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Rogowski coil current transducer compensation method for harmonic active power error

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ABSTRACT

In the harmonic active power measurement, the highest uncertainties are generally introduced by the current and voltage transducers. In a previous paper, the authors showed that the current transformer (CT) can introduce significant errors in such measurement, especially if the phase shift between voltage and current is close to ±90°. In such condition the errors on harmonic power measurement are mainly due to the CT phase displacement. This paper shows that better results can be achieved with more linear transducers, such as the Rogowski coil current transducers (RCCTs), whose metrological performance in distorted condition can be improved, by means of a proper compensation method. The proposed method for RCCTs compensation is based on the frequency response and it allows to reduce the errors on harmonic power measurement, also for phase shift close to ±90°. The study is supported by several experimental tests.

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1. Introduction

The increasing massive impact of power electronics and renewable energy sources is the cause of the progressive deterioration of the energy quality in power systems. A distributed monitoring of energy and power quality parameters is an essential requirement for the modern smart grid networks and also the metrological characterization of instruments for energy and power quality measurements is a very important issue [1–7].

In this framework, one of the most significant elements is the influence of current and voltage transducers on the measurement of the aforesaid quantities. Currently many types of current transducers are used for power and energy measurements: shunts, current transformers (CTs), hall-effect current transducers and Rogowski coil current transducers (RCCTs). Some of them are included in the PCB boards of the energy meters [8]; others can be clamped on the line and their output can be connected to the instrument. In [9] a broad review is made, concerning their metering principle and the advantages and/or drawbacks of their employment. In many cases, transducers introduce one of the largest contributions to the measurement uncertainty [10–12]. For example, in literature a particular attention has been devoted to the transducers influence in power quality measurement [13–21]. The starting point of these studies is the definition of an appropriate characterization procedure for the evaluation of transducers performances. As regards this, the standards on electronic current transformers, IEC 60044-8 [22], and on power quality instrumentation, IEC 61000-4-30 [23], suggest to use the frequency response to characterize the current transducers performance under distorted conditions. Thus some manufacturers [24] include the frequency response among the technical specifications of their current transducers. In previous papers the authors studied the reliability of the frequency response for the evaluation of the transducers

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performance in distorted conditions. The study was carried out by measuring the ratio error and phase displacement of each harmonic component in the presence of nonsinusoidal signals. This approach was applied to characterize different types of current transducers [17–21]. It was concluded that the characterization based on the frequency response is a reliable approach only for linear transducers, such as Hall effect [19] and RCCTs [20]. For such transducers a correction of their measuring performance can be implemented by using the frequency response. On the contrary, in [17] it was shown that for non linear transducers, such as the CTs, the frequency response is not adequate for their characterization and correction in distorted condition.

In this paper the attention is focused on how the influence of the RCCTs on the measurement of the harmonic active power can be reduced. Harmonic active power is a significant parameter for many applications, such as power quality monitoring or harmonic sources detection [25–29]. A RCCTs compensation method is proposed, which is based on the frequency response characterization; such compensation allows to reduce the uncertainty on the harmonic active power measurement. The paper is organized as follows. Section 2 describes the proposed compensation method for the harmonic active power error in the case of RCCTs. Section 3 is devoted to the experimental tests. The measurement test bench is described, with a particular attention to the accuracy of the reference system used for the characterization of the transducers under test. The experimental characterization of two RCCTs is carried out and their influence is evaluated on the harmonic active power measurement, before and after the RCCTs error correction.

2. RCCT Compensation method in distorted condition of harmonic active power error

The errors introduced by the RCCTs in the measurement of the harmonic active power can be expressed as follows [21,30]:

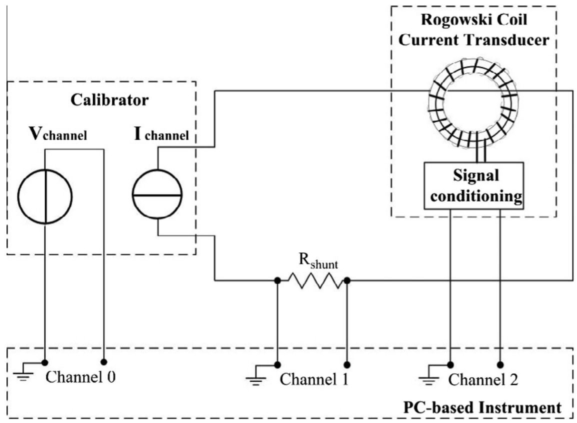

Fig. 2. Test bench used to measure $E_{Ph}\%$, $e_h\%$ and ε_h.

$$E_{Ph}\% = \frac{P_{sh} - P_{ph}}{P_{ph}} \cdot 100 \approx e_h\% + 100\varepsilon_h \tan(\theta_h) \quad (1)$$

$$E_{Ph\_FS}\% = \frac{P_{sh} - P_{ph}}{V_h I_{ph}} \cdot 100 \approx e_h\% \cos(\theta_h) + 100\varepsilon_h \sin(\theta_h) \quad (2)$$

where V_h is the h-order harmonic voltage rms value and I_{ph} is the rms values of the h-order harmonic components of the primary current, θ_h is the phase shift between the h-order harmonic voltage and current, ε_h is the h-order harmonic phase displacement (expressed in radians), $e_h\%$ is h-order harmonic ratio error, and P_{ph} and P_{sh} are the primary and secondary h-order harmonic active powers [31], respectively.

It should be noted that in Eqs. (1) and (2) the denominators are the harmonic active power and the harmonic apparent power, respectively.

The errors introduced by the RCCTs on the harmonic power ($E_{ph}\%$ and $E_{ph\_FS}\%$) can be reduced by compensating the harmonic ratio errors and phase displacements ($e_h\%$ and ε_h).

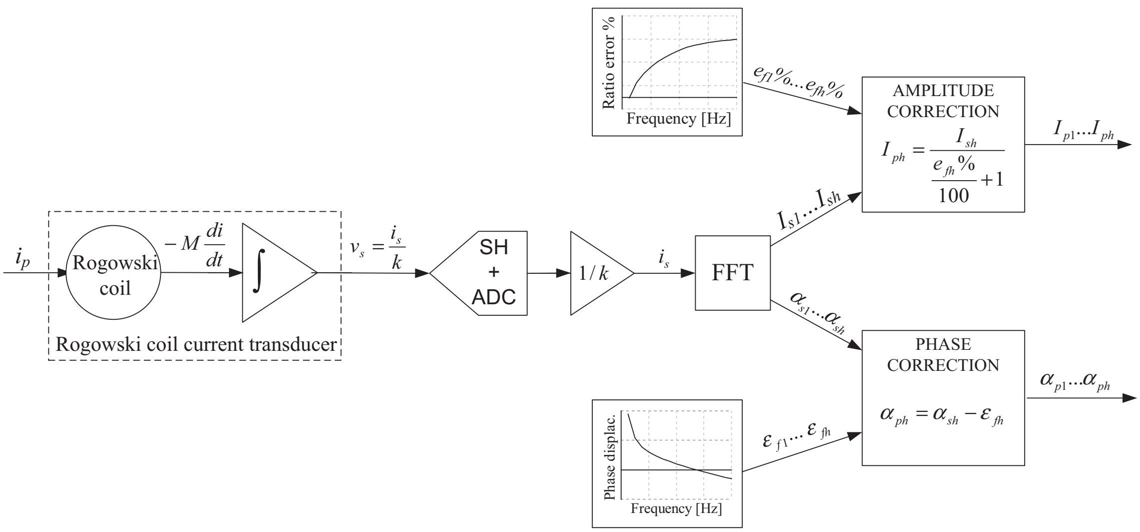

Fig. 1. Flow chart of the correction method.

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