HIGH VALUE RESISTORS: STUDY OF THEIR BEHAVIOUR VERSUS APPLIED VOLTAGE

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Abstract: Experimental results concerning the behaviour of some high value resistors versus applied dc voltage are given. The measurements have been carried out at IEN on typical standard resistors, normally available in National and secondary laboratories, in the field 10 MW ÷ 1 TW by means of the measurement systems described in [1, 2]. The measurement results, with which we tried to determine the voltage coefficients, showed for most of the measured resistors a behaviour versus voltage that is the addition of linear and quadratic components.
Keywords: high value resistor, voltage coefficient, resistance versus voltage

1 INTRODUCTION

In the last period the need of making more accurate measurements in the field of high dc resistance due to the requests of the secondary and industrial laboratories, is sensitively increased. To satisfy this need at IEN a Digital Multimeter (DMM) based measuring system for calibration of standard resistors in the field 100 kΩ ÷ 10 TΩ has been developed and characterised [1, 2].

This method was also used to execute the measurement related to the participation to an international CCEM key comparison on high value resistors. Having this measurement system the possibility of making measurements on resistors at whatever voltage up to 1000 V, it is suitable for studying the voltage behaviour of typical high value standard resistors.

The voltage behaviours of some high value standard resistors, normally available in National and secondary laboratories, in the field 10 MΩ ÷ 1 TΩ, were investigated and the results are reported in the following.

2 THE MEASUREMENT SYSTEM

A scheme of the measurement system is shown in Fig. 1. R_x is the high value resistor under calibration and R_s is the reference standard.

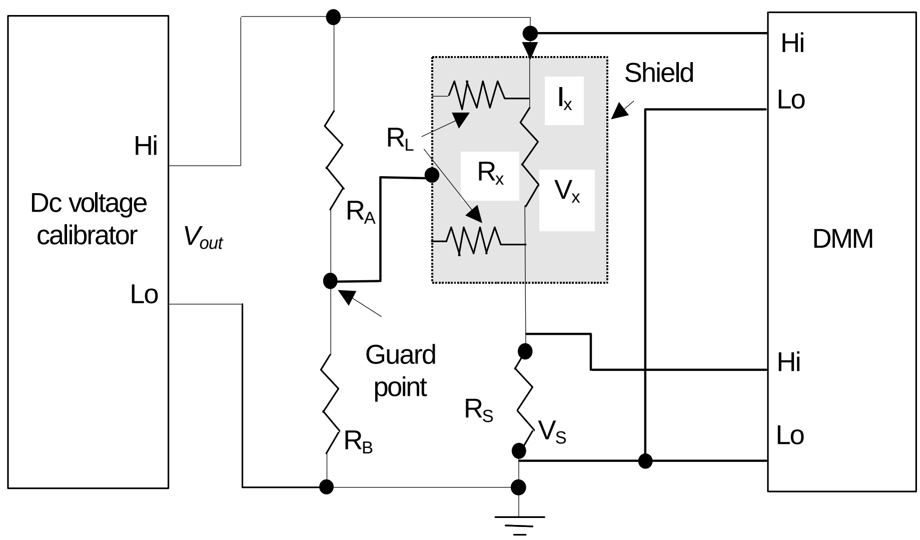

Figure 1. Scheme of a DMM based measurement method.

A programmable voltage source supplies the series R_x + R_s and a DMM is used to measure the voltage V_s across the standard resistor and the voltage V_{out} applied to the series. The polarity of V_{out} is reversed in order to minimise the effects of thermal voltages and of the input offset current of the DMM. An auxiliary resistive divider, R_A and R_B, provides a suitable guard voltage which minimises the effect of leakage resistances R_L . Further details on this measurement system are reported in [1,2].

This measurement system has been compared with other methods also described in [1, 2] in order to evaluate the compatibility of the measurement results.

The measurement system was implemented at IEN also with the development of a new Reference and Switching Unit (RSU) that together with a dc calibrator and a DMM constitute the whole measurement system. Inside the RSU there are, in particular, a switching system for the high value resistors under calibration, four reference standard resistors with another switching system for their selection and a set of resistive components that, selected in a proper way, provide a guard voltage for the whole measurement circuit [3].

Since high value resistors can have temperature coefficients even of several ppm/°C, variations of their resistance values can be due, besides to the different applied voltages, also to the temperature variations of the laboratory. In order to avoid this problem, the tested resistors were placed, during the measurements, in an air temperature-controlled enclosure, also built at IEN, with a mid-term stability of temperature better than 0.01°C. A photo of the whole measurement system appear in Fig. 2.

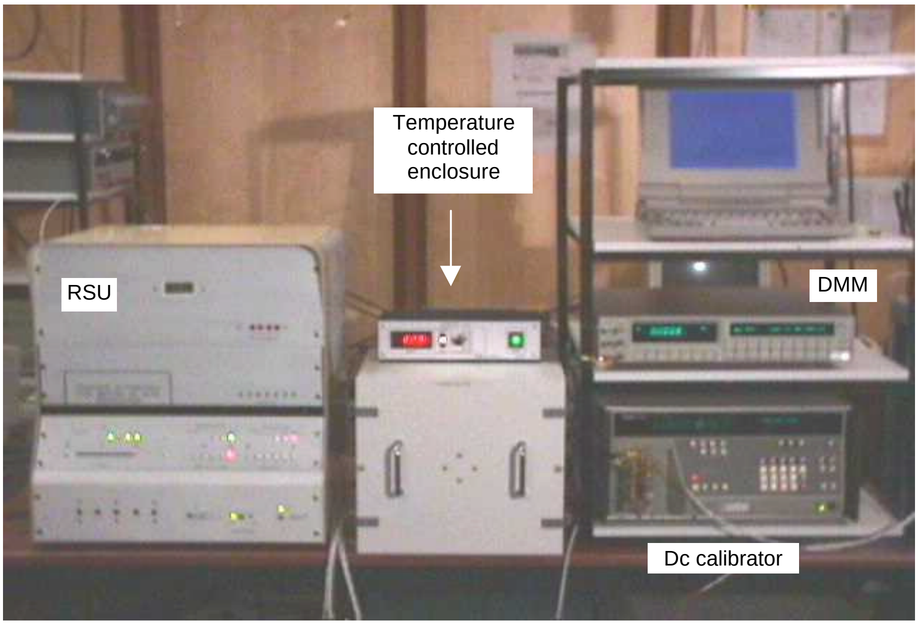

Figure 2. The measurement system which comprehends the RSU, a DMM, a calibrator and the air temperature-controlled enclosure in which the measured high value resistors were placed

The reference standard resistors in the RSU are a Leeds & Northrup mod. 4040-B (10 kΩ), mod. 4045-B (100 kΩ), mod. 4050-B (1 MΩ) and Guildline mod. 9330 (10 MΩ). The temperature inside the air temperature-controlled enclosure can be measured by means of a platinum thermo-resistance connected to a DMM.

3 EXPERIMENTAL RESULTS

The resistors involved in the analysis of their behaviour versus applied voltage are reported in Table 1.

The measurements have been carried out placing alternatively the resistors under measure (except the resistors of the Welwyn box) in the air temperature-controlled enclosure at the temperature of 23,00 °C in a laboratory in which the relative humidity was comprised within (30 ÷ 45) % and measuring them at almost four voltage values.

The measurements on most resistors have been repeated different times and their measurement results were interpolated at a mean date in order to take into account of their possible drift.

Table 1. Identification of the characterised resistors.

Resistor	Manufacturer	Model	serial number
10 MΩ	Guildline	9330	60768
100 MΩ	Guildline	9330	61489
1 GΩ	Guildline	9334W	63246
1 GΩ	ABAG	AEP-RES-001G	93001
10 GΩ	ABAG	AEP-RES-010G	95007
100 GΩ	ABAG	AEP-RES-100G	95001-968.12
1 TΩ	ABAG	AEP-RES-01T	5106
10 MΩ ÷ 1 TΩ	WELWYN BOX		LW85

The behaviours, of the measured resistors versus applied voltage have been evaluated fitting, with the least squares method, the measurement results at different voltages.

In the graphs, reported in Fig. 3 to 15, the relative differences between the single measurement values with respect a reference value, denoted as R/R, versus applied voltage are reported.

A behaviour with linear plus quadratic components following the relation:

$$R = a + bV + cV^2 \tag{1}$$

where R is the resistive value and V the applied voltage, has been considered. Only for the 1 TΩ ABAG standard resistor (Fig. 7) a simple linear component has taken into consideration.

On each figure appear also the confidence band relative to a confidence level of 95% and the coefficient of the linear part (b=B1) and of the quadratic part (c=B2).

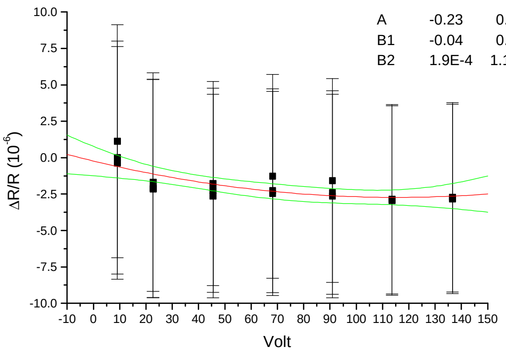

Figure 3. Behaviour of the 10 MΩ Guildline standard resistor.

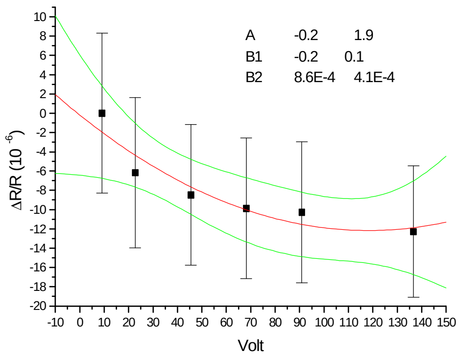

Figure 4. Behaviour of the 10 MΩ Welwyn standard resistor.

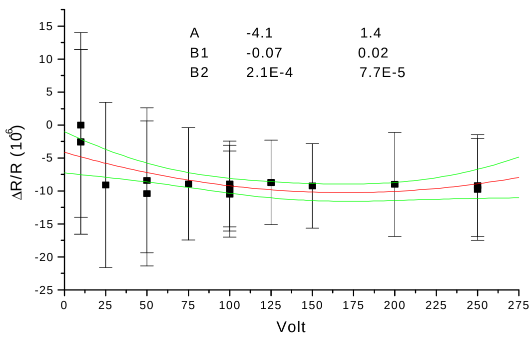

Figure 5. Behaviour of the 100 MΩ Guildline standard resistor.

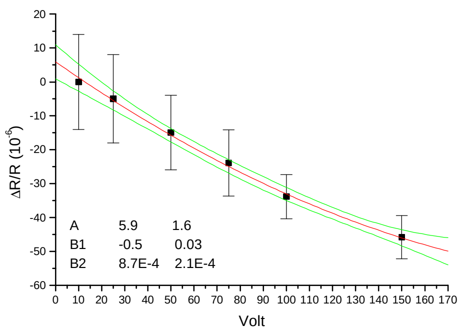

Figure 6. Behaviour of the 100 MΩ Welwyn standard resistor

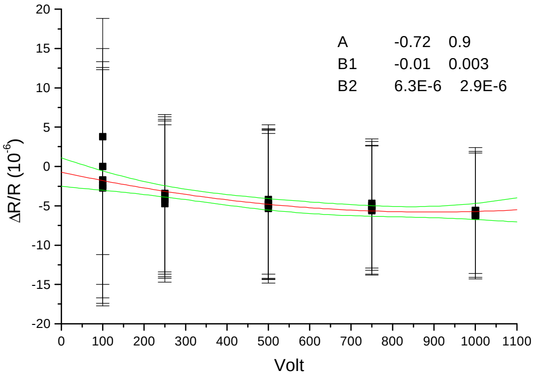

Figure 7. Behaviour of the 1 GΩ Guildline standard resistor.

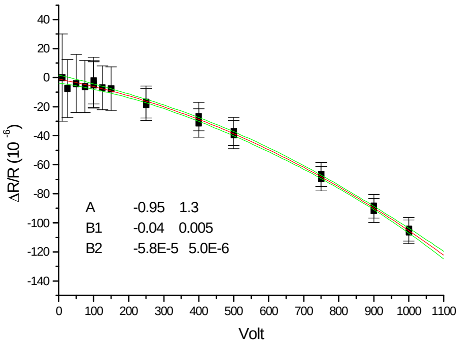

Figure 8. Behaviour of the 1 GΩ ABAG standard resistor.

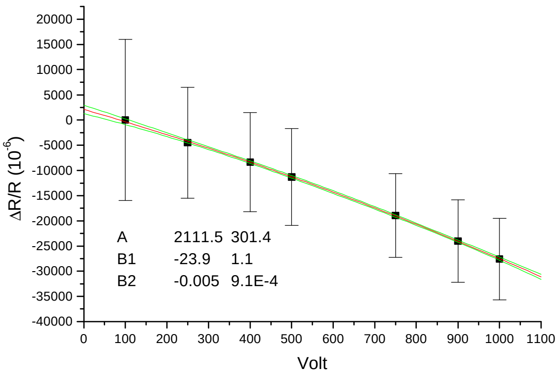

Figure 9. Behaviour of the 1 GΩ Welwyn standard resistor.

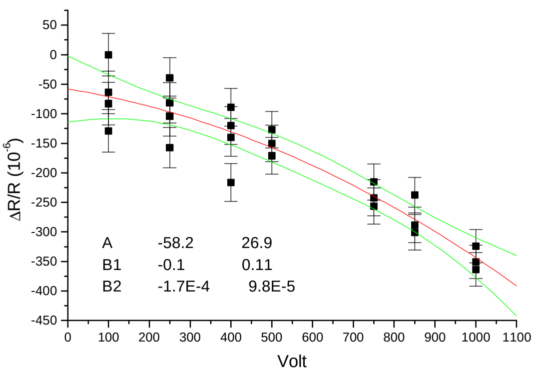

Figure 10. Behaviour of the 10 GΩ ABAG standard resistor.

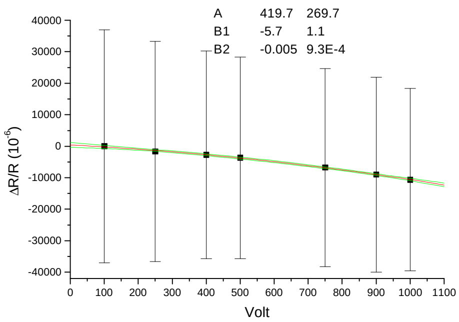

Figure 11. Behaviour of the 10 GΩ Welwyn standard resistor.

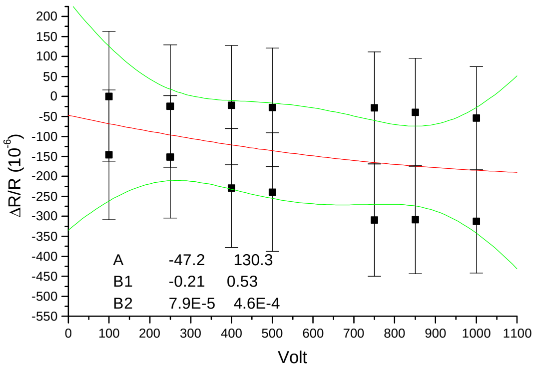

Figure 12. Behaviour of the 100 GΩ ABAG standard resistor.

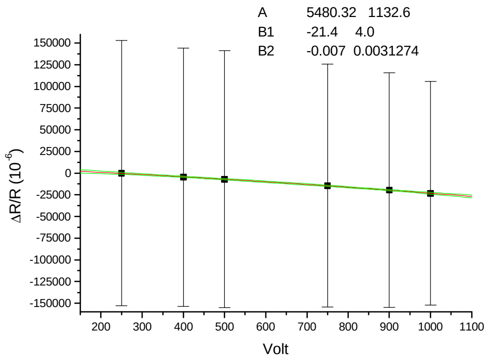

Figure 13. Behaviour of the 100 GΩ Welwyn standard resistor.

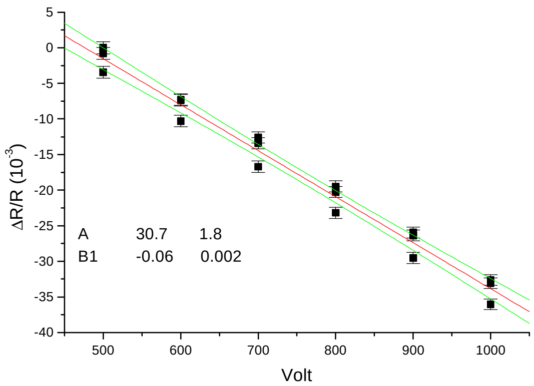

Figure 14. Behaviour of the 1 TΩ ABAG standard resistor.

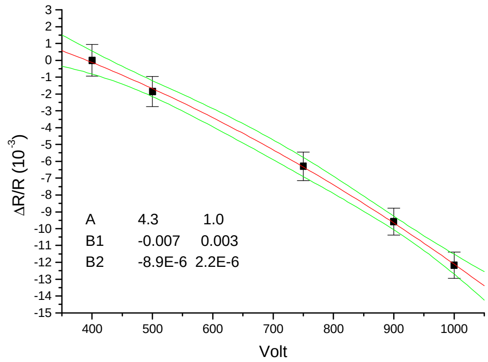

Figure 15. Behaviour of the 1 TΩ Welwyn standard resistor.

Since the quadratic components for each resistor is less significant and have a larger uncertainty than the linear ones, in order to compare the different measured resistors, in Table 2 only the coefficients regarding the linear part of relation (1) are summarised.

4 CONCLUSIONS

The several measurement sessions performed on these standard resistors seem to confirm that the behaviour of their resistive values versus applied voltage has a linear and a quadratic component.

Nevertheless, the different forms of the curves seem to depend by the nominal value of the resistors; as a matter of fact the 10 MΩ and 100 MΩ standard resistors and also almost all the resistors in the field 1 GΩ ÷ 1 TΩ have nearly the same curve forms.

This can depend by the type of the material of the resistive element and by the dependence of this material by the humidity of the laboratory.

Future aims of this work can be the check of the obtained measurement results with the other measurement methods available at IEN for high value resistors calibration [1, 2] and the investigation of the behaviour versus applied voltage in a wider range of variation of the relative humidity placing the resistors in climatic cell in order to verify how much the humidity can affect this behaviour.

Table 2. Voltage coefficients and relative uncertainties of some measured resistors.

Standard Resistor	Manufacturer	Voltage Coefficient	Relative Uncertainty 1 σ (%)
(MΩ)			
10	Guidline	$-4.3 \cdot 10^{-8}$/V	≅ 25
	Welwyn	$-2.0 \cdot 10^{-7}$/V	≅ 50
100	Guidline	$-7.1 \cdot 10^{-8}$/V	≅ 29
	Welwyn	$-4.7 \cdot 10^{-7}$/V	≅ 6
(GΩ)			
1	Guidline	$-1.1 \cdot 10^{-8}$/V	≅ 32
	ABAG	$-4.6 \cdot 10^{-8}$/V	≅ 12
	Welwyn	$-2.4 \cdot 10^{-5}$/V	≅ 4.6
10	ABAG	$-1.1 \cdot 10^{-7}$/V	≅ 110
	Welwyn	$-5.7 \cdot 10^{-6}$/V	≅ 19
100	ABAG	$-2.1 \cdot 10^{-7}$/V	≅ 252
	Welwyn	$-2.1 \cdot 10^{-5}$/V	≅ 19
(TΩ)			
1	ABAG	$-6.4 \cdot 10^{-5}$/V	≅ 5.8
	Welwyn	$-7.2 \cdot 10^{-6}$/V	≅ 42

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