APPLYING INDUSTRIAL SOLUTIONS TO THE CONTROL OF HEP EXPERIMENTS

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Abstract

An increasing number of industrial systems are now using PLCs (Programmable Logical Controllers) and SCADA systems (Supervisory Control And Data Acquisition systems) for process control. These technologies have been used at CERN in the L3 Muon controls project[1] and the NA48 experiment[2]. Under the auspices of JCOP[3], the control systems of B1GCS, the ATLAS-TRT[4] and the ALICE-HMPID[5] have all used the above off the shelf technologies plus OPC (OLE for Process Control) and the PROFIBUS fieldbus. These latter control systems include only a small number of devices, but nevertheless they demonstrate all of the layers of a complete system. In this paper a synthesis will be made of the experience gained and conclusions drawn as to the possible use of these technologies for the CERN LHC detector controls.

1 INTRODUCTION

There is a wide range of industrial products on the market potentially applicable to the different components of a High Energy Physics Detector Control System (DCS). PLCs, Fieldbus components and SCADA tools have all been used successfully in existing systems at CERN. This paper describes our experience, discusses the fields of application of these industrial products and makes observations relevant to their possible use in the DCS systems at LHC.

A PLC is a diskless compact computer including all the necessary hardware interfaces for the process control: CPU, fieldbus interface, input/output module. A fieldbus is a data transport medium designed for use in control systems. A SCADA package comprises a development toolkit and a run-time system. The SCADA run-time system supports the supervisory level functions of the user developed DCS. The technology of PLCs, fieldbus and SCADA is widely used in industry. OPC (OLE for process control) is an emerging non-proprietary software standard to interface these different components.

2 INDUSTRIAL SOLUTIONS USED IN EXISTING SYSTEMS AT CERN

2.1 NA48 control system

The NA48 control system is a large system designed and written for the NA48 startup in 1996. Since that time, there has been a programme of continuous enhancement during the life of the experiment such that it now controls

- 795 High Voltage channels
- 167 crates
- 750 other miscellaneous items

In total this represents 22,000 individual I/O elements and 72,000 internal SCADA tags. The architecture is divided into two parts, known as the back-end and the front-end, depicted in Figure 1.

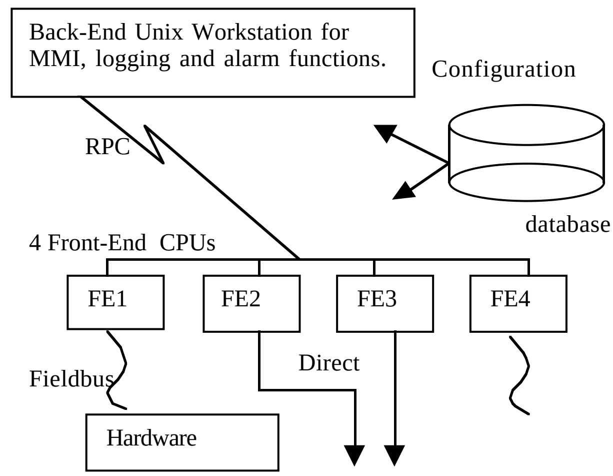

Figure 1: The Architecture of NA48

The back-end comprises a single HP-Unix workstation. This is connected to a series of front-end processors which are in turn connected to the hardware being controlled.

The back-end workstation runs the main control system application. This was implemented using Factorylink, a SCADA tool from USDATA. The controls application is connected to the “front-end” (FE) part using remote procedure call (RPC) over Ethernet.

Four front-end computers are connected to the equipment being controlled. Some equipment is directly connected, typically through VME with custom hardware. Other equipment, in particular the high voltage power supplies, are daisy chained on a CAENet fieldbus. The front-end machines take care of all equipment polling.

The front-end machines support CERN written drivers for the hardware being controlled. The detector hardware is enumerated in a database and this information is used to configure the object-oriented (OO) generic front-end code at run-time.

The back-end controls application provides the usual Man-Machine Interface (MMI) functionality of buttons and status displays, as well as sophisticated trending tools. All displays are available anywhere in the Ethernet local area network (LAN) as Factorylink uses X-windows. Access control facilities were implemented using a 3rd party add-on package to Factorylink.

The back-end application also implements extensive alarm condition checking plus data and event logging functions. The application is event driven, stimulated by change notification from the front-ends. Parameter loading (from a recipe) is also supported.

2.2 L3 Muon control system

The L3 Muon chambers are part of the L3 experiment. This is a medium size overall system controlling several independent sub-systems:

- 136 values from discriminators accessed over RS232
- 512 proximity sensors over standard ±5v interface
- 4 independent CAEN high voltage systems accessed via VME with a total of 544 HV channels
- 2100 float values in the alignment system using VME RASNIK hardware

The control software was re-engineered with a commercial product DAMATIC-XD/XIS from VALMET Automation. DAMATIC XD is a distributed and scalable control system toolkit based on VME. It is equivalent to a PLC with supervisory facilities such as an X-window MMI and basic alarm management being provided. VALMET's own modules can be connected into the system over a proprietary fieldbus. Non-VALMET VME I/O modules are also permitted with provision for incorporating custom drivers and other software written in C.

The control program was developed on a PC with AUTOCAD and was then downloaded onto the target CPU. DAMATIC XIS, the supervisory system, runs on HP-Unix. It provides archiving, alarm logging, MMI through X-windows and an Application Programmer's Interface (API). The communication between XD and XIS is based on a proprietary TCP-IP-like protocol over Ethernet.

The L3 Muon control system was distributed over 5 VALMET CPUs and a Motorola MVME-167 CPU with both VALMET hardware (ADCs, RS232) and non VALMET hardware (RASNIK, CAEN). C functions were written to interface the latter.

Custom hardware was required to connect the ±5 Volt proximity sensor signals to the 0-10 Volt ADC.

The data from the system was first archived in the proprietary DAMATIC-XIS database and then sent to the L3 database for offline analysis. In total the L3 Muon detector involves around 6700 SCADA I/Os and around 13,400 SCADA tags.

2.3 ATLAS-TRT control system

The Gas Working Group[6] has implemented a short-term gas system hardware prototype for the ATLAS-TRT (Transition Radiation Tracker) sub-detector. The gas system comprises a gas supply module plus mixer, purification, distribution and circulation modules. This is a small system, there are in total only 21 analog and 18 digital I/Os. Most of the equipment is standard for gas systems, e.g. valves, pressure transmitters, flow meters with standard analog interfaces (4-20 mA, 0-10 Volt, etc.). The TRT gas system has two identifiable portions:

- A process control task that handles all the process' periodic and asynchronous events.
- A supervision task that provides MMI, alarm handling, logging, archiving and access control.

The ATLAS-TRT gas system is a single layer system, meaning that both of the process control and the supervision tasks are implemented within the same BridgeVIEW SCADA tool available from National Instruments. The hardware sensors were connected to WAGO PROFIBUS-DP modules. PROFIBUS is one of the three fieldbuses recommended by CERN and was selected because a wide range of equipment is already available offering integrated PROFIBUS connections. BridgeVIEW was connected to PROFIBUS using the PC1500PFB APPLICOM card.

2.4 B1GCS gas control and HMPID liquid control systems

B1GGCS is a gas system under development by the Gas Working Group on behalf of the CMS Micro Strip Gas Chamber. HMPID (High Momentum Particle IDentification) is an ALICE subdetector for which a prototype of the liquid distribution system has already been built. A control system for this prototype hardware has been implemented. The prototype hardware is a scaled-down version of the final system, and has only 8 analog and 11 digital I/O points. The HMPID and B1GCS control systems are considered small systems. The equipment used in both systems is similar, including mass flow controllers and temperature probes using standard analogue interfaces (4-20 mA, 0-10 Volts). The functionality for both includes two distinct layers:

- The process control layer in which the closed loop control is performed
- The supervisory layer providing MMI, alarm handling, logging, archiving and access control

In contrast with the TRT system, both layers can be operated independently from each other. The process control layer was implemented in a SIEMENS PLC S7-300 using SIEMENS I/O modules directly connected to the hardware (i.e. without a fieldbus). The supervision layer is implemented with BridgeVIEW for the ALICE-HMPID and with PANORAMA for the B1GCS system. OPC was used as a communication interface between the two layers in both systems. SIEMENS provides an OPC Server running under Windows NT and a library to access the PLC via Ethernet. An OPC Client is included within BridgeVIEW and PANORAMA.

3 DISCUSSION OF THE DIFFERENT APPROACHES

The experience described above shows the use of industrial solutions in a variety of different CERN contexts. The TRT example connects a fieldbus to a SCADA run-time system; HMPID connects PLCs directly to a SCADA system. In the laboratory we have successfully connected PLCs directly to a fieldbus. These examples show that the industrial components can be arranged in a very flexible manner.

PLCs are effective at performing autonomous and secure local process control with closed loops. A fieldbus is an ideal solution in a geographically dispersed environment. The advantage of using a standard bus relates to its ease of use. There are no drivers to write nor maintain. If the fieldbus is connected to a SCADA product or to a PLC component then neither is there any communications software to write.

The OPC software standard offers several advantages. First, it acts as glue between independent layers of the system, allowing change of an individual layer without breaking the entire system. Second, it permits separately developed components to be readily incorporated into the overall DCS.

The re-engineering of the L3 Muon control system further shows how an industrial product can be interfaced into an existing experiment, in this case into one where in years gone by, it was necessary to write custom code.

Using standard hardware components is convenient, but entails a cost and at CERN there is a considerable investment already in other equipment, for example VME. Nevertheless, it has been shown to be possible and worthwhile to provide supervisory functionality using a SCADA tool even when interfacing to VME.

The NA48 experience underlines how the Object-Oriented paradigm maps well onto external hardware. Each device being controlled is represented as a software object in the front end. Instances of devices can be created at run-time as required, according to configuration information coming from a database. OO software lends itself well to re-use and indeed many of the equipment drivers were taken over from the preceding WANF[7] beamline project. Unfortunately, the Factorylink SCADA does not support an OO style of working directly. This meant that the interface with the front-end objects was somewhat contrived. We observed a 1:3 ratio between the number of I/O points and the number of tags in the SCADA system. Managing such a large number of tags is not easy and needs careful engineering. Some higher level configuration tool is clearly required to build a system any larger than NA48. We are aware of at least one enterprise that has successfully written an in-house configuration tool on top of Factorylink, expressly for this purpose.

Industrial SCADA development tools offer many advantages when preparing individual DCS control systems. The NA48 experiment was able to capitalise on the power of Factorylink for implementing not only the user interface but also for its alarm handling, trending and logging capabilities. At this level, constructing a DCS with a SCADA tool typically requires configuration-style work rather than detailed coding. This work can be performed by less highly trained personnel and is quicker to implement and easier to maintain than custom code. It is important to note that DCS systems built this way remain open for custom code inserts if required.

Whilst industrial development tools permit enormous leverage to be gained when implementing one's own DCS systems, they are not a cure for all problems. Today's tools are frequently not integrated with each other unless one is prepared to lock oneself into a proprietary system. This can mean that one has to use more than one tool to achieve an overall development goal.

Whatever tools are used, commercial or home-made, there always remains the need to perform proper engineering, performing systems analysis developing "Use Cases" with the experiments.

4 CONCLUSIONS

Existing Detector Control Systems at CERN are successfully using industrial component technology in a variety of configurations. These examples demonstrate that the technology exists now and we believe it is appropriate for use at LHC.

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