BEHAVIOUR OF HIGH VALUE STANDARD RESISTORS VERSUS RELATIVE HUMIDITY: FIRST EXPERIMENTAL RESULTS

F. Galliana, P.P. Capra, E. Gasparotto

Istituto elettrotecnico nazionale Galileo Ferraris, IEN, str. delle Cacce, 91 – 10135 TURIN, Italy
Tel. +39 011 39 19 446; Fax +39 011 34 63 84; E-mail: galliana@al.ien.it
Tel. +39 011 39 19 427; Fax +39 011 34 63 84; E-mail: capra@me.ien.it
Tel. +39 011 39 19 425; Fax +39 011 34 63 84; E-mail: gasparo@me.ien.it

Abstract – *In this paper we report the first experimental results in the characterization of high value standard resistors versus relative humidity. For this aim we adopted a digital multimeter (DMM) based measurement method, already used for characterization of high value resistors versus temperature and applied voltage and to participate in the CCEM-K2 comparison on high resistance. For the realization of the environment with specific values of relative humidity we realized a thermostatic enclosure in which it is possible to set the desired humidity value in the range (10 ÷ 90)% with a long term instability of the humidity up to ±1%.*

The preliminary experimental results of characterization suggest us that the value assigned to a high value standard resistor is affected not by the humidity during the calibration period, but by the humidity with which it was maintained several days or weeks before calibration.

Keywords – high value standard resistor, relative humidity, thermostatic enclosure

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 characterized [1, 2]. With this measurement system, using thermostatic enclosures with active control of the internal temperature [3], we performed a characterization of high value resistors versus temperature and applied voltage [4, 5].

Another environment parameter that can highly influence the value of a high value standard resistor is the relative humidity; the control of the humidity in wide environments like the measurement laboratories can be very difficult, and the humidity can vary according to the seasons. So it can happen that one performs the calibration of a high value resistor in different humidity conditions with respect the humidity conditions in which it will be used in the time interval until the next calibration.

For this reason it is important to characterize high value resistors versus relative humidity in order to perform suitable corrections of their resistive values when they are used in different humidity conditions with respect the calibration conditions.

So we began a work of characterization of high value resistors, in particular in the field 1 GΩ ÷ 1 TΩ, versus relative humidity; moreover, recently, other interesting studies were conducted on electrical quantities standards versus relative humidity [6, 7].

2. THE MEASUREMENT SETUP

2.1 The enclosure

The first experimental measurements were conducted placing the high value resistors under test in an enclosure in which it is possible to set some relative humidity values by means of suitable salt solutions (Fig. 1) [6]; the enclosure is constituted by two plastic shells with ring tight with the measuring cables passing across a brass structure. Temperature and relative humidity inside the enclosure are monitored respectively by a thermo-resistance and by a humidity sensor. The values supplied by these two devices are acquired by a DMM.

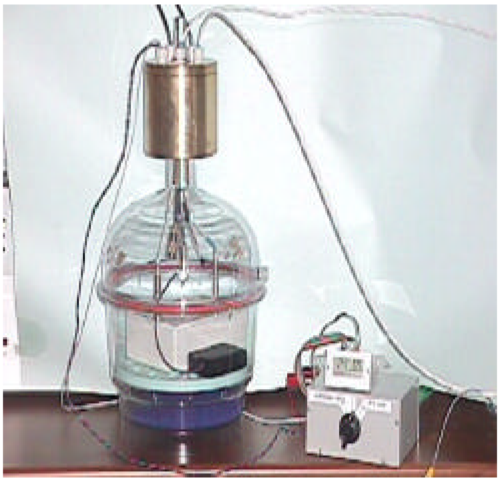

Fig. 1 - Enclosure with a resistor under test: it is separated from the salt solution by a plate with holes.

ISBN 972-98115-4-7

More recently a new enclosure [8] has been developed with the possibility of maintaining the temperature at the level of about ± 0.01 °C and varying the relative humidity in the field (10 ÷ 90)% and the electronic control of the device maintains this setting with a long term instability of the humidity up to ± 1%, that is suitable for our scope of characterization of standards of electrical quantities versus relative humidity.

The enclosure (Fig. 2) is realized by two aluminium concentric cylinders with a polystyrene insulation while a polystyrene cube surrounds both the cylinders.

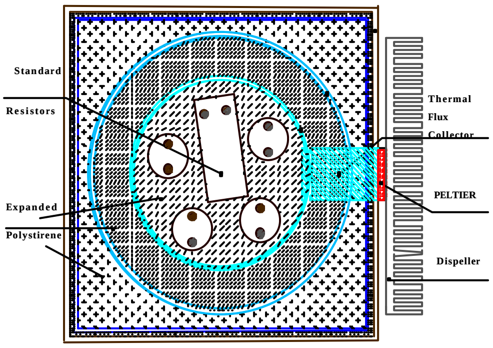

Fig. 2 – Top view of the enclosure without the two top covers.

2.2 Temperature and relative humidity controls

The temperature sensor inside the enclosure is a platinum thermo-resistance, mod. PT100: this thermo-resistance increases its resistive value proportionally with the temperature at the level of 0,39 Ω/°C, with nominal value of 100 Ω at 0 °C. Fig. 3 reports the behaviour of the temperature inside the thermal enclosure, with the working point set to 23°C: the test was performed in a laboratory with controlled temperature in the field (23 ± 1)°C: from the picture we can observe that, with a variation of the laboratory temperature of ± 0.45 °C in the time interval of ten days, the maximum difference inside the enclosure was not superior to 0,008 °C.

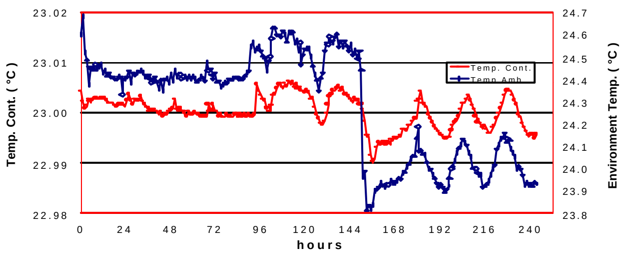

Fig. 3 – Comparison of environment temperature and the temperature inside the enclosure.

The control of the relative humidity inside the enclosure is obtained by an external system, controlled by a microprocessor. Inside the enclosure a is placed thermo-hygrometer, mod. THGM-880, with digital output. The resolution of the instrument is 1%, while the accuracy is 3%. The complete scheme of the control system is reported in Fig. 4.

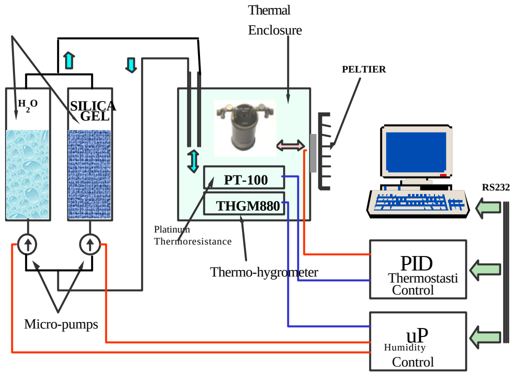

Fig. 4 – Scheme of the enclosure. The units for the thermostatic control (PID) and for the relative humidity control (uP) are visible. All the devices reported in the picture are external from the enclosure.

The control circuit, based on the microprocessor, receives the data of the measured relative humidity by the hygrometer in BCD format and compares them with the set values. When the difference by the measured and set relative humidity exceed a (variable) threshold value, one of the two micro-pumps for the conditioning of the air inside the enclosure is enabled. Both the pumps take the air inside the enclosure and send it in one of the two conditioning containers, one emptied with silica gel and the other with water, (Fig. 5), according to the need to increase or to decrease of the humidity inside the enclosure.

Fig. 5 – Humidity conditioning containers of the air inside the enclosure.

3. FIRST EXPERIMENTAL RESULTS OF CHARACTERIZATION

By using the thermostatic enclosure, varying the relative humidity inside the enclosure at three humidity values (7%, 40% and 77%) and maintaining the temperature at the level of 23,00 °C, we studied the humidity dependence of four high value standard resistors.

The measurement were performed with the DMM based measurement method [1, 2].

In Fig. 6 and 7 is reported the behaviour versus the days of permanence at a specific humidity of a 50 GΩ standard resistor, ABAG mod. AEP-RES-050G, n. 95008. This is a three terminals resistors, with the third terminal connected to the shield and with thick film resistive element; it was placed in dry environment (10% relative humidity) for about a month, then, subsequently, it was placed in wet environment (77% relative humidity) for about 40 days and then again placed at 10% for about other 10 days. The resistor was measured only during these last two phases, at 77% and 10% of relative humidity.

In Fig. 6 is visible the behaviour of the 50 GΩ standard resistor at 77% of relative humidity; we can see that it increases its resistive value for still about a week. This behaviour is probably due to the effect of the humidity (10%) in which the resistor was placed in the previous weeks before the beginning of the measurement period. Then after the first week of measurement it decreases its resistive value and it seem to reach a stabilization point only after about a month.

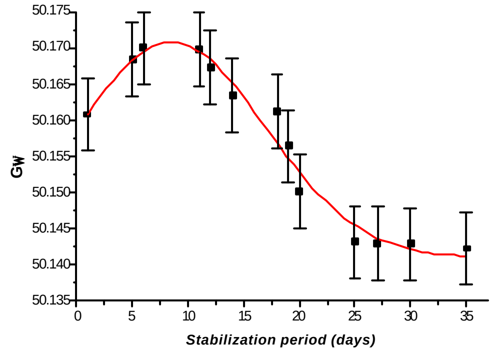

Fig. 6 – Behaviour of the 50 GΩ at a relative humidity of 77%.

These consideration seems to be confirmed by the behaviour of the same resistor showed in Fig. 7 where the resistor, placed again in dry environment, continues to decrease its resistive value for about a week and then starts to increase its value.

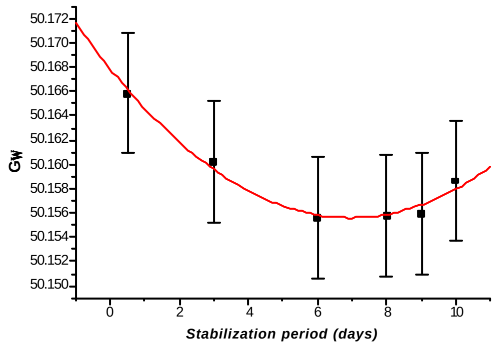

Fig. 7 – Behaviour of the 50 GΩ at a relative humidity of 10%.

While in Fig. 6 the resistor seems to reach a stabilization value after a transitory period of about a month, in Fig. 7 the transitory period is not yet completed.

In Figg. 8 ÷ 10 are reported the behaviours of a 1 GΩ standard resistor, Guildline mod. 9334W, n. 63246 versus the stabilization period (in days) and with a measurement voltage of 1000 V. These figures show an exponential behaviour (growing in the first case and decaying in the last two cases) versus the stabilization period: the resistor seems to reach a stabilization value within about a month.

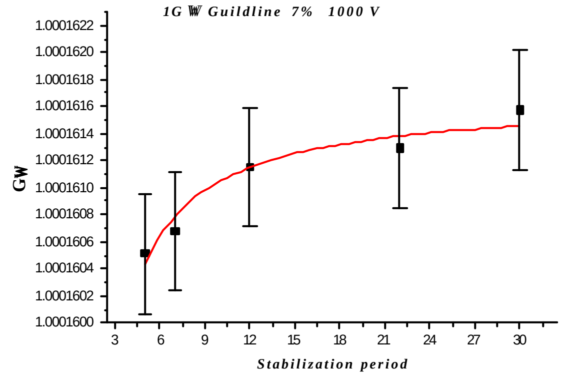

Fig. 8 – Behaviour of the 1 GΩ at a relative humidity of 7 %.

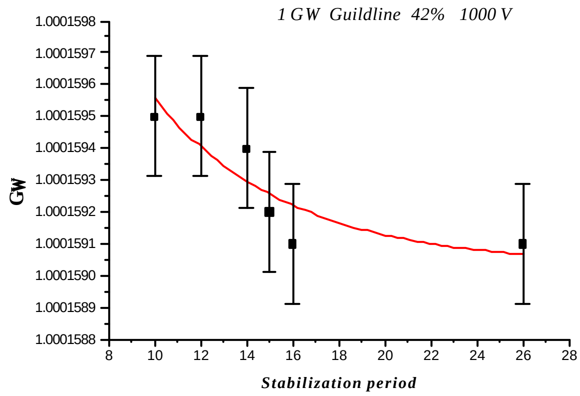

Fig. 9 – Behaviour of the 1 GΩ at a relative humidity of 40 %.

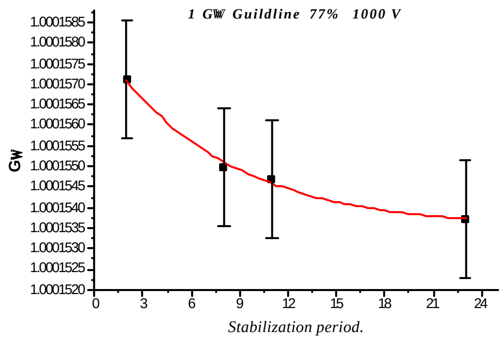

Fig. 10 – Behaviour of the 1 GΩ at a relative humidity of 77 %.

In Figg. 11 and 12 are visible the behaviours of the same 1 GΩ resistor measured at 23 °C, 500 V, 750 V and

1000 V and at the three specified humidity values, respectively ordered versus the humidity values (Fig. 11) and versus the applied voltages (Fig. 12). In Fig. 11 the resistive values seem to be an addition of linear and quadratic components following a relation as:

$$R(U) = R(0)\cdot[1+\delta\cdot U + \gamma\cdot U^2] \qquad (1)$$

with δ negative, where R is the resistance value and U the relative humidity.

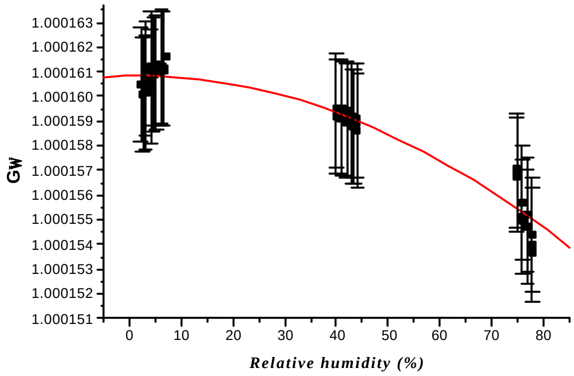

Fig. 11 – Behaviour of the 1 GΩ measured at 500 V, 750 V and 1000 V, relative humidity of 7 %, 42 % and 77 %, versus humidity values.

In Fig. 12 the resistive values are much less repeatable: as we determined in [4, 5] that the behaviour of the resistive value of this resistor versus applied voltage seems to be also an addition of linear and quadratic components, this could mean that the behaviour versus relative humidity is prevalent on the behaviour versus applied voltage.

ACKNOWLEDGMENTS

The authors wish to thank D. Serazio and F. Francone for their competent and precious contributes for the development of the thermal enclosure.

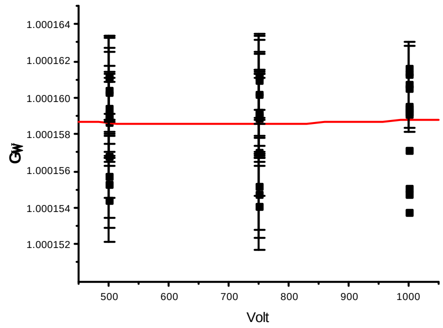

Fig. 12 – Behaviour of the same 1 GΩ measured versus applied voltages.

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