CIGRE Study committe A2

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

JWG A2/C4/D1.77

NAME OF THE CONVENOR
JURISIC Bruno (CROATIA)

TITLE
Design of transformers for very fast transient overvoltages

THE WG APPLIES TO DISTRIBUTION NETWORKS: YES

ENERGY TRANSITION
5 / Grids and Flexibility

POTENTIAL BENEFIT OF WG WORK
2 / potential interest from a wide range of stakeholders
3 / likely to contribute to new or revised industry standards
4 / state-of-the-art or innovative solutions or directions

STRATEGIC DIRECTION
1 / The electrical power system of the future reinforcing the End-to-End nature of CIGRE: respond to speed of changes in the industry by preparing and disseminating state-ofthe-art technological advances
2 / Making the best use of the existing systems

SUSTAINABLE DEVELOPMENT GOAL
0 / Other SDGs or not applied

BACKGROUND :
Increasingly, for different technical-economic reasons, gas-insulated substations (GIS) are being used in electrical systems instead of conventional air-insulated substations (AIS).

The switching transients originating in GIS are completely different from those originating in AIS, with different frequencies, amplitudes and waveforms, and their effects on transformers have been a matter of discussion in recent years.

These transients are called Very Fast Transient Overvoltages (VFTO) and are characterized by a very steep front wave and high oscillation frequency. The rise time of such a wave is in the range of some nanoseconds (5 to 20 ns) and the peak value is about 1.5 and 2.5 p.u. of the rated operating voltage. The oscillation frequencies are in the range up to 5 to 10 MHz.

Conventional power transformers are designed to withstand the standard lightning and switching impulses (LI, LIC and SI according to IEC 60076-3). Modelling and behaviour of transformers for this frequency range (< 500 kHz) is well known, proved in the factory acceptance tests, and validated by successful operation in service. For VFTO, no standard tests are available yet. Therefore, the customer needs to define the VFTO test voltage to be considered in the design of the transformer.

Although there is no statistical evidence that these VFTO cause a higher failure rate than conventional overvoltages, the fact of not being able to test the withstand of the equipment to VFTO during the factory acceptance tests leaves a big question open.

PURPOSE / OBJECTIVE / BENEFIT OF THIS WORK :

The design of the withstand capability of a transformer at an overvoltage applied to its terminals consists of first making an appropriate model of the transformer, for the frequency range of the applied wave, that allows us to determine accurately how the applied voltage is distributed inside the windings.

Then, knowing the value of the voltage applied to each internal insulation part, it is possible to determine the electric field to which the insulating materials that make up said insulation are subjected.

Finally, the calculated electric fields must be compared with the field values supported by the insulating materials that depend on the amplitude, front time, oscillation frequency, and duration of the applied wave.

For conventional overvoltages we have representative waves that have been used successfully for decades. We have different types of detailed white-box models that allow us to calculate with acceptable accuracy how these voltages are distributed in the internal insulation of the transformer, and we have the required knowledge about the withstand capability of the insulating materials (liquids and solids), for these representative waves.

For VFTO, however, we do not have standardized waves that represent them. The white box models must now be adapted for use in the frequency range of the VFTO, and there is little or no information regarding how liquids and solid insulating materials behave when they are subjected to this type of overvoltages.

SCOPE :

We therefore consider it necessary to make a complete and detailed review of the design process of transformers that are going to be subjected to VFTO in service, which involves the knowledge of at least three CIGRE study committees:

- Study Committee C4 (Power System Technical Performance) to define types of representative VFTO waveforms that can be used for design purposes:
  - Review and describe the most relevant sources of VFTO stresses relevant for power transformers.
  - Describe procedures for establishing VFTO waveforms for use in transformer design.
  - Provide examples of time domain waveforms.
- Study Committee A2 (Power Transformers and Reactors) to define the type of transformer models that should be applied in the VFTO's frequency range:
  - Review the existing knowledge on white-box modeling of power transformers when subjected to VFTO, including the effect of the bushings.
  - Assess to what extend the white-box models can produce “accurate” voltage waveforms.
  - Clarify to what extent simplifications to the modeling procedures are possible, with the objective of reaching a feasible calculation procedure.
- Study Committee D1 (Materials and Emerging Test Techniques) to define the withstand characteristics of liquids and solid insulating materials to VFTOs:
  - Review the knowledge about the withstand capability of the insulation system, when subjected to VFTO. Clarify whether it is possible determine the dielectric withstand based on knowledge about field stress in terms of peak, value, steepness, oscillation frequency and duration, or whether the actual waveshape must be considered.
  - Clarify how to best divide the transformer insulation system into discrete parts, for comparison of overvoltage stresses with withstand capability.
  - Provide example(s) describing how to determine the withstand capability for practical transformer designs.

DELIVERABLES AND EVENTS

Deliverables Types

Annual progress and activity report to Study Committee
Electra report
Technical Brochure and Executive Summary in Electra
Tutorial
Webinar

Time schedule

Q1	2025	Recruit members (National Committees, WiE, NGN)
Q3	2025	Develop final work plan
Q4	2027	Draft Technical Brochure for Study Committee review
Q3	2028	Final draft Technical Brochure
Q3	2028	Tutorial

APPROVAL BY TECHNICAL COUNCIL CHAIRMAN:
Rannveig S. J. Løken
January 13th, 2025