CIGRE Study Committee A2

## PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP[1]

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| **WG N° A2.63** | **Name of Convenor:** Ebrahim Rahimpour (Germany)<br>**E-mail address**: ebrahim.rahimpour@de.abb.com | |
| **Strategic Directions #[2]: 1, 3** | **Technical Issues #[3]: 8, 10** | |
| **The WG applies to distribution networks[4]: No** | | |
| **Potential Benefit of WG work #[6]: 2, 3** | | |
| **Title of the Group: Transformer impulse testing** | | |

**Scope, deliverables and proposed time schedule of the Group:**

**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.
The impulse parameters can vary depending on testing schemes and transformer design. One of typical issues is influence of impulse parameters on electrical stresses inside the transformer winding and limitation of its permissible deviations. In the last editions of IEC 60060-1 and IEC 60076-3 a k-factor approach was introduced to compensate for the overshoot at the front of the full wave lightning impulse. This approach was initially developed for the testing of dielectric materials, and, despite all its advantages, it is not applicable to complex transient phenomena in transformer windings. In general, the transient voltages in the oil ducts located far from winding terminals reach their maxima at times far beyond the impulse front and they are not affected by the overshoot. As a result, in the case of test impulse voltages with superimposed oscillations having extreme values $U_e$, the stresses on longitudinal insulation are not equivalent to the stresses under the application of test voltages $U_t$ as per IEC 60060-1.
Chopped wave parameters such as time to first voltage zero, oscillation frequency after the instant of chopping and overswing factor strongly influence on winding insulation stresses. The frequency of oscillations after chopping can be close enough to natural frequencies of inter-disc oscillations of large windings of EHV and UHV transformers and reactors, and in such a case the electrical stresses in oil ducts between discs can be higher due to the development of resonant inter-disc oscillations.
Thus IEC 60076-3 and IEC 60076-4 recommendations do not take into account all the complexity of transient phenomena in transformer windings and have to be reconsidered.
Another issue is testing with switching impulse which has its own questions, for instance, overexcitation of magnetic systems, resonance behaviour and nonlinear voltage transfer leading to overstressing of phase-to-phase insulation when testing phase-to-earth insulation.
Another typical issue is the influence of impulse polarity. Currently the IEC standards prescribe usage of the impulses with negative polarity. It became standard long time ago based on considerations for oil-immersed transformers and small air-insulated transformers. For instance, in oil-immersed transformers the impulse stresses on main insulation generally are not critical due to high impulse ratio of dielectric strength, and the stresses on longitudinal insulation have oscillatory behaviour, so the impulse polarity has almost no effect. In case of small-size air-insulated transformers there is nearly uniform electric field

and the air gaps are short thus the effect of impulse polarity can be negligible. Recently the situation changed with introducing of new materials such as ester liquids having electric strength impulse ratio different from the strength of mineral transformer oils and with increasing of rated voltage of dry-type transformers (up to 72,5 kV and above) in which the electric fields became non-uniform because air gaps increased in size.
Internal surge arresters which are now used more widely have an influence on transient behavior of transformers and require special considerations during testing. Their application is linked to insulation coordination and determination of their rating to guarantee transformer reliability. Not all related questions of their application are now covered by IEC standard.

**Scope:**

The working group will focus on studying of transient phenomena and material properties and on accumulation of best practices for testing in order to establish the recommendations for IEC 60076-3 and IEC 60076-4 improvement.

The proposed scope of work will include following topics:

1) Full wave lightning impulse test
- Influence of front time and tail time, improving of IEC 60076-3.
- Influence of overshoot on insulation stresses, applicability and improvement of k-factor.
- Recommendations for IEC 60076-3 (modification related to k-factor and overshoot).

2) Chopped wave lightning impulse test
- Influence of undershoot, frequency of oscillation after chopping.
- Testing the low voltage windings and providing the zero crossing after chopping.
- Recommendations for IEC 60076-3.

3) Switching impulse test
- Avoiding of phase-to-phase insulation overstressing when testing phase-to-earth insulation.

4) Non-standard waveforms and high-frequency overvoltages
- Assessment of insulation stresses.
- Evaluation of equivalent factory test (if necessary) and recommendations on factory test.
- Investigation on real wave forms occurring in the field.
- Recommendation for tests representatives of VFTO by studying the withstand of insulating materials to VFTO.
- Impulse wave forms for HVDC transformers.

5) Positive and negative polarities in impulse test
- Influence of polarity on the insulation system.
- Test instruction about the procedure with positive and negative polarity.
- Advantages and risks with positive impulse test.
- Influence of polarity on air clearances.
- Recommendations for IEC 60076-3.

6) Use of internal surge arresters
- Considerations for the transformer reliability.
- The effect on testing.
- Consideration of insulation coordination and protective margins.

**Deliverables:**

☒ Technical Brochure and Executive summary in Electra

☒ Electra report

☒ Tutorial[5]

**Time Schedule**: Start: Summer 2019 **Final Report**: Summer 2023

**Approval by Technical Council Chairman**:

**Date**: December 6th, 2018

Notes: [1] or Joint Working Group (JWG), [2] See attached Table 2, [3]See attached Table 1, [4] Delete as appropriate, [5] Presentation of the work done by the WG, [6] See attached table 3

**Table 1: Technical Issues of the TC project "Network of the Future" (cf. Electra 256 June 2011)**

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| **1** | Active Distribution Networks resulting in bidirectional flows |
| **2** | The application of advanced metering and resulting massive need for exchange of information. |
| **3** | The growth in the application of HVDC and power electronics at all voltage levels and its impact on power quality, system control, and system security, and standardisation. |
| **4** | The need for the development and massive installation of energy storage systems, and the impact this can have on the power system development and operation. |
| **5** | New concepts for system operation and control to take account of active customer interactions and different generation types. |
| **6** | New concepts for protection to respond to the developing grid and different characteristics of generation. |
| **7** | New concepts in planning to take into account increasing environmental constraints, and new technology solutions for active and reactive power flow control. |
| **8** | New tools for system technical performance assessment, because of new Customer, Generator and Network characteristics. |
| **9** | Increase of right of way capacity and use of overhead, underground and subsea infrastructure, and its consequence on the technical performance and reliability of the network. |
| **10** | An increasing need for keeping Stakeholders aware of the technical and commercial consequences and keeping them engaged during the development of the network of the future. |

**Table 2: Strategic directions of the TC (ref. Electra 249 April 2010)**

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| **1** | The electrical power system of the future |
| **2** | Making the best use of the existing system |
| **3** | Focus on the environment and sustainability |
| **4** | Preparation of material readable for non-technical audience |

**Table 3: Potential benefit of work**

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| **1** | Commercial, business or economic benefit for industry or the community can be identified as a direct result of this work |
| **2** | Existing or future high interest in the work from a wide range of stakeholders |
| **3** | Work is likely to contribute to new or revised industry standards or with other long term interest for the Electric Power Industry |
| **4** | State-of-the-art or innovative solutions or new technical direction |
| **5** | Guide or survey related to existing techniques. Or an update on past work or previous Technical Brochures |
| **6** | Work likely to have a safety or environmental benefit |