MAGNETIC SHIELDING OF ROGOWSKI COILS

ENG61 FUTURE GRID

Non-conventional voltage and current sensors for future power grids

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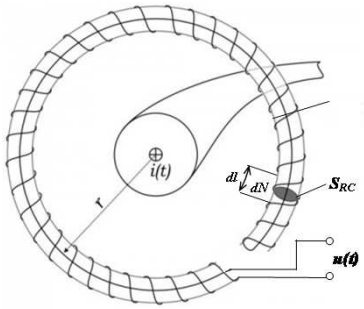
THE PURPOSE OF RC MAGNETIC SHIELDING

➢ **TO REDUCE THE IMPACT OF STRUCTURAL IMPERFECTIONS ON MEASUREMENT ACCURACY**



RC STRUCTURAL IMPERFECTIONS

IDEAL CASE:

✓FOR ALL POINTS ALONG THE RC CIRCUMFERENCE IS FULFILLED

$S_{RC} \cdot dN/dl = S_{RC} \cdot H_N = \text{const.}$ (1)

where S_{RC} is cross-section of the supporting frame
$dN/dl = H_N$ is winding density in the cross-section point

If eq. (1) is fulfilled and parasitic capacitances are not taken in to account then for an ideal RC would be valid:

1. RC does not encircle the conductor with measured current

$\oint \boldsymbol{H} dl = \Sigma \boldsymbol{I} = 0$, then $\boldsymbol{U}_{RC} = 0$ (2)

where H is magnetic field strength along the mean magnetic path
$\Sigma \boldsymbol{I}$ is sum of currents which are encircled by RC
$\boldsymbol{U}_{RC}$ is RC output voltage

REAL CASE:

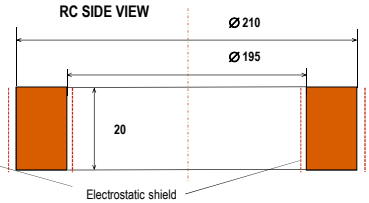
EQUATIONS (1) AND (2) ARE NOT VALID

$S_{RC} \cdot dN/dl = S_{RC} \cdot H_N \neq \text{const.}$ (1)
$\oint Hdl = \Sigma I = 0$, then $U_{RC} \neq 0$ (2)

1. Mutual inductance M is not constant and varies depending on the position of the conductor passed by measured current within RC.
2. There applies an influence of AC magnetic fields induced by conductors with currents outside RC.

IMPACT INVESTIGATION OF THE POSITION OF CONDUCTORS INSIDE RC

USED RC:
RC CMI
d_1 = 210 mm; d_2 = 195 mm
h = 20 mm; N = 6 000
f = 70 Hz

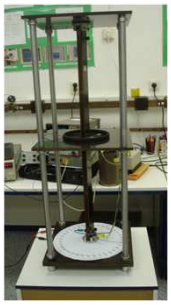


DEPENDENCE OF RC CONSTANT ON PRIMARY CONDUCTOR POSITION

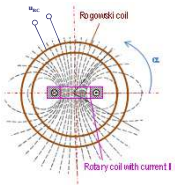
Conductor distance from RC center (mm)	0	20	40	60
RC constant (A/mV)	0,5450	0,5454	0,5455	0,5458
Expanded uncertainty of RC constant (A/mV)	0,0006			
Influence of conductor position on RC constant (%)	0,15			

The RC constant was measured using Agilent 3458A voltmeters.

EXAMINATION OF RC STRUCTURAL IMPERFECTIONS



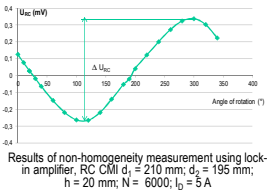
USE OF DIPOLE FIELD FOR NON-HOMOGENEITY DETERMINATION



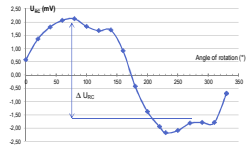
FOR IDEAL RC IS FULFILLED:

$\oint Hdl = \Sigma I = 0, U_{RC} = 0$

RC ABB KECA 80B I = 5 A



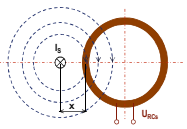
Results of non-homogeneity measurement using lock-in amplifier, RC CMI d_1 = 210 mm; d_2 = 195 mm; h = 20 mm; N = 6000; I_D = 5 A



Results of non-homogeneity measurement using lock-in amplifier, RC ABB KECA 80B; I_D = 5 A

Result:
From equivalent RCs could be selected a RC with minimum non-homogeneity.

DEPENDENCE OF RC OUTPUT VOLTAGE ON EXTERNAL SPURIOUS MAGNETIC FIELD

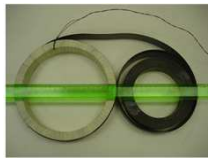


x (cm)	3	6	9	12
I (A)	U_{IRCs} (μV)	U_{IRCs} (μV)	U_{IRCs} (μV)	U_{IRCs} (μV)
20	56	55	52	46
40	110	110	103	93
60	167	165	154	139
80	223	220	215	184
100	280	278	258	231

RESULT OF MEASUREMENT OF SPURIOUS MAGNETIC FIELD INDUCED BY THE CURRENT I_S ; RC CMI :d_1 = 210 mm;d_2 = 195 mm h = 20 mm; N = 6000

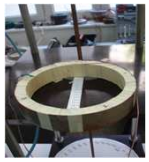
USE OF RC MAGNETIC SHIELDING

Shielding against spurious magnetic field induced by conductors outside RC (used only outer RC shield



Realization of magnetic shielding

RC with electrostatic and magnetic shielding



Measurement of shielding effect of magnetic shielding

Magnetic shielding is made from permalloy (mumetal) tape with thickness of 0,2 mm; shield is formed by 4 turns.

INFLUENCE OF MAGNETIC SHIELD ON RC CONSTANT

- Measurement was performed using a conductor placed in the RC center.
- Range of measured currents (10 – 400) A, frequency 50 Hz.
- Resulting values of RC constant without magnetic shield was calculated from 30 measurement in the current range (10 – 400) A.
- Influence of magnetic shield on RC constant was measured at currents (10; 20; 50; 100; 200 & 400) A.
- Measurement uncertainty does not exceed 0,15%.

K_{RC} without shielding (A/mV)	0,5430					
Measured current (A)	10	20	50	100	200	400
K_{RC} with shielding (A/mV)	0,5443	0,5439	0,5436	0,5439	0,5437	0,5434

Workplace for measurement of shielding effect of magnetic shield

I (A)	x (cm)	3		6		9		12	
	Shielding	U_{IRCs} (μV)	Shielding coefficient	U_{IRCs} (μV)	Shielding coefficient	U_{IRCs} (μV)	Shielding coefficient	U_{IRCs} (μV)	Shielding coefficient
20	no	56	19	55	18	52	16	46	16
	yes	3		3		3,3		2,9	
40	no	110	34	110	23	103	19	93	19
	yes	3,2		4,7		5,4		5	
60	no	167	48	165	32	154	23	139	21
	yes	3,5		5,2		6,7		6,6	
80	no	223	70	220	40	215	28	184	23
	yes	3,2		5,5		7,6		7,9	
100	no	280	122	278	46	258	30	231	25
	yes	2,3		6		8,6		9,2	

Results of measurement of magnetic shielding effect

CONCLUSIONS:

- Magnetic shielding is particularly suitable for suppressing external spurious field. This field produces a signal even if the measured current is zero. This shield has effect in the area of small currents.
- Magnetic shielding has effect on changing RC constant in the area of smaller currents, before reaching saturation.
- The magnetic shield loses effect when its saturation occurs. In our case it occurred at currents above 15 A.
- Future work will be focused on use split magnetic shield with air gaps to prevent oversaturation.