Materials and Emerging Test Techniques, SC D1

SPECIAL REPORT FOR SC D1

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Special Reporter

1. General

The aim of Study Committee D1 is to facilitate and promote the progress of engineering and the international exchange of information and knowledge in the field of materials and emerging test techniques. The committee contributes to this information and knowledge by synthesizing state-of-the-art practices and by developing recommendations.

These activities include follow up and evaluation of new developments within:

- new and existing materials for electrotechnology,
- diagnostic techniques and related knowledge rules,
- emerging test techniques which may be expected to have a significant impact on power systems in the medium to long term.

2. Group Discussion Meeting

Within this context SC D1 invited for the Group Discussion Meeting (GDM) contributions within three preferential subjects (PS), as follows:

Preferential Subject No 1:
Testing, Monitoring and Diagnostics

- Experience and insight from monitoring systems
- Reliability of test equipment and systems for testing, monitoring, and diagnostics
- Data handling, analytics, and advanced condition assessment

Preferential Subject No 2:
Functional Properties and Degradation of Insulation Materials

- New stresses, e.g. power electronics, load cycling, higher temperatures, and compact applications
- Characterization methods for validating functional properties

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- Reliability of test equipment and systems for testing, monitoring, and diagnostics
- Data handling, analytics, and advanced condition assessment

Preferential Subject No 3:
Insulation Systems of Advances Components

- Materials under high stresses, e.g. field stress, flux, electric current, and frequency
- Experience and requirements for new test procedure and standards
- Development of new materials, e.g. 3D printing, lamination, casting, and additive or subtractive manufacturing

This year (2020 & 2021) in total 45 papers from 21 countries have been accepted. 23 papers cover Preferential Subject PS 1, 12 papers cover Preferential Subject PS 2, and 10 papers cover Preferential Subject PS 3. During the e-Session in 2020, the GDM meeting held over two days, 42 papers were presented by the authors and discussed during the live Q&A.

3. Important information for delegates and contributors concerning the Group Discussion Meeting (Tuesday, August 24th and Wednesday, August 25th), further details are given here: General Programme | Cigre.

The **Group Discussion Meeting** shall address questions of general interest related to the topic of the preferential subjects, and thus will focus on the questions raised by the Special Reporters. It is not intended that individual papers will be presented and discussed in the Group Discussion Meeting during this some unique GDM Session. Delegates who wish to make contributions in the Group Discussion Meeting must upload their contribution on the Registration Platform – https://session.cigre.org/registration before **July 31th, 2021.** For Session details day-by-day have a look https://session.cigre.org/schedule-daily-summaries?cat=group-discussion-meetings; "**Group Discussion Meetings**".

A) Dear Contributor, you should upload your contribution on the Registration Platform – https://session.cigre.org/registration using your existing account and own credentials before **July 31th, 2021.** This will allow the Special Reporters a prior screening and allow a good organization of the GDM by them.

Some additional important remarks:

- Access to contribution uploading is given only to duly registered delegates.
- Consequently, registration to CIGRE Session 2021 should be finalized before uploading contribution(s) online.
- Register now for the Centennial Session 2021 and follow this link: https://session.cigre.org/registration.
- Contributions uploading will be open at the beginning of May 2021.

B) Special Reporters will review the prepared contributions (PowerPoint presentation with max. 3 slides plus written contribution with max. 1000 words per contribution) and select accepted contributions. A guide for contributors as well as templates and sample pages will be available on the CIGRE Centennial website, follow this link: https://session.cigre.org/introduction and press button "**Download Guides & Templates**".

C) Any recommendations or changes to the contributions will be provided to the contributors by the Special Reporters directly via the Registration Platform by August 1th, 2021. Contributors are encouraged to visit their account on the Registration Platform to see the result of their review.

D) The complete list of all papers can be found in the General Program, https://session.cigre.org/general-programme, button "Download the Programme".

In the following parts of this Special Report each of the Preferential Subjects is separately discussed. We will not discuss every paper in detail, as this was already done during the e-Session 2020. Instead, we have formulated some generic questions for each Preferential Subject. We have selected some papers which cover the bigger and main points, which may serve as illustration to our questions. Finally, we hope, that these questions will trigger a fruitful, informative, and lively discussion at our Group Discussion Meeting.

PS1 - Testing, Monitoring and Diagnostics

Many utilities are experiencing a loss of older skilled staff, as well as, downsizing and outsourcing of some activities. These factors lead to a loss of knowledge from within the utility and particularly for older assets a reduction in the tribal memory of the organization which is hard to replace.

A few papers specifically address methods for improving knowledge about an asset's condition and in turn strategies for maintenance. Better knowledge of an asset's condition should improve asset management provided there is sufficient understanding of the test results. In recent years, numerous automated approaches have been proposed for processing data, from simple methods like Duval's triangle for interpreting dissolved gas analysis results to far more complex Artificial Intelligence methodologies.

Question 1.1: What other techniques in development or trial hold significant promise to deliver improved diagnostics and/or detection of incipient faults in the field?

Question 1.2: What new diagnostic or monitoring tools are becoming available to improve the understanding of asset condition? Are there examples which show the benefit of these approaches?

Question 1.3: What experience is there in using algorithms to determine asset condition and/or determine the appropriate interventions?

The adoption of longer cable circuits both onshore and offshore is leading to new challenges during cable development, testing and ultimately commissioning. Long HVDC cables are now being deployed onshore, for example routes over 1000 km in Germany, as well as to distant offshore windfarms and more traditional interconnectors. Higher voltages and new materials need tools to probe the charge dynamics within the insulation not just on laboratory samples but also full-sized cables or DC-GIL: **Paper D1-106** ("Challenges for space charge measurements with the PEA technique in the thick insulation of HVDC Cables", Italy) and

Paper D1-107 ("Cigré Prototype Installation Test for Gas-Insulated DC Systems – Testing a Gas-Insulated DC Transmission Line (DC-GIL) for +/- 550 kV and 5000 A under Real Service Conditions", Germany) report on such measurement and tests.

Various commissioning methods are covered in international standards and guides, but longer higher voltage AC and DC cables present significant challenges. Paper **D1-112** ("Extended frequency range testing of HV cables", Australia**)** proposes extending the allowable frequency range to reduce the power needed for testing.

Question 1.4: Are there other examples of previous laboratory techniques now being used on full size assets to improve product development?

Question 1.5: What new modelling methods, analytical tools or measurement techniques are becoming available to provide new information and support product development?

Away from the physical assets, the fourth digital industrial revolution is upon us characterized by a fusion of technologies that blur the lines between the physical and digital spheres. The electric power industry has developed apparatus and methods based on an understanding of the physics and chemistry for assessing product quality and the ageing of materials. In the future data analytics (e.g. machine learning or neural networks) and digital twins are proposed as potential approaches to streamline network operation and asset management, but will these negate the need for an understanding of physics and chemistry?

Question 1.6: Are there examples of ageing models of functional behaviour and ageing of materials that combined with feasible sensors will provide datasets suited for integration into digital twins for operation and asset management of e.g. transformers, cables or power lines?

Question 1.7: Are there examples where diagnostic databases correlated with service experience and failure statistics are used for scheduling maintenance and renewal?

Question 1.8: Will old rules and interpretation schemes be valid for new materials?

Paper D1-109 ("Partial Discharge Analysis in Gas-Insulated HVDC Systems Using Conventional and Non-Conventional Methods") discusses the application of PD measurement techniques and analysis for DC-GIS insulated with SF_6. **Paper D1-123** ("Measurement and behavior of partial discharge for SF6 substitute gases in HVDC GIS/GIL") investigates and compares the PD behavior of new gases in HVDC GIS & GIL.

PS2 - Functional Properties and Degradation of Insulation Materials

In 2020 CIGRE published TB 822, "Methods for dielectric characterisation of polymeric insulating materials for outdoor applications" and has two further Working Groups looking at the properties of polymeric insulators, D1.58, "Evaluation of dynamic hydrophobicity of polymeric insulating materials under AC and DC voltage stress" and D1.72, "Test of material resistance against surface arcing under DC". **Paper D1-209** ("The electrical characteristics of low current surface discharges with liquid electrodes and the adaption of test parameters for a DC inclined-plane-test", Germany) addresses the latter issue through a modified incline plane test.

Paper D1-207 ("A new type of failure of composite insulators: service experience, degradation characteristics, root cause, and countermeasures", China, Sweden, South Africa), describe a new and rare type of failure of composite insulators under AC stress.

Question 2.1: What challenges exist in HVDC materials development and testing? Where are the current standards still lacking?

Determining ageing in many insulation systems is a significant challenge; similar to paper **D1-106** ("Challenges for space charge measurements with the PEA technique in the thick insulation of HVDC Cables", Italy), **D1-212** ("Implementation of space charge measurement using the Pulsed Electro-Acoustic method during ageing of HVDC model cable", France) addresses the application of the Pulsed Electro-Acoustic (PEA) technique to HVDC cables, although in this case to monitor ageing.

Question 2.2: What <u>new</u> modelling methods, analytical tools or measurement techniques are becoming available to provide new information about properties, performance and ageing of materials?

The increasing penetration of renewable energy sources and use of power electronics is causing more complex stresses on assets in operation, such as , more dynamic loading, more harmonics, and different waveforms etc. For example, dynamic loading of transformers leads to deformation of the cellulose as discussed in **D1-206** ("Characterization of pressboard mechanical properties for understanding the dynamic behaviour of transformer winding clamping pressure", Australia). At the same time there is a wish to improve environmental performance by introducing new materials e.g. SF_6 replacements. If these materials have the same functional properties they can be used in the apparatus without redesign, however, if their functional properties differ then then some adaptations may be required to the apparatus.

Good standards for the functional behaviour of materials are required both for manufacturers during the design phase and for end-users when specifying an apparatus. For example, IEC TC 14 has recently issued a technical report (IEC60076-26) mapping the needs for standards for electrically insulating fluids, both relating to design and to operation of transformers. Esters are a new type of insulating liquid that can replace mineral oils in transformers as discussed in three papers **D1-202**, **D1-203** and **D1-204** ("Proposal of test method for evaluating the induction time (IT) of natural ester insulating oils", Brazil, "LCA and smoke test of dielectric fluids based on natural esters", Italy and "Investigation into the effect of cold temperature on the physical properties of dielectric liquids", UK).

Question 2.3: Are existing test standards for the functional properties of materials sufficient for the design and operation of electric apparatus? And do these test methods sufficiently reveal differences in the functional behaviour of different materials?

Question 2.4: Are there examples of redundant tests in existing standards which do not reveal quality or functional behaviour and potentially limit trade, and that therefore should be withdrawn?

None of the submitted papers specifically addressed materials with a lower environmental footprint, during production, operation, or disposal.

Question 2.5: Apart from SF_6 alternatives, what examples are there of reducing the carbon footprint of products through the use of new materials, production processes or recycling in the transition to a Net Zero world? Can these changes be quantified?

PS3 - Insulation Systems of Advances Components

There is often a need to increase the rating of a replacement asset when decommissioning older units; this can be made more difficult by needing to stay within the original apparatus footprint. Solutions include increasing the voltage or thermal loading thereby increasing the stress on the materials. Examples include replacement of AIS equipment with GIS, transformers with hybrid insulation systems or cables using High Performance Thermoplastic Elastomer (HPTE) insulation both of which use high temperature materials, e.g. **D1-302** ("Replacement of area substation transformers with flexible units of reduced footprint and increased overloadability", Poland). In contrast to the latter thermoplastic solution paper **D1-301** ("Byproduct-free curing of a highly insulating polyethylene copolymer blend: an alternative to peroxide crosslinking", Norway) reports a new crosslinking method which removes the need for curing and degassing, making cable production faster and more energy efficient, while still maintaining the benefits of a crosslinked final product.

Question 3.1: Accelerated ageing tests on insulating systems are assumed to give similar acceleration factors to service ageing to evaluate how the materials will function in the real world. How can results from accelerated thermal or voltage endurance test be used to estimate service life? Are there examples of accelerated tests giving similar acceleration factors for different materials or insulation systems?

Question 3.2: Are the current standards sufficient for the use of new materials or systems in equipment with higher temperature classes?

New manufacturing techniques, such as 3D printing and casting **D1-305** ("3D printed solid insulator: possibilities and challenges", Japan) and **D1-307** ("Electric Field Relaxation by Functionally Graded Insulating Materials in GIS", Korea, Germany), subtractive manufacturing or laminating all offer means to create components in new ways and/or control material properties on a very localized manner. This offers the prospect of creating novel components with highly controlled properties which vary in three dimensions. Such components will likely require new methods of assessment and testing.

Paper **D1-303** ("New test procedure intended to evaluate adhesion of core/housing interface of composite insulators", Sweden) proposes a new method of assessing the bonding at the interface between the core and housing of a composite insulator. This work delivered by seven countries is a good example of how in-service failures lead to new learning and ultimately new assessment methods.

Paper D1-304 ("Measurement and simulation of transient field stresses and impacts on advanced insulation design and new test procedures for HVDC components", Germany) and **Paper D1-309** ("Dielectric stress on and design of GIS support insulators for HVDC-applications", Switzerland, Sweden) present measurements and improved simulation models to calculate electrical fields for HVDC components such as bushing or spacers.

Question 3.3: What improvements or step changes in manufacturing techniques in the longer term will deliver improved/modified material or component properties which will drive up product reliability, reduce costs or deliver other benefits to end users?

Question 3.4: Are there examples of components made with novel manufacturing techniques under development or testing?

Question 3.5: What new modelling methods, analytical tools or measurement techniques are becoming available to enhance product quality control during and after manufacture?

4. Conclusion & final remarks about the Group Discussion Meeting

According to the limited time for each contribution (3 to 5 minutes), probably not every contribution can be accepted and presented. In addition to these contributions, the Special Reporters, the Chairman, the convenors of the Advisory Groups and some selected Working groups will give additional but brief and important information about their tasks and status of and within Study Committee SC D1.