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INTEGRATION OF PLC AND PXI CONTROL SYSTEMS

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Abstract

Engineers are often challenged with the need to integrate several technologies to find optimal solutions when designing new control architectures. Generally, the technical solutions chosen require the combination of various industrial products such as PXI systems for applications requiring fast acquisition, analysis and reaction times, while PLCs are commonly used for their reliability and their ability to withstand industrial environments. The needs to exchange information between these different technologies can today be solved by using industrial fieldbuses such as Profibus DP or Profinet IO. This paper describes the technical aspects of the two options, focussing on their advantages and constraints. The experience gained with integrating PXI and PLC systems as part of the 2016 consolidation project of the control of the kicker systems of the Antiproton Decelerator (AD) at CERN will be presented.

INTRODUCTION

In the late 1980s, the PLC-based automation systems became increasingly popular in the manufacturing industry aiming to improve their productivity. The need to reduce costs and downtime while ensuring a high level of flexibility has led to the search for innovative decentralized solutions. Some automation manufacturers decided to join their efforts on a "fieldbus" project to find out a homogenous common solution. The Profibus standard was born. Today, the PI Organisation (Profibus and Profinet International) count over 1400 member companies worldwide [1]. Subsequently, a protocol based on the Ethernet, the Profinet, was designed with a first version available from 2001 onwards [2]. Meanwhile, National Instrument (NI) developed the PXI technology (PCI eXtensions for Instrumentation) for fast measurement applications as electronic testing equipment. The need to add fast measurement devices to a manufacturing plant is today essential and a communication channel between the two is therefore mandatory. Because PLCs have already their own industrial communication solutions and are generally the core of plant processes, the PXI based solutions have to become compatible and adapt to the industrial communication standards.

CONTEXT

The Accelerator Beam Transfer group (TE-ABT) at CERN, which is responsible for all beam injection and extraction systems across the accelerator complex, has a control architecture based on a slow control, fast control and timing control. With the introduction of PXI based solutions to replace old electronics for the fast control, a study of industrial communication solutions based on fieldbuses was carried out in order to ensure a homogeneous exchange of data between the slow control and the fast control. However, the modernisation of the slow control with off-the-shelf components had already been done using Siemens PLCs, leading to Profibus DP and Profinet IO as possible choices.

The Control group (BE-CO) at CERN provides a communication solution that could also be consider to build a communication channel between a PLC and a PXI through their Front-End Software Architecture (FESA). Unfortunately, the choice of such a solution would lead to additional software layers, more complexity and dependence on external services, which would not allow the exchange of critical data such as interlocks.

FIELDBUS

Definition

A *fieldbus* is a digital, serial, multidrop, data bus for communication with industrial control and instrumentation devices such as -– but not limited to - transducers, actuators and local controllers [3].

Profibus DP[1]

Profibus DP, for **Pro**cess **Fi**eld **Bus** **D**ecentralized **P**eriphery, is a fast and deterministic master-slave fieldbus standardized in IEC 61158 and compliant with the OSI model (Open Systems Interconnection) standard, which make uses of only three separate layers of the OSI model [4]. The physical layer defines the data transmission technique, the three main ones being: the RS485, the optical-fibre and Manchester Bus Powered. The data link layer specifies the communication functions. Today, three version exists, DP-V0 that ensure the basic functions with cyclic data and diagnostics transmission, DP-V1 adding acyclic data transmission for process oriented services (configuration, alarms), and, DP-V2 for isochronous needs (Direct slave communication, motion applications). Finally, the application layer is specific to the manufacturer.

In Profibus terminology, a *device profile* defines functionalities and services a device has to be able to deliver and perform. A profile is always encapsulated in a standardized General Station Device (GSD) file, which allows the user to integrate any device into its automation project.

Profinet IO

Profinet IO, for **Pro**cess **Fi**eld **Net**, is a full duplex network for industrial automation applications build on standard Ethernet technology and compliant with CEI 61158 and CEI 61784 [5].

The communication networks used in the industry must ensure data transfer between different devices in real time in order to guarantee the response time of the processes.

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[1] The Profibus and Profinet fieldbuses exist in several variants. This paper will consider only the Profibus DP and the Profinet IO versions without safety frames.

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Thus, three different communication channels are defined in the Profinet IO standard:

- the TCP/IP channel for parametrization and acyclic read/write operations,
- the Real Time (RT) channel for cyclic data transfer,
- the Isochronous Real Time (IRT) channel for specific applications.

The devices are divided in three classes: the IO-Controllers, which are similar to Profibus Masters, the IO-Devices, similar to Profibus Slaves and the IO-Supervisors, similar to the Human Machine Interfaces (HMI) [6].

As for Profibus DP, each device has a unique description that is specified in a General Station Device Mark-up Language (GSDML) file, GSD written in XML format, including a description of the device and its network characteristics.

Profibus DP vs. Profinet IO

Profibus DP and Profinet IO share the same aim of allowing decentralized architecture in control systems in order to optimize the global costs and have many similarities in their engineering concept as the use of a standardized language to define each device. Indeed, Profinet IO is the natural successor of Profibus DP and is often referred to as Profibus over Ethernet.

Today, most of the control engineers tend to design new installations based on Profinet IO, taking benefit of the Ethernet technology allowing a consistent communication approach across the plant. Additionally, the choice of Profinet IO also means a high transmission rate and a data transfer capacity six times that of Profibus DP. However, Profibus is still widely used in industry and lots of technician are already qualified. Its ease of implementation is also to be consider when designing an upgrade of an existing facility or a new automated system.

Table 1 shows a comparison of the main technical features between Profibus DP and Profinet IO [7].

Table 1: Profibus vs. Profinet

	Profibus DP	**Profinet IO**
Device description	GSD file (ASCII)	GSDML file (XML)
Topology	Line	Line Tree Ring Star
Speed	12 Mbit/s	100 Mbit/s
Max. number of Devices	126	Unlimited (manufacturer limitations)
Telegram	244 Bytes	1440 Bytes
Technology	Master/Slave	Provider/consumer
Wireless	Possible	IEEE802.11
Motion	32 axes	150 axes
Openness	No	Yes

PLC AND PXI INTEGRATION

The original study initiated by the TE-ABT group considers three communication solutions: the Profibus DP, the Profinet IO and the S7-TCP [8]. This last option was quickly excluded as a viable operational solution as it requires separate configuration/settings routers, higher programming technique and is only usable in homogeneous SIMATIC[1] environment [9].

Hardware

A PLC is a set of specific modules, which always includes a power supply and a CPU. The same concept applies for a PXI system. Hence, dedicated communication modules have to be added to the configurations to be able to establish a PLC/PXI communication.

In the Siemens PLC environment, a wide range of communication modules exist and the choice is only dependent on the PLC series used. The TE-ABT studies has been done using S7-300 series and consequently IM153-1 DP interface was chosen for the PROFIBUS DP configuration while Simatic NET CP343-1 communication processor was chosen for PROFINET IO communication. Figure 1 shows some Siemens communication processors available on the market.

Figure 1: Siemens communication processors.

On the PXI side, less options exist to connect them to a fieldbus architecture. Hardware communication modules from Kunbus Industrial Communication, formerly Comsoft, have been used to connect PXI system either to Profibus DP (DF PROFI II module) or to Profinet IO (DF PROFINET IO module), i.e. Fig 2.

Figure 2: PXI/Profibus interface module (left) and PXI/Profinet interface module (right) from Kunbus Industrial Communication.

[2] SIMATIC is the Siemens software suite for automation environment.

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No additional devices are then needed to establish the link between a PLC with a PXI.

Configuration

The power of Profibus DP and Profinet IO fieldbuses is their standardization and openness leading to certified interchangeable products from a wide range of suppliers. Thus, all control system manufacturers can easily make their devices compatible with the standard by integrating the device configuration directly into their user application suite.

Siemens provides the SIMATIC suite for their PLC programming, Step 7 and more recently TIA-portal, which is dedicated to the newest products. The integrated hardware configurator of these suites has a GSD/GSDML interpreter that simplifies the configuration of any Profibus DP or Profinet IO device into an automation project.

In contrast, PXI systems can be programmed from different software suite as LabView or LabWindows/CVI from National Instrument or C++ on LINUX. As a result, the Kunbus company provides a third-party software, the "Configurator III", which is required to configure and integrate its fieldbus products into PXI systems and to obtain their function libraries compatible with programming suites.

Both Profibus DP and Profinet IO fieldbuses are master-slave oriented, which means that the master has the unidirectional control over all slaves. If Profibus DP allows only one master per bus, Profinet IO doesn't have this limitation. Considering the communication between a PLC and a PXI system, it's important to note that the Kunbus Profinet IO module is only configurable as a master, while the Profibus DP module can be configured as master or slave.

AD KICKER EXPERIENCE

In June 2011, CERN approved the ELENA project, the **E**xtra **L**ow **EN**ergy **A**ntiproton ring, with the aim of building a new synchrotron to further decelerate anti-protons from 5.3 MeV down to 100 keV [10]. As the proposed location for the ELENA ring was occupied by the AD injection and extraction kickers, a relocation of these systems has taken place and the more than 30 years old electronics and controls of these systems has been fully consolidated and refurbished at this occasion.

The new control architecture had to take advantage of the solutions developed for the LHC and had to use the latest technologies. Therefore, the last generation of Siemens PLC family, S7-1500, was chosen for the slow control, while a PXI based solution has been used for the fast control. The two systems contribute in the proper functioning of the kickers and interact in real time to guarantee a safe operation. Formerly made with wiring, few data were exchanged and implementing a fieldbus would allow transmitting more data for diagnostic purposes with the advantage of being less expensive.

The slow control is the centre of the control architecture and links all sub-systems together (Electrical distribution, Safety, Timing, Fast control, diagnostics, HMI, SCADA). This leading responsibility requires assigning it to the master of the fieldbus and therefore only the Profibus DP fieldbus can be used, i.e. Fig 3.

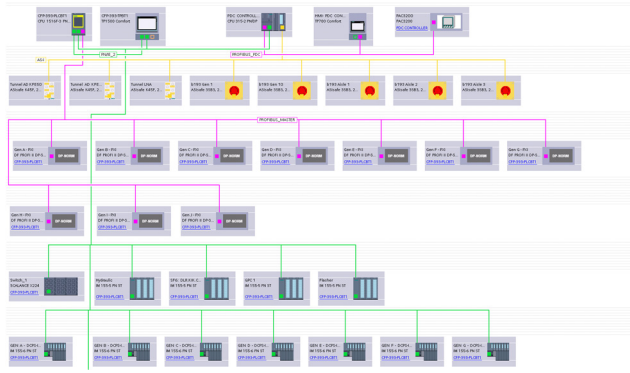

Figure 3: fragment of the AD control architecture showing the Profibus link (purple) between the PLC master and all PXIs slave, the Profinet link (green) for PLC slaves and the AS-i link (yellow) for safety slaves.

Due to the preliminary studies, which resulted in a detailed configuration procedure [8], the AD control design included the implementation of the communication fieldbus without many difficulties. The new AD control kicker system with 10 PXI slaves connected to the Siemens master S7-1516F CPU is in service for 2 years and no major failures have been reported during operation.

CONCLUSION

The needs for different types of technologies to exchange data is a challenge that found solutions in the use of standard fieldbuses. The use of Profibus DP and/or Profinet IO standards are solutions to integrate heterogeneous hardware. These standards are supported by 1400 manufacturers guarantying the openness of the technology used for data collection and for process control. The success of the consolidation of the AD kickers with the integration of Siemens PLC and PXI hardware highlights the efficiency of using such solution and has proven its robustness with no major failure since its commissioning in 2015.

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