An Automatic System for Current Transformer Test Set Calibrations

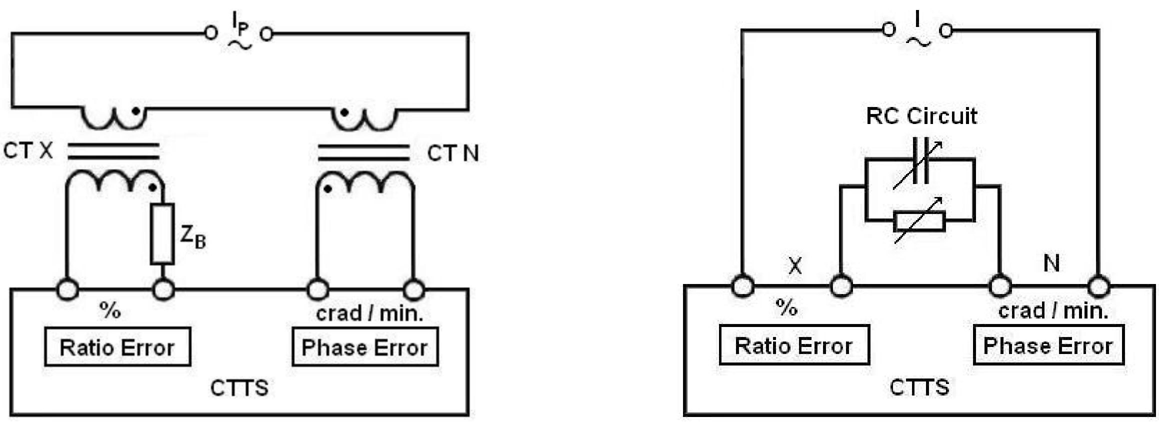
Hüseyin Çaycı

National Metrology Institute of Turkey, TUBITAK UME, P.O.Box:54, 41470, Gebze, Kocaeli, Turkey, phone: +90 262 6795000, fax: +90 262 6795001, e-mail: huseyin.cayci@ume.tubitak.gov.tr

***Abstract*-**A practical method with high accuracy in generation and application of error values for calibration of current transformer test sets is described. A PC-controlled three-phase power source with a standard wattmeter is used for generating the nominal and error test currents while an electronically compensated current comparator is used to provide summation and subtraction of them, precisely. With this method, any ratio error and phase displacement value could be generated automatically and nominal and test currents could be grounded on the test set safely. Because of its high accurate ratio and phase error generating capability, any type of test set regardless of its operating principles could be calibrated.

I. Introduction

Calibration of an instrument current transformer (CT) is commonly performed by comparison with a reference current transformer by using a current transformer test set (CTTS). Basically, ratio error (ε) and phase displacement (δ) of a CT against a reference CT with the same ratio is determined by direct comparison of their secondary. Since, the reference CT is assumed to be ideal and error-free, a CTTS directly gives ratio and phase differences of two secondary currents as in-phase and quadrature errors of the tested CT (Figure 1a).



(a) (b)

Figure 1. (a) Basic CT calibration circuit with CTTS, (b) Calibration of a CTTS with R-C circuit application

Since the traceability of CT calibrations is directly dependent on the CTTS, several direct and indirect methods have been developed for their calibrations. Measuring individual components of a CTTS or inserting an R-C circuit between two input terminals of a CTTS (Figure 1b) are common methods for the calibration of electromechanical CTTSs. However, these methods are not applicable for some CTTSs particularly for those having electronic circuits instead of passive components.

However, a calibration system [1] based on the generation of error values would be suitable for any type of CTTS. In this paper, a relatively practical and high accurate calibration setup is discussed.

II. Theory of Operation

A. Generation of calibration values

Two isolated current signals with known ratio and phase differences are first generated by a three-phase power source and a wattmeter. A current signal which is used for simulating the secondary current of a reference CT, is generated by first phase of the PC-controlled power (current) source and applied both to N input of the CTTS and to the ECCC as main primary current. An in-phase current signal which differs from reference signal with 0º or 180º is generated by the second phase of the source and applied to one of the auxiliary windings of the ECCC. Finally, a quadrature-phase current signal which differs from reference signal with +90º or -90º is generated by the third phase of the source and applied to the second auxiliary winding of the ECCC. The secondary winding which has the same number of turns with primary winding will then induce a complex total of the primary and two auxiliary currents proportional to their number of turns.

The ECCC has a full isolation between the primary and secondary since it is necessary to ground the N and X current signals on the CTTS, safely. Any error desired for a CTTS calibration can be obtained with the combination of PC-controlled three-phase power source and ECCC.

B. Electronically-compensated current comparator

The compensated current comparator is a well-known high accurate ratio standard [2]. Construction of a hollow toroid core prevents almost all external unwanted electromagnetic fields to reach the detector core so that the detector can sense the unbalanced currents almost without error. Because of this physical advantage, current comparator based ratio standards have been used in a wide application range.

Several techniques have been developed to achieve error-free current transformations. Recently, the introduction of electronic circuitry is preferred because of its simplicity and success in compensation. Use of electronic circuitry within the current comparator structure showed that one could design a current transformer with errors not more than few ppm [3].

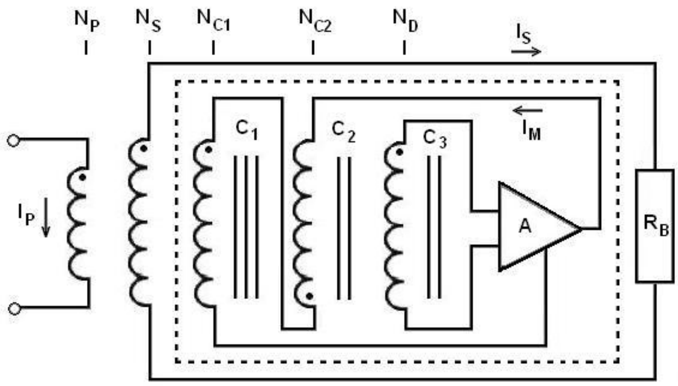


Figure 2. Electronically-compensated current comparator

A special electronically-compensated current comparator (Figure 2) has been developed to use in CTTS calibration system [4]. Similar to others, it has a detector core C_3, a detection winding N_D, a hollow toroid core C_3 surrounding the detector core, a primary winding N_P and a secondary winding N_S. Then, two additional windings N_{C1}, N_{C2} with the same number of windings are wound to inside and outside of the hollow toroid core, and connected each other in series but inversely. Their number of windings should be the same with secondary winding as well. Here, C_2 represents a thick magnetic shield surrounding the detector core and winding. The dashed line shown in the figure represents a thick copper shield to prevent N_{C1} from the stray fields of primary and secondary currents.

The electronic circuitry is designed as a transconductance amplifier which amplifies the voltage obtained from the detector winding and converts it into a current. And, it forces this current to the inner and outer compensation windings not only for compensating the secondary current but also for zeroing the detection voltage, automatically.

III. Performance and verification

The errors and linearity of the ECCC was measured in unity ratio mode and with a maximum burden of 0.5Ω. First, a commercial CTTS, with the ratio error and phase displacement measurement resolution of 1ppm, was used. However, because of its instability below the currents of 0.5A, an auxiliary CCC based detector was used. The sensitivity of auxiliary detector is ten times more than the detector of ECCC and it gives more stable results than the commercial CTTS in lower excitation currents. The measurement results from both CTTS and auxiliary CCC, at currents between 1% and 200% of nominal current 5A, are given in Table 1.

Table 1. Calibration results of ECCC in 1:1 ratio.

<table>
<tr><th rowspan="2">Applied Current</th><th colspan="3">Measured Relative Error
Burden 0.5 Ω</th></tr>
<tr><th colspan="2">with CTTS</th><th>with CCC Detector</th></tr>
<tr><th>I_P</th><th>Ratio error</th><th>Phase displacement</th><th>Composite error</th></tr>
<tr><td>10 A</td><td rowspan="8">ε ≤ -1 ppm</td><td rowspan="8">δ ≤ 2 µrad</td><td>1.3 ppm</td></tr>
<tr><td>5 A</td><td>1.4 ppm</td></tr>
<tr><td>2 A</td><td>1.7 ppm</td></tr>
<tr><td>1 A</td><td>1.6 ppm</td></tr>
<tr><td>0.5 A</td><td>1.6 ppm</td></tr>
<tr><td>0.2 A</td><td>1.6 ppm</td></tr>
<tr><td>0.1 A</td><td>1.2 ppm</td></tr>
<tr><td>0.05 A</td><td>0.5 ppm</td></tr>
</table>

Further tests on the ECCC showed that the errors given in the table are inherent errors of the ECCC. And, these inherent errors are almost phase errors which arise because of capacitive interactions between the primary, secondary and outer compensation windings.

Several additional tests have been performed not only to check self performance of the ECCC but also for verification of the calibration system including the three-phase current source and the ECCC.

Electronically-compensated current comparator has 200 turns (T) primary and secondary windings in 1:1 ratio configuration. An additional 1T to the primary or secondary windings will mean ±0.5% ratio difference between primary and secondary currents. However, ratio errors obtained with an additional winding on primary side can be compensated perfectly with the same configuration on the secondary, or vice versa. Additional or inverse windings up to 10T on the primary and secondary showed no significant additional error from 1% up to 200% of nominal current.

Then, such ratio errors obtained with the primary or secondary winding configurations were tried to be compensated with auxiliary windings and appropriate currents applied from second phase of the current source. Since, the basic amplitude accuracy of the source together with the reference wattmeter is below 100 ppm, a 1T compensation results with a negligible error (less than 1 ppm). Appropriate tests with different winding configurations result with errors not more than 5 ppm.

Similar tests were performed by using two auxiliary windings and ignoring any additional primary or secondary winding. Any ratio error generated by a current from the second phase of the current source and by using one of the auxiliary windings was compensated successfully, with currents applied from the third phase to the other auxiliary winding.

Finally, similar tests were performed for the verification of the system in generating the phase displacements. Since the phase accuracy of each phase is not worse than 100µrad (0.005º), the final errors will also be very low. Both ratio and phase related test results showed a good agreement with the theoretical considerations.

IV. Conclusion

An automatic calibration system for current transformer test sets has been described. With this method, any ratio error and phase displacement value could be generated automatically and nominal and test currents could be grounded on the test set, safely. Because of its high accurate ratio and phase error generating capability, any type of test set regardless of its operating principles could be calibrated. It is obviously seen that the errors in generating the desired values will never affect the overall uncertainty of the calibration system more than 5 ppm and 5 µrad for ratio and phase error measurements, respectively. The overall accuracy of the system is not more than 10 ppm independent of the measured ratio and phase error values including dividers.

Acknowledgement

The assistance of Power & Energy Laboratory stuff in the construction of the CCC, in the design and the adoption of electronic circuit, and in the testing of the ECCC is greatly appreciated.

References

[1] G. Ramm, G. Roeissle, H. G. Latzel, “Rechnergesteuerte kalibrierung von messeinrichtungen für strom- und spannungswandler”, PTB-Mitteilungen 108, pp. 188-200, 1998.
[2] W. J. M. Moore and P. N. Miljanic, “The current comparator”, Inst. Elec. Eng. Electrical Measurement Series, vol. 4, London, UK: Peter Peregrinus, 1988.
[3] P. N. Miljanic, Eddy So and W. J. M. Moore, “An electronically enhanced magnetic core for current transformers”, IEEE Trans. Instrum. Meas., vol. 40, no. 2, April 1991.
[4] Hüseyin Çaycı, “Electronically compensated current comparator”, TUBITAK UME Technical Report (in Turkish), 2010.