DISCUSSION MEETING SUMMARY

Study Committee A3

(Transmission and Distribution Equipment)

August 26th, 2026

Chair: **N. Gariboldi**

Secretaries: **P. Mazza and F. Richter**

Special Reporters: **R.P.P. Smeets, P. Mazza, T. Minagawa, E. Sperling and N. Gadacz**

Spark-up Manager: **M. Kriegel**



1. INTRODUCTION

The SC A3 Group Discussion Meeting reflected the rapid transformation of transmission and distribution equipment driven by decarbonisation, digitalisation, resilience requirements and evolving grid conditions. The 2026 call for papers attracted a record 135 synopses. Of these, 121 progressed to full reports, and 113 reports from 31 countries were accepted following review by 56 specialists. The accepted reports comprised 65 accepted contributions under all Preferential Subjects, while eight reports were rejected.

Due to the broad scope of SC A3 activities, the Special Report did not follow the structure of the three Preferential Subjects. Instead, the accepted contributions were synthesised into four thematic groups: SF_6 alternatives (31 contributions), Miscellaneous T&D Equipment and Systems (14 contributions), Monitoring, Asset Management, Reliability and Digital Technology (12 contributions), and Instrument Transformers (8 contributions).

The prepared contributions and the subsequent discussions demonstrated that several technologies previously regarded as emerging solutions have now entered the stages of qualification, pilot operation and commercial deployment. Consequently, the meeting focused not only on technical feasibility, but increasingly on operational experience, lifetime confidence, system integration and lifecycle performance.

During the meeting, awards were presented to the authors of the three best SC A3 papers, one for each Preferential Subject.

In addition, the SC A3 Technical Committee Award was presented to Erik Sperling in recognition of his outstanding contributions to CIGRE, including his work as Working Group Chair, tutorial presenter and Special Reporter.

2. RUNNING OF THE MEETING

The Group Discussion Meeting was held on Wednesday, 26th of August 2026, from 08:45 to 18:00 in Amphi Bleue at the Palais des Congrès de Paris. It was chaired by N. Gariboldi, supported by the SC A3 Secretaries, the Special Reporters and the spark-up manager. The Chair welcomed the participants and introduced the format of the meeting, which was based on the questions raised in the Special Report and the prepared contributions submitted by delegates. The meeting followed the thematic structure of the Special Report. For reporting purposes, Group 1 was divided into Group 1A (Questions Q1-1 to Q1-4) and Group 1B (Questions Q1-5 and Q1-6), allowing a clearer distinction between technology deployment topics and the discussions related to lifetime performance and regulatory challenges.

Each discussion block was introduced by the respective Special Reporter, giving a very short, single-slide overview of the trends as identified by the reports, followed by the presentation of prepared contributions. The high number of prepared contributions enabled a comprehensive discussion covering the four thematic groups addressed by SC A3. Audience participation was further encouraged through spontaneous interventions and a highly interactive use of the Sparkup platform. During the meeting, Sparkup was extensively used to conduct live polls, collect questions and gather feedback from delegates in real time. The platform was managed by the spark-up manager, who supported the interaction between the audience, the Chair and the Special Reporters.

The strong participation via Sparkup demonstrated the high level of interest in the topics discussed. Questions and poll results were regularly incorporated into the discussion and helped identify both areas of broad consensus and issues where different technical approaches continue to coexist. The interaction showed particular interest in the future deployment of SF_6-free technologies, qualification and lifetime performance of alternative solutions, the use of digital technologies and AI for asset management, and the increasing role of LPITs and digital substations. The Sparkup platform significantly enhanced audience engagement and contributed to a lively and productive discussion throughout the day.

CONTRIBUTIONS TO GROUP 1

Equipment using SF6 alternatives

Group 1A - Technology deployment and applications (Q1-1 to Q1-4)

The contributions confirmed substantial progress in SF_6-free equipment. Fluoronitrile-based mixtures were presented as a practical pathway for compact installations and for retrofilling selected existing GIS (non-switching sections) and GIL assets. Reported projects at high and extra-high voltage showed that dielectric performance can be achieved with carefully optimised mixtures and moderate pressure adjustments, subject to the mechanical limits and qualification of the original equipment.

Emission reduction was addressed through improved sealing, disciplined gas handling, recycling, digital pressure and temperature monitoring, and the gradual reduction of the installed SF_6 inventory. Contributions stressed that leakage performance depends on equipment design, operational practice and long-term

monitoring rather than on the choice of insulating medium alone. One contributor showed a method to measure very small leakages of C4-FN gas.

Shunt-reactor switching highlighted the continuing need to control re-ignitions and switching overvoltages. Controlled switching, added capacitance and RC-based mitigation were presented for vacuum-interruption applications. Other contributions noted that gas circuit-breaker solutions may provide a wide re-ignition-free window without the same auxiliary measures. The discussion underlined that technology selection must reflect the specific switching duty and network configuration. It was highlighted that non-SF_6 gas breakers show similar rei-gnotion behaviour as SF_6 breakers.

For future high-voltage and EHV applications, three complementary technology paths emerged. Fluoronitrile mixtures currently offer compactness, strong dielectric performance and application in 420-550 kV metal enclosed (GIS, dead tank) switchgear. CO_2/O_2 F-gas free mixtures offer solutions in air-insulated switchgear up to 420 kV, having similar size as SF_6 AIS. Dry air combined with vacuum interruption eliminates fluorinated gases and offers lifecycle advantages, but may require higher pressure, greater dimensions and further optimisation of insulation and interruption functions. All non-SF_6 mixtures, except CO_2/O_2 are used in retrofill projects. Participants did not identify a single universal solution; a portfolio approach is expected to remain necessary.

Group 1B - Lifetime, qualification and regulation (Q1-5 and Q1-6)

Confidence in long service life was a central topic. Contributors advocated technology-specific qualification because alternative insulation and interruption principles introduce different ageing mechanisms. Accelerated ageing, material compatibility, sealing performance, gas stability, moisture control and monitoring of gas composition were repeatedly identified as important elements. Growing field experience at voltage levels up to 550 kV was presented as an essential complement to laboratory qualification.

The regulatory discussion covered the SF_6 phase-out, possible PFAS restrictions and Ecodesign requirements. A strong common message was that environmental assessment should consider the full lifecycle, including manufacturing, material use, operational losses, maintenance and end-of-life treatment. PFAS-related substances may occur not only in insulating media but also in seals, lubricants and supply chains, making complete substitution a wider materials challenge.

Group 1 conclusion: SF_6-free technology has progressed beyond demonstration and has penetrated into the 420 - 550 kV range. Continued deployment will depend on application-specific selection, robust qualification, field feedback and lifecycle-based environmental decisions.

CONTRIBUTIONS TO GROUP 2

Miscellaneous T&D equipment and systems

Group 2 addressed advanced interruption, equipment qualification under severe service conditions, and sustainability-oriented asset renewal. Fast fault-current-limiting devices and protection concepts for AC and DC grids were presented as responses to increasing fault levels. Vacuum interrupters were recognised as a promising technology because of their interruption capability, dielectric recovery and low contact erosion. Contributions on HVDC testing also emphasised the need for realistic methods capable of reproducing network stresses and rapid operating sequences.

A recurring conclusion was that nominal ratings alone may not adequately represent modern service conditions. Actual applications can combine transient recovery voltage, reactor switching, contamination, thermal effects, seismic loading and mechanical stress. Validated numerical models and service-oriented studies can complement type testing, but physical validation remains essential. Qualification is therefore evolving from verification of ratings towards demonstration of resilience in realistic applications.

Lifecycle assessment and total cost of ownership were proposed as the principal frameworks for asset-renewal decisions. Contributions noted that replacing SF_6 changes the environmental balance of equipment and can make material production, particularly aluminium, more prominent. Substation- and fleet-level assessments can help utilities identify measures that deliver the greatest system-wide environmental benefit.

Group 2 conclusion: Future equipment selection must balance interruption performance, network resilience, realistic qualification, environmental impact, supply constraints and lifecycle cost.

CONTRIBUTIONS TO GROUP 3

Monitoring, asset management, reliability and digital technology

Group 3 demonstrated a clear shift from time-based maintenance towards condition- and risk-based asset management. Digital twins combined field measurements with physical equipment models to support diagnosis, maintenance planning and fleet optimisation. Dynamic contact-resistance measurement was recognised as diagnostically valuable, but wider adoption still requires standardised procedures, suitable reference data, improved test equipment and specialist training.

Artificial intelligence is already being applied to partial-discharge diagnosis, series-capacitor monitoring, circuit-breaker assessment and design optimisation. The contributions showed that AI can detect patterns, classify defects and accelerate analysis. At the same time, there was broad agreement that AI should support, not replace, engineering judgement. Physical testing, cybersecurity, explainability and human oversight remain necessary, particularly outside the range represented by training data.

Data quality and governance were prominent cross-cutting issues. Contributors argued that strategic decisions do not always require perfect data, but they do require transparent uncertainty and a quality level proportionate to the consequence of the decision. AI cannot compensate for unreliable source data. Robust asset models also depend on collaboration between utilities and manufacturers, with clear arrangements for intellectual property, data access, interoperability and value sharing.

Group 3 conclusion: Digitalisation is creating measurable value, but its success depends on trustworthy data, validated models, domain expertise, governance and continued human accountability.

CONTRIBUTIONS TO GROUP 4

Instrument transformers

The instrument-transformer contributions were mostly provided by Manufacturers, excepted 2 coming from Stakeholders: information was provided about long-term experience with the use of LPITs. One reported fleet included more than 1,000 units in over 150 substations, with the first pilot in continuous operation for ten years. Parallel metering comparisons indicated stable performance across the whole trial. Experience from China over approximately two decades also identified technology-specific issues, including electromagnetic interference, temperature effects, vibration, optical-component ageing and partial discharge, together with practical mitigation through shielding, compensation, redundancy and online monitoring.

Advanced modelling and characterisation are moving LPIT development from empirical iteration towards predictive, multiphysics design. Presented examples combined electrical, mechanical, dielectric and signal-processing models with material testing, accelerated ageing and type-test validation. Tangible results included improved transient representation, wider dynamic range, more compact integrated partitions and lower component mass. The discussion nevertheless retained physical testing and field validation as indispensable.

Process-bus applications are progressing in both transmission and distribution, but no single architecture suits every project. Direct low-power analogue interfaces, stand-alone merging units, hybrid outputs, distributed process bus and more centralised protection and control each have appropriate use cases. Competence, commissioning, test methods,

time synchronisation, measurable communication-link quality, diagnostics and cybersecurity remain important barriers.

Manufacturers underlined also LPITs' contribution to sustainability. A comparative assessment for 36 kV GIS reported lower material use, reduced losses, improved recyclability and a lower lifecycle global-warming impact. The key message from Manufacturers was that LPITs should be evaluated not only as a replacement for other technologies, but as enabling components for compact, digital and resource-efficient substations.

Awards

During the meeting, the SC A3 Best Paper Awards were presented to the authors of the highest-ranked papers for each of the three Preferential Subjects addressed during the 2026 Session.

A3-PS1 – Transformation of T&D Assets for Evolving Grid Conditions

Paper 11149 "Corrosion in Gas-Insulated Switchgear and Circuit Breakers with Respect to Gas Leakage: Causes, Prevention, Lifecycle Impact, Field Experience, Laboratory Studies, and Recommendations"

Authors: Tarachand Wankhede, Matthew Barnett, Aaron Jones, Rob Slaughter, Glenn Waktare, Matthew Kitchen, David Armit, Greig Safian and Stephanie Mann.

A3-PS2 – Sustainability and Circular Economy of T&D Equipment

Paper 10767 "Evaluation of Current Switching Performance with Synthetic-Air Disconnector and Earthing Switch"

Auhors: Tomoya Onishi, Naokazu Iwanade, Toru Koike, Akihisa Mukaida, Taiki Ozeki and Kentaro Iwahara.

A3-PS3 – Asset Management Strategies for T&D Equipment

Paper 10770 "Criteria for Renovating Circuit-Breakers of 500 kV MTS"

Authors: Kenji Sasamori, Motohiro Sato, Nobuki Igura, Akinori Hatsuzaki, Yuma Yamamoto and Akinori Sugawara.

In addition, the SC A3 Technical Committee Award was presented to Erik Sperling in recognition of his outstanding contributions to CIGRE, including his activities as Working Group Convenor, Tutorial Presenter and Special Reporter.

5. CONCLUSION

The 2026 SC A3 Group Discussion Meeting confirmed that transmission and distribution equipment is undergoing simultaneous technological and organisational transformation. Three major trends were evident across all discussion groups: the accelerating transition towards environmentally sustainable technologies, the increasing adoption of data-driven asset management approaches, and the growing integration of advanced modelling, monitoring and artificial intelligence into both equipment development and operation.

The discussions also demonstrated that progress cannot be assessed solely on the basis of individual technologies. Long-term value depends on the entire lifecycle and system context, including qualification under realistic service conditions, maintainability, data quality, digital-chain integrity, material availability, environmental performance and confidence gained through operational experience. Continued collaboration between utilities, manufacturers, testing organisations, research institutions, regulators and standardisation bodies remains essential to successfully address these challenges.

The extensive use of the Sparkup platform and the high level of audience participation demonstrated the strong engagement of the international SC A3 community and contributed significantly to the quality and diversity of the discussions. Live polls, real-time questions and audience feedback provided valuable insights into current industry priorities and helped identify areas of broad consensus as well as topics requiring further investigation.

Overall message: The next generation of transmission and distribution equipment will be defined not by a single technology, but by the successful combination of reliability, sustainability, digital interoperability and lifecycle value.

The Chair closed the meeting by thanking the contributors, Special Reporters, SC A3 secretaries, Martin Kriegel for managing the Sparkup platform, and all participants for their valuable contributions and for the high quality of the discussions throughout the day.