# THE MICROSERVCIES OF CERN'S CRITICAL CURRENT TEST BENCHES

P. Koziol, C. Barth, J. Fleiter, S. Hopkins, H. Reymond, C. Charrondiere, A. Ballarino, O. Ø. Andreassen, T. Boutboul
CERN, Geneva, Switzerland

## ABSTRACT

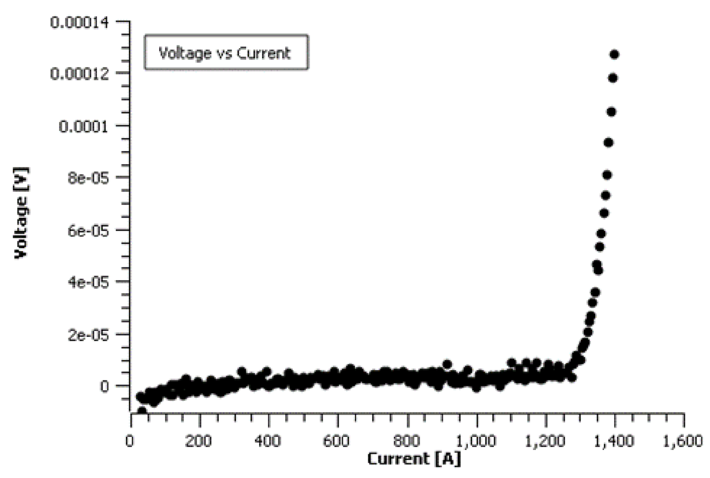
In order to characterize the critical-current density of low temperature superconductors such as niobium–titanium (NbTi) and niobium–tin (Nb3Sn) or high temperature superconductors such as magnesium-diboride MgB2 or Rare-earth Barium Copper Oxide REBCO tapes, a wide range of custom instruments and interfaces are used.
The critical current of a superconductor depends on temperature, magnetic field, current and strain, requiring high precision measurements in the nano Volt range, well-synchronized instrumentation, and the possibility to quickly adapt and replace instrumentation if needed. The microservice-based application presented in this paper allows operators to measure a variety of analog signals, such as the temperature of the cryostats and sample under test, magnetic field, current passing through the sample, voltage across the sample, pressure, helium level etc

During the run, the software protects the sample from quenching, controlling the current passed through it using high-speed field programmable gate array (FPGA) systems on Linux Real-Time (RT) based PCI eXtensions controllers (PXIe). The application records, analyzes and reports to the external Oracle database all parameters related to the test.

In this paper, we describe the development of the microservice-based control system, how the interlocks and protection functionalities work, and how we had to develop a multi-windowed scalable acquisition application that could be adapted to the many changes occurring in the test facility.

## INTRODUCTION

The upgrade project for the Large Hadron Collider (LHC) aims to achieve higher luminosity, necessitating the use of superconducting magnets with higher magnetic fields, for which Nb3Sn was chosen as the conductor material of choice. It's worth noting that Nb3Sn is more brittle and challenging to manufacture into cables compared to the NbTi conductor material used in the current LHC magnets.
Additionally, this high luminosity LHC project (HL-LHC) includes the installation of eight Superconducting Links (SC) comprised of high-current magnesium diboride (MgB2) cables cooled by helium gas, and connected to rare-earth-barium-copper-oxide (REBCO) cables that can operate at 60K.

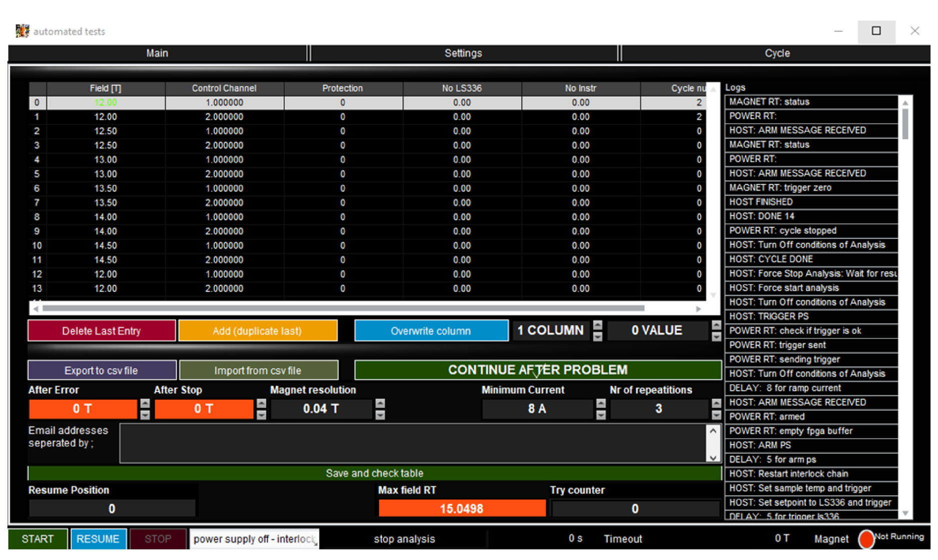



To ensure the proper assembly of these various wires and tapes, especially for the creation of Rutherford cables for magnets and round cables for the SC Link, comprehensive characterization of these materials is crucial. The critical-current density (Jc) is the main parameter for assessing superconductors, and depends on various factors such as temperature, strain, and magnetic field. The most effective method for measuring the critical current is the transport method, in which current flows through the sample, and the voltage is measured along its length.
To compare different superconductors, the critical current (Ic) is divided by the cross-sectional area (A) of the conductor, defining the critical current density (Jc)

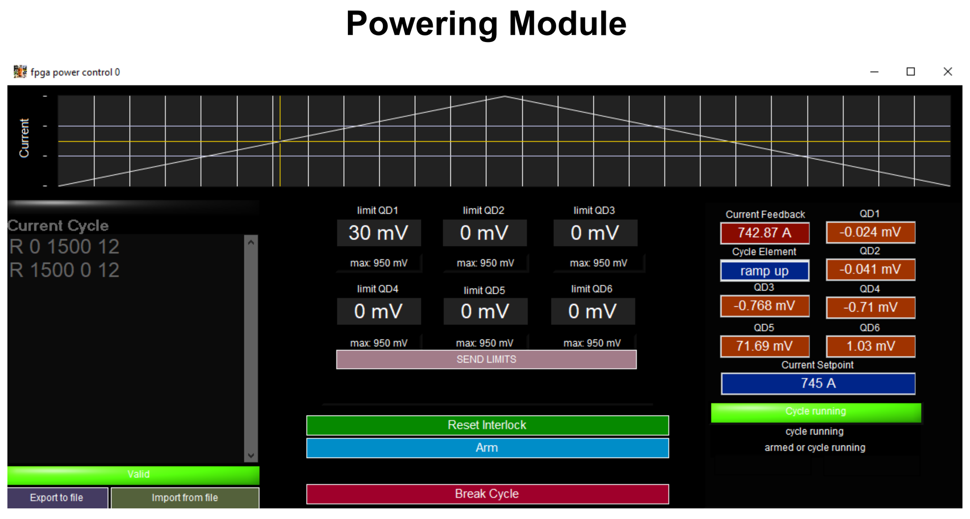
Historically, four smaller cryostats were employed to test the critical current density of superconductive strands, while one large cryostat was dedicated to FRESCA (Facility for the Reception of Superconducting Cables) for characterizing the critical current of superconductive cables.
The existing measurement systems used in these test benches had become outdated, relying on older computers running SELinux and LabVIEW® 2012. Furthermore, the need to incorporate two systems for characterizing High Temperature Superconductor (HTS) tapes and the introduction of a new FRESCA2 system prompted a renovation campaign in 2020. In this paper, we will elaborate on the new demands and developments associated with this campaign.

## DEVELOPMENTS

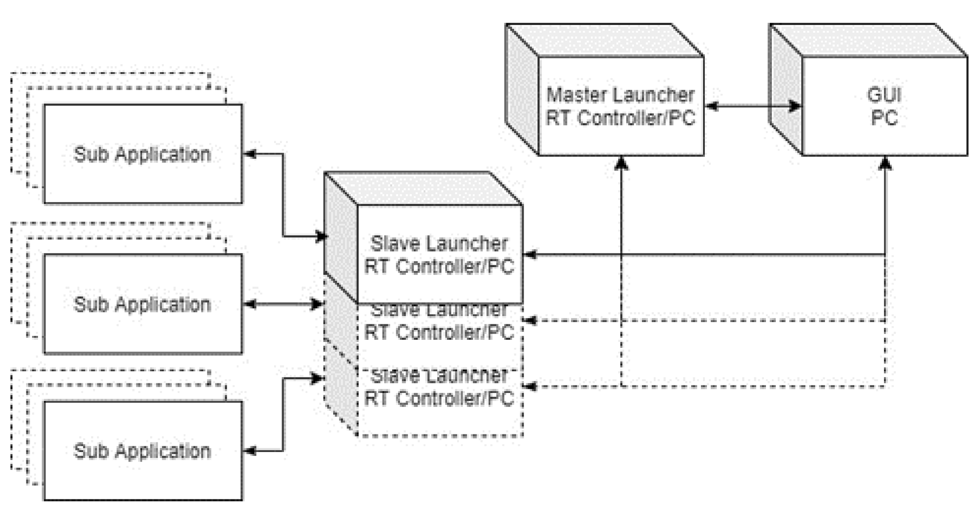
### Sequencer



### Powering Module

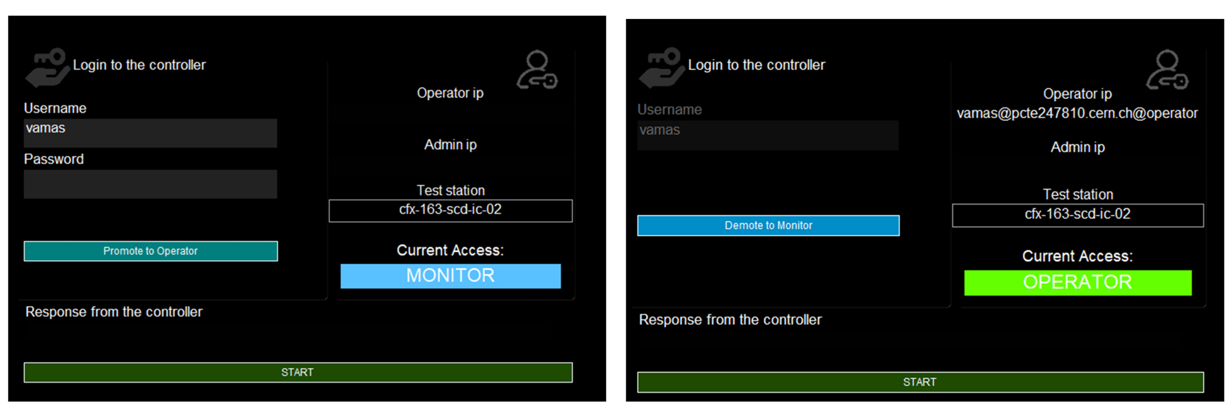


### Microservice Application




The user interface application can be compiled and run on any Intel x86 based computers running Windows or Linux operating systems. At the start of the application the software requires users to enter correct credentials for the operation or monitor.

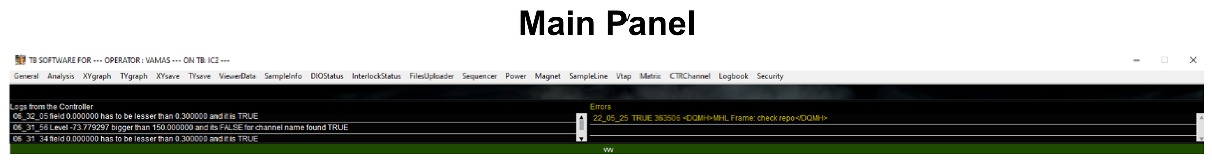
### Login Control




When correctly logged in, the software subscribes to the master launcher to obtain information of each module running on any of the controllers. If found, it tries to establish communication with all data channels as well as to the channel information. The master launcher also publishes the information about the host panels allowed to operate selected test bench, to block the possibility of operators controlling the hardware that is not connected to the specific test bench.

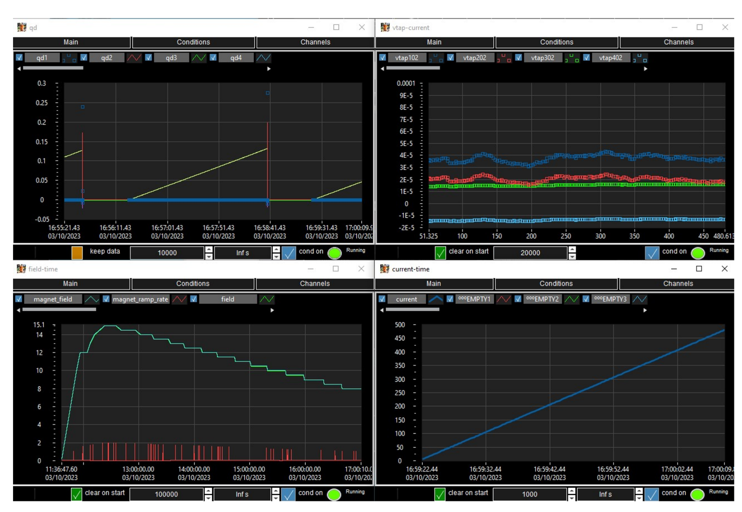
If all the conditions are met, the software opens all host config files which location is connected to the account. The software is reading and checking the files to verify that all data channels specified by the operators exist on RT application and highlights those that are not valid.

### Main Panel



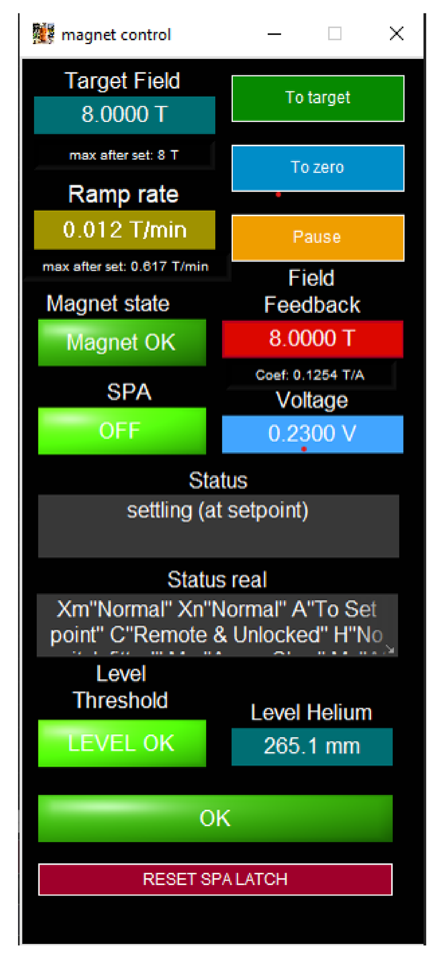
The software continuously analyses which modules are allowed to run by the type of operation, for example user monitoring the test bench should not be allowed to run the power supply panel, and if user is demoted during the operation, it should close operational and configuration panels.

### Signal Viewers

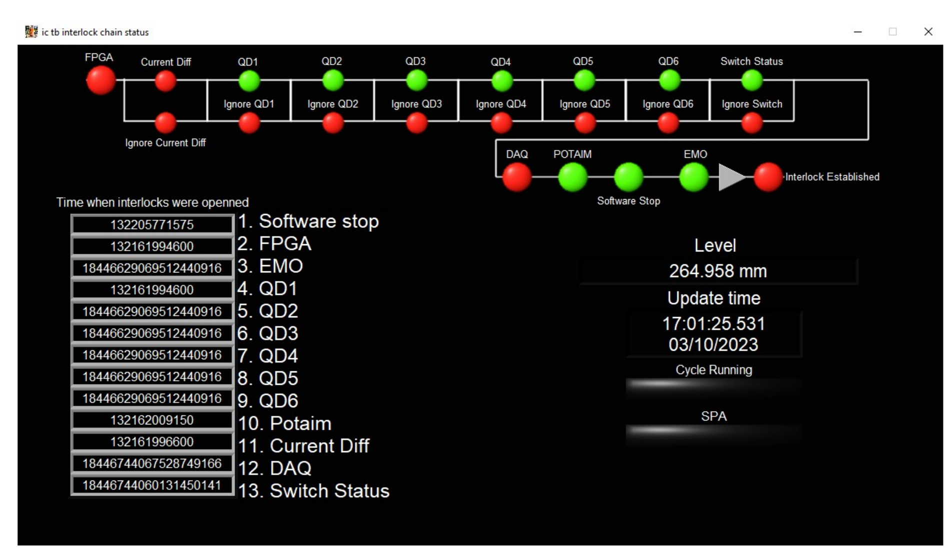


All the users can run monitoring modules such as time value plots, or time value saving modules, where the users identify signals to plot or to save. The operators can run modules to show sample power, magnet power, interlock security control or control channel to have a full control of the program during the test.

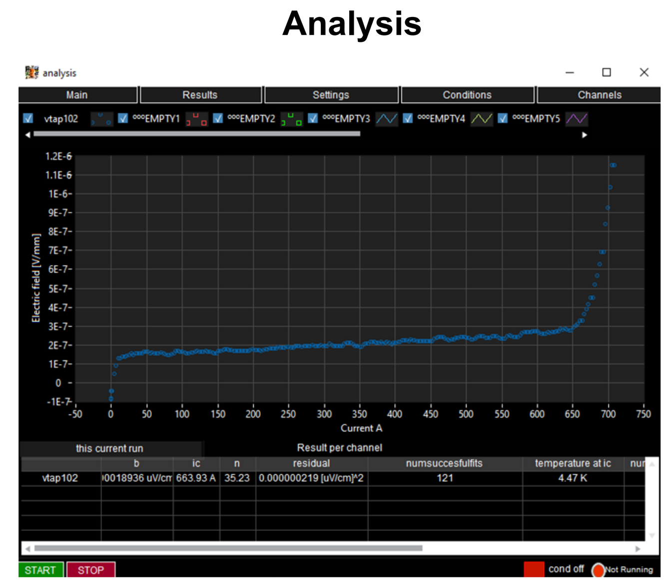
### Host Magnet Control




### Interlock Security Viewer




### Analysis



## CONCLUSIONS

The microservice based software for characterizing superconductors has been successfully implemented, commissioned, and deployed at CERN. It can effectively evaluate both low-temperature superconductors such as NbTi and Nb3Sn, and high-temperature superconductors such as MgB2 or REBCO, both before and after the production of superconducting cables.

The automated nature of these tests empowers operators to conduct more tests and, consequently, evaluate a larger number of samples. These automated tests now perform the stable testing of approximately 200 measurements per day.

Integrating additional hardware into the system is now a straightforward process via the GOOP based scalable architecture and abstraction layer. In case of any issues, each submodule can be independently tested, helping identify and resolve potential problems.

Currently, the application has been operational for a year without any significant disruptions affecting its performance.