A SAFETY SYSTEM FOR EXPERIMENTAL MAGNETS BASED ON COMPACTRIO

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PH-DT
Detector Technologies

Introduction

The design of the custom Magnet Safety System (MSS) for the large LHC experimental magnets began in 1998 and it was first installed and commissioned in 2002. Some of its components like the isolation amplifier or ALTERA Reconfigurable Field-Programmable Gate Array (FPGA) are not available on the market any longer.
A review of the system shows that it can be modernized and simplified by replacing the Hard-wired Logic Module (HLM) by a CompactRIO device (Fig.1). This industrial unit is a reconfigurable embedded system containing a processor running a real-time operating system (RTOS), FPGA, and interchangeable industrial I/O modules.
A prototype system, called MSS2, has been built and successfully tested using a test bench based on PXI crate. Two systems are currently being assembled for two experimental magnets at CERN, for the COMPASS solenoid and for the M1 magnet at the SPS beam line.

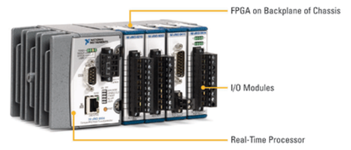


Figure 1 : CompactRIO

Upgraded Magnet Safety System (MSS2)

MSS Structure

An analog interface ACS containing the safety measurement channels, deciding whether a safety parameter has been exceeded, thus generating an alarm. Detections are made with 3 purpose-built signal condition modules:

- A dual/differential voltage detection module - DVM
- A dual bridge measurement module -DBQD
- A dual resistive measurement module - DRM


Figure 2 : DVM


Figure 3 : DBQD


Figure 4 : DRM

A logical decision unit LCS determining the current machine status based on received parameters and alarms. The main electronic card of this unit is the Hard-wired Logic Module - HLM based on ALTERA FPGA.

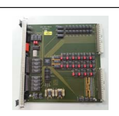
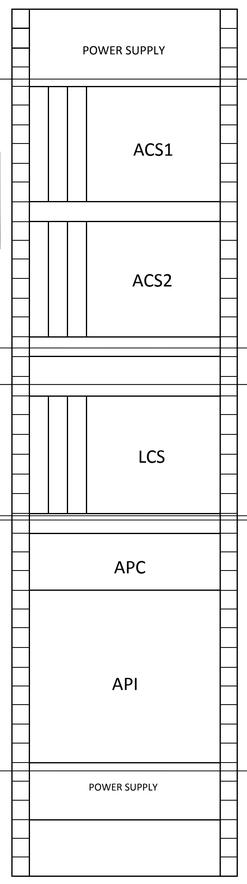
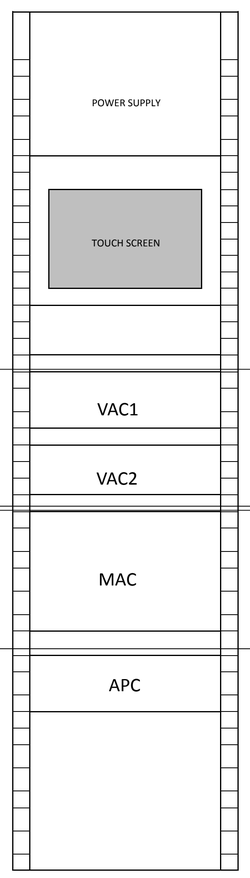


Figure 5 : HLM

An application interface API/APC between the logic unit and the actual machine which is the magnet with services. This interface controls main breakers, quench heaters, power converter, etc.



MSS2 Structure



VAC module: Versatile Analogue Chassis, Analogue 3U chassis containing 8 Versatile Analogue Modules - VAM (2 or 4 channels), interfaces and redundant power supplies.


Figure 6 : VAM

MAC module: Main Chassis, Principal 6U chassis of the MSS2 system; contains CRIO controller, interfaces and redundant power supplies


Figure 7 : MAC

Diagnostic Tools

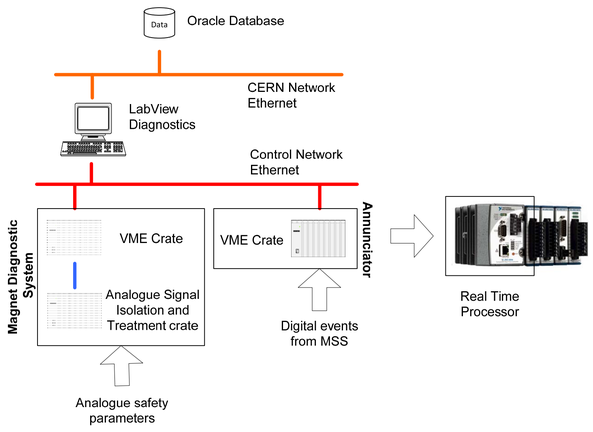


Figure 8: MDS and Annunciator Architecture

For post analysis, there are two VME-based systems for data acquisition, as shown in Fig.8:

- The Annunciator is a fast digital data acquisition with a resolution of 1 ms, storing all logical events from MSS to be able to discriminate events clearly,
- The Magnet Diagnostic System (MDS) provides from the analog safety parameters a slow data acquisition at a rate of 1 Hz and a post-mortem file after a magnet quench (1mn before and 5 mn after at a rate of 100 Hz)

For MSS2, the annunciator and MDS for small application is implemented in the real-time embedded processor.

MSS2 Test Bench

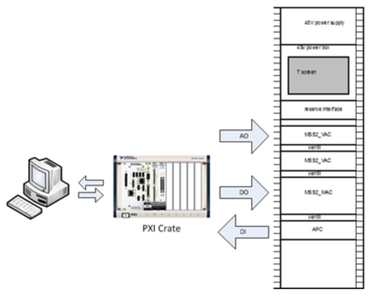


Figure 9: Test Bench structure consisting of a PXI Crate with analogue and digital cards connected to the MSS2 rack.

MSS2 racks are built and tested in-house. A test bench has been developed to test the hardware elements (internal cabling, crates) and the response of the system to digital or analogue stimulus (Fig.9).
This test system is based on PXI Crate with Analogue and Digital Cards and permits carrying out tests in manual or automated modes.

IMPLEMENTATIONS OF MSS2

M1 magnet at the SPS beam area

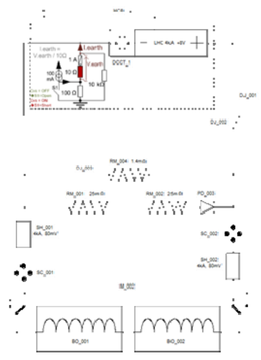


Figure 10 : M1 Electrical Circuit

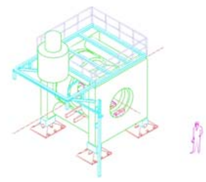


Figure 11 : M1 Magnet

The M1 magnet at the SPS beam area is a 40 years old magnet composed of two superconductive coils in different cryostats. It provides 3T on axis in the center.

The parameters included in MSS2 for magnet protection are:

- Foot current leads temperatures
- Helium level for each cryostat
- Voltage of each coils
- Bus bars temperatures

The Compass magnet system

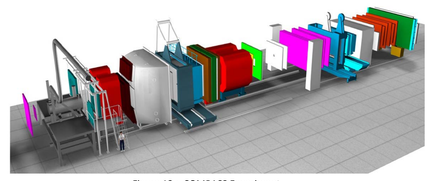


Figure 12 : COMPASS Experiment

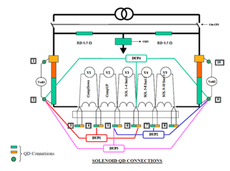


Figure 13 : Solenoid Electrical Circuit

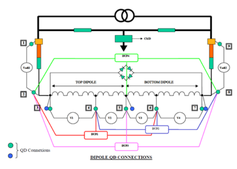


Figure 14 : Dipole Electrical Circuit

A set of magnets is used to polarize a target for physics. In the axis of the solenoid, it provides a 2.5 T magnetic field.

The COMPASS magnet system is composed of several units, all in the same cryostat.

- 1 solenoid (Inom = 660A, L = 12.65H)
- 1 dipole (Inom = 590A, L= 2.6H)
- 16 correctors magnets (Inom < 15A)

The quench detection system has been designed as follows:

For the solenoid (Fig.13):

- 4 bridges DUP1, DUP2, DUP3 and DUP4
- 2 voltages of the current leads Vadi1 and Vadi2
- 1 SQD for each Current Lead

For the dipole (Fig.14):

- 3 bridges DUP1, DUP2, DUP3
- 2 voltages of the current leads Vadi1 and Vadi2
- 1 SQD at the bottom of each CL

Conclusion

The evolution of MSS to MSS2 permits to:

- Reduce the system size by integrating the annunciator in the cRIO processor and a new design of the analogue card,
- Simplify and improve system maintenance by limiting the number of custom analogue cards to one and integrating industrial material like cRIO.