▶ *DISCUSSION MEETING SUMMARY*
Study Committee A2
Power Transformers and Reactors

August 30th, 2024

Chairman: Pascal MÜLLER (CH)
Secretary: Marc FOATA (DE)

Special Reporters:

PS1	PS2	PS3
B. JURIŠIĆ (HR)	**T.L. MacARTHUR (AU)**	**S. SCHREITER (DE)**
Ž. JANIĆ (HR)	**P. PICHER (CA)**	**E. MacKENZIE (UK)**

1. INTRODUCTION

The A2 Group Discussion Meeting was held in the Amphitheatre Bleu on Friday August 30th, from 8h45 to 18h00. The preferential subjects for discussion were:

PS1: Design of resilient transformers
› Stresses from the environment: Impact of global warming, high temperatures heavy rain, high winds, offshore installations, etc.
› Stresses from the system: switching impulses, reverse flow, emergency overloading, harmonics, GIC, short-circuits and internal arcing etc.
› Specifications: design criteria, materials and testin g requirements for new transformers. Suitable maintenance standard and refurbishment strategies.

PS2: Advances in transformer analytics
› Data management: digitalisation and information model, online and offline test data, integration of condition and multiple data sources, data preparation for analytics.
› Diagnostic and on-line monitoring: algorithm/guidelines for on-line monitoring, advanced interpretation of condition data, case studies.
› Modelling: transformer digital twins (thermal, dielectric, mechanical, etc.), physics-based and hybrid models, failure probability and ageing models,applications of artificial intelligence.

PS3: Reliability of transformers for renewable energy
› Transformers for low carbon technologies: voltage < 100kV, wind and photovoltaic parks, battery energy storage and electric vehicle charger etc.
› Case studies and lessons learned: type of failure, root cause analysis, mode of operation. Recommendations concerning procurement, design, operation and asset management strategies.
› Failure Prevention: useful diagnostic methods and monitoring systems. Optimization of operating conditions and additional measures such as overvoltage protection, harmonic reduction, cooling optimisation etc.

2. RUNNING OF THE MEETING

After a brief presentation by the Chair of the scope and activities of SC A2, the discussion was chaired by the Special Reporters, which paired NGN and young members with senior experts. Keynote addresses by invited speakers served as an introduction to the discussion of the preferential subjects, they were followed by NGN showcase presentations and the prepared contributions. After authors presented their prepared contributions,

the special reporters invited the attendance to start the discussion by making spontaneous contribution or asking questions.

A short award ceremony took place before lunch, during which Bjorn GUSTAVSEN (NO) was presented the 2024 Technical Council Award by SC A2 Chair Pascal MÜLLER.

3. CONTRIBUTIONS TO PREFERENTIAL SUBJECT 1

The first preferential subject received 37 papers, with the paper titled "On-Site GIC Withstand Experiment on a 1000 MVA 3-limb Autotransformer and a 300 MVA 5-limb Transformer (Part I and II)" by a team of investigators from Norway, Germany, and Sweden winning the Best Paper award. The keynote speech was delivered by Gabor GURSKY (HU), followed by the NGN presentation, "Impact of Cellulose Degradation on Space Charge Dynamics and Conductivity of Synthetic Ester Liquid-Impregnated Kraft Paper Insulation," presented by Abdelrahman ALSHEHAWY (UK).

In total, 24 contributions addressing all questions of the special report were presented. It was followed by an open discussion that is summarized below:

Special reporters invited spontaneous contribution from the floor. As none was expressed, selected questions transmitted by the audience through the application were submitted for comments.

Are maintenance and testing of offshore considered during the design? This question did not receive any comment/reply from the audience.

For the refurbished transformers, do they also must fulfill the routine tests and type tests according to the currently standard and. Requirements? Are they also able to pass these tests? Is there acceptance (regulatory, customer) for refurbished transformers having higher no-load than new ones (with modern lower-loss e-steel) or is this limiting? Two participants replied that all type tests are normally repeated except the heat run. Levels are at 80% according to IEC unless all components are replaced.

What are vendors of bushing monitoring doing to prevent Very Fast Transients? No direct reply from the audience, only one comment was to refer to CIGRE impulse testing brochure and Working Group on very fast transient and that measurements are needed.

How can we "train" purchasers who know nothing about transformers to provide the required details in the specification? A first comment was to refer to IEC and IEEE application guides as training material. A second comment was to the effect the Brazilian mirror A2 committee has established a working group and a brochure from the WG has just been released on the subject: Specification of Power Transformers and Shunt Reactors - Technical Requisites and Best Practices. It is in Portuguese language; however it could be a good starting point to work within A2 on an international WG.

Do you think that it is possible to extrapolate the SN curves up to higher cycles? Sometimes these curves could have different shapes at very high cycles, and it is only possible to recognise this by testing? The reply from one contributor was that the SN curves might change shape at higher cycle numbers, also depending on temperature, immersion of oil, aging.

3. CONTRIBUTIONS TO PREFERENTIAL SUBJECT 2

The second preferential subject received 51 papers, with the paper titled "Analysis of Non-Accelerated Aging of Model Windings Immersed in Mineral Oil and Natural Ester" by a team of investigators from USA, Argentina and Italy winning the Best Paper award. The keynote speech was delivered by Luiz CHEIM (US), followed by two NGN presentations on "Modelling of Dual Core Phase Shifting Transformer in ATP-EMTP Environment" by Gabriele TRESSO (IT) and on "Estimating the Dynamic Rating of Distribution Transformers using Digital Twins" by Saravanan BALAMURUGAN (IN).

In total, 25 contributions addressing all questions of the special report were presented, it was followed by an open discussion that is summarized below:

Tim GRADNIK (SI) presented a spontaneous contribution about: Securing reliability, supporting standardisation and future proof development of Transformer models and Digital Twins. CIGRE WG A2.60 produced an open source platform for benchmarking and development of dynamic transformer thermal models (CIGRE DTTM-BP). As a proof of the concept described above the WG has created a proposal for improvement of the upcoming revision of the IEC 60076-7 loading guide dynamic transformer thermal models. CIGRE community is encouraged to review the open source CIGRE DTTM-BP platform for benchmarking, and to extend the suggested approach to other modelling applications.

Question to Khayakazi Dioka: do you use simple (hydrogen or/and moisture) or multi gas (up to 9 gases) DGA monitors for your asset and why so? Majority (about 60%) of this utility's transformer are equipped with gas sensors, with a diversity of technical specifications.

On a question about the theoretical bathtub failure curve, it was commented that early failures are not frequent, not always reported and are therefore difficult to observe. Failures are random for most of the lifespan, showing only a slight increase for older units.

Models require large training data sets. As the number of transformers are limited and luckily the number of failures small, how to ensure enough real data? What could be the strategies ? Collecting data for digital twin means that even characteristics of the paper insulation and oil which have been used for each specific unit will be needed to be shared in order to have a better understanding on the behavior? Organization like IEEE and CIGRE are working to provide neutral and open support for data collection initiatives (currently 51.000 DGA records). Utilities and operators should also be more open to share their data for the greater and mutual good.

One participant asked if there are any investigation that AI models are accurate and suggested that the question could the topic for a future WG.

Another comment was to keep in mind long term effects on the reliability such as the loss of clamping pressure, and not only the immediate cause of failures.

4. CONTRIBUTIONS TO PREFERENTIAL SUBJECT 3

The third preferential subject received 14 papers, with the paper titled "Effects of Rooftop Photovoltaics on the Load and Ageing of Distribution Transformers" by a team of investigators from Australia winning the Best Paper award. The keynote speech was delivered by Peter WERLE (DE).

In total, 15 contributions addressing all questions of the special report were presented, it was followed by an open discussion that is summarized below:

Any consideration in the use of ester oil to improve management of stresses specially for fire mitigation in transformers for wind turbine application ? Do you use ester natural /synthetic oils for this application? One manufacturer replied that synthetic esters are indeed used in transformers mounted in the turbine nacelle.

Do you see the need for new or adopted diagnostic measurement techniques to assess the condition of transformers connected to renewables? Two contributors replied that the methods are the same than for other applications but that the parameters and interpretation thresholds can be different.

How is global warming going to affect the transformer lifespan as the transformers could be sized for an ambient temperature of 35 degrees Celsius but in 10 years we could be seeing 40 plus degrees Celsius. How do we consider for 40 year lifespans? IEC TC 14 Chair Christoph PLOETNER (DE) answered that the upcoming revision of the standard will clarify this issue.

How are the harmonics from the converters are considered during the design phase of the transformers? One comment was to the effect that too much focus is on harmonics and that other effects such as switchgear, restrike, lack of insulation coordination would deserve more attention.

About concerns raised by a contribution that issues beyond CO_2 emissions, such as the depletion of copper sources, could have a greater environmental impact, question was what will happen then ? In response, it was mentioned that extracting copper would become more costly and result in higher CO_2 emissions as deeper deposits are mined. As an alternative, aluminum was suggested, being more abundant than copper.

6. CONCLUSION

The General Discussion Meeting had 325 people attending throughout the day. Participation from the delegates to the discussion was quite good, unfortunately not all questions posted on the Sparkup application could be addressed due to the tight schedule. More time should be allowed for the open discussion in future sessions.