XX IMEKO World Congress
Metrology for Green Growth
September 9–14, 2012, Busan, Republic of Korea

REMARKS ON DIGITAL MULTIMETER CALIBRATION METHODOLOGIES

João Claudio D. Carvalho[1], *Marcelo M. Costa*[2], *Rafael T. Barros*[3], *Thiago B. P. Souza*[4]

[1]Eletrobras Eletronorte, Belém, Brasil, jclaudio@eletronorte.gov.br
[2]Eletrobras Eletronorte, Belém, Brasil, marcelo.melo@eletronorte.gov.br
[3]Eletrobras Eletronorte, Belém, Brasil, rafael.barros@eletronorte.gov.br
[4]Eletrobras Eletronorte, Belém, Brasil, thiago.brito@eletronorte.gov.br

Abstract: This paper presents the comparison among three methodologies of digital multimeter calibration, two established by Brazilian and international guides, and one developed by the Eletrobras Eletronorte Electrical Calibration Laboratory. In each methodology, aspects as number of calibration points, calibration time and reliability are evaluated.

Keywords: digital multimeter, calibration, calibration guides.

1. INTRODUCTION

Digital multimeters (DMMs) are electrical measurement instruments widely used in utilities in such activities as routine maintenance, daily measurements, and others. As all other measurement instruments, their measurements must be reliable, so these instruments should be periodically calibrated using traceable standards. The calibration process of such instruments can take from some hours to a few days, depending on the number of functions and ranges as well as on the number of calibration points in each function/range.

There are some published methodologies for DMM calibration, like the ones established by [2] and [3]. Reference [2] defines a methodology especially for DMMs calibration, while the reference [3] establishes a general methodology for electrical measurements instruments calibration, which can be applied to DMMs calibration. These methodologies are mainly characterized by:

- Number and distribution of the calibration points through the ranges;
-
- Uncertainty contributions to be considered;
- Other aspects.

Eletrobras Eletronorte Electrical Calibration Laboratory developed a new methodology for DMMs calibration that specifies less calibration points in few ranges, and more points in the other ranges compared to the other two methodologies.

2. OBJECTIVES

The main purpose of this paper is to compare the three methodologies in terms of reliability versus work-time expense. To do this, two different DMMs were calibrated, using these three methodologies, applying suitable electrical standards traceable to the Brazilian National Metrology Laboratory (INMETRO). The DMMs differ in terms of:

- Accuracy
- Type of use (bench or handheld)
- Number of digits or counts.

Others aspects of the methodologies are also compared: uncertainty contributions, measurement characteristics, etc.

3. METHODOLOGIES

To perform the comparison of the calibration results, the three methodologies were used for DC voltage and AC current calibration for each DMM considered. Calibration results for other quantities (AC voltage, DC current and resistance) are not discussed in this article, due to lack of space. Each methodology has its particular characteristics. Some of these characteristics are present in more than one methodology. Table 1 summarizes the main characteristics of the methodologies: methodology denoted as M1 is the one defined by [2], the methodology defined by [3] is denoted by M2 and M3 is the methodology developed by Eletrobras Eletronorte Electrical Calibration Laboratory. The next three subsections show the definition of calibration points considering these two functions.

3.1 METHODOLOGY 1

This methodology based on [2], was published by the European Association of National Metrology Institutes – EURAMET. The number of measurement points differs according to the instrument accuracy. In some cases, different frequencies are used for the same quantity value. The settings of the measuring points used are defined in the tables 2 to 5. The values of the measurement points are reported as a percentage of full scale.

Table 1. Main characteristics of the methodologies applied

Main Characteristics	Methodologies		
	M1	**M2**	**M3**
Traceable measurement results	**X**	**X**	**X**
Change in the instrument conditions in each reading		**X**	**X**
Different frequencies from the mains on measurements of AC values	**X**		
Preliminary zero operation in each range for DC functions	**X**		**X**
Measurement of negative values for DC calibration points	**X**		
Preliminary functional checking such as ACAL, SELFCAL, etc.	**X**		**X**
Guidance on the selection of calibration points may sometimes also be obtained from the manufacturer's instructions or according to the user needing	**X**	**X**	**X**

Table 2. Measurement points for low-accuracy DMMs (resolution of no more than 4 ½ digits) – DC voltage.

Instrument ranges	*Measurement points*	
	No.	*Values*
All	3	10%, 90%, -90%
One (Intermediate)	5	10%, 50%, 90%, -10%, -90%

Table 3. Measurement points for low-accuracy DMMs (resolution of no more than 4 ½ digits) – AC current.

Instrument ranges	*Measurement points*		
	No.	*Values and frequencies*	
All	2	90%	58 Hz, 1 kHz
One (Intermediate)	3	10%	58 Hz
		90%	58 Hz, 1 kHz

Table 4. Measurement points for high-accuracy DMMs (resolution of more than 4 ½ digits) – DC voltage.

Instrument ranges	*Measurement points*	
	No.	*Values*
All	3	10%, 90%, -90%
One (Intermediate)	7	10%, 30%, 50%, 70%, 90%, -10%, -90%
Nominal value >200V	4	10%, 50%, 90%, -90%

Table 5. Measurement points for high-accuracy DMMs (resolution of more than 4 ½ digits) – AC current.

Instrument ranges	*Measurement points*		
	No.	*Values and frequencies*	
All	4	10%	1 kHz
		90%	58 Hz, 1, 20 kHz

3.2 METHODOLOGY 2

This methodology is based on reference [3], published by INMETRO. Definitions of the measuring points used are shown in tables 6 and 7. The values of the measurement points are reported as a percentage of range.

Table 6. Measurement points for DC voltage.

Instrument ranges	*Measurement points*	
	No.	*Values*
All	1-2	50%[1] 95%
One (Intermediate)	3	10%, 50%, 95%

Table 7. Measurement points for AC current.

Instrument ranges	*Measurement points*		
	No.	*Values and frequency*	
All	1-2	50%[1] 95%	58 Hz
One (Intermediate)	3	10%, 50%, 95%	58 Hz

[1] Values to be done only on high-accuracy instruments (resolution equal to or higher than 5 ½ digits).

3.3 METHODOLOGY 3

This methodology is documented on the Technical Procedures of Voltage and Current Calibration, developed and currently used by the Eletrobras Eletronorte Electrical Calibration Laboratory. Definitions of measurement points for instruments of high and low accuracy are shown in tables 8 and 9. The values of the measurement points are reported as a percentage of full scale.

Table 8. Measurement points for DC voltage.

Instrument ranges	*Measurement points*	
	No.	*Values*
All	3	10%, 50%, 95%

Table 9. Measurement points for AC current.

Instrument ranges	*Measurement points*		
	No.	*Values and frequency*	
All	3	10%, 50%, 95%	60 Hz

4. METHODOLOGIES APLICATION

Two DMMs were calibrated to compare the methodologies. The main characteristics of these instruments are shown in table 10. The standards used to calibrate the DMMs, using the calibration methodologies under evaluation, were traceable to metrological standards, with adequate Test Uncertainty Ratios (TUR).

Table 10. DMMs used in the comparison.

Brand and model	Basic accuracy	Resolution (Best)
Fluke 77 III	0.3%	3 200 counts
Fluke 8846A	0.0024%	6 ½ digits

Table 11 shows the points for the Fluke 77 III (fig. 1) calibration, while Table 12 shows Fluke 8846A (fig. 2) calibration points, considering in both cases only DC voltage and AC current. For the low-accuracy DMM, only calibration points with the same frequency from the mains were measured.

Fig. 1. Fluke 77 III digital multimeter.

Table 11. Fluke 77 III DMM calibration points considered.

Function	Methodology 1	M2	M3
DC Voltage	32mV, 288mV, -288mV; 0.32V, 2.88V, -2.88; 3.2V, 16V, 28.8V, -3.2V, -28.8V; 32V, 288V, -288V; 100V, 900V and -900V – total 17 points	300 mV ; 3V; 3.2V, 16V, 30V; 300V; 950V – total 7 points	32mV, 160 mV, 300 mV ; 0.32V, 1.6V, 3V; 3.2V, 16V, 30V; 32V, 160V, 300V; 100V, 500 and 950V – total 15 points
AC Current	28.8mA ; 32mA, 288mA; 9A (all 60 Hz) – total 4 points	30mA; 32mA, 160mA, 300mA; 9.5A (all in 60 Hz) – total 5 points	3.2mA, 16mA, 30mA; 32mA, 160mA, 300mA; 1A, 5A and 9.5A (all in 60 Hz) – total 9 points

Fig. 2. Fluke 8846A digital multimeter.

Table 12. Fluke 8846A DMM calibration points considered.

Function	Methodology 1	M2	M3
DC Voltage	10mV, 90mV, -90mV; 0.1V, 0.9V, -0.9V; 1V, 3V, 5V, 7V, 9V; -1V, -9V, 10V, 90V, -90V; 100V, 500V, 900V and -900V – total 20 points	50mV, 95mV; 0.5V, 0.95V; 1V, 5V, 9.5V; 50V, 95V; 500V and 950V – total 11 points	10mV, 50mV, 95mV, 0.1V, 0.5V, 0.95V, 1V, 5V, 9.5V, 10V, 50V, 95V, 100V, 500V and 950V – total 15 points
AC Current	10mA (1kHz), 90mA (58 Hz, 1, 20kHz); 0.1A (1kHz), 0.9A (58 Hz, 1, 20kHz); 1A(1kHz), 9A (58 Hz, 1, 20kHz) – total 12 points	50mA, 95mA; 0.1A 0.5A, 0.95A; 5A and 9.5A (all in 58Hz) – total 7 points	10mA, 50mA, 95mA; 0.1A, 0.5A, 0.95A; 1A, 5A, 9.5A (all in 60 Hz) – total 9 points

5. RESULTS

Tables 13 and 14 summarize the calibration results of the Fluke 77 III DMM and the Fluke 8846A DMM. *Total points* describes the number of measurement points used in the DMM calibration. *Points in conformance* indicate how many points are inside the limits of conformance. *Worktime* shows the time in minutes of calibration.

Until the moment of conclusion of this paper, the measurement points with high frequencies were not performed, therefore were not considered in the results.

Figure 3 illustrates the calibration time of each DMM. The columns represent the time in minutes corresponding to each methodology, as shown in the label.

Table 13. Fluke 77 III calibration results

	M1	M2	M3
Total points	21	12	24
Points in conformance	21	12	24
Worktime (min)	28	14	33

Table 14. Fluke 8846A calibration results

	M1	M2	M3
Total points	32	18	24
Points in conformance	32	18	24
Worktime (min)	90	54	68

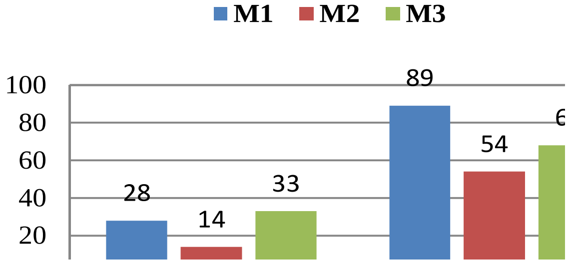

Figure 3. Worktime comparison graphs (in minutes)

As it can be seen on the previous tables and graphs, calibration time considering methodologies 1 and 2 was reduced in comparison to methodology 3 calibration time. This reduction was proportional to the reduction of calibration points. Of course there was a work time reduction in other activities related to the calibrations, like the calibration certificate elaboration. In spite of the reduction of calibration points, calibration results shown that the process of metrological confirmation (which includes the calibration) remained reliable.

It was also possible to verify that, if methodology M1 should be followed in the strict sense, traceability of the standards have to be extended, in order to cover frequencies from the fundamental up to hundreds of kilohertz.

6. CONCLUSIONS

Comparison results shown that, with the use of methodology with lower number of points, calibration time can be saved while the reliability of the metrological confirmation process of the DMMs remains. Regarding to the methodologies comparison, it could be seen that none of them must be followed in the strict sense: definitions should be considered as orientations and suggestions. Manufacturers' definitions and users' needs should always be considered. In the case of AC quantities (voltage), one of the methodologies suggests the frequencies different of the fundamental frequency (kHz) that should be calibrated, while the others do not suggest. One methodology defines calibration points based on percentage of range, which can be inadequate in some cases where the full scale is much higher than the value of the range.

For further work, it is planned the evaluation of the calibrations of more DMMs, differing in terms of brand, accuracy and resolution, using the methodologies discussed in this paper. The results of these researches must support the revision of Eletrobras Eletronorte Calibration Technical Procedures.

REFERENCES

[1] Carvalho, J.C.D., Costa, M.M., Barros, R.T., Souza, T.B.P., "Comparisons among Three Different Digital Multimeter Calibration Methodologies". *in Proc. 18th IMEKO Symposium in Measurement of Electrical Quantities*, 2011.

[2] Guidelines on the Calibration of Digital Multimeters, EURAMET Calibration Guide 15/v.01, Jul. 2007.

[3] Electrical Digital and Analog Measurement Instruments Calibration Guide, INMETRO Guidance Document, Sep. 2006.

[4] Calibration: Philosophy in Practice, 2nd ed., Fluke Corporation, 1994.