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Faisal, Agah; Jung, Jae Kap; So, Eddy

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A MODIFIED TECHNIQUE FOR THE CALIBRATION OF A CURRENT-COMPARATOR-BASED HIGH VOLTAGE CAPACITANCE BRIDGE AND ITS COMPARISON BETWEEN KRISS AND NRC

Agah Faisal¹, Jae Kap Jung¹ and Eddy So²

¹Korea Research Institute of Standards and Science, Yuseong, Daejeon, Republic of Korea

²NRC, National Research Council of Canada, Ottawa, Canada

faisal@kim.lipi.go.id, jkjung@kriss.re.kr and eddy.so@nrc-cnrc.gc.ca

Abstract

A modified technique for calibrating both the capacitance ratio and dissipation factor (DF) dials of a current-comparator-based high voltage capacitance bridge (CCB-HVCB) has been developed at KRISS. The capacitance ratio and DF dials are calibrated, respectively, in the ratio range from 1/1 to 100/1 and in DF range from 10×10^{-6} to 1×10^{-1} . From the calculated and measured values of the corresponding dial balanced readings, the errors in the capacitance ratio and DF dial readings can be derived. This modified calibration technique has been implemented on a commercial version of a NRC developed CCB-HVCB. The comparison results of the calibration performed at KRISS and NRC will be presented and discussed.

Introduction

The magnitude ratio errors of current-comparator-based capacitance bridges can be calibrated using a scale of low-loss gas-dielectric capacitors with substitution and build-up techniques. At the National Research Council of Canada (NRC), home-made gas-dielectric capacitors that can be trimmed to exact values are used. This would avoid having to calculate minute corrections. For the dissipation factor (DF) errors of the capacitance bridge, a known amount of quadrature currents using an inductive voltage divider in series with a conductance are then injected to one of the ratio windings at unity ratio setting [1].

At Korea Research Institute of Standard and Science (KRIS), a modified calibration techniques has been developed using commercially available low-loss gas-dielectric capacitors with fixed capacitance values for the calibration of magnitude errors. For the calibration the DF, a quadrature current injection circuit consisting of a T-resistor network in parallel with a variable capacitor is used. To verify the performance of this modified calibration technique, the calibration result of commercial version of a NRC developed CCB-HVCB is compared to that performed at NRC.

Modified Calibration Technique

A. Ratio Dials Calibration

The 1/1 ratio calibration of CCB-HVCB is performed in two steps using two capacitors of a nominal 1000 pF value. In step 1, as shown in Fig.

1(a), one capacitor (C_S) and the other (C_X) are connected to N_S and N_X windings, respectively. In step 2, as shown in Fig. 1(b), the two capacitors are interchanged with each other.

Figure 1. Configuration circuit at 1/1 ratio setting calibration

The systematic error (δ_{sys}) at 1/1 ratio is given by:

$$\delta_{sys} = \frac{1}{2} \left(\left(\frac{C_X}{C_S} \right)_{norm} + \left(\frac{C_X}{C_S} \right)_{intrch} - 2 \right) [ppm] \quad (1)$$

Where $(C_X/C_S)_{norm}$ and $(C_X/C_S)_{intrch}$ are the balanced reading values in the normal and interchange connections, respectively.

Two ratio bases are used for the build-up calibration process in the ratio range from 2/1 up to 100/1. The ratio base of 1/1 is used in the ratio range from 2/1 to 10/1. The ratio dials are calibrated using a capacitor (C_S) with a nominal value of 1000 pF connected to N_S , while parallel capacitors (C_{Xi}) with the same nominal value of 1000 pf are connected to N_X by build-up technique at the corresponding measured ratio range, as shown in Fig. 2.

Figure 2. Calibration circuit in the ratio range from 2/1 to 10/1 ratio setting dial

Meanwhile, the ratio base of 10/1 is used for build-up calibration process in the ratio range from 20/1 to 100/1 by using capacitor (C_S) of 100 pF connected to N_S winding.

The measured ratio of C_X and C_S from CCB-HVCB reading in the ratio setting dial of $n/1$ is given by:

$$\left(\frac{C_X}{C_S} \right)_{meas} = n \cdot \left(\frac{C_X}{C_S} \right)_{read} \quad (2)$$

The calculated values for ratios of 1/1 and 10/1 as the base are, respectively, given by:

$$\left(\frac{C_X}{C_S}\right)_{\text{calc}} = 1 \cdot \left(\sum_{i=1}^n \left(\frac{C_{Xi}}{C_S}\right)\right) \quad (3)$$

$$\left(\frac{C_X}{C_S}\right)_{\text{calc}} = 10 \cdot \left(\sum_{i=1}^n \left(\frac{C_{Xi}}{C_S}\right)\right) \quad (4)$$

By comparing the measured value (MV) with the calculated value (CV), the error (δ) is as follows;

$$\delta = \frac{MV - CV}{CV} \cdot 10^6 \text{ [ppm]} \quad (5)$$

B. DF Dials Calibration

The DF dials are calibrated by using precise quadrature current injection circuit consisting of parallel circuit of resistor-capacitor to cover a whole range of DF from 10×10^{-6} up to 1×10^{-1} for both positive and negative polarity.

The calibration circuit for positive DF polarity is shown in Fig. 3. Positive DF is calibrated by having a 10 pF in parallel with 1000 pF capacitors connected to the N_S winding. At the same time, a T-resistor network and a 10 -110 pF (variable capacitor) in parallel with 1000 pF capacitors are connected to the N_X winding. The measured value of the DF is obtained by subtracting the offset from the reading value of the corresponding calibration points.

Figure 3. Configuration circuit for calibration of positive DF dial.

The negative polarity is achieved by interchanging between N_X and N_S arms and replacing the capacitor of 10 pF with 100 pF.

The calculated value (D_{calc}) for DF calibration points is given by:

$$D_{\text{calc}} = \frac{1}{\omega \cdot R_X \cdot (C_{X1} + C_{X2})} \quad (6)$$

Where:

$$R_X = \frac{R_1 R_2 + R_2 R_3 + R_1 R_3}{R_2} \quad (7)$$

Calibration Results

The calibration results in ratio and DF dials are listed in Table 1 and 2, respectively. The results are compared to those from the NRC to verify the performance of the modified calibration techniques. The capacitance ratio and DF dial errors measured in KRISS were not more than 6×10^{-6} and 2.0 % of DF dial readings, respectively. This relatively high error

of the DF dial was only for DF dial settings of less than 100×10^{-6} . For DF dial settings of higher than 100×10^{-6} , the measured DF dial errors were not more than 0.8 %. The difference between the calibration results in KRISS and NRC are within 8×10^{-6} for the ratio dials and 0.8 % for the DF dial settings higher than 500×10^{-6} .

The uncertainty ($k=2$) of the modified calibration technique is estimated to be 10×10^{-6} and 0.5 % for the ratio dial and the DF dial readings, respectively.

Table 1. Calibration results of ratio dial and differences between KRISS and NRC.

Ratio Dial	Error of Ratio Dial [ppm]		
	KRISS	NRC	KRISS-NRC
1/1	4	3	1
2/1	3	7	-4
5/1	5	7	-2
10/1	5	8	-3
20/1	0	8	-8
50/1	3	10	-7
100/1	6	14	-8

Table 2. Calibration results of DF dial and differences between KRISS and NRC.

DF Dial	Dissipation Factor (10^{-6})		Error (% of reading)		
	Calc. Value	Meas. Value	KRISS	NRC	KRISS-NRC
10	10	10	0.0	-	-
50	51	50	-2.0	-	-
100	101	101	0.0	-	-
500	504	506	0.4	0.5	-0.1
1,000	1,004	1,003	-0.1	-0.2	0.1
5,000	4,999	4,996	-0.1	-0.3	0.2
10,000	9,998	9,986	-0.1	-0.4	0.3
50,000	49,990	49,871	-0.2	-0.4	0.2
100,000	100,307	100,628	0.3	-0.4	0.7
-10	-10	-10	0.0	-	-
-50	-50	-50	0.0	-	-
-100	-100	-100	0.0	-	-
-500	-500	-501	-0.2	-0.5	0.3
-1,000	-1,001	-1,000	0.1	-0.7	0.8
-5,000	-5,005	-4,998	0.1	-0.5	0.6
-10,000	-10,006	-9,987	0.2	-0.4	0.6
-50,000	-49,975	-49,987	0.0	-0.4	0.4
-100,000	-99,825	-100,618	-0.8	-0.4	-0.4

Conclusion

The calibration results of the CCB-HVCB done at KRISS and NRC indicated good agreement, within the uncertainty of the measurements, of the measured errors of the ratio and dissipation factor dials within 8×10^{-6} and 0.8 %, respectively. It confirms the validity of the modified calibration technique.

References

- [1] W. J. M. Moore and P. N Miljanic, "The current comparator," *IEEE Electrical Measurement Series*, vol. 4, London, United Kingdom, Peter Peregrinus LTD, 1988.