EVALUATION OF VOLTAGE TRANSFORMERS’ ACCURACY IN HARMONIC AND INTERHARMONIC MEASUREMENT

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1. INTRODUCTION

In modern energy systems, the evaluation of Power Quality (PQ) is a key task to assure the quality of the energy distribution and transmission. It is gaining more and more importance, due to the growing presence of switching power converters, as part of distributed generation systems as well as of non-linear loads. The PQ monitoring is traditionally carried out in Low Voltage (LV) grids. In recent years, due to the advance in the technology of switching devices, power converters can be directly connected also to Medium Voltage (MV) grids. These devices contribute to inject several types of PQ disturbances and in particular harmonic and interharmonic components, so making PQ measurements become a key task also in MV grids. The monitoring of PQ at MV levels can be only performed using suitable Voltage and Current Transformers (VTs and CTs) to scale voltage and current to suitable levels that can be acquired by a Power Quality Instrument (PQI) or, more in general, by a data acquisition system or a Stand Alone Merging Unit (SAMU) and then processed by a software implementing the PQ measurement algorithms. However, the relevant CT and VT standards do not deal with the case of their employment in PQ measurements. In this context, this paper aims at defining an integrated approach for evaluating the IT performances in the measurement of PQ phenomena. As a first step, this entails identifying: 1) relevant PQ phenomena for IT characterization as well as their range of variation; 2) the definition of a new time-variant synthesized test waveform that enables quick and efficient testing of ITs under single and multiple PQ disturbances; 3) the identification of possible performance indices (IT-PIs) for the quantification of IT errors in the measurement of specific PQ events; 4) finally, the design of a basic measurement setup that could be used for standardized IT performance assessment in PQ measurements.

2. PROPOSED METHOD, PIs AND SYNTHETIC TEST WAVEFORMS

The basic measurement setup is shown in Fig. 1. It consists of a waveform generator, able to generate arbitrary test waveforms at MV level, an IT under test (IT_{UT}), a linear reference device (Ref) and a comparator for the evaluation of the IT-PIs. The generation system should allow for generating tones at frequency f, in addition to the fundamental one, with amplitude A_f according to the curve provided in Fig. 2.

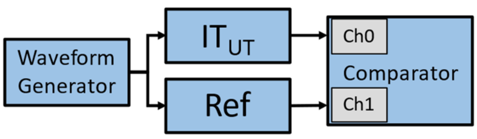

Figure 1. The basic measurement setup for the evaluation of harmonic and interharmonic performance indices.

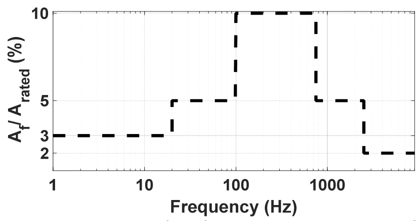

Figure 2. Amplitude generation capability versus frequency of a possible waveform generator for VT testing in presence of PQ phenomena.

The basic measurement time interval is chosen equal to 10 cycles (12 cycles) for a 50 Hz (60 Hz) power systems, in compliance with **Errore. L'origine riferimento non è stata trovata.**. Without loss of generality, but only for sake of simplicity and clarity, in the following reference will be made to a power system with a fixed frequency equal to 50 Hz. In this case, 10 cycles of the fundamental component will be always equal to 200 ms. The quantities to be

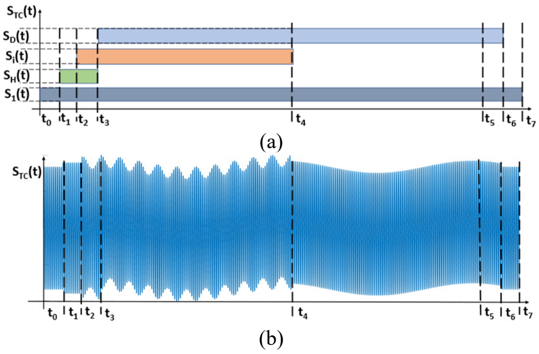

Figure 3. Time combined waveform: a) proposed waveform scheme and b) time domain numerically simulated signal with one harmonic H=2, one interharmonic I=55 Hz and one subharmonic D=0.5 Hz.

measured are the phasors of the voltage or current at both primary as well as secondary windings of the IT under test. These values can be obtained by performing a spectral analysis, f.i. with the Discrete Fourier Transform (DFT), provided that a coherent sampling is performed. Starting from these quantities, the IT errors can be quantified in terms of PIs at single harmonic or interharmonic tones, PIs in a delimited frequency range or PIs over the bandwidth from a few millihertz up to 9 kHz.

Since harmonics and interharmonics in power systems can have a dynamic behavior, in order to verify the measurement performance of ITs under actual working conditions, it can be necessary to verify the effects of combined events with a time variant waveform. An example of this kind of waveform is shown in Fig. 3.

3. MEASUREMENT RESULTS

The VT tested is an inductive resin insulated voltage transformer with 3 kV rated primary voltage, 30 V/V rated transformation ratio and 0.5 accuracy class. the generated test waveform is composed by:

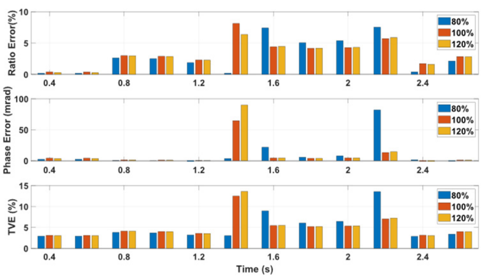

Figure 4. Ratio error, phase error and TVE at the second harmonic frequency versus time, with different values of the fundamental amplitudes.

1) the fundamental component $s_1(t)$ at 50 Hz; 2) the $s_H(t)$ harmonic components that, for sake of simplicity, include only the second harmonic; 3) the $s_I(t)$ interharmonic components with one tone at 55 Hz and 4) the $s_D(t)$ disturbances composed by one subharmonic at 0.5 Hz.

In Fig.2 we can see that the maximum values of the second harmonic ratio error, phase error and TVE, at 0.4 s and 0.6 s, are equal to about, respectively, 0.4 %, 4 mrad and 3.5 %. Therefore, the VT accuracy at second harmonic is not influenced by the presence of the interharmonic at 55 Hz. On the contrary, the PI values change dramatically, when the subharmonic at 0.5 Hz applies, i.e. starting from 0.8 s. The maximum variations are equal to about 7.7 %, 90 mrad and 10.7 %, respectively for ratio error, phase error and TVE. Differently from the case of fundamental frequency, here the variations are much higher than the limits of the 0.5 accuracy class.

4. CONCLUSIONS

This paper has proposed possible performance indices, test procedure and synthetic waveforms that could be employed for the accuracy evaluation of ITs used for harmonic and interharmonic measurements. A commercial MV VT has been tested by using the proposed approach. Experimental results show that the accuracy of the VT in the measurement of a specific PQ phenomenon is dependent on the presence of other PQ phenomena.

RIFERIMENTI BIBLIOGRAFICI

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