The Detector Control System for the HMPID in the ALICE Experiment at LHC.

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Abstract

The DCS (Detector Control System) of the ALICE experiment at LHC aims to integrate, configure, and monitor all the participating sub-detectors.
The HMPID (High Momentum Particle Identification Detector), based on a Ring Imaging Cherenkov, is one of the ALICE sub-detectors. Its control system (CS) has to ensure the detector configuration, standalone running mode for test and maintenance, and integration in the ALICE DCS.

In order to design the HMPID CS, we present in this paper an approach based on the GRAFCET Model. First results from the application of the GRAFCET to the liquid circulation apparatus, an HMPID sub-system, are reported. The impact of the solutions for the HV-LV sub-systems on the CS is also presented.

I. INTRODUCTION

ALICE [1] is one of the four experiments planned to run at the Large Hadron Collider at CERN. Since it is located in an underground tunnel and it will not be accessible during the LHC running period, an efficient DCS has to be implemented in order to remotely configure, monitor and maintain the detector.

The DCS reacts to events that can take from fraction of second to some hours to develop therefore it may also be named Slow Control System.

The ALICE DCS architecture [2] is based on three layers: the process layer, the control layer and the supervisory layer. In the first one are detectors, sensors and actuators; in the second are controller devices reading data from the process layer and sending there commands. These devices supporting the TCP/IP protocol are networked and exchange information with the supervisory layer by means of the OPC server/client model. In the third layer the supervisory software provides the user panels (MMI, Machine Man Interfaces) where all the relevant information about the status of the detector are displayed. CERN has selected the PVSS II package as Supervisory Control And Data Acquisition system (SCADA) [3] where the MMI will be developed.

In Fig. 1 is shown a possible DCS architecture where the functionality of each device is reported.

In order to build a CS, two main phases should be accomplished: design and implementation.

In the design phase a map of the detector sub-systems (i.e. gas, LV, HV etc..), and a list of requirements for each of them, as well as for the detector, have to be provided. These requirements include all the actions to be performed to run properly the detector.

When the list and sub-systems have been defined then a graphic tool, which assumes the CS as a finite state machine, can be adopted for its representation, validation and simulation.

This approach is very effective especially when a complex CS, consisting of concurrent hierarchical processes, must be designed. In addition these tools can also produce an Instruction List (IL) which fits the requirements of the control devices defined during the implementation phase.

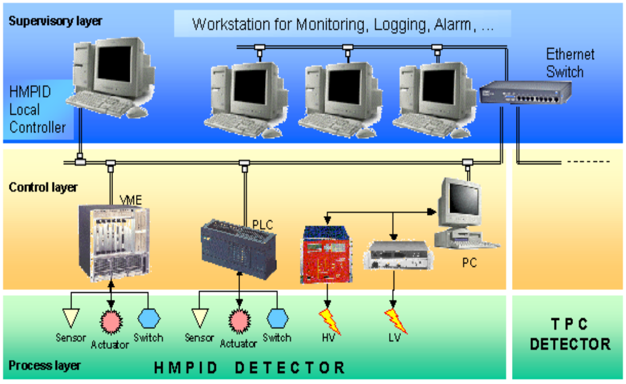

Figure 1: Architecture of the ALICE Detector Control System

II. THE DCS OF THE HMPID

A. DCS design

Generally for small CS the design phase is performed simultaneously with the implementation of the software in the control devices.

The HMPID [4] consists of an array of 7 MWPC's with a CsI photo-cathode. To run it properly about 1500 parameters have to be controlled thus resulting in a quite complex CS.

According to the HMPID operational conditions, the following sub-systems and relative lists of requirements have been defined: physical parameters

(P&T of environment), LV, HV, liquid radiator circulation apparatus and gas.

In this paper, we intend to verify the benefits of designing the CS of such a detector by means of a graphical tool, in a software-assisted environment, not depending on the chosen technology.

The GRAFCET (GRAphe Fonctionel de Commande Etape/Transition) model has been selected [5].

GRAFCET was introduced in France in 1977. It is a graphical tool developed to design industrial control systems assumed as a finite state machine.

To explore its capabilities, we applied this model on the liquid circulator sub-system. The concerned CS includes only a small number of devices and is designed for a particular application, nevertheless it covers all layers of a complete CS.

Since the HV-LV sub-systems are crucial for the DCS structure (for both economic and technical aspects), before including them in this test, we have studied the impact on the DCS for a couple of solutions that will be presented in section *E*.

B. The Control System for the liquid circulation system

A prototype of the circulation system was built and equipped with Siemens PLC's as control devices [6]. The IL (control software) was written according to the Functional Control Block (FCB), a technique foreseen in the Step7 (the Siemens PLC programming language).

In this work we have developed, in the freeware environment GRAF7-C [5], the CS including its representation, validation, and simulation as well as the corresponding IL written in Step7.

In Fig. 2, is reported the schematic diagram of the liquid circulation system. It consists of a main tank, a pump, a column and a radiator module. At first the column and then the radiator module are filled through some cleaning filters (not shown in the figure) with the pumped liquid. A fixed hydrostatic head (height difference between the column overflow and the outlet at the top of the radiator) allows the radiator module to be fed by gravity. Liquid from the radiator outlet falls unimpeded towards the main tank.

Fig. 3 shows the GRAFCET representing the CS for the liquid circulation system. Each state is numbered and according to its value, the representing variable can assume the active or NOT active value. On the right of each state, in the relevant rectangle, are reported the actions performed by the CS.

To move from one state to another the boolean condition for the transition must be fulfilled.

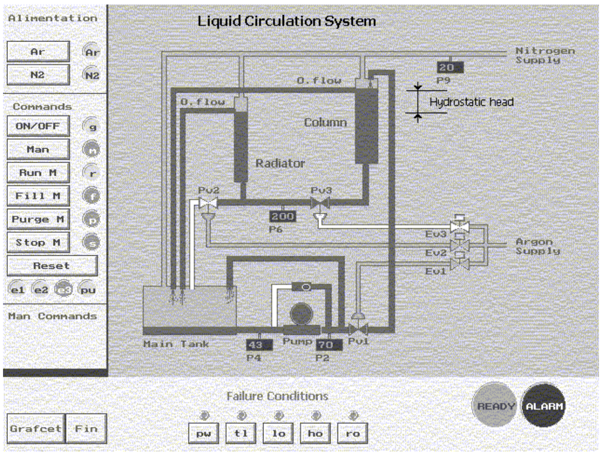

Figure 2: Schematic of the circulation system in the control panel of its simulation

A relevant aspect of this model is the possibility to define a master GRAFCET, that when activated can force the normal (or slave) GRAFCET to a predefined state. As an example, if the system in Fig. 3 is stopped then the state 11 becomes active and the normal GRAFCET is forced on the state 2 which becomes active. Then the STOP variable becomes true.

C. CS validation and simulation

In order to validate the CS, a qualitative simulation of the circulation system has been written in the C programming language. It exchanges data with the running GRAFCET in the GRAF7-C environment. The left side of the control panel in Fig. 2 shows the status of variables in the GRAFCET. At the bottom of the same panel some failure conditions can be simulated, consequently all the related alarm conditions may be verified by the GRAFCET and flagged on the panel.

This procedure has been very effective in order to define and verify the alarm conditions necessary to safely operate our circulation system and eventually our detector.

In addition this simulation has proven to be useful for user training and system maintenance. The GRAFCET and related simulation are available on the web site [7].

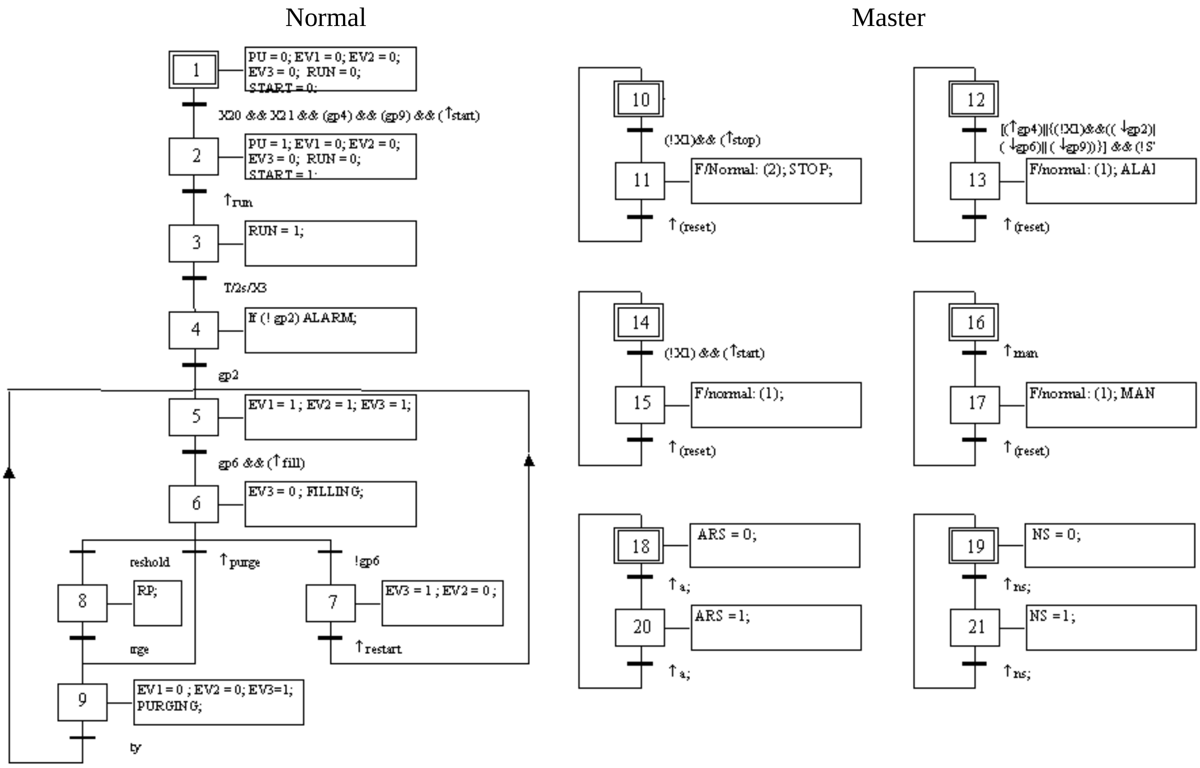

Figure 3: GRAFCET representation of the control system for the liquid radiator circulation system.

D. CS implementation

According to the norm IEC 61131-3 relative to the implementation of a GRAFCET into a PLC, we produced the IL written in Step7 from the GRAFCET in Fig. 3.

Meanwhile we have also investigated the possibility to buy some industrial software as CoDESys [8] and AUTOMGEN [9] where the CS design as well as the IL can be done in more reliable and assisted conditions.

This CS consists at the end of a graphical user interface (in the supervisory layer) and an IL running in the control layer. Since many CPUs are there available, we think that some control software should be locally running in order to bring the detector in a safe state when a supervisory system crash might happen. In other words the control layer should not be solely devoted to send data from the process layer to the supervisory one but also able of autonomous decisions. This will simplify the structure and debugging of supervisory software when the ALICE DCS will be implemented.

E. Definition of the HV-LV sub-systems

In order to evaluate impacts and costs of the HV-LV solutions on the HMPID DCS, we divided the HMPID module in 12 elementary segments (Fig. 4). Each one consists of a defined FEE number of channels facing 24 anode wires. This geometrical correspondence is imposed from the operating condition of this detector based on a CsI solid state photo cathode. Indeed in case of LV or HV failure, the fault segment can be switched OFF, with the proper sequence, independently from the others.

Assuming this segmentation, in order to design the LV-HV CS we are exploring two possibilities:

the first one, shown in fig 5, is based on a CAEN HV-LV frame, with OPC server and supporting TCP/IP protocol. It allows its complete remote control and integration in the HMPID DCS;

the second one is a custom solution based on high current low cost LV units controlled via auxiliary electronics and PLC devices. In this case the HV system is still based on the CAEN frame. Fig. 6 shows the hardware and software diagram for a single LV channel. In order to switch ON/OFF a channel, to monitor the absorbed current and detect the fault conditions, this solution requires dedicated control software running in the PLC's CPU. In addition this custom solution will affect the FEE and readout electronics (RO) since some components (voltage regulator, current sensors..) have to be installed in the FEE-RO PC boards.

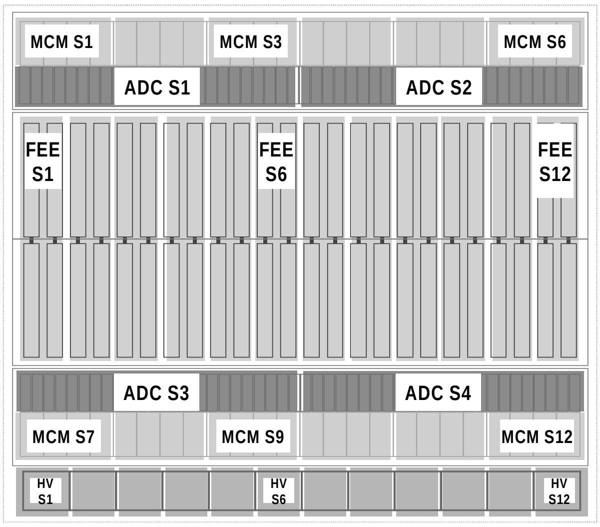

Figure 4: HMPID HV-FEE segmentation

Although this custom solution seems to be about 30% less expensive then the commercial ones, additional manpower to develop the control software and auxiliary electronics is necessary. In addition it requires a non-standard maintenance compared to what is ensured on long-term operation by companies which supply crates with proper connectivity and LV modules with complete remote control. Moreover, the custom solution is not based on LV floating units as the CAEN ones thus resulting in a more difficult matching with the HMPID ground level. Although we are inclined to adopt the HV-LV power supply system based on the CAEN SY1527 (or 527) frame, we intend anyhow to explore better both these solutions especially reducing the HMPID segmentation.

F. *Discussion*

Our opinion on using the GRAFCET model in order to design a CS is positive. In fact the control operated in the GRAF7-C environment while the control system is drawn, the representation of the CS as a finite state machine, the validation of the final design, are very helpful tools.

From what we have learned on GRAFCET we believe that this design procedure can be extended (if adopted), to the custom LV solution as well as to the physical parameter sub-system which is also based on ADC modules of a PLC. In fact according to the pressure and temperature values measured on the HMPID, many related actions will be taken. To handle such a complex system, the GRAFCET approach could finally becomes mandatory.

In addition as reported in [10], we also believe that this model will be useful when the HMPID CS will be designed. In fact the detector configuration through the setting of five sub-system, the CS validation and simulation, and the alarm condition management, may profit again of the GRAFCET model. Therefore, at present we are encouraged to pursue this approach.

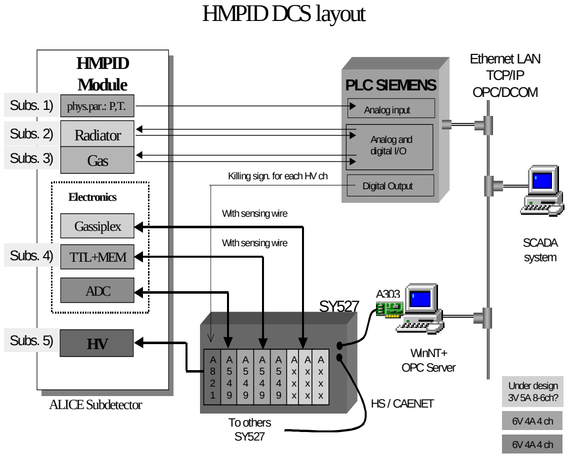

Figure 5: DCS representation with HV-LV CAEN based solution

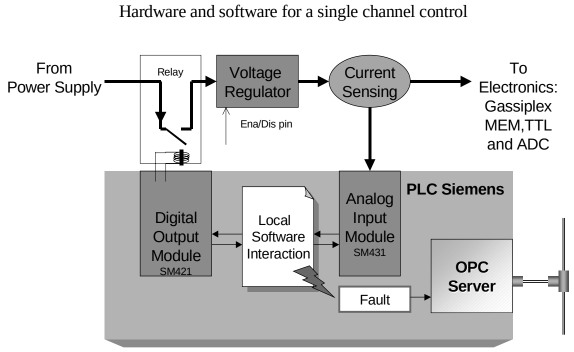

Figure 6: controlling scheme of LV channel based on custom solution

G. *Conclusion*

The application of the GRAFCET model in designing a control system seems very effective. The representation, validation, and simulation of the control system for the HMPID liquid circulation apparatus, in the freeware environment GRAF7-C, have shown the potentiality of this approach. We intend to explore the possibility to extend this method to the complete HMPID CS using industrial software environment as CoDeSys or AUTOMGEN. Although more expensive then a custom solution, we are inclined to adopt the HV-LV CAEN systems based on the frame SY 1527 (or 527), since its complete remote control which allows an easy integration in the DCS.

H. Acknowledgements

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III. REFERENCES

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