THE DETECTOR SAFETY SYSTEM OF NA62 EXPERIMENT

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Abstract

The aim of the NA62 experiment is the study of the very rare decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ at the CERN SPS. The Detector Safety System (DSS) developed at CERN is responsible for assuring the protection of the experiment's equipment. DSS requires a high degree of availability and reliability. It is composed of a Front-End and a Back-End parts, the Front-End being based on a National Instruments cRIO system, to which the critical safety part is delegated. The cRIO Front-End is capable of running autonomously and of automatically taking predefined protective actions whenever required. It is supervised and configured by the standard CERN PVSS SCADA system. This DSS system can easily adapt to evolving requirements of the experiment during the construction, commissioning and exploitation phases. The NA62 DSS is being installed and has been partially commissioned during the NA62 Technical Run in autumn 2012, where components from almost all the detectors as well as the trigger and the data acquisition systems were successfully tested. The paper contains a detailed description of this innovative and performing solution, and that can be considered as a good alternative to the LHC systems based on redundant PLCs.

INTRODUCTION

The NA62 experiment at CERN [1] consists of the order of eleven sub-detectors with dedicated services like power, cooling, gas supply, environmental monitoring. A novel Detector Safety System has been designed to detect possible operational problems, take preventive actions, and to sense potentially dangerous situations at an early stage to bring the concerned systems into a safe state.

The DSS system should be:

- Reliable, simple, robust, and 100% available.
- Able to take immediate action to protect equipment.
- Maintainable over the lifetime of the experiment.
- Flexible and easily configurable.
- Supervised via PVSS.

The DSS in the LHC experiments [2] [3] is based on two redundant Siemens PLC for the front-end and a PVSS SCADA for the back-end (Fig. 1). The two CPUs constantly compare their states and automatically detect abnormalities. In the event of a problem, only the "good" branch continues to operate.

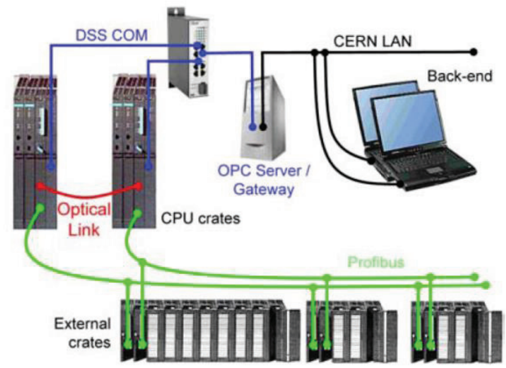

Figure 1: LHC Detector Safety System.

For the NA62 experiment, a new DSS front-end was developed using an innovative solution based on cRIO components of National Instruments. The supervisor remains based on PVSS SCADA in order to easily integrate it into the overall architecture of the experiment. The cRIO controller [4] fulfills all the requirements described previously, offers additional advantages:

- As it is based on FPGAs there is no need of redundancy, and therefore it implies a significant cost reduction.
- The development time is reduced, indeed only the safety matrix programming is needed.
- The process treatment is faster (less than 1ms, i.e. around 20ms for the PLC).

DSS REQUIREMENTS

The NA62 experiment is composed of several sub-detectors installed underground the CERN SPS north area (Fig. 2). For each sub-detector, high and low voltage equipment is installed in racks placed very close to the sub-detectors. This very sensitive equipment must be stopped in case of abnormal conditions, as described below.

The NA62 DSS system is required to check:

- The temperatures of 40 electronic racks installed along the experiment in TCC8 and ECN3 (Fig. 2). A first level alarm releases an interlock to the equipment installed in the rack in order to switch it off. If the temperature continues to rise reaching the second alarm level, the power of the entire rack will be cut (power cut in a rack may cut more than one rack). The temperature alarm thresholds are configurable from the PVSS supervisor.
- The vacuum conditions of the NA62 decay volume ($\approx$500 m^3) generating an interlock for the LAV HV controllers, if the vacuum conditions are not good

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(10^{-4}mb < P < 900mb) LAV HV equipment switch it off to avoid discharges.
- The digital status of three radiation monitors in surface building where are situated the NA62 control room and the Data Acquisition System. These alarms mean the evacuation of personnel in surface buildings.
- The Level 3 alarms in the experimental area: fire, fast stop emergency, evacuation and oxygen deficiency.
- The status of the gas for the Straw Tracker, with generation of an interlock in the relevant racks and to transmit any fault or alarm condition to the PVSS supervisor.
- The redundant power supplies of the DSS front-end electronics generating an alarm on the PVSS supervisor in case of problem with one of the two redundant power supplies.
- The status of the 220V power distribution (canalis) in TCC8 and ECN3.

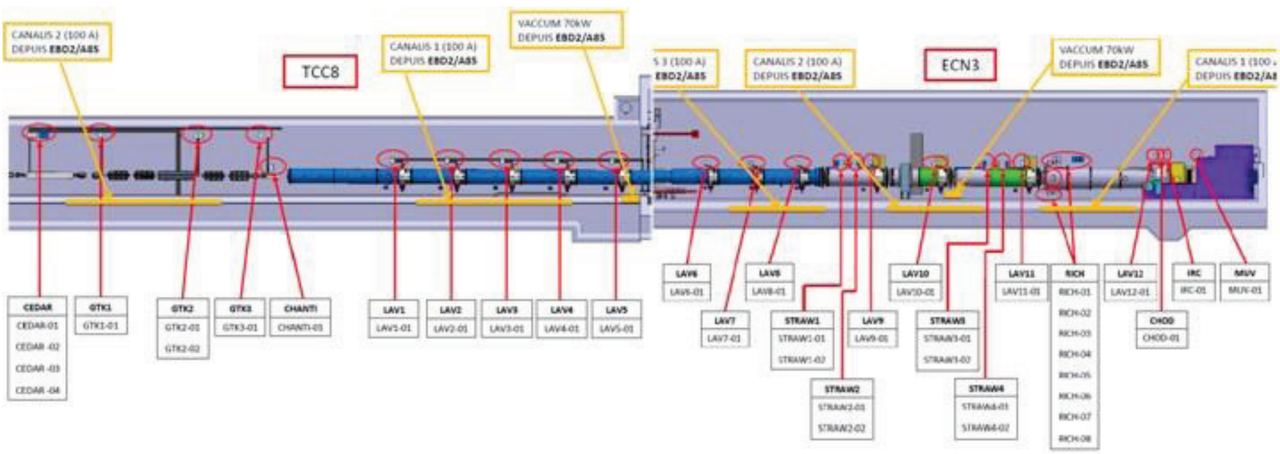

Figure 2: Layout of NA62 sub detectors.

IMPLEMENTATION

Architecture

Figure 3 shows the architecture of the DSS system. Due to the safety requirements for the system, the connections between sensors/actuators and the front-end are made hardwired. The safety matrix in the cRIO controller is programmed in an FPGA and the data exchange with the supervisor is made with a real time processor via a communication bus (Modbus TCPIP). Thus any communication problem between the supervisor and the real time processor of the cRIO does not affect the safety system. The supervisor is a PVSS SCADA application and all data are stored in a data server.

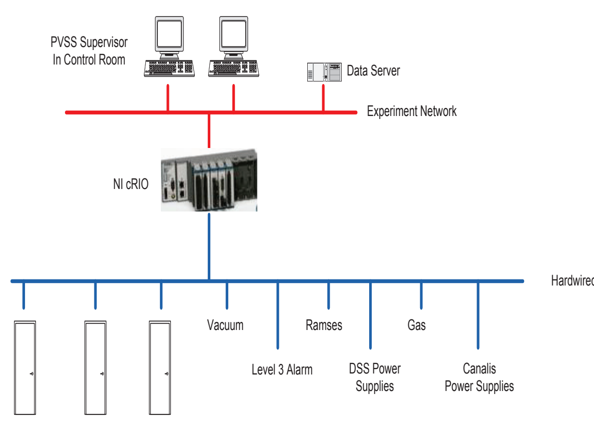

Figure 3: DSS Architecture.

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Sensors and Actuators

The connections between sensors and actuators in the underground experimental area and the cRIO acquisition system located in the surface have been hardwired.

All sensors and actuators follow the "Positive Safety" rule, thus in case of broken wires an alarm will be generated. All sensors and actuators are also powered by 24Vdc redundant power supplies, described in the next section.

A 3U chassis has been developed and installed in each rack located underground to survey each rack's temperature (Fig. 4). It contains a PT 100 temperature sensor and its safety controller; this controller (from JUMO) is able to transmit an analogue value 4/20mA that is proportional to the temperature sensor, and a digital information if the temperature is higher than a threshold level adjustable in the controller. This chassis is also equipped with an interlock relay that provides three free contacts by Lemo connectors to give an interlock signal to the sensitive equipment installed in the rack. Finally this chassis also has a function of patch panel to reduce the number of long cables to be installed between the surface and underground areas.

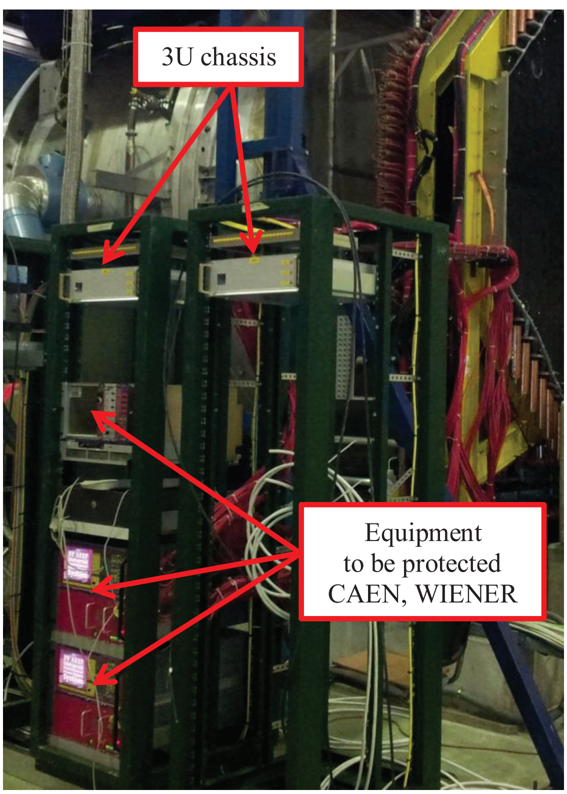

Figure 4: 3U chassis in experiment.

Hardware Front-End

The most critical part of the DSS system is the power supply of the acquisition system cRIO and sensors/actuators. In order to guarantee uninterrupted operation two redundant 24Vdc power supplies (Fig. 5) are used and supplied from an UPS. The 24Vdc power supply states are continuously monitored and generate an alarm on the DSS supervisor in case of a problem in one of the power supplies.

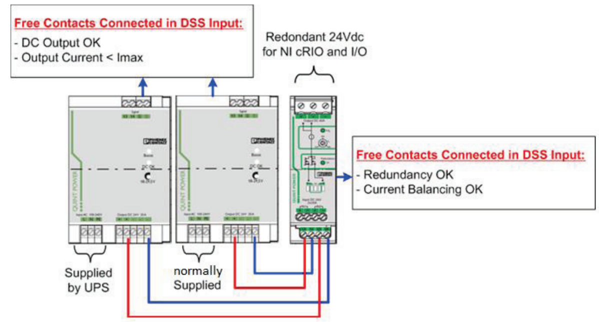

Figure 5: Redundant 24Vdc power supplies.

Safety Matrix

The conditions to trigger actions are defined by the GLIMOS of the experiment in collaboration with all sub detectors responsibles and the experiment technical coordinator. This document is used as source to programme the DSS frond-end.

Software Front-End

The communication between the back-end and the cRIO material has been realized by a Modbus TCP/IP protocol, it was therefore necessary to develop this communication in the real time controller of the cRIO.

The programming of the safety matrix was done in the Labview environment (Fig. 6). After compilation, the file is downloaded in the FPGA of the cRIO, and it can be easily modified in case the safety matrix would evolve.

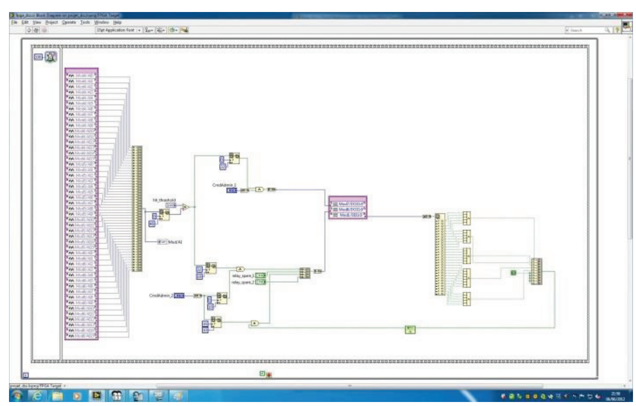

Figure 6: Labview VI Safety Matrix.

PVSS Supervisor Back-End

The human interface for the DSS supervisor must be PVSS SCADA which is the standard supervisor at CERN. The DSS back-end must be integrated in the general control architecture of the NA62 experiment in order to exchange data with other control systems.

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The communication between the PVSS SCADA and the cRIO materiel has been realized by a Modbus TCP/IP protocol. The advantage of this solution is that an OPC server is not needed, as compared with the DSS systems used in the LHC experiments.

The DSS supervisor must provide the following functionalities:

- Graphical user interface displaying sensors and actuators, their status, and graphs of status and values as a function of time.
- Display and acknowledgement of alarms (mode Monitor).
- Administration of settings, e.g. change of alarm thresholds (mode Admin).
- Generation of alarms.
- Send alarms per email or/and SMS.

Figure 7 shows the general PVSS interface with the functionalities described before.

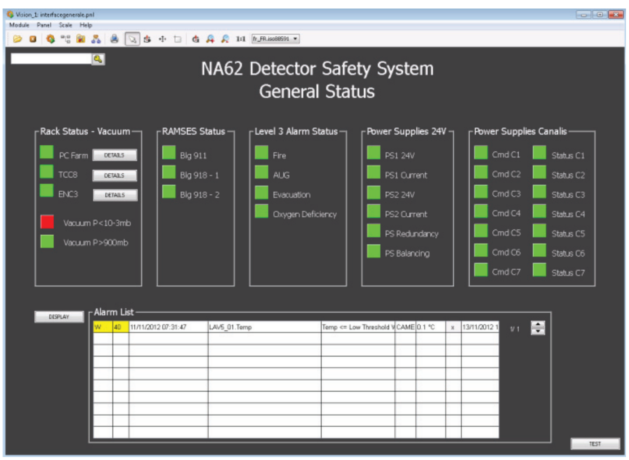

Figure 7: PVSS general interface.

Figure 8 shows the graph of a temperature versus time. In admin mode the thresholds level warning and alarm can be changed.

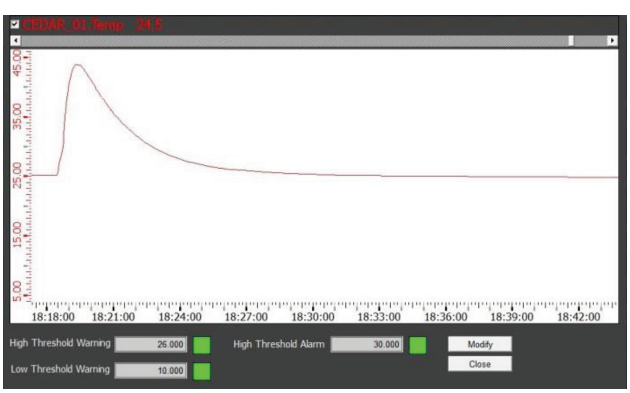

Figure 8: Temperature evolution and threshold.

Figure 9 shows the alarm screen accessible from the general interface with a complete list of alarms (date, status and message) and the possibility of acknowledgment.

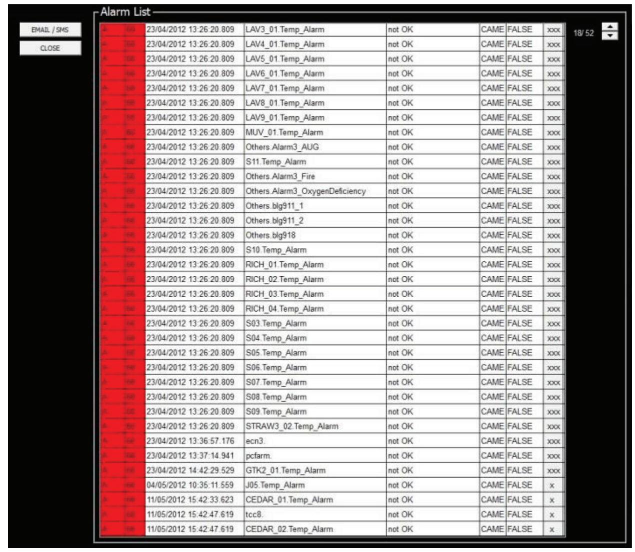

Figure 9: Alarm screen interface.

SUMMARY

The NA62 DSS system was installed and successfully tested during the Technical Run in autumn 2012.

The solution based on cRIO components from National Instruments has proven to be fully satisfactory for the requirements of a Detector Safety System. This is the first time at CERN that the standard PVSS supervisor is used with National Instrument as front-end.

The first experience during the Technical Run has shown that this architecture is appropriate and reliable, in particular during the vacuum commissioning where the DSS system has generated a large number of interlocks to the HV LAV. A PVSS warning message has also been reported following a JUMO temperature controller failure requiring the replacement of this element.

The full completion of the DSS system, which will include the information from all the sub-detectors of the NA62 spectrometer, will take place during 2014.

REFERENCES

[1] http://na62.web.cern.ch/NA62

[2] S. Lüders, R. B. Flockhart, G. Mopurgo, S. M. Schmeling, “The CERN Detector Safety System for the LHC Experiments”, ICALEPCS (2003).

[3] DSS Working Group, “A Detector Safety System for the LHC Experiments - Final Report,” CERN, Geneva, CERN-JCOP-2002-013, April (2002).

[4] http://www.ni.com/compactrio

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