Uma proposta de calibração de analisador eletrocirúrgico

A proposal of electrosurgical analyzer calibration

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Resumo: O presente artigo tem a finalidade de propor um método de calibração de analisador eletrocirúrgico em corrente AC, por meio da medição da impedância e corrente na faixa de radiofrequência. Adicionalmente, é apresentado o resultado de uma calibração e as componentes de incerteza envolvidas nessa calibração.

Palavras-chave: equipamento eletromédico; calibração; analisador eletrocirúrgico.

Abstract: The present article has the purpose of proposing a method of calibration of electrosurgical analyzer in alternating current, by measuring the impedance and current in the radiofrequency range. In addition, the result of a calibration and the uncertainty components involved in this calibration are presented.

Keywords: electromedical equipment; calibration; electrosurgical analyzer.

1. INTRODUCTION

An electrosurgical generator is a high frequency source, which usually operates in the range of hundreds of kilohertz to a few units of megahertz. This equipment is used in hospital environment by a surgeon and has the purpose of cutting tissue and cauterizing blood vessels [1], avoiding bleeding and other problems.

The use of this equipment without the proper guarantee of its perfect functioning, can be potentially dangerous, as it can lead to serious injuries to patients, mainly due to burns in inappropriate areas of the body.

One of the ways to ensure the proper functioning of an electrosurgical generator is by means of tests using an electrosurgical analyzer (EA), which, in turn, must be calibrated periodically.

In order to simulate the impedance of the skin and human tissues during a surgical procedure, an EA has a wide range of load impedance, typically 30 Ω to 2000 Ω.

The calibration of an AE requires the use of standards that operate in the radio frequency range and must have metrological traceability in the measurement quantities, which include measurement of the internal impedance of the AE and alternating current, both at high frequency.

2. EXPERIMENTAL ARRANGEMENT

The proposed method consists in the calibration of the impedance of the equipment (Z) and the alternating current of the EA (I) in different frequency values, besides the linearity of the current indicator in 500 kHz. The current value was obtained indirectly from (1).

$$I = \frac{U}{Z} \ (1)$$

Measurement of the impedance of the equipment (Z) was performed using a vector network analyzer (VNA), and the measurement of the voltage drop in the EA (U) was performed by means of a digital oscilloscope.

In addition, a radiofrequency amplifier was used to generate the power required to obtain the current value to be calibrated. Because the radio frequency amplifier has an internal impedance of 50 Ω and because the impedance matching is required for the maximum power transfer, ensuring that the transmitted power does not return to the amplifier, the EA impedance must also have been set to 50 Ω.

2.1. Impedance calibration

The 50 Ω impedance of the AE was calibrated using a vector network analyzer. Although this equipment has the means of performing direct impedance measurement, determining its uncertainty is not trivial. This is because the traceability of this measurement is obtained from the calibration of the vector network analyzer by the ripple method, using as standard a beadless airline [2]. In this calibration, parameters are determined that are directly related to the reflection coefficient measurement, which is a scalar magnitude.

Therefore, the calibration of the EA impedance was performed indirectly by measuring the reflection coefficient and its respective phase. The impedance value is calculated from (2).

$$Z = 50 \times \left(\frac{1+\rho}{1-\rho}\right) \ (2)$$

Where, ρ consists of a vector quantity, that is, it has a real part and an imaginary part.

2.2. Alternating current calibration

The current measurement range of an EA may vary from a few tens mA to A units, and the frequency also varies from a few tens of kHz to MHz units. This information is important in evaluating which equipment would be used in the calibration. For calibration of high current values, it was necessary to use a voltage probe coupled to the digital oscilloscope. Figure 1 shows the set-up used for alternating current calibration.

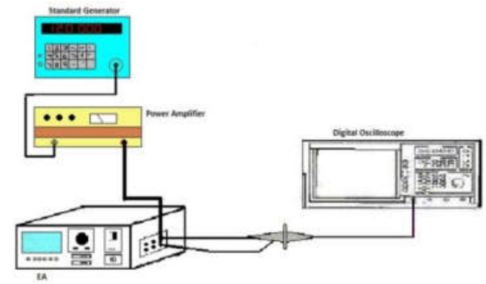

Figure 1 - Alternating current calibration.

The standard oscilloscope and the high voltage probe must have a bandwidth greater than the maximum frequency value of the current being calibrated. Thus, a digital oscilloscope with 1 GHz bandwidth and a high voltage probe with a bandwidth of 70 MHz was used. The internal impedance of the standard oscilloscope was set to 1 MΩ, compatible with the used probe and thereby it did not interfere in the impedance match between the EA and the source, since both were in 50 Ω.

A signal generator was used at the input of the radio frequency amplifier to adjust the level and frequency of the signal in calibration. The amplifier used has the capacity to amplify signals with a power up to 150 W, with a frequency between 10 kHz and 100 MHz. Both the generator and the amplifier are used only as transfer devices, and were not considered for the determination of the expanded uncertainty of the measurement.

It was not necessary to use the high voltage probe for the calibration of the current frequency response, since the voltage value measured directly by the oscilloscope was less than the maximum value allowed without the risk of damaging the equipment.

The calibrated alternating current points are shown in table 1.

Table 1. Current points calibrated.

Frequency (kHz)	Current (mA)
300	150
500	150
1000	150
2000	150
5000	150
500	500
500	1000
500	1500
500	2000

2.3. Traceability of standards used

Figure 2 shows, briefly, the traceability chains of the standards used, both for the calibration of the internal impedance of the EA and for the measurement of the voltage drop. The gray blocks represent the reference standards. All standards belonging to the traceability chain were calibrated in laboratories accredited in ISO 17025:2005, including the VNA and the standard oscilloscope.

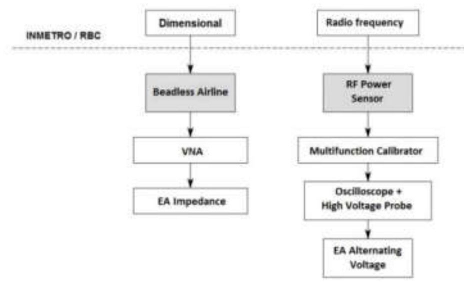

Figure 2 - Traceability of measurements.

3. RESULTS

The results obtained in the calibration (figure 3 and 4) were divided into two graphs: current linearity, which corresponds to the error obtained in different current values for the same frequency of the signal (500 kHz); and frequency response, which corresponds to the error obtained in the current of 150 mA, for several frequency values. For each calibrated point, its respective measurement uncertainty was calculated.

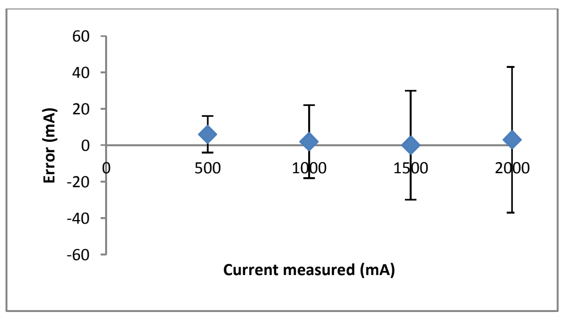

Figure 3 - Current linearity.

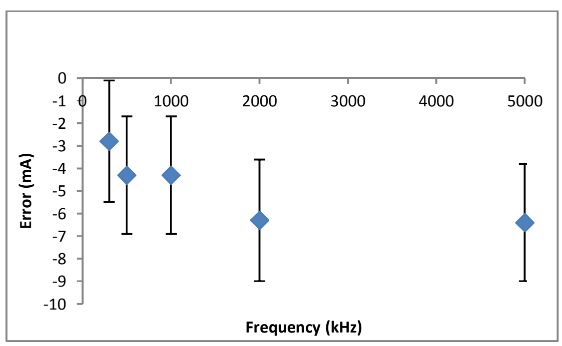

Figure 4 - Current frequency response.

3.1. Composition of the expanded uncertainty of the measurement

The uncertainty bars presented in figures 3 and 4, for each calibrated point, were calculated according to the uncertainty contributions of the standards used. The contributions of uncertainty are presented in table 2.

Table 2. Uncertainty budget.

Component	Uncertainty	Divisor	Standard Uncertainty
VNA (phase)	0.19 %	$\sqrt{3}$	0.110 %
VNA (reflection coefficient)	0.059 %	$\sqrt{3}$	0.034 %
Digital oscilloscope + high voltage probe	2.0 %	$\sqrt{3}$	1.15 %
Expanded uncertainty: U=k.u$_c$			2.3 %

The components of uncertainty presented in table 2 took into account the accuracy of instruments and the calibration certificates. The worst cases of uncertainty were presented, however the uncertainties varied slightly for each calibrated point. The components of uncertainties due to resolution and variability of the standards (and the EA) were considered negligible for the estimate of the expanded uncertainty of the measurement and therefore were not presented, although they were computed for the estimate of the expanded measurement uncertainty.

When we compared the expanded uncertainties obtained as those specified by the manufacturer of the calibrated item [3], it was found that, for the measurement of the impedance through the VNA, the uncertainties obtained are adequate because their values are much lower than the indicated accuracy of 5 % in the equipment manual. However, for current measurement, the expanded uncertainty of the measurement is slightly less than the 2.5 % accuracy indicated by the manufacturer.

4. CONCLUSION

The work proposed a method for alternating current calibration of the electrosurgical analyzers. The method was applied and the results of the calibration were presented, in both current linearity and frequency response.

By means of the analysis of the components of uncertainty, it was verified that the greater part of uncertainty comes from the measurement of alternating voltage with the digital oscilloscope in conjunction with the high voltage probe, whose set-up was used in the calibration of alternating current.

It is intended, as future work, to improve the uncertainty for alternating current measurement, by another system of standards that act in the radio frequency range and also to measure other values of impedance in radiofrequency.

5. REFERENCES

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ACKNOWLEDGMENT

We would like to address our special acknowledgment to MCTIC and Finep for their support through *Sistema Brasileiro de Tecnologia* (SIBRATEC).