Automation of an X-ray calibration system using LabVIEW

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ABSTRACT

The Brazilian regulation ABNT ISO/IEC 17025/2005 specifies general requirements for the competence of testing and calibration facilities. One of these requirements states that these facilities must always optimize their processes. In order to achieve this goal, the Laboratory of Instrument Calibration (LCI - IPEN/CNEN) have acquired some equipment for its X-Ray calibration system, such as a rotating filter holder, and it has also been developing software in order to provide more reliable calibration results. Also, the International Atomic Energy Agency's (IAEA) Technical Document IAEA-TECDOC-1585 details a list of influence factors that may increase the uncertainty in dosimetry laboratories, so, an analysis of those influence factors was performed, being later implemented in the software, so that the system may be able to calculate not only calibration factors, but also uncertainties. A later analysis was made to show how this system at LCI have optimized the whole calibration process, lowering the occupational dose, reducing uncertainties and preventing errors caused by the operators.

Keyword: LabVIEW, automation, X-ray, calibration.

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1. Introduction

ABNT is the Brazilian body responsible for creating standards. One of these standards, ABNT ISO/IEC 17025:2005, specifies general requirements for the competence of testing and calibration facilities [1] . One of these requirements is the optimization of the laboratory's processes. The Laboratory of Instruments Calibration (LCI) is a facility that performs different types of dosimeter calibrations. The LCI has recently acquired some equipment for the X-ray laboratory in order to improve its services, minimizing uncertainties and lowering the occupational dose of the facility employees. Since then, the laboratory has been developing automated systems for some calibration procedures. Data acquisition software was built in 2007 [2] and it is currently being used, but there are some issues that have to be solved in order to achieve better results. One of these issues is the calculation of uncertainties that has to be done apart from the data acquisition software, as well as the calculation of calibration factors. Also, the document IAEA-TECDOC-1585 may be used for those calculations, as it describes influence quantities and methodologies for calculation of those measurement uncertainties.

The main goal of this work is to develop an automated calibration system, with minimum user interaction in order to reduce the probability of errors, while lowering uncertainties.

2. Materials and methods

2.1. Radiation System

The LCI radiation system is a Pantak Seifert that operates with voltage and current values up to 160kV and 20mA, respectively. The reference standard detector is a Radcal ionization chamber model RC6M, with 6cm^3 of sensitive volume coupled with a Keithley electrometer, model 6517A, connected to a PC via GBIP (IEEE-488) port. A monitor chamber is also used, PTW, model 77334, connected to an electrometer PTW UNIDOS E and controlled via Serial port (RS-232). Temperature measurements are taken with a pair of thermopars connected to a thermometer Hart Scientific, model 1529 Chub E-4 and the air pressure is measured with a barometer Druck, model DPI 142. Both instruments are linked to the computer system via RS-232 port.

2.2. LabVIEW programming language

The LabVIEW (Laboratory Virtual Instrument Electronic Workbench) uses a programming language called “G” (for graphical), a graphical language based on icons that represent functions connected by wires. Programs written in LabVIEW are called VIs (Virtual Machines), because they simulate the function and appearance of real instruments [3] . A special design pattern was used in the development of the system, called State Machine. A state machine is an architecture commonly used to quickly build applications, but powerful enough to implement complex algorithms, in which the program checks successively a keyword, called “state”, to see which part of the code will be executed next.

2.3. Influence quantities and correction factors

The reference ionization chamber was calibrated at a Primary Standard Dosimetry Laboratory (PSDL) in terms of air kerma, using X-rays. Therefore, measurements need correction for air density, against the reference conditions (T_{ref}=293,15K and P_{ref}=101,325 kPa). Also some others corrections are needed, due to influence quantities that may change the reading of an equipment. Most of these quantities are described in the IAEA document TECDOC-1585 [4] and their correction values were implemented (when needed) in the software.

2.4. Software description

2.4.1. Current software

The currently used software is a set of 3 different programs. A correct sequence of execution is necessary for the system to work correctly and It is the operator who is responsibility for its execution. The first is used to check communication via serial port with all equipment used. Then, an automated program selects the correct scale for the monitor. Later, the calibration program must be executed 5 times (to do 5 measurements) manually and a set of buttons control the output, creating a text file with all data acquired automatically (temperature, pressure and kerma measure by the monitor chamber) and the reading from the instrument being calibrated, that is input by the user. The beam shutter is controlled by the program via digital port, but this control can be bypassed. After acquiring all data, the user must open the output text file and copy its data to an Excel spreadsheet, in order to calculate the calibration factor.

The software has three major problems that may cause the system to stop working or miscalculate the calibration factor. The first, happens when any of the connected equipment is not working properly, what causes the system to loop indefinitely. The second happens in the “scale selection” program, as it was updated for the radiation qualities implanted in the laboratory. A gap left between qualities makes the software work accurately only for RQR qualities.

The third problem is the high level of user interaction that may cause human errors. Still, lack of documentation is another great problem that makes it difficult to update the software.

2.4.2. The new software

Although it is not finished, the new software is fully functional (only RQR were implemented, but others may be added easily), being able to calculate both calibration factors and uncertainties. Unlike the current software, the new consists of a single program (state machine) with several sub-Vis that are dynamically called. A new functionality was added, that allows the user to perform a calibration on the monitor chamber. Also, a VI for security was built to prevent usage from non-authorized people. The software is fully automated and only little user interaction is needed. The shutter is still controlled by the program via digital port and instructions messages are shown to help the user. No database has been implemented so far, but the software also does not need to use text files or third-party software to do the calculations.

3. Results and discussions

3.1. Correction factors for influence quantities

The factor for departure from reference air density is dynamically calculated. Although a deeper study of the chamber stability is needed, it is known that chambers used as Reference Dosimeter Standards are very stable. Therefore, its factor is neglected, as well as the factor for distance from the source, as a set of lasers is used to achieve a better precision in positioning the chamber. Leakage current measurements were made and the values obtained were about $7 \times 10^{-15} \pm 3 \times 10^{-15}$, with +200 VDC bias. The chamber specifications [5] shows an electrical leakage of $<5 \times 10^{-15}$, with 300 VDC applied. As the values found are close to the specifications, no correction is needed, as values commonly measured are much higher (~nA). A saturation test was performed by placing the reference standard in the beam with fixed conditions and measuring its response while varying the applied chamber voltage. The figure 1 shows its response.

At applied voltage values beyond ±50V, the current collection is fully saturated, so the correction factor for lack of saturation and for changing in the polarizing voltage value may be ignored, as the calibration process uses 200V of applied polarizing voltage, at least. The laboratory has dehumidifiers that provide a 50%±10% RH atmosphere. Therefore, a correction for relative humidity may be safely ignored. The homogeneity of the beam was studied by DIAS [6] . He found the field homogeneity above 95%, which doesn't affect measurements as the whole volume of the chamber is place inside the field.

3.2. Test results and future improvements

During tests, results obtained with the use of the new software showed to be more reliable than those obtained with the old (currently installed) software or by manual procedures. This happens because the software makes the process of calibration of both instruments and monitor chamber simpler, reducing human errors due to low user interaction and lowering the time of calibration. Also, its use limits the number of times the operator enters the irradiation room, minimizing the probability of accidental exposure. The creation of a mobile database for storage of all calibration data and the automatic generation of a calibration certificate will be the next functionalities to be implemented.

4. Conclusion

The use of LabVIEW© as main development tool was proved very effective as it provided tools for a flexible programming as well as easy customization for the needs of the laboratory. Results obtained with the use of the new software proved to be more reliable than other methods, as the software saves time, minimizes human errors and calculates uncertainties dynamically, without need for other software. Further improvements are currently under way in order to generate a calibration certificate automatically and if possible, create a mobile database for the application, with easy access of data.

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Reference

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