AN OPC-UA BASED ARCHITECTURE FOR THE CONTROL OF THE ESPRESSO SPECTROGRAPH @ VLT

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Abstract

ESPRESSO is a fiber-fed, cross-dispersed, high-resolution echelle spectrograph for the ESO Very Large Telescope (VLT). The instrument is designed to combine incoherently the light coming from up to 4 VLT Unit Telescopes. To ensure maximum stability the spectrograph is placed in a thermal enclosure and a vacuum vessel. Abandoning the VME-based technologies previously adopted for the ESO VLT instruments, the ESPRESSO control electronics has been developed around a new concept based on industrial COTS PLCs. This choice ensures a number of benefits like lower costs and less space and power consumption requirement. Moreover it makes possible to structure the whole control electronics in a distributed way using building blocks available commercially off-the-shelf and minimizing in this way the need for custom solutions. The main adopted PLC brand is Beckhoff, whose product lineup satisfies the requirements set by the instrument control functions. OPC-UA is the chosen communication protocol between the PLCs and the instrument control software, which is based on the VLT Control Software package.

INTRODUCTION

ESPRESSO is a fiber-fed, cross-dispersed echelle spectrograph which will be installed in the Coudé Combined Laboratory (CCL) of the VLT. In order to achieve the maximum stability, the spectrograph will be installed in a thermal enclosure and a vacuum vessel. ESPRESSO can be operated with one or up to 4 Unit Telescopes (UT) of the VLT. The instrument will cover the whole visible wavelength range (380-780 nm) and its radial velocity precision will reach the 10 cm s^{-1} level [1].

INSTRUMENT SUBSYSTEMS

The telescope light is conveyed to the CCL via a Coudé Train optical system (one for each UT). Inside the CCL, a Front-End (F/E) unit combines the light coming from the telescope(s) and feeds it into the spectrograph fibers. The F/E is composed by and Atmospheric Dispersion Corrector (ADC), a focus translational stage and by a system that performs the field and pupil stabilization (composed in turn by a set of piezo tip-tilt stages for performing the corrections, a technical CCD (TCCD) and a neutral filter). This F/E structure is repeated four times (one for each beam light coming from a single UT). Moreover, the F/E provides a mode selector mounted on a rotary stage whose task is to feed the spectrograph with the proper fibers coming from the selected telescopes.

Two fibers feed the spectrograph simultaneously: the target fiber and the sky/calibration fiber.

The ESPRESSO calibration unit is composed by the traditional flat-field and spectral calibration sources. Moreover, the use of a Laser Frequency Comb (LFC) is foreseen as calibration source. The LFC, if available, will provide high resolution repeatable calibrations.

The two-arm (red and blue) echelle spectrograph, placed inside a thermal enclosure and a vacuum vessel, has a fixed optical layout, with no moving part foreseen in order to maximize the stability and repeatability of the instrument performances.

The instrument has two scientific detectors, one for the red arm and one for the blue one.

ESPRESSO is also equipped with an exposure meter that measures the flux entering the spectrograph as a function of time.

ESPRESSO CONTROL ARCHITECTURE

The ESPRESSO control system can be seen as composed by two entities: control software and control electronics.

The ESPRESSO control software architecture is compliant with the ESO/VLT standards and is based on the VLT Control Software package. The Observation Software (OS) coordinates an exposure. It receives the command sequences to be executed by the Broker for Observation Blocks (BOB) and forwards them to the involved control software subsystems: the Telescope Control Software (TCS), the Detector Control Software (DCS) and the Instrument Control Software (ICS). At the end of the exposure, OS merges the information coming from the different subsystems and archives them. The ESPRESSO control software runs in a dedicated Instrument Workstation (IWS) located in the VLT computer room. A detailed description of the ESPRESSO control software can be found in [2].

The ESPRESSO Control Electronics is based on industrial PLCs. This approach is completely different from that of the VLT instruments of first and second generation, which are based on VME technology. One of the main points in the adoption of PLCs is to have a system built, as much as possible, on "Commercial-Off-The-Shelf" (COTS) components, leaving in this way the maintenance of the boards and driver code to the vendor. Moreover, the PLC choice grants a number of benefits

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like lower cost, requires less space and less power consumption.

The PLC supplier chosen for ESPRESSO is Beckhoff, one of the ESO approved hardware suppliers, whose lineup of products covers all ESPRESSO control system requirements.

ICS and OPC-UA - Control Software Side

The control of all the low-level functionalities of ESPRESSO is delegated to ICS, which is the only software responsible for controlling the instrument hardware (excluded the detectors).

In recent years, support for field-bus technologies has been provided for the instrument control at VLT. The new VLT Control Software architecture to interface and control devices connected to field-buses is named ICS Field-Bus Extension (ICSFB).

ICSFB allows controlling devices not only via "classical" field-buses like Profibus/Profinet or EtherCAT, but also e.g. via Ethernet or CANbus. It can be seen as a SDK used to implement device drivers and also provides the run-time environment for deploying device drivers and control processes [3]. The ICSFB Device Server acts as host application for one ICSFB Device Driver instance.

In order to communicate with the device hardware, ICSFB makes use of an adapter referred to as the ICSFB Communication Interface. At present, the ICSFB Communication Interface supports the following protocols: CCS (proprietary ESO), OPC-UA and Siemens/Softnet [4].

For ESPRESSO, the OPC-UA communication protocol has been adopted. A distinguishing feature of this protocol is to ensure hardware independence, allowing to choose among any hardware supplier that support this protocol.

The OPC-UA is a platform-independent standard through which various kinds of systems and devices can communicate by sending messages between clients and servers over TCP networks. A typical OPC-UA application is composed by two entities: a "server" and a "client". The "server" is usually supplied by the hardware manufacturer and represent the interface between proprietary protocols and OPC-UA standard. It is usually a thread on the process controller which exposes process data and methods and communicates with the hardware with proprietary protocols. The "client" implements the OPC-UA communication stack by means of APIs and allows the user application to access the data and methods exposed by the "server".

Both client and server can be implemented on any platform and can be supplied by different suppliers and still guarantee the interoperability, as defined by the standard.

In this architecture, the ESPRESSO ICSFB Device Drivers play the role of the "clients".

PLC and OPC-UA - Control Electronics Side

The ESPRESSO control electronics is distributed in several subsystems that are physically located in the CCL and hosted in separate 19'' rack cabinets.

The instrument functions are managed by the control software running on the IWS via PLCs located in proximity of the spectrograph.

Figure 1 shows the ESPRESSO cabinets and their interconnections.

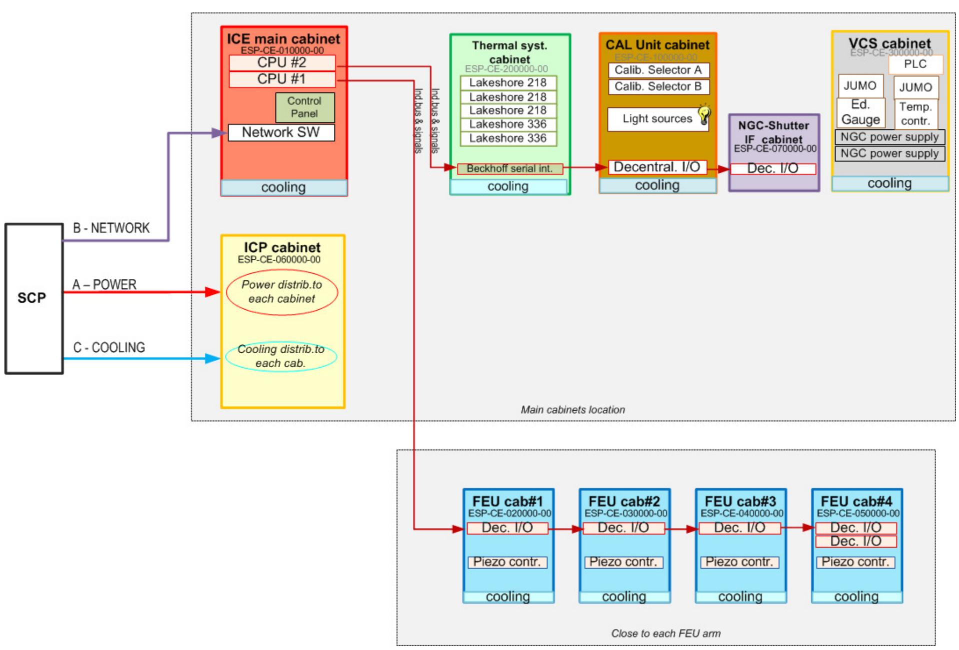

Figure 1: ESPRESSO cabinets layout.

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The system is built by using controllers and functional modules that can be combined in a modular way to obtain the required functionality.

All components are meant for DIN rail mounting. The PLC CPUs chosen belong to the CX2000 series, with TwinCAT 3 runtime installed.

Two CPUs will be installed in the main cabinet to balance the workload with the control of the following subsystems:

- PLC#1 – F/E, mode selector and exposure meter functions
- PLC#2 – Calibration, shutter control and thermal monitoring functions; control panel management

The EK1100 module provides the possibility to decentralize the functional modules away from the CPUs via EtherCAT.

The functional modules used for I/O and other tasks required by the instrument can be classified in four types:

- Digital I/O – for devices with discrete control signals and status output
- Analog I/O – for devices with continuous control signals and status output and measurement devices
- Communication Modules – for devices with high level interface (e.g. serial interface)
- Motion control modules – for the motorized functions

ESPRESSO has a total 14 motorized functions located in the F/E, 8 for the ADCs and 8 in the calibration unit. All the motorized stages were chosen from the MICOS supplier.

The motion control concept is based on the Beckhoff TwinCAT NC software layer that operates between the hardware modules and PLC software runtime. Its purpose is to offer a standard software interface to the PLC software on one side (PLCopen MC compliant), and a flexible and heavily configurable software-controlled axis positioning system on the other side. The TwinCAT NC environment has fully configurable parameters for setting up PID control loops for the control of the velocity and positioning (see Fig. 2). A setpoint generator provides the facilities for the control of the acceleration, deceleration and jerk of the axis.

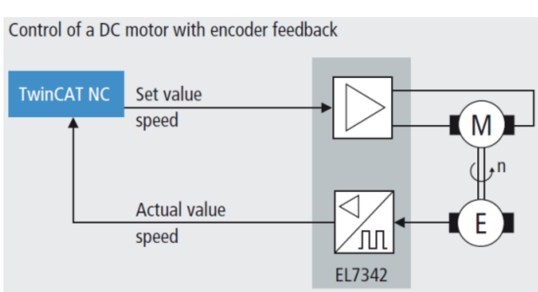

Figure 2: Beckhoff TwinCAT NC axis velocity control loop.

The Beckhoff modules that were selected for building the basic motion control blocks are:

- EL7342 - 2 channel DC motor output stage 50 V DC, 3.5 A
- EL5101 - incremental encoder interface
- EL1084 - 4 channel input , 24 VDC, switching to negative potential

Using the configuration software package provided by the supplier (Beckhoff System Manager), the modules are configured to obtain the proper motion control closed loop. Figure 3 shows a general motor control.

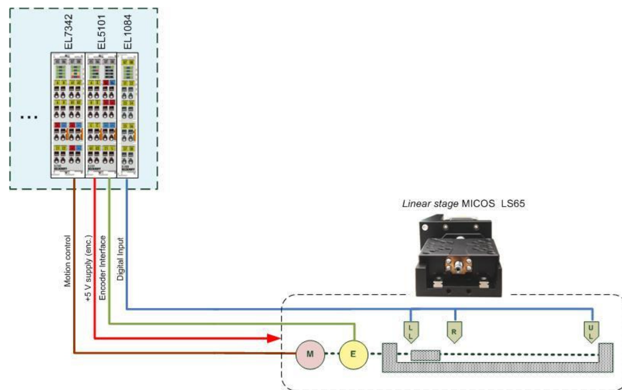

Figure 3: General motor electronic control.

The task of the PLC is to implement the low level code for managing the devices. On purpose, the code is kept as simple as possible (relative to the device complexity) and generally implements just the tasks that require a real time response. Every device driver exposes, by means of the OPC-UA server, a set of process variables that are accessible by the higher levels of the control software running on the IWS. The simplest drivers are just wrappers between I/O port variables and the OPC-UA exposed variables. This structure reduces the maintenance of the PLC code, as the major part of the task is implemented by the control software on the IWS.

CONCLUSIONS

The ESPRESSO spectrograph will adopt new technologies for the instrument control not present in the VLT instruments of first and second generation. In particular, the communication between low-level software and hardware is performed by means OPC-UA, an industry accepted and vendor independent architecture.

OPC-UA, supported by the ICSFB architecture of the VLT control software, opens the possibility to choose among hardware suppliers that support this protocol. The adoption of an industrial PLC supplier (Beckhoff) allows to reduce the complexity of ESPRESSO in terms of ease of operation, costs and maintenance.

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