

C4 **TECHNICAL BROCHURE**

Power system technical performance

Measuring techniques and characteristics of fast and very fast transient overvoltages in substations and converter stations

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Measuring techniques and characteristics of fast and very fast transient overvoltages in substations and converter stations

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Executive summary

In recent decades, the application of new power equipment and transmission technologies in power systems has made power grids much more complex than before. As a consequence, power equipment insulation systems are exposed to transient voltages with increasingly shorter rise-times and thus higher frequency components.

For most insulating materials, their insulation withstand levels and aging strongly depend on the waveform characteristics of the applied voltage. However, the insulation performance tests for almost all high-voltage power equipment are conducted using voltage waveforms specified in the various product-specific international standards (such as the standard lightning impulse voltage, the standard switching impulse voltage, etc.). However, the actual transient voltage waveforms which occur on site may differ substantially from the standard impulse voltages adopted in high-voltage tests, and may thus pose an unpredictable risk of damage to the power equipment insulation. The presence of such transient voltages in the field with new and unaccounted for characteristics makes it necessary to review the applicability of existing high-voltage test standards and insulation coordination standards, especially for power grids operating newer and higher voltage grades along with ones equipped with a large number of new power equipment. Moreover, the transient voltages caused by grid faults contain much information on the occurrence and development of the faults which can be used in analyzing failure causes and locating the faults. Therefore, field measurements of the actual fast and very fast transient voltages are worthwhile and can benefit development of acceptable high-voltage dielectric test methods and economic insulation design schemes, as well as analyzing grid failure causes.

Fast and very fast transient voltages normally have very short front times (rise-times) and thus very wide frequency spectra. Front times can be shorter than several nanoseconds, resulting in bandwidths ranging from the power frequency up to 100 MHz. Meanwhile, the appearance of some transient voltages such as lightning transients or fault transients are unpredictable. Unfortunately, conventional voltage measuring equipment (such as capacitive voltage transformers, potential transformers etc.) typically found in substations are usually incapable of measuring fast and very fast transient voltages, due to their narrow bandwidths and low sampling rates.

The characteristics of fast and very fast transient voltages require measuring systems with ultra-high performance in field measurement. In recent years, some institutes, universities, and companies have developed several kinds of measuring systems to deal with fast and very fast transient voltages. Measurements of such transient voltages carried out in the field have helped researchers to understand the new overvoltage events, solve the corresponding insulation problems, and review the applicability of the existing high-voltage test and insulation coordination standards. However, concerning transient voltages in the existing power grid, there are still lots of questions unanswered. Meanwhile the application of new power equipment and new transmission technologies constantly produce new transient phenomena. Thus, there could be a long-term need for field measurement of transient voltages. As there are no relevant guides or standards, the researchers and engineers who carry out field measurements may face the following questions:

1. How to choose suitable sensors, signal transmission techniques, and recording instruments to develop the measuring system according to the situations they face,
2. How to specify the performance requirements of the measuring system to ensure the accuracy of measured transient voltages,
3. How to test the performance of the measuring system to confirm if they have met the expectations, and how to calibrate them?
4. When doing field measurements, what test lay-outs are suitable, and what are some typical results obtained by other researchers and engineers?

In order to provide a base-line reference for those concerned with transient voltages in the field and to provide a technical basis for the possible future preparation of a technical standard, this technical brochure will address the following aspects:

1. Review the classifications, definitions, and characteristics of transient voltages along with the basic concepts of transient measurement in existing standards.
2. Introduce the basic principle, key technical points, advantages and disadvantages as well as performance of multiple sensing techniques; present the appropriate signal transmission and recording techniques.

3. Propose performance requirements, testing methods for measuring systems, and provide guidance for setting performance parameters such as measurement accuracy, bandwidth, scale factors, etc.
4. Provide examples of field measurement case studies for the references of the users.
5. Provide guidance to assist users dealing with the attendant electromagnetic compatibility (EMC) problems encountered when carrying out VFT measurements (proper grounding and shielding, avoiding damage to sensitive equipment, etc.).

This technical brochure should help users design and develop their own measuring system for transient voltages, ensure accuracy and reproducibility of the field measurements by different groups, and better understand fast and very-fast transient phenomena and their effects in power grids.

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