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Traceability of impulse test for diagnostic measurements of power apparatus

Ernst Hanique¹, Eddy So²

¹DNV-KEMA GL Energy, The Netherlands
Emst.hanique@dnvkema.com

²Measurement Science and Standards
National Research Council of Canada

Abstract — This paper describes the diagnostic measurements involved while performing impulse tests. For most applications during impulse tests, the impulse voltage and impulse current are measured. Because of the nature of impulse test it is very common that Electro Magnetic Interference signals (EMI) are generated. This EMI will influence the measurement. Therefore these tests are done in well-shielded high voltage laboratories. Also the relevant sensors e.g. voltage dividers, current shunts and other components used for the measurements, including traceability issues, will be discussed in this paper.

Index Terms — Divider, electro mechanical compatibility, impulse, measurement, shunt and uncertainty.

I. INTRODUCTION

Most high power apparatus are tested in High Voltage laboratories to verify the technical integrity and to prove that the apparatus fulfils the specifications as per international standards. One of the tests performed is the impulse test [1]. Impulse tests simulates a lightning struck of the apparatus in service, but is also more often used as a quality test on components who will never experience a lightning struck in service. Because of the nature of impulse tests high frequencies up to 2 MHz for a standard waveform of 1.2/50us are involved. This will result in EMI disturbance within the measurement circuit. Special measures have to be taken to minimize the impact to the quality of the measured signals.

II. SENSORS FOR IMPULSE MEASUREMENT

To be able to measure the impulse voltage and current dedicated voltage dividers and shunts are used. These are specially designed and constructed to be able to measure fast impulses. The frequency band width of these devices should be high enough to cover the frequency spectrum of the applied impulse. These device should not only be able to measure the correct peak value, but also give a exact representation of the waveform, without interference due to EMI and other disturbances. The devices should be corona free. The location and measurement arrangement of the sensors are very important. The voltage divider should be connected to the test object by its own lead directly to the test object. By doing so

this lead is not carrying any (impulse) current other than the current through the divider. Ideally the same thing is true for the grounding part of the divider. The divider should only measure the voltage over the test object and nothing else.

Shunts are typical designed as tubular coaxial shunts [2]. These shunts usually consist of two tubes slides into each other. The current enters the shunt via the inner tube made of non-magnetic resistive material and leaves via the outer tube made of non-magnetic material only. This way the inner tube resides in a field-free environment. This is important to make the inductive component of the shunt as small as possible. The shunt resistance ranges from 0.01-1 Ohm. Care should be taken to connect the shunt in the correct way with respect to ground. The necessary frequency spectrum will be discussed in the paper.

Voltage dividers can be either resistive, mixed ohmic-capacitor damped divider. For very high voltages > 500 kV damped capacitive dividers are commonly used. They are normally designed to have the high-voltage arm and low-voltage arm constructed on top of each other. The maximum low-voltage arm output voltage is 2000V. Dividers with a relative wide frequency bandwidth also have an extra compensation resistance placed on top of the divider. Other details of the dividers are discussed in the paper.

III. THE MEASUREMENT SYSTEM

A complete digital impulse measurement system consists of a hardware part and a software part. Both parts should fulfil specific specs and should be correctly calibrated..

A. Hardware

To be able to process the signals coming from the sensors a nowadays a sophisticated digital measurement system is used. Such a measurement system consists basically of a suitable digitizer and voltage-probes.

The digitizer user should fulfill the specifications of IEEE-1122 [3]. This assures that the frequency bandwidth is sufficient and that the used digitizer internal *A/D* is accurate

enough for this type of application. More details are presented in the paper.

The system uses precise high frequency high voltage probes to adapt the maximum input voltage of the sensor of 2000V to the input range of the digitizer. Also the frequency bandwidth of the probes should be wide enough for this type of application. The paper will go into that in more detail.

B. Software

Besides hardware the impulse measurement system should also contain software.

First, this software should control the whole system to be able to perform measurements within a sufficient short time interval.

Second, the system should evaluate the waveform recorded accordance international standards. The software should allow the verification of this part by allowing to load the Test Data Generator test files from which the waveform parameters are exactly determined. Besides that the software should always present the raw data waveform on the screen. For waveform parameter evaluation purpose each software will produces processed data (e.g. filtered waveforms), but is not allowed to present them without the original data containing the waveform really applied to the test object.

Third, the system may include diagnostically software tools like signal comparison and transfer functions. These tools can be used as an extra tool to verify, if the test object past the impulse test or not. These tools can also help in the case of a failure in the failure analyses process. For instance, by means of the transfer function it can be determined if the failure is inside or outside the test object. The frequency spectra can be compared to accomplish this. This can even be done by comparing the frequency spectra of a full wave and a chopped wave if some facts are taken in account. To obtain the best time domain resolution the sampling frequency of the waveform by the digitizer should be at least 100 MHz/sample. To obtain sufficient frequency resolution at this sampling frequency the memory length of the recorded waveform should be long longer that 128MB per measured channel. The paper will go into that in more detail.

IV. CALIBRATION AND TRACEABILITY

Each component used for any measurement should be calibrated correctly. This means that there should not only be a calibration certificate of every component but the calibration procedure and ranges should match for this type of application. The appropriate calibration intervals depend on the type of measurement system and its components and should initially follow the recommendation of the manufacturer of the components and the measurement system. Once a history of calibration is developed, the appropriate frequency of calibration for a particular component can be determined or continuously maintaining the quality of the

measurement, means must be provided for regular in-house checking of the components and the complete measurement system in between calibration intervals.

The accuracy ratings of all components/sensors shall be verified and determined using calibration techniques and methods with an overall uncertainty of at least four times less than the error allowed for the sensor system under test, that is, a Test Uncertainty Ratio (TUR) of 4:1. In other words, the tolerance of the component/sensor system specification being tested shall be equal to or greater than four times the combined uncertainties of all the measurement standards employed in the test as specified in ANSI/INCSL Z540-1-1994 [4]. The equipment used for accuracy tests shall be traceable to the SI units through national/international standards maintained by a National Metrology Institute. Records of accuracy verification for the calibration systems by an independent laboratory shall be regularly maintained.

Traceability only exists when there is documented evidence of the traceability chain and the quantification of its associated measurement uncertainties. The values of standards, their uncertainties, and the corrections and uncertainties of associated measurement systems have time-dependent components. Evidence should therefore be collected at appropriate intervals and used on a continuing basis to remove measurement biases and to re-determine the associated uncertainties. After properly accounting for all these errors, their associated uncertainties must be evaluated to obtain a combined overall uncertainty of the impulse measurement. It is recommended that this combined overall uncertainty be based on a 95% confidence interval [1].

The calibration process and traceability of impulse test for diagnostic measurements of power apparatus will be presented.

V. CONCLUSION

An overview of impulse test for diagnostic measurements of power apparatus and its traceability issues are presented. It is very important to perform the measurement in a correct way with properly calibrated devices to ensure that the measurements would meet the proper traceability requirements. Also, it is very important to verify the results with other diagnostic measurements to be able to have consistent conclusions.

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