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VERY HIGH VOLTAGE CONTROL FOR ALICE TPC

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ABSTRACT

The Time Projection Chamber (TPC) is the core of the ALICE (A Large Ion Collider Experiment) experiment at CERN. Its task is to track and to identify the particles after the collision. The ALICE TPC is an 88m^3 cylinder filled with gas and divided in two drift regions by the central electrode located at its axial centre. The field cage secures the uniform electric field along the z-axis [1].

The TPC Very High Voltage project covers the development of the control system for the power supply that provides the drift field in the TPC field cage.

This paper reports the project progress, highlighting the control system architecture and its security features.

INTRODUCTION

The TPC (Fig. 1) is the main tracking detector of the ALICE central barrel and, together with the other central barrel detectors, has to provide charged-particle momentum measurements [2]. Charged particles traversing the TPC volume ionise the gas along their path, liberating electrons that drift towards the end plates of the cylinder. Moving from the anode wire towards the surrounding electrodes, the positive ions created in the avalanche induce a positive current signal on the pad plane. The readout of the signal is done by the 570132 pads that form the cathode plane of the multi-wire proportional chambers located at the TPC end plates.

Under operating conditions the system must safely apply a DC voltage of 100kV to the central electrode placed half way between the two end plates of the detector. Four resistor rods like the one in Fig. 2 supply the proper potential to the Mylar strips of the potential degrader [3]. Each rod is composed of 167 resistors and the total resistance is $2.84 \cdot 10^8$ ohms.

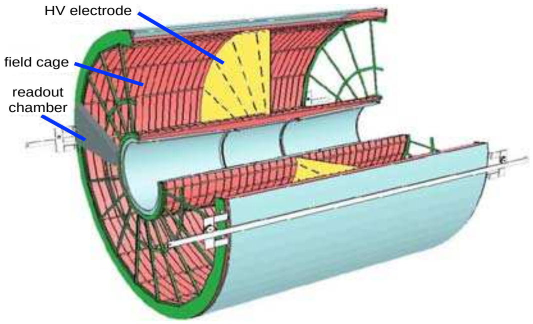

Figure 1 – ALICE TPC.

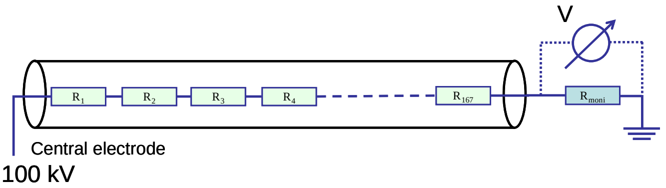

Figure 2 - Resistor rod.

The TPC Very High Voltage control system must provide and control the necessary voltage for creating drift field in the TPC field cage. The project includes: control system (CS) design based on end users' requests; PLC programming; interface building; SCADA (Supervisory Control And Data Acquisition) development.

PROJECT REQUIREMENTS

Features

The CS was developed following the TPC subsystems requirements [4], covering the following features:

- Control and monitoring of the High Voltage power supply,
- Monitoring of the current in the resistor rods,

- Control and monitoring of the cooling of the resistor rods,
- Monitoring of some additional equipment (e.g. strain gauges).

Voltage must be smoothly applied by a ramping. Each step of 10kV is followed by one minute pause during which the voltage is held while the system is checked (Fig. 3). After 50kV, check pauses last 2 minutes. During the periodical check pauses voltage and current over the resistor rods are verified. At any time, the control system checks the state of all the services used by the TPC (cooling, gas, UPS…). In the case of a problem, the control system performs a ramp down. This ramp down can be software-controlled (i.e. smoother and with pauses) or direct (i.e. performed by the power supplier itself - faster). The former is executed in case of low priority faults, the latter in case of severe faults. All the parameters (final voltage, ramping speed, nominal values…) are downloaded by the supervisory system and accepted by the control system only in predefined, safe states. Final voltage reaches 100kV after about 21 minutes ramping.

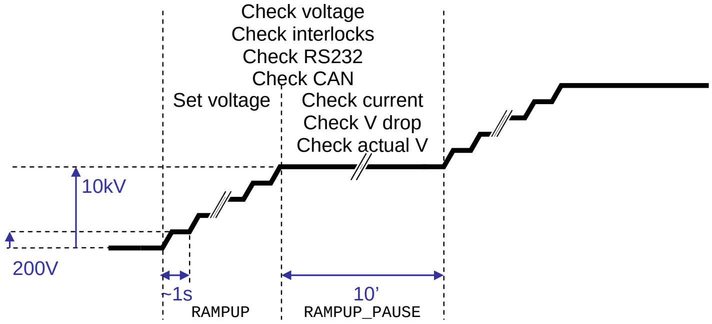

Figure 3 - Ramping up scenario.

Devices

The choice of the CS components was made in order to obtain features that can match the requirements.

Because of the reached high voltage, it is imperative to design a robust CS. In order to provide more reliability, the control system is totally independent; therefore, it can run as well in case of loosing supervision. For such a reason, a Programmable Logic Controller was preferred to a common PC, since its simple architecture grants more robustness at runtime. Also, as any industrial device, its spare components long term availability is more probable than for a PC. The chosen PLC is a Schneider Electric P575634M, which can support RS232 and CAN interface modules.

The very high voltage power supply (PS) is a Heinzinger P150000-2. It was customized by the manufacturer for the TPC needs: it is equipped with an internal ramping generator that limits the maximum variation of the output voltage. It has a RS232 digital interface for full control and an analog interface for reading status and sending emergency information (i.e. stop). During normal operation, the PLC controls the PS through RS232 interface. It retrieves the PS status also by dedicated inputs and outputs.

Twelve current monitoring (as voltage drop over the last resistor – see Fig. 2) are performed by an Embedded Local Monitor Board (ELMB) placed at each side of the detector. ELMB is radiation and noise insensitive, therefore more suitable than the analog inputs provided by the PLC. Communication between ELMB and PLC is done through CAN field bus, allowing to move the PLC away from the harsh detector environment.

SYSTEM OVERVIEW

Connections

The CS schema is visible in Fig. 4. It is connected to the PS via RS232 interface. This permits full control and monitoring of the power supply. The *digital interface* becomes active as soon as a message is sent from the CS. Nevertheless, for security reason a button in the PS must be pressed for allowing

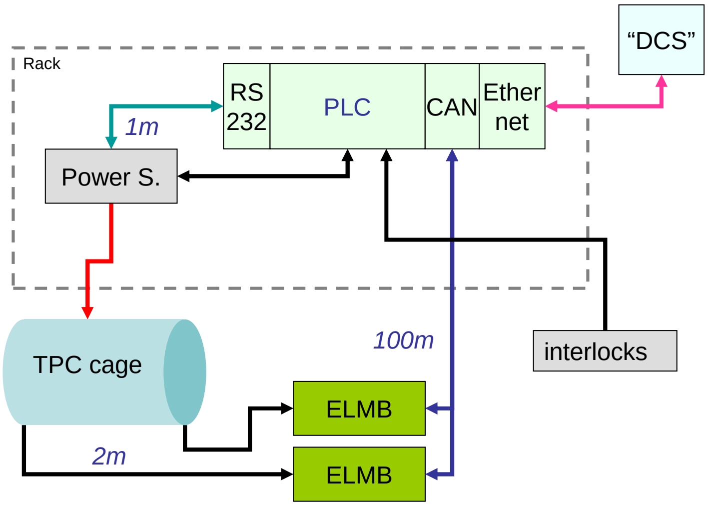

Figure 4 - System overview.

the remote control to set voltage values. In order to provide control redundancy in case of emergency, PLC and PS are as well connected through an analogical interface.

Status levels of relevant parameters for the operation of the PS are monitored through 13 interlocks (digital inputs). They provide status information about cooling water, UPS, gas condition and circulation.

PS is monitored through RS232 and through two ELMB. Each of the 12 ELMB channels is red by the PLC through CAN protocol [5].

Finally, the CS is connected to the SCADA system through TCP/IP.

Control Implementation

The system was developed in order to be independent from the supervisory level. In this way an interruption of the communication between PLC and SCADA will not stop the whole process. Its structure was designed in order to respect (where possible) the existing state diagram already implemented for High Voltage control at ALICE experiment. This will provide a more standard user environment when developing the PVSS interface using Final State Machine (Fig. 5).

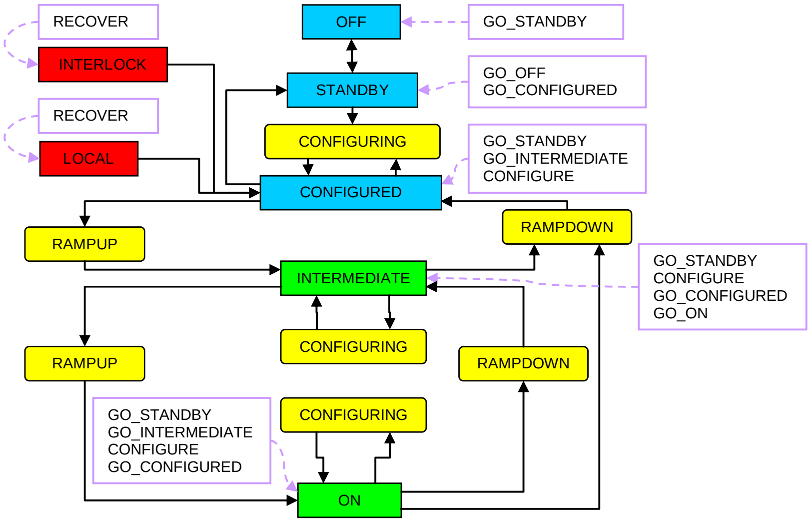

Figure 5 - Finite State diagram.

The control code was developed using the Schneider Unity environment. It is a mixture of structured text and SFC coding.

Security features

The CS performs proper reaction in case of a fault detection. Supervisory system is limited to monitor such reactions. However, after recovery, manual intervention is necessary in order to resume normal conditions.

Depending on their gravity, errors trigger the CS to two different behabiours. At any time, in case of an interlock bad condition, the CS performs a ramping down to 0 volts; this is a less severe fault and it can be resumed via operator intervention at SCADA level. After the problem is solved, it it immediately possible to rump up again the system. `LOCAL` state is an emergency state: if the CS sets the PS directly to `LOCAL` (i.e. 0V), no ramping down is performed and it requires a resuming intervention directly in the PS - no remote resuming is possible.

As an example, a voltage trip over one of the resistor rods or a malfunctioning in the CAN net trigger a ramping down. Other more severe errors, like RS232 communication failure, lead to `LOCAL`. Table 1 summaries the errors and the following reactions.

Error	Reaction	After Recovery
Any interlock is bad	Ramp down	Wait for sw resuming
Voltage trip	Ramp down	Wait for sw resuming
ELMB is not active	Ramp down	Wait for sw resuming
RS232 communication	Go to Local	Wait for hw resuming
Current trip	Go to Local	Wait for hw resuming
HV Output is off	Go to Local	Wait for hw resuming
Enable Set Value is off	Go to Local	Wait for hw resuming
PLC not running	Go to Local	Restart the system

Table 1 - Errors handling.

`RAMPUP` status is in reality composed of different sub statuses for generating the necessary ramping steps. For security reason, the PLC is ready to take configuration data only when in `STANDBY`, `INTERMEDIATE` or `ON` state.

An `INTERMEDIATE` state, tipically 50kV, is reached before getting to `ON`. Manual intervention is needed in order to continue ramping from 50 up to 100kV.

Since RS232 does not handle communication loss, the PS does not react in case of PLC fault. This problem was solved using a simple device that sets the PS to `LOCAL` if it does not receive a heartbeat signal from the PLC (digital output).

At each check pause, resistor rods’ current is compared to nominal values. A 12×11 matrix stores nominal values for each channel at each step of 10kV. Channel values are then compared to the nominal value relative to the current voltage. A trip leads to an ramping down. Intermediate values are interpolated.

CONCLUSION AND FUTURE WORK

First version of the CS is ready and tested. This will be used for the commissioning of the TPC in the end of this year. Work will continue on the development of the SCADA interface for integrating this subsystem into the Detector Control System (DCS).

Installation of the final CS is planned in the year 2006, well in time for the start of the ALICE experiment in 2007.

ACKNOWLEDGEMENTS

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REFERENCES

[1] C. Vanoli, “ALICE Time Projection Chamber”, CERN-Poster-2002-045, CERN, Switzerland, January 2002.

[2] ALICE Collaboration, “ALICE Technical Design Report of the Trigger, Data Acquisition, High Level Trigger and control System”, CERN, Switzerland, January 2004.

[3] A. Augustinus, “DCS User Requirements Document for the ALICE TPC Field Cage - Version 4”, CERN, Switzerland, December 2001.

[4] http://alicedcs.web.cern.ch/AliceDCS/Detectors/TPC/Fieldcage/OperationHeinzinger.doc

[5] H. Boterenbrood, “CANopen Application Software for the ELMB128”, NIKHEF, Netherlands, January 2005.