Power and Energy Workshop
22-23 March 2011, Noordwijk, The Netherlands

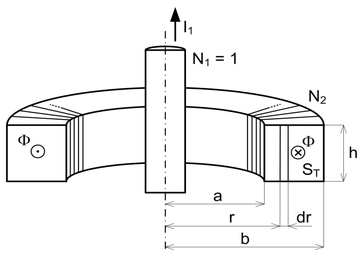
DESIGN AND CALIBRATION OF ROGOWSKI COILS

Renata Styblíková
Czech Metrology Institute
Laboratory of fundamental metrology
V Botanice 4
150 72 Prague 5
E-mail: rstyblikova@cmi.cz

Karel Draxler
Czech Technical University
Faculty of electrical engineering
Technická 2
166 27 Prague 6
E-mail: draxler@fel.cvut.cz

TYPICAL CONSTRUCTION OF ROGOWSKI COILS

RECTANGULAR CROSS-SECTION

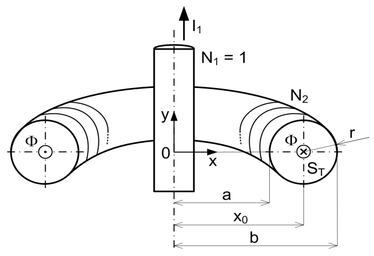


$$M_{21} = \frac{\mu_0}{2\pi} N_2 h \ln\left(\frac{b}{a}\right)$$

$$L_2 = \frac{\mu_0 N_2^{\,2} h}{2\pi} \ln\frac{b}{a}$$

$$Z_2 = \sqrt{R_2^{\,2} + (\omega L_2)^2}$$

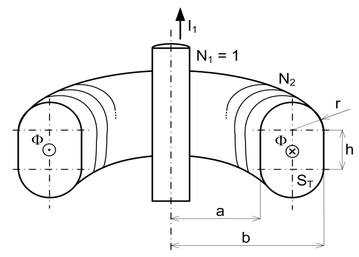
CIRCULAR CROSS-SECTION



$$M_{21} = \frac{\mu_0 N_2}{2}\left(a+b-2\sqrt{ab}\right)$$

$$L_2 = \frac{\mu_0 N_2^{\,2}}{2}\left(a+b-2\sqrt{ab}\right)$$

OVAL CROSS-SECTION



$$M_{21} = \frac{\mu_0 N_2}{2}\left[\left(a+b-2\sqrt{ab}\right)+\left(\frac{h}{\pi}\ln\left(\frac{b}{a}\right)\right)\right]$$

$$L_2 = \frac{\mu_0 N_2^{\,2}}{2}\left[\left(a+b-2\sqrt{ab}\right)+\left(\frac{h}{\pi}\ln\left(\frac{b}{a}\right)\right)\right]$$

THE UNCERTAINTY OF THE MUTUAL INDUCTANCE

$$u(M) = \sqrt{\left(\frac{\partial M}{\partial a}\mathrm{u}(a)\right)^2 + \left(\frac{\partial M}{\partial b}\mathrm{u}(b)\right)^2} \qquad \mathrm{u}(M) = \frac{\mu_0\, N_2}{2}\sqrt{\frac{(a+b-2\sqrt{a\,b})(b\,\mathrm{u}_a^2 + a\,\mathrm{u}_b^2)}{a\,b}}$$

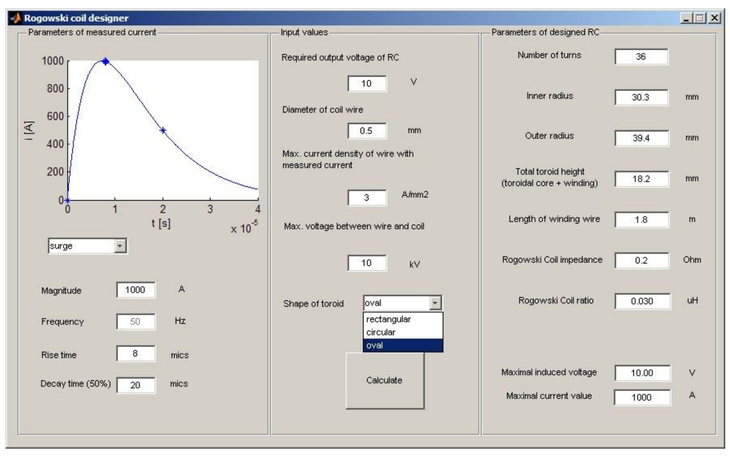
$$\mathrm{u}(M) = \frac{\mu_0\, N_2\, \mathrm{u}}{2}\sqrt{\frac{(a+b-2\sqrt{a\,b})(b+a)}{a\,b}} \qquad u = \sqrt{\frac{a\,b\,(a+b-2\sqrt{a\,b})}{a+b}}\cdot\delta u(M)$$

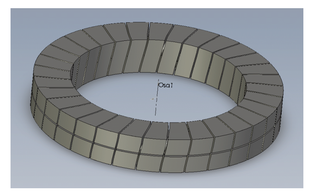
DEPENDENCE OF THE UNCERTAINTY OF THE M ON THE UNCERTAINTY OF THE RC DIMENSIONS

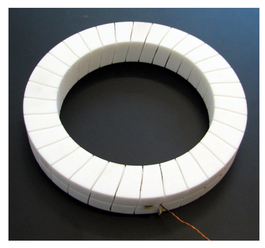
δu(M) (%)	0.1	1	10
$U_1(a_1,b_1)$ (mm)	0.0076	0.076	0.76
$U_2(a_2,b_2)$ (mm)	0.0092	0.092	0.92

ROGOWSKI COIL DESIGN

MAIN WINDOW OF THE SOFTWARE FOR ROGOWSKI COIL DESIGN

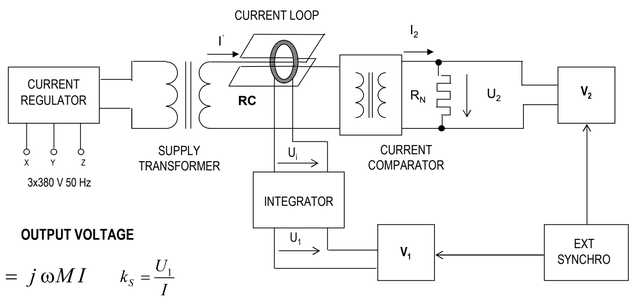






ROGOWSKI COIL CALIBRATION

THE LAYOUT FOR ROGOWSKI COIL CALIBRATION AT 50 HZ



OUTPUT VOLTAGE

$$u_i = j\omega M I \qquad k_S = \frac{U_1}{I}$$

CONSTANT OF THE COMPLETE SYSTEM

$$k_S = \frac{U_1}{I} = \frac{U_1}{U_2}\frac{R_N}{N\,p_I}$$

CURRENT PASSING THROUGH RC

$$I = N\,I' = N\,p_I\,\frac{U_2}{R_N}$$

RELATIVE TYPE B UNCERTAINTY

$$u_{K_S}(B) = \sqrt{u_{U_1}^2 + u_{U_2}^2 + u_{R_N}^2 + u_{p_I}^2}$$

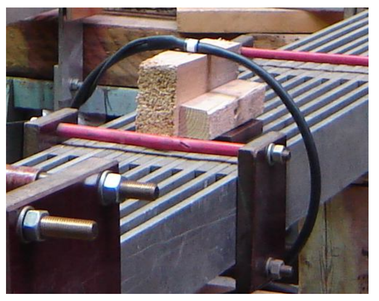
COMBINED UNCERTAINTY

$$u_{k_S}(C) = \sqrt{u_{k_S}(A)^2 + u_{k_S}(B)^2}$$

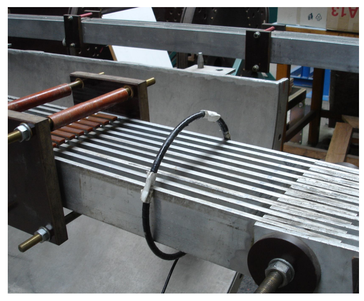
EXPANDED UNCERTAINTY

$$u_{k_S}(C) = 2\sqrt{u_{k_S}(A)^2 + u_{k_S}(B)^2}$$

USING A CURRENT LOOP

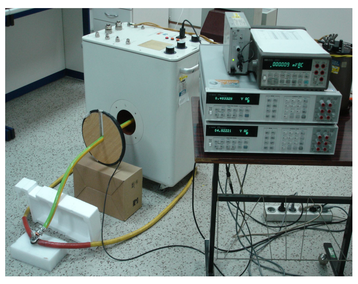


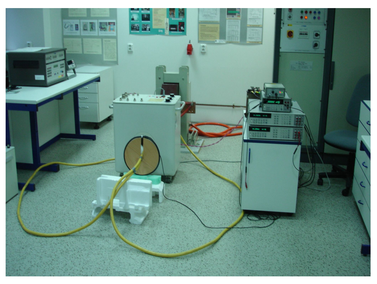
RC 340/310 mm

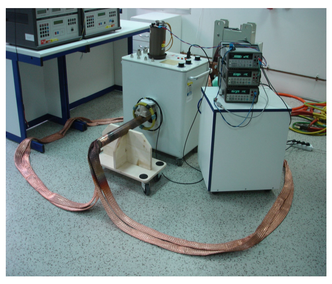


RC 275/250 mm

USING 1 CONDUCTOR







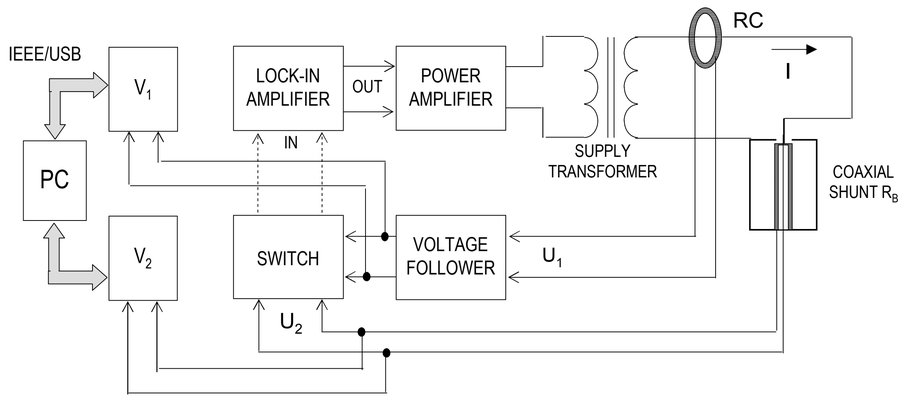
Current loop for RC calibration up to 30 kA

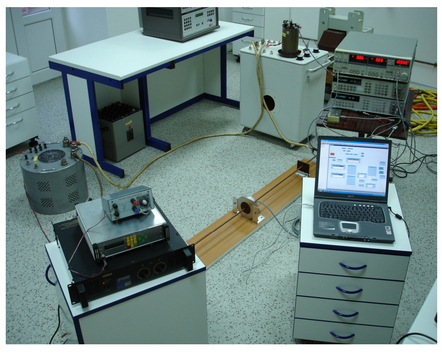
RESULTS OF MEASUREMENTS

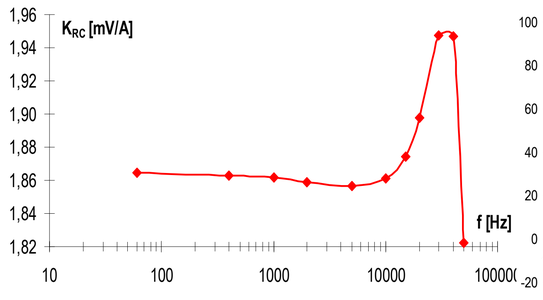
Calibrated value (kA)	25	15	25	15	10	5	4	3	2	1
integrator constant (mV/kA)	10	10	100	100	100	100	100	1 000	1 000	1 000
k_{S1} 10 turns (mV/kA)	9,9893	9,9874	99,7580	99,7373	99,8805	99,8784	99,8907	999,286	999,158	999,352
$U(k_{S1})$ (mV/kA)	±0,0025	±0,0028	±0,0249	±0,0299	±0,0220	±0,0210	±0,0220	±0,230	±0,260	±0,220
k_{S2} 1 turn (mV/kA)	-	-	-	-	-	99,9100	99,8970	998,840	998,854	999,776
$U(k_{S2})$ (mV/kA)	-	-	-	-	-	±0,0210	±0,0220	±0,230	±0,260	±0,200
Rogowski coil with diameter 310/340 mm										

Calibrated value (kA)	30	30	25	22	20	17	13	9	6,5	4	4	2,5	1
integrator const. (mV/kA)	100	200	200	200	200	500	500	500	1000	1 000	2 000	2 000	2 000
k_{S1} 10 turns (mV/kA)	99,80	199,2	199,0	199,20	199,50	497,60	497,30	497,80	995,50	995,40	1989,60	1989,70	1989,80
$U(k_{S1})$ (mV/kA)	0,03	0,06	0,04	0,06	0,06	0,14	0,16	0,14	0,27	0,28	0,53	0,55	0,74
k_{S2} 1 turn (mV/kA)	-	-	-	-	-	-	-	-	998,3	998,1	1996,80	1995,50	1994,00
$U(k_{S2})$ (mV/kA)	-	-	-	-	-	-	-	-	0,28	0,28	0,53	0,55	0,65
Rogowski coil with diameter 250/275 mm													

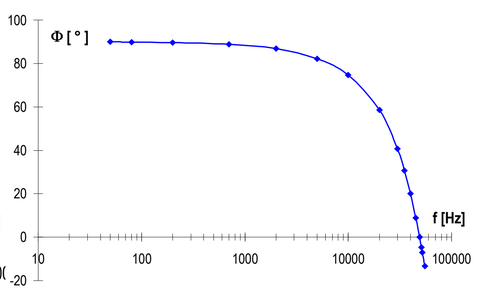
CALIBRATION AT WIDER FREQUENCY RANGE







Frequency dependence of the K_{RC} constant



Frequency dependence of phase displacement Φ between measured current and induced voltage