

Measurement Methods and Procedures for Assessing Accuracy of Instrument Transformers for Power Quality Measurements

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Abstract — Instrument transformers (ITs) are vital components of power quality (PQ) measurement systems in electrical transmission and distribution grids. Whereas measurement methods and accuracy are well defined for PQ measurement instruments, accurate knowledge about IT performance in presence of grid disturbances is missing. Main research themes of a project recently funded within the EMPIR program are described in the paper. The project focuses on the set-up of a metrological framework to enable the traceable measurement of PQ parameters when ITs are included in the measurement chains. Attention is focused on the development of reference measurement systems and the definition of IT test procedures, as well as on the quantification of the performance of ITs under realistic disturbance conditions. Moreover, an extensive characterization of voltage and current ITs will provide the basis for the identification of different sets of limits for the IT accuracy performance in PQ application and the definition of PQ accuracy classes.

Index Terms — Instrument transformers, calibration, measurement standards, measurement techniques, measurement uncertainty, precision measurements, uncertainty.

I. INTRODUCTION

Transition towards a large-scale electrification of the energy systems relies on a reliable and resilient transmission and distribution of the electrical energy. The distribution system in particular will become a crucial element, as a large share of variable renewables and power electronic based equipment are more and more connected to it, with the consequence of increasing grid disturbance levels [1]. This will extend the need for accurate monitoring of power flows as well as power quality (PQ) parameters. PQ measurement chains in high voltage (HV) transmission and distribution systems necessarily include instrument transformers (ITs) to adapt grid voltage and current levels to the input ranges of the PQ measurement instruments. Whereas the behavior of ITs is established and standardized

under rated AC power frequency signals, there is a lack of knowledge on their performance under perturbed grid conditions. Traceable measurement methods for PQ parameters, accuracy requirements and test methods are defined for PQ measurement instruments only. To fill this gap, the research project *Measurement methods and test procedures for assessing accuracy of Instrument Transformers for Power Quality Measurements* has been recently funded within the European Metrology Programme for Innovation and Research (EMPIR). It aims at developing a metrological framework that allows the traceable measurement of PQ parameters in distribution grids, when ITs are included in the measurement chain. Particular attention is focused on the development of reference measurement systems and the definition of test procedures, as well as on the quantification and classification of the performance of ITs under realistic conditions.

II. ACCURACY CLASS AND UNCERTAINTY LIMIT DEFINITION

Quantification of the IT performance is presently provided by their accuracy class, which gives the maximum limit ratio and phase errors associated with the measurement of AC voltage or current at rated power frequency. Limit errors for harmonic measurements only are provided in the relevant standards for electronic ITs, when used for metering or in PQ measurements. However, all the possible uncertainty contributions of the IT to the measurement, provided by the low voltage PQ measuring instrument, of a PQ parameter, have to be investigated.

Data for a structured knowledge and classification of IT behavior are missing. To this aim, suitable performance indexes for the IT error in the measurement of single PQ parameters will be proposed and experimentally validated. The concept of IT accuracy class will then be extended to PQ measurements, by

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defining a new overall performance index, capable to quantify the behavior of the IT when facing PQ disturbances.

The analysis will focus on distribution grids (rated voltages up to 36 kV, currents up to 2 kA, spectral components with frequency up to 9 kHz), considering the increasing PQ monitoring needs as well as the high number of installed voltage and current ITs. An experimental characterization of ITs (inductive, electronic, low power IT with analog or digital output) under different PQ phenomena will provide a basis for quantification of performance indexes and definition of PQ accuracy classes.

III. REFERENCE MEASURING SYSTEMS AND TEST PROCEDURES

Study and definition of ITs errors and uncertainty contributions in the PQ phenomena measurement require that suitable systems are developed, to enable the characterization of ITs with reference waveforms representative of the actual disturbances of PQ. Starting from knowledge gathered in past projects [2]-[5], existing laboratory set-ups will be modified, extended and integrated into reference systems for the traceable calibration of current and voltage ITs, under realistic PQ phenomena. They will allow characterization of different technologies of current and voltage ITs, from the still extensively used inductive ITs to the more recent generation of Low Power Instrument Transformers (LPIT) with analog or digital output.

As to the waveform generation and measurement capability, steady-state and time-varying PQ disturbances with frequency spectrum up to 9 kHz, will be considered. Target basic measurement uncertainty of IT ratio and phase errors are better than 0.005% and 0.005 crad respectively. For the measurement of PQ parameters, target uncertainties up to two orders of magnitude lower than the uncertainties prescribed for frequency characterization of electronic ITs and for PQ measurement instruments will be considered. Limit values within which voltage characteristics are expected to remain in medium voltage networks will also be taken into account. Characterization of ITs by the reference systems will provide the information needed for the evaluation of the PQ parameter performance indexes and of the PQ accuracy class as described in the previous section.

Starting from the reference facilities and from results of IT calibration under realistic perturbed waveforms, an architecture and procedures for traceable simplified calibration setups will be worked out, suitable for implementation in test laboratories. In particular, a simplified calibration system for stand-alone or embedded LPITs, will be developed, as well as a general use metrology grade comparator for comparing current ITs, voltage ITs or combined ITs in frequency and time domain, including non-stationary signals up to 9 kHz.

IV. IT PERFORMANCE UNDER COMBINED INFLUENCE FACTORS

Actual performance of ITs may be influenced by on-site factors (such as burden, temperature, magnetic and electric fields produced by adjacent phases, proximity effects). Attention is generally focused on the analysis of one parameter at the time, with main focus on the relatively new generation of LPITs. This aspect becomes a critical one, as there is no evidence that the influence effects can always be combined linearly. By suitably extending the developed reference set-ups, the IT behavior under PQ disturbances will be investigated and quantified under the presence of separate and combined influence factors. Considering the high number of influence quantities and their possible combinations, the analysis is limited to the characterization in presence of two at the time combined influence factors. Criteria for the significance of the effect of a combination of influence factors will be also identified.

VI. CONCLUSION

The outcome of the project, in terms of calibration reference set-ups, measurement methods and uncertainty evaluation procedures, as well as the study of ITs and LPITs performance under PQ disturbances, will allow covering of existing knowledge gaps and missing traceability. We expect that the project achievements will also significantly contribute to the issue of new or improved guides, recommendation and standards on the use of ITs in PQ measurements.

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