

SOFTWARE TOOLS FOR ELECTRICAL QUALITY ASSURANCE IN THE LHC

Mateusz Bednarek, CERN, Geneva, Switzerland,
Jaromir Ludwin, IFJ-PAN, Kraków, Poland

Abstract

There are over 1600 superconducting magnet circuits in the LHC machine. Many of them consist of a large number of components electrically connected in series. This enhances the sensitivity of the whole circuits to electrical faults of individual components. Furthermore, circuits are equipped with a large number of instrumentation wires, which are exposed to accidental damage or swapping. In order to ensure safe operation, an Electrical Quality Assurance (ELQA) campaign is needed after each thermal cycle. Due to the complexity of the circuits, as well as their distant geographical distribution (tunnel of 27km circumference divided in 8 sectors), suitable software and hardware platforms had to be developed. The software combines an Oracle database, LabView data acquisition applications and PHP-based web follow-up tools. This paper describes the software used for the ELQA of the LHC.

INTRODUCTION

A great diversity of circuits and configurations met in the LHC machine forces the use of several software technologies within one application.

This quality assurance system was developed in parallel with the machine assembly. It was expected to verify the correctness of many parameters that have never been measured before and thus be able to quickly adapt to the new circumstances. Therefore, the set of measurements and the acceptance criteria were expected to change as the installation and development works were progressing.

A flexible software platform had to flawlessly drive the dedicated hardware [1], stay in accordance with the machine layout and safely store the measured values, while allowing a central management of the full software structure.

TEST FAMILIES

The applications have been divided into three families: TP4 (Test Procedure 4) for superconducting circuits powered via the DFBs (Distribution Feed Boxes), DOC (Dipole Orbit Corrector) for locally powered superconducting orbit correctors and MIC (Magnet Instrumentation Check) for local magnet voltage pickups and quench heaters. Hardware setup for each type of tests has been described in [1].

DATABASE

A database system constitutes a core of each application. It is used in order to read application settings and store measured values. As there is no access to the

network at the measurement positions each system is working on a local database (MS Access). After coming back to the surface infrastructure it synchronises its local database with the centrally hosted Oracle storage: the measured values are copied in the Oracle structure; all the settings used for the tests in the tunnel as well as the most recent layout of the machine are copied from the Oracle to the local database.

Communication between LabVIEW applications and databases is done using ODBC technology.

Some tables located in the central database have no correspondence in local MS Access files. Those tables are used by web applications. Central database includes also a number of synonyms which are pointing to views in LHC Layout database. Such synonyms are used as reference data sources for all our applications. Currently central database consists of over 80 tables.

DATA ACQUISITION

The hardware part of the measurement system as well as the user interface for the test benches are driven by a set of LabVIEW applications. Families of aforementioned applications are further divided into separate sub programs for specific types of tests like high voltage insulation tests, AC transfer function measurements, or DC ohmic parameters measurements. Typical window of measurement sub program is presented on Figure 1.

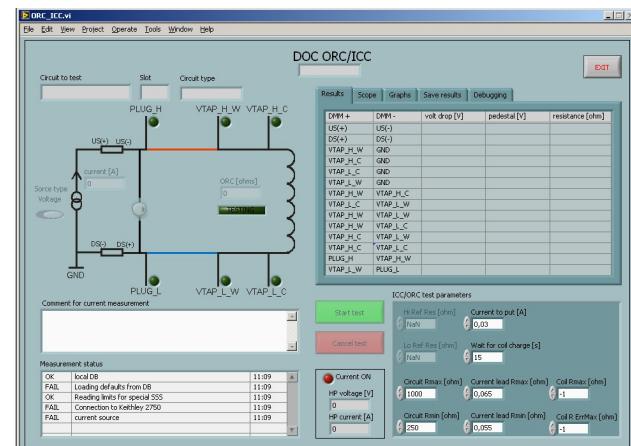


Figure 1: DOC Instrumentation Continuity Check application window.

Each data acquisition application is launched via special panels that help the user to identify the tested circuit and perform proper connections. Figure 2 presents a window of one of such panels.

Panels are designed in a way which makes skipping of the measurement by mistake impossible. Test object lists are ordered by the physical position in the LHC tunnel.



Figure 2: MIC Test Launcher, with list of available magnets to be tested and information about hardware connections that are required to perform tests on a selected magnet.

SYSTEMS' FLEXIBILITY

There were several issues that had to be kept in mind when developing the test applications for the TP4 family:

- There exist many types of circuits with different kinds of diagnostic connectors and various types and numbers of current leads.
- At the development's starting point it was not clear which signals should be measured and which precision was needed.
- A very flexible way of validating the results was needed as the acceptance criteria had to be adjusted together with the measurement campaign progress and more statistics becoming available.

Taking into account those requirements it was decided to create an application which makes use of independently prepared test scripts and validation scripts. The idea of test scripts is presented on Figure 3.

The scripts are stored in the central database. A dedicated tool can be used by a manager in order to create and store a correct script. The script is then copied to the local database of each test bench as soon as their network connection is established.

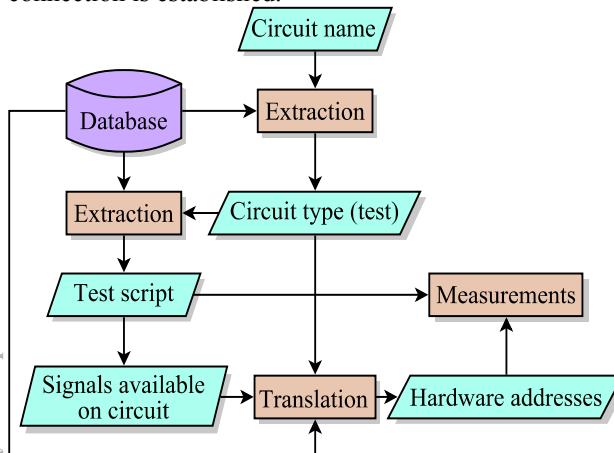


Figure 3: Signal translation in low voltage test applications.

The application determines the type of a given circuit based on the circuit's name and lookup table and extracts

the proper test script. Then based on the type, it translates the signal names available on the circuit into the hardware addresses of the measurement system. This translation is used when parsing the test script. Like this no specific information is hard-coded in the source code. Adding tests, measurements and introducing new connector pin-outs is as easy as adding new records in the database.

A similar idea was applied to the verification criteria of recorded values. The great complexity of the cabling requires taking different criteria for each circuit type. As already mentioned the acceptance thresholds were often modified in order to follow the best, growing knowledge about the qualified circuits. Furthermore checking the correctness of electrical connections in the circuit often requires evaluating several mathematical formulas. Therefore the application responsible for the validation process is equipped with a mathematical formula parser.

Figure 4 shows dataflow used during the measurement results verification.

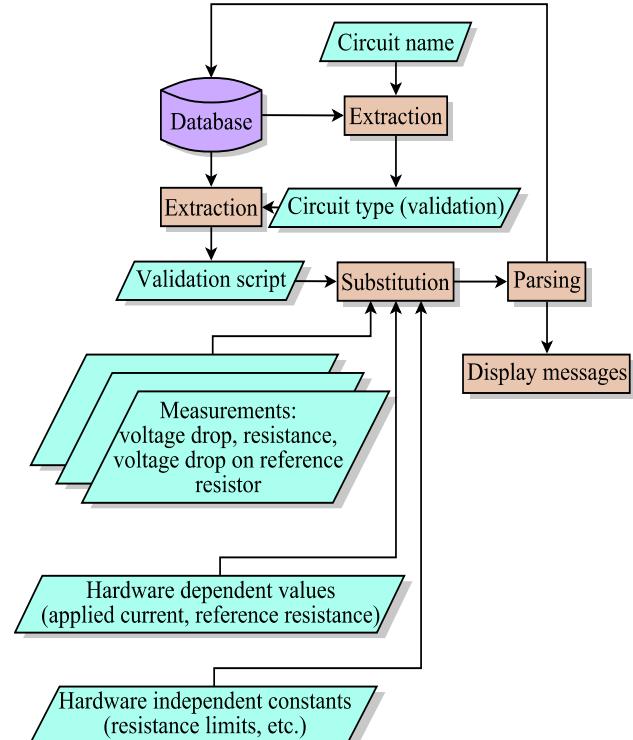


Figure 4: Measurement results validation process.

The most important data stored in the validation script are: left and right value saved in a form of mathematical expression containing test specific variables, comparison operator between left and right value, short information about the circuit property that is being checked and a message to be displayed in case the comparison of left and right values has failed.

TESTS FOLLOW UP AND REPORTING

Each application family has its own set of web pages used to check the current status of tests, analyse results and modify or add nonconformities data. Example of TP4 follow-up page is shown on Figure 5.

| Tools | DFB | Circuit | IRC | ICC | TFM | TFM vs GND | HVQ | Flag | Comments |
|-------|-----------|-----------|-----------------|--------|---------|------------|--------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ✓ T | DFBAD.7R2 | RB.A23 | OK | OK | OK | OK | OK (2) | | Tests after nQPS cables refurbishment in sector 2-3 (1) 18/01/10: Old QPS HV test in C21R2: 1900V, 2min, 411 GOhm/ 4.72 nA, 1900V, 2min, 205 GOhm/ 9.40 nA Test successfully repeated after repair, on the 20/01/10. |
| ✓ T | DFBAD.7R2 | RCD.A23B1 | OK | OK | OK | OK | OK | | |
| ✓ T | DFBAD.7R2 | RCD.A23B2 | OK (3) | OK | OK | OK | OK | | |
| ✓ T | DFBAD.7R2 | RCO.A23B1 | OK | OK | OK | OK | OK | | Tests at cold in sector 2-3 (1) IRC Failed. Voltage limit is 1.05 times higher than 0.21 of current limit. It is 1.5 ton higher (4.3 instead of 1.20hm). Diagnostic is ongoing. NC 1003638 Diagnostic showed that the problem is coming from connector P93-1, Pin 1, at the level of PE. A new canon bin replaced the old one (bad contact). Test repeated and passed. NC closed. |
| ✓ T | DFBAD.7R2 | RCO.A23B2 | OK | OK | OK | OK | OK | | |
| ✓ T | DFBAD.7R2 | RCS.A23B1 | FAILED (1 of 3) | OK | OK | OK | OK | | tests completed |
| ✓ T | DFBAD.7R2 | RCS.A23B2 | OK | OK | (2) | OK | OK | | |
| ✓ T | DFBAD.7R2 | RQ10.R2 | OK | OK | (3) | OK | OK | | |
| ✓ T | DFBAD.7R2 | RQ6.R2 | FAILED (1 of 2) | OK | (3) | OK | OK | | tests completed |
| ✓ T | DFBAD.7R2 | RQ7.R2 | OK (2) | OK (2) | (6) (2) | repaired | OK | | tests completed |
| ✓ T | DFBAD.7R2 | RQ8.R2 | OK | OK | (3) | OK | OK | | tests completed |
| ✓ T | DFBAD.7R2 | RQ9.R2 | OK | OK | (3) | OK | OK | | |
| ✓ T | DFBAD.7R2 | RQD.A23 | OK | OK | OK | OK | OK | | Tests at cold in sector 2-3 (1) Test is OK. Tests at cold in sector 2-3 (1) IRC test completed. No error above limit, and issue about stability and filter on RQD and RQD. |

Figure 5: TP4 Follow-up page.

Access to the web pages is controlled via CERN's authentication system. After authorisation the web application is checking user permissions. A certain group of users is allowed to add or change data. All the others are only allowed to view. Any data change made via the web page is logged.

In case of tests where the result is represented as a set of multiple values, the user can export the data in a Comma Separated Values format by clicking the proper link on the test results page. For some measurements, where many identical objects are tested (e.g. quench heaters) web based statistical analysis tools were created.

In addition, a set of LabVIEW report generating programs was created, which can be used to prepare well formatted MS Word documents containing a complete history of the selected circuit within the selected LHC commissioning campaign. Such a document can be then printed and used during an intervention on site.

OTHER TASKS

Having many LabVIEW applications installed on many computers combined with the fact that most of the applications are under constant development it was necessary to create a tool that would help to deploy the new software versions.

The package manager is an application used for installation and update of the ELQA software. It is a batch script that can be started on any MS Windows machine. The script uploads test data to the central database, creates a back-up of the currently installed software, installs the most recent released version and downloads the most recent test parameters. Most of those operations are performed by calling old or freshly downloaded LabVIEW applications with proper command line parameters.

The log of the operation is available for the administrators so that all the errors can be easily tracked.

CONCLUSIONS

The very difficult and complex task of performing the electrical quality assurance of a big prototype machine such as the LHC was successfully accomplished thanks to the described software tool-chain.

The applications are based on a centrally managed database system that automatically propagates the machine layout changes, safely stores the measured data and allows a follow-up in order to avoid accidental omitting of some tests.

The three application families described in this paper are utilising over 500 LabVIEW Virtual Instruments created for the LHC electrical circuits' tests.

FURTHER WORK

Currently the hardware part of the measurement system is being upgraded in view of the upcoming long shutdown in the LHC. As new functionalities and improvements will be added, the software upgrade will follow.

In the future it is planned to add more web based statistical analysis tools. Another planned web application type are tools for easy tracking of circuit parameters change over whole time of LHC operation.

ACKNOWLEDGEMENTS

The authors would like to thank their supervisors for the great opportunity of taking part in the commissioning of the LHC. Also they would like to express their gratitude to the colleagues that supported the development of the system with clever hardware solutions without which the software would not exist. A great number of collaborators from CERN and IFJ-PAN have taken part in the measurements in the LHC tunnel and acted as testers providing the developers with precious comments and hints.

REFERENCES

- [1] A. Kotarba et al., "Automatic Measurement System for Verification of the LHC Superconducting Circuits", IPAC'11, San Sebastian, September 2011, TUPS093; <http://www.JACoW.org>.
- [2] D. Bozzini et al., "Automatic system for the D.C. high voltage qualification of the superconducting electrical circuits of the LHC machine", EPAC'08, Genoa, June 2008, WEPD008. p. 2416; <http://www.JACoW.org>.
- [3] A. Kotarba et al., "Electrical quality assurance of the superconducting circuits during LHC machine assembly", EPAC'08, Genoa, June 2008, WEPD016. p. 2440; <http://www.JACoW.org>.