A new Current Calibration Laboratory for Rogowski Coil used in Energy Systems and Power Electronics

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Abstract-- **During the last decade the use of the well known Rogowski Coil (RC) sensor gain a wide spread due to its many applications in testing laboratories, industrial measuring instruments, power electronics and unconventional measuring systems used in energy transport networks.**

These sensors have been rendered valuable due both to the special dynamic properties, lack of saturation etc. and to the important progresses made in the acquisition and processing systems of the experimental data.

The drawing up of the first IEC standard referring to high current measurement (IEC 62475) where the metrological properties of the shunts and are stated both in permanent and in transient duty are proofs of the progresses in this domain.

After a short review of the main RC types, their operating duties, specific testing installations and measurement uncertainty are analysed.

At the same time as the accreditation of the High Current Calibration Laboratory granted by DKD (German Calibration Service) in 2008, there are placed at disposal the own standards with traceability to the international standards and certain RC specific tests described in this paper could be added to the tests already evaluated within the usual frame of accreditation extension.

Index Terms—**High Current measurements, Rogowski Coils, Shunts, Accredited Calibration, Traceability**

I. INTRODUCTION

The High Power Laboratory from ICMET Craiova is one of the most important independent laboratories of this kind from Europe.

In is intended to testing the high voltage equipments mounted in the transformer stations and on the high voltage lines that should be capable to connect and interrupt the currents specific to some normal and short circuit duties having values of hundreds of kV respectively tens of kA.

The product standards shall be thoroughly observed form the viewpoint of the testing voltage and current parameters.

Such a laboratory credibility to its customers is got by accreditation according to [1], the main standard defining the competence of testing and calibration laboratories and by active participation in the works of professional organisation STL (Short-Circuit Testing Liaison) [2]. In this case, the High Power Laboratory has double accreditation: RENAR – Romania and DATech – Germany as testing laboratory.

The quality assurance system imposes periodical calibration of the voltage and current measuring instruments used in the laboratory.

Four years ago, it began the achievement of a calibration laboratory for high current measuring devices (shunts and RCs) that succeeded at the end of 2008 due to accreditation DKD [3] according to [4].

It is easy to understand that such calibration laboratories shall use the current/ voltage sources already existing in the testing laboratories, which represent huge investments.

If not long ago, the shunt represented the main measuring mean irrespective of the measured current (DC, AC, transient, impulse), things have completely changed: the shunt was replaced by the RC, a device that has been known for 100 years but the advantages of which could be exploited only at present by the unprecedented development of microelectronics.

But this is not all, even the market position of the inductive current transformers is threatened by the RC that, due to some constructive improvements and to including it in hybrid systems based on fiber optics transmission of signals from high potential, lead to the appearance of current electronic transformers the parameters of which are standardized at present [5] both for metering and for protection.

The paper presents the test installations and calibration methods in steady state and transient duty including the additional tests which to allow the development of electronic current transformers with optical transmission (framing in accuracy class) and also measurement uncertainty determination.

II. ABOUT ROGOWSKI COIL

RC represents an uniformly distributed winding going round the conductor through which the current is passing, its output signal being proportional with the time variation of the current (di/dt).

In comparison with the classical shunt, RC has the advantage of not having any grounded point and therefore the common mode disturbances superposing the measured signal

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are avoided.

In exchange, it can measure only the time variable currents.

As compared to the current transformer, RC has the advantage of having an intrinsic linearity (no ferromagnetic core) and therefore its amplitude dynamic domain is at least 3-4 decades and the frequency band is ranged within about 0.2Hz and a few tens of MHz.

From the constructive viewpoint, RC can be achieved in the form of a flexible belt or a rigid one. The rigid RCs have a measurement accuracy higher than the flexible ones that have the advantage of mounting capability round any bar passed by current without disconnecting it.

RCs may have two operating duties:

- Rogowski duty (winding closed on a high impedance) when the output signal is proportional with di/dt. In order to get the current, a passive integrator (either passive, active or numerical) is used;
- Current transformer duty (winding included on a low value resistor so that to achieve a RL type passive integrator). In this case the output signal is proportional with the measured current (from a critical frequency upwards).

As regarding the measurement uncertainties of RCs, it has a typical value of 1% being possible to reach 0.1% at special designs [6].

III. Accredited tests for shunts and RCs

The High Current Calibration Laboratory from ICMET is accredited on the basis of some technical procedures specific to the following tests [3,4,7]:

- *Scale factor determination*

The scale factor is the ratio of the value measured by the reference standard of the laboratory to the value measured with the device to be calibrated. The measurement uncertainty of the scale factor is obtained by statistical processing [8].

The scale factor is determined with symmetrical AC current 50 Hz for currents from 100A to 60 kA_{RMS} and duration of maximum 10 periods (200ms).

The shortcircuit generators and transformers from the high power testing laboratory are used as sources.

The records are made with a numeric multichannel Transient recorder with 10bits resolution and 10 MS/s sampling rate.

The best measurement capability for this test is 2% including the measurement uncertainty of the transient recorder and of the reference shunt. According to [8] it expresses the expanded uncertainty of measurement with a coverage factor of k=2.

- *Measurement device linearity determination*

According to [4], 50Hz asymmetrical currents with RMS values of 20, 40, 60, 80 and 100% of the rated current of the device to be calibrated and a K factor 2,5...2,8 for the peak value namely currents between 250 A and 150kA peak are applied to the testing circuit where the laboratory reference standard is placed in series with the device to be calibrated. The current duration is maximum 6 periods (120ms).

Results evaluation is made taking into account the value of the first peak of each current with a view to providing an extension of the previously determined scale factor up to the peak value of the asymmetrical current.

Linearity determination is a good opportunity to check RCs behaviour from the viewpoint of reproducing the lower limit frequency contained in the asymmetrical signal (fig. 1). In the present case, RC is capable to reproduce a frequency of 2,1Hz.

RC placed in a fixed position has a very good linearity in a wide range of currents and may be considered an ideal measuring device for such tests provided that to avoid the proximity of some massive ferromagnetic pieces.

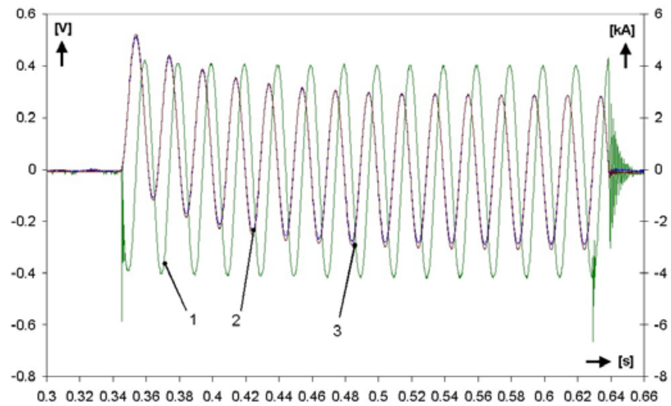

Fig. 1 Comparative measurements in transient duty
1 –RC output voltage 2 – shunt measured current ; 3 – RC output voltage integral . Aperiodic component - 2,1 Hz

- *Determination of the response to current step signal*

To this end it is used a suitable current step generator and a current impulse with an amplitude of 200A and rise time below 20ns. Though the generator works by discharging a capacitor and consequently does not generate a rectangular impulse [14], the solution is applicable for the shunt case. Fig.2 presents the response to current step impulse for a 2kA coaxial shunt. The measured response time is 37 ns namely a frequency band of about 10MHz. This shunt is the reference standard of the laboratory but most shunts used as working standards have a frequency band of about 10 kHz.

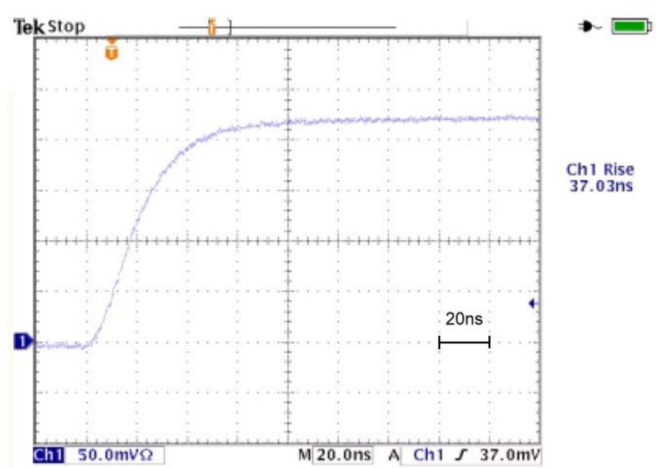

Fig. 2. 2kA coaxial shunt step response.

The best measurement capability is here 2,5% for a response time within 24ns and 1000ns.

In exchange, the use of the current step to determine the response of common RCs type is not efficient due to the operating principle (di/dt measurement). That is why, the next paragraph will present a frequency domain method the result of which is easier to evaluate.

- *DC current resistance determination*

Is used only to evaluate the shunts; the best measurement capability for them is 0,5%.

In order that the above presented accredited calibrations to be recognised worldwide, the traceability of laboratory reference standards shall be ensured.

The traceability diagram of ICMET calibration laboratory is presented in fig. 3.

It shows how the laboratory reference measuring systems are related to the reference measuring systems recognised at European/ worldwide level.

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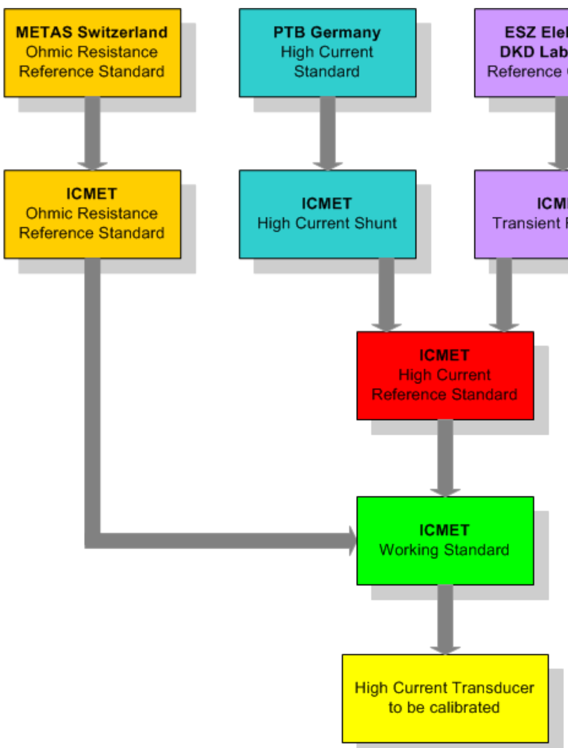

Fig. 3 Traceability chart for current reference devices

IV. RCs Calibration at Variable Frequency Currents

In order to study RCs dynamic behaviour, a high current generation equipment was achieved on the basis of the principle diagram from fig.4.

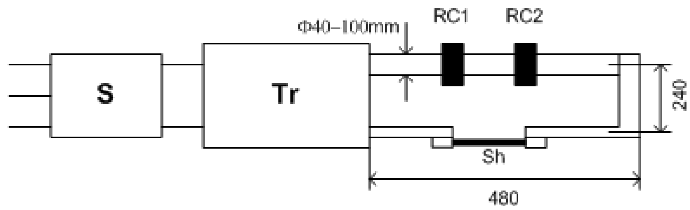

Fig. 4 Equipment for variable frequency high current generation; S–power electronic source, 4kVA, 50Hz-10kHz; Tr-step-up transformer with variable ratio, max 5kA, 4kVA; RC1, RC2 – RC standard respectively RC to calibrate; Sh- standard shunt (high current circuit dimensions in mm)

The installation uses a precision variable-frequency voltage electronic source free of HF disturbances. The output voltage may have a sinusoidal or programmable shape so that to be used also to calibrate the RCs used in power electronics. In the case of the sinusoidal input voltage, RC intrinsic conversion factor named sometimes [9] RC (K_{RC}) can be determined. It results from the ratio between the voltage induced in RC, U_i and applied current I namely if:

$$U_i = j\omega MI \qquad (1)$$

then

$$K_{RC} = \left|\frac{U_i}{I}\right| = \omega M = f(\omega) \qquad [\text{V/A}] \qquad (2)$$

This conversion factor is obviously different from the global conversion factor of an RC followed by integrator (K_{gRC}) which theoretically is constant in the approved frequency domain.

The source supplies a special step-up current transformer (Tr) so that to enable operation in a wide frequency range. There are created conditions to achieve the shortest connections for standard and test object mounting, as it can be seen in fig.5.

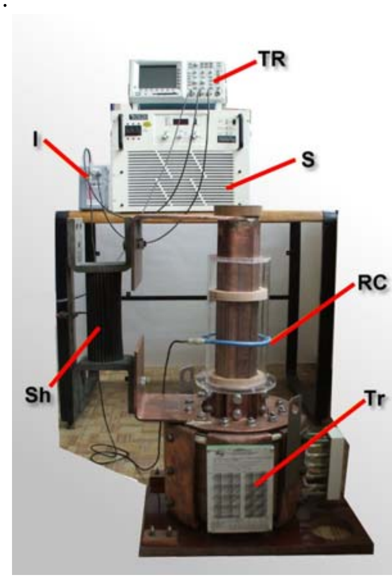

Fig. 5. Photo of the equipment of Fig.4. S–power electronic source 4kVA, 50Hz-10kHz; Tr- step-up current transformer with variable ratio, max 5kA, 4kVA; RC1, RC2 – standard RC respectively RC to calibrate; Sh- standard shunt; I – electronic integrator ; TR-transient-recorder/ digital oscilloscope.

The main technical characteristics of the Tr transformer are given in Table 1.

TABLE 1
MAIN PARAMETERS OF HIGH CURRENT STEP-UP TRANSFORMER

Primary winding (number of turns)	25			50			100		
Secondary winding (number of turns)	1	3	6	1	3	6	1	3	6
Transformer ratio	25	8,33	4,1	50	16,6	8,33	100	33,3	16,66
Primary DC resistance (mΩ)	6,6			26,57			106,2		
Secondary DC resistance (mΩ)	0,05	0,12	0,33	0,05	0,12	0,33	0,05	0,12	0,33
Shortcircuit impedance at 50Hz (mΩ)	85,7	15,6	2,85	342	61,6	36	1362	249	147

With a view to reducing the skin effect, the primary winding is achieved from multiple conductors, is uniformly distributed on a toroidal ferromagnetic core and consists of four sections having 25 turns each that can be connected in series, parallel or series-parallel.

The secondary winding of plate copper bar consists of 6 turns that can be connected in series, parallel or series-parallel as the primary one.

Irrespective of the connection type, the secondary winding is also uniformly distributed over the primary winding under the form of a cage so that the leakage (shortcircuit) reactance to have minimal values and in the same time, minimum disturbing influence on RC output signal

Usually, the use of a step-up current transformer is justified only at a 50 Hz frequency [10,11] because at the same time as the frequency increases the shortcircuit internal impedance also increases and limits the secondary current value.

To avoid this important disadvantage, this transformer with several windings in primary and secondary was achieved.

Simple calculations show that, in this case, optimum connection diagrams can be achieved maintaining the primary absorbed power within acceptable limits at supply frequency variation.

So, the achieved transformer has the following optimal connections:

- at 50Hz transformer ratio 100: 1
- at 1kHz transformer ratio 100:6 or 50:3
- at 10kHz transformer ratio 50:3 or 25:3

In these conditions, only 4 times instead of 20 times current decrease versus frequency was obtained between 50Hz and 1kHz; only 4.5 times instead of 10 times decrease was obtained between 1 kHz and 10 kHz and only 16 times instead 200 times decrease was obtained between 50Hz and 10kHz.

The utility of a dynamic test domain wider than the one indicated by [4]:

$$f_{max} = 7f_N = 350\text{Hz}$$

for electric power equipments is related to the RC used in power electronics and for electric power quality measurement.

The test set-up enables the achievement of several calibration methods:

1. Calibration with respect to a standard shunt
2. Calibration with respect to the second standard RC located on the insulating tube.
3. Determination of RC insertion impedance.

An example for case 1 is given in fig. 6. In this case, for a current of 1kA, the current through the standard shunt (1), voltage across RC (2) and integrated voltage (3) were recorded at a frequency of 5 kHz.

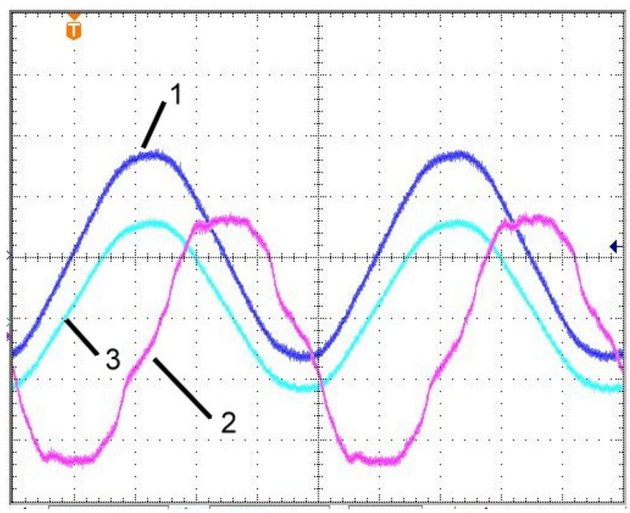

Fig. 6. RC calibration with respect to a standard shunt at a frequency of 5kHz (explanations in text).

The K_{RC} measurement uncertainty varies between 1,5 and 3% in the frequency range 50Hz-5kHz.

V. PROXIMITY AND INTERFERENCE EFFECTS DETERMINATION

The proximity effect is generated by the current busbars placed in the vicinity of the measuring system.

The proximity effect is evaluated by the ratio between the signal indicated by RC (not passed by current) and the normal current through the adjacent busbar located at a distance of 1 m [4].

It is accepted that this ratio not to exceed 1%.

The interference effect has in view to provide a high immunity of the measuring system with respect to the conducted and radiated electromagnetic fields in the working conditions of the test set-up.

The test is performed with the RC connected to the measuring circuit but with the signal cable shortcircuited and grounded.

The ratio between the amplitude of the interference signal measured by the system in this situation and the amplitude of signal measured in normal operation conditions is defined as interference ratio and it has also to be smaller than 1%.

Both the proximity and interference effects have contributions to the combined uncertainty of the measuring system To be noticed that in practice the shunts generates an interference effect greater than the RCs due to the common mode disturbances generated by grounding loop while at the proximity effect the situation is reversed.

VI. RCs Calibration for Current Impulse Measurement

Current impulse parameter measurement has a special importance in many applications from: power electronics [12,13], LI and SI measuring and protection circuits [14,15], dielectric test circuits for the measurement of partial discharges, leakage currents and Corona effect [16].

The amplitude and duration of these current impulses is very different: from hundreds of kAs to mAs and from hundreds µs to ns. It is possible to build an adequate RC for any other application of this kind. The IEC standard [4] has in view this situation and defines the time and amplitude parameters for the testing current impulses.

So, for 8/20µs current impulses (Lightning Current impulse) and 1,2/50µs (Lightning Voltage Impulse) there are allowed tolerances, respectively combined measurement uncertainties of ±20% (10%) at the time parameters (rise time/ time to half-value) and of ±10% (3%) at the peak values.

The calibration procedure used in ICMET is based on the comparison with a standard shunt or a high frequency current transformer (HFCT). The time and amplitude parameters comparison is made on the basis of the output signal obtained from the integrator associated by the manufacturer to the RC to be calibrated. Fig. 7 presents the signal shapes that were on the basis of tolerances and measurement uncertainties determination at a miniature RC (loop diameter 24 mm) when applying an impulse 8/20µs of 1,15kA generated by EMC 2004 generator manufactured by HiloTest. C1 is the current given by the generator measured with a standard shunt with f_{lim} >10MHz, C2 is RC output voltage, C3 is the current measured by HFCT (Current Monitor ION Physics Corp tip CM-1-L) and C4 is the integrated C2 signal.

To be noticed RC sensitivity at the transient phenomena accompanying the current impulse generation: in areas 1 and 2 specified on the oscillogram it is to notice the parasitic commutations, when the generator static switch gets in and out of conduction, that can be sensed only by the standard shunt to a certain extent. Both the current monitor and RC smooth these distortions without affecting the global shape of the current impulse.

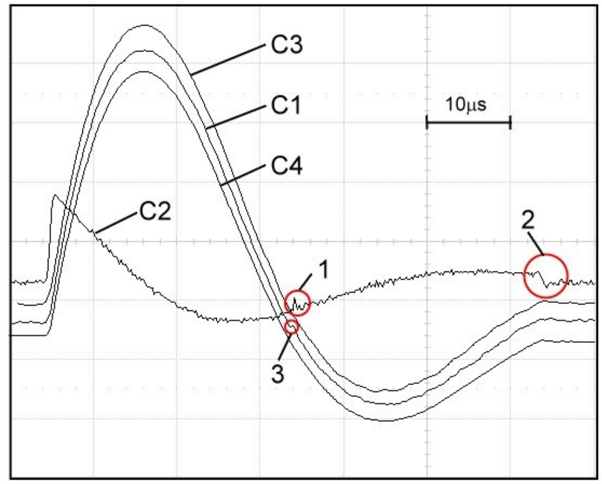

Fig. 7 Oscillogram of a current impulse 8/20µs, 1,15kA obtained when calibrating an RC with integrator (explanations in text)
C1 – i(t), shunt, 0,5V/div; C2 – di/dt, RC 10V/div; C3 – i(t), HFCT, 0,5V/div; C4 - i(t), RC, 0,5V/div. Record with LeCroy Wawe Runner type204Xi sampling rate 5MS/s

The performed experiments lead to the following results for i(t) related to the standard shunt:

- The time parameters/ combined uncertainty 6,741 µs/5,5% for the rise time respectively 18,586 µs/7,5% for the time to half-value;
- The amplitude/ combined uncertainty parameters 1134A/2,5% for the positive oscillation respectively 340A/2,8%.

Fig.8 presents another RC with a loop diameter of 60mm subjected to a unipolar current type 1,2/50µs with an amplitude of about 40A obtained by discharging a voltage impulse with an amplitude of 3kV on a non-inductive resistor.

C1 is the applied voltage impulse measured with a voltage divider, C2 is RC output voltage and C3 is integrated C2 signal.

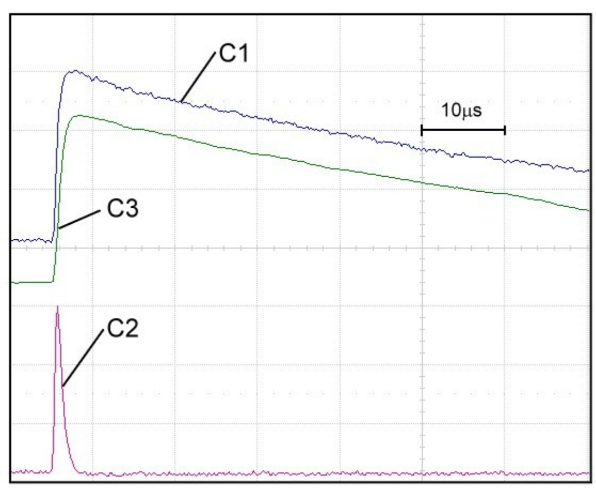

Fig.8 Oscillogram of a current impulse type 1,2/50µs obtained by discharging a voltage impulse 1,2/50µs on a non-inductive resistor of about 75 Ω (explanations in text) C1 – applied impulse u(t), 1kV/div; C2 – di/dt, RC, 0,25V/div; C3 – i(t), RC, 15A/div

The accuracy of current impulse reproduction draws attention on the possibility to use RC to measure some low amplitude short current impulses (below 100A).

VII. Metrologic Performances of Electronic Current transformers using RC as primary Sensor

IEC standard[5] creates the general frame by which an electronic current transformer may be used for metering and protection in an electric power transport and distribution network.

In [17] it is presented an equipment for measurement accuracy checking at inductive current transformers used in electric power stations after a long operation time. For accuracy class checking it is used a RC primary sensor with performances higher than class 0,1 that is constituent part of the device for numerical transmission of information from high potential by fiber optic. Power energy supply of the remote module is performed also by fiber optic within the frame of an optical power data link.

We aim at checking the extent to which a RC with a special design may obtain the requested performances (time stability performances imposed by [5] for class 0,2).

Due to the constructive measures the supplier of this primary sensor provided at least the following conditions: RC centring on the current busbar, non-magnetic winding core that is not sensitive to temperature variations, electromagnetic shielding that is effective for 50Hz electric and magnetic fields, immunity to HF conducted and radiated disturbances etc.

Phase and amplitude error determination was made with a instrument transformer measuring system type MIT300 manufactured by Mtronix/Omicron traceable to PTB standard. The device is capable to check inductive or electronic voltage and current transformers and has the following performances:

- Phase measurement uncertainty 1.10^{-5} for phase variation range 5.10^{-5} ...∞;
- Transformer ratio measurement uncertainty 0,002%
- Frequency measurement uncertainty 2ppm.

The following quantities are displayed during the measuring process:

- $\mathbf{I_m}$(%) current in percentages from the rated value of the test current sensor;
- $\mathbf{F_i}$(%) ratio error between the standard current transformer and test object
- **PhaseDiff**(min) phase error with its sign
- **Frequency** (Hz) supply source frequency
- $\mathbf{I_{refRMS}}$(A) effective value of standard current transformer indication.

The preliminary tests were performed on an RC with the rated current I_N=400A at 5, 20, 100 respectively 120I_N.

The measurement errors compared with the values imposed in paragraph 8.9.2 "Basic Accuracy Test" and paragraph 12.1 "Measurement Errors" of [5] at an ambient temperature of 20±3°C are presented in Table 2.

Table 2 Imposed Errors (Class 0,2) And Respectively Measured Errors According To [5] At An RC With I_N =400A

Errors % I_N	5	20	100	120
Imposed ratio [%]	0.75	0.35	0.2	0.2
Measured ratio [%]	-1.05	-0.39	0.21	0.2
Imposed phase [min]	30	15	10	10
Measured phase [min]	-45	-25	-12	-6

It can be noticed that RC lays just on the line in class 0,2 at I_N and 1,2 I_N both for ratio and phase; in exchange, there are great deviations at 0,05 and 0,2 I_N . The obtained values are reproducible and enable product framing in class 0,5. These errors do not take into account either RC temperature errors or the errors introduced by the electronic assembly for primary sensor information processing.

VIII. Conclusions

The paper describes a laboratory for high current measuring system calibration accredited by DKD in 2008.

The Laboratory has supply sources that can generate power frequency symmetrical and asymmetrical currents with values up to 250kApeak and durations up to 0,5 s. The laboratory reference standards have traceability to PTB standards.

Due to a wider and wider spread of RCs both in the testing laboratories and in research and industrial applications it is analysed the possibility to calibrate them at current impulses 8/20µs up to 25kA and 1,2/50µs up to 100A.

It is described a high current generation equipment up to 5kAs in the frequency range 50Hz-10kHz intended to plotting RCs frequency characteristic.

The Laboratory also performs development tests for the customers who manufacture and tune special purpose RCs. An example is RC for electronic current transformers with optical transmission of information.

Instrument transformer measuring system of the Laboratory enables the determination of electronic current transformer errors in class 0,1.

In the near future the Laboratory aims at getting the accreditation for the achievement of all tests provided by standard [5] for electronic current transformers.

In its position of STL associated member, the Laboratory participates in the intercomparison of the high current measuring devices that is based on the round robin circulation of a transfer standard in all European member laboratories.

IX. Acknowledgment

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At the same time authors wish to thank to their colleagues Mr. D. Manta and Mr. H. Ionescu for the participation in the measurements.

X. References

[1] *ISO/IEC General requirements for the competence of testing and calibration laboratories*, ISO/IEC Standard 17025, 2005.

[2] STL (Short-Circuit Testing Liaison) [Online] Available: http//www.stl-liaison.org

[3] DKD (Deutsche Kalibrierdienst)[Online] Available: http://www.dkd.eu/laboratorien/de/pdf/18701.pdf

[4] *IEC High-Current test techniques*, IEC Standard 62475-2008, CDV, Apr. 2008.

[5] *IEC Instrument transformers - Part 8: Electronic current transformers*, IEC Standard 60044-8, 2002.

[6] J. D. Ramboz, "Machinable Rogowski Coil, Design and Calibrations", *IEEE Trans. Instrum. Meas.,* vol 45, no.2, pp. 511-212, Apr. 1996.

[7] A. Marinescu, C. Chiciu, H. Ionescu, C. Ilinca, A. Ionescu "Calibration Laboratory for High Currents Measuring Devices", in Proc. 2007 International Proficiency Testing Conference, Sinaia, pp. 291-299.

[8] *ISO Guide to the Expression of Uncertainties in Measurement*, ISO Guide, 1995.

[9] K. Draxl, R. Styblikova, "Determination of Rogowski Coil Constant" in *Proc. 2006 IEEE Applied Electronics Conference*, Pilsen, pp. 1-3.

[10] Y. Chekurov, J. Hällström, "Influence of Busbar Geometry on AC Current Measurement using Rogowski Coil", in *2008 CPEM Conf. Digest*, pp.1-2.

[11] J. D. Ramboz, D.E. Destefan, R.S. Stant, "The Verification of Rogowski Coil Linearity from 200A to greater than 100kA using Ratio Methods", in *Proc. 2002 IEEE Instrum. And Meas. Technology Conference*, pp.687-692

[12] S. Liehr, "Optical Measurement of Currents in Power Converters", *Master's Thesis Project, Microsystem Technology Group, Royal Institute of Technology*, Stockholm, March 2006.

[13] C. Xiao, L. Zhao, T. Asada, W.G. Odendahl, J.D. van Wick, "An overview of Integratable Current Sensor Technologies", in *Proc. 2003 Industry Applications Conference*, pp. 1251-1258.

[14] K. Schon, E. Mohns, A. Gheorghe, "Calibration of Ferromagnetic Coils used for Impulse Current Measurements", in *Proc. 2001 International Symposium of High Voltage Engineering*, Bangalore, pp. 1-4.

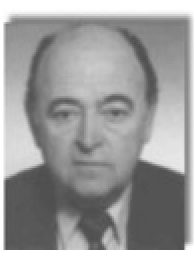
[15] M. Rigoni, J.S.D. Garcia, A.P. Garcia, P.A. da Silva, N.J. Batistela, P.K. Peng, "Rogowski Coil Current Meters in Nonconventional Applications" *IEEE potentials*, pp. 40-45, July/August 2008.

[16] G. Robles, J.M. Martinez, J. Sanz, B. Tellini, C. Zappacosta,M. Rojas, "Designing and Tuning an Air-cored Current Transformer for Partial Discharges Pulses Measurements" in *Proc. 2008 IEEE Instrum. And Meas. Technology Conference*, Vancouver, pp. 1-5.

[17] C. Cherbaucich, P. Mazza, N. Kuljaca, G. de Dona, S. Weiss, U. Brand, "A New Tool for Live, on-site, HV Instrument Transformers accuracy Check", in *Proc. 2007 CIRED*, session 1, paper 0778, pp. 1-4.

[18] Mtronix Company, Instrument Transformer Measuring System MIT300 *User's Manual*, 2007.

XI. Biographies



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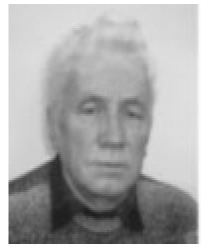

Nicolae PADURARU graduate (1957) of Craiova, Electrical Engineering Institute. Since 1957, designer engineer of Electroputere, Craiova. Within 1958-1964 main designer in measuring transformers and since 1964 Head of the this Project Collectiv of Electroputere, Craiova.Within 1968-1998, Head of the Project Group for Measuring Transformers of Electroputere Research Institute. Since 1980 part time professor at Craiova University. From 1999 and so far Project engineer of the Research, Development and Testing National Institute for Electrical Engineering, ICMET Craiova for high voltage unconventional insulated systems and measuring systems.