PLCs WITHIN ESO ELT FRAMEWORK

A. Sulich – I. Coretti – P. Di Marcantonio – G. Calderone

INAF - Osservatorio Astronomico di Trieste

II TETIS Workshop – Roma 02-03 Febbraio 2023

SUMMARY

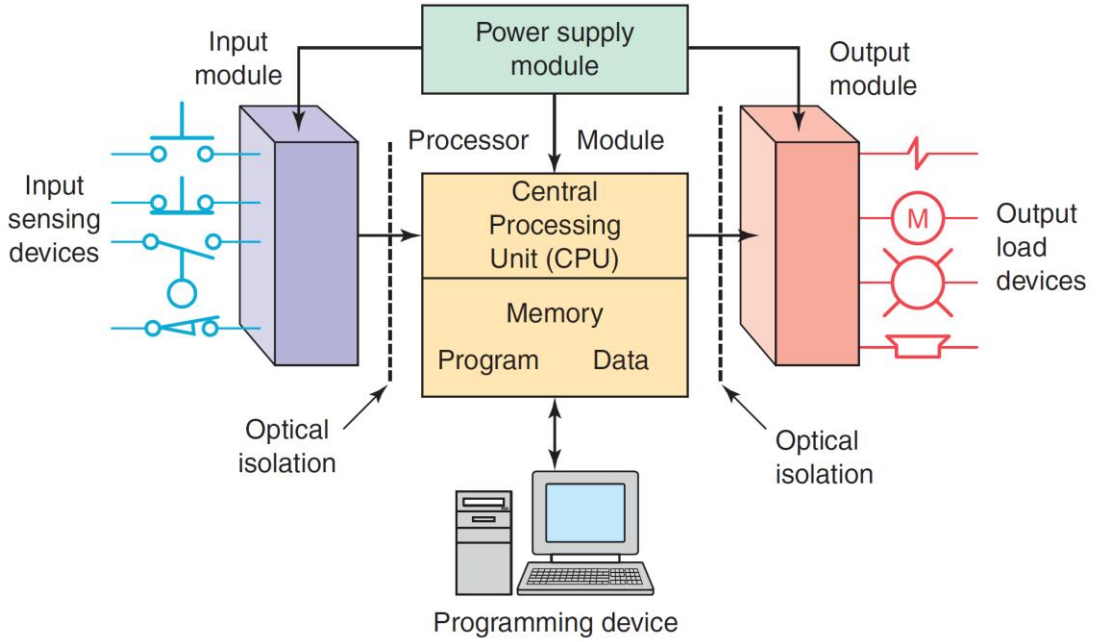
- Programmable logic controller
- The advantages of a PLC control system
- Beckhoff devices and tools
- PLCs at ESO

PROGRAMMABLE LOGIC CONTROLLER

- PLC is an autonomous device capable of controls physical outputs in reaction to physical inputs
- Parameters can be given externally - network, memory cards, HMI
- High level management and coordination of multiple devices
  - SCADA - Supervisory Control and Data Acquisition
    - Coordination of parameters and setup
    - Readout and modification of process data (Process Variables)
    - Remote commands (by means of Process Variables)
- Standardized communication protocol for data exchange
  - OPC-UA - is a cross-platform, vendor independent standard

PROGRAMMABLE LOGIC CONTROLLER

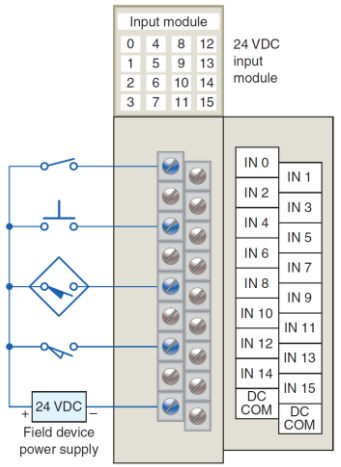
- Main components
  - Power supply
  - CPU
  - I/O modules
  - Communication
  - Human - Machine Interface
  - Programming device

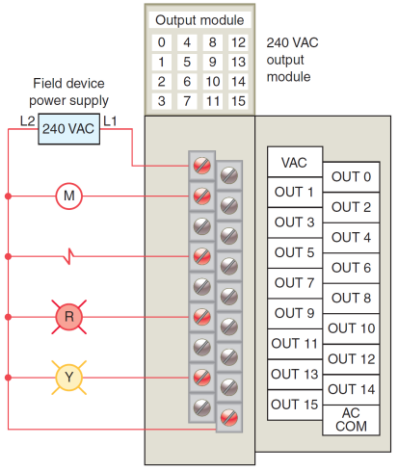


PROGRAMMABLE LOGIC CONTROLLER

Digital I/O modules

- Power isolated from control unit
- Reference levels 5V, 12V, 24V, 230V
- Digital Inputs
  - Pushbuttons, switches
  - Sensors (limit switches)
- Digital Outputs
  - Lamps
  - Actuators
  - Relays
  - Shutters

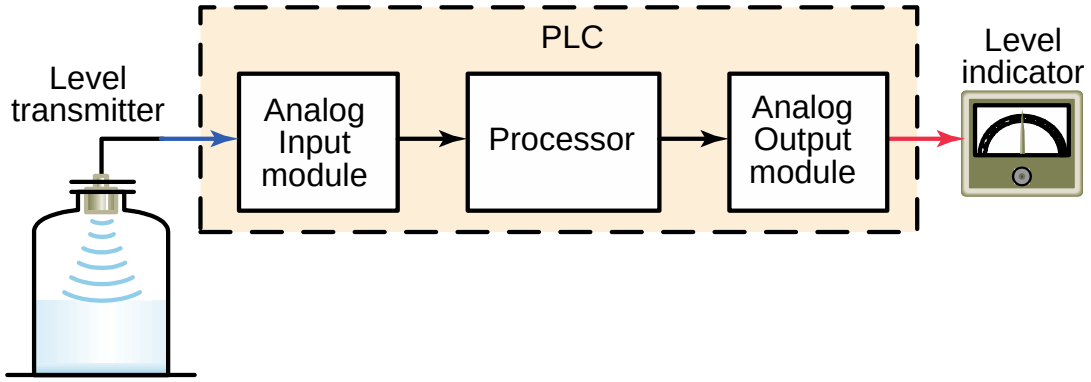




PROGRAMMABLE LOGIC CONTROLLER

Analog I/O modules

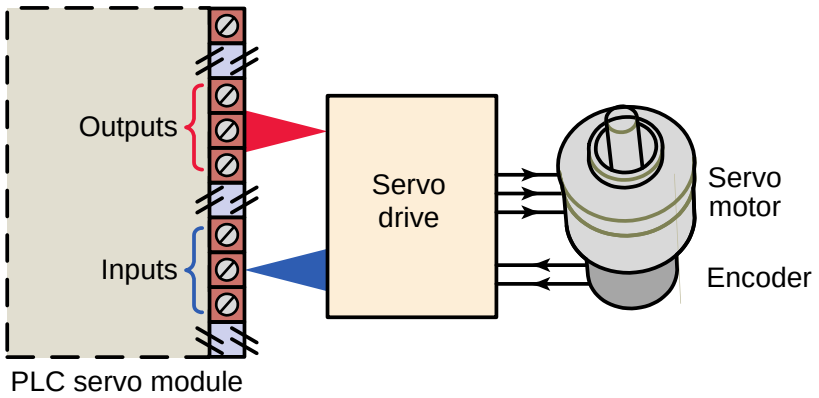
- Voltage, Current
  (e.g. 0-10V, 4-20mA, …)
- Analog Input
  - Measurement device
  - Temperature sensor
- Analog Output
  - Proportional actuator
    - Valves
    - Controllers (piezo)
  - Indicator

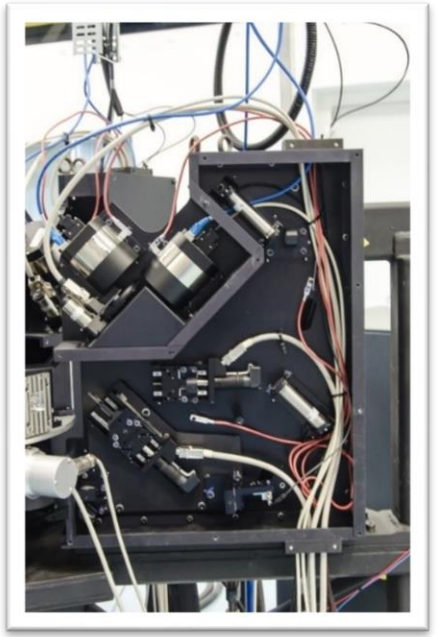


PROGRAMMABLE LOGIC CONTROLLER

Special functions

- Motor controllers
  - linear or rotational stages
- Position measurement
- Communication functions
  - Serial
  - Industrial bus





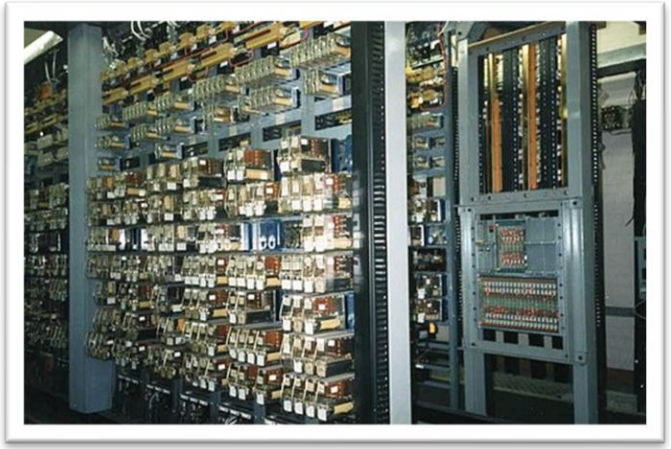
SUMMARY

- Programmable logic controller
- The advantages of a PLC control system
- Beckhoff devices and tools
- PLCs at ESO

THE ADVANTAGES OF A PLC CONTROL SYSTEM

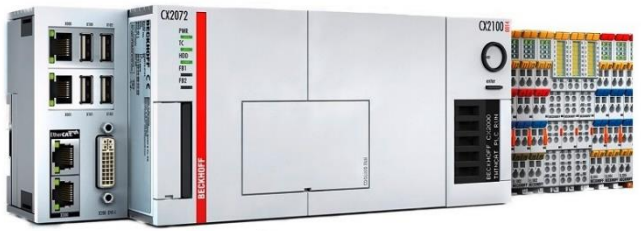
- Convenience:

Derived from wired relay logic, a plc-based system means less space, less consumption and rapid diagnostics in the event of faults



Relays control circuit

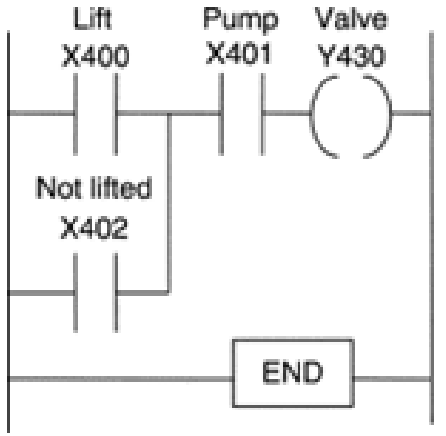
First PLC: Modicon 084 (1968)



Beckhoff CX2030

THE ADVANTAGES OF A PLC CONTROL SYSTEM

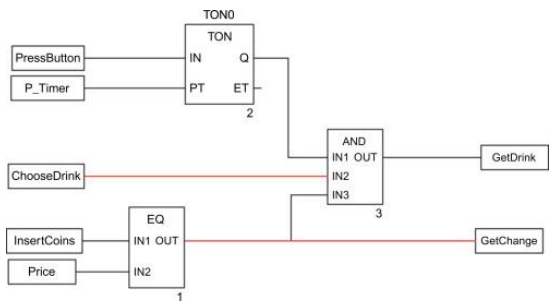
- Initially provided very simple programming
  - Ladder Diagram (resembling wired logic schemes)
  - Instruction List (kind of assembly language)



Ladder

THE ADVANTAGES OF A PLC CONTROL SYSTEM

- Today are very complex and powerful machines
  - Standardized with IEC 61131 (1993), part 3 defines programming languages adding Structured Text, Functional Block Diagram and Sequential Function Chart and support for OOP
  - Extensions for C/C++ , Matlab…



FBD

```
PROGRAM POU
VAR
MotorOverload : ARRAY[1..3] OF BOOL;
MotorOverCurrent : ARRAY[1..3] OF BOOL;
MotorPBSTart : ARRAY[1..3] OF BOOL;
MotorPBStop : ARRAY[1..3] OF BOOL;
MotorCoil : ARRAY[1..3] OF BOOL;
i : INT;

END_VAR
```

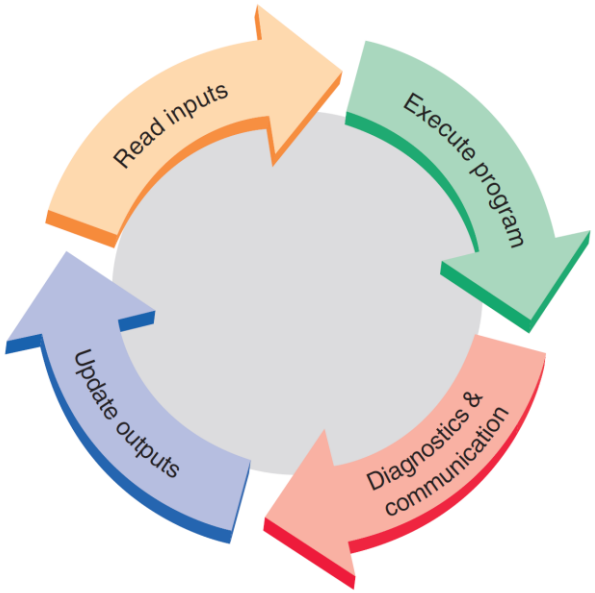
```
FOR i:=1 TO 3 BY 1 DO

IF  MotorPBStop[i] OR MotorOverload[i] OR MotorOverCurrent[i] THEN
    MotorCoil[i]:=0;
ELSIF MotorPBSTart[i] THEN
    MotorCoil[i]:=1;
END_IF
END_FOR
```

Structured text

THE ADVANTAGES OF A PLC CONTROL SYSTEM

- Real-time

The CPU of a PLC is able to process logics in real time, guaranteeing the time period at each program cycle



THE ADVANTAGES OF A PLC CONTROL SYSTEM

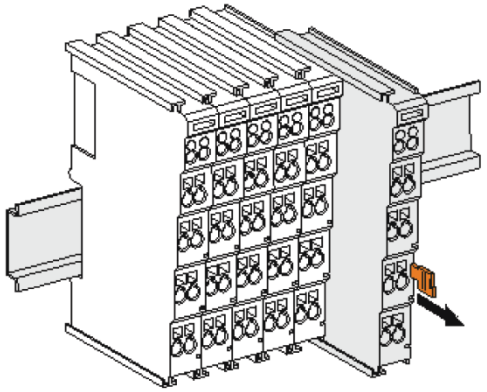
- Flexible

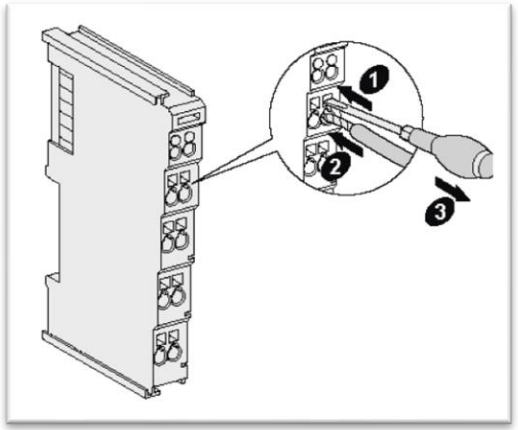
In a control system created with a PLC, it is possible to add or modify the installed modules without redesigning the entire system architecture

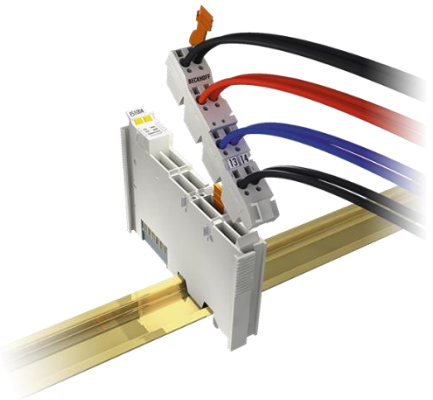
THE ADVANTAGES OF A PLC CONTROL SYSTEM

- Easy installation, operation and troubleshooting

PLCs are designed to be installed and replaced quickly to minimize system downtime



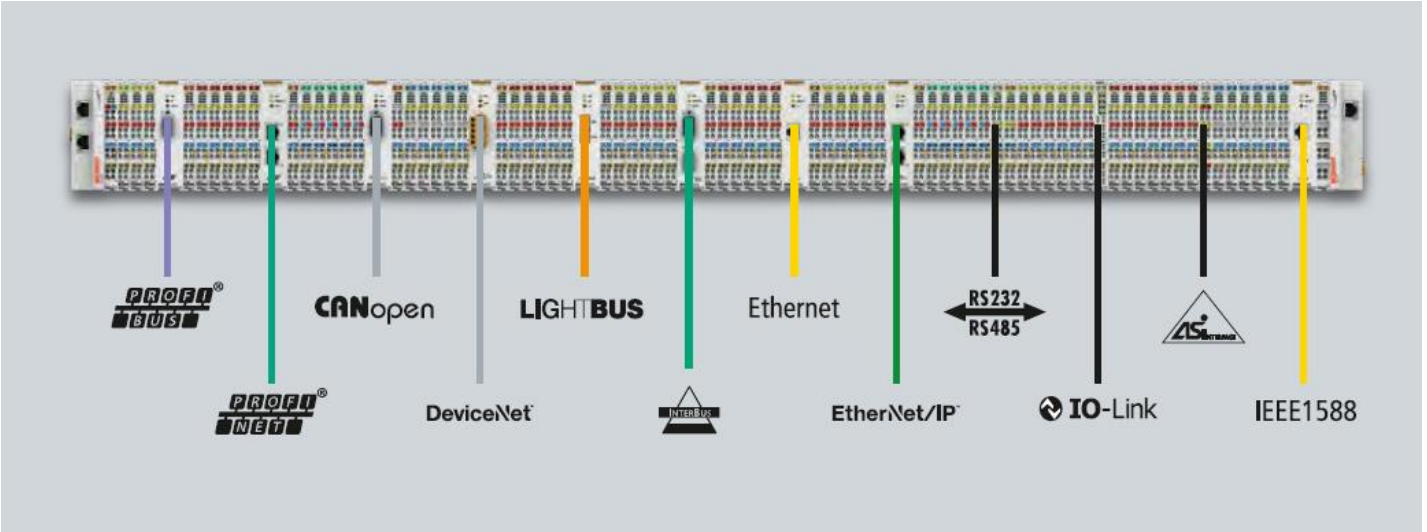




THE ADVANTAGES OF A PLC CONTROL SYSTEM

- Standard communication protocols

PLCs support many communication protocols allowing a connection to many type of device, even between PLCs from different brands



THE ADVANTAGES OF A PLC CONTROL SYSTEM

- Resilient

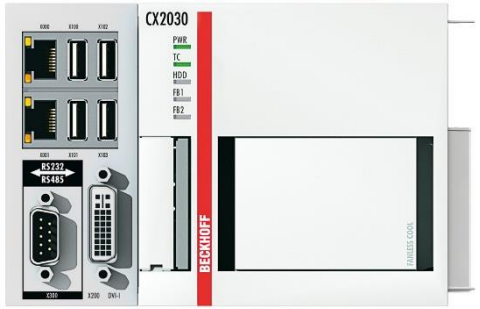
PLCs can operate in different types of environments or where particular certifications are required

SUMMARY

- Programmable logic controller
- The advantages of a PLC control system
- Beckhoff: devices and tools
- PLCs at ESO

BECKHOFF: DEVICES AND TOOLS

- CPU
  - Open, PC-based control technology
  - Embedded platforms (DIN mount), industrial PCs or standard PCs
  - Based on Windows or Free-BSD



BECKHOFF

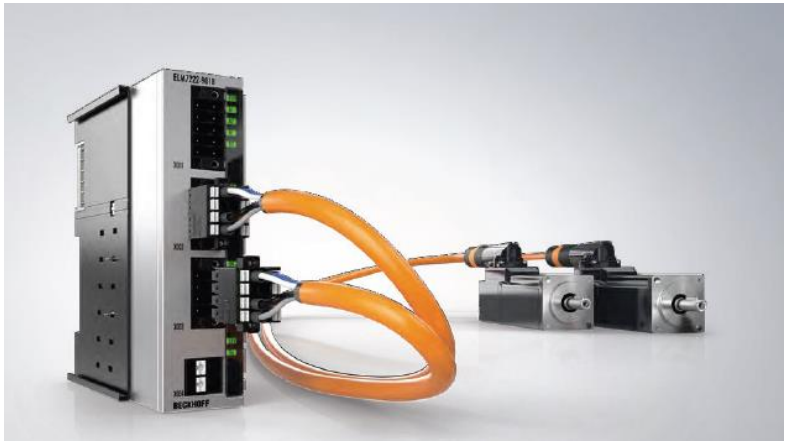
TwinCAT®

BECKHOFF: DEVICES AND TOOLS

- Support for all the basic I/O

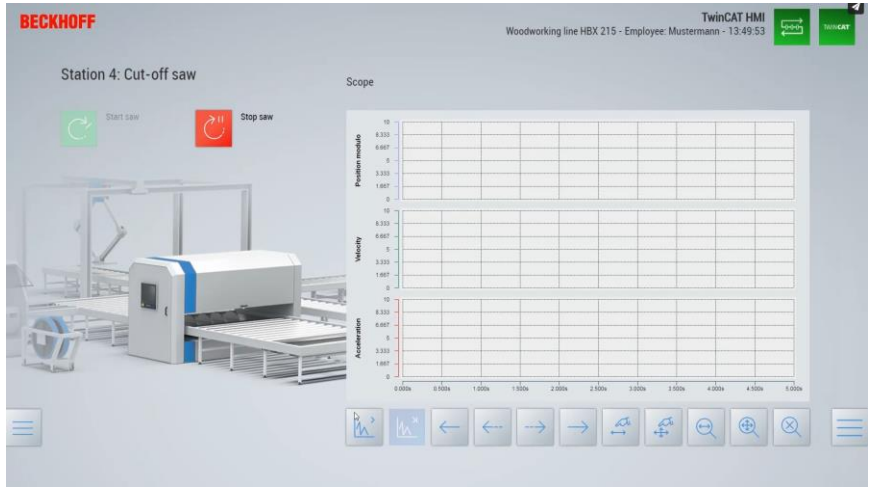
BECKHOFF: DEVICES AND TOOLS

- Motion control is provided by the PLC runtime
- All motor technologies supported with dedicated modules
- Very compact solutions are possible



BECKHOFF: DEVICES AND TOOLS

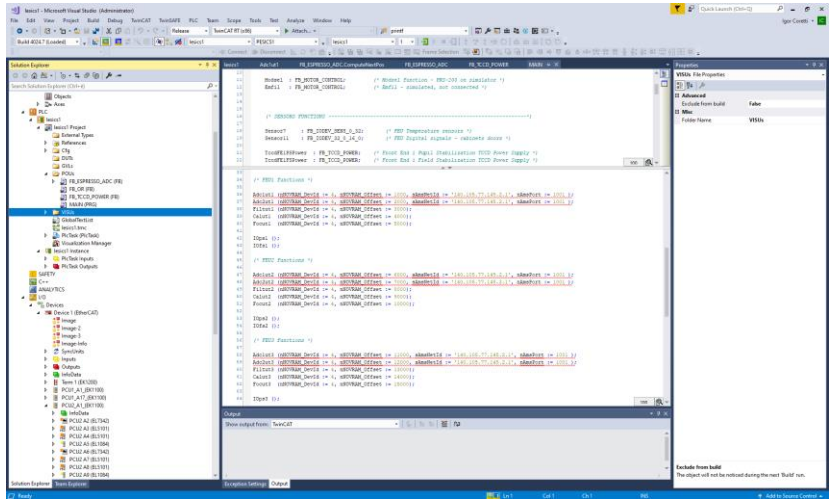
- HMI
- Basic support on all panels and IDE
- Advanced HMI based on HTML5 available as extension



BECKHOFF: DEVICES AND TOOLS

- PLC IDE → TwinCAT3 XAE (eXtended Automation Engineering)
  - Based on Visual Studio
  - Requires Windows
  - Supports all programming options
  - Hardware management
  - Motion control configuration and management
  - HMI design
  - Debugging

TwinCAT® 3



BECKHOFF: DEVICES AND TOOLS

- PLC runtime → TwinCAT 3 - XAR (eXtended Automation Runtime)
  - Communicates with XAE using with ADS protocol
  - Runs on any windows platform with guaranteed real-time
  - Scales seamlessly
  - Has different levels, depending on motion control requirements
  - Many extension available (special functions, communication, HMI, etc.)
  - Licensing costs are tied to CPU power
  - Development licenses are free

SUMMARY

- Programmable logic controller
- The advantages of a PLC control system
- Beckhoff: devices and tools
- PLCs at ESO

PLCs AT ESO

- In the past: VME based
  - Used in many big physics experiments
  - VME implements the Local Control Unit
    - real-time control
  - Unix - Linux based workstation manages the high-level control

PLCs AT ESO

- Current : PLC based
  - PLC substitutes the VME
  - Brand of choice : Beckhoff
    - ESO provide a list of standard modules
  - Mandatory in all VLT /ELT projects
  - Communication standard
    - OPC-UA
    - Is used for all data exchange between Workstation and PLC
  - Instrument workstation is the supervisor
    - Similar approach to SCADA - it mainly sends commands to PLCs

PLCs AT ESO

- Standardize the PLC also on the software side: the ESO libraries
- Devices include a state machine management
- Some ESO "Standard" device:
  - Lamp
  - Generic digital and analog input and output
  - Motor
    - Includes ADC, Derotator and multi-axis devices
  - Actuator
  - Shutter
  - Communication device
    - Temperature controllers

PLCs AT ESO

Library content:

- Function block (FB) for function control (e.g. FB_LAMP)
  - Some libraries deliver more than one FB (e.g. motor.library)
- Function block for testing when no hardware is available (e.g. FB_SIM_LAMP)
- GUI for local control (e.g. GUI_TEMPLATE_LAMP)
- Enumerations and data structures
  - CFG
  - CTRL
  - INFO
  - STAT

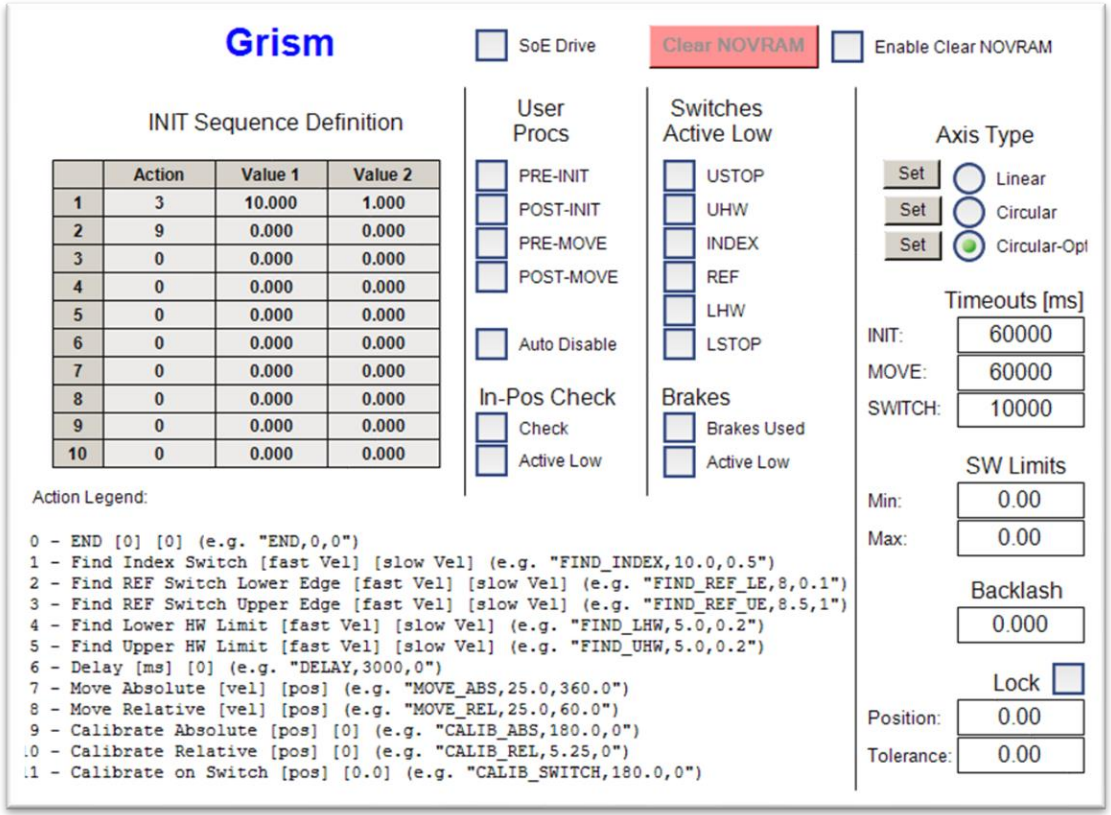
PLCs AT ESO

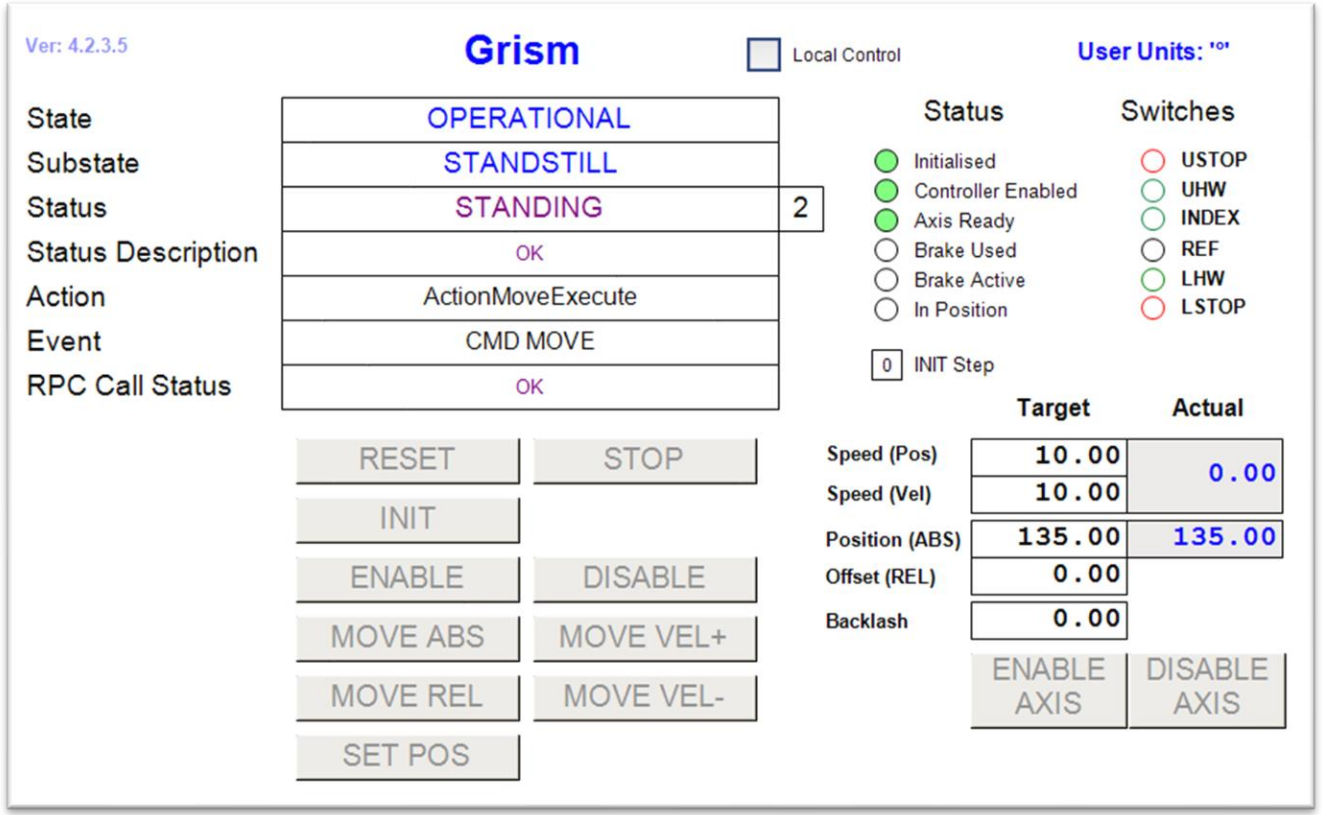
Inside a ESO standard device function block:

- FB_BASE with common methods to handle the device (most placeholders)
- FB_DEVICE extended from FB_BASE with specific methods
- List of methods to interface to ICS (changes to the state machine)
  - RPC_init
  - RPC_enable
  - RPC_disable
  - RPC_stop
  - RPC_reset
  - Other RPC related to the device (e.g. RPC_On for the Lamp)

PLCs AT ESO

- Examples of template GUI





PLCs AT ESO

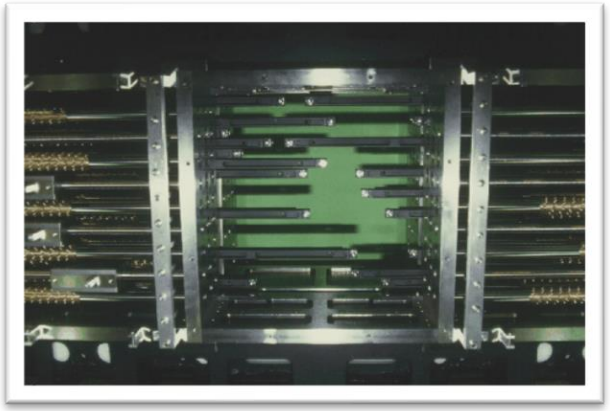
Special devices:

- Control of non-standard hardware
- Control of standard hardware in non-standard way
- Coordination of standard and/or non-standard devices
- Specific applications not related to hardware

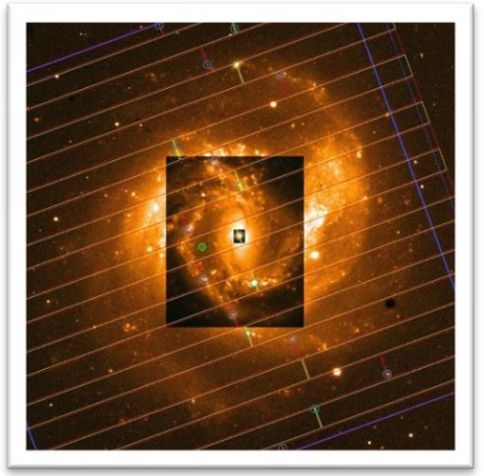
PLCs AT ESO

An example of special device: MOS (Multi-object spectroscopy)

- Used in FORS-Up to observe up to 19 objects simultaneously.
- Every slit obtained by pair of slitlets individually driven by a motor via a precision spindle, controlled by an absolute encoder.



MOS slit jaws



MOS observing tecnique

PLCs AT ESO

SIEMENS:

- PLC chosen by ESO for special tasks like cryostats and vacuum control systems
- TIA Portal: Innovative simulation tools, seamlessly integrated engineering, energy monitoring and transparent plant operation

PLC S7-1500

TIA PORTAL

THE END

Thank you for your attention