, is proposed and adopted as the reference solution for sequence impedance calculation three core double armored submarine cables. The method captures the helical geometry of both armor layers, longitudinal magnetic field components, and frequency-dependent skin and proximity effects. In parallel, a 2.5D method of moments - surface operator (MoM-SO) model is developed, offering a significantly reduced computational cost.
12572	This study compares naturally ventilated and sealed trough configurations by analysing their thermal environments, airflow characteristics, and cable temperature distributions. Naturally ventilated troughs promote heat dissipation through buoyancy-driven convection and air exchange with the surrounding environment, potentially increasing cable ampacity and thermal margins. In contrast, sealed troughs restrict air movement, suppressing convection and leading to heat accumulation around the cables, which results in elevated operating temperatures.
12573	The paper presents a comprehensive Finite Element Method (FEM) approach to model water diffusion in power cables, a critical degradation mechanism leading to water treeing. The study examines all possible geometrical representations, including 1D, 1D-axisymmetric, 2D, 2D-axisymmetric, and 3D models, to analyze water transport. The findings aim to support the design and optimization of cable components and water barrier systems, thereby enhancing the long-term reliability of power cables in humid environments and aligning with industry recommendations and standards.
12574	Single-point bonding reduces losses in HV cables, but introduces sheath voltage rise. Earth Continuity Conductors (ECCs) are used to mitigate this rise, yet their necessity in installations inside substation earthing mats remains unproven. Despite recommendations in CIGRE TB 797, no published studies quantitatively validate the effectiveness of ECCs. Overall, the findings verify that the use of ECCs has insignificant impact on the cable induced voltages and personnel safety in well-grounded HV onshore substations or offshore platforms.

12613	This work evaluates the fidelity of IEC 60287 against a hybrid analytical-FEA approach using a 2D thermal FEA model in an open-source software and public Lua scripts that model buried submarine AC cables with lead sheaths. In the hybrid analysis, IEC-based analytical formulas are used to calculate electrical losses. It is shown that the hybrid analysis tends to predict higher conductor temperatures than IEC, with the dominant discrepancy linked to differences in extracted thermal resistances (notably T2), rather than a change in the analytical loss formulation used as input.
12634	This paper presents an indirect method for locating faults in high-voltage cable lines by utilizing distributed temperature monitoring. The proposed method is based on using an optical fiber integrated into the cable structure as a Distributed Temperature Sensing (DTS) element. System implementation and analysis allows temperature recording exceedances relative to load and the identification of local overheating at crossings with heating pipelines and other urban utility networks. Consequently, the method detects temperature anomalies at potential fault locations, prevents emergency shutdowns, and enables precise fault localization.

PS2 Discussion

The contributions to PS2 reflect the continued expansion and increasing complexity of underground and submarine cable systems, driven by urbanization, the integration of renewable energy, and the growing deployment of both HVAC and HVDC transmission technologies. Across the papers, several converging trends emerge, highlighting a transition from traditional design approaches toward more data-driven, model-based, and operationally integrated solutions.

A significant portion of the contributions focuses on the increasing reliance on **advanced modelling techniques** to better capture real installation conditions and system behaviour. Numerous papers demonstrate that classical IEC-based methods for thermal rating, impedance calculation, and transient analysis are often either overly conservative or insufficiently accurate when applied to complex configurations such as ducts, crossings, or heterogeneous seabed environments. As a result, more sophisticated approaches based on 3D FEM, EMTP-coupled simulations, and hybrid analytical–numerical models are being adopted to account for dynamic loading, environmental variations, and electromagnetic interactions. While these approaches enable improved accuracy and better utilisation of cable capacity, they also underline the need for validation, standardisation, and practical simplification to ensure applicability in engineering practice.

Thermal performance and ampacity optimisation emerge as a central driver across both HVAC and HVDC systems, with many contributions addressing the identification and mitigation of local thermal bottlenecks, the role of installation materials and techniques, and the increasing use of dynamic rating approaches. The studies show that better understanding of thermal behaviour, combined with enhanced monitoring, can unlock additional capacity, improve asset utilisation, and support the integration of renewable energy sources. At the same time, the results highlight that increased utilisation can introduce new risks, including accelerated ageing, local overheating, and higher sensitivity to installation defects, pointing to the need for a balanced approach between performance optimisation and long-term reliability.

In parallel, there is a strong and consistent shift toward **advanced monitoring, diagnostics, and condition assessment techniques**, with many papers presenting developments in distributed sensing, partial discharge detection, optical and acoustic monitoring, and integrated health index frameworks. These solutions enable earlier fault detection, improved localisation, and more informed maintenance strategies, although challenges remain in system integration, data interpretation, and the establishment of standardised methodologies.

A substantial number of contributions are based on operational and project experience, emphasising that **real-world installation and environmental conditions remain critical for system performance.** Issues such as mechanical stresses, water ingress, soil variability, and interaction with surrounding infrastructure are shown to significantly influence reliability and lifetime. These findings demonstrate that deviations between design assumptions and actual conditions are often unavoidable, reinforcing the importance of site-specific analysis and quality control during installation.
In addition, several papers address **reliability and failure mechanisms**, highlighting the role of transient overvoltages, insulation degradation processes, and weaknesses in accessories such as joints and terminations. The increasing use of structured forensic investigation methods and systematic root cause analysis reflects a growing emphasis on learning from operational experience and feeding this knowledge back into design and standards development, although further work is required to fully understand complex multi-stress ageing processes.

The evolution of HVDC systems is another prominent theme, with multiple contributions demonstrating the continued increase in voltage levels, power ratings, and operational demands. While the technology has reached a high level of maturity, the papers underline emerging challenges related to transient behaviour, frequency-dependent effects, and interactions with adjacent infrastructure such as pipelines and grounding systems. These aspects require further refinement of modelling approaches and may lead to the adaptation of existing test and qualification methods.

In summary, the contributions show a clear shift from conventional, standardised design practices toward more integrated and adaptive approaches based on **detailed modelling, real-time monitoring, and operational feedback**. While this transition enables significant improvements in performance and flexibility, it also increases system complexity and introduces new challenges related to validation, standardisation, and risk management. The need to balance enhanced utilisation with reliability and long-term performance emerges as a central topic across the contributions and forms a common foundation for further discussion.

PS2 Questions

Q2.01. Balance between advanced modelling and practical application:
To what extent should advanced modelling techniques (such as 3D FEM, EMTP, and hybrid approaches) replace traditional IEC-based methods in cable system design and operation, and how can a balance be achieved between modelling accuracy and practical usability in engineering workflows?

Q2.02. Optimisation of ampacity versus long-term reliability:
How can operators effectively balance the increasing drive for higher cable utilisation (e.g. through dynamic rating and thermal optimisation) with the associated risks of accelerated ageing, local overheating, and reduced system reliability?

Q2.03. Integration and standardisation of monitoring systems:
With the rapid deployment of monitoring technologies (DTS, DAS, PD, AI-based diagnostics), is the industry truly improving decision-making, or are we creating systems where the volume and complexity of data exceed our ability to interpret and act on it effectively?

Q2.04. Impact of real installation conditions on system performance:
Given the consistent gap observed between design assumptions and real installation conditions (e.g. soil variability, mechanical stresses, and environmental impacts), how should design methodologies and standards evolve to better account for site-specific and operational realities?

Q2.05. Emerging challenges in HVDC cable systems:
As HVDC cable systems continue to increase in voltage level, capacity, and operational complexity, what are the key technical challenges related to transient behaviour, system interactions, and qualification methods that need to be addressed to ensure reliable long-term operation?

PS3 - Environmental impact and cable lifecycle

- Development in more sustainable materials and production methods, recover, recycle, reuse of cable materials and SF6 alternatives.
- Best practices in LCA and environmental certification.
- Environmental impact of cable systems with regards to climate change.

PS3 Paper summaries

10356	This paper presents the design and installation experience of a 400 kV AC XLPE cable system for power evacuation from an underground GIS to an outdoor pothead yard in a high-altitude hydroelectric project, highlighting the key routing challenges and the practical solutions adopted. The approach involved detailed assessment of the cable route, identification of topographical, spatial, electrical and seismic constraints and development of coordinated design and installation measures.
10827	In this paper, we examine and report on the potential and effects of enlarging cable sizes and installing joint boxes on utility poles in the overhead cable laying method for 77 kV solid insulated cables. In Japan, overhead cable laying method is commonly adopted for 6.6 kV distribution cable. For 77 kV transmission system, overhead cable laying method has been rarely used and could be applicable only for relatively small cable sizes. This study clarifies the technical challenges and facility configuration related to enlarging the cable size for 77 kV in the overhead cable laying method, as well as installing joint boxes on utility poles.
11793	This paper investigates the influence and evolutionary patterns of riprap dikes on seabed scouring development, analyzes the periodic VIV characteristics of suspended submarine cables under ocean current action, and predicts the fatigue failure process of the lead alloy sheaths of submarine cables subjected to long-term dynamic loads.
11870	This paper presents a Life Cycle Assessment (LCA) of the production and installation of submarine power cables used to connect offshore wind farms to the mainland electrical grid. The analysis compares two types of three-phase high-voltage 245 kV cables with XLPE insulation. The main difference between the two cable types lies in the conductor material, where one uses an aluminium conductor and the other a copper conductor.
12273	The rapid expansion of HVDC transmission driven by the global energy transition is forcing cable manufacturers to move from project-based, low-volume production toward large-scale, repetitive manufacturing of identical extruded HVDC cables and standardized accessories. While current industry investments are largely focused on expanding manufacturing capacity, this paper demonstrates that capacity expansion alone is insufficient to control quality, cost, and delivery risks in high-volume production environments.

PS3 Discussion

The five papers in PS3 address different phases of the cable lifecycle, from installation and operation to environmental assessment and manufacturing.

A common theme is the **increasing interaction between cable systems and their environment**. This is demonstrated both for land installations in difficult terrain and for submarine cables, where geotechnical conditions, seabed dynamics, and long-term mechanical effects directly influence design and reliability.

At the same time, new application concepts are being explored, such as extending overhead insulated cable solutions to higher voltage levels, showing a need for **greater flexibility in infrastructure design** under spatial and practical constraints.
From a different perspective, lifecycle assessment is being introduced as a **systematic tool to quantify environmental impact**, highlighting the influence of material choices such as conductor type.

In parallel, the industrial context is evolving, with increasing demand for HVDC systems driving a shift toward **large-scale and standardized manufacturing**, where quality, consistency, and scalability become key concerns.

Overall, the contributions indicate a transition from individual project optimization toward a more **integrated lifecycle approach**, where environmental conditions, material choices, and production strategies are increasingly interconnected.

PS3 Questions

Q3.01. From environmental constraint to design driver

- Are current cable system design practices still too reactive to environmental conditions, and how can the industry shift toward treating geotechnical and environmental factors as primary design drivers rather than boundary conditions?

Q3.02. Lifecycle assessment: decision tool or box-ticking exercise?

- Is lifecycle assessment (LCA) truly influencing key technical decisions in cable projects, or does it risk becoming a formal "box-ticking" exercise, and what changes are needed to make LCA a decisive factor in material and system selection?

Q3.03. Industrial scale vs. sustainability ambition

- With the rapid scale-up and standardization of HVDC cable manufacturing, is there a risk that sustainability ambitions are being compromised, and how can industry ensure that environmental performance is not subordinated to cost, volume, and delivery pressures?