A guarded switching system for automatic selection of high value resistors under calibration

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Abstract-At IEN, a guarded switching system for automatic selection of high value resistors under calibration was developed and metrologically characterized. By means of this system it is possible to select and connect to the measurement system [1, 2] high value resistors in three terminals configuration. As a matter of fact, its guard system allows to reduce the effects due to all the dispersion currents, due to insulation resistances between the resistors under calibration and their shields and due to the switching and connection system (such as insulation resistances among connections, of cables and connectors used for resistors connections). This system utilizes some details of the device described in [6, 7]. The uncertainties that can be reached with the measurement system in connection with the scanner in the calibration of high value resistors and a compatibility test of measurement performed with and without the scanner, are also given.

I. Introduction

In the latest years the interest in study and characterization of high value standard resistors is much increased, so the needs of traceability and calibration of standards in this measurement sector are also sensitively increased. IEN performed a revision of the metrological chain for the high resistance scale: this led to the project, development and characterization of a DMM based measuring method for calibration of standard resistors in the field 10 MΩ ÷ 10 TΩ and also the implementation of a very reliable and accurate measurement system for calibration of high value standard resistors developed at NPL [3] and also implemented at NIST and PTB [4, 5]. Moreover, when there is an high number of resistors or resistance boxes that must be calibrated is necessary to select and connect to the measurement circuit, in a guarded mode and automatically, the resistors under calibration. This also in order to eliminate thermal noises and due to the presence of the operator.

II. The measurement method based on a digital multimeter (DMM)

This system is described in detail in [1, 2]: a scheme of the measurement circuit is shown in Fig. 1. R_x is the high value standard resistor under calibration and R_s is the reference standard resistor with nominal value of some order lower. A programmable dc voltage calibrator supplies the series $R_x + R_s$ and a DMM is used to measure the voltage V_s across R_s. The polarity of V_{out} is reversed in order to minimize 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 minimizes the effect of the leakage currents, due to the finite insulation resistances between R_x and its shield, R_L . A measurement process is chosen in order to reduce the effects, typical of high voltage measurements, of dielectric absorption; delays are inserted during each measurement cycle in order to minimize all transients due to shunt capacitance and to dielectric absorption in the insulator material of the high resistance standard resistor and its connecting cables. R_A and R_B are chosen in such a way that their resistance ratio is always equal to R_x/R_s

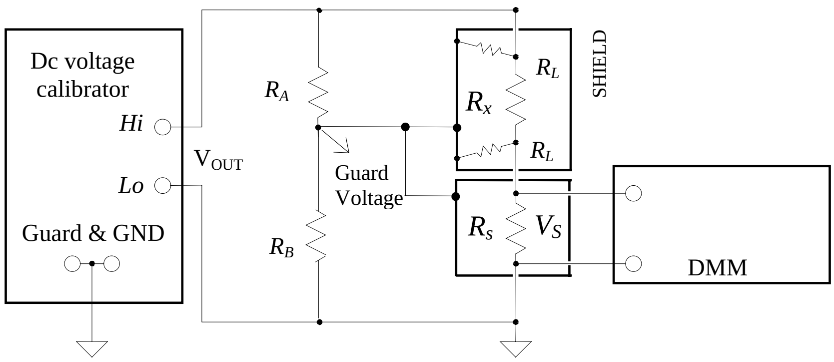

Fig. 1. Scheme of the DMM-based measurement system. R_x is the high value standard resistor under calibration and R_s is the reference standard resistor.

Being V_x the voltage across R_x, the value of R_x is given by:

$$R_x = V_x/I_x = R_sV_x/V_s = (V_{out} - V_s)R_s/V_s \qquad (1)$$

III. Features of the switching system

The switching system consists in a scanner suitable to operate at high voltages and with high insulation resistances. It allows to connect up to six resistors in calibration; each section is a single unity independent from the others. Fig. 2 shows a block diagram in which is visible the entire system for calibration of high value resistors in which the scanner is inserted. Besides the switching system, are visible a digital multimeter, (DMM). a dc voltage calibrator and a portable PC that manages the selection of the resistors under calibration and the measurement procedure.

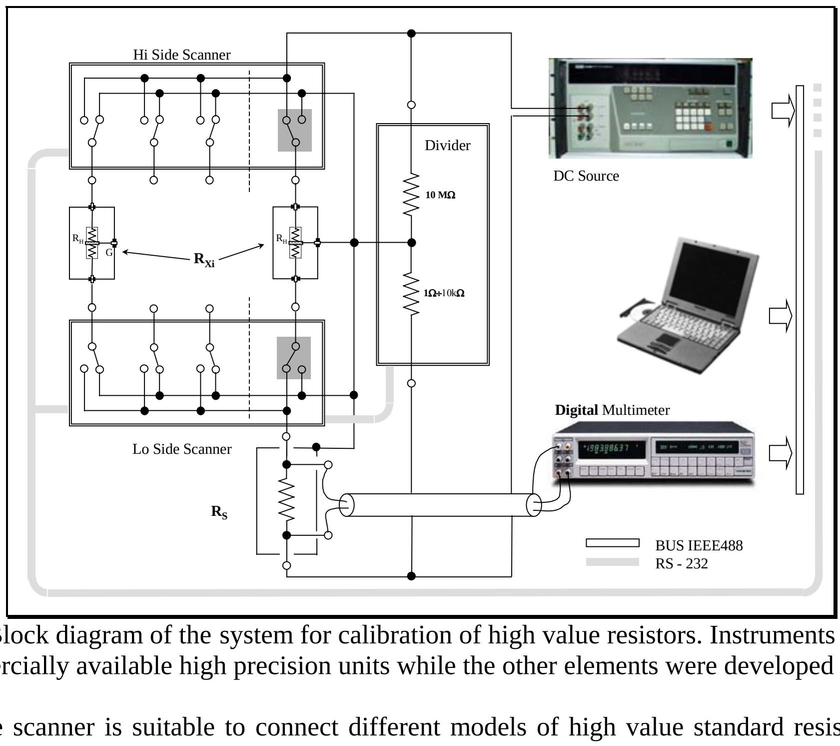

Figure 2. Block diagram of the system for calibration of high value resistors. Instruments and PC are commercially available high precision units while the other elements were developed at IEN.

The scanner is suitable to connect different models of high value standard resistors. On the external panel of the scanner the green terminal (see Fig. 3) is electrically connected to an internal auxiliary resistive divider. [1]

[1] All photos of the device reported in this paper were made during the phase of construction.

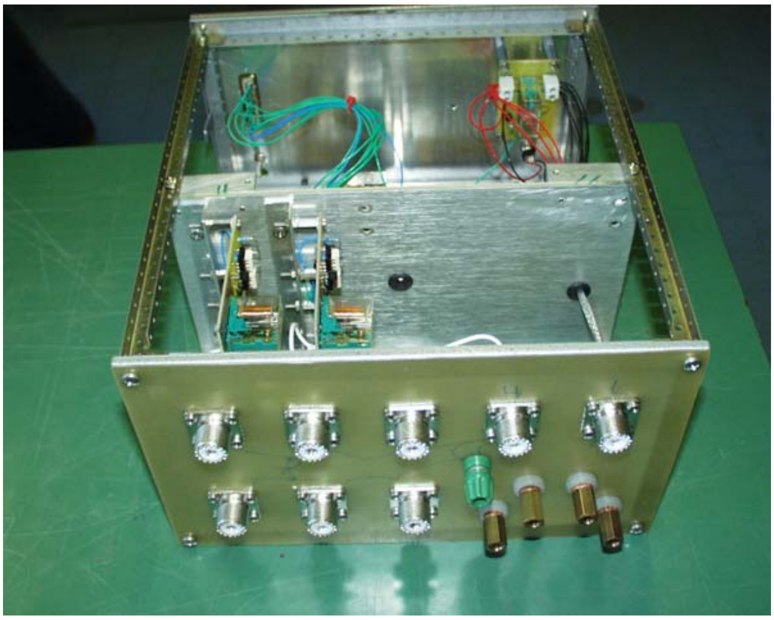

Fig. 3): Front view of the scanner: are visible three pairs of UHF connectors for the connection of high value resistors under calibration and four terminals for the connection of the standard resistor.

Moreover, this solution allows to obtain a high insulation level among the various section of the scanner. As a matter of fact, inside the scanner there is the resistive divider that supplies a guard voltage to the shields of the resistors, to the sections of the scanner and to the shields of connection cables and connectors (right side of Fig. 4). The external box, in which all elements of the scanner are inserted, is instead connected to a ground point.

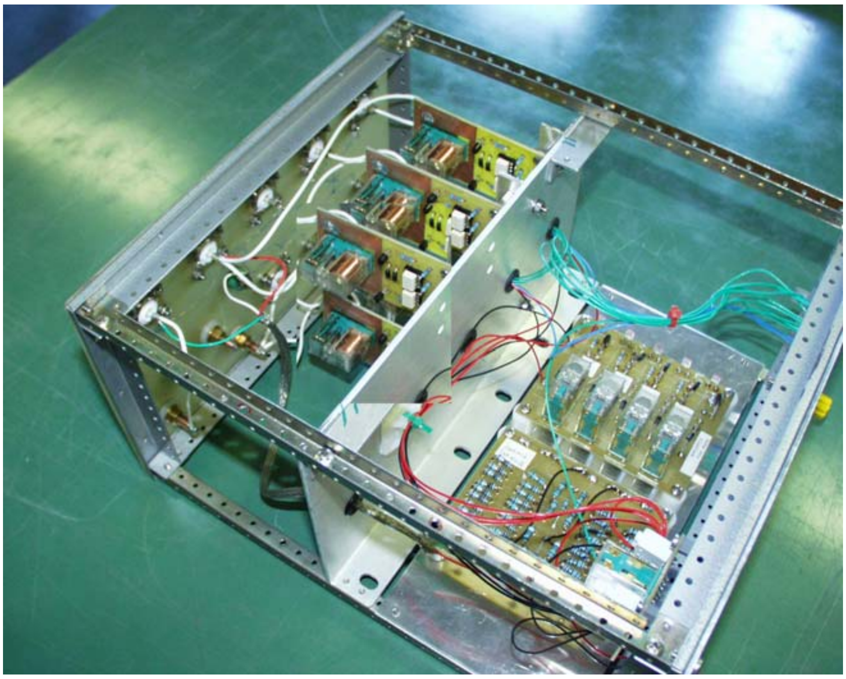

Fig. 4 right side): fiber glass surfaces with on which are mounted the resistors of the resistive divider and the relays for their selection in order to form several resistive ratios R_A/R_B.

This resistive divider maintains a guard voltage equal to the one present at the "Low" terminal of the resistor under calibration [1, 2]. In order to reduce the effect of the insulation resistances among the connections of the relays, the contacts of the sections are realized as in Fig. 4. With this configuration, the insulation resistances are connected to the guard circuit, and the resistors not in measure at the moment but connected to the scanner, are short linked.

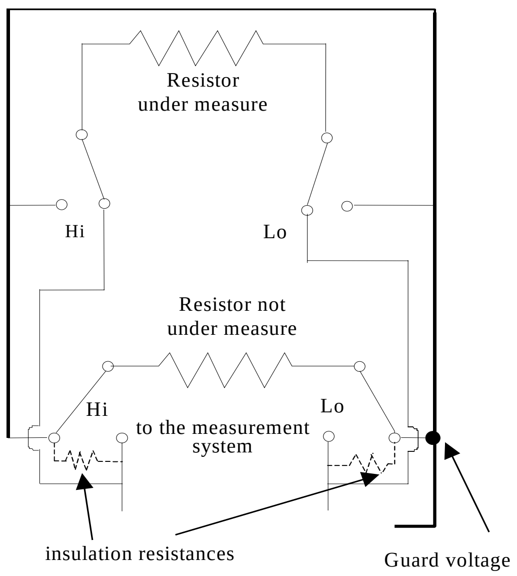

Fig. 4): Connection system adopted in the scanner: here the insulation resistances and the resistors not inserted for measure are connected to the guard circuit.

Before the construction of the device were performed some measurements on the used components: the results are reported in Tab. 1.

Tab. 1 - Insulation resistance of the elements used in the construction of the scanner.

measured parameter	Meas. condition	measured value
Insulation resistance between relay spools and terminals	100 V	$\sim 3{\cdot}10^{13}\,\Omega$
Insulation resistance between relay sections	100 V	$\sim 3{\cdot}10^{13}\,\Omega$
Insulation resistance between of relay open contact	100 V	$\sim 5{\cdot}10^{13}\,\Omega$
Insulation resistance cable RG 223/U	6 m, 250 V	$\sim 1{\cdot}10^{15}\,\Omega$/m
Insulation resistance panel connector UHF	500 V	$\sim 1{\cdot}10^{15}\,\Omega$
Insulation resistance cable connector UHF	500 V	$\sim 1{\cdot}10^{15}\,\Omega$
Fibre glass insulation resistance	500 V	$\sim 1{\cdot}10^{14}\,\Omega$

The entire system (switching and measurement systems) is controlled with a software program developed in Visual Basic 6.0 for Windows This program allows to insert suitable waiting times during the measurement procedure in order to minimize transient effects due to the commutation from a resistor to another besides the effects of dielectric absorption in the insulator material of the high resistance standard resistor under calibration and its connecting cables. As we can see in Fig. 5, with this software it is possible, besides to select the nominal values of the resistor under calibration, of the reference standard and the measurement voltages, to select the position to which the resistor under calibration is connected to the scanner, the ratio of the resistive divider and to measure the environmental parameters (temperature and humidity) in which the measurements are performed [8].

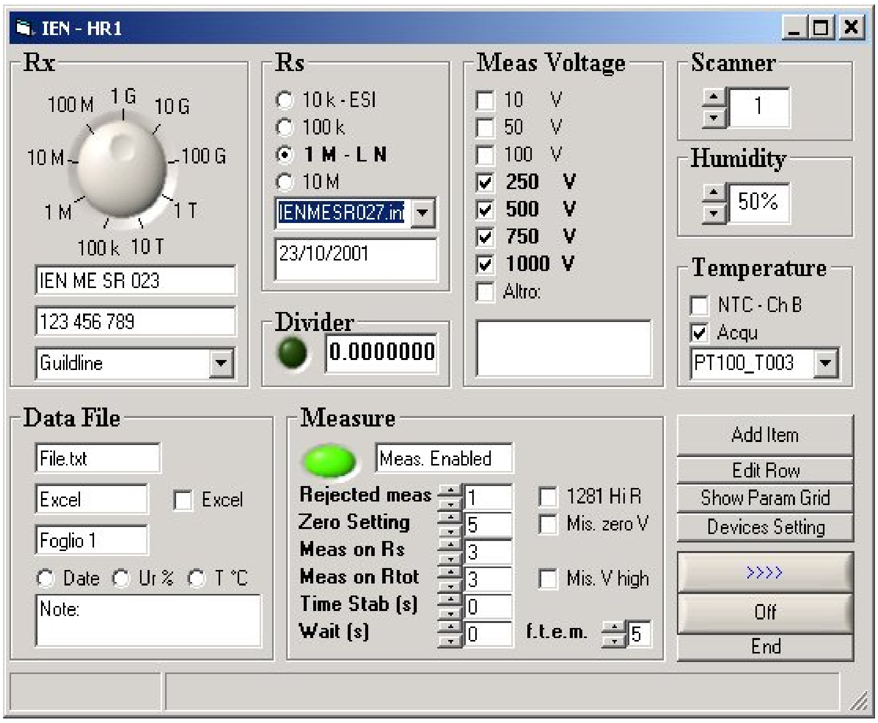

Fig. 5): View of the software program managing the scanner and the measurement

IV Evaluation of the uncertainties and first experimental results of characterization

Table 2 reports a first evaluation of the type B and type A uncertainties at 2σ level of the whole measurement system at some of typical measurement voltages in the measurement range in which the entire (switching and measurement) system was tested (1 ÷100) GΩ.

In Table 3 the mean results of some measurements performed with and without scanner together with their relative differences, are reported. The measurements with scanner were performed connecting the resistors under test to different channels of the scanner and connecting other resistors to the scanner at the same time.

Tab. 2 – Evaluated uncertainties the field (1÷100 G)Ω at some measurement voltages.

		Uncertainties	
Resistor	Meas. voltage	Type B($\cdot 10^{-6}$)	Type A($\cdot 10^{-6}$)
1 GΩ	500	9.0	3.0
	750	8.5	3.1
	1000	8.0	2.3
10 GΩ	250	19.0	45
	500	14	39
	750	14	37
	1000	15.5	33
100 GΩ	500	153	74
	750	140	57
	1000	140	51

Tab. 3 — Comparison of some measurements performed with and without scanner.

	measurements with scanner		measurements without scanner	difference ($\cdot 10^{-6}$)
	meas. voltage			
1 GΩ	100	1,0001606 GΩ	1,0001568 GΩ	-3.8
	250	1,0001526 GΩ	1,0001531 GΩ	0.5
	500	1,0001520 GΩ	1,0001519 GΩ	-0.2
10 GΩ	100	9,955982 GΩ	9,956080 GΩ	-9.8
	250	9,955937 GΩ	9,955800 GΩ	14
	1000	9,953315 GΩ	9,953340 GΩ	-2,5
100 GΩ	500	100,24329 GΩ	100,2490 GΩ	57
	750	100,24321 GΩ	100,2452 GΩ	-20
	1000	100,24060 GΩ	100,2445 GΩ	-39

We can consider these first results satisfactory, moreover further investigations will be needed**.**

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