Many Thanks

- **The University of Manchester, sponsoring the meeting room. Lunch and Tea/Coffee Breaks are sponsored by the CIGRE-UK.**

- **CIGRE-UK A2 Team**
  - ✓ Regular Member – Zhongdong Wang (The University of Manchester)
  - ✓ Additional Member – Elizabeth MacKenzie (MacKenzie Consultant)
  - ✓ Technical Panel Secretary – Jose Quintana (SP Energy Networks)
  - ✓ Secretary – (Tee) Shengji Tee (SP Energy Networks)

- **Support from CIGRE-UK:**
  - ✓ Martin Ansell (Events/Marketing)
  - ✓ James Yu (Technical Committee Chair)

- **Support from The University of Manchester:**
  - ✓ Qiang Liu
  - ✓ Shanika Matharage

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Agenda

- 10:30 Registration and Tea/Coffee
- 11:00 Welcome and Introduction to SC A2
- 11:15 Technical Brochures Published in 2024 | CIGRE 2024 Reflection | New WGs & Future Events | A2 Technical Activities and Working Group Updates
- 12:30 Introduction to D1 and Updates from Relevant Technical Activities
- 13:00 Networking Lunch
- 14:00 Updates from IEC 60076 Parts 1 and 2 Revision
- 14:15 In-depth A2 Technical Presentation & Discussion (Life Cycle Assessment and Dynamic Thermal Modelling)
- 15:15 Any Other Business
- 15:30 End of Meeting, Tea/Coffee/Networking

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CIGRE UK A2|D1 Liaison

Introduction to CIGRE Study Committee A2

UK A2 Regular Member

Zhongdong Wang (The University of Manchester)

27/11/2024

CIGRE Study Committees

Group A - Equipment

- A1: Power generation and electromechanical energy conversion
- A2: Power transformers and reactors
- A3: Transmission and distribution equipment

Group B - Technologies

- B1: Insulated cables
- B2: Overhead lines
- B3: Substations and electrical installations
- B4: DC systems and power electronics
- B5: Protection and automation

Group C - Systems

- C1: Power system development and economics
- C2: Power system operation and control
- C3: Power system sustainability and environmental performance
- C4: Power system technical performance
- C5: Electricity markets and regulation
- C6: Active distribution systems and distributed energy resources

Group D - New Materials and IT

- D1: Materials and emerging test techniques
- D2: Information systems telecommunications and cybersecurity

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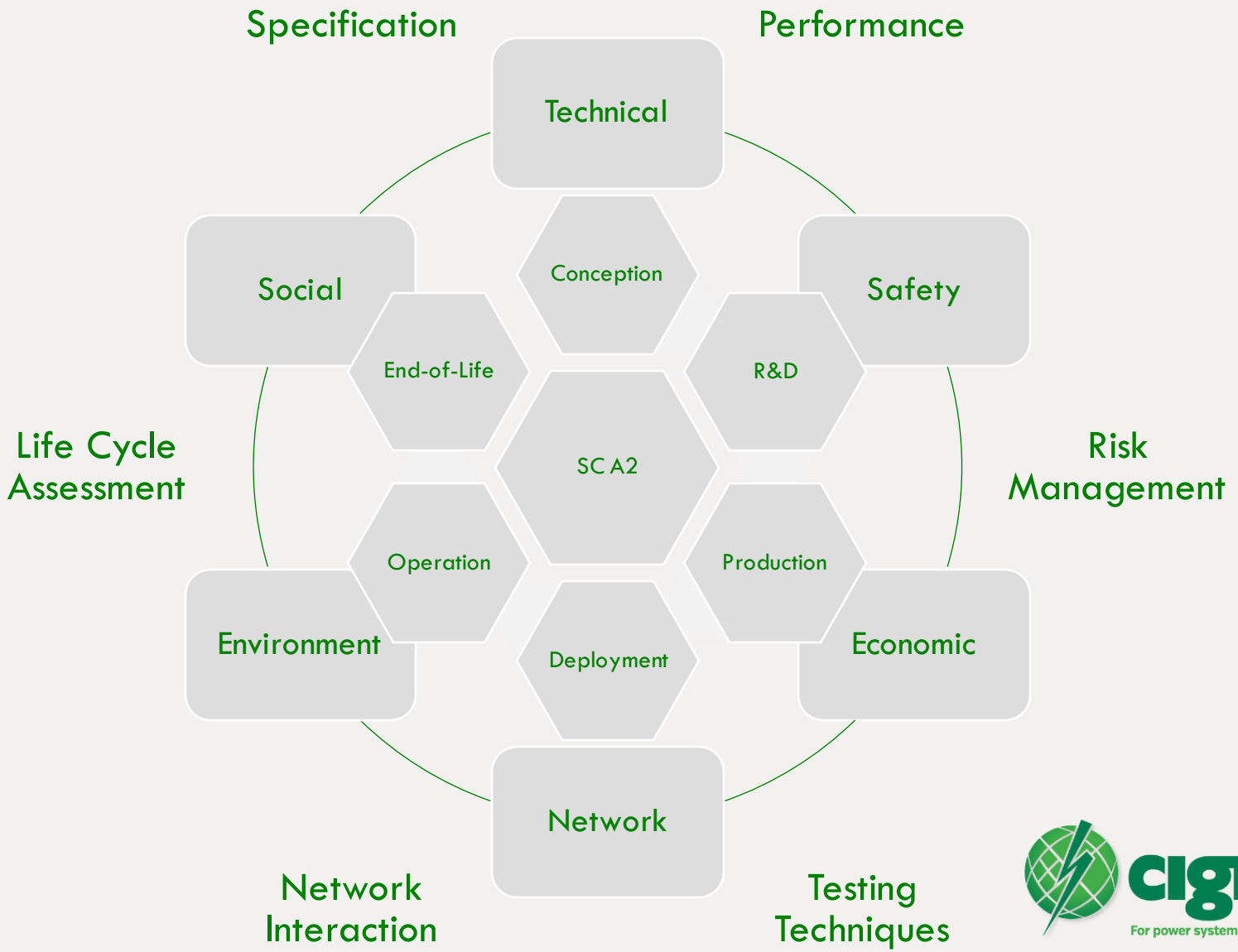
Study Committee SC A2

Mission

- To facilitate and promote the progress of engineering and the international exchange of information and knowledge in the field of transformers and reactors.
- To add value to this information and knowledge by means of synthesizing state-of-the-art practices and developing recommendations.

Study Committee SC A2

- Fields of activity:
  - Power transformers (industrial, DC converter, generator step-up, phase-shifting)
  - Reactors (shunt, series, saturated, smoothing)
  - Transformer components (bushings, tap changers, accessories)
- UK Representation:
  - Prof. Zhongdong Wang (RM)
  - Elizabeth MacKenzie (ARM)



CIGRE A2 Study Committee

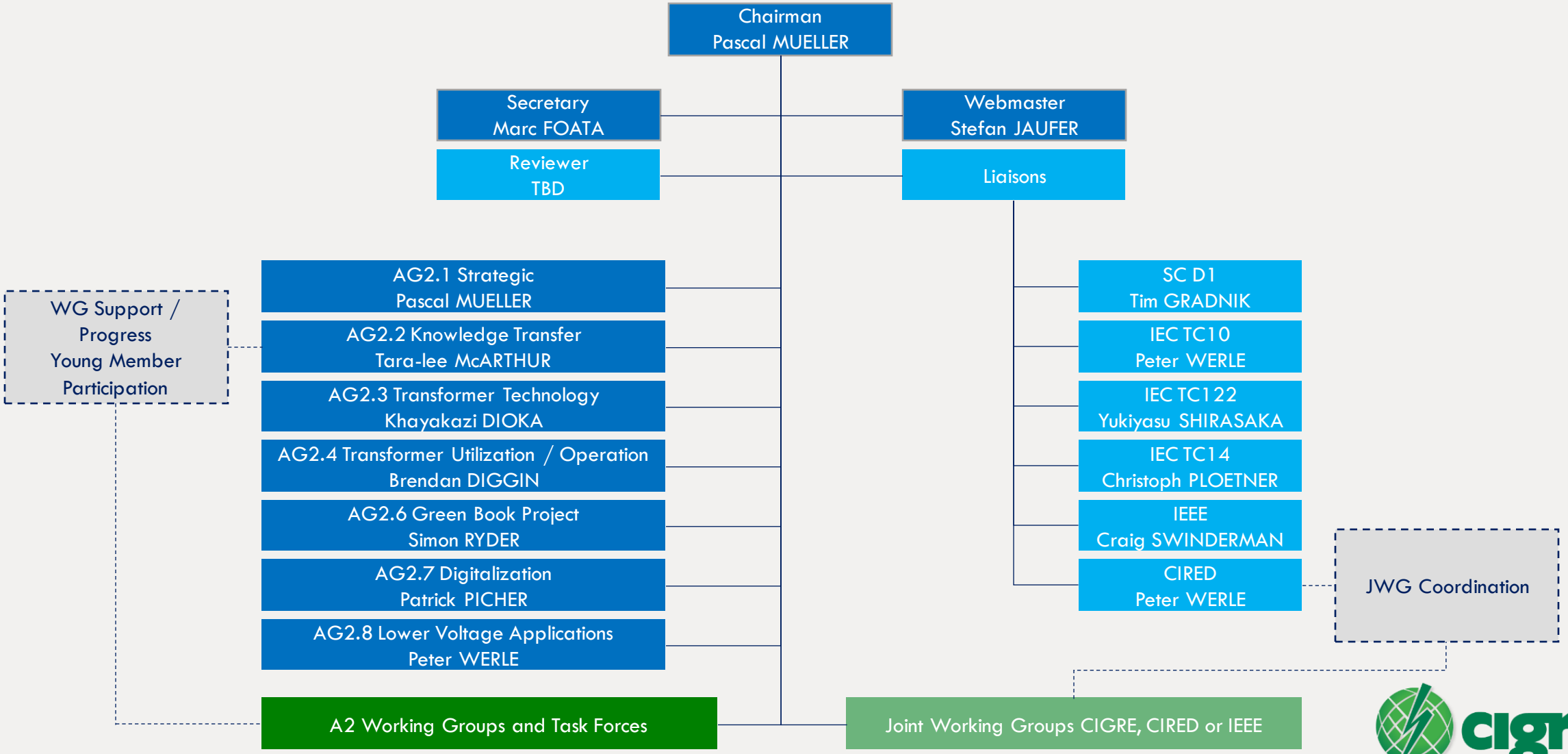
Scope

Within its technical field of activity, Study Committee A2 addresses topics throughout the asset management life-cycle phases; from conception, through research, development, design, production, deployment, operation, and end-of life. At all stages, technical, safety, economic, environmental and social aspects are addressed as well as interactions with, and integration into, the evolving power system and the environment. All aspects of performance, specification, testing and the application of testing techniques are within scope, with a specific focus on the impact of changing interactions and demands due to evolution of the power system. Life cycle assessment techniques, risk management techniques, education and training are also important aspects.

Within this framework additional specific areas of attention include:

- Theory, principles and concepts, functionality, technological development, design, performance and application of materials, efficiency.
- Manufacturing, quality assurance, application guidance, planning, routing and location, construction, erection, installation.
- Reliability, availability, dependability, maintainability and maintenance, service, condition monitoring, diagnostics, restoration, repair, loading, upgrading, uprating.
- Refurbishment, re-use/re-deployment, deterioration, dismantling, disposal.

Latest change on the CIGRE A2 structure



Key Personnel and Activities – CIGRE Study Committee A2

- Chairman
  - **Pascal MUELLER**
- Secretary
  - **Marc FOATA**
- Webmaster
  - **Tim GRADNIK**
- UK Regular Member
  - **Zhongdong WANG**
- UK Additional Regular Member
  - **Elizabeth MACKENZIE**
- Working Groups
  - **Currently 15 working groups under the scope of SC A2**

e-cigre

This website is the online library and bookstore for CIGRE.

There is a wealth of information that can be searched by title, keyword, document type or study committee. It can be downloaded free by Cigre members or purchased by non-members.

Documents include Technical Brochures, CIGRE SC. & ENG. Electra, Colloquia Papers, Symposia Papers, Green Books, Session Papers, ISH Collection, Reference Papers, Working Group Reports, Webinars, Membership Directory, Tutorials.

CIGRE UK A2|D1 Liaison

SC A2 – Technical Brochure Updates

UK A2 Additional Regular Member

Elizabeth MacKenzie (MacKenzie Consultant)

27/11/2024

Technical Brochure Updates

WG	Title	Status
CSE	Mitigation of fire due to higher energy internal arc in bushing turrets	Published Feb 2024
A2.62	Analysis of Power Transformers Reliability	Published, TB939
A2.64	Condition of cellulose insulation in oil immersed transformers after factory acceptance test	Published, TB937
A2.57	Effects of DC Bias on Power Transformers	Publication October
A2.54	Power Transformer Audible Sound Requirements	Published, TB940
A2.56	Power Transformer Efficiency	Final draft under review
TF	Power Transformers Sound Levels on Site	Final draft under review

CIGRE UK A2|D1 Liaison

CIGRE 2024 Reflection

UK A2 Additional Regular Member

Elizabeth MacKenzie (MacKenzie Consultant)

27/11/2024

CIGRE Session 2024

- Tutorial – Analysis of Transformer Reliability
  - **New TB 939**
- Workshop A2-A3-B3-C3-D1
  - **Driving T&D substations and equipment towards ZERO emissions**
- Study Committee Meeting
- Poster Session
- Group Discussion Meeting
- Awards – David Walker, Distinguished Member

CIGRE 2024 Workshop Summary: Defining Future Priorities of SC A2

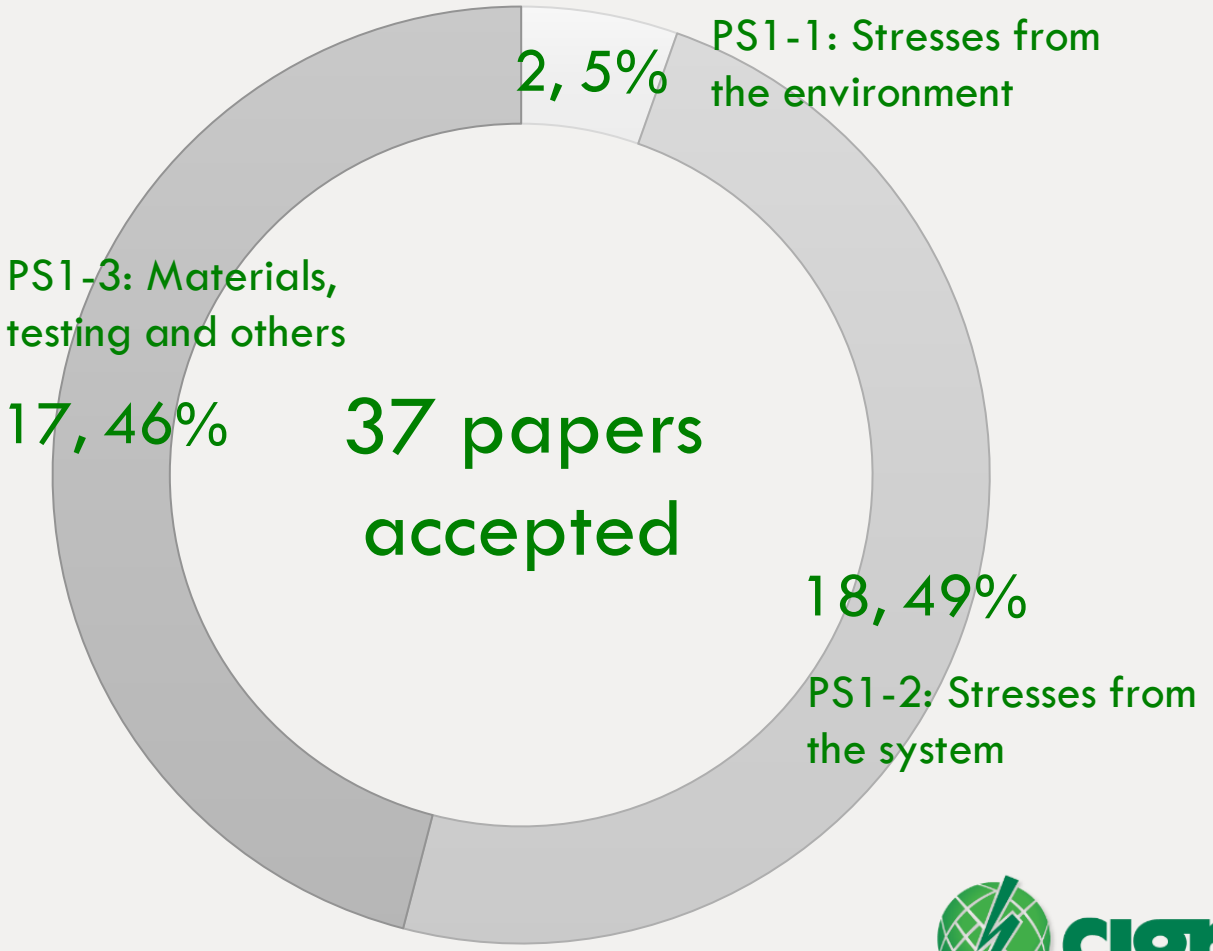
- Increased Tutorials and Webinars
  - Expanding educational resources to support ongoing learning.
- Environmental Focus
  - Addressing climate change impacts, life cycle assessment (LCA), and circularity.
- Digital Innovations
  - Emphasizing digital twins, condition assessment, industry surveys, and monitoring.
- Emerging Applications
  - Exploring new use cases such as floating offshore and submerged transformers.
- Enhanced Safety and Reliability
  - Strengthening standards for operational safety and dependability.

CIGRE 2024 A2 Special Reporters

- Main reporter – younger member
  - PS1 Bruno Jurišić (HR)
  - PS2 Tara-Lee Macarthur (AU)
  - PS3 Sebastian Schreiter (DE)
- Additional Reporter – senior member
  - PS1 Žarko Janic (HR)
  - PS2 Patrick Picher (CA)
  - PS3 Elizabeth MacKenzie (UK)

CIGRE 2024 A2 General Session – Preferential Subject 1

- **Preferential Subject 1 (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 testing requirements for new transformers. Suitable maintenance standard and refurbishment strategies
- **5 papers with UK authors listed**

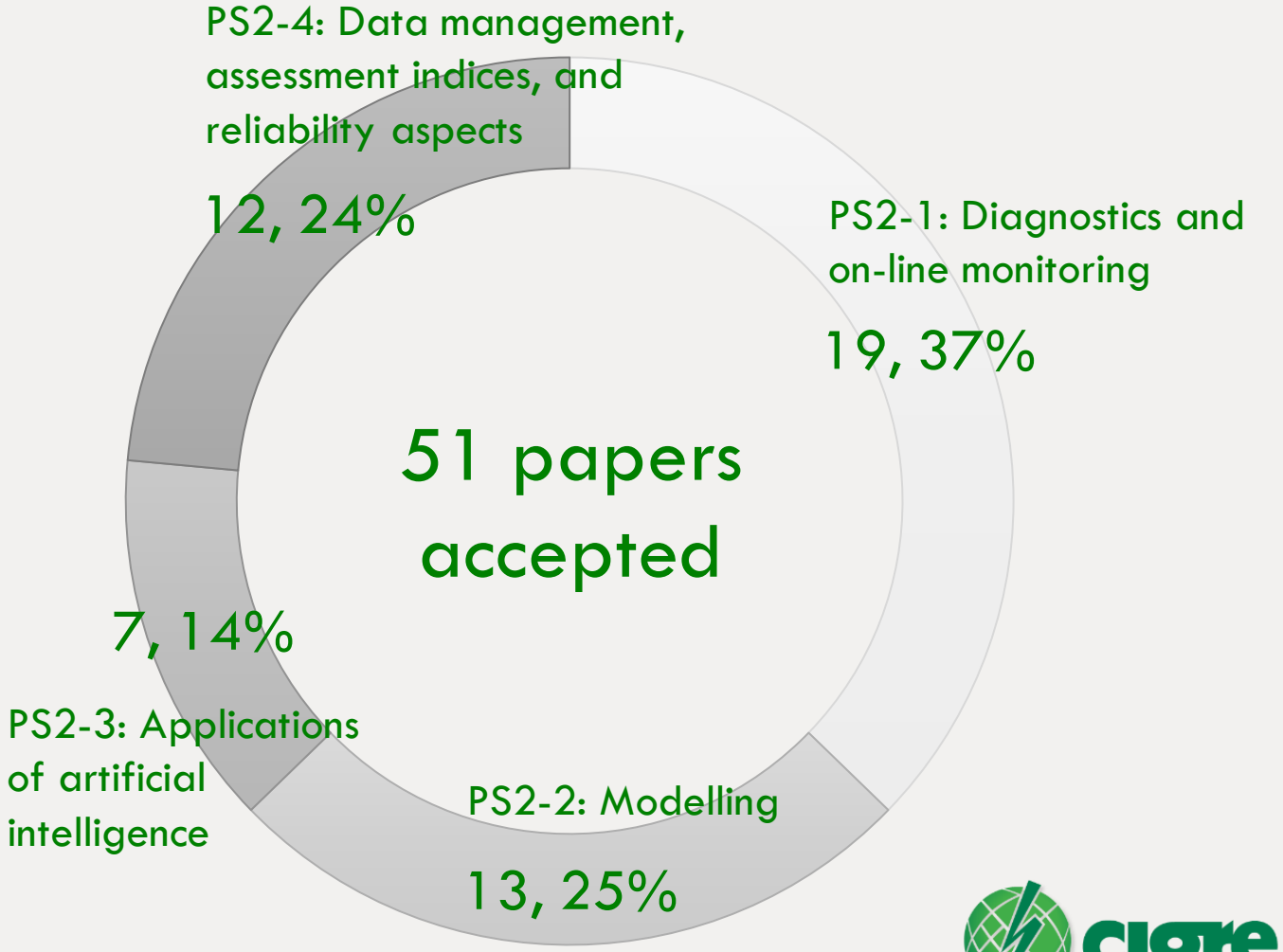


CIGRE 2024 A2 General Session – Preferential Subject 1

- Best paper of PS1
  - **"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**
- Keynote speech was delivered by Gabor GURSKY (HU)
- 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)**

CIGRE 2024 A2 General Session – Preferential Subject 2

- **Preferential Subject 2 (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
- **3 papers with UK authors listed**

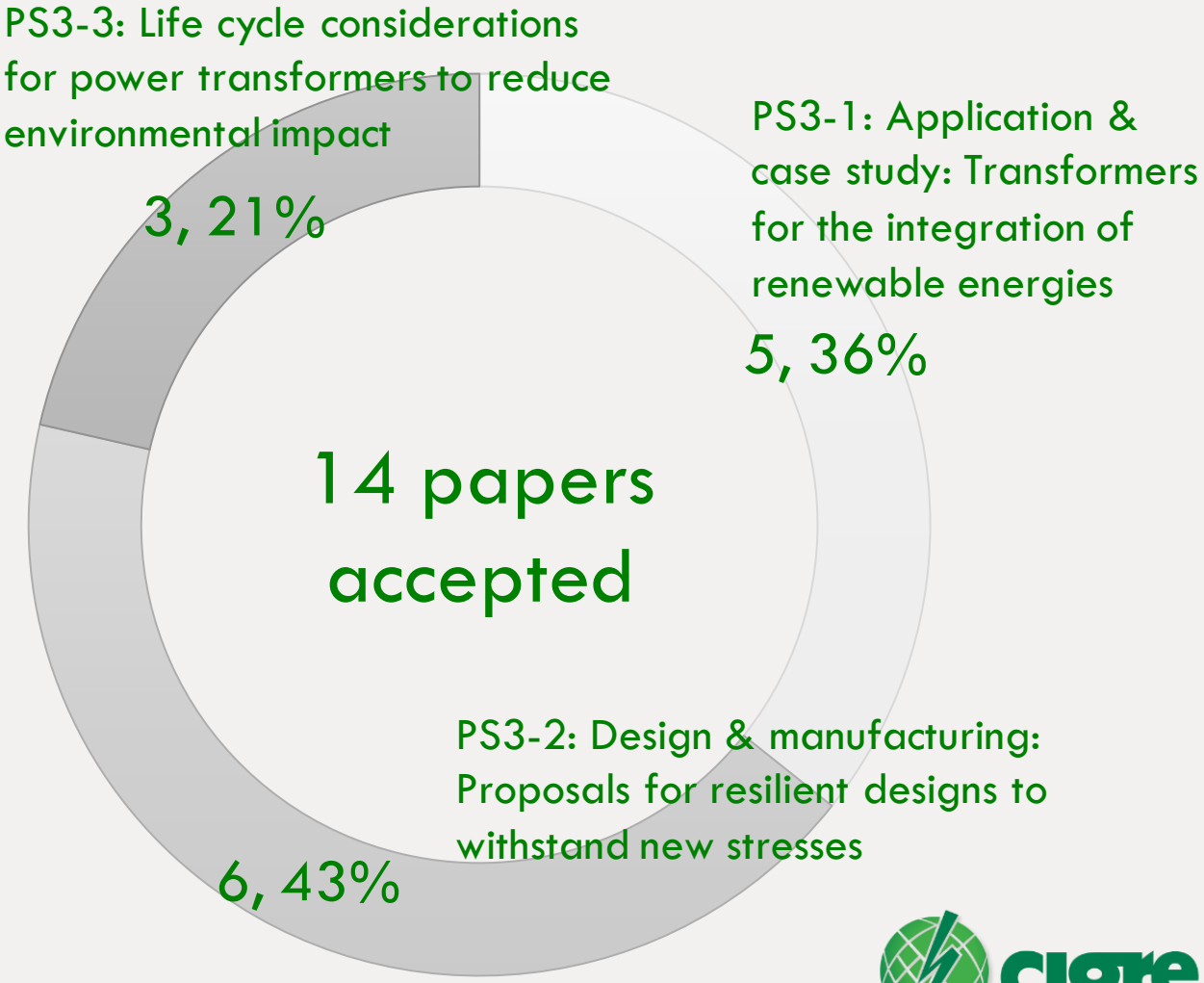


CIGRE 2024 A2 General Session – Preferential Subject 2

- Best paper of PS2
  - **"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**
- Keynote speech was delivered by Luiz CHEIM (US)
- Two NGN presentations
  - **"Modelling of Dual Core Phase Shifting Transformer in ATP-EMTP Environment" by Gabriele TRESSO (IT)**
  - **"Estimating the Dynamic Rating of Distribution Transformers using Digital Twins" by Saravanan BALAMURUGAN (IN)**

CIGRE 2024 A2 General Session – Preferential Subject 3

- **Preferential Subject 3 (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. Optimisation of operating conditions and additional measures such as overvoltage protection, harmonic reduction, cooling optimisation etc.
- **0 papers with UK authors listed**



CIGRE 2024 A2 General Session – Preferential Subject 3

- Best paper of PS3
  - **"Effects of Rooftop Photovoltaics on the Load and Ageing of Distribution Transformers" by a team of investigators from Australia**
- Keynote speech was delivered by Peter WERLE (DE)
- No NGN paper for this PS

CIGRE UK A2|D1 Liaison

Visit to Brush Transformers

(Tee) ShengJi Tee (SPEN)

27/11/2024

CIGRE-UK A2 and NGN – Visit to Brush Transformers

- 7 November 2024
  - Welcome from CIGRE UK and Brush Transformers
  - Introduction to CIGRE UK and the CIGRE UK NGN
  - Introduction to Brush Transformers/Brush Engineering & Design team presentations
  - Factory & Design office tours (2 Groups of 10)
  - Summary of A2 related activities/updates from CIGRE Paris Session.
  - Networking lunch
  - Q&A and re-cap on visit

CIGRE UK A2|D1 Liaison

SC A2 – CIGRE A2 New WGs & Future Events

UK A2 Additional Regular Member

Elizabeth MacKenzie (MacKenzie Consultant)

27/11/2024

New Working Groups for A2|D1 and D1|A2

B3/A2/A3/C3/D1.66	Guidelines for life cycle assessment in substations considering the carbon footprint evaluation	UK Member: Hang XU
Task force	Silver Corrosion in Transformer	
A2.73	Enhancing the exchange of Transformer information through digitalisation	
A2/D1.74	Online moisture monitoring of transformers for ageing assessment	
A2.75	Tap Changer Specification, Condition Assessment, Testing and Maintenance Guidelines	

Looking for members:A2/D1:71
Modern insulating liquids qualification for OLTC, bushings and other accessories

SC A2 Sponsored Events

2025: CIGRE-UK A2 and CIGRE-UK NGN – Presentation Competition, 7 Mar 2025 - More details to follow soon

2025: **CIGRE Symposium, Montréal, Canada, 29 Sep 2025 to 2 Oct 2025** - Abstract submission deadline: 27 Jan 2025

2025: CIGRE A2|D1 Joint Colloquium, Seoul, Korea, 27 Oct 2025 to 1 Nov 2025 - Abstract submission deadline: 31 Mar 2025

2025: CIGRE-UK A2|D1 Liaison Meeting, Nov 2025 - More details to follow soon

2026: **7th International Colloquium Transformer Research and Asset Management, Catvat, Croatia, 6-9 May 2026** - Abstract submission deadline October 1st, 2025

2026: **CIGRE Paris Session, 23-28 Aug 2026**

CIGRE UK A2|D1 Liaison

Advisory Group AG A2.06:

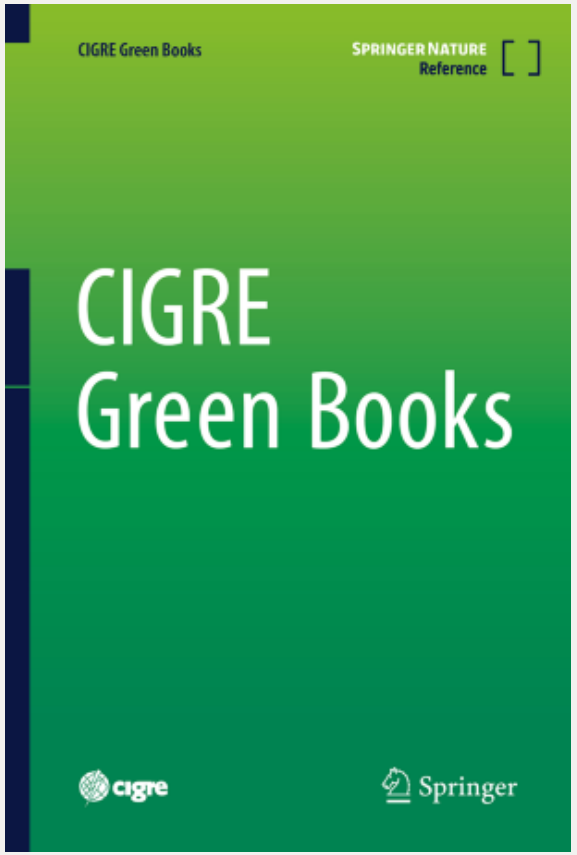
Green Book

Simon Ryder (Doble PowerTest Ltd) – Editor in Chief

27/11/2024

AG A2.06 Scope

- Green Books are CIGRE's state of the art, flagship reference publications. CIGRE aims to produce the very best, most comprehensive set of reference publications encompassing all the subjects covered by CIGRE and its Study Committees. Green Books consolidate, in a single book, all the CIGRE knowledge in a domain of work, i.e. all of the Technical Brochures, reorganised and carefully compiled.
- **SC A2 has two Green Books:**
  - **Transformer and Reactor Procurement**
    - Published in September 2022
  - **Transformer and Reactor Life Management**
    - In progress
    - Planned completion 2025



A2 Working Group Updates

1. A2.54 - Power Transformer Audible Noise Requirements
2. A2.56 - Power Transformer Efficiency (No Updates)
3. A2.57 - Effects of DC Bias on Power Transformers (No Updates)
4. A2.58 - Installation and Pre-Commissioning of Transformers and Shunt Reactors
5. A2.60 - Dynamic Thermal Behaviour of Transformers
6. A2.63 - Transformer Impulse Testing
7. A2.64 - Condition of Cellulose Insulation in Oil Immersed Transformers After Factory Acceptance Test
8. A2|D2.65 - Transformer Digital Twin – Concept and Future Perspectives
9. A2|D1.66 - Breathing Systems of Liquid Filled Transformers and Reactors
10. A2|D1.67 - Guideline for Online Dissolved Gas Analysis Monitoring
11. A2.68 - Failure Survey of Lower Voltage Generator Step Up Transformers installed in Wind farms and Photovoltaic Parks
12. A2.69 - Guide for Transformer Maintenance Update (No Updates)
13. A2|C3.70 - Life Cycle Assessment (LCA) of Transformers
14. A2|D1.72 - Retro-fill of Mineral Oil in Transformers
15. D1|A2.77 - Liquid Tests for Electrical Equipment

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CIGRE UK A2|D1 Liaison

WG A2.54:
Power Transformers Audible Sound Requirements

Convenor: Christoph Ploetner
Secretary: Emanuel Almedia
Members: 24 regular members from 14 countries

UK Members:
Janine Dickinson (National Grid Electricity Transmission)
Mark Warren (Wabtec)

27/11/2024

WG A2.54 Introduction

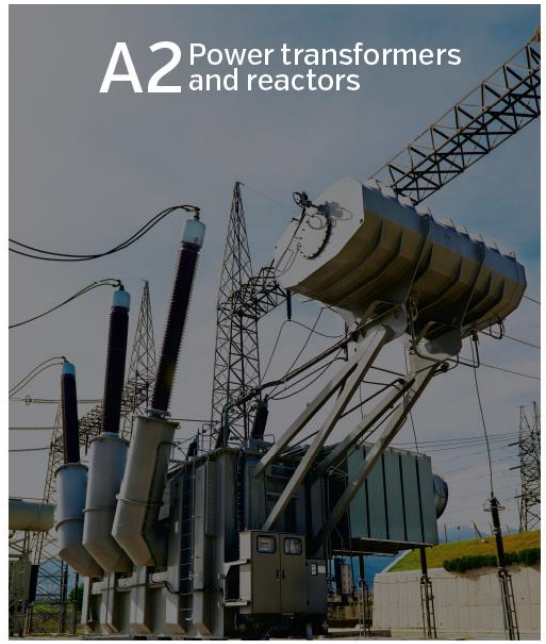
- Context / Scope
  - Lack of reliable **guidance** on how to **specify** Tx sound power levels.
  - Insufficient guidance on range of **typical** and **achievable sound power levels** for Txs of different rated power.
  - Sound power levels for new Txs frequently specified **too low** and **impossible** to achieve.

- Aims / Objectives
  - **Best practice guidelines** for sound level **specification** of Txs.
  - Guidance on range of **typical** and **achievable** sound power levels for Txs of different rated power (10kVA….1000MVA).
  - **Distinguish components**: no load, load and cooling sound and combined sound level
  - Consider 50Hz/60Hz, 3~/1~, sound level legislation and sound mitigation techniques

WG A2.54 Timeline and Progress

- Start and end dates
  - March 2016 – September 2024
- Progress to-date
  - Brochure complete and published (TB 940 - September 2024)

Chapter	Title
1	Introduction (3 pages)
2	Background (29 pages)
3	Sound levels of liquid-immersed transformers (26 pages)
4	Sound levels of other transformer types – Dry-type, Gas insulated, Amorphous cores (8 pages)
5	Sound level specification and legislation (17 pages)
6	Sound mitigation techniques – Barrier design and installation at factory and at site (15 pages)
7	Conclusion and future work (2 pages)
Appendix A	Typical sound power level ranges of power transformers – Summary information (4 pages)
Appendix B	References
Appendix C	Sound level specification using frequency bands (8 pages)
Appendix D	Extension of the formulation for load sound power levels (1 page)
Appendix E	Cavitation (2 pages)
Appendix F	Survey on transformer sound level specification – questionnaire and results (11 pages)



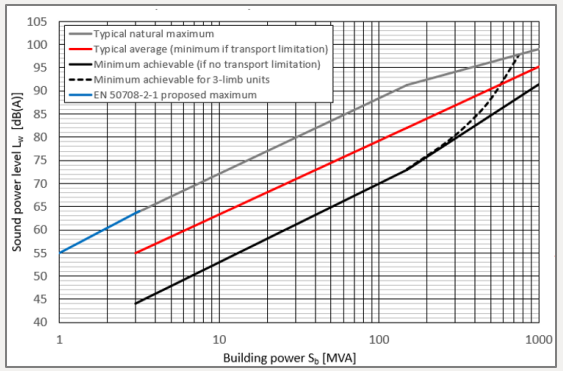
WG A2.54 Technical Highlights

- Sound Level Ranges – no load/load/cooling
  - WG collected data from >1000 FATs (12 manufacturers)
  - Set of graphs (no load/load/cooling) can be used for specification
  - Typical average & Typical min/max sound power
  - No load sound based on Building Power (MVA)
  - Load sound based on Reactive Power (MVAr)
  - Cooling system sound based on rated power (MVA)

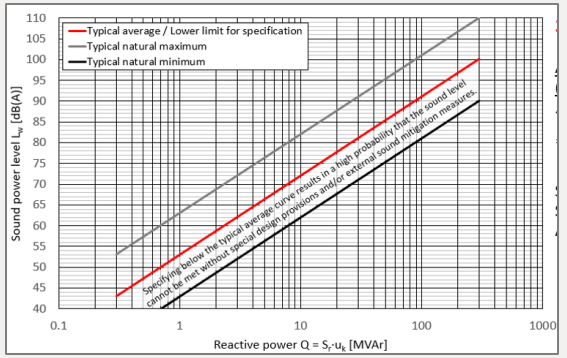
- Cooling System Sound
  - Description of main sources of sound e.g. fans, oil/water pumps
  - Influencing factors e.g. aerodynamics, rotational speed, air flow, fan vibration
  - Cavitation – gas filled cavities implode
  - Design for lower sound e.g. larger cooling area = lower air velocity = lower sound
  - AC (constant speed) vs EC (variable speed) fans

- Sound Level Specification
  - Legislation and noise limits
  - Best practice developed (sound power, defined test parameters, no load/load/cooling/ combined sound, commercial conditions in tender docs, measurement pre & post installation)
  - Practical guidance and examples on how to use graphs for sound level specification

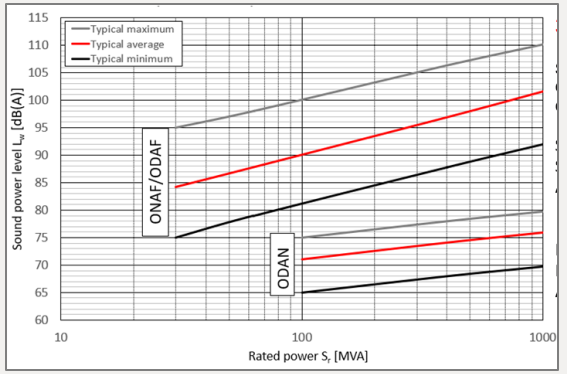
No Load



Load



Cooling



CIGRE UK A2|D1 Liaison

TF A2.01:
Power Transformers Sound Levels on Site

Convenor: Janine Dickinson

Secretary: Martin Stoessl

Members: 10 regular members from 6 countries

UK Members:

Janine Dickinson (National Grid Electricity Transmission)

27/11/2024

TF A2.01 Introduction

- Context / Scope
  - Sound levels measured on site often **differ** from those measured in the factory
  - **No clear guidance** within the industry **why** this is the case

- Aims / Objectives
  - Identify **differences** between FAT and SAT measurements
  - Provide information on **key variables** and **effects** on sound levels
  - Recommend **Best Practice** to improve **accuracy** between FAT and SAT sound level determination
  - Consider whether a **WG** is recommended
  - Highlight key areas for **further research**

TF A2.01 Timeline and Progress

- Start and end dates
  - August 2022 – August 2024
  - TF to become **WG** (completion ~ August 2027)

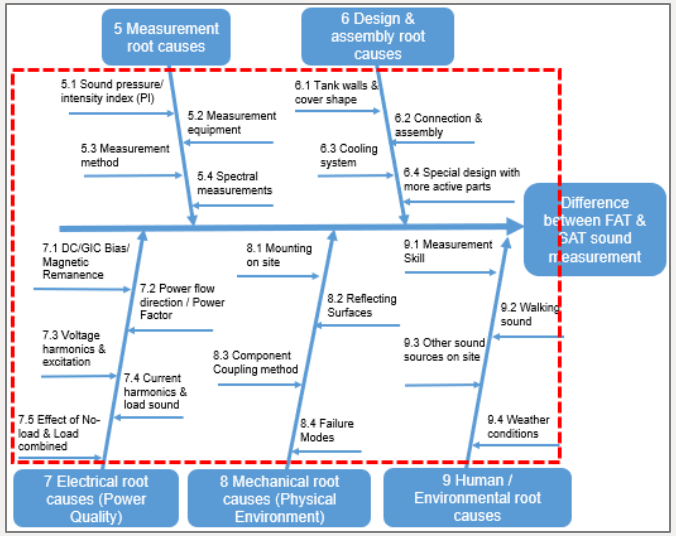
- Progress to-date
  - 6 in person meetings & 6 virtual meetings
  - **60-page** document submitted to Cigre
  - Identified **factors** influencing FAT/SAT
  - **Root causes** of effect
  - Recommendations for **best practice**
  - Recommendations for future **WG**

Chapter	Title	%
1	Introduction	100
2	Variation in Legislation and Noise Limits	100
3	Process flow & overview	100
4	Factors influencing FAT & SAT sound levels	100
5	Root Causes	100
6	dB impacts on determination of sound power level	100
7	Recommendations for Best Practice	100
8	Recommendations for future Working Group	100
9	Conclusions	100
Appendix A	General Terms	100
Appendix B	Trouble Shooting Guide	100
Appendix C	Direct and Indirect Effects	100
Appendix D	Recommendations for Best Practice	100
Appendix E	Recommendations for a Working Group	100
Appendix F	Calculations – difference between ISO and IEC surface calculations	100

- Work plan
  - Meeting of TF members Dec 2024 to **review recommendations** of TF.
  - Determine recommendations to **take forward** as WG.
  - Production of WG **ToR** Feb 2025
  - Recruit additional members
  - **TF document** to form basis of WG brochure.

TF A2.01 Technical Highlights

- Root Causes
  - Identified & described **root causes** for **differences** in factory & site measurements
  - Key variables split into **4 categories of effect**:
    - Sound Level Measurements, Calculation of Sound Power, Sound Power of Tx, Propagation of Sound.
  - **5 root causes** identified:
    - Measurement, Design and Assembly, Electrical (Power Quality), Mechanical, Human/Environmental.
  - Factors affecting sound levels fall into one of the 5 root causes of effect.



- Best Practice Guidance
  - Aim to **improve correlation** between FAT/SAT measurements
  - **43 best practice recommendations** eg:
    - **Align** FAT with conditions on Grid (energisation & loading)
    - Test under different load scenarios & power flow directions
    - **Measurements** – SI, walkaround, 1/3 octave, fully enclosed surface, reflecting surfaces, other sound sources
    - Consider component **decoupling** to minimise vibration transmission
    - Verify if **power quality limits** are met, measure DC/GIC bias on site.

- Recommendations for Future Working Group
  - **31 recommendations** for future WG split into:
    - **Topics** for a WG to **research further** e.g effect of measuring at low height
    - **Tools** for a WG to **develop** to aid the industry e.g. troubleshooting guide to identify cause of increased sound

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CIGRE UK A2|D1 Liaison

WG A2.58:

Installation and Pre-Commissioning of Transformers and Shunt Reactors

Convenor: Ross Willoughby (AUS)
Secretary: Mike Lamb (US)
Members: 12 regular members from 12 countries

UK Members:
John Lapworth (Doble)
Simon Ryder (Doble)
Ian Hunter (Polaris)

27/11/2024

WG A2.58 Introduction

- Context / Scope
  - Installation of new transformer at site
  - Pre-commissioning inspection and site acceptance testing before entering service
  - Trial Operation monitoring during warranty period
  - So, this is a very wide ranging scope

- Aims / Objectives
  - Practical advice for all interested parties: not only practitioners and potential owners, but also project managers and any other interested parties, e.g. insurance companies and new owners taking over renewable assets from developers

WG A2.58 Timeline and Progress

- Start and end dates
  - September 2018? –2025 (Expected)

- Progress to-date
  - Many meetings before, during and after 2020 COVID
  - Initially face-to face at Sydney, Nuremberg, Prague and CIGRE Sessions and Colloquia
  - Recently regular Teams meetings

- Work plan
  - Three task forces
  - Wide ranging, comprehensive and detailed Brochure (>200 pages)
  - Brochure completion and SC review scheduled for December 2024

WG A2.58 Technical Highlights

- Installation
  - Health and Safety and Environmental requirements
  - Assembly
  - Oil processing and checking dryness

- Pre-commissioning
  - Health and Safety and Environmental requirements
  - Visual inspections and checklists
  - Site acceptance tests – reasons for tests and acceptance criteria
  - Tests before and after first energisation

- Trial Operation
  - Importance of monitoring during warranty period to detect faults not identified by FAT/SAT
  - DGA Interpretation: IEC 60599 v IEEE C57.104-2019
  - Other on-line testing

CIGRE UK A2|D1 Liaison

WG A2.60:
Dynamic Thermal Behaviour of Power Transformers

Convenor: Tim Gradnik

Secretary: Xiang Zhang

Members: 37 regular members from 21 countries

UK Members:

Jose Quintana (SP Energy Networks)

Muhammad Daghrah (M&I Materials)

Paul Jarman (The University of Manchester)

Xiang Zhang (Manchester Metropolitan University)

Zhongdong Wang (The University of Manchester)

27/11/2024

WG A2.60 Introduction

- Context / Scope
  - Review current state-of-the-art tools and approaches for Dynamic Transformer Thermal Modelling (DTTM)
  - Propose improvements to the standard IEC model, specifically:
    - Addressing cooling system states
    - Evaluating impacts of new insulating liquids
    - Considering effects of sub-zero ambient temperatures
- Aims / Objectives
  - Explanation of transformer thermal behaviour fundamentals and phenomena
  - Literature review on historical development of DTTM
  - DTTM Benchmarking and evaluation of possible DTTM improvements
  - Applications of DTTMs

TF1 Transformer thermal behaviour

TF2 DTTM Literature review

TF3 DTTM Benchmarking

TF4 DTTM Applications

Transformer thermal behaviour

Provide explanation of physical principles and phenomena observed, provide recent advances in steady state thermal behaviour, describe modelling approaches.

Dynamic Transformer Thermal Modelling (DTTM) literature review

Review modelling approaches from int. standards and literature and identify possible improvements of std. DTTM

Benchmarking of Dynamic Transformer Thermal Models

*Develop a benchmarking platform for **transparent, objective** and **repeatable** evaluation and comparison of DTTMs, to quantify the proposed improvements of the std. DTTM.*

Dynamic Transformer Thermal Model applications

Review of DTTM applications, showcase best practices, supported by an international survey.

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WG A2.60 Timeline and Progress

- Start and end dates
  - September 2019 – September 2025 (Expected)
- Progress to-date
  - Most of the Technical Brochure structure content has been defined
  - DTTMBP - Dynamic Thermal Transformer Model Benchmarking Platform is published and accessible
  - Most of DTTMs planned for benchmarking are implemented
- Work plan
  - TTS – Transformer Thermal Scenario database needs expansion
  - Results of proprietary DTTMs to be integrated and analysed using DTTM-BP
  - Implement the improved standard DTTM in the DTTM-BP
  - Compile draft TB
  - Electra report and LinkedIn announcement for DTTM-BP

WG A2.60 Technical Highlights

- Highlight 1
  - Explanation of the physical principles and thermal phenomena associated with transformers.
  - Recent advances in understanding steady-state and dynamic thermal behaviour.
  - Various modelling approaches to depict transformer thermal dynamics.
- Highlight 2
  - Development of a benchmarking platform, the DTTM Benchmarking Platform (DTTMBP), to enable transparent, objective, and repeatable evaluation of DTTMs.
  - Implemented most of the planned Dynamic Transformer Thermal Models (DTTMs)
  - Implemented error metrics and result filters in the platform
  - Platform is publicly accessible via GitLab
- Highlight 3
  - Compilation of best practices and applications of DTTM across different scenarios, supported by insights from an international survey.
  - Exploration of DTTM use cases for various cooling systems, new insulating liquids, and conditions.

CIGRE UK A2|D1 Liaison

WG A2.63:

Transformer Impulse Testing

Convenor: Ebrahim Rahimpour

Secretariat: Alvaro Portillo

Members: 35 (26 regular and 9 corresponding)

<u>UK Member:</u>

Qiang Liu (The University of Manchester)

27/11/2024

WG A2.63 Overview

Background:

- Transformer impulse testing is defined in details in existing standards, for instance, IEC 60060-1, IEC 60076-3 and IEC 60076-4.
- But there are still a lot of unclear or unsolved questions which arise frequently among the test engineers.
- Improvement of standards on transformer impulse testing needs studying of transient phenomena and material properties, and accumulation of best practice of testing.

Scope:

- Full wave lightning impulse test
- Chopped wave lightning impulse test
- Switching impulse test
- Non-standard waveforms and high-frequency overvoltages
- Positive and negative polarities in impulse test
- Use of internal surge arresters

Meetings:

- Meeting 1 – 08 Oct 2019
- Meeting 2 – 17-19 Aug 2020 (online)
- Meeting 3 – 23-24 Nov 2020 (online)
- Meeting 4 – 19-20 April 2021 (online)
- Meeting 5 – 16-17 August 2021 (online)
- Meeting 6 – 29 November 2021 (online)
- Meeting 7 – 04-05 April 2022 (online)
- Meeting 8 – 27-29 June 2022 at Manchester (hybrid)
- Meeting 9 – 26-28 September 2022 at Zagreb (hybrid)
- Meeting 10 – 12-14 December 2022 at Porto (hybrid)
- Meeting 11 – 27-28 November 2023 at Split (in-person)
- No meetings in 2024

WG A2.63 Task Forces

- **TF1: High Frequency Power System Transients (Bruno Jurišić)**
  - Measurement equipment and measurement techniques
  - Field measurement and simulation – Lightning, switching
  - Comparison of actual overvoltage waveshapes with standard dielectric test
  - Contribution to draft brochure – finished
- **TF2: Power Transformer Testing - Test Equipment and Techniques (Stefan Dragostinov)**
  - Impulse testing (standard comparison)
  - Non-standard waveforms and high-frequency overvoltages
  - Positive and negative polarities in impulse test (dry and liquid immersed)
  - Contribution to draft brochure – nearly finished
- **TF3: Transformer Transient Simulations (Ricardo Castro Lopes)**
  - Transformer transient modelling using a common template)
  - Effects of LI front time, tail time, chopped LI waveform and etc.
  - Effect of non-standard waveforms on winding internal insulation stress
  - Contribution to draft brochure – nearly finished
  - Simulations almost completed, results analysis and writing are ongoing

CIGRE UK A2|D1 Liaison

WG A2.64:
Condition of Cellulose Insulation in Oil Immersed Transformers after Factory Acceptance Test

Convenor: Claes BENGTSSON
Secretary: Emre OZTURK
Members: 17 regular members from 12 countries

UK Members:
Hongzhi DING (Doble PowerTest Ltd)
Andrew FIELDSEND-ROXBUROUGH (National Grid)

27/11/2024

WG A2.64 Introduction

- Scope
  - To address fundamental question about “What Should a Buyer Expect from the Insulation Properties of a New Transformer”
- Aims / Objectives
  - Which insulation material parameters have a significant impact and are relevant for the long-term function of a transformer
  - If physical cellulosic insulation samples are required, what material to use and how to get representative samples before and after the drying process?
  - Guidelines for acceptance criteria for the properties of the insulation system after completed Factory Acceptance Test, including repeated tests
  - Guidelines for measures and compensation in case the criteria are not met

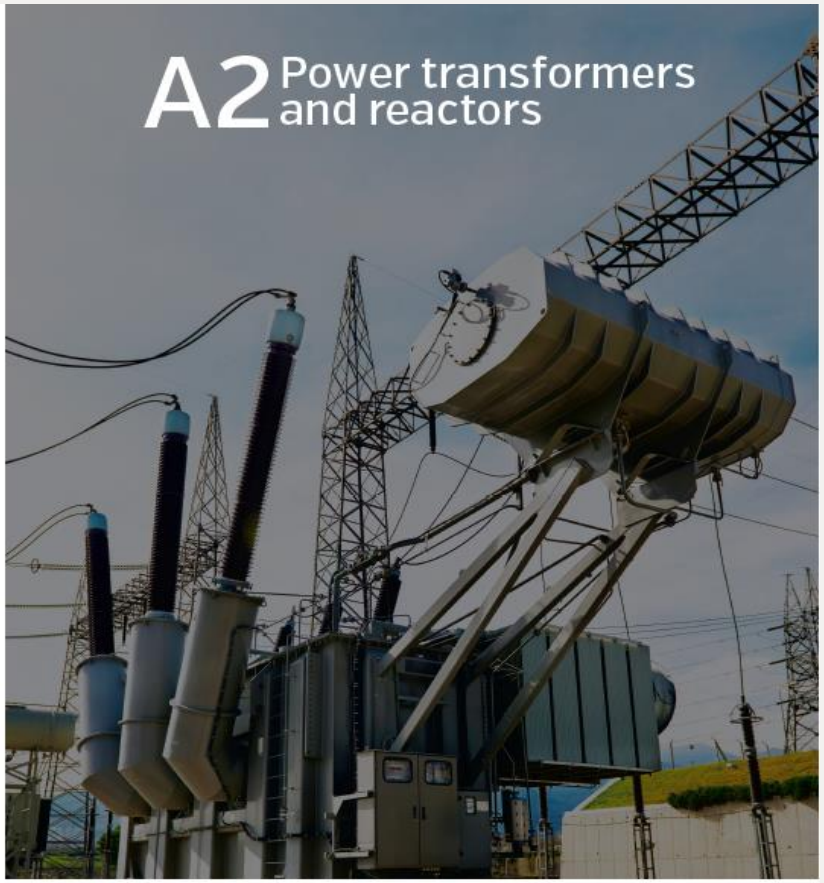
WG A2.64 Membership

- 17 regular members of which 5 women (30%)
- 12 Countries represented (NAM, SAM, EU)
- Repartition
  - 1 from utilities
  - 4 from transformer manufacturers
  - 2 from component manufacturers
  - 5 from service providers / consultants
  - 1 from academic / research institutes
  - 4 Retirees

Members

Claes BENGTSSON, **Convenor**	SE	Emre OZTURK, **Secretary**	TR
Claude BEAUCHEMIN	CA	Anabela MARQUES PEIXOTO	PT
Lucie BOIRON	FR	Lena MELZER	SE
Wilerson CALIL	BR	Alfredo ORTIZ FERNÁNDEZ	ES
Hongzhi DING	GB	Tom PREVOST	US
Anabela FALCAO	PT	Mario SCALA	AT
Andrew FIELDSEND-ROXBUROUGH	GB	Dharam VIR	US
George FRIMPONG	US	Dijana VRSALJKO	HR
Christoph KRAUSE	CH		

WG A2.64 Timeline and Progress



- Start and end dates
  - October 2019 – First Meeting
  - April 2024 – Last Meeting
- Progress to-date
  - Complete
  - Technical Brochures –September 2024 Reference 937

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WG A2.64 Technical Highlights

- **Moisture** and **DP (degree of polymerisation)** are selected for acceptance criteria because they are measurable with achievable limits.
- Expected (shortened) insulation lifetime due to the heat impact of drying must be assessed by evaluating the DP together with the moisture content of the cellulose insulation as a value pair. **These two parameters must not be assessed and specified separately**.
- The brochure provides instructions for both the measurement and interpretation of DP0 and moisture content. The intention is to serve as a common basis for the transformer manufacturer and for the transformer purchaser or user.
- Compensation schemes, if any, in case of discrepancies between measured and expected DP0 and/or moisture level, should preferably be defined early in the purchasing process, i.e. as part of the specification and quotation process. Also, the validation model and acceptance criteria should be agreed in advance between supplier and buyer.
- For more information, see **CIGRE TB 937** – September 2024.

CIGRE UK A2|D1 Liaison

JWG A2|D2.65:
Transformer Digital Twin – Concept and Future Perspectives

Convenor: Patrick Picher

Secretary: Alexander Alber

Members: 40 regular members from 20 countries

UK Members:

Zhongdong Wang (The Univeristy of Manchester)

Sicheng Zhao (SEPRI)

27/11/2024

JWG A2|D2.65 Introduction

- Objectives:
  - Definition of the digital twin for power equipment.
  - Transformers, as the strategic assets, are used to demonstrate what a twin looks like
- Task Forces:
  - Literature review
  - Application and benefits
  - Methodology: physics-based, data-driven, knowledge-based models
  - The reliability of a transformer digital twin
  - Future perspectives and standardisation

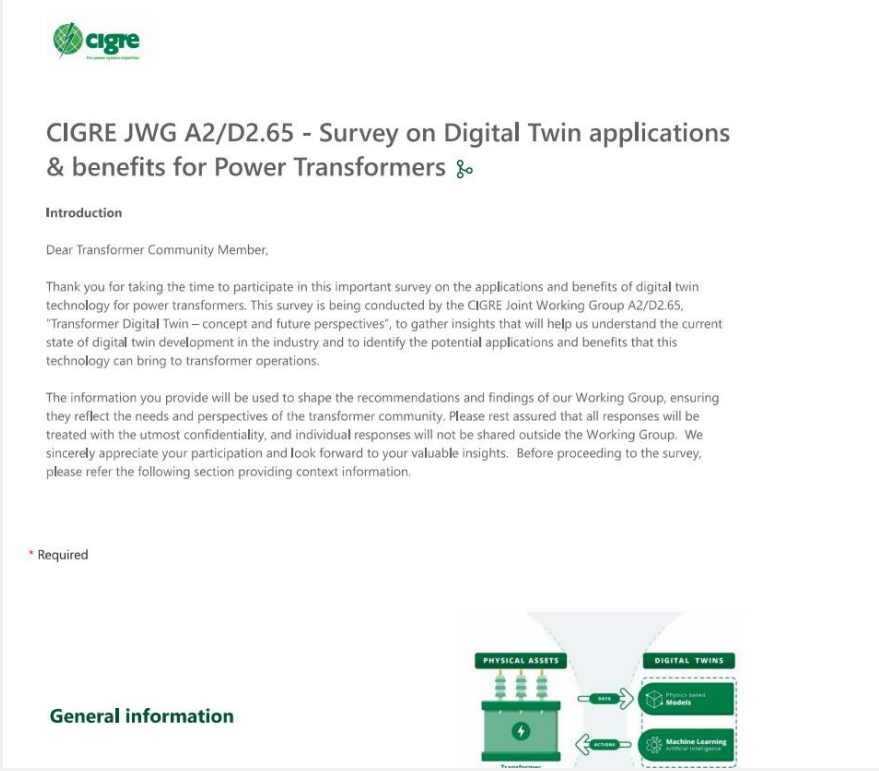
JWG A2|D2.65 Timeline and Progress

- Start and end dates
  - March 2022 – December 2025 (Expected)
- Progress to-date
  - 6 meetings held in total, and 2 meetings face-to-face in 2024!
  - A draft of the TB is completed by 50%.
- Work plan
  - Questionnaire started in Oct 2024
  - Two meetings are planned in Feb and Oct in 2025, respectively.

JWG A2|D2.65 Highlights

- A questionnaire was designed to help understanding the applications and benefits of transformer digital twins around the world.
  - Designed with 29 questions.
- The present status of the TB:

Chapter	Title	Progress				
1	**Introduction** of the subject and the content of the TB					
2	**Definition and framework** history of digital twin developments, definition, framework					
3	**Applications and benefits**					
4	**Digitalisation** of transformer condition asset assessment, data aspects					
5	**Physics-based models** Electromagnetic, Thermal Mechanical, Dielectric / degradation, etc.					
6	**Data-driven models** AI, statistical, hybrid					
7	**Trustworthiness** of transformer DT predictions					
8	**Recommendations** research gaps, challenges					



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CIGRE JWG A2/D2.65 - Survey on Digital Twin applications & benefits for Power Transformers

Introduction

Dear Transformer Community Member,

Thank you for taking the time to participate in this important survey on the applications and benefits of digital twin technology for power transformers. This survey is being conducted by the CIGRE Joint Working Group A2/D2.65, "Transformer Digital Twin – concept and future perspectives", to gather insights that will help us understand the current state of digital twin development in the industry and to identify the potential applications and benefits that this technology can bring to transformer operations.

The information you provide will be used to shape the recommendations and findings of our Working Group, ensuring they reflect the needs and perspectives of the transformer community. Please rest assured that all responses will be treated with the utmost confidentiality, and individual responses will not be shared outside the Working Group. We sincerely appreciate your participation and look forward to your valuable insights. Before proceeding to the survey, please refer the following section providing context information.

* Required

General information

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CIGRE UK A2|D1 Liaison

JWG D1|A2.66:
Breathing systems of liquid filled transformers and reactors

Convenor: Daniel Koch (DE)

Members: 18 regular members

UK Members:

Russell Martin (Midel & MIVOLT Fluids Ltd)

27/11/2024

JWG D1 | A2.66 Scope & Aims

- Give an overview of transformer breather and sealed expansion systems.
- Investigate and report on their ability to control the oxygen and water content of the liquid and insulation over the transformer lifetime.
- Report on the likely influence of the systems on transformer operation including thermal capability and lifetime.
- Report on maintenance and installation/retrofitted upgrades needs and failure rates for the various systems.
- The effects of a closed system on corrosive sulphur or dissolved gas formation.
- Gather data from operational transformers.
- Report on the effect of breathing and sealing systems on any other relevant factors such as DGA interpretation, additive concentration or effectiveness and alternative liquids.
- Give recommendations on when and how to use breathing and sealing systems.
- Give recommendation on the choice of system in terms of condition monitoring and lifecycle cost of the breathing system.

JWG D1 | A2.66 Timeline and Progress

- Start and end dates
  - Start: March 2022
  - Final Report: December 2025
- Progress to-date
  - 7 meetings
- Work Strategy
  - Split the group into task forces dealing with different topics of the brochure.
  - Each task force will have a leader, responsible for the individual contribution. Task force leaders are chosen according to their domain of expertise and/or link to other working groups.
  - The frequency of group meetings shall be 2 months as agreed in previous meeting. The task forces can align independent from that schedule whenever necessary.

JWG D1 | A2.66 TF Structure

Tasks		Leads	TF Members
Literature review	Working groups dealing with relevant topics / papers	Lamine	Marius
Mechanical components Market overview		Daniel	Karsten (Maintenance free breathers)
Oil & insulation Condition monitoring DGA		Senja	Edward (Esters) Carl Lamine Senja Vesna
Questionnaire Data assessment	Sanity check of data Metrics for the assessment	Jon	Daniel
Sustainability Carbon footprint		Daniel	Senja Vesna

JWG D1 | A2.66 Utilities Questionnaire

- To understand what breathing system is used or preferred for a particular transformer type.
- Surveillance/status monitoring of the preservation system in use.
- Observed lifetime of an oil/air-separator bag. Expected lifetime (maker statement) is 10 years. How do the bags do in actual operation?
- Are there influences (e.g. location, humidity level) that shorten or extend the lifetime.
- What level of status monitoring is applied resp. what data is collected?
- Anonymous & not ask for sensitive information.
- The questionnaire has been reviewed and is ready to be released.
- Distribution will be via national committee & A2 study committee members.

CIGRE UK A2|D1 Liaison

WG A2|D1.67:
Guideline for Online Dissolved Gas Analysis Monitoring

Convenor: Tara-lee MacARTHUR (AU)

Secretary: Toni Mellin (FI)

Members: 44 regular members from 20 countries

UK Members:

Michelle Fiddis (GE Vernova)

Shuhang Shen (The University of Exeter)

27/11/2024

WG A2|D1.67 Introduction

- Context / Scope
  - Dissolved gas analysis (DGA) has been an industry standard for detecting and determining faults in transformers for over 50 years.
  - Online DGA monitoring devices have been a valuable tool for the detection of incipient faults as well as an aid in the condition assessment of power transformers.
  - Industry lacks information about the typical values and, most importantly, typical rates of gas formation based on continuous online measurements.
- Aims / Objectives
  - Develop
    - Guidelines for the interpretation, acceptable limits and trends for online DGA monitoring equipment
    - Recommendation for the application of key gas or multiple gas monitors
    - Recommended actions users should take when an alarm occurs
    - A guide to selecting an online DGA system
    - Evaluation criteria for online DGA systems
    - Guidelines for maintenance requirements for online DGA systems
  - Gather online sensors data based on anonymity for initial analysis
  - Compare the different interpretation methods for monitoring electrical equipment
  - Provide examples of the different use cases for online DGA systems

WG A2|D1.67 Timeline and Progress

- Start and end dates
  - Autumn 2022 – Spring 2024 (Extended)
- Progress to-date
  - 5 online WG meetings & 1 in-person WG meeting during CIGRE 2024
  - Six TFs were formed with multiple individual TF meetings held
  - Chapters (Alarm Response; Monitor Specifications; Maintenance) started drafting
  - Data collection template produced and collection ongoing;
  - OEM survey on maintenance closed and analysis pending;
  - User survey on maintenance being produced and collection to be launched;
  - Case studies collected and to be continued
- Work plan in 2025
  - Analysis for OEM/User survey and ODGA data collection scheduled
  - Development of case studies scheduled
  - Brochure write-up scheduled
  - Electra Report scheduled
  - Tutorial scheduled

WG A2|D1.67 Technical Highlights

- Highlight 1 – DGA Data Collection
  - Data collected include equipment meta data (application, transformer specs), online data, offline data
  - To be done in collaboration with IEEE, with a Gitlab space hosted by IEEE
- Highlight 2 - OEM survey on Maintenance
  - Information surveyed include type of product, type of gases detected, accuracy, calibration, lifetime, expected maintenance, expected replacement of components, etc.
  - Clarifications on 'maintenance/repair/calibration/adjustment'
- Highlight 3 – User Survey on Maintenance
  - Information surveyed include general product info, budget's issues, routine checks and replacements, user's maintenance plan, lab verification, etc.
  - Verification with laboratory tests; Expected actions on DGA monitors over lifetime
- Highlight 4 – Alarm Response Plan
  - Guidelines to setting alarm limits are being formed; collaborate and informed by TF2 data analysis results
  - Alarm response philosophy drafted; focuses given to rate of changes, acetylene and ethylene levels, false alarms, wind farm and other renewable generation transformers
  - Case studies from utilities and literature on alarm response strategy

CIGRE UK A2|D1 Liaison

WG A2.68:

Failure Survey of Lower Voltage GSUs installed in Wind Farms and Photovoltaic Parks

Convenor: Peter Werle

Secretary: Janusz Szczechowski

Members: 35 regular members from 19 countries

UK Regular Members:

Muhammad Daghrah (MIDLE and MIVOLT Fluids Ltd)

Elizabeth MacKenzie (Consultant)

Denis Nesbitt (Doble Engineering)

Florian MARPAUX (EDF Renewable)

27/11/2024

WG A2.68 Introduction

- Context / Scope
  - Due to increase in renewable based installation, more transformers are subjected to unique stress levels specifically under PV (Harmonics) and Wind (Environmental) stresses
  - Need to understand most common failure modes to better recommend further investigations
  - Failure modes and failure rate data are missing. Need to gather information from operators to provide recommendations for design improvements and for enhanced maintenance/monitoring

- Aims / Objectives
  - Design a questionnaire for getting data from wind and photovoltaic park operators
  - Identify and convince operators all over the world to share their data from GSU failures
  - Identify main failure root causes for different GSU technologies
  - Provide information concerning how to identify failures in an early stage
  - Provide information concerning best practices of design of GSUs
  - Recommend to start additional working groups to analyse failure root causes in dept

WG A2.68 Timeline and Progress

- Start and end dates
  - Autumn 2022 – Autumn 2025 (Expected)

- Progress to-date
  - 15 meetings, 2 face to face and rest virtual with focus on survey questionnaire
  - Survey questionnaire ready and out
  - Data base gathered – total of 2000 transformers, 500 more expected from Germanly

- Work plan
  - Present in key conferences to encourage data sharing through the servery
  - PhD student is working on data acquisition, data base and evaluation (with Peter Werle)
  - Next face to face meeting in Switzerland (March/April 2025)

CIGRE UK A2|D1 Liaison

WG A2|C3.70:
Life Cycle Assessment (LCA) of Transformers

Convenor: Myles Margot
Secretary: Hang Xu
Members: 40 regular members from 22 countries

UK Members:
Steven Vallance (SP energy network)
Hang Xu (The University of Manchester)

27/11/2024

JWG A2|C3.70 Introduction

- **Purposes of this working group:**
  - Alignment of the various guidelines/procedures/standards (including the influence or integration from product to system level)
  - Comparability and evaluation basis for manufacturers, customers and other regulatory entities.
  - Investigate and establish the influence of different technologies, manufacturing techniques, operational influence and end of life (Circularity).
  - Best practices and/or framework for CO2 reduction.
- **Scope**
  - Define emission databases for materials and energy use during the lifetime.
  - Define a valid Product Category Rule (PCR) for transformers (either based on existing or new).
  - Agree on standard parameters (lifetime, load-factor, etc.) for above mentioned PCR and methodology for End of Life (EoL).
  - Impact and influence the energy mix has on the parameters or baseline.
  - Environmental impact of transport of materials and transformer (distance, type of transport).
  - Evaluation of sustainability measures linked to Transformers (Lifetime).

WG A2|C3.70 Timeline and Progress

- Start and end dates
  - October 2023 – Q2 2025 (Expected)

- Progress to-date
  - Additional members to cover white spots (e.g. suppliers)
  - Structure defined, agreed and staffed
  - Data collection, review implemented and in progress
  - Mirror group created and staffed
  - Alignment with other JWG's

- Work plan
  - Data collection scheduled for Q4 2024
  - Draft TB scheduled for Q1 2025
  - Final TB for Q2 2025

WG A2 | C3.70 Technical Highlights

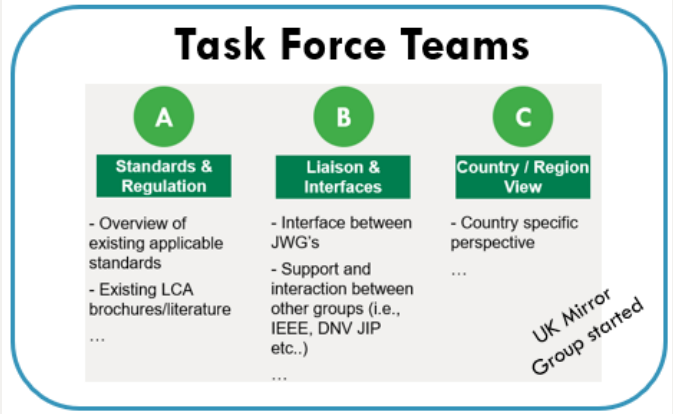
- **Chapter 1 – Definition of LCA**
  - Definition and development of LCA
  - Overview of existing standards and regulations
- **Chapter 2 – Literature Review of Existing LCA for transformers and limitations**
- **Chapter 3 – Methodology of LCA calculations for transformers**
  - Scope definition (goal, function unit, system boundary and characterization methods, existing transformer techniques)
  - LCI database (raw material, manufacture, operation, maintenance and recycling)
  - LCA software
  - Recommendations and limitations
- **Chapter 4 – Case studies**
  - Case studies based on five working streams
  - Case studies based on country/regions
- **Chapter 5 – Conclusion and Future Work**

What we doing…

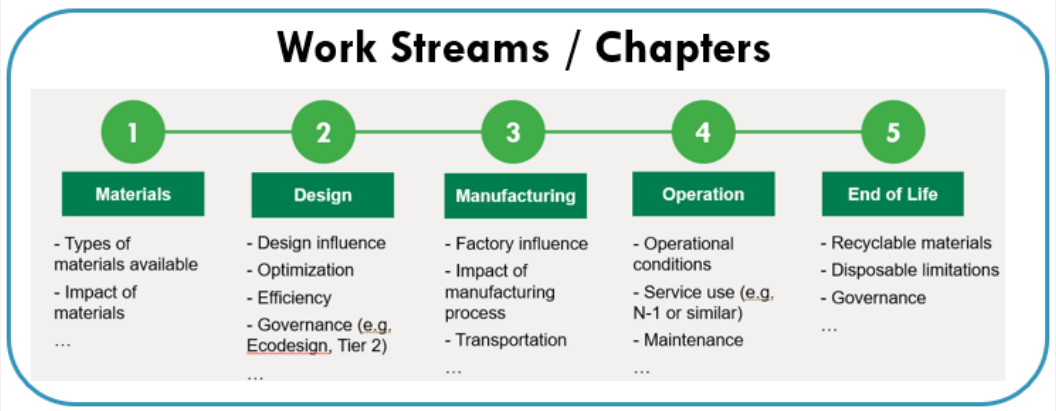
Phase 1: Data and research through **Task force** and **Workstreams**

Phase 2: Develop TB with proposed structure

How we doing…



- *Supports the Work Streams and provides literature content for Technical Brochure.*
- *Country view supported by Mirror Groups*



- *Definitions & Methodology*
- *Structure for Technical Brochure addressing subjects (e.g. databases, software/standard method & case studies)*
- *Case studies demonstrating material, design, technology, operational and country perspectives*

CIGRE UK A2|D1 Liaison

WG A2|D1.72:
Retrofill of Mineral Oil in Transformers – Motivations, Considerations and Guidance

Convenor: Roberto Asano Jr
Secretary: Gregoire Amato
Members: 34 Regular Members

UK Members:
Paul Dyer (UKPN)
Caleb Walker (SPEN)
Gordon Wilson (NG)
Attila Gyore (MIDEL)

27/11/2024

WG A2|D1.72 Goals

- Aims / Objectives
  - Define where replacement of liquid insulation in transformer is considered replacement or retrofill based on whether the fluid is considered equivalent or if a form of design review is required.
  - Describe the benefits and trade-offs that may arise as a result of retrofilling with reference to case studies.
  - Identify the necessary considerations, information and analysis that must be undertaken to determine whether retrofill is technically feasible and therefore likely to achieve the intended benefits.
  - Provide guidance on the steps to be taken in carrying out retrofill activities successfully.
  - Identify any changes in maintenance and testing activities arising from the retrofill process for example: flash point testing to show that the mixed fluid (new fluid with residual oil) maintains the flash point above 300 °C to accomplish with the requirements for K class fluids.
  - Review test methods for testing the fluid (mix) and its compatibility with transformer's materials. Collect experiences on test met

WG A2|D1.72 Timeline and Progress

- Start and end dates
  - March 2024 – October 2026 (Expected)

- Progress to-date
  - 8 meetings have been held so far.
  - Presentations from experts on the interdisciplinary topics
  - 3 Task Forces have been set up with topics of focus agreed –
    - TF#1 - Motivation, desired outcomes and practical results from retrofill.
    - TF#2 - Technical suitability to retrofill. Design/ rating impact due to fluid different characteristics.
    - TF#3 - Processing; liquid treatment before, along and after retrofill.
    - TF#4 - Testing; recommendations to existing physical/ chemical tests, their known limitations and their interpretation, appropriated to the new liquid mix and chemical compatibility with other components.

WG A2|D1.72 Highlights

- Expert Presentations:
  - User perspective of (minimal) operational requirements after retrofill
  - Effect on the dielectric and thermal performance
  - Components compatibility and performance
  - Fluid is replaced appropriately
  - Achievement of the desired benefits with tests/ experience

- Working Group Deliverables:
  - Technical Brochure
  - Electra article 3-4 pages
  - Trade magazine 1-page article
  - Tutorial slides
  - Webinar

CIGRE UK A2|D1 Liaison

WG D1|A2.77:
Liquid Tests for Electrical Equipment

Convenor: Fabio Scatiggio
Secretary: CarlWolmarans, (GE Vernova)
Members: 70 regular members, 7 corresponding members

UK Members:
Attila Gyore (Midel & MIVOLT Fluids)
Qiang Liu (Manchester University)
Russell Martin (Midel & MIVOLT Fluids)
David Walker (SPEN)
Gordon Wilson (National Grid)

27/11/2024

JWG D1 | A2.77 Introduction

- Context / Scope
  - The mission of this group is to improve and to extend the current knowledge on chemical and electrical tests applicable to electrical equipment to other liquids than mineral oil.
- Aims / Objectives
  - Verification of Ostwald coefficients.
  - Improving interpretation models for natural and synthetic esters.
  - Recommend a data format or template for DGA and other liquid tests.
  - Providing guidance to differing gas levels/patterns in different transformer types i.e. small distribution transformers, wind & solar transformers, traction vs large power transformers.
  - Clustering of oil test results (DGA, furans, alcohols, chemical and physical tests) as function of the transformer age, type, liquid preservation system, etc.
  - Investigate, based on real failure cases, if different DGA interpretation criteria (Rogers, IEC, IEEE, Duval, etc.) lead to the same conclusion.
  - Verification of new DGA detectors (helium, NDIR, PAS) not in accordance with existing standards.

JWG D1 | A2.77 Timeline and Progress

- Start and end dates
  - ToR signed off: 24 March 2020
  - JWG Meeting 1: 8 Oct 2020
  - Final Report: February 2023, aim to finish December 2024
- Progress to-date
  - JWG 13 meetings; TF1 = 2 meetings; TF2 = 3 meetings; TF3 = 5 meetings
  - Draft Technical Brochure (KMS): Version 16

JWG D1 | A2.77 Technical Brochure Chapters

- Insulating Liquids
- Chemical and Physical tests
- Solubility, Extraction, Detection and Quantification of Dissolved Gases (Partition Coefficients and Ostwald's Constants)
- Template for Data Collection
- DGA Theory and Interpretation
- Appendix A: Requirements of Transformers and Tap Changers on Insulating Liquids
- Appendix B: Case Studies
- Appendix C: Oil Breakdown Voltage (BDV) Interpretation Temperature Correction

D1 Updates

Materials and Emerging Test Techniques

- **UK Regular Member**
  - **Thomas Andritsch (University of Southampton)**

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D1 - Materials and Emerging Test Techniques

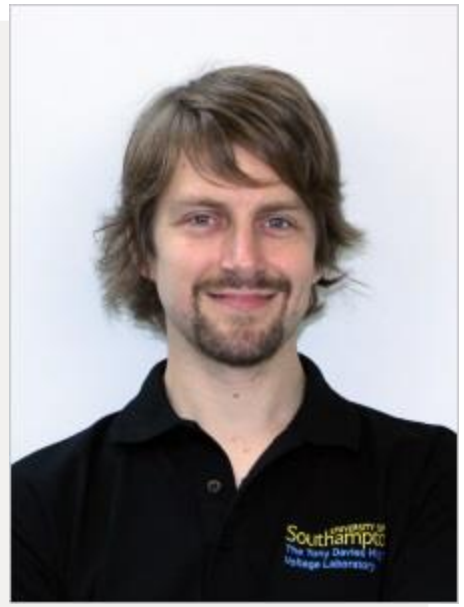
Dr Thomas Andritsch - D1 UK Regular Member

27th November 2024

Introduction

Dr Thomas Andritsch - D1 UK Regular Member

T.Andritsch@soton.ac.uk



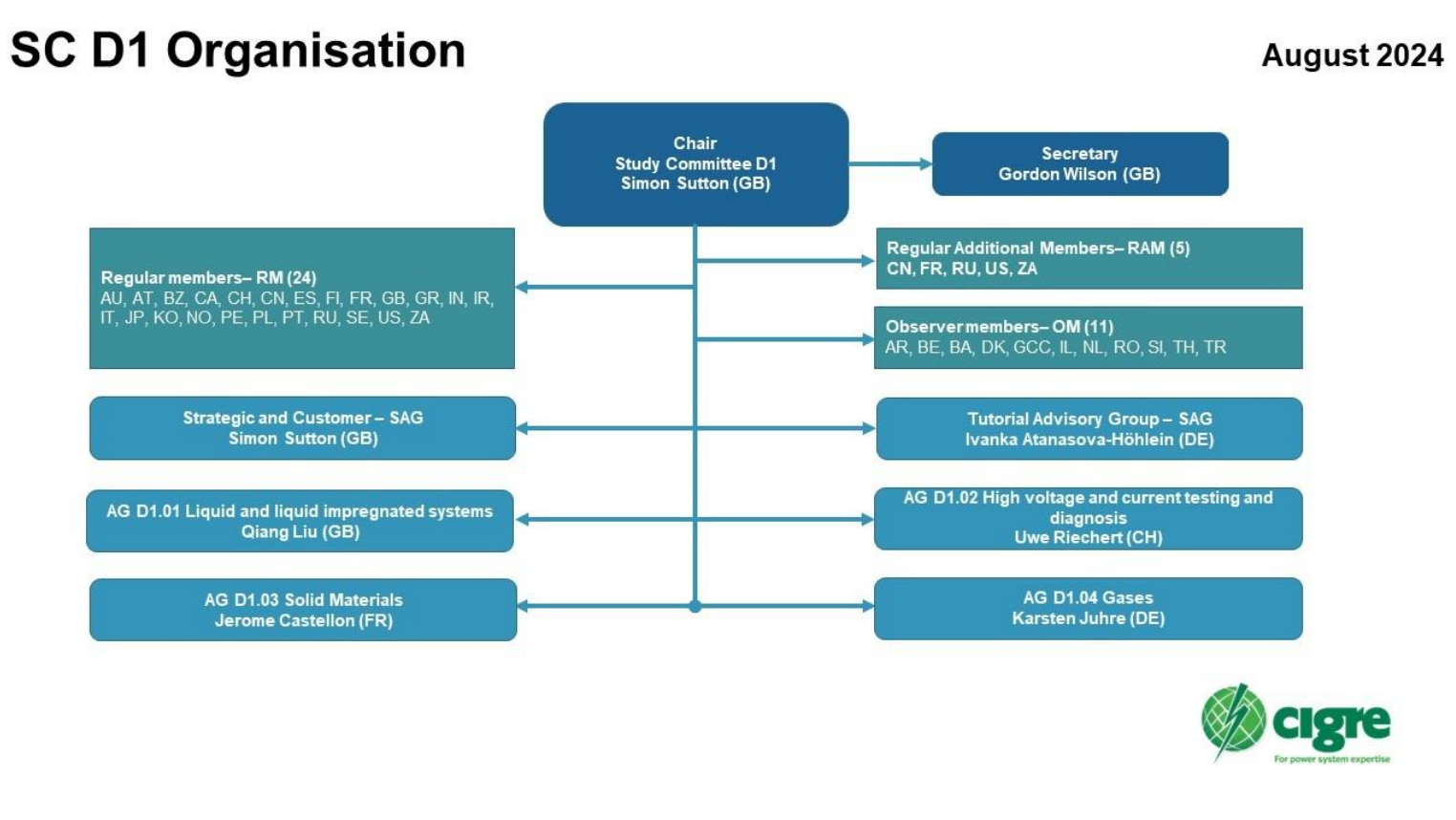
- Associate Professor, University of Southampton
- Role includes Education (UG and MSc), Research (Industry and research council funded R&D on materials for HV systems, PhD supervision), Enterprise (HV consultancy) and Management (Tony Davies HV Laboratory)
- Previously roles at TU Delft (NL),TU Graz (AT), and Prince Songkhla University (TH)
- Cigre activities include UK member of D1.73, B1/D1.75 and previously D1.40
- Also active in IEEE (Senior Member, DEIS Administrative Committee, TC on Transport Electrification, Smart Grids, Nanodielectrics)

Study Committee D1 Scope

The scope of SC D1 is concerned with the monitoring and evaluation of:

- 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.
- Support of other study committees in their analysis of recently introduced and developing materials, emerging test techniques and diagnosis techniques

Study Committee D1 - Organisation



SC Chair: Simon Sutton, UK

Secretary: Gordon Wilson, UK

Strategic Advisory Groups:

AG D1.01 Liquids and Liquid Impregnated Insulation Systems (Qiang Liu, UK)

AG D1.02 High Voltage and Current Testing and Diagnostic (Uwe Riechert, CH)

AG D1.03 Solid Materials (Jerome Castellon. FR)

AG D1.04 Gases (Karsten Juhre, DE)

Tutorial AG (Ivanka Atanasova-Hoehlein, DE)

Strategic and Customer AG (Simon Sutton, UK)

2025 SC A2 & D1

Cigre2025seoul-a2-d1.com

- Date: 27th October (Monday) to 1st November (Saturday)
- Venue: Korea Chamber of Commerce and Industry, Seoul, South Korea
- Abstract deadline: 31 March 2025

Preferential Subjects:

[PS1] Environmental Performance of Power Transformers for Substation of Power System

[PS2] Testing and Modelling for New Applications and Operating Environments

[PS3] Failure Prevention and Investigation

	10/27 (Mon)	10/28 (Tue)	10/29 (Wed)	10/30 (Thu)	10/31(Fri)	11/2(Sat)
Morning	Working Groups Meetings	Working Groups Meetings	Study Committee A2/D1	Colloquium Optional Panel Discussion	Colloquium Optional Panel Discussion	Technical Tour
Noon	Lunch Break					
Afternoon	Working Groups Meetings	Study Committee A2/D1	Tutorials	Colloquium Optional Panel Discussion	Colloquium Optional Panel Discussion	
Evening	Welcoming Party	SC Dinner		Banquet		

Study Committee D1 Active Working Groups

CIGRE UK SC A2|D1 Liaison Meeting, 27th November 2024

SC D1 Working Groups

Study Committee D1

August 2024

Liquid and liquid impregnated systems (AG D1.01)

WG D1.68 Natural and synthetic esters - Evaluation of the performance under fire and the impact on environment - M.Pompili (IT)

WG D1.76 Tests for verification of quality and ageing performance of cellulose insulation for power transformers - J.Lukic (RS)

JWG D1/A2.77 Liquid Tests for Electrical Equipment - F.Scatiggio (IT)

JWG D1/A2.79 Improved understanding of dynamic behaviour of winding insulating materials in liquid insulated power transformers - O.Girlanda (SE)

JWG A2/D1.66 Breathing systems of liquid filled transformers and reactors - R. Kurte (DE)

JWG A2/D1.71 Modern Insulating Liquids Qualification for OLTC, Bushings and other Accessories – L.Liden (SE)

JWG A2/D1.72 Retrofill of Mineral Oil in Transformers – Motivations, Considerations and Guidance – R.Asano Jr (BZ)

High voltage and current testing and diagnosis (AG D1.02)

WG D1.60 Traceable measurement techniques for very fast transients – Y.Li (AU)

WG D1.61 Optical corona detection and measurement – N.Mahatho (ZA)

WG D1.63 Partial Discharge Detection under DC voltage stress R.Plath (DE)

WG D1.69 Guidelines for test techniques of High Temperature Superconducting (HTS) systems – R.Taylor (AU)

WG D1.72 Test of material resistance against surface arcing under DC – C.Bär (DE)

WG D1.74 PD measurement on insulation sytstems stressed from HV power electronics – A.Cavallini (IT)

WG D1.81 Methods and common data file format for Time-Domain Reflectometry – A.Barclay (GB)

JWG B1/B3/D1.75 Recommendations for dielectric testing of HVDC gas insulated system cable sealing ends C.Plet (NL)

JWG A2/D1.67 Guideline for online dissolved gas analysis monitoring – T.Macarthur (AU)

JWG B3/A2/A3/C3/D1.66 Guidelines for Life Cycle Assessment in Substations considering the carbon footprint evaluation - A.Prabakar (IN)

Solid Materials (AG D1.03)

WG D1.62 Surface degradation of polymeric insulating materials - B.Komanschek (DE)

WG D1.73 Nanostructured dielectrics: Multi-functionality at the service of the electric power industry - J.Castellon (FR)

JWG D1/B1.75 Strategies and tools for corrosion prevention for cable systems - J.Tusek (AU)

JWG D1/A2.80 Functional properties of non-metallic solid materials for liquid filled transformers and reactors and their compatibility with insulating liquids – D.Vukovic (DE)

WG D1.82 Additive Manufacturing/3D Printing in Service of the Electrical Power Industry

JWG B1/D1.75 Interaction between cable and accessory materials in HVAC and HVDC applications - A.Gustafsson (SE)

Gases (AG D1.04)

WG D1.66 Requirements for partial discharge monitoring systems for gas insulated systems W.Koltunowicz (DE)

WG D1.78 Partial discharge properties of non-SF6 insulating gases and gas mixtures M.Walter (CH)

WG B3/D1.63 Guideline for assessing the toxicity of used SF6 gas onsite and in the lab of T&D equipment above 1 kV in substations R.Kurte (DE)

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Study Committee D1 – New Working Groups (approved 2023)

WG	Title	UK Member
D1.82	Additive Manufacturing/3D Printing in Service of the Electrical Power Industry	Thomas Andritsch
A2/D1.74	Online moisture monitoring of transformers for ageing assessment	TBC
B3/A2/A3/C3/D1.66	Guidelines for Life Cycle Assessment in Substations considering the carbon footprint evaluation	TBC

D1.63

PARTIAL DISCHARGE DETECTION UNDER DC VOLTAGE STRESS

- Convenor: Ronald Plath
- UK Member: Malcolm Seltzer-Grant
- Start Date: 2015
- Completion Date: 2024

Scope of Activities:

TF-1 Physics, TF-2 Solid Insulation, TF-3 Liquid Insulation, TF-4 Gas Insulation

Status Update:

- Draft technical brochure undergoing finalisation before circulation to study committee.

D1.66

Requirements for partial discharge monitoring systems for gas insulated systems

- Convenor: W. Koltunowicz
- UK Member:
  - ✓ **Graeme Coapes**
    graeme.coapes@siemens-energy.com
  - ✓ **Fraser Cook, Carl Johnstone**
- Start Date: 2016
- Completion Date: 2024

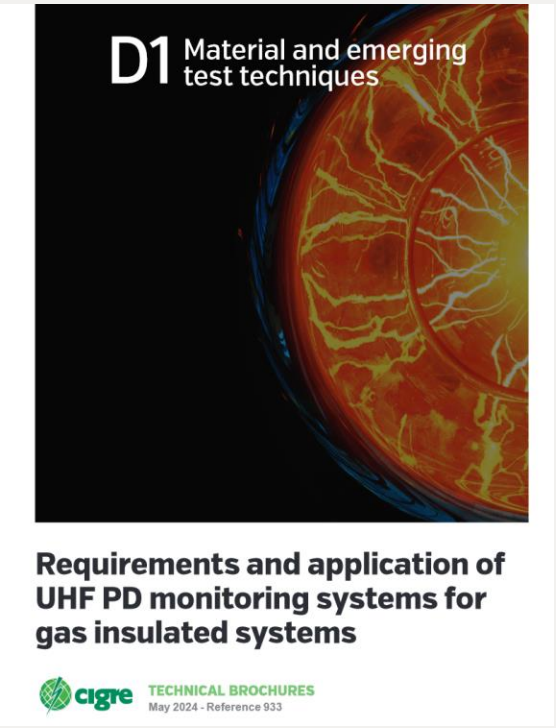
Scope of Activities:

The WG activity will concentrate on the technical requirements of PDM. A survey on UHF PDM technology will be performed to collect available knowledge from the field and understand the expectations and needs of the users. The technical advantages and disadvantages of different monitoring solutions will be described.

The new WG will prepare a technical guidance and help users to choose a PDM system best fitting to their needs and their level of PD knowledge.

Status Update:

- Full technical brochure 933 released 2024



D1.68

Natural and synthetic esters - Evaluation of the performance under fire and the impact on environment

- Convenor: Massimo Pompili
- UK Member: Russel Martin
- Start Date: 2017
- Completion Date: 2023

Scope of Activities:

1. Fire behavior comparison between natural and synthetic esters and mineral insulating oils;
2. Environmental impact comparison in case of spills of natural and synthetic esters and mineral insulating oils.

Status Update:

- Large interest of IEC TC10 for natural and synthetic ester insulation liquids
- Activities practically stopped during pandemic
- Activities restarted in Autumn 2021
- Questionnaire circulated to the 34 WG members on local fire and environmental rules
- TB expected to be ready soon

D1.69

Guidelines for test techniques of High Temperature Superconducting (HTS) systems

- Convenor: Richard Taylor
- UK Member: Bartek Glowacki
- Start Date: Q1/2017
- Completion Date: 2020*

Scope of Activities:

To study the existing HTS power installations and compile the relevant data that will assist the power industry to test HTS technology used in the transmission and distribution grid

Status Update:

- TB is being reviewed and chapters reconfigured before sending it out to WG members to comment, will pay attention to:
- The present and future need for HTS power installations.
- Update on the status of field test experience of HTS power installations and comparison with existing guidelines.
- Aging of electrical insulation, superconductors and cooling systems.
- Failure mode analysis

D1.70

Functional properties of modern insulating liquids for transformers and similar electrical equipment

- Convenor: Ivanka Hoehlein-Atanasova
- UK Member: Qiang Liu, Attila Gyore, Zhongdong Wang
- Start Date: 01/2017
- Completion Date:

Scope of Activities:

Review the need for revising or establishing standards concerning traceability of origin and thermal stability of liquids.

Review the requirements and test standards of dielectric liquids as seen from a transformer designer.

Review the test methods for establishing thermal performance parameters of liquids.

Status Update:

- New TB 927 published in 2024 (more later)
- Very active WG
- TF3 has published a technical brochure 856 in Dec 2021.
- A tutorial was delivered during ICDL2022, at Seville, Spain on 29th May 2022.
- An A2/D1 joint webinar was delivered online on 13th June 2023.

D1.73

Nanostructured dielectrics: Multi-functionality at the service of the electric power industry

- Convenor: Jerome Castellon
- UK Member: Thomas Andritsch and Raed Ayoob
- Start Date: 01/2020
- Completion Date: 10/2023 (delayed)

Scope of Activities:

- Review of recent progress in the field of nano-dielectrics.
- Design, manufacture, and characterisation of nano-dielectrics with improved properties.
- Propose different possible applications for the use of nano-dielectrics in the power industry.

Status Update:

- Literature review ongoing.
- Some samples have been manufactured and are currently being characterised in different laboratories.
- 5 meetings have been held so far.
- WG meeting at Paris 2022 session.
- Delays due to materials lost in transit and RRT

D1.74

PD measurement on insulation systems stressed from HV power electronics

- Convenor: Andrea Cavallini
- UK Member: -
- Start Date: 2019
- Completion Date:

Scope of Activities:

Transversal sub-WGs

Measurements, UHF, Antennas, Systems, Electrical, Acoustic, Optical, Propagation

Apparatus-specific sub-WGs

Rotating machines, power electronics

Status Update:

Rotating Machines

- Review of antennas suitable for PD detection
- Analysis of PD emission spectra
- Comparison between different detection mechanisms
- Most likely failure modes -> sensor position

Power Electronics

- Review of failure modes
- Oil- or gel-filled modules (RRT)

D1.76

Tests for verification of quality and aging performance of cellulose insulation for power transformers

- Convenor: Jelena Lukic
- UK Member: Gordon Wilson (corresponding) plus others
- Start Date: April 2021
- Completion Date: December 2025

Scope of Activities:

Improve assessment of ageing of cellulosic insulation in transformers:

- Improve accelerated ageing tests
- Investigate new algorithms for modelling ageing
- Improve current DP test

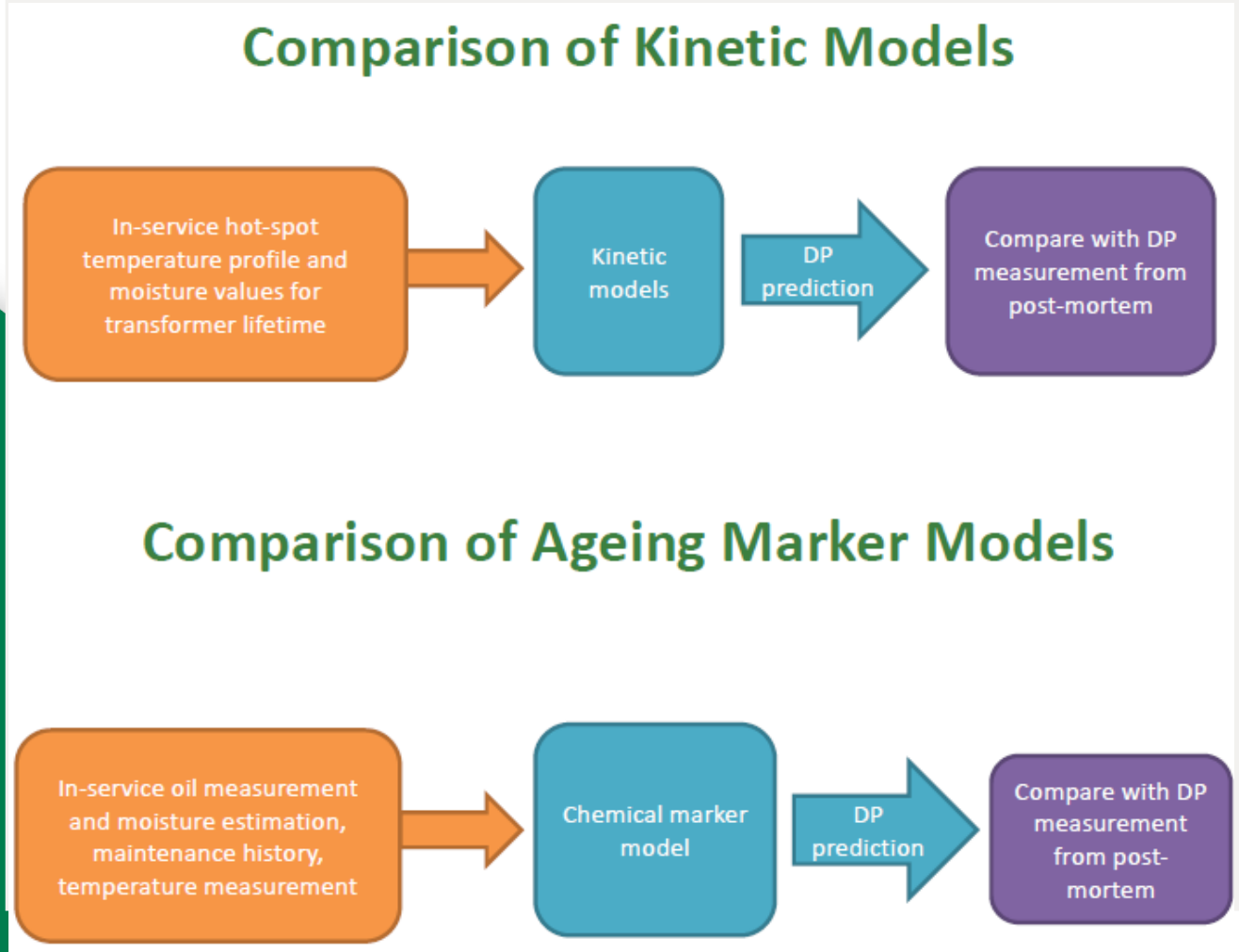
Status Update:

Three task forces delivering the work:

- TF1 Revision of method for DP
  - ✓ **Robustness study under way**
  - ✓ **Second RRT expected end of 2024**
  - ✓ **TB text around ~50 % complete**
- TF2 Development of paper ageing tests
  - ✓ **Ageing tests underway >50 % complete**
  - ✓ **TB text around 80 % complete**
- TF3 Paper ageing algorithms
  - ✓ **Literature review of 27 papers**
  - ✓ **Case study data collected**
  - ✓ **Kinetic modelling underway**

D1.76

Tests for verification of quality and aging performance of cellulose insulation for power transformers



More detail on TF3 approach

- Post mortem data collected on 60 tx
  - ✓ **Generator, transmission transformers and reactors**
  - ✓ **>7,000 oil test results**
  - ✓ **~1,000 DP measurements**
  - ✓ **Some load and heat run data**
- Data wrangling and exploratory analysis
- Kinetic model developed to estimate DP

D1.78

Partial discharge properties of non-SF6 insulating gases and gas mixtures

- Convenor: M. Walter
- UK Member:
  - ✓ **Graeme Coapes (NGN)**
    graeme.coapes@siemens-energy.com
  - ✓ **Fraser Cook**
- Start Date: 2023
- Completion Date: 2026

Scope of Activities:

The Working Group will collect and summarize the current knowledge on the PD properties of major natural-origin and fluorinated non-SF6 insulating gases and gas mixtures which are currently proposed by the equipment manufacturers. Wherever required and feasible, further studies shall be conducted (e.g. by testing).

Status Update:

- First meeting in Zurich June 2023
  - ✓ Structure of technical brochure defined
  - ✓ Chapter sub-groups have been nominated
- Second meeting scheduled Berlin Nov 2023

Plan is to complete literature review on state-of-the-art knowledge. This will be followed by defining experiments to be completed at various laboratories upon different gas mixtures.

JWG D1/B1.75

Strategies and tools for corrosion prevention for cable systems

- Convenor: Joe Tusek
- UK Member:-
- Start Date: 02/2020
- Completion Date: ???

Scope of Activities:

1. Collect case studies of unexpected corrosion and detail the root cause of the problem.
2. Report on practical measures adopted by asset owners to mitigate against corrosion, either through enhanced specifications, factory audits, onsite testing etc.
3. Strategies adopted by asset owners to safeguard against corrosion in service

Status Update:

- Follow on from more general D1.71
- Collect case studies on unexpected corrosion
- Report on practical measures to mitigate corrosion
- Specifications, factory audits, onsite testing
- Strategies to safeguard against corrosion in service
- *Lack of progress over the past year*

JWG B1/D1.75

Interaction between cable and accessory materials in HVAC and HVDC applications

- Convenor: Anders Gustafsson
- UK Member: Thomas Andritsch
- Start Date: 02/2020
- Completion Date: imminent

Scope of Activities:

- Generate reference guide on interface issues in HV cables
- Propose testing methodologies to assess compatibility
- HVAC, HVDC, land and submarine cables in scope

Status Update:

- TB drafted and reviewed, includes development tests
- 29 meetings so far (of which 21 were online)
- TB draft completed and reviewed before 2024 Paris session
- Updated TB being finalised
- Electra article planned by end of 2024

D1.82

Additive Manufacturing/3D Printing in Service of the Electrical Power Industry

- Convenor: Thomas Andritsch
- UK Member: Dave Clark, Calum Macdonald (NGN)
- Start Date: 08/2024
- Completion Date: 2027

Scope of Activities:

- Review of the state of the art of AM.
- Highlight existing work on additive manufacturing in the field of electrical (power) engineering.
- Provide an overview of potential benefits for the power industry.
- Report on challenges in terms of standardisation and limits of the technology.

Status Update:

- Membership established (12 members from 9 different countries)
- First meeting scheduled early 2025

Study Committee D1 New Technical Brochures

CIGRE UK A2|D1 Liaison Meeting, 27th November 2024

Study Committee D1 – New Technical Brochures

In the past 12 months the following technical brochures have been published:

- TB927 New Laboratory Methodologies for Investigating of Insulating Liquids - Further Developments in Key Functional Properties

  e-Cigre link

- TB933 Requirements and application of UHF PD monitoring systems for gas insulated systems

  e-Cigre link

TB 927

New Laboratory Methodologies for Investigating of Insulating Liquids - Further Developments in Key Functional Properties (WG D1.70)

- Proposes methodologies concerning the fault free gassing of some liquids in service,
- Proposes use of oxidation inhibitor as ageing markers in mineral oils
- Evaluation of methods able to distinguish between individual hazardous compounds like PAC/PAHs
- Assesses measurement uncertainty for thermal characteristics of insulating liquids

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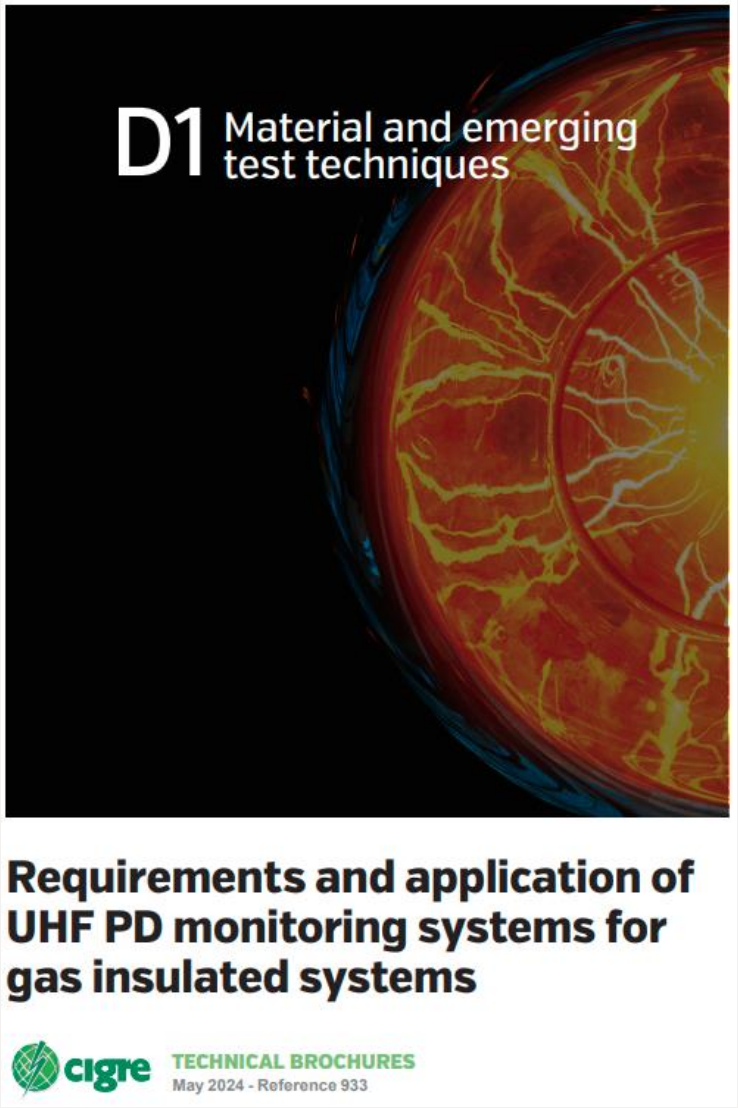
TB 933

Requirements and application of UHF PD monitoring systems for gas insulated systems (WG D1.66)

- Hardware and software requirements of modern ultra-high frequency (UHF) partial discharge monitoring (PDM) systems for GIS are determined
- Based on field experience
- Provides comprehensive technical guidance to help users chose PDM systems best fitting their needs and level of PD knowledge
- To enable more effective use of PDM systems



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Thank you for your attention!

CIGRE UK SC A2|D1 Liaison Meeting, 27th November 2024

Updates from IEC 60076 Parts 1 and 2 Revision

IEC TC14 Power Transformers

- Jose Quintana (SPEN)
- Tom Breckenridge (TB TCS)

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CIGRE UK A2|D1 Liaison

IEC TC14
Power Transformers

Prepared by:

Tom Breckenridge (BSI PEL/14 Chair)

Presented by:

Jose Quintana (SPEN)

27/11/2024

New Approved TC14 Scope

- Standardization in the field of:
  - **power transformers**
  - **reactors (inductors)**
  - **their auxiliary equipment (tap changers, cooling systems, etc.), fittings and accessories**
  - **neutral grounding devices (transformers, reactors, resistors etc. for grounding)**
- for use in power generation, transmission and distribution as well as for industrial applications.

- Power transformers and reactors covered by TC14 have at least one highest voltage for equipment above 1000 V and a power rating equal or above 1 kVA per phase.
- TC14 technical standards may be applied to power transformers and reactors with lower voltages if the application is not covered by another TC.
- Insulated bushings are covered by SC 36A and insulating fluids are covered by TC 10.

- Excluded:
  - Instrument transformers
  - Testing transformers
  - Traction transformers mounted on rolling stock
  - Welding transformers
  - Transformers for applications covered by TC 96

TC14 Structure

- Chair – Christoph Ploetner (Germany)
- Secretary – Stephanie Lavy (UK)
- IEC Personnel
  - Technical Officer
  - Standards Project Administrator
  - Editor
- 3 Working Groups
- 2 Project Teams
- 16 Maintenance Teams
- 1 Joint Working Group
- 1 Advisory Group
- 1 Ad-hoc Group

38 Participating Countries

13 Observer Countries

Last plenary meeting –
18 April 2024 in Rome, and
21 October 2024 in Edinburgh

Next plenary meeting –
8-12 September 2025 in New Delhi

TC14 Role

- IEC TC14 is responsible for developing and maintaining the following international standards
  - **IEC 60076 series – 32 documents and sub-documents**
  - **IEC 60076-57 series – 2 documents jointly published with IEEE**
  - **IEC/IEEE 60076-16**
  - **IEC 60214**
  - **IEC TR 60616 – in process of being integrated as IEC 60076-9**
  - **IEC 61378 series – 2 documents**
  - **IEC 62032**

TC14 Update

- Current Work in Progress Includes:
  - **IEC 60076-1** – Major update started 2018
  - **IEC 60076-2** – Major update started 2018
  - **IEC 60076-4** – Guide to impulse testing – supporting IEC 60076-3
  - **IEC 60076-5** – Short circuit withstand
  - **IEC 60076-6** – Reactors
  - **IEC 60076-9** – This is an update to IEC 60616 terminal marking
  - **IEC 60076-18** – This is the SFRA measurement standard
  - **IEC 60076-19-2** – Uncertainty in loss measurement for reactors
  - **IEC/IEEE 60076-57-129** – This is a joint MT revising the Standard for HVDC Converter TXs
  - **IEC/IEEE 60076-57-1202** – This is a revision of the existing joint Standard which will integrate the work of IEC/IEEE 60076-57-135, which is essentially maintenance of IEC 62032 in the IEC world

TC14 Update

- **IEC 60076-1 – Power transformers - Part 1: General**
- **MT Co-conveners Paul Jarman (UK) and Antonia Stefanec (HR)**
  - First CD published in May 2023 for comment
  - 1040 Comments received; comments don't suggest any fundamental disagreement with the direction of development
  - Meetings held in Rome in April 2024, and in Glasgow/ Edinburgh in Oct 2024 to resolve comments received. Each of these meetings were over multiple days
  - Next meeting in Nurnberg in Feb 2025, again planned for 3 days.
  - Meetings are F2F and held over at least three days
  - Intention is to get a CDV prepared for issue by mid 2025, with a projected publication date sometime in 2026

TC14 Update

- **IEC 60076-2 – Power transformers - Part 2: Temperature rise for liquid-immersed transformers**
- **MT Convener Dejan Susa (AUS)**
- **This work is closely linked to that of IEC 60076-1 and meetings have been running in parallel – all virtual meetings since 2020**
  - First CD published in May 2023 for comment
  - 108 pages of comments received; UK submitted 14 pages of comments
  - Meetings to resolve comments being hosted remotely at the moment, but it is difficult to work this way as each meeting lasts only two hours due to timing issues globally to accommodate all relevant parties.
  - Intention is to keep this document on track with IEC 60076-1
  - Hopefully with a CDV published by mid 2025, with the new standard to be published simultaneously with IEC 60076-1.

TC14 Update

- **IEC 60076-4 – Power transformers - Part 4: Guide to the lightning impulse and switching impulse testing - Power transformers and reactors**
- **MT Convener Thang Hochanh (CA)**
- **This document has been in maintenance since just after the publication of IEC 60076-3 Ed 3 in 2013:**
  - CDV document approved last week and the FDIS will follow shortly
  - Forecast date of publishing new standard is still 2025

TC14 Update

- **IEC 60076-5 – Power transformers - Part 5: Ability to withstand short circuit**
- **MT Convener Jean-Christophe Riboud (FR)**
- **The MT working on this has been meeting for a number of years and have had quite a lot of meetings but with not a lot of progress – however:**
  - First CD issued for comment just before Christmas 2022
  - Comment resolution still ongoing 1 year later – expected completion in March 2024
  - Still quite a bit of uncertainty as to how this maintenance team will proceed with guidance from the main TC 14 meeting requested
  - No dates available for expected publications at this time

TC14 Update

- **IEC 60076-6 – Power transformers - Part 6: Reactors**
- **MT Convener Rob Verhoeven (NL)**
- **The MT working on this has met quite a few times:**
  - 286 comments on first CD received in January 2024
  - Comment resolution ongoing but no major obstacles identified
  - Expect to see the CDV towards the end of 2024, or early 2025
  - UK represented by David Walker and Paul Jarman

TC14 Update

- **IEC 60076-9 – Power transformers Part 9: Terminal Marking – to replace existing IEC 60616**
- **PT Convener Miguel Cuesto (ES)**
- **The PT working on this has met a few times:**
  - First CD was expected by summer 2024, but nothing has been seen so far
  - Not seen as a critical update, but more of a good houskeeping exercise in bringing this subject under the 60076-x banner

TC14 Update

- **IEC 60076-18 – Power transformers Part 18: Measurement of Frequency Response**
- **MT Convener Alexander Kraetge (AT)**
- **The MT working on this has met a few times:**
  - MT is progressing well with topics for discussion and action items agreed
  - First CD is expected to be available Q1 of 2025

TC14 Update

- **IEC 60076-19-2 – Power transformers Part 19-2: Rules for determination of uncertainties in loss measurements of reactors**
- **MT Convener Anders Bergman (SE)**
- **Decision made earlier to split this work into two parts**
  - Part 1 on losses on Power Transformers already published
  - Part 2 – will focus on Reactors where the challenges of being able to accurately measure losses are much greater
  - Niche subject area with limited expertise, MT has identified 2 experts who have agreed to support the work going forward
  - MT still holding virtual meetings as all interested parties are largely European based
  - No date yet for the first CD to be available

TC14 Update

- **IEC 60076-21 – Power transformers Part 21: Standard requirements, terminology, and test code for step-voltage regulators**
- **MT Convener Anders Bergman (SE)**
- **This is a Standard linked to IEEE C57.15 which is entering maintenance now**
  - May be difficult to form a parallel IEC MT due to lack of interest in the subject matter
  - The preference is to develop a joint standard, however, if it is not possible to form an IEC MT, it is expected that the revised IEEE document will be adopted as an IEC Standard to replace the existing document
  - A call for IEC experts to form the IEC parallel MT team will be made

TC14 Update

- **IEC 60076-57-129 – Power transformers Part 57-129: Transformers for HVDC Applications**
- **MT Convener Frank Trautmann (DE)**
- **This is a Standard linked to IEEE C57.15 which is entering maintenance now**
  - A new IEC parallel MT has been created to allow the existing joint development status to remain
  - TC 14 has asked MT 60076-57-129 to consider the inclusion of the content of IEC 61378-3 Converter Transformers – Part 3: Application guide in the revision
  - A call for IEC experts to form the IEC parallel MT team will be made

TC14 Update

- **IEC 60076-57-135 – Power transformers Part 57-135: Technical guideline for the Application, Specification, and Testing of Phase-Shifting Transformers**
- **MT Convener Kevin Juchem (DE)**
- **This is essentially maintenance of IEC 62302 which is the IEC implementation of IEEE C57-135**
  - IEEE also indicated a decision has been made to revise IEC/IEEE 60076-57-1202: which is the joint Standard for Liquid Immersed Phase Shifting transformers
  - IEC has decided to take part in the joint revision of IEC/IEEE 60076-57-1202
  - The two items of work will be undertaken in parallel to ensure best possible alignment of the documents
  - MT team 60076-57-135 will be disbanded and all members of the MT transferred to the new MT for 60076-57-1202

TC14 Update

- **IEC/IEEE 60076-16 – Power transformers Part 16: Transformers for Wind Turbine Applications**
- **MT Convener Tom Breckenridge (UK)**
- **This is a joint Standard with IEEE**
  - IEEE has advised they intend to start maintenance of this document
  - It is likely that IEC will also start maintenance of this document in the future once the major work around IEC 60076-1 and -2 is concluded
  - This will likely mean losing the joint status, but this will mean no IEEE references in the next IEC version of the Standard

In-depth A2 Technical Presentation & Discussion

- **Life Cycle Assessment (LCA)**
- **Dynamic Thermal Modelling**

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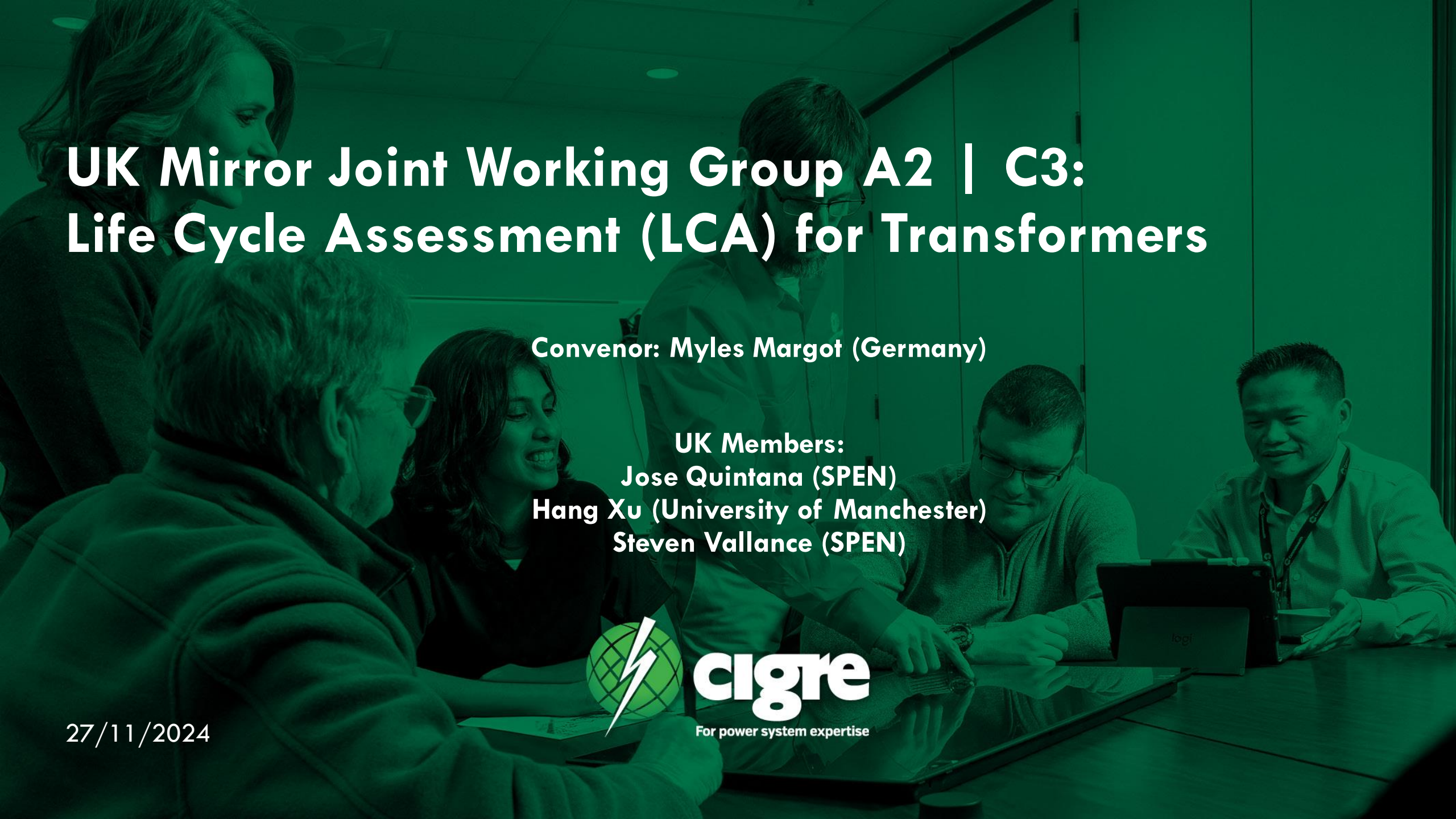

UK Mirror Joint Working Group A2 | C3: Life Cycle Assessment (LCA) for Transformers

Convenor: Myles Margot (Germany)

UK Members:
Jose Quintana (SPEN)
Hang Xu (University of Manchester)
Steven Vallance (SPEN)

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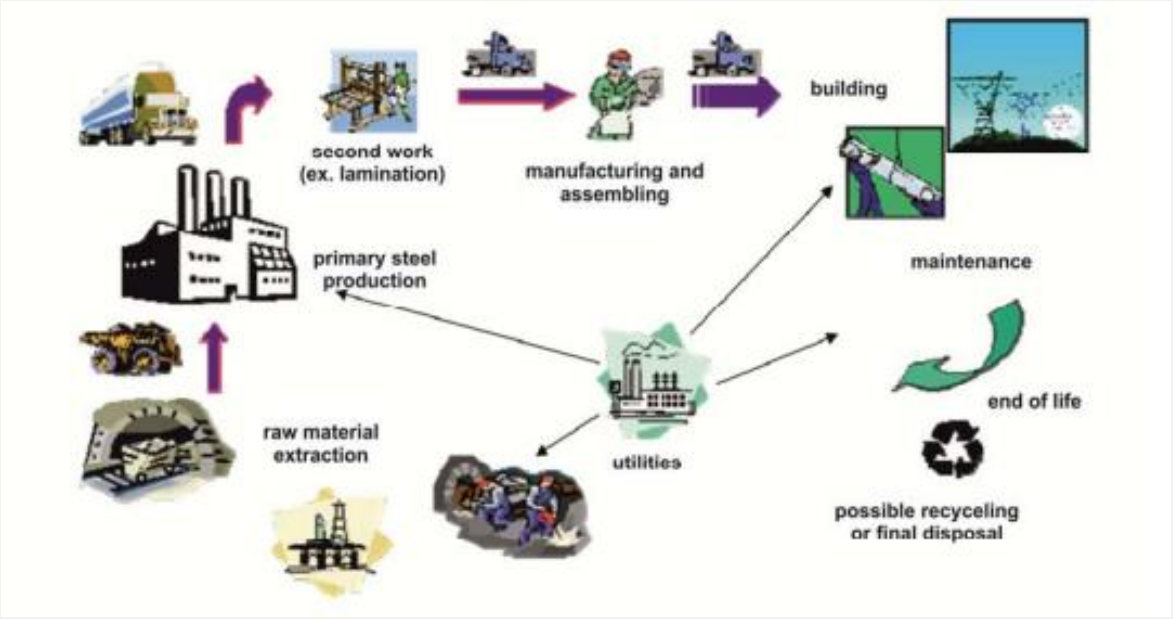
27/11/2024

Agenda

- **Introduction**
  - CIGRE Antitrust guidelines
  - Member overview and self-introduction
  - Scope of CIGRE mirror group
- **Introduction of JWG A2.C3.70**
  - Scope of work
  - Group structure
  - Work streams and task forces
  - Survey and data collection from members
- **General discussions**
  - Information exchange
  - Initial feedback
- **Next meeting**
- **AOB**

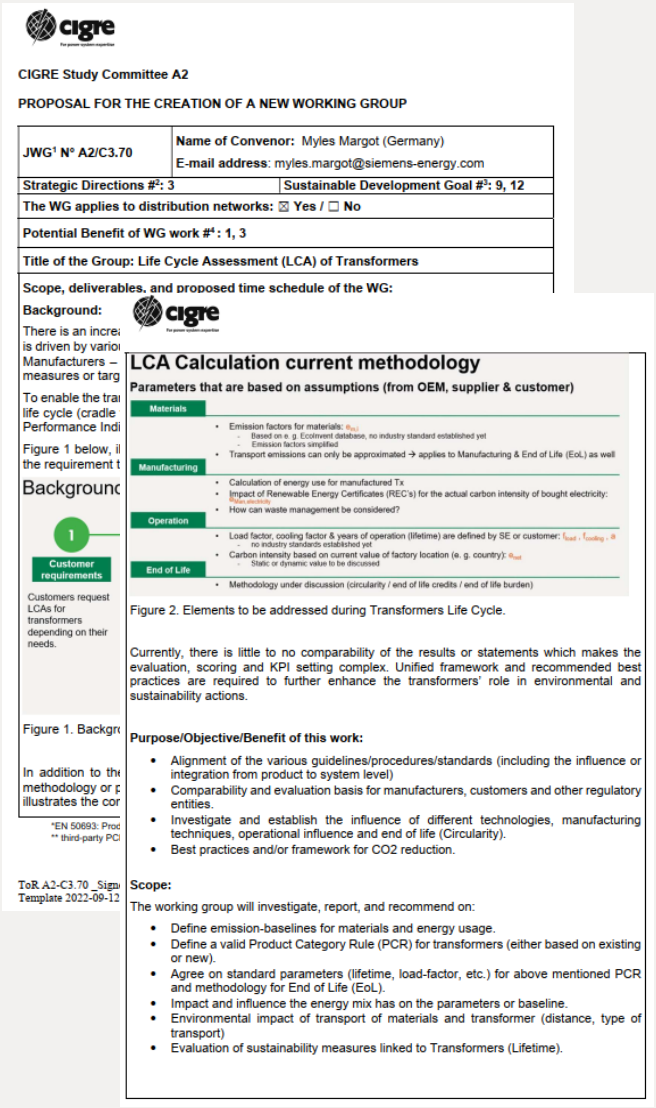


Scope: JWG A2/C3.70: LCA for Transformers

- **Purpose/Objective/Benefit of this work:**
  - Alignment of the various guidelines/procedures/standards (including the influence or integration from product to system level).
  - Comparability and evaluation basis for manufacturers, customers and other regulatory entities.
  - Investigate and establish the influence of different technologies, manufacturing techniques, operational influence and end of life (Circularity).
  - Best practices and/or framework for CO2 reduction.
- **Scope:**

The working group will investigate, report, and recommend on:

- Define emission-baselines for materials and energy usage.
- Define a valid Product Category Rule (PCR) for transformers (either based on existing or new).
- Agree on standard parameters (lifetime, load-factor, etc.) for above mentioned PCR and methodology for End of Life (EoL).
- Impact and influence the energy mix has on the parameters or baseline.
- Environmental impact of transport of materials and transformer (distance, type of transport).
- Evaluation of sustainability measures linked to Transformers (Lifetime).



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CIGRE Study Committee A2

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

JWG[1] N° A2/C3.70	Name of Convenor: Myles Margot (Germany) E-mail address: myles.margot@siemens-energy.com
Strategic Directions #[2]: 3	Sustainable Development Goal #[3]: 9, 12
The WG applies to distribution networks: ☒ Yes / ☐ No	
Potential Benefit of WG work #[4]: 1, 3	
Title of the Group: Life Cycle Assessment (LCA) of Transformers	
Scope, deliverables, and proposed time schedule of the WG:	

Background:

There is an increa
is driven by vario
Manufacturers –
measures or targ

To enable the tra
life cycle (cradle
Performance Indi

Figure 1 below, il
the requirement t

Backgrounc

1 Customer requirements

Customers request LCAs for transformers depending on their needs.

Figure 1. Backgr

In addition to th
methodology or p
illustrates the cor

*EN 50693: Proc
** third-party PC

ToR A2-C3.70 _Sign
Template 2022-09-12

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LCA Calculation current methodology

Parameters that are based on assumptions (from OEM, supplier & customer)

Materials
- Emission factors for materials: e_{mat}
  - Based on e. g. Ecoinvent database, no industry standard established yet
  - Emission factors simplified
- Transport emissions can only be approximated → applies to Manufacturing & End of Life (EoL) as well

Manufacturing
- Calculation of energy use for manufactured Tx
- Impact of Renewable Energy Certificates (REC's) for the actual carbon intensity of bought electricity: *Now electricity*
- How can waste management be considered?

Operation
- Load factor, cooling factor & years of operation (lifetime) are defined by SE or customer: f_{load} ; $f_{cooling}$; ϑ
  - no industry standards established yet
- Carbon intensity based on current value of factory location (e. g. country): e_{fact}
  - Static or dynamic value to be discussed

End of Life
- Methodology under discussion (circularity / end of life credits / end of life burden)

Figure 2. Elements to be addressed during Transformers Life Cycle.

Currently, there is little to no comparability of the results or statements which makes the evaluation, scoring and KPI setting complex. Unified framework and recommended best practices are required to further enhance the transformers' role in environmental and sustainability actions.

Purpose/Objective/Benefit of this work:

- Alignment of the various guidelines/procedures/standards (including the influence or integration from product to system level)
- Comparability and evaluation basis for manufacturers, customers and other regulatory entities.
- Investigate and establish the influence of different technologies, manufacturing techniques, operational influence and end of life (Circularity).
- Best practices and/or framework for CO2 reduction.

Scope:

The working group will investigate, report, and recommend on:

- Define emission-baselines for materials and energy usage.
- Define a valid Product Category Rule (PCR) for transformers (either based on existing or new).
- Agree on standard parameters (lifetime, load-factor, etc.) for above mentioned PCR and methodology for End of Life (EoL).
- Impact and influence the energy mix has on the parameters or baseline.
- Environmental impact of transport of materials and transformer (distance, type of transport)
- Evaluation of sustainability measures linked to Transformers (Lifetime).

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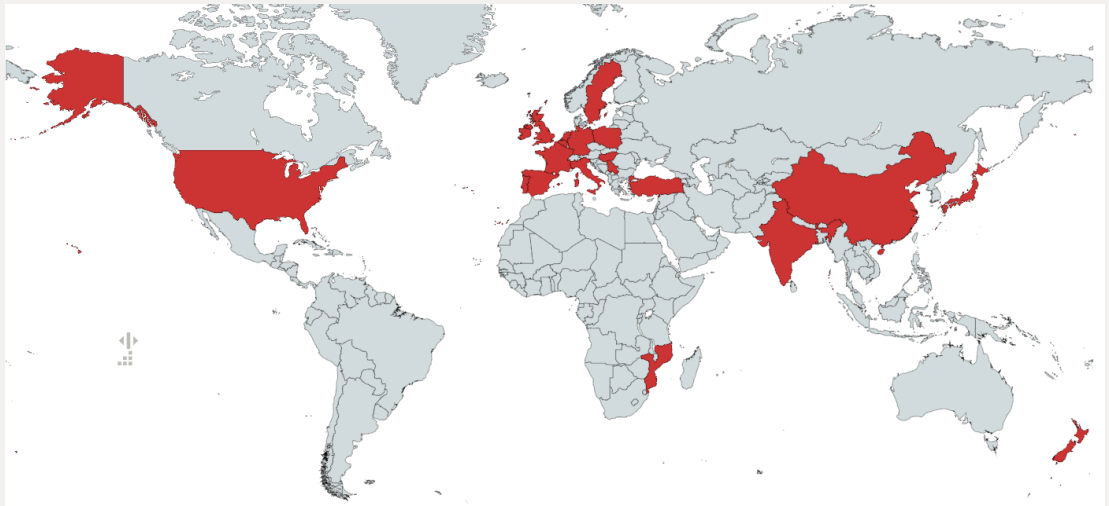
JWG Membership

38% are 1st time CIGRE members/participants

- 40 of regular / 5 corresponding / 6 NGN / 13 WiE in JWG
- 22 of Countries represented
- Repartition:
  - 12 from utilities
  - 13 from transformer manufacturers
  - 7 from material suppliers
  - 5 from service providers / consultants
  - 3 from academic / research institutes



UK Mirror Group Membership

- 14 regular members
- Repartition :
  - 2 from academia
  - 1 from material supplier
  - 3 from service provider / consultancy
  - 2 from distribution
  - 1 from manufacture
  - 4 from transmission
  - 1 from generation

SP Energy Networks
University of Manchester
Wilson Power Solutions
Doble Powertest
Midel
Cundall
Omicron
Drax
SSEN
Northern Powergrid

Table of Content

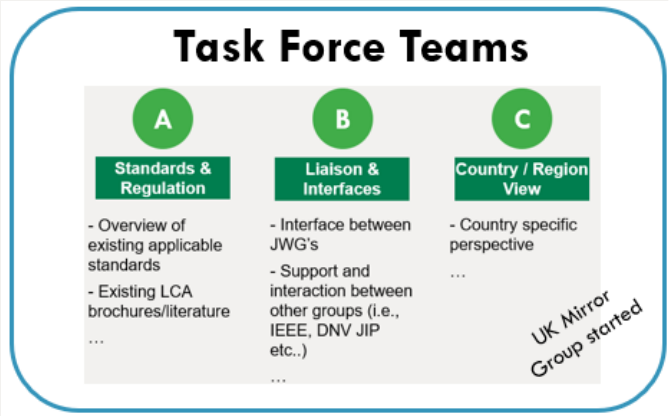
- **Chapter 1 – Definition of LCA**
  - Definition and development of LCA
  - Overview of existing standards and regulations
- **Chapter 2 – Literature Review of Existing LCA for transformers and limitations**
- **Chapter 3 – Methodology of LCA calculations for transformers**
  - Scope definition (goal, function unit, system boundary and characterization methods, existing transformer techniques)
  - LCI database (raw material, manufacture, operation, maintenance and recycling)
  - LCA software
  - Recommendations and limitations
- **Chapter 4 – Case studies**
  - Case studies based on five working streams
  - Case studies based on country/regions
- **Chapter 5 – Conclusion and Future Work**

What we doing…

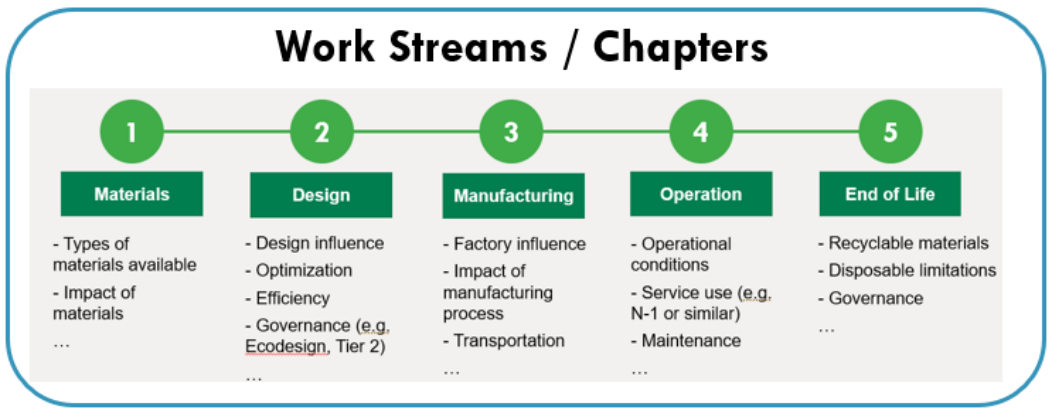
Phase 1: Data and research through **Task force** and **Workstreams**

Phase 2: Develop TB with proposed structure

How we doing…



- *Supports the Work Streams and provides literature content for Technical Brochure.*
- *Country view supported by Mirror Groups*



- *Definitions & Methodology*
- *Structure for Technical Brochure addressing subjects (e.g. databases, software/standard method & case studies)*
- *Case studies demonstrating material, design, technology, operational and country perspectives*

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Data Collection (Surveys etc…)

- **Proposals:**
  - **Working Group Members present their current works / literature on LCA or similar**
  - **Prepare survey to collect data from UK point of view**
    - **database**
    - **methodology**
    - **LCA software**
    - **case studies**
    - **application of new techniques**
    - **use of renewable energy**

Meeting Plan

- **Call for members**
  - Q3 2024

- **First mirror group meeting**
  - October 2024
  - Introduction of the working group and current progresses

- **Future meetings**
  - Align with the actual WG meeting, with a reasonable delay (2-3 weeks)
  - Share the latest developments and discussions and facilitate feedback to be provided to our UK representatives before the next WG meeting

CIGRE UK A2|D1 Liaison

CIGRE Working Groups on Power Transformer Thermal Aspects

Dr. Xiang Zhang

The Manchester Metropolitan University

27/11/2024

Agenda

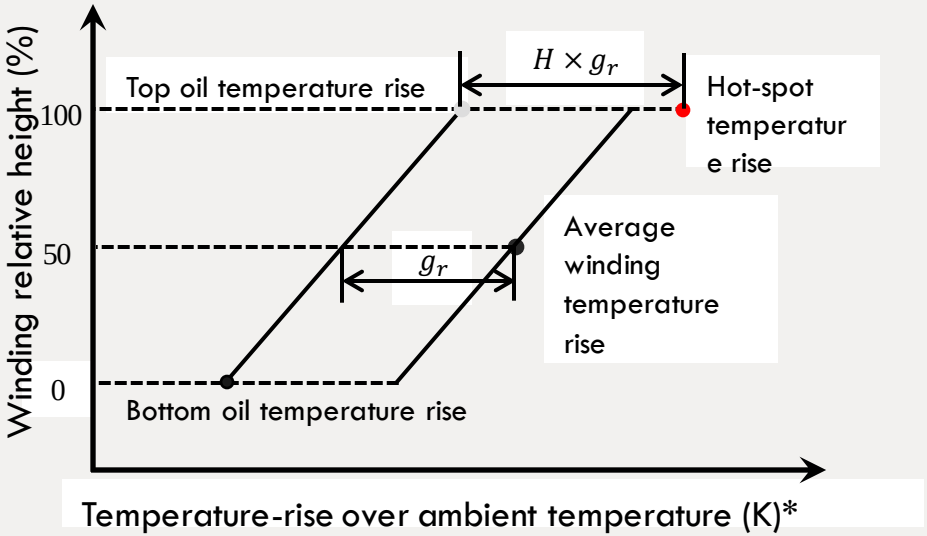
- History of CIGRE WGs on Transformer Thermal Aspects
  - **WG 12.09 (Thermal Aspects of Transformers)**
  - **WG A2.24 (Thermal Performance)**
  - **WG A2.38 (Thermal Modelling)**
  - **WG A2.60 (Dynamic Thermal Behaviour)**
- Dynamic Transformer Thermal Modelling and Benchmarking
  - **DTTM Benchmarking Platform**
  - **Different Cooling Stages**
  - **OF Cooling**

WG 12.09 (Thermal Aspects of Transformers)

- Brochure published in August 1995
- Contents
  - **Heat run test procedure and companion dissolved gas analysis**
  - **Direct measurement of the hot-spot temperature**
  - **Lifetime evaluation of transformers**
  - **Analytical and experimental determination of hotspot factor**
  - **Survey on maximum safe operating temperature and overload field practices**

Conclusion

Based on the above explanations, WG 12-09 did not find it reasonable to recommend any formula for the H factor.



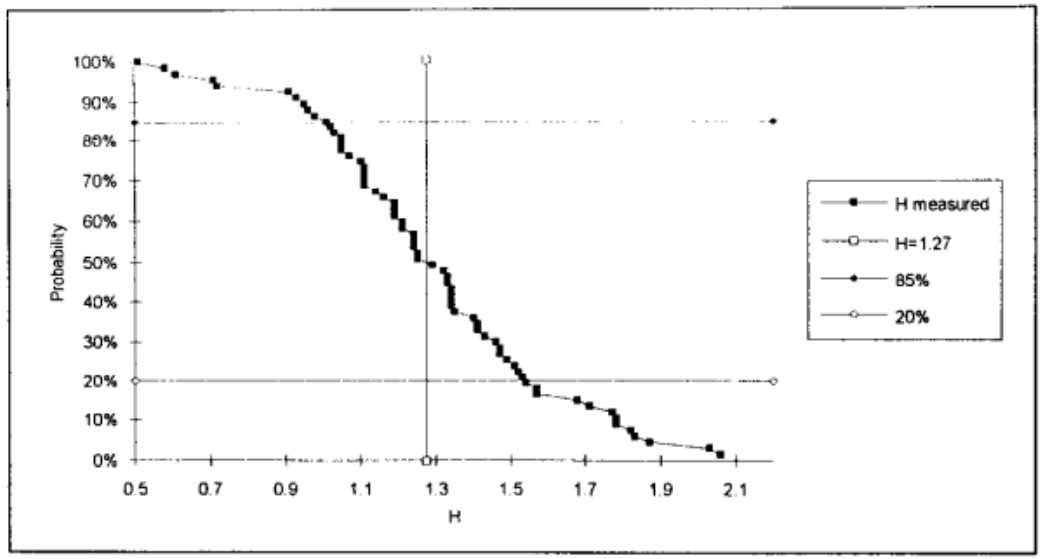


Figure 1 Inverse accumulated distribution of "H" factors

WG A2.24 (Thermal Performance)

- Brochure published in October 2009
- Contents
  1. **Main ageing mechanisms affecting transformer life**
     1. Cellulose degradation (oxidation, hydrolysis, pyrolysis)
     2. Oil degradation and its impact on insulation
     3. Moisture and oxygen as key accelerating factors
  2. **Critical temperature limits**
  3. **Key diagnostic methods: DP, DGA, Temperatures (fibre optics, OTI, WTI)**

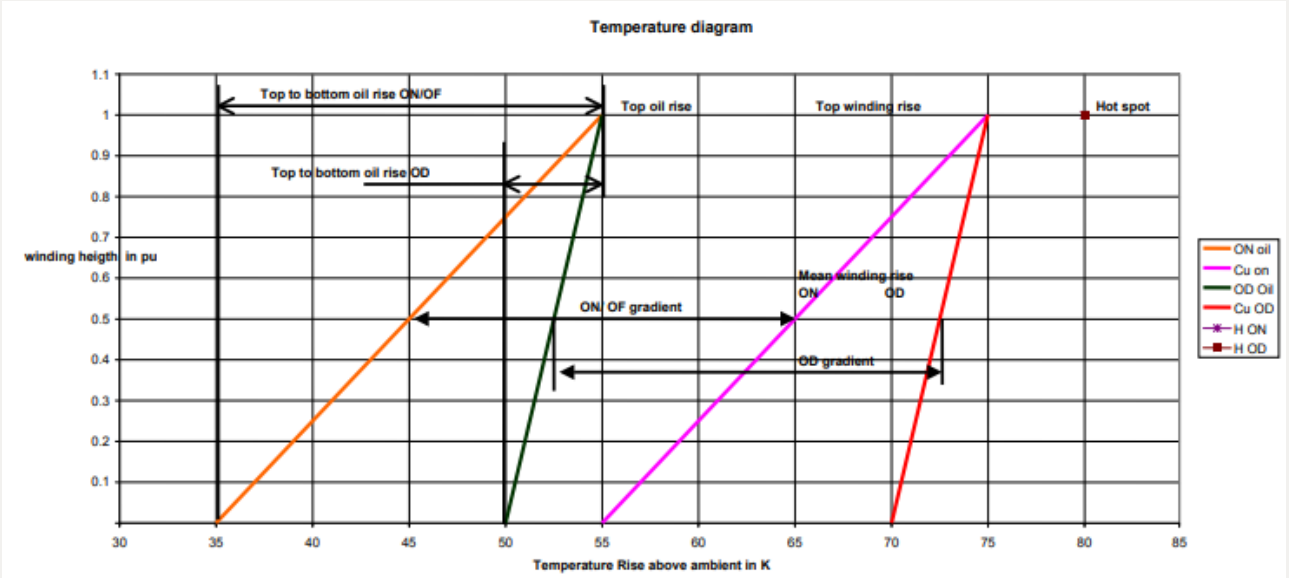


Figure 5-1: Typical temperature rise profile of ON/OF and OD cooled transformers.

WG A2.38 (Thermal Modelling)

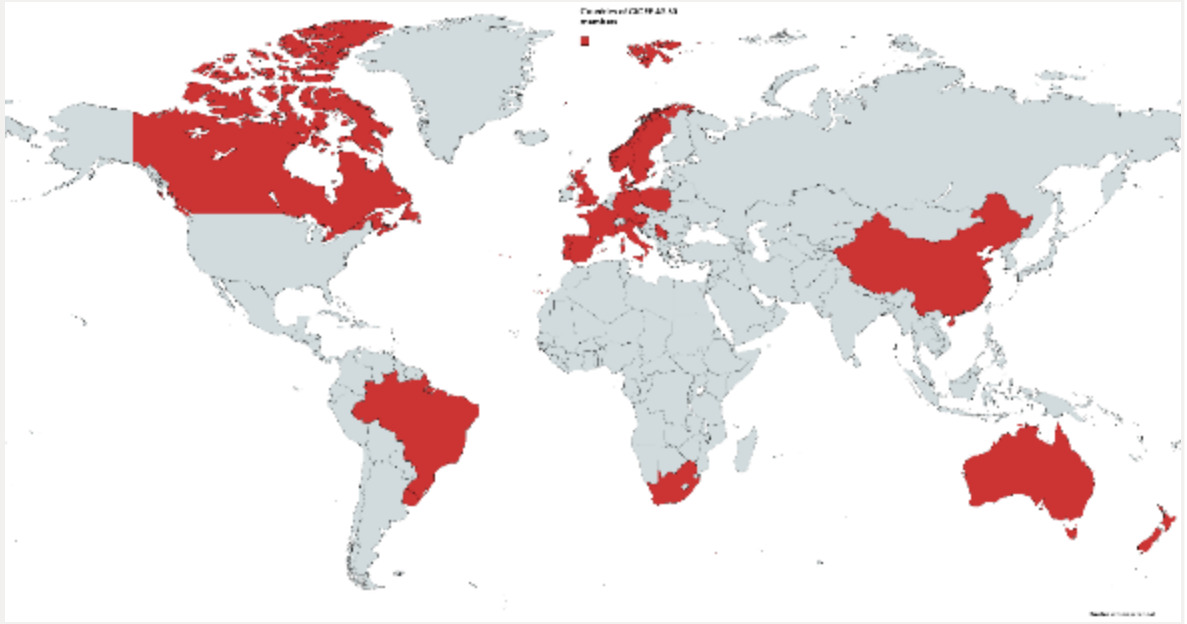
- Brochure published in June 2016
- Contents
  1. **Modelling Approaches (THNM and CFD)**
  2. **Key Technical Findings:**
     - "hot streak" effect shown by CFD
     - CFD predicts lower oil flows at top of passes vs THNM models
     - For OD cooling, stagnant/reverse flow possible in first horizontal duct
     - Hotspot factors often range from 1.5-2.0
  3. **Dynamic Thermal Models:**
     - Loading guide algorithms need improvement for sub-zero conditions
     - Oil viscosity effects dominant at low temperatures
     - Current models underestimate temperatures during transients
  4. **Fiber Optic Measurements**
     - Recommended minimum sensors per winding:
       - 8 sensors for large transformers
       - 6 sensors for medium transformers
       - 4 sensors for small transformers

Table C.4: Hotspot factors at different load currents.

Transformer	Oil flow in windings	Load current %	Winding gradient / K	Hotspot to top oil gradient / K	Hotspot factor H
25 MVA ONAF	Axial	70 100 120	15.1; LV 19.6; LV 23.0 LV	19.1; LV 27.8; LV 32.6; LV	1.26 1.42 1.42
400 MVA ONAF	Axial	100 139	19.7; LV 28.5; LV	20.7; LV 30.5; LV	1.05 1.07
400 MVA ONAF	Axial	100 140	18.7; LV 29.2; LV	20.1; LV 26.5; LV	1.07 0.91
250 MVA ONAF	Zig-Zag	100 149	14.5; LV 24.6; LV 12.5; HV 22.6; HV	18.0; LV 35.1; LV 11.7; HV 23.1; HV	1.24 1.43 0.94 1.02
400 MVA ONAF	Zig-Zag	100 129 160	15.6; LV 18.6; LV 23.4; LV 15.5; HV 21.2; HV 29.8; HV	21.2; LV 23.6; LV 28.2; LV 18.2; HV 25.2; HV 35.8; HV	1.36 1.27 1.21 1.17 1.19 1.20
1000 MVA OFAF	Axial	100 120	19.6; HV 23.9; HV	38.3; HV 42.6; HV	1.95 1.78
63 MVA OFAF	Zig-Zag	70 100 140	11.9; HV 20.8; HV 36.9; HV	16.2; HV 27.7; HV 49.3; HV	1.36 1.33 1.34
230 MVA OFAF	Zig-Zag	70 100 130	9.7; LV 14.5; LV 25.1; LV 9.4; HV 15.0; HV 21.0; HV	11.7; LV 16.5; LV 20.5; LV 12.9; HV 20.3; HV 28.1; HV	1.21 1.14 0.82 1.37 1.35 1.34
605 MVA OFAF	Zig-Zag	100 130	11.7; LV 15.2; LV 23.0; HV 35.2; HV	21.3; LV 34.3; LV 30.1; HV 51.2; HV	1.82 2.26 1.31 1.45

CIGRE A2.60 Dynamic Thermal Behaviour of Power Transformers

- WG started in 2019
- 37 of regular / 3 corresponding / 6 women
- 21 of Countries represented
- Repartition
  - 7 from utilities
  - 8 from transformer manufacturers
  - 10 from service providers / consultants
  - 12 from academic / research institutes



WG A2.60 Introduction

- Context / Scope
  - Review current state-of-the-art tools and approaches for Dynamic Transformer Thermal Modelling (DTTM)
  - Propose improvements to the standard IEC model, specifically:
    - Addressing cooling system states
    - Evaluating impacts of new insulating liquids
    - Considering effects of sub-zero ambient temperatures
- Aims / Objectives
  - Explanation of transformer thermal behaviour fundamentals and phenomena
  - Literature review on historical development of DTTM
  - DTTM Benchmarking and evaluation of possible DTTM improvements
  - Applications of DTTMs

TF1 Transformer thermal behaviour

Transformer thermal behaviour

Provide explanation of physical principles and phenomena observed, provide recent advances in steady state thermal behaviour, describe modelling approaches.

TF2 DTTM Literature review

Dynamic Transformer Thermal Modelling (DTTM) literature review

Review modelling approaches from int. standards and literature and identify possible improvements of std. DTTM

TF3 DTTM Benchmarking

Benchmarking of Dynamic Transformer Thermal Models

*Develop a benchmarking platform for **transparent, objective** and **repeatable** evaluation and comparison of DTTMs, to quantify the proposed improvements of the std. DTTM.*

TF4 DTTM Applications

Dynamic Transformer Thermal Model applications

Review of DTTM applications, showcase best practices, supported by an international survey.

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DTTM Benchmarking Platform

CIGRE Dynamic Transformer Thermal Model – Benchmarking Platform

(TTS) Input data

Transformer Thermal Scenario (TTS)

TTS*yxx.**

y: transformer nr.

xx: input dataset nr.

TTS description
TTS*yxx-information.pdf*

TTS parameters
TTS*yxx-parameters.xlsx*

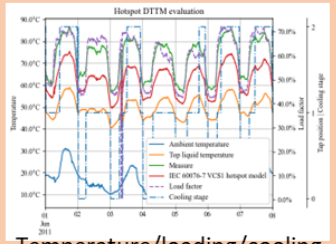
TTS timeseries
TTS*yxx-timeseries.xlsx*

(DTTM) Model

Dynamic Transformer Thermal Model

ModelName-top_liquid

ModelName-hot_spot



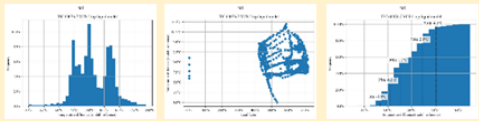
Temperature/loading/cooling timeseries

Results analysis

TTS characterisation metrics

	load	t_amb	t_tl	t_hs
mean	0,6	18,3	49,7	72,6
std	0,1	4,6	4,2	8,5
min	0,0	9,5	40,4	39,3
1%	0,4	10,3	40,6	55,9
99%	0,7	30,7	57,9	84,4
max	0,7	31,1	58,3	85,6

DTTM error graphs



PDF err vs. load cPDF

DTTM error metrics

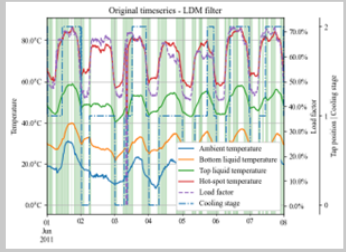
	IEC 60076-7 hotspot model	IEC 60076-7 VTP 1 hotspot model
count	2593,0	2593,0
mean	-0,2	-0,2
std	1,4	1,4
min	-14,7	-14,7
1%	-3,9	-3,9
99%	2,2	2,2
max	3,1	3,1
rmse	1,4	1,4
avg(v_dttm/v_tts)	1,0	1,0
L_dttm/L_tts	0,8	0,8

Results filtering

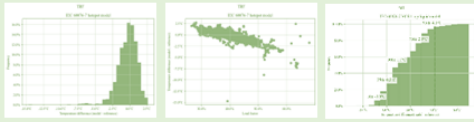
Transient Response Filter

Steady State Response Filter

On-load Response Filter



Filtered DTTM error graphs



Filtered DTTM error metrics

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1%	0,4	10,3	40,6	55,9
99%	0,7	30,7	57,9	84,4
max	0,7	31,1	58,3	85,6

CIGRE DTTM Benchmarking platform

Project ID: 45586720

Topics: Python thermal model transformer

https://gitlab.com/cigrea2.60/cigre-dttm-benchmarking-platform

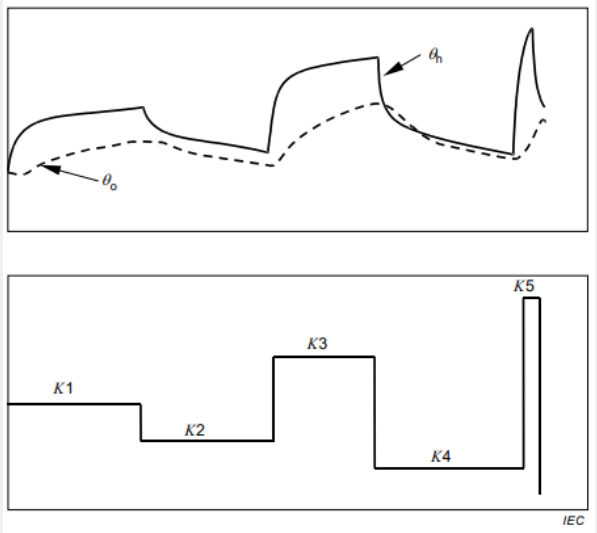
Thermal Modelling for Variable Cooling Stages (VCS)

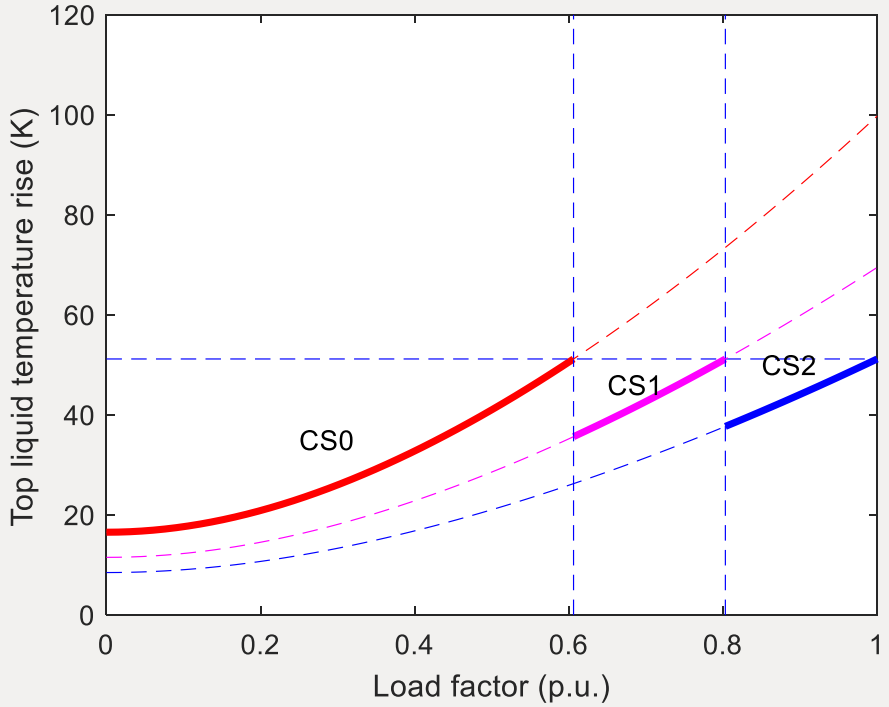
- Large transformers often operate below nominal power, using variable cooling stages (VCS) to optimise operation
- International standard models treat thermal parameters as static, ignoring VCS effects

Parameter	Symbol	Cooling stage rated value		
Cooling stage power rating	S_x	66 MVA (S_n)	52 MVA (S_1)	40 MVA (S_0)
Cooling stage index	x	2	1	0
Cooling method		ONAF (100% of cooling groups activated)	ONAF (50% of cooling groups activated)	ONAN (all fans off)
Losses ratio	R_x	7.44	5.80	3.31
Load factor rescaling	$(\frac{S_n}{S_x})$	1	1.154	1.364

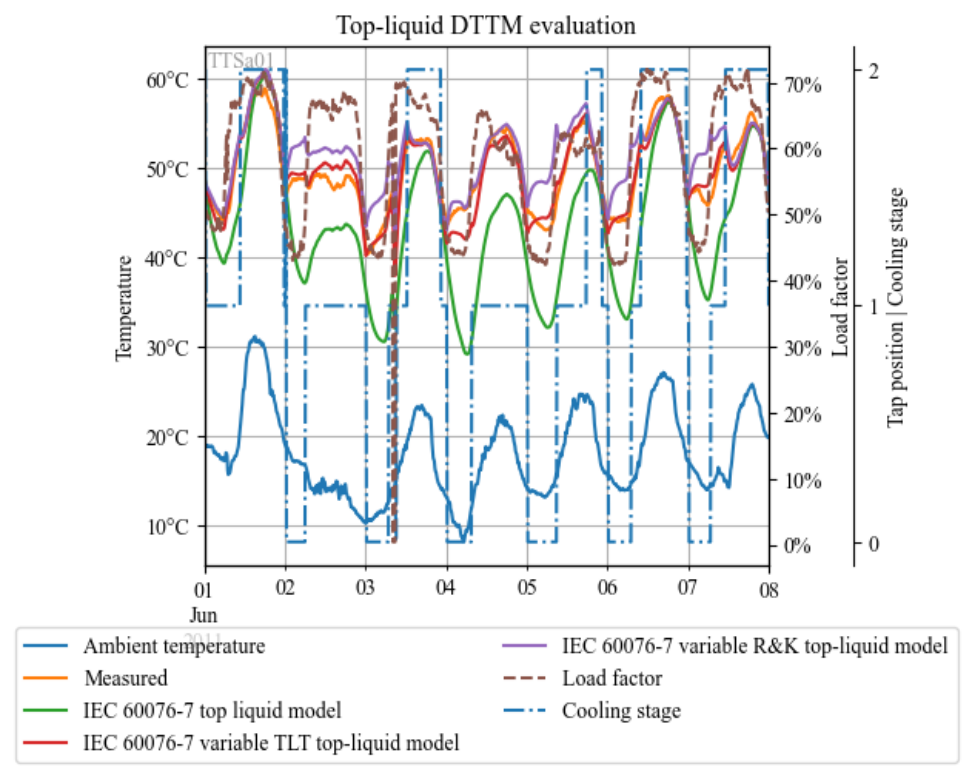
Determination of Thermal Parameters

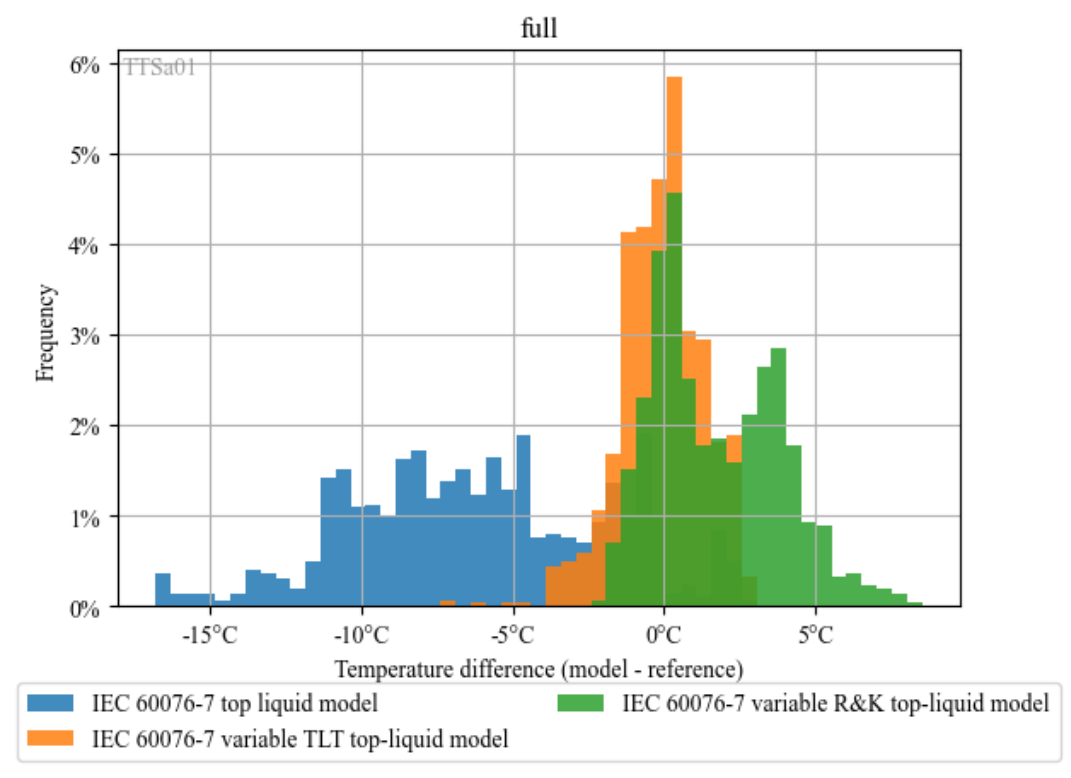
- Two Parameters: Rated temperature rise and time constant
- $\Delta\theta_{TLn} = \Delta\theta_{TLx}\left(\frac{1+RK_x^2}{1+R}\right)^x$
- Cooling stage specific time constants τ_{TLx}





Case Study





DTTM error metrics	IEC 60076-7 top-liquid generic	IEC 60076-7 top-liquid variable R&K	IEC 60076-7 top-liquid variable TLT
mean	-6,1	1,8	-0,1
STD	4,2	2,1	1,4
min	-16,8	-2,2	-7,3
max	2,6	8,5	2,9
RMSE	7,4	2,7	1,4

OF Cooling

- OF cooling uses a pump between tank and cooler to supply cold bottom oil around windings, increasing winding pressure head compared to ON cooling.
- Despite forced oil flow, heat transfer from active part to tank oil still relies on natural convection.

Advantages

• Compact cooler reduces transformer footprint

• Increased winding cooling efficiency enables compact design

Challenges

• Pump adds potential failure point

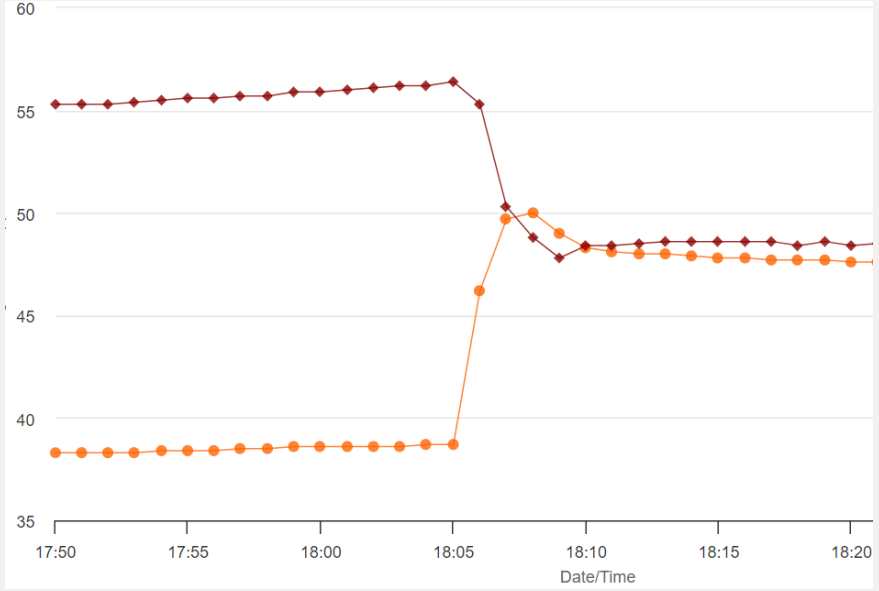
• Fixed pump capacity limitations as natural convection determines required pump capacity

• Changing pump capacity reduces cooling performance

• Radiator use requires careful consideration due to low pressure drop risks

Oversized Pump in OF Cooling

- Observed behaviour in a 20/30 MVA ONAN/OFAF transformer:
  - **When pump is ON, top and bottom oil temperatures merge**
  - **When pump is OFF, 15-20°C difference between top and bottom oil**
- Indication of oversized pump:
  - **Excess oil volume not consumed by windings enters cooler top**
  - **Leads to decreased top oil temperature but increased bottom oil temperature**
  - **Increased winding temperatures (average and hotspot) as a consequence**



30-minute recording of top and bottom temperatures in radiator-tank connecting pipes

Conclusion

- CIGRE Working Groups efforts on transformer thermal modelling over the past 3 decades:
  - **WG 12.09 (1995) on fundamental thermal aspects and testing procedures**
  - **WG A2.24 (2009) on understanding of ageing mechanisms and temperature limits**
  - **WG A2.38 (2016) on modelling approaches (THNM and CFD)**
  - **WG A2.60 (present) on DTTM modelling and benchmarking**
- WG A2.60 focus and progress
  - **Development of standardised DTTM Benchmarking Platform**
  - **Improved modelling of Variable Cooling Stages (VCS) effects as an example**
- Critical Findings for OF Cooling:
  - **Pump sizing significantly impacts cooling efficiency**
  - **Need for balanced design between pump capacity and natural convection**

Agenda

- 10:30 Registration and Tea/Coffee
- 11:00 Welcome and Introduction to SC A2
- 11:15 Technical Brochures Published in 2024 | CIGRE 2024 Reflection | New WGs & Future Events | A2 Technical Activities and Working Group Updates
- 12:30 Introduction to D1 and Updates from Relevant Technical Activities
- 13:00 Networking Lunch
- 14:00 Updates from IEC 60076 Parts 1 and 2 Revision
- 14:15 In-depth A2 Technical Presentation & Discussion (Life Cycle Assessment and Dynamic Thermal Modelling)
- 15:15 Any Other Business
- 15:30 End of Meeting, Tea/Coffee/Networking

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Many Thanks

- **The University of Manchester, sponsoring the meeting room. Lunch and Tea/Coffee Breaks are sponsored by the CIGRE-UK.**

- **CIGRE-UK A2 Team**
  - ✓ Regular Member – Zhongdong Wang (The University of Manchester)
  - ✓ Additional Member – Elizabeth MacKenzie (MacKenzie Consultant)
  - ✓ Technical Panel Secretary – Jose Quintana (SP Energy Networks)
  - ✓ Secretary – (Tee) Shengji Tee (SP Energy Networks)

- **Support from CIGRE-UK:**
  - ✓ Martin Ansell (Events/Marketing)
  - ✓ James Yu (Technical Committee Chair)

- **Support from The University of Manchester:**
  - ✓ Qiang Liu
  - ✓ Shanika Matharage

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