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ELT ICS Framework - Function Control Framework - User Manual

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Release

This document corresponds to `ifw-fcf`[1] v4.0.0.

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	See CRE ET-1249
All	All sections updated (IFW version 4.0)

[1] https://gitlab.eso.org/ifw/ifw-fcf

Contents

1 Introduction

The FCF is the ICS Framework component with the purpose of helping consortia in building the FCS software. Its main goal is to provide ready to use and configurable software entities for controlling and monitoring instrument hardware functions and sensing systems. The FCF includes subcomponents along the three layers of the ICS three-tier architecture.

1.1 Scope

This document is the user manual for the ELT ICS Framework - FCF. The intended audience are ELT users, consortia developers or software quality assurance engineers.

This release is to be used by the Consortia developers in trying out the control of instrument hardware functions using the provided libraries and applications, as well as getting acquainted with the design choices and their implementations.

1.2 Acronyms

ADC	Atmospheric Dispersion Correction
DB	Database
CCS	Central Control System
ELT	Extremely Large Telescope
FCF	Function Control Framework
FCS	Function Control System
GUI	Graphical User Interface
ICS	Instrument Control System
LCS	Local Control System
PLC	Programming Logical Controller
RAD	Rapid Application Development
RPC	Remote Procedure Call
SCXML	State Chart XML

1.3 Main Components

The present version of the FCF (v4.0.0) covers the following main components:

- A *Device Manager* implementation that can control a configurable number of devices from a standard ELT WS.
- A generic *GUI* for the Device Manager that allow users to control devices graphically.
- A set of *Device Simulators* capable of emulating the behaviour of a device controller and its interface within a WS.

- A set of *PLC libraries* implementing the supported device controllers, corresponding PLC simulators and HMIs for local control.

1.4 Top Directory Structure

The first level of the `fcf` directory contains the following:

```
<root>              # FCF component root
├── devmgr          # directory containing the FCF manager and devices classes
├── devsim          # directory containing the device simulators
├── gui             # directory containing the different GUIs modules
├── doc             # directory containing the FCF user manual (sphinx format)
├── test            # directory containing the FCF integration tests
└── wscript         # WAF build script
```

1.5 Device Manager (devmgr)

The server implementation is based on the ICS application framework (rad). Following the ELT and ICS development standards, the client and server are implemented in C++.

1.5.1 Directory Structure

In the present version of the FCF, the device manager contains:

```
<root>              # devmgr root directory
├── cli             # FCF CLI  added in version 3
├── client
├── common
├── devices
├── fcfif
├── clib            # Renamed in version 4
├── server
├── templates
└── wscript
```

Where:

- `cli` is a dedicated shell to interact with the Device Manager. the server from the command line.
- `client` is an application that can be used to send commands to the server from the command line.
- `common` is a library implementing core server classes like actions and activities.
- `devices` is a library implementing the device classes.
- `fcfif` is the CII XML interface module with the payload definition for commands and topics.

- `clib` is a python library that simplifies the interaction with the server from Python scripts.
- `server` is the server application (devmgrServer). This is a reference implementation that can be configured to control instrument functions of a given type.
- `templates` is a directory containing templates for code and configuration generation. Template files use the Jinja2 template engine: Jinja 2 documentation[1]

1.6 Device Simulators (devsim)

The FCF includes a set of Simulators with the purpose of allowing the Device Manager to run without the need for a PLC. These Simulators are implemented in Python and they run on a Linux WS. Each Device Simulator implements an OPC-UA Server as well as the business logic of a particular Device Controller.

1.7 Graphical Interfaces (gui)

In order to simplify the usage of the server, the `fcf` provides a prototype of an engineering interface. The graphical interface has been implemented in Qt using the QtWidget library.

1.7.1 Directory Structure

In the present version of the FCF, the `gui` contains:

```
<root>              # gui root directory
├── fcfgui          # FCF generic engineering graphical interface
├── wdglib          # Motor device engineering graphical interface
├── pymotgui        # Motor device engineering graphical interface implemented in␣
↪Python.
├── pylampgui       # Lamp device engineering graphical interface implemented in␣
↪Python.
├── msglib          # Library for sending commands to the server from GUIs.
└── wscript
```

1.8 PLC Libraries (controllers)

With the adoption of GIT, some components have been split into high and low level parts. This is the case of the FCF where PLC controller projects are found now under the `ifw-ll` GIT project which contains the controller directory with all PLC library projects. This directory contains the list of TwinCAT projects implementing the Device Controllers and Simulators for each of the hardware functions to be controlled by the FCF at the local level. These directories are Microsoft Visual Studio projects and they shall be edited under Windows using the TwinCAT IDE.

[1] http://jinja.pocoo.org/docs/dev/

- ifw-ll release (fcf controllers)[2]

Warning: Unlike the previous IFW version, these TwinCAT projects do not contain the compiled libraries only the source code.

We have compiled and packed all PLC libraries binaries into a dedicated GIT project. In this project it is stored PLC libraries, C++ modules and some sample projects. They can be retrieved from the GIT repository here[3].

1.8.1 Directory Structure

In the present version of the FCF, the `libraries` folder contains:

```
<root>                 # libraries root directory

├── IODev              # IoDev PLC library
├── Lamp               # Lamp PLC library
├── Motor              # Motor PLC library
├── Mudpi              # Motor PLC library
├── Piezo              # Piezo PLC library
├── Shutter            # Shutter PLC library
├── Actuator           # Actuator PLC library
├── ccslib             # CCS PLC library
├── ccssim             # CCS simulation PLC library
├── cryo               # Cryogenic Toolkit PLC library
├── plctpl             # PLC Template library
├── rsCommCommon       # Serial communication Common PLC library
├── rsCommSerial       # Serial communication PLC library
├── rsCommTcp          # Serial communication TCP PLC library
├── rsCommTcpRt        # Serial communication TCP RT PLC library
└── timer              # Timer PLC library
```

[2] https://gitlab.eso.org/ifw/ifw-ll/-/releases
[3] https://gitlab.eso.org/ifw/ifw-resource

2 Device Manager

The Device Manager provides the functionality for supervision and management of a configurable set of devices.

The Device Manager provides a library of devices implementing the communication with the respective device controllers in the PLC. Devices are created at the manager start-up by a device factory class. The main components of the *Device Manager* server are:

- State Machine engine based on SCXML and implemented in RAD. It contains a set of action and activity classes.
- A Device Factory class that creates the instances of all device classes at start-up and based on the server configuration.
- A set of Device classes. Each device has two additional classes: one for the device configuration and the other one for the interface with the Local Control System (LCS).
- A Facade class that manages the interface between the state machine engine and the device classes.

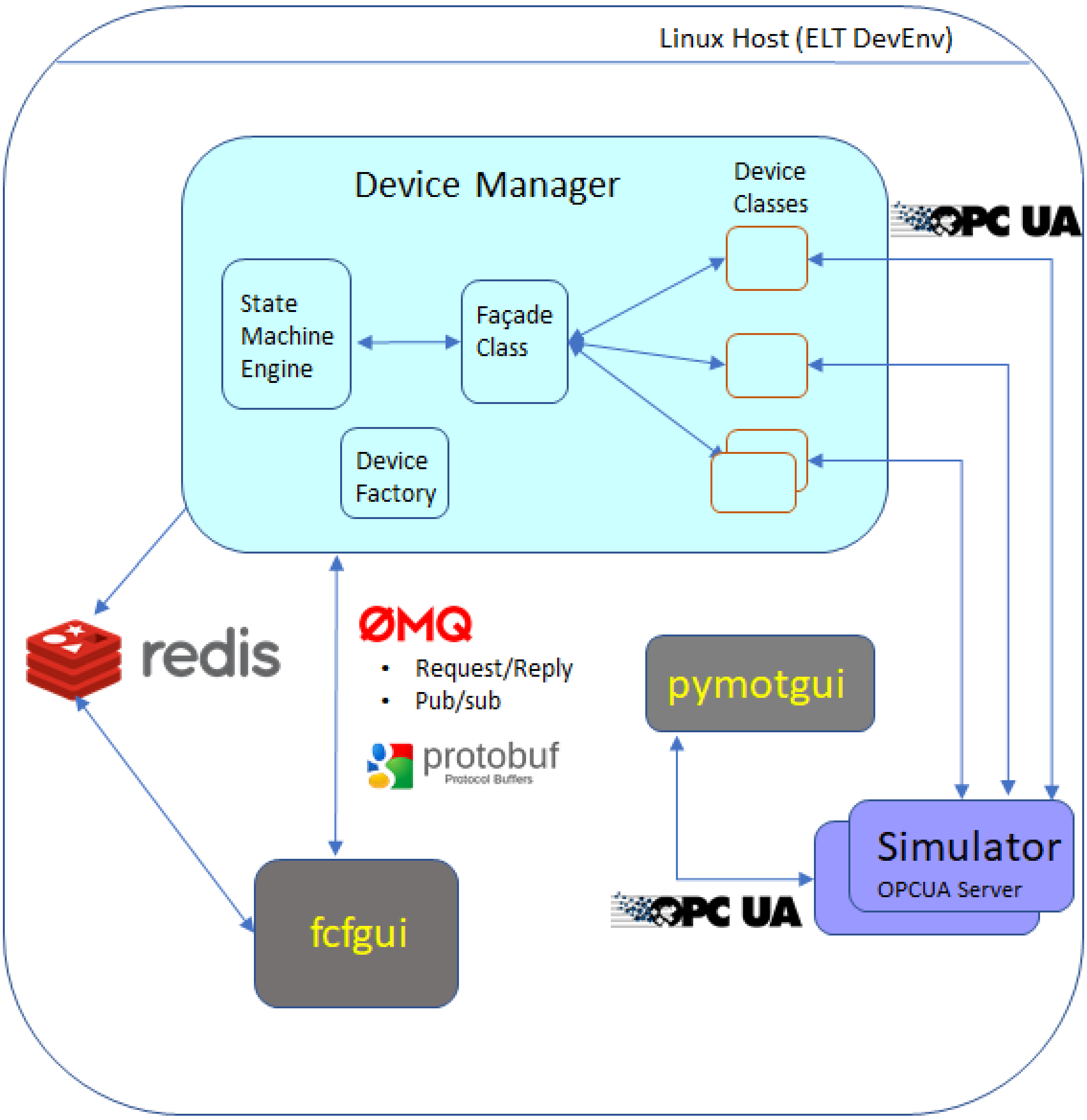

Fig. 2.1: Device Manager Components without LCS.

Client applications, such as *fcfGui*, send commands to the Device Manager using the CII MAL library (request/reply). The *fcfGui* reads the information about the devices from the Redis DB using polling.

The Device Manager uses the Redis Database to store run-time information about itself and about the devices it controls. In absence of a Local Control System, device classes can connect to the Device Simulator via the OPC-UA protocol, see figure above.

In normal operation, device classes connect to the OPC-UA server running under the Windows OS side of the Beckhoff IPC, e.g .CX2030. This communication is based on the execution of RPC calls (OPC-UA Method profile). Each Device Controller running in the TwinCAT PLC declares a number of methods defining the interface with the Device Manager. Additionally, the device classes subscribe to the status data produced by the device controllers. Each time the status changes, the device classes are notified and they updates the Redis DB and publish the corresponding changes via CII (pub/sub).

The PLC OPC-UA Server connects to the device controllers via the vendor specific protocol (ADS). The device controllers trigger the changes in the hardware via the TwinCAT I/O mapping.

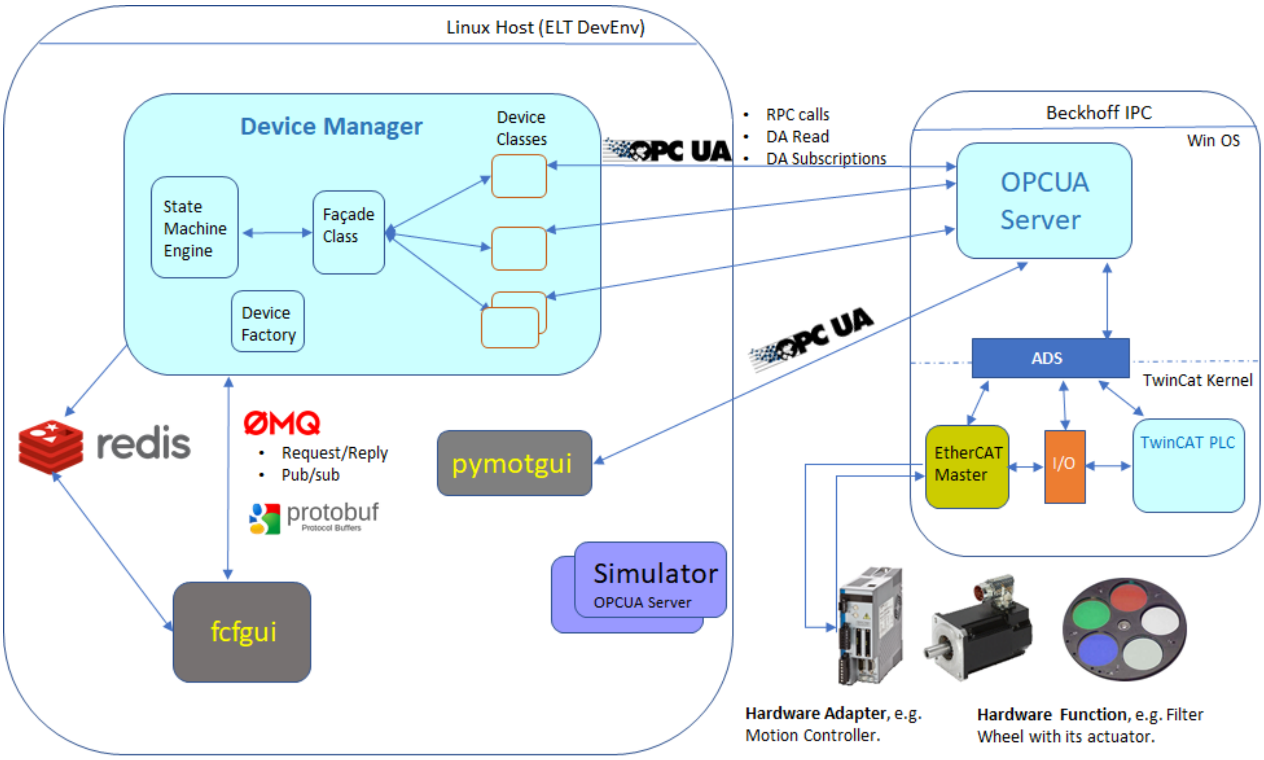

Fig. 2.2: Device Manager connecting to a Beckhoff IPC.

2.1 Supported Devices

2.1.1 Shutters

The *Shutter* device is a general purpose device for controlling a shutter hardware function. The device can control the shutter open/close.

2.1.2 Lamps

The *Lamp* device is a general purpose device for controlling a lamp hardware function. The device can switch a lamp on/off, control the intensity and handle warm-up and cool-down times when this is supported.

2.1.3 Motors

The *Motor* device is a general purpose device that controls different types of motors. It provides the following features:

- Support three different axis types: Linear, Circular and Circular-Optimized. Circular-Optimized means that the motor will always take the shorter path to reach the target position.
- Definition of named positions in user units (UU) or encoder values.
- Arbitrary positioning given in user units or encoder values.
- Positioning in absolute or relative units.
- Support for configurable Initialization Sequence.
- Support for SW limits.
- Support for various timeouts.
- Auto disabling when standing.
- Support for brake handling.
- Support for backlash compensation.

2.1.4 Sensors

The *Sensor* device is a device that groups instrument engineering variables for the purpose of monitoring and recording the instrument status and its subsystems over time. It can be configured with a variable number of channels that are grouped logically. The *Sensor* device supports three different channel types: Digital input, Analog input and Integer input.

2.1.5 Derotators

The *Derotator* device is an aggregated motor device that continuously adapt its position according to the field or pupil rotation. It supports four different modes:

- **Stationary**: Derotator moves to a target position based on the position angle and remains standstill after reaching the target.
- **Sky**: The Derotator is continuously moving to compensate the field rotation.
- **Elevation**: The Derotator is continuously moving to compensate the pupil rotation.

- **User**: The Derotator is continuously moving according to a customized computation of the position defined by the user.

2.1.6 ADCs

The *ADC* device manages the position of two prisms with the aim of correcting for the atmospheric dispersion.

The device supports two modes:

- **Auto**: The ADC is continuously positioning the two motors based on the telescope RA/DEC, the environmental parameters and the ADC configuration.
- **Off**: The ADC moves to a target position and remains standstill after reaching the target.

2.1.7 Piezos

The ‘Piezo’ device manages the control of the output signals of a piezo hardware. It supports up to three axes. The device can be set in two modes:

- **Auto**: The Piezo is correcting continuously the outputs based on the feedback signals.
- **Pos: The Piezo set the output of the axes to a fixed value. In this mode, the Piezo can** be controlled in user positions (normally volts) or directly in bits.

2.1.8 Actuator

The *Actuator* device is a general purpose device for controlling actuators through a switch signal (on/off). The most common use of actuators is for power control.

2.2 Device Manager State Machine

The Device Manager uses a state machine described in a SCXML format that is interpreted by the state machine engine provided by the `rad` application framework. (SCXML specification[4]).

[4] https://www.w3.org/TR/scxml/

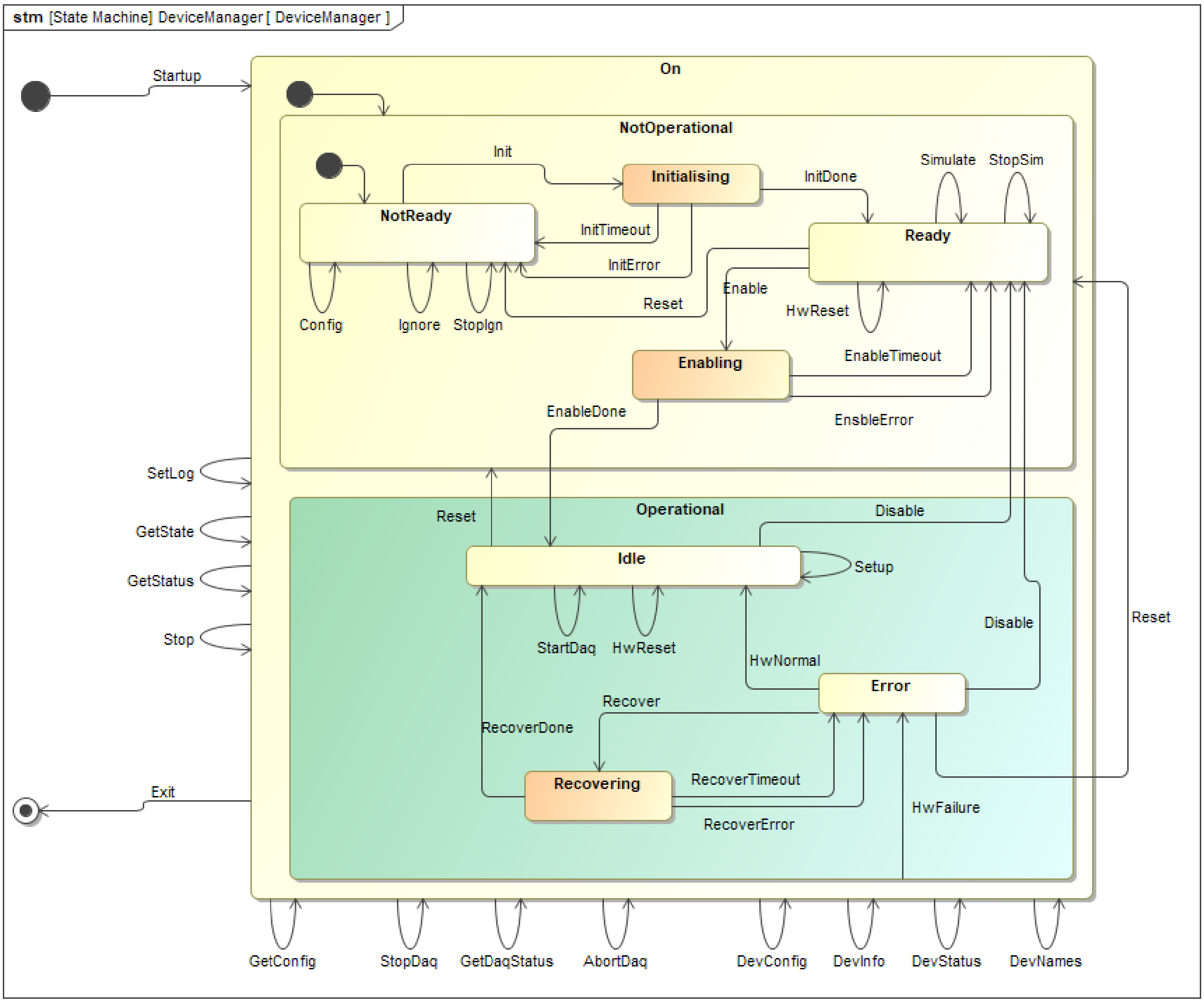

Fig. 2.3: Device Manager State Machine Diagram.

Off –> NotReady*, event: *Startup

The Device Manager starts up and goes automatically to *NotOperational/NotReady*. Main server objects are instantiated including the basic application that uses the State Machine engine. The Device Manager reads its own configuration and completes its initialisation.

***NotReady –> Ready*, event: Init**

The server connects to each of the device controllers through the device objects. Depending on the device configuration, it establishes the connection to the real HW or to the simulator. If any of the device objects fails to establish the connection, the server will remain in substate *NotReady*.

NotOperational/Ready –> Operational/Idle*, event: *Enable

The Device Managers goes through the Enabling state. If Device Controllers are already Operational, the Device Manager does not affect their state and goes immediately to the Operational state. If Device Controllers are not operational, Device Manager will trigger the events (via OPC-UA method calls) to reach the operational state for each of the local devices under the manager control. If it does not succeed within the defined timeout (configuration parameter, see *CII Configuration Service (config-ng)*), it will reply with a failure remaining in NotOperational/Ready state. During the transition from *NotOperational/Ready* to *Operational/Idle*, the Device Manager downloads the configuration to each Device Controller. If at least one Device Controller cannot reach the Operational state, the Device Manager will remain in state *NotOperational/Ready*.

Operational/Idle –> Operational/Error*, event: *HwFailure

Problems in at least one of the managed devices will bring the Device Manager into the Error state (Operational/Error). A typical example would be when the PLC, running the Device Controller, is power-cycled.

Operational/Error –> Operational/Idle*, event: *HwNormal

In the situation when an error condition is recovered, the Device Manager will go back automatically to *Operational/Ready* state (event *HwNormal*). For instance, if the network connection is lost, the Device Manager will go to *Error* but when the network is restored, the Device Manager will update its state automatically.

Operational –> NotOperational/Ready*, event: *Disable

The Device Manager disables the operation of devices but the state of controllers is not affected. If the state of the controllers is to be changed to NotReady, this has to be done separately. The reason for the above is to avoid affecting the state of the controllers by changing the state of the manager and thus achieve minimal impact on the hardware. In case of error going from Operational to *NotOperational/Ready*, the end state will be nevertheless *NotOperational/Ready*.

NotOperational/Ready –> NotOperational/NotReady*, event *Reset

The subscription to the OPC-UA server is stopped and the sessions of the managed devices are disconnected. In case of error going from *Ready* to *NotReady*, the end state will be nevertheless *NotReady*.

Extract of the current State Machine specification for the Device Manager.

```
<state id="On">
<initial>
  <transition target="NotOperational"/>
</initial>
<state id="NotOperational">
  <initial>
    <transition target="NotReady"/>
  </initial>
  <state id="NotReady">
    <transition event="Events.Reset" target="NotReady">
       <customActionDomain:ActionReset name="ActionReset"/>
    </transition>
    <transition event="Events.Init" target="Initialising"/>
    <transition event="Events.Config">
     <customActionDomain:ActionConfig name="ActionConfig"/>
    </transition>
  </state>
  <state id="Initialising">
    <onentry>
      <customActionDomain:ActionInitStart name="ActionInitStart"/>
    </onentry>
    <invoke id="ActivityInitialising"/>
           <transition event="Events.InitDone" target="Ready">
              <customActionDomain:ActionInitDone name="ActionInitDone"/>
           </transition>
           <transition event="Events.InitError" target="NotReady">
              <customActionDomain:ActionInitError name="ActionInitError"/>
           </transition>
```

2.3 Configuration

2.3.1 CII Configuration Service (config-ng)

The FCF in version 4.0.0 has been ported to the CII config-ng library. This library allows to define type information for the configuration parameters and supports inheritance. The FCF has included a predefined set of configuration definitions. These files are part of the FCF configuration and can be found in the fcf/server/resources/config directory. This config directory contains the following subdirectories:

- definitions: it contains the basic types for the server and devices.
- mapping: it contains the instances of the mapping files for each device type.
- devices: it contains examples of configuration for each device type.

- server: it contains an example of the configuration for the server.

You can find more information about CII config-ng in the following link. (Config-ng manual[5]).

Warning: Please note that due to the porting to the CII config service, all applications shall be updated accordingly.

2.3.2 Device Manager Configuration

The server configuration is a set of files written in `yaml` format. (YAML specification[6]). YAML is easy to read format that has been adopted by the CII configuration service.

Many resources about YAML can be found on the web. One could also validate the format online, see http://yaml.org/spec/

The CII config-ng defines a set of `yaml` custom tags for defining types, e.g. `!cfg.type:int32` defines an integer parameter. Applications can define additional types. The FCF has defined a number of types including one per device.

Note: The entry point for the *Device Manager* configuration is the file that contains the server configuration and the mapping to the device configuration files. The configuration of each device should be given in a separate file for better readability and maintenance. Each device type uses the corresponding mapping file that defines the real names of the attributes in the OPC-UA address space.

[5] https://www.eso.org/~eltmgr/CII/latest/manuals/html/docs/config-ng.html
[6] http://yaml.org/spec/

Config Item	Type	Optional	Default	Description
server::server_id	string	no		This is the id associated with the specific server.
server::req_endpoint	string	no		This is the endpoint for CII MAL request/reply. The server will listen to incoming commands using this endpoint.
server::pub_endpoint	string	no		This is the endpoint for CII MAL pub/sub. The server will publish its status using this endpoint.
server::db_endpoint	string	no		This is the endpoint used by the server for connecting to the Redis DB.
server::db_timeout	double	yes	2000 [ms]	This is the timeout for connecting to the Redis DB.
server::log_properties	string			log4cplus property file to be used by the server.
server::scxml	string	no		This is the state machine specification file used by the server.
server::fits_prefix	string	no		This is the prefix to be used for the FCS meta-data.
server::oldb_prefix	string	no		This is the prefix to be used for the DB. This prefix is meant to identify uniquely a given system, e.g. micado.
server::req_timeout	double	yes	2000 [ms]	General command timeout for sending commands to the Local Control System (LCS).
server::mon_timeout	double	yes	1000 [ms]	General timeout for monitoring.
server::dictionaries	**vector** of string	no		Vector of dictionaries to be used by the server.
server::devices	**vector** of devices	no		This is a vector of devices which are active in the server configuration. Only devices listed here will be managed by the server.

Each element in the device vector has the following attributes:

name

This is the device name.

cfgfile

Configuration filename for a device.

type

Device type.

An example of a server configuration is provided below.

```
# server definition
!cfg.include fcf/devmgr/definitions/server.yaml:

server: !cfg.type:FcfServer
    server_id        : 'fcs1'
    req_endpoint     : "zpb.rr://127.0.0.1:12082/"
    pub_endpoint     : "zpb.ps://127.0.0.1:12345/"
    db_endpoint      : "127.0.0.1:6379"
    db_timeout       : 2000
    scxml            : "fcf/devmgr/server/sm.xml"
    dictionaries     : ['dit/stddid/primary.did', 'fcf/devmgr/server/fcf.did']
    log_properties   : "fcf/devmgr/server/log_properties.cfg"
    fits_prefix      : "FCS1"
    oldb_prefix      : "ins8"
    req_timeout      : 300000
    devices          : [
    {
    name: 'shutter1',
    type: Shutter,
    cfgfile: "fcf/devmgr/devices/shutter1.yaml"
    },
    {
    name: 'lamp1',
    type: Lamp,
    cfgfile: "fcf/devmgr/devices/lamp1.yaml"
    },
    {
    name: 'actuator1',
    type: Actuator,
    cfgfile: "fcf/devmgr/devices/actuator1.yaml"
    },
    {
    name: 'motor1',
    type: Motor,
    cfgfile: "fcf/devmgr/devices/motor1.yaml"
    },
    {
```

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```
    name: 'piezo1',
    type: Piezo,
    cfgfile: "fcf/devmgr/devices/piezo1.yaml"
    },
    {
    name: 'sensor1',
    type: Sensor,
    cfgfile: "fcf/devmgr/devices/sensor1.yaml"
    },
    {
    name: 'adc1',
    type: Adc,
    cfgfile: "fcf/devmgr/devices/adc1.yaml"
    },
    {
    name: 'drot1',
    type: Drot,
    cfgfile: "fcf/devmgr/devices/drot1.yaml"
    }
    ]
```

2.3.3 Device Base Configuration

Each device has a common set of configuration parameters.

<device id>::type

It specifies the type of the device. Valid types are: *Shutter*, *Lamp*, *Motor*, *Sensor*, *Drot*, *Adc*, *Piezo* and *Actuator*.

<device id>::interface

It defines the communication interface that will be used by the device. At present, the only valid value is: *Softing*. This is the name of the OPC-UA toolkit used to communicate to the LCS (PLC). The needed libraries are included in the installation of the ELT standard machine.

<device id>::identifier

It defines the PLC object identifier.

<device id>::namespace

It defines the OPC-UA address space number.

<device id>::prefix

It defines the prefix for the address space nodeId of the device.

<device id>::simulated

Flag indicating if device is simulated.

<device id>::ignored

Flag indicating if the device is ignored. When a device is ignored, the device will ignore most of the commands received by the server until it receives the stop ignoring command (StopIgn).

<device id>::dev_endpoint

It defines the endpoint of the OPCUA server for the device controller.

Note: address has been renamed to dev_endpoint in this version.

<device id>::sim_endpoint

It defines the endpoint of the OPCUA server for the device simulator.

Note: simaddr has been renamed to sim_endpoint in this version.

<device id>::mapfile

File providing the configuration of the attributes in the OPC address space per each of the supported device types.

An example of a mapping file configuration is included below.

```
!cfg.include fcf/devmgr/definitions/shutterMap.yaml:

Shutter: !cfg.type:ShutterMap
   cfg:
      low_closed:      cfg.bActiveLowClosed
      low_fault:       cfg.bActiveLowFault
      low_open:        cfg.bActiveLowOpen
      low_switch:      cfg.bActiveLowSwitch
      ignore_closed:   cfg.bIgnoreClosed
      ignore_fault:    cfg.bIgnoreFault
      ignore_open:     cfg.bIgnoreOpen
      initial_state:   cfg.bInitialState
      timeout:         cfg.nTimeout
   stat:
      state:          stat.nState
      substate:       stat.nSubstate
      local:          stat.bLocal
      error_code:     stat.nErrorCode
   rpc:
      rpcInit:        RPC_Init
      rpcEnable:      RPC_Enable
      rpcDisable:     RPC_Disable
      rpcClose:       RPC_Close
      rpcOpen:        RPC_Open
      rpcStop:        RPC_Stop
      rpcReset:       RPC_Reset
```

Note: With the information contained in the mapping file, combined with the PLC prefix and the namespace, the device obtains the NodeId for each of the attributes and the RPCs defined in the ICD with the device controller.

<device id>::fits_prefix

Prefix used by the device when generating the metadata information. This data is included in the FITS file generated by the server at the end of the exposure.

2.3.4 Shutter Specific Configuration

The *Shutter* device defines a set of configuration parameters that will be transferred to the device controller running in the LCS (PLC). All these parameters are under the `ctrl_config` heading.

> **Warning:** The *ctrl_config* parameters are downloaded to the device controller when the device is not *Operational*. If the controller is already *Operational*, the user shall force the transition from *Operational* to *NotOperational/NotReady* and back to Operational.

Config Item	Type	Optional	Default	Description
ctrl_config::low_closed	bool	yes	false	If true, the *closed* signal is active low.
ctrl_config::low_fault	bool	yes	false	If true, the *fault* signal is active low.
ctrl_config::low_open	bool	yes	false	If true, the *open* signal is active low.
ctrl_config::low_switch	bool	yes	false	If true, the *switch* signal is active low.
ctrl_config::ignore_closed	bool	yes	false	If true, the *closed* signal is ignored.
ctrl_config::ignore_fault	bool	yes	false	If true, the *fault* signal is ignored.
ctrl_config::ignore_open	bool	yes	false	If true, the *open* signal is ignored.
ctrl_config::initial_state	bool	yes	false	If true, the initial state for shutter will be open.
ctrl_config::timeout	uint	yes	3000 [ms]	Shutter timeout for transitions.

An example of a shutter configuration is given below.

```
!cfg.include fcf/devmgr/definitions/shutter.yaml:

# Please note some parameters are inherited and therefore not defined here.
shutter1: !cfg.type:Shutter
  identifier: PLC1                              # OPCUA Object Identifier
  prefix: MAIN.Shutter1                         # OPCUA attribute prefix
  simulated: true
  dev_endpoint: opc.tcp://134.171.59.98:4
  sim_endpoint: opc.tcp://127.0.0.1:7576             # Simulation address
  fits_prefix: "SHUT1"
  ctrl_config: !cfg.type:ShutterController
     initial_state:  false                              # If T, initial state is␣
↪open
```

2.3.5 Lamp Specific Configuration

The *Lamp* device defines a set of configuration parameters that will be transferred to the device controller running in the LCS (PLC). All these parameters are under the `ctrl_config` heading.

> **Warning:** The *ctrl_config* parameters are downloaded to the device controller when the device is not *Operational*. If the controller is already *Operational*, the user shall force the transition from *Operational* to *NotOperational/NotReady* and back to Operational.

Config Item	Type	Optional	Default	Description
ctrl_config::low_fault	bool	yes	false	If true, the *fault* signal is active low.
ctrl_config::low_on	bool	yes	false	If true, the *on* signal is active low.
ctrl_config::low_switch	bool	yes	false	If true, the *switch* signal is active low.
ctrl_config::ignore_fault	bool	yes	false	If true, the *fault* signal is ignored.
ctrl_config::invert_analog	bool	yes	false	If true, the analog feedback is active.
ctrl_config::initial_state	bool	yes	false	If true, the initial state will be switched on.
ctrl_config::analog_threshold	int	yes	0 [bits]	Analog feedback signal threshold
ctrl_config::analog_range	uint	yes	32767	Full range of A/D converter for analog output.
ctrl_config::cooldown	uint	yes	0 [s]	Cooldown time.
ctrl_config::maxon	uint	yes	0 [s]	Maximum time for the lamp to be On. If value is zero means no maximum is defined.
ctrl_config::warmup	uint	yes	0 [s]	Warmup time.
ctrl_config::timeout	uint	yes	3000 [ms]	Lamp timeout for transitions.

An example of a lamp configuration is given below. This configuration file can be found in module devmgr/server

```yaml
!cfg.include fcf/devmgr/definitions/lamp.yaml:

# Please note some parameters are inherited and therefore not defined here.
lamp1: !cfg.type:Lamp
  identifier: PLC1                             # OPCUA Object Identifier
  prefix: MAIN.Lamp1                           # OPCUA attribute prefix
  dev_endpoint: opc.tcp://134.171.59.98:4840
  sim_endpoint: opc.tcp://134.171.12.182:4840
  fits_prefix: "LAMP1"
  ctrl_config:
     initial_state:     false                    # If T, initial state is on
```

2.3.6 Sensor Specific Configuration

The sensor devices defines currently no configuration that will be downloaded to the LCS. However, it defines the configuration of the sensor channels. The sensor channels are known only at the server side.

Config Item	Type	Optional	Default	Description
readonly	bool	yes	false	Flag to indicate that sensor will only read the data from the controller without attempting to execute RPC calls. This flag is used for sensors running in commercial devices not running in a PLC but having an embedded OPC-UA server. To be used only in special cases.
ctrl_config::timeout	uint	yes	3000 [ms]	Sensor timeout for transitions.
channels	**vector** of channels	no	na	List of channels.

Each channel contains the following configuration parameters:

Config Item	Type	Optional	Default	Description
name	string	no	“”	Channel name.
description	string	yes	“”	Channel description.
type	string	no	na	Channel type. Allowed types are: DI (bool), AI (double), II (integer), ST (string).
header	bool	yes	true	If true, the channel will be included in the metadata FITS file.
log	bool	yes	true	If true, the sensor value will be logged (Not available yet !).
map	string	no	na	Channel internal mapping to the name in the LCS.
prefix	string	no	na	Channel FITS prefix.
unit	string	yes	na	Channel unit.

Warning: The *channels* parameter has been modified in version 4.0.0 with the porting to the CII config-ng.

An example of a sensor configuration is given below. This configuration file can be found in module devmgr/server. In this case, the sensor device has two channels: *ch1* and *ch2*.

```
!cfg.include fcf/devmgr/definitions/sensor.yaml:
# Please note some parameters are inherited and therefore not defined here.

sensor1: !cfg.type:Sensor
   identifier: PLC1
   prefix: MAIN.IODev1
   dev_endpoint: opc.tcp://134.171.59.98:4840
   sim_endpoint: opc.tcp://134.171.57.209:4840
   fits_prefix: "SENSOR1"
   ctrl_config:
      timeout:          20000
   channels: [
   {
    name: ch1,
    description: "channel1",
    fits_prefix: "CH1 STAT",
    type: DI,
    header: true,
    log: true,
    unit: mm,
    map: di1
    },
    {
    name: ch2,
    description: "channel2",
    fits_prefix: "CH2 STAT",
    type: DI,
    header: true,
    log: true,
    unit: dd,
    map: di2
    }
    ]
```

2.3.7 Motor Specific Configuration

The *Motor* device defines a set of configuration parameters that will be transferred to the device controller running in the LCS (PLC). These parameters are under the `ctrl_config` heading. The motor initialisation sequence will be also downloaded to the LCS.

The motor also defines a set of configuration parameters that are only known at the server level, for instance the named positions of the motor.

Tolerance of the named position in user units (UU). If the actual position is within the tolerance, the device will report the named position otherwise its name will be empty.

Warning: The *ctrl_config* parameters are downloaded to the device controller when the device is not *Operational*. If the controller is already *Operational*, the user shall force the transition from *Operational* to *NotOperational/NotReady* and back to Operational.

Config Item	Type	Optional	Default	Description
axis_type	string	yes	LINEAR	Axis type. Allowed options are: *LINEAR*, *CIRCULAR* and *CIRCULAR_OPT*.
tolerance	double	yes	1 [uu]	Tolerance of the named position in user units (UU). If the actual position is in the tolerance, the device will report the named position otherwise its name will be empty.
positions	vector of positions	no	na	Vector of named positions, see description below.
initialisation	vector of steps	no	na	Vector of initialisation steps, see description below.
ctrl_config::min_pos	double	yes	0 [uu]	Minimum position in user units.
ctrl_config::max_pos	double	yes	0 [uu]	Maximum position in user units.
ctrl_config::velocity	double	yes	1.0 [uu/s]	Default velocity for moving the motor in position mode
ctrl_config::active_low_lstop	bool	yes	false	If true, the *Lower Stop* signal is active low.
ctrl_config::active_low_lhw	bool	yes	false	If true, the *Lower Hw* signal is active low.
ctrl_config::active_low_ref	bool	yes	false	If true, the *Reference* signal is active low.
ctrl_config::active_low_index	bool	yes	false	If true, the *Index* signal is active low.
ctrl_config::active_low_ustop	bool	yes	false	If true, the *Upper Stop* signal is active low.
ctrl_config::active_low_uhw	bool	yes	false	If true, the *Upper Hw* signal is active low.
ctrl_config::exec_pre_init	bool	yes	false	If true, the pre-init execution is activate
ctrl_config::exec_post_init	bool	yes	false	If true, the post-init execution is activate.

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Table 2.1 – continued from previous page

Config Item	Type	Optional	Default	Description
ctrl_config::exec_pre_move	bool	yes	false	If true, the pre-move execution is activate.
ctrl_config::exec_post_move	bool	yes	false	If true, the post-move execution is activate.
ctrl_config::low_brake	bool	yes	false	If true, the *Brake* signal is active low.
ctrl_config::low_inpos	bool	yes	false	If true, the *In Position* signal is active low.
ctrl_config::backlash	double	yes	0 [uu]	Backlash compensation. If value is zero means no backlash compensation is active.
ctrl_config::disable	bool	yes	false	If true, the power of the motor will be disabled after positioning.
ctrl_config::lock	bool	yes	false	If true, the motor position will be locked
ctrl_config::lock_pos	double	yes	0 [uu]	Position that will be locked in case lock configuration is activated.
ctrl_config::lock_tolerance	double	yes	0 [us]	Tolerance of the lock position
ctrl_config::init_timeout	int	yes	60000 [ms]	Motor initialisation timeout.
ctrl_config::move_timeout	int	yes	60000 [ms]	Motor move timeout.
ctrl_config::switch_timeout	int	yes	150000 [ms]	Motor timeout for going out of the switch during initialisation.

Note: An optional parameter in this context means that FCF provides a default value in the parent device type configuration. This default value will be used unless users redefine it in the device instance configuration.

Motor Initialisation

Note: The motor has a set of configuration parameters dedicated to the motor initialisation sequence. The initialisation sequence is downloaded to the LCS only when device controller is not operational.

step

Step name.

value1

Parameter 1 of the initialisation step.

value2

Parameter 2 of the initialisation step.

Note: In case parameters are not applicable (*na*) please use 0 instead, for instance *END, 0, 0*

Table 2.2: Motor Initialisation Steps

Step	Description	Parameter 1	Parameter 2
END	Finish the sequence, no more actions are performed.	na	na
FIND_INDEX	Motor moves until finding the index pulse.	Fast velocity [UU/s]	Slow velocity [UU/s]
FIND_REF_LE	Motor moves until finding lower edge of reference switch.	Fast velocity [UU/s]	Slow velocity [UU/s]
FIND_REF_UE	Motor moves until finding upper edge of reference switch.	Fast velocity [UU/s]	Slow velocity [UU/s]
FIND_LHW	Motor moves until finding lower hardware limit.	Fast velocity [UU/s]	Slow velocity [UU/s]
FIND_UHW	Motor moves until finding upper hardware limit.	Fast velocity [UU/s]	Slow velocity [UU/s]
DELAY	Motor wait for a fixed amount of time before to continue.	time in [ms]	na
MOVE_ABS	Motor moves to an absolute position.	Velocity [UU/s]	Target position [UU]
MOVE_REL	Motor moves to a relative position.	Velocity [UU/s]	Target position [UU]
CALIB_ABS	Motor calibrates an absolute position.	Position [UU]	na
CALIB_REL	Motor calibrates a relative position.	Position [UU]	na
CALIB_SWITCH	Motor calibrates switch position.	Position [UU]	na

Note: Some of the initialisation steps require parameters, for instance the speed of the motor. These parameters are defined together with the initialisation step.

Named Positions

The motor device supports a configuration of named positions that associate specific motor position in user units (UU) to names. The aim of name positions is to facilitate the setting of motor positions by end users.

name

Position name.

value

Value of the position name in user units (UU).

Note: An example of a motor configuration is given below. This configuration file can be found in module devmgr/server.

```
!cfg.include fcf/devmgr/definitions/motor.yaml:

# Please note some parameters are inherited and therefore not defined here.
motor1: !cfg.type:Motor
  identifier: PLC1                              # OPCUA Object Identifier
  prefix: MAIN.Synchro1                         # OPCUA attribute prefix
  dev_endpoint: opc.tcp://134.171.59.98:4840
  sim_endpoint: opc.tcp://134.171.57.209:4840        # Simulation address
  fits_prefix: "MOT1"
  ctrl_config:
     velocity:              3.0
     min_pos:               0.0
     max_pos:               359.0
     active_low_ref:        true
     active_low_uhw:        true
  initialisation: [
     {
      step: 'FIND_LHW',
      value1: 4.0,
      value2: 4.0
     },
     {
      step: 'FIND_UHW',
      value1: 4.0,
      value2: 4.0
     },
     {
```

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```
      step: 'CALIB_ABS',
      value1: 0.0,
      value2: 0.0
     },
     {
      step: 'END',
      value1: 0.0,
      value2: 0.0
     }
  ]
 positions: [
  {
   name: 'ON',
   value: 30
  },
  {
   name: 'OFF',
   value: 100
   }
  ]
```

2.3.8 Derotator Specific Configuration

As for other devices, the *Derotator* device defines a set of configuration parameters that will be transferred to the device controller running in the LCS (PLC). All these parameters are under the `ctrl_config` heading.

Since the *Derotator* is just an aggregated motor device, it includes all *Motor* configuration parameters (see *fcf_devmgr_motor_config_ref*) plus a few parameters specific to derotators.

Warning: The *ctrl_config* parameters are downloaded to the device controller when the device is not *Operational*. If the controller is already *Operational*, the user shall force the transition from *Operational* to *NotOperational/NotReady* and back to Operational.

Config Item	Type	Optional	Default	Description
ctrl_config::dir_sign	int	yes	1	Motor direction sign
ctrl_config::focus_sign	int	yes	-1	Focus direction sign.
ctrl_config::trk_period	int	yes	20 [ms]	Period of the tracking corrections within the PLC.
ctrl_config::stat_ref	double	yes	0.0 [uu]	Reference position for stationary mode.
ctrl_config::sky_ref	double	yes	0.0 [uu]	Reference position for sky mode.
ctrl_config::user_ref	double	yes	0.0 [uu]	Reference position for user mode.
ctrl_config::user_par1	double	yes	0.0	Specific parameter 1 for user mode.
ctrl_config::user_par2	double	yes	0.0	Specific parameter 2 for user mode.
ctrl_config::user_par3	double	yes	0.0	Specific parameter 3 for user mode.
ctrl_config::user_par4	double	yes	0.0	Specific parameter 4 for user mode.

Note: An example of a Derotator configuration is given below. This configuration file can be found in module devmgr/server.

```yaml
!cfg.include fcf/devmgr/definitions/drot.yaml:

# Please note some parameters are inherited and therefore not defined here.
drot1: !cfg.type:Drot
    identifier: PLC1                              # OPCUA Object Identifier
    prefix: MAIN_FAST.drot                        # OPCUA attribute prefix
    dev_endpoint: opc.tcp://134.171.59.98:4840
    sim_endpoint: opc.tcp://134.171.57.209:4840        # Simulation address
    fits_prefix: "DROT1"
    ctrl_config:
        velocity:             3.0
        min_pos:              0
        max_pos:              0
    initialisation:
        sequence: ['FIND_LHW', 'FIND_UHW', 'CALIB_ABS', 'END']
        FIND_LHW:
            value1: 4.0
            value2: 4.0
        FIND_UHW:
```

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```
            value1: 4.0
            value2: 4.0
        CALIB_ABS:
            value1: 0.0
            value2: 0.0
        END:
            value1: 0.0
            value2: 0.0
    positions:
        posnames: ['ON', 'OFF']
        tolerance: 1.0                              # Tolerance in UU
        ON:    30.0
        OFF: 100.0
```

Note: The derotator uses Circular Optimize (CIRCULAR_OPT) as axis type. In this axis mode you have to reset the software limits to zero or simply not define them.

2.3.9 Derotator Control

Operation modes

Alias	Name	Description
eng	Engineering	In this mode, the *Derotator* behaves like a standard motor. This means that it can be moved in user units and encoders.
stat	Stationary	In this mode, the *Derotator* is stationary and it can be positioned at given angle according to the following formula: **pos := stat_ref + dir_sign * (posang)/2.0;**

sky	Sky	The *Derotator* tracks following the field rotation.
		fieldRotation := parallactic - focus_sign * altitude;
		pos := sky_ref + dir_sign * (posang - fieldRotation)/2;
		angleOnSky := posang;
		modeAngle := angleOnSky;

elev	Elevation	The *Derotator* tracks following the pupil rotation.
		pos := elev_ref + (focus_sign * dir_sign * altitude) /2.0;
		angleOnSky := parallactic;
		modeAngle := angleOnSky;

user	User	The *Derotator* tracks according to the user custom computation.

2.3.10 ADC Specific Configuration

As for other devices, the *ADC* device defines a set of configuration parameters that will be transferred to the device controller running in the LCS (PLC). These parameters are under the `ctrl_config` heading. Considering that the ADC is a multi-axis device, it includes as well the configuration of two standard motor devices. The configuration of each motor device is defined in separate files and they correspond to the configuration of a standard motor device (see *fcf_devmgr_motor_config_ref*).

Warning: The *ctrl_config* parameters are downloaded to the device controller when the device is not *Operational*. If the controller is already *Operational*, the user shall force the transition from *Operational* to *NotOperational/NotReady* and back to Operational.

Config Item	Type	Optional	Default	Description
ctrl_config::motors	vector	no		Vector of motors controlled by the ADC. See the table below.
ctrl_config::trk_period	int	yes	20 [ms]	Period of the tracking corrections within the PLC.
ctrl_config::pslope	double	yes	0.0023 [arcsec/mbar]	Pressure slope.
ctrl_config::poffset	double	yes	743.0 [mbar]	Pressure offset.
ctrl_config::tslope	double	yes	-0.0061 [arcsec/C]	Temperature slope.
ctrl_config::toffset	double	yes	12 [C]	Temperature offset.
ctrl_config::afactor	double	yes	3.32 [1/arcsec]	A Factor
ctrl_config::zdlimit	double	yes	0.0174533	Zenith distance limit
ctrl_config::minelev	double	yes	27.64 [deg]	Minimum Elevation.
ctrl_config::mot1_signoff	int	yes	1	Motor 1 sign for off mode
ctrl_config::mot1_signauto	int	yes	1	Motor 1 sign for auto mode
ctrl_config::mot1_signphi	int	yes	1	Motor 1 sign for phi
ctrl_config::mot1_refoff	double	yes	0 [deg]	Motor 1 offset for off mode
ctrl_config::mot1_refauto	double	yes	0 [deg]	Motor 1 offset for auto mode

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Config Item	Type	Optional	Default	Description
ctrl_config::mot1_coffset	double	yes	1.7387 [arcsec]	Motor 1 C parameter
ctrl_config::mot1_poffset	double	yes	90 [deg]	Motor 1 Position offset
ctrl_config::mot1_drotfactor	double	yes	2	Motor 1 derotator offset
ctrl_config::mot2_signoff	int	yes	1	Motor 2 sign for off mode
ctrl_config::mot2_signauto	int	yes	1	Motor 2 sign for auto mode
ctrl_config::mot2_signphi	int	yes	1	Motor 2 sign for phi
ctrl_config::mot2_refoff	double	yes	0 [deg]	Motor 2 reference position for off mode
ctrl_config::mot2_refauto	double	yes	0 [deg]	Motor 2 reference position for auto mode
ctrl_config::mot2_coffset	double	yes	1.7387 [arcsec]	Motor 2 C parameter
ctrl_config::mot2_poffset	double	yes	90 [deg]	Motor 2 Position offset
ctrl_config::mot2_drotfactor	double	yes	2	Motor 2 derotator offset

Each element in the motor vector has the following parameters:

Config Item	Type	Optional	Default	Description
name	string	no		Name of the motor configuration.
prefix	string	no		Internal name used by the ADC for motor1 (fixed)
cfgfile	string	no		File path for the motor configuration.

Note: An example of an Adc configuration is given below. This configuration file can be found in module devmgr/server.

```
!cfg.include fcf/devmgr/definitions/adc.yaml:

# Please note some parameters are inherited and therefore not defined here.
adc1: !cfg.type:Adc
```

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```
    identifier: PLC1                                      # OPCUA Object Identifier
    prefix: MAIN_FAST.adc                               # OPCUA attribute prefix
    dev_endpoint: opc.tcp://134.171.59.98:4840
    sim_endpoint: opc.tcp://134.171.57.209:4840            # Simulation address
    fits_prefix: "ADC1"
    ctrl_config:
    motors: [
    {
        name: 'adc1_motor1',
        prefix: "motor1",
        cfgfile: "fcf/devmgr/devices/adc1Motor1.yaml"
    },
    {
        name: 'adc1_motor2',
        prefix: "motor2",
        cfgfile: "fcf/devmgr/devices/adc1Motor2.yaml"
    }
    ]
```

2.3.11 ADC Control

Operation modes

The *ADC* operates two motorized functions. In engineering mode, each motor can be controlled independently.

Alias	Name	Description
eng	Engineering	In this mode, the *ADC* behaves like the standard motor. This means that each motor can be moved in user units and encoders.
off	Off	In this mode, the *ADC* is stationary and it can be positioned at given angle according to the following formula: **pos := off_ref + sign_off * posang;**
auto	Auto	The *ADC* tracks following the default formula. This formula can be replaced by the user in order to accommodate instrument specific requirements.

2.3.12 Piezo Specific Configuration

The *Piezo* device defines a set of configuration parameters that will be transferred to the device controller running in the LCS (PLC). All these parameters are under the `ctrl_config` heading.

> **Warning:** The *ctrl_config* parameters are downloaded to the device controller when the device is not *Operational*. If the controller is already *Operational*, the user shall force the transition from *Operational* to *NotOperational/NotReady* and back to Operational.

Config Item	Type	Optional	Default	Description
ctrl_config::num_axes	short	no	3	Configured number of piezo axes. This parameter gives flexibility to adapt to different type of piezos.
ctrl_config::max_on	int	yes	0	Maximum time that outputs will be maintained. If it is zero means there is no time counter.
ctrl_config::full_range[]	short	yes	32767	Full range per axes in bits.
ctrl_config::home[]	double	yes	0	Home position per axes in user units.
ctrl_config::lower_limit[]	double	yes	0	lower limit per axes in user units.
ctrl_config::upper_limit[]	double	yes	32767	upper limit per axes in user units.
ctrl_config::user_to_bit_input[]	double	yes	3276.7	user to bit conversion factor per axes for inputs.
ctrl_config::user_offset_input[]	double	yes	0	user offset per axes for inputs.
ctrl_config::user_to_bit_output[]	double	yes	3276.7	user to bit conversion factor per axes for outputs.
ctrl_config::user_offset_output[]	double	yes	0	user offset per axes for outputs.

An example of a piezo configuration is provided below.

```
!cfg.include fcf/devmgr/definitions/piezo.yaml:

# Please note some parameters are inherited and therefore not defined here.
piezo1: !cfg.type:Piezo
    identifier: PLC1                              # OPCUA Object Identifier
    prefix: MAIN.Piezo1                         # OPCUA attribute prefix
    dev_endpoint: opc.tcp://134.171.59.98:4840
```

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```
    sim_endpoint: opc.tcp://134.171.57.209:4840       # Simulation address
    fits_prefix: "MOT1"
    ctrl_config:
        num_axis:       3
        max_on:         180
```

2.3.13 Actuator Specific Configuration

The *Actuator* is one of the few devices that is not transferring any configuration to the controller in the transition from Ready to Operational. The *Actuator* assumes to have all the configuration defined in the controller (PLC). For knowing the controller configuration, please refer to the PLC Actuator section.

An example of a actuator configuration is provided below.

```
!cfg.include fcf/devmgr/definitions/actuator.yaml:

# Please note some parameters are inherited and therefore not defined here.
actuator1: !cfg.type:Actuator
    identifier: PLC1                                 # OPCUA Object Identifier
    prefix: MAIN.Actuator1                           # OPCUA attribute prefix
    address: opc.tcp://134.171.59.99:4840
    simaddr: opc.tcp://134.171.12.182:4840          # Simulation address
    fits_prefix: "MECH1"
    ctrl_config:
```

2.4 Database Attributes

The *Device Manager* uses the Redis DB to store the actual server configuration and run-time parameters. The Redis keys used by the server follow a hierarchical naming convention starting with the id of the server. Specific keys for devices use the id of the device in the name. The DB keys can be monitored using the *dbbrowser* utility. All *Device Manager* keys have a flat structure in Redis DB.

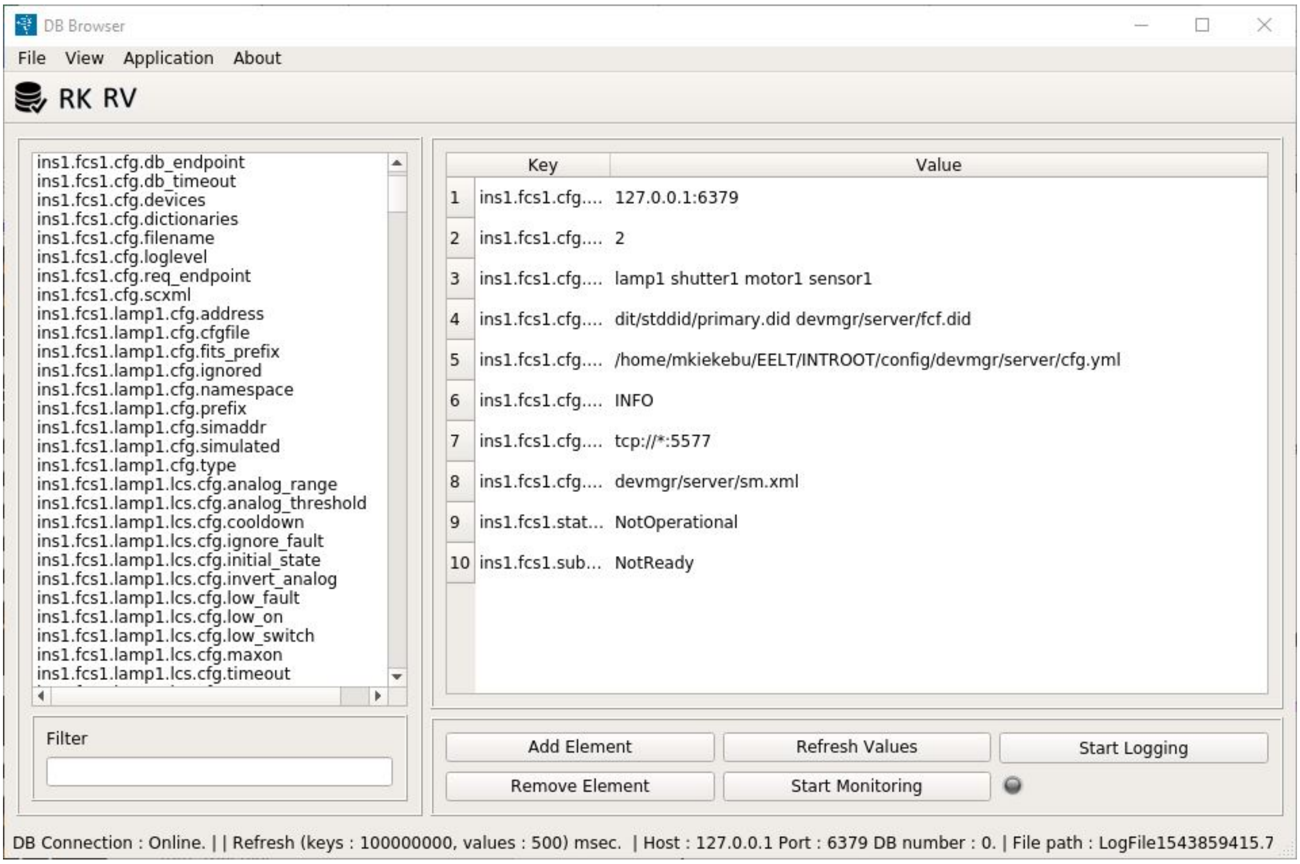

Fig. 2.4: *dbbrowser* utility

2.4.1 Server configuration

The server stores the actual values of the server configuration parameters into the Redis DB . This helps to verify whether the configuration has been loaded correctly. For details of the server configuration parameters, see *CII Configuration Service (config-ng)*.

Table 2.4: Server configuration Redis DB keys

Redis Key
<instrument id>.<server id>.cfg.db_endpoint
<instrument id>.<server id>.cfg.db_timeout
<instrument id>.<server id>.cfg.dictionaries
<instrument id>.<server id>.cfg.filename
<instrument id>.<server id>.cfg.fits_prefi
<instrument id>.<server id>.cfg.log_properties
<instrument id>.<server id>.cfg.mon_timeout
<instrument id>.<server id>.cfg.oldb_prefix
<instrument id>.<server id>.cfg.pub_endpoint
<instrument id>.<server id>.cfg.req_endpoint
<instrument id>.<server id>.cfg.scxml
<instrument id>.<server id>.cfg.server_id

2.4.2 Server Status

The server stores the string representation of its state and substate into the Redis DB.

Table 2.5: Server status Redis DB keys

Redis Key
<instrument id>.<server id>.states.state
<instrument id>.<server id>.states.substate

2.4.3 Common Device Keys

Each device has a number of common Redis DB keys.

Table 2.6: Common device Redis DB keys

Redis Key
<instrument id>.<server id>.cfg.devices.<device id>.dev_endpoint
<instrument id>.<server id>.cfg.devices.<device id>.sim_endpoint
<instrument id>.<server id>.cfg.devices.<device id>.cfgfile
<instrument id>.<server id>.cfg.devices.<device id>.fits_prefix
<instrument id>.<server id>.cfg.devices.<device id>.ignored
<instrument id>.<server id>.cfg.devices.<device id>.simulated
<instrument id>.<server id>.cfg.devices.<device id>.namespace
<instrument id>.<server id>.cfg.devices.<device id>.prefix
<instrument id>.<server id>.cfg.devices.<device id>.type

2.4.4 Shutter

Each shutter device defines a set of specific Redis DB keys:

Table 2.7: Shutter Specific Redis DB keys

Redis Key
<instrument id>.<server id>.cfg.devices.<device id>.lcs.ignore_closed
<instrument id>.<server id>.cfg.devices.<device id>.lcs.ignore_fault
<instrument id>.<server id>.cfg.devices.<device id>.lcs.ignore_open
<instrument id>.<server id>.cfg.devices.<device id>.lcs.initial_state
<instrument id>.<server id>.cfg.devices.<device id>.lcs.low_closed
<instrument id>.<server id>.cfg.devices.<device id>.lcs.low_fault
<instrument id>.<server id>.cfg.devices.<device id>.lcs.low_open
<instrument id>.<server id>.cfg.devices.<device id>.lcs.low_switch
<instrument id>.<server id>.cfg.devices.<device id>.lcs.timeout
<instrument id>.<server id>.devices.<device id>.lcs.stat.error_code
<instrument id>.<server id>.devices.<device id>.lcs.stat.error_str
<instrument id>.<server id>.devices.<device id>.lcs.stat.local
<instrument id>.<server id>.devices.<device id>.lcs.stat.state
<instrument id>.<server id>.devices.<device id>.lcs.stat.substate

2.4.5 Lamp

Each lamp device defines a set of specific Redis DB keys:

Table 2.8: Lamp Redis DB keys

Redis Key
<instrument id>.<server id>.cfg.devices.<device id>.lcs.analog_range
<instrument id>.<server id>.cfg.devices.<device id>.lcs.analog_threshold
<instrument id>.<server id>.cfg.devices.<device id>.lcs.cooldown
<instrument id>.<server id>.cfg.devices.<device id>.lcs.ignore_fault
<instrument id>.<server id>.cfg.devices.<device id>.lcs.initial_state
<instrument id>.<server id>.cfg.devices.<device id>.lcs.invert_analog
<instrument id>.<server id>.cfg.devices.<device id>.lcs.low_fault
<instrument id>.<server id>.cfg.devices.<device id>.lcs.low_on
<instrument id>.<server id>.cfg.devices.<device id>.lcs.low_switch
<instrument id>.<server id>.cfg.devices.<device id>.lcs.maxon
<instrument id>.<server id>.cfg.devices.<device id>.lcs.timeout
<instrument id>.<server id>.cfg.devices.<device id>.lcs.warmup
<instrument id>.<server id>.devices.<device id>.lcs.stat.error_code
<instrument id>.<server id>.devices.<device id>.lcs.stat.error_str
<instrument id>.<server id>.devices.<device id>.lcs.stat.intensity
<instrument id>.<server id>.devices.<device id>.lcs.stat.local
<instrument id>.<server id>.devices.<device id>.lcs.stat.state
<instrument id>.<server id>.devices.<device id>.lcs.stat.substate

2.4.6 Sensor

Each sensor device defines a set of specific Redis DB keys:

Table 2.9: Sensor Redis DB keys

Redis Key
<instrument id>.<server id>.cfg.devices.<device id>.<channel id>.description
<instrument id>.<server id>.cfg.devices.<device id>.<channel id>.fits_prefix
<instrument id>.<server id>.cfg.devices.<device id>.<channel id>.header
<instrument id>.<server id>.cfg.devices.<device id>.<channel id>.log
<instrument id>.<server id>.cfg.devices.<device id>.<channel id>.map
<instrument id>.<server id>.cfg.devices.<device id>.<channel id>.type
<instrument id>.<server id>.cfg.devices.<device id>.<channel id>.unit
<instrument id>.<server id>.devices.<device id>.lcs.stat.<channel id>
<instrument id>.<server id>.devices.<device id>.lcs.stat.state
<instrument id>.<server id>.devices.<device id>.lcs.stat.substate

2.4.7 Motor

Each motor device defines a set of specific Redis DB keys:

Table 2.10: Motor Redis DB keys

Redis Key
<instrument id>.<server id>.cfg.devices.<device id>.lcs.active_low_indec
<instrument id>.<server id>.cfg.devices.<device id>.lcs.active_low_lhw
<instrument id>.<server id>.cfg.devices.<device id>.lcs.active_low_lstop
<instrument id>.<server id>.cfg.devices.<device id>.lcs.active_low_ref
<instrument id>.<server id>.cfg.devices.<device id>.lcs.active_low_uhw
<instrument id>.<server id>.cfg.devices.<device id>.lcs.active_low_ustop
<instrument id>.<server id>.cfg.devices.<device id>.lcs.axis_type
<instrument id>.<server id>.cfg.devices.<device id>.lcs.backlash
<instrument id>.<server id>.cfg.devices.<device id>.lcs.brake
<instrument id>.<server id>.cfg.devices.<device id>.lcs.check_inpos
<instrument id>.<server id>.cfg.devices.<device id>.lcs.disable
<instrument id>.<server id>.cfg.devices.<device id>.lcs.exec_post_init
<instrument id>.<server id>.cfg.devices.<device id>.lcs.exec_post_move
<instrument id>.<server id>.cfg.devices.<device id>.lcs.exec_pre_init
<instrument id>.<server id>.cfg.devices.<device id>.lcs.exec_pre_move
<instrument id>.<server id>.cfg.devices.<device id>.lcs.init_seq<number>_action
<instrument id>.<server id>.cfg.devices.<device id>.lcs.init_seq<number>_value1
<instrument id>.<server id>.cfg.devices.<device id>.lcs.init_seq<number>_value2
<instrument id>.<server id>.cfg.devices.<device id>.lcs.lock
<instrument id>.<server id>.cfg.devices.<device id>.lcs.lock_pos
<instrument id>.<server id>.cfg.devices.<device id>.lcs.lock_tolerance
<instrument id>.<server id>.cfg.devices.<device id>.lcs.low_brake
<instrument id>.<server id>.cfg.devices.<device id>.lcs.low_inpos
<instrument id>.<server id>.cfg.devices.<device id>.lcs.max_pos
<instrument id>.<server id>.cfg.devices.<device id>.lcs.min_pos
<instrument id>.<server id>.cfg.devices.<device id>.lcs.tout_init
<instrument id>.<server id>.cfg.devices.<device id>.lcs.tout_move
<instrument id>.<server id>.cfg.devices.<device id>.lcs.tout_switch
<instrument id>.<server id>.cfg.devices.<device id>.lcs.velocity
<instrument id>.<server id>.devices.<device id>.lcs.stat.axis_brake
<instrument id>.<server id>.devices.<device id>.lcs.stat.axis_enable
<instrument id>.<server id>.devices.<device id>.lcs.stat.axis_info_data1
<instrument id>.<server id>.devices.<device id>.lcs.stat.inposition
<instrument id>.<server id>.devices.<device id>.lcs.stat.lock
<instrument id>.<server id>.devices.<device id>.lcs.stat.ready
<instrument id>.<server id>.devices.<device id>.lcs.stat.error_code
<instrument id>.<server id>.devices.<device id>.lcs.stat.error_str

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Table 2.10 – continued from previous page

Redis Key
<instrument id>.<server id>.devices.<device id>.lcs.stat.init_action
<instrument id>.<server id>.devices.<device id>.lcs.stat.init_step
<instrument id>.<server id>.devices.<device id>.lcs.stat.initialised
<instrument id>.<server id>.devices.<device id>.lcs.stat.local
<instrument id>.<server id>.devices.<device id>.lcs.stat.mode
<instrument id>.<server id>.devices.<device id>.lcs.stat.pos_actual
<instrument id>.<server id>.devices.<device id>.lcs.stat.pos_error
<instrument id>.<server id>.devices.<device id>.lcs.stat.pos_target
<instrument id>.<server id>.devices.<device id>.lcs.stat.scale_factor
<instrument id>.<server id>.devices.<device id>.lcs.stat.signal_index
<instrument id>.<server id>.devices.<device id>.lcs.stat.signal_lhw
<instrument id>.<server id>.devices.<device id>.lcs.stat.signal_lstop
<instrument id>.<server id>.devices.<device id>.lcs.stat.signal_ref
<instrument id>.<server id>.devices.<device id>.lcs.stat.signal_uhw
<instrument id>.<server id>.devices.<device id>.lcs.stat.signal_ustop
<instrument id>.<server id>.devices.<device id>.lcs.stat.state
<instrument id>.<server id>.devices.<device id>.lcs.stat.substate
<instrument id>.<server id>.devices.<device id>.lcs.stat.vel_actual
<instrument id>.<server id>.devices.<device id>.pos_actual_name
<instrument id>.<server id>.devices.<device id>.pos_enc
<instrument id>.<server id>.devices.<device id>.target_enc

2.4.8 Derotator

The *Derotator* device uses the same set of Redis keys as the *Motor* device plus some additional derotator specific ones that are described below:

Table 2.11: Derotator Redis DB keys

Redis Key
<instrument id>.<server id>.cfg.devices.<device id>.lcs.trk_period
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_par1
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_par2
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_par3
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_par4
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_ref
<instrument id>.<server id>.cfg.devices.<device id>.lcs.sky_ref
<instrument id>.<server id>.cfg.devices.<device id>.lcs.tat_ref
<instrument id>.<server id>.devices.<device id>.lcs.stat.angle_on_sky
<instrument id>.<server id>.devices.<device id>.lcs.stat.alpha
<instrument id>.<server id>.devices.<device id>.lcs.stat.delta
<instrument id>.<server id>.devices.<device id>.lcs.stat.track_mode

2.4.9 ADC

The *Adc* device defines a set of specific Redis keys:

Table 2.12: Adc Redis DB keys

Redis Key
<instrument id>.<server id>.cfg.devices.<device id>.lcs.trk_period
<instrument id>.<server id>.cfg.devices.<device id>.lcs.afactor
<instrument id>.<server id>.cfg.devices.<device id>.lcs.minelev
<instrument id>.<server id>.cfg.devices.<device id>.lcs.poffset
<instrument id>.<server id>.cfg.devices.<device id>.lcs.pslope
<instrument id>.<server id>.cfg.devices.<device id>.lcs.toffset
<instrument id>.<server id>.cfg.devices.<device id>.lcs.tslope
<instrument id>.<server id>.cfg.devices.<device id>.lcs.zdlimit
<instrument id>.<server id>.cfg.devices.<device id>.lcs.mot1_coffset
<instrument id>.<server id>.cfg.devices.<device id>.lcs.mot1_drotfactor
<instrument id>.<server id>.cfg.devices.<device id>.lcs.mot1_poffset
<instrument id>.<server id>.cfg.devices.<device id>.lcs.mot1_refauto
<instrument id>.<server id>.cfg.devices.<device id>.lcs.mot1_refoff
<instrument id>.<server id>.cfg.devices.<device id>.lcs.mot2_coffset
<instrument id>.<server id>.cfg.devices.<device id>.lcs.mot2_drotfactor
<instrument id>.<server id>.cfg.devices.<device id>.lcs.mot2_poffset
<instrument id>.<server id>.cfg.devices.<device id>.lcs.mot2_refauto
<instrument id>.<server id>.cfg.devices.<device id>.lcs.mot2_refoff
<instrument id>.<server id>.cfg.devices.<device id>.ignored
<instrument id>.<server id>.cfg.devices.<device id>.simulated
<instrument id>.<server id>.devices.<device id>.lcs.stat.alpha
<instrument id>.<server id>.devices.<device id>.lcs.stat.delta
<instrument id>.<server id>.devices.<device id>.lcs.stat.error_code
<instrument id>.<server id>.devices.<device id>.lcs.stat.error_str
<instrument id>.<server id>.devices.<device id>.lcs.stat.local
<instrument id>.<server id>.devices.<device id>.lcs.stat.state
<instrument id>.<server id>.devices.<device id>.lcs.stat.substate
<instrument id>.<server id>.devices.<device id>.lcs.stat.track_mode
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor1.axis_brake
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor1.axis_enable
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor1.axis_lock
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor1.local
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor1.pos_actual
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor1.pos_enc
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor1.scale_factor
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor2.axis_brake
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor2.axis_enable

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Table 2.12 – continued from previous page

Redis Key
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor2.axis_lock
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor2.local
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor2.pos_actual
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor2.pos_enc
<instrument id>.<server id>.devices.<device id>.lcs.stat.motor2.scale_factor
<instrument id>.<server id>.devices.<device id>.motor1.pos_enc
<instrument id>.<server id>.devices.<device id>.motor2.pos_enc

2.4.10 Piezo

The *Piezo* device defines a set of specific Redis keys:

Table 2.13: Piezo Redis DB keys

Redis Key
<instrument id>.<server id>.cfg.devices.<device id>.lcs.home1
<instrument id>.<server id>.cfg.devices.<device id>.lcs.home2
<instrument id>.<server id>.cfg.devices.<device id>.lcs.home3
<instrument id>.<server id>.cfg.devices.<device id>.lcs.lower_limit1
<instrument id>.<server id>.cfg.devices.<device id>.lcs.lower_limit2
<instrument id>.<server id>.cfg.devices.<device id>.lcs.lower_limit3
<instrument id>.<server id>.cfg.devices.<device id>.lcs.upper_limit1
<instrument id>.<server id>.cfg.devices.<device id>.lcs.upper_limit2
<instrument id>.<server id>.cfg.devices.<device id>.lcs.upper_limit3
<instrument id>.<server id>.cfg.devices.<device id>.lcs.max_on
<instrument id>.<server id>.cfg.devices.<device id>.lcs.num_axes
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_offset_input1
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_offset_input2
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_offset_input3
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_to_bit_input1
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_to_bit_input2
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_to_bit_input3
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_offset_output1
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_offset_output2
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_offset_output3
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_to_bit_output1
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_to_bit_output2
<instrument id>.<server id>.cfg.devices.<device id>.lcs.user_to_bit_output3
<instrument id>.<server id>.devices.<device id>.lcs.stat.actual_pos_bit1
<instrument id>.<server id>.devices.<device id>.lcs.stat.actual_pos_bit2
<instrument id>.<server id>.devices.<device id>.lcs.stat.actual_pos_bit3

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Table 2.13 – continued from previous page

Redis Key
<instrument id>.<server id>.devices.<device id>.lcs.stat.actual_pos_user1
<instrument id>.<server id>.devices.<device id>.lcs.stat.actual_pos_user2
<instrument id>.<server id>.devices.<device id>.lcs.stat.actual_pos_user3
<instrument id>.<server id>.devices.<device id>.lcs.stat.error_codes
<instrument id>.<server id>.devices.<device id>.lcs.stat.error_str
<instrument id>.<server id>.devices.<device id>.lcs.stat.local
<instrument id>.<server id>.devices.<device id>.lcs.stat.state
<instrument id>.<server id>.devices.<device id>.lcs.stat.substate

2.4.11 Actuator

Each actuator device defines a set of specific Redis DB keys:

Table 2.14: Actuator Redis DB keys

Redis Key
<instrument id>.<server id>.devices.<device id>.lcs.stat.local
<instrument id>.<server id>.devices.<device id>.lcs.stat.state
<instrument id>.<server id>.devices.<device id>.lcs.stat.substate
<instrument id>.<server id>.devices.<device id>.lcs.stat.error_code
<instrument id>.<server id>.devices.<device id>.lcs.stat.error_str

2.5 Commands

The commands currently supported by the server are listed here: *List of Commands*.

2.5.1 Error Handling

FCF Commands throw exceptions in case of errors or timeouts. Client applications can catch the exceptions and obtain the error message associated with the function **getDesc()**. This error does not contain neither the history nor the error stack but it normally indicates precisely where the error occurred.

```
try {
    auto reply = client->GetStatus();
 } catch (const fcfif::ExceptionErr& e) {
    RAD_LOG_ERROR() << "Error reply " << e.getDesc()  << ").";
}
```

2.5.2 Serialization

The *Device Manager* uses the CII MAL ZPB (ZeroMQ + Google Proto buffers) for serialising commands.

Note: Each command has two parts: a payload and its corresponding reply, see the details in the *fcfif* module. The normal replies are plain strings.

Setup Command

The *Setup* command is intended to produce a change in the run-time configuration. It is also a way of triggering operational actions on the devices. It is possible to switch a lamp on, close a shutter and move a motor in separate messages or within the same one. This means that the content of the message varies. The devices will de-serialise the message and communicate the actions to be taken to the corresponding PLCs via the interface with the LCS.

The DevMgr is not blocked when receiving concurrent Setup commands (messages). It executes them in separate worker threads that are spawned per each new Setup command. The threads will be running until the commands have been executed successfully, an error occured, the timeout has elapsed or a *Stop* command is received, see figure below.

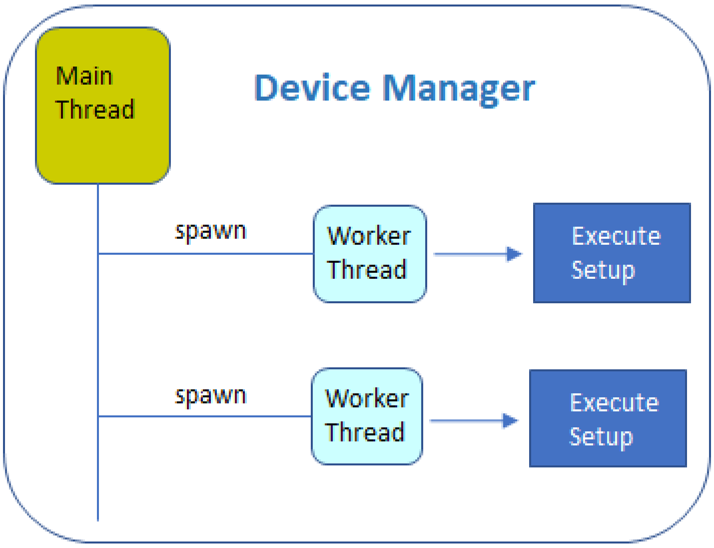

Fig. 2.5: Device Manager Setup worker threads.

Note: A *Stop* command finalizes all ongoing worker threads that are being handled by the Device Manager.

Warning: Conflicting requests across different *Setup* commands running in parallel are not handled by the Device Manager. They are pushed down to the PLC. The PLC is resolving them depending on the actual status. This means that, if the user sends two consecutive commands with conflicting requests, most likely the second one will get an error from the PLC. The exact behaviour will depend on the specific Device Controller implementation.

Setup Interface Definition

The interface definition of the *Setup* command can be found in module *fcfif*. The payload is based on an array of unions. The union may contain any device supported by the Device Manager.

```
<union name="DeviceUnion">
    <discriminator type="nonBasic" nonBasicTypeName="DeviceType" />
    <case>
        <caseDiscriminator value ="SHUTTER"/>
            <member name="shutter" type="nonBasic" nonBasicTypeName=
↪"ShutterDevice" />
    </case>
    <case>
        <caseDiscriminator value ="LAMP"/>
            <member name="lamp" type="nonBasic" nonBasicTypeName="LampDevice" />
    </case>
    <case>
    <caseDiscriminator value ="MOTOR"/>
            <member name="motor" type="nonBasic" nonBasicTypeName="MotorDevice" /
↪>
    </case>
    <case>
    <caseDiscriminator value ="DROT"/>
            <member name="drot" type="nonBasic" nonBasicTypeName="DrotDevice" />
    </case>
    <case>
    <caseDiscriminator value ="ADC"/>
            <member name="adc" type="nonBasic" nonBasicTypeName="AdcDevice" />
    </case>
    <case>
    <caseDiscriminator value ="PIEZO"/>
            <member name="piezo" type="nonBasic" nonBasicTypeName="PiezoDevice" /
↪>
    </case>
    <case>
    <caseDiscriminator value ="ACTUATOR"/>
            <member name="actuator" type="nonBasic" nonBasicTypeName=
↪"ActuatorDevice" />
    </case>
    <case>
    <caseDiscriminator value ="CUSTOM"/>
```

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```
            <member name="custom" type="nonBasic" nonBasicTypeName="CustomDevice
↪" />
        </case>
</union>
```

Warning: The array does not have a fixed size but it has a limit of 100 elements. A limit is needed by the CII XML ICD.

```
<method name="Setup" returnType="string" throws="ExceptionErr">
    <argument name="payload" type="nonBasic" nonBasicTypeName="SetupElem"␣
↪arrayDimensions="(100)"/>
</method>
```

Each device structure may contain parameters and one action per device that can be serialized. An example of the device ICD is shown below.

```
<struct name="ShutterDevice">
    <member name="id" type="string" />
    <member name="action" type="nonBasic" nonBasicTypeName="ActionShutter" />
</struct>

<struct name="LampDevice">
    <member name="id" type="string" />
    <member name="intensity" type="double" />
    <member name="time" type="uint32_t" />
    <member name="action" type="nonBasic" nonBasicTypeName="ActionLamp" />
</struct>

<struct name="BaseMotorDevice">
   <member name="id" type="string" />
    <member name="name" type="string" />
    <member name="pos" type="double" />
    <member name="enc" type="int64_t" />
    <member name="speed" type="double" />
    <member name="unit" type="nonBasic" nonBasicTypeName="MotorPosUnit" />
</struct>

<struct name="MotorDevice" baseType="BaseMotor">
    <member name="action" type="nonBasic" nonBasicTypeName="ActionMotor" />
</struct>

<struct name="DrotDevice" baseType="BaseMotor">
    <member name="mode" type="nonBasic" nonBasicTypeName="ModeDrot" />
    <member name="action" type="nonBasic" nonBasicTypeName="ActionDrot" />
</struct>
```

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```
<struct name="AdcDevice" baseType="BaseMotor">
    <member name="axis" type="nonBasic" nonBasicTypeName="AxesAdc" />
    <member name="mode" type="nonBasic" nonBasicTypeName="ModeAdc" />
    <member name="action" type="nonBasic" nonBasicTypeName="ActionAdc" />
</struct>

<struct name="PiezoDevice">
    <member name="id" type="string" />
    <member name="bit1" type="uint32_t" />
    <member name="bit2" type="uint32_t" />
    <member name="bit3" type="uint32_t" />
    <member name="pos1" type="double" />
    <member name="pos2" type="double" />
    <member name="pos3" type="double" />
    <member name="action" type="nonBasic" nonBasicTypeName="ActionPiezo" />
</struct>

<struct name="ActuatorDevice">
    <member name="id" type="string" />
    <member name="action" type="nonBasic" nonBasicTypeName="ActionActuator" />
</struct>

<struct name="CustomDevice">
    <member name="parameters" type="string" />
</struct>
```

Note: The CustomDevice is to be used for implementing custom devices where the payload data can be serialized in JSON. The serialization shall be done by the client applications using the parameters in the `CustomDevice` structure to carry the information encoded in JSON. The above enables extendability without the need to provide specific CII XML ICDs which is a significant simplification for instruments.

DevStatus Command

The DevStatus command provides information about each device controlled by the *Device Manager*. An example of the output generated by the DevStatus command is shown below.

```
$ fcfClient zpb.rr://127.0.0.1:12083 DevStatus ""
shutter1.simulated = true
shutter1.lcs.state = Operational
shutter1.lcs.substate = Close
lamp1.simulated = true
lamp1.lcs.state = Operational
lamp1.lcs.substate = Off
```

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```
lamp1.lcs.intensity = 0.000000
motor1.simulated = true
motor1.lcs.state = Operational
motor1.lcs.substate = Standstill
motor1.lcs.pos_target = 30.000000
motor1.lcs.pos_actual = 30.002197
motor1.lcs.vel_actual = 0.000000
motor1.lcs.axis_enable = true
motor1.pos_actual_name = ON
motor1.pos_enc = 341

OK
```

The user could request the status of a specific device or a subset of the devices, see below.

```
$ fcfClient zpb.rr://127.0.0.1:12083 DevStatus "motor1"
motor1.simulated = true
motor1.lcs.state = Operational
motor1.lcs.substate = Standstill
motor1.lcs.pos_target = 30.000000
motor1.lcs.pos_actual = 30.002197
motor1.lcs.vel_actual = 0.000000
motor1.lcs.axis_enable = true
motor1.pos_actual_name = ON
motor1.pos_enc = 341

OK

$ fcfClient zpb.rr://127.0.0.1:12083 DevStatus "lamp1, motor1"
lamp1.simulated = true
lamp1.lcs.state = Operational
lamp1.lcs.substate = Off
lamp1.lcs.intensity = 0.000000
motor1.simulated = true
motor1.lcs.state = Operational
motor1.lcs.substate = Standstill
motor1.lcs.pos_target = 30.000000
motor1.lcs.pos_actual = 30.002197
motor1.lcs.vel_actual = 0.000000
motor1.lcs.axis_enable = true
motor1.pos_actual_name = ON
motor1.pos_enc = 341

OK
```

Note: The list of devices is comma-separated.

Ignore Command

This command tells the *Device Manager* to completely ignore a device. It can be used when there are hardware failures or when the hardware is not yet available. The following example shows a sequence that ignores device *lamp1*, gets the status of the devices and then stops ignoring the device.

Note: When a device is ignored, no other information is provided for this device when processing the status command.

```
$ fcfClient zpb.rr://127.0.0.1:12083 Ignore "lamp1"
$ fcfClient zpb.rr://127.0.0.1:12083 Status "lamp1"
lamp1.ignored = true

OK
$ fcfClient zpb.rr://127.0.0.1:12083 StopIgn "lamp1"
$ fcfClient zpb.rr://127.0.0.1:12083 Status "lamp1"
lamp1.simulated = true
lamp1.lcs.state = Operational
lamp1.lcs.substate = Off
lamp1.lcs.intensity = 0.000000

OK
```

Simulate Command

This command tells the *Device Manager* to use the simulation address of the device. If the *Device Manager* is already connected, it will disconnect from the normal address and connect to the simulator. When the simulation is stopped, the server reverts the action and the device is back to normal mode.

The purpose of the simulation is to be able to validate the response of the *Device Manager* under different error conditions. It also allows to test the high-level SW when the HW is not yet available.

```
$ fcfClient zpb.rr://127.0.0.1:12083 Simulate "lamp1"
$ fcfClient zpb.rr://127.0.0.1:12083 Status "lamp1"
lamp1.simulated = true
lamp1.lcs.state = Operational
lamp1.lcs.substate = Off
lamp1.lcs.intensity = 0.000000

OK
$ fcfClient zpb.rr://127.0.0.1:12083 StopSim "lamp1"
$ fcfClient zpb.rr://127.0.0.1:12083 Status "lamp1"
lamp1.lcs.state = Operational
lamp1.lcs.substate = Off
```

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```
lamp1.lcs.intensity = 0.000000

OK
```

2.6 Troubleshooting

2.6.1 Logging

The *Device Manager* has implemented logging based on the log4cplus package. The log4cplus package defines four standard logging levels that could give additional information to the developer for troubleshooting.

Name	Verbosity	Description
ERROR	very low	Provide logging only in case of errors (default).
INFO	low	Provide information for the most important actions.
DEBUG	medium	Provide additional information for the developer.
TRACE	very high	Includes all the function tracing.

To activate a new logging, the command SetLogLevel shall be used. See the example below.

```
$ fcfClient zpb.rr://127.0.0.1:12083 SetLogLevel "TRACE"
```

Note: This logging level affects only the general Devmgr logger.

2.6.2 Loggers

The Devmgr provides a default configuration (log_properties.cfg) for the logging. This configuration defines one general logger (`app`) and a logger per device type, e.g. (`shutter`). The device loggers will help when troubleshooting specific devices.

Logger	Description
app	General logging for common server classes.
shutter	Specific logging for Shutter classes.
lamp	Specific logging for lamp classes.
motor	Specific logging for motor classes.
sensor	Specific logging for sensor classes.
piezo	Specific logging for piezo classes.
actuator	Specific logging for actuator classes.
drot	Specific logging for drot classes.
adc	Specific logging for adc classes.

To activate a new logging level for a specific logger, one should use the FCF CLI, see the example below.

```
$ fcfcli
$ fcsSh> setloglevel TRACE,lamp
```

The server will start logging the tracing information for the lamp classes and you should see something like the following:

```
2021-07-02T14:30:17.624 TRACE ENTER: virtual void
↪fcf::devmgr::lamp::Lamp::Setup(const std::any&)
2021-07-02T14:30:17.624 TRACE EXIT:  virtual void
↪fcf::devmgr::lamp::Lamp::Setup(const std::any&)
2021-07-02T14:30:17.638 TRACE ENTER: virtual bool
↪fcf::devmgr::lamp::Lamp::IsSetupActive(const std::any&) const
2021-07-02T14:30:17.638 TRACE EXIT:  virtual bool
↪fcf::devmgr::lamp::Lamp::IsSetupActive(const std::any&) const
...
```

Note: If a the second parameter is not provided, the logging level will affect the general logger.

Note: If you are missing some logging information for some devices, it might be that the logging is happening in the specific device classes so you need to enable the device logger to see all the logging. When you use the application logger, it affects only to the common classes.

2.6.3 Log File

The default log configuration provides two appenders. One for the console and another one for a file. The file is stored by default in the home directory of the user running the Devmgr. The name of the file is fcfDevmgr.log.

2.6.4 OPC-UA Client

Sometimes it is better to check the status of the PLC using an OPC-UA client. One of the best tools available is the UaExpert from Unified Automation. This tool enables the control and monitoring of all device variables independently of the *Device Manager*. The user can trigger the execution of RPCs and monitor the device state changes. The UaExpert is an essential tool for troubleshooting.

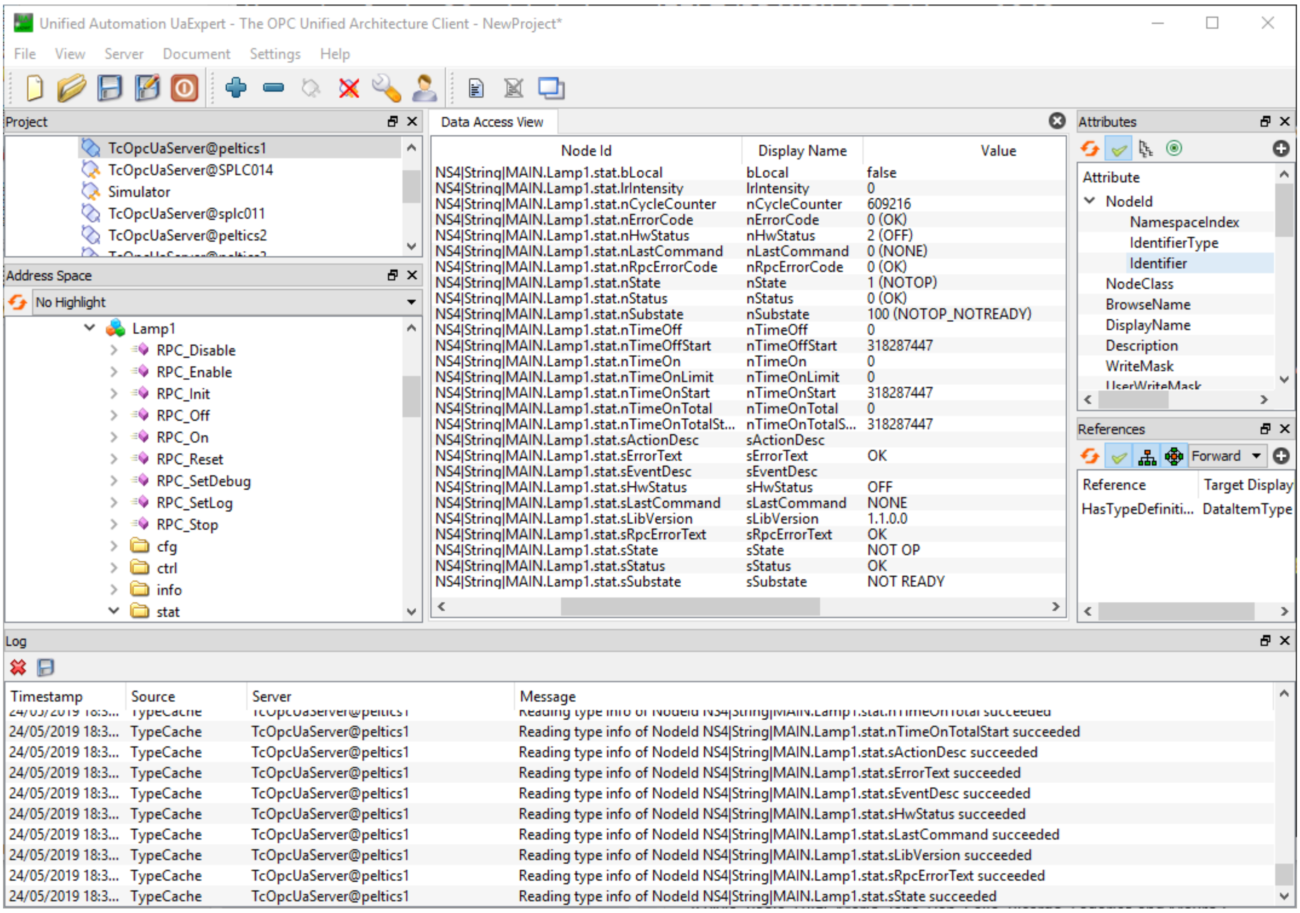


Fig. 2.6: UaExpert OPC-UA client.

3 PLC Libraries

3.1 Common Attributes and Functionality

Note: ESO PLC libraries have to be installed in the TwinCAT development environment before they can be used in projects.

3.1.1 Library content

For each function, e.g. lamp, shutter, motor, etc, the corresponding PLC library delivers:

- A function block (FB) for function control, e.g. FB_LAMP. Note that some libraries deliver more than one FB, e.g. motor.library.
- A function block for the HW simulator, e.g. FB_SIM_LAMP
- A template GUI, e.g. GUI_TEMPLATE_LAMP

3.1.2 Input parameters

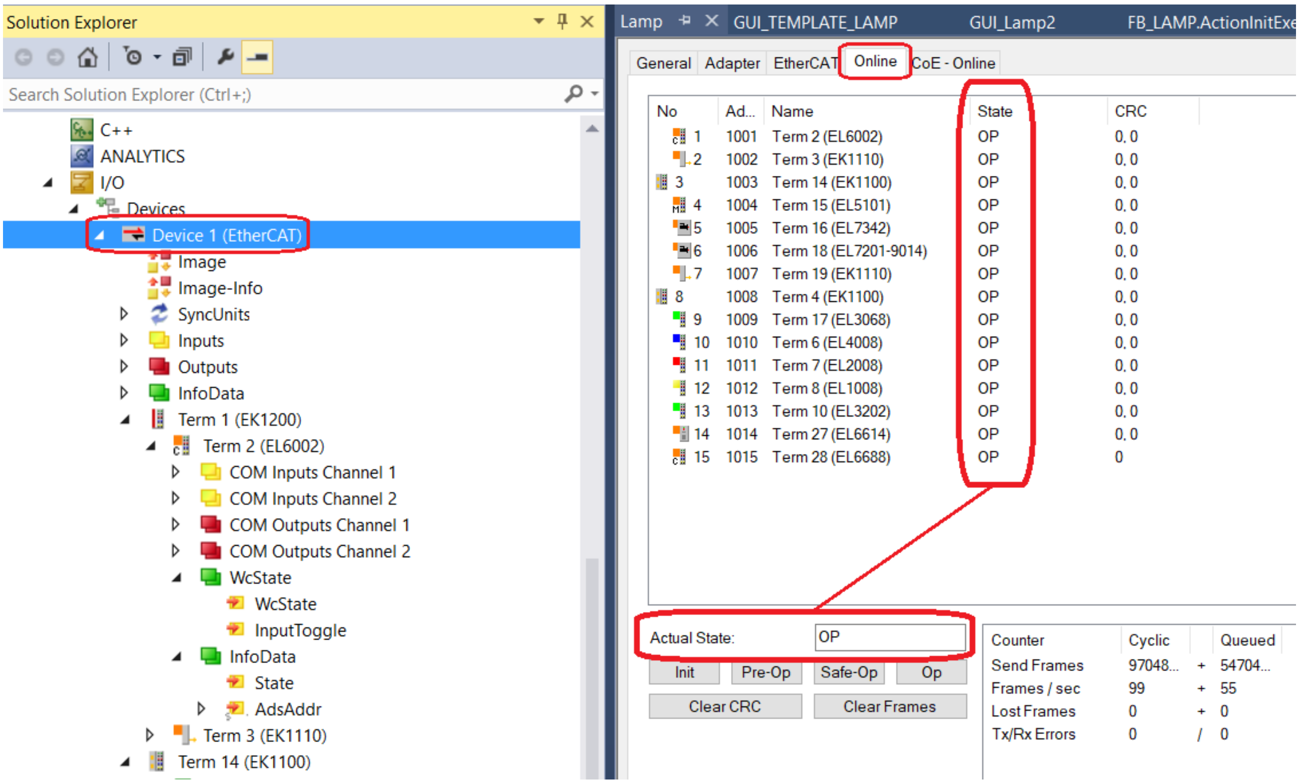
In most cases, apart from the Motor library, the configuration parameters can be given in the execution part, i.e. the FB call. This way some configuration parameters that are known that will not change, e.g. active low, timeouts, etc, can be 'hard-coded'. Input parameters have the prefix *in_*. There is a mandatory input parameter called 'in_sName' that sets the name of the device. On PLC reboot these parameters will be set in the device configuration. However, the configuration defined in the Device Manager will overwrite the device configuration on INIT. This way, by giving input parameters the number of configuration parameters can be reduced or completely avoided but still with the flexibility of correcting any configuration parameter by the Device Manager without modifying the PLC code.

Example:

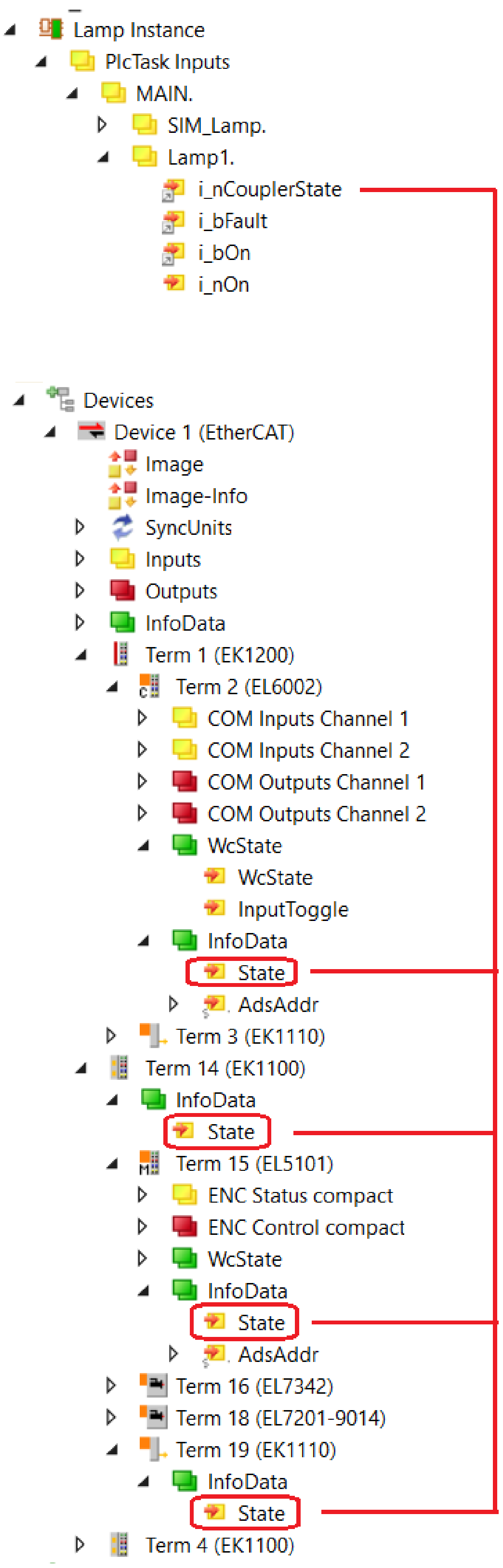
```
Lamp1(in_sName:='Lamp1', in_bActiveLowFault:=TRUE);
```

3.1.3 EtherCAT Operational State and FB Input variable i_nCouplerState

In order for the EtherCAT system to operate, it has to be in OPERATIONAL state with its corresponding value equal to 8. Any value other than 8 indicates that the system is not OPERATIONAL. The EtherCAT system is OPERATIONAL only if all I/O terminals in the system are OPERATIONAL. The figure below shows an OPERATIONAL EtherCAT system and the individual state of each I/O terminal in the system.



Each FB that controls HW has got an input variable called *i_nCouplerState*. This variable is used to monitor the state of the EtherCAT system. The variable has to be linked (mapped) to the *State* variable, found in the *InfoData* structure of the I/O terminal, that indicates its operational state. Normally, the variable is linked to the *State* of the EK1100 coupler that holds the I/O termials used by the FB. That's why the variable is called *i_nCouplerState*. However, the *State* variable of any other I/O terminal, e.g. EL2008, could also be used for that purpose. The figure below shows some possible mapping options for *i_nCouplerState*.


Lamp Instance
PlcTask Inputs
MAIN.
SIM_Lamp.
Lamp1.
i_nCouplerState
i_bFault
i_bOn
i_nOn
Devices
Device 1 (EtherCAT)
Image
Image-Info
SyncUnits
Inputs
Outputs
InfoData
Term 1 (EK1200)
Term 2 (EL6002)
COM Inputs Channel 1
COM Inputs Channel 2
COM Outputs Channel 1
COM Outputs Channel 2
WcState
WcState
InputToggle
InfoData
State
AdsAddr
Term 3 (EK1110)
Term 14 (EK1100)
InfoData
State
Term 15 (EL5101)
ENC Status compact
ENC Control compact
WcState
InfoData
State
AdsAddr
Term 16 (EL7342)
Term 18 (EL7201-9014)
Term 19 (EK1110)
InfoData
State
Term 4 (EK1100)

3.1.4 Interface with Device Manager

Device managers control the PLC device exclusively via RPC methods. There are a number of mandatory RPC methods that are common to all PLC devices. They are related to device state changes and logging. Each library, in addition to the function specific RPC methods, delivers the following RPCs:

- RPC_Init()
- RPC_Enable()
- RPC_Disable()
- RPC_SetDebug()
- RPC_SetLog()
- RPC_Stop()
- RPC_Reset()

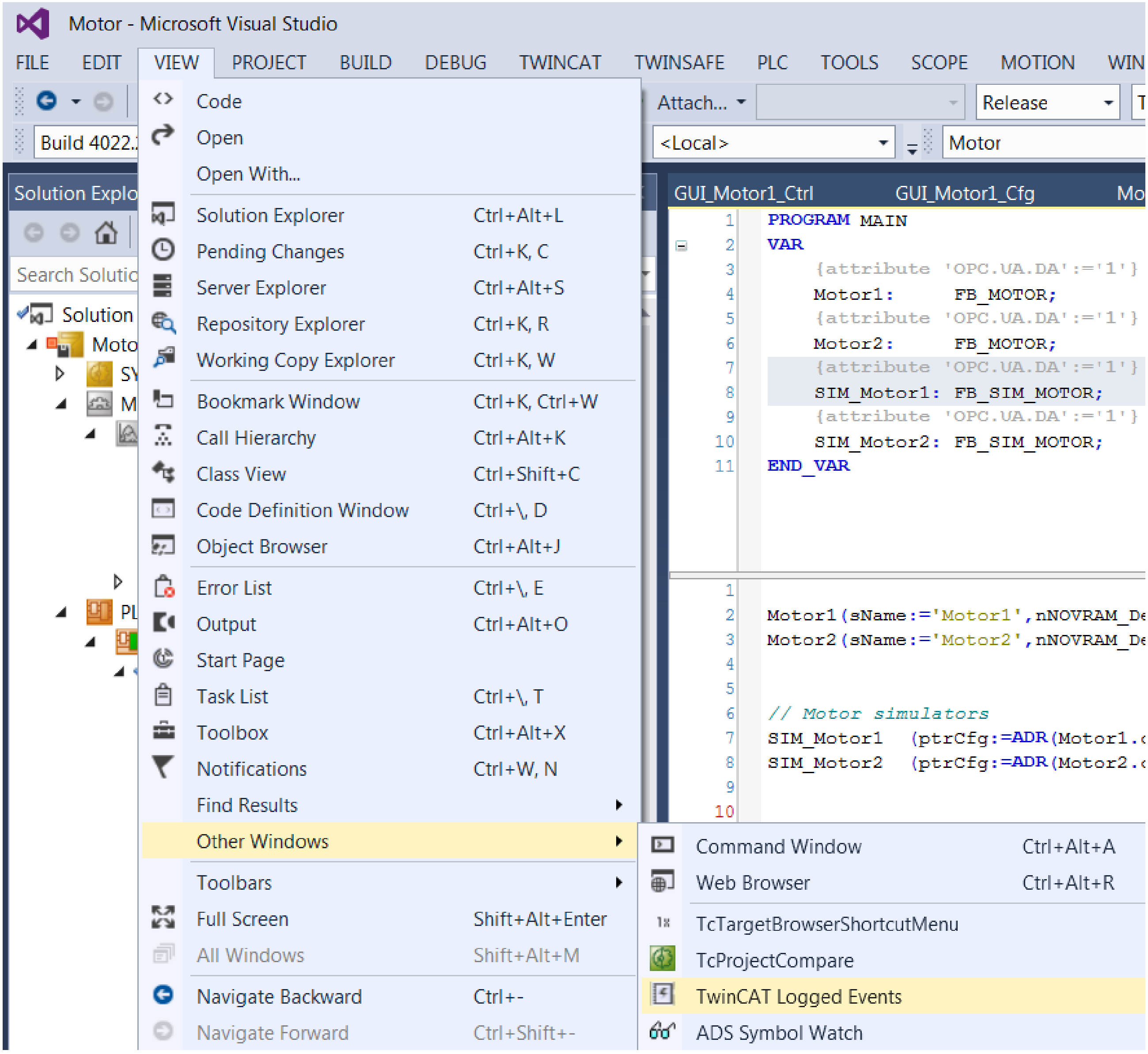
In order to have RPC methods visible in the OPC UA address space, each declaration of an FB has to be coupled with a pragma statement {attribute 'OPC.UA.DA':='1'}.

Example:

```
{attribute 'OPC.UA.DA':='1'}
Lamp1: FB_LAMP;

{attribute 'OPC.UA.DA':='1'}
Lamp2: FB_LAMP;
```

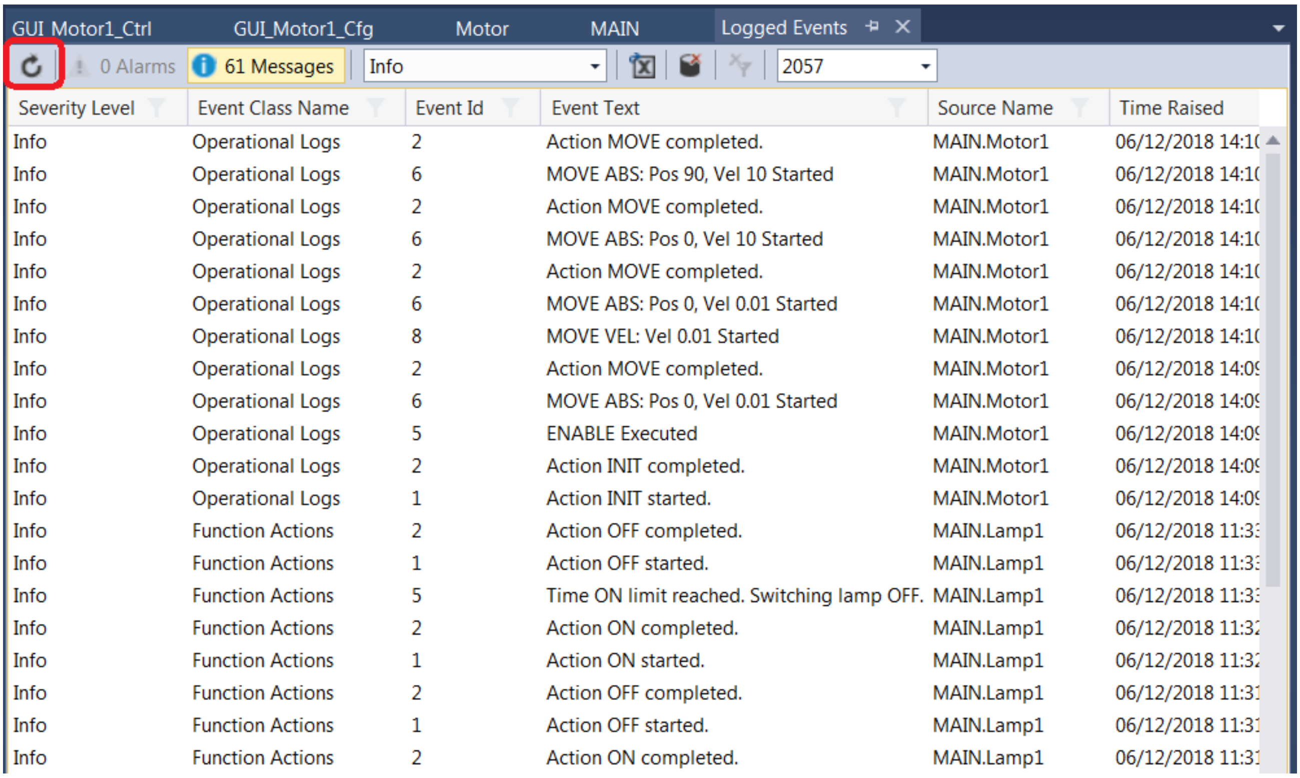
3.1.5 Operational Logs at PLC Level

Device operations are by default logged on the PLC. The screenshot below shows how to open Twin-CAT Logged Events Window.



RPC methods RPC_SetDebug() and RPC_SetLog() are used to control the amount of logging information. If provided, debugging logs should be activated only for troubleshooting purpose since they could generate large amount of data.

In order to see the logs, the window has to be refreshed as shown below:



Severity Level	Event Class Name	Event Id	Event Text	Source Name	Time Raised
Info	Operational Logs	2	Action MOVE completed.	MAIN.Motor1	06/12/2018 14:1
Info	Operational Logs	6	MOVE ABS: Pos 90, Vel 10 Started	MAIN.Motor1	06/12/2018 14:1
Info	Operational Logs	2	Action MOVE completed.	MAIN.Motor1	06/12/2018 14:1
Info	Operational Logs	6	MOVE ABS: Pos 0, Vel 10 Started	MAIN.Motor1	06/12/2018 14:1
Info	Operational Logs	2	Action MOVE completed.	MAIN.Motor1	06/12/2018 14:1
Info	Operational Logs	6	MOVE ABS: Pos 0, Vel 0.01 Started	MAIN.Motor1	06/12/2018 14:1
Info	Operational Logs	8	MOVE VEL: Vel 0.01 Started	MAIN.Motor1	06/12/2018 14:1
Info	Operational Logs	2	Action MOVE completed.	MAIN.Motor1	06/12/2018 14:0
Info	Operational Logs	6	MOVE ABS: Pos 0, Vel 0.01 Started	MAIN.Motor1	06/12/2018 14:0
Info	Operational Logs	5	ENABLE Executed	MAIN.Motor1	06/12/2018 14:0
Info	Operational Logs	2	Action INIT completed.	MAIN.Motor1	06/12/2018 14:0
Info	Operational Logs	1	Action INIT started.	MAIN.Motor1	06/12/2018 14:0
Info	Function Actions	2	Action OFF completed.	MAIN.Lamp1	06/12/2018 11:3
Info	Function Actions	1	Action OFF started.	MAIN.Lamp1	06/12/2018 11:3
Info	Function Actions	5	Time ON limit reached. Switching lamp OFF.	MAIN.Lamp1	06/12/2018 11:3
Info	Function Actions	2	Action ON completed.	MAIN.Lamp1	06/12/2018 11:3
Info	Function Actions	1	Action ON started.	MAIN.Lamp1	06/12/2018 11:3
Info	Function Actions	2	Action OFF completed.	MAIN.Lamp1	06/12/2018 11:3
Info	Function Actions	1	Action OFF started.	MAIN.Lamp1	06/12/2018 11:3
Info	Function Actions	2	Action ON completed.	MAIN.Lamp1	06/12/2018 11:3

3.1.6 PLC simulators

In most cases the library includes a HW simulator that is linked to the device FB and gives quite realistic response. This way it is possible at a very early stage of the project to test Device Managers with a PLC. The device manager is not aware of the simulation at the PLC level and 'believes' that it communicates with a real HW.

Note: It is important to note that the PLC application, i.e. program MAIN, has to be modified in order to use simulators. In addition to the inclusion of a device simulator instance in MAIN, the device I/O variables have to be linked to the corresponding simulator I/O signals rather than to the real I/O.

HW simulators capture device INIT event and adjust their internal configuration ensuring that the device will work properly after the initialisation. For example, the simulator response time will be shorter than the device timeout.

Simulators provide RPC calls that are used to modify their response in order to test failure conditions of the device driver. For example, the Lamp RPC_SetFault() method can be used to set the fault signal of the lamp.

3.1.7 C++ Modules

For some PLC devices, additional software developed in C++ might be needed. TwinCAT enables the implementation of modules in C++ that run inside the TwinCAT real-time kernel. These modules communicate with the PLC via normal I/O mapping (Communication between C++ modules and PLC[7]).

The FCF provides some C++ modules for the computation of the field rotation in the CCS simulator library.

The installation of the C++ module must be done on every computer used to build and download PLC projects that include projects using C++ modules. These modules have been already compiled and published by ESO and archived here[8].

Note: Visualisation and recompilation of the C++ module sources is only possible using commercial versions of Visual Studio (VS), e.g. VS Professional. However, C++ modules can be imported into the standard TwinCAT environment without the need to recompile them.

The procedure describing how to import modules into TwinCAT is available on Beckhoff website: (Importing C++ modules[9]).

Note: In IFW version 4, C++ modules are not required for tracking devices since the information will be provided by CCS (deterministic network) instead of being computed locally. However, the ccssim library contains these modules for providing simulation capabilities when CCS would not be available.

3.1.8 Tracking

Tracking controllers are motorized devices which update continuously the position of one or more motor axes as a function of the telescope coordinates, UTC time or variations of the temperature. Tracking controllers share some common characteristics that are described below.

- They support at least two modes of operations: one where motor axes are stationary and another one for tracking. In both cases the motor axes are moving in position mode.
- They may require an additional TwinCAT runtime license in case of using a C++ module. The required TwinCAT license is the C++ runtime.
- They may require a connection to the ELT time synchronization system to maximize tracking accuracy of the motor axes. A dedicated terminal (EL6688) is needed to connect to the ELT time synchronization system.

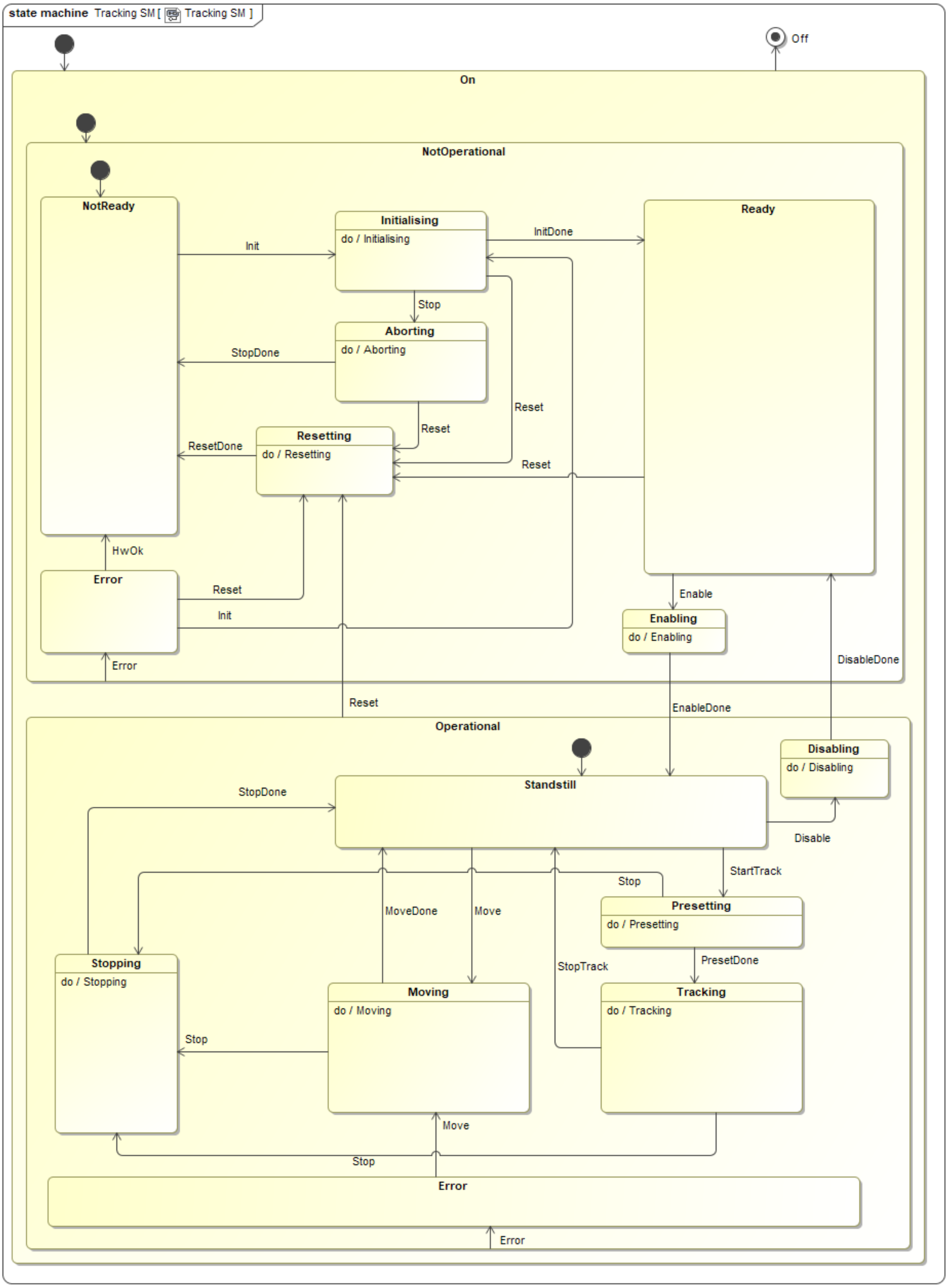
[7] https://infosys.beckhoff.com/content/1033/tc3_c/18014401000519947.html?id=5760242511836135973
[8] http://svnhq9.hq.eso.org/p9/trunk/EELT/ICS/PLC/Modules
[9] https://infosys.beckhoff.com/content/1033/tc3_c/63050394893968011.html?id=5466309176056117169

- The tracking position control loop is handled at lower level (PLC) by dedicated function blocks. The period of the position control loop is configurable and does not depend on the PLC cycle.

3.1.9 State Machine of Tracking Devices

The generic state machine of tracking devices is shown below. The main operational states are *Standstill*, *Moving*, *Presetting* and *Tracking*.

Note: The following State Machine is common to all tracking devices, e.g. Derotators, ADCs, etc.


state machine Tracking SM [Tracking SM]
Off
On
NotOperational
NotReady
Init
Initialising
do / Initialising
InitDone
Ready
Stop
Aborting
do / Aborting
StopDone
Reset
Reset
Resetting
do / Resetting
ResetDone
Reset
HwOk
Error
Reset
Init
Error
Enable
Enabling
do / Enabling
DisableDone
Reset
EnableDone
Operational
Disabling
do / Disabling
Standstill
StopDone
Disable
StartTrack
Stop
MoveDone
Move
Presetting
do / Presetting
Stopping
do / Stopping
StopTrack
PresetDone
Moving
do / Moving
Tracking
do / Tracking
Stop
Move
Stop
Error
Error

Note: **Important note**: The cycle time of the task (e.g. *PlcTask*) that executes an instance of a tracking function, i.e. *FB_MA_ADC*, *FB_MA_DROT*, etc, must be the same or longer than the cycle time of the *NC-Task 1 SAF* task. In other words, the instance of these FBs must not be executed faster than the *NC-Task 1 SAF* task. Otherwise, there could be some synchronization problems when exiting tracking mode.

Note that the default cycle time of the *NC-Task 1 SAF* task is 2 ms. Therefore, if the *PlcTask* cycle time is for example set to 1 ms, the *NC-Task 1 SAF* task cycle time has to be set to the same value.

3.1.10 Automatic TwinCAT Project Creation

A Windows utility called *MakeTcProject.exe* is provided for automatic creation of TwinCAT projects with a selectable number of all available controllers. The utility generates a fully operational project that includes the selected number of devices/controllers and their simulators, i.e. every device is simulated at PLC level.

This can be very useful at very early stages of projects when HW is still not available, since it makes it possible to test the complete control system as if the HW were present.

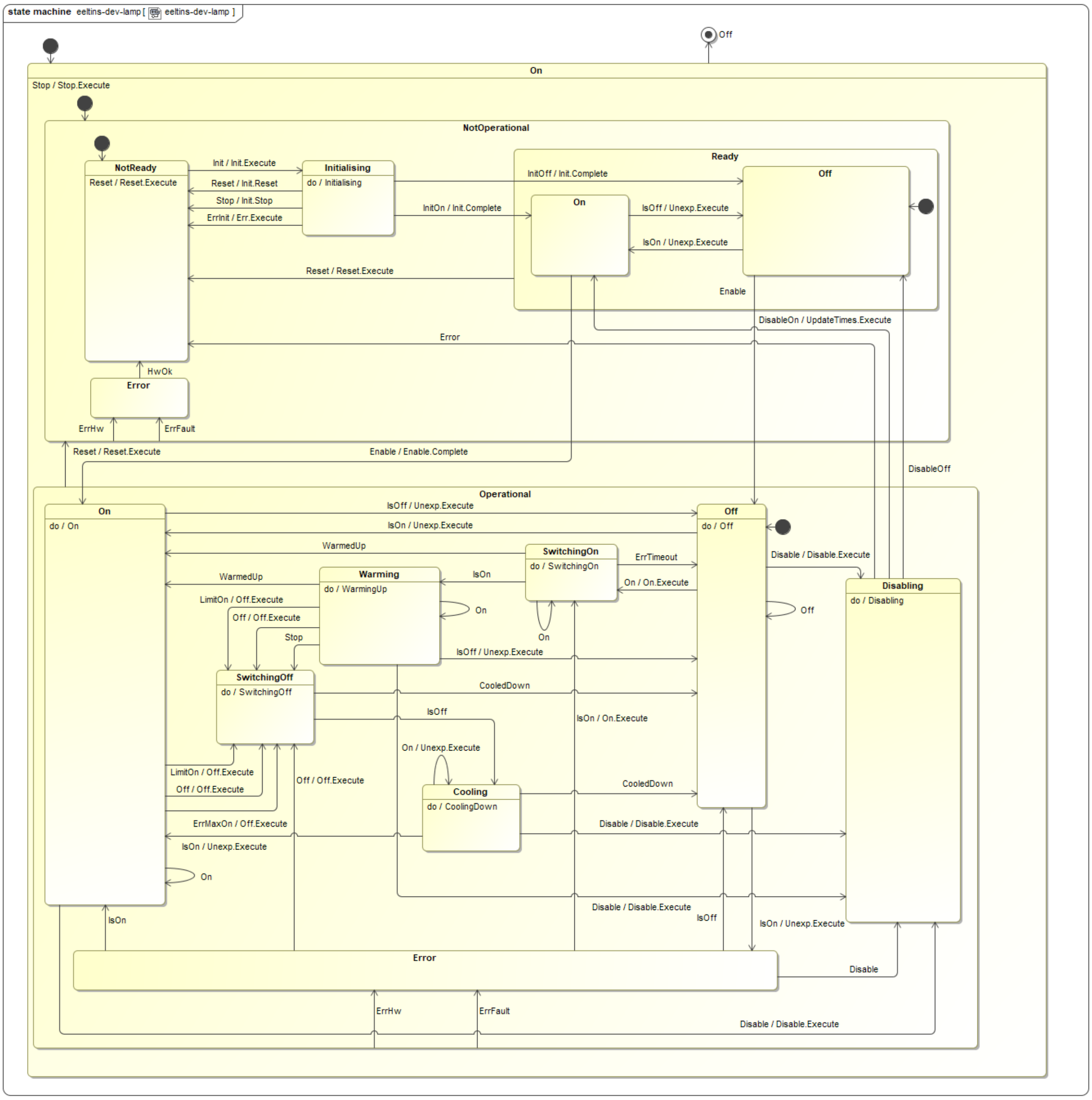
The utility is explained in detail in *Creating PLC Applications with MakeTcProject Utility*.

3.2 Lamp Library (lamp.library)

FB_LAMP is the TwinCAT PLC Function Block for the low level control of the standard lamp device with or without intensity control.

3.2.1 State Machine

The state machine of the lamp controller is shown below. The main operational states are *On*, *Off* *Warming* and *Cooling*.



3.2.2 Input parameters

FUNCTION_BLOCK FB_LAMP_BASE

VAR_INPUT	**in_sName**	STRING	*Instance name*
VAR_INPUT	**in_bActiveLowFault**	BOOL	*If TRUE, Fault signal is Active Low*
VAR_INPUT	**in_bActiveLowOn**	BOOL	*If TRUE, On signal is Active Low*
VAR_INPUT	**in_bActiveLowSwitch**	BOOL	*If TRUE, Switch ctrl signal is Active Low*
VAR_INPUT	**in_bIgnoreFault**	BOOL	*If TRUE, Fault feedback signal is ignored*
VAR_INPUT	**in_bInitialState**	BOOL	*default lamp state is OFF*
VAR_INPUT	**in_bInvertAnalog**	BOOL	*If TRUE, analog feedback is active, if signal < n...*
VAR_INPUT	**in_lrInitialIntensity**	LREAL	*Initial intensity [%]. Default 0.0.*
VAR_INPUT	**in_nAnalogThreshold**	DINT	*Analog feedback signal threshold [bits]. If this si...*
VAR_INPUT	**in_nFullRange**	UDINT	*Full range of A/D converter for analog output fo...*
VAR_INPUT	**in_nSigStablePeriod**	UDINT	*signal is stable if it has been constant for so lon...*
VAR_INPUT	**in_nTimeout**	UDINT	*timeout for transitions [msec]*
VAR_INPUT	**in_nCooldown**	UDINT	*Cooldown time [sec]*
VAR_INPUT	**in_nMaxOn**	UDINT	*Maximum time for lamp to be ON [sec]. Zero m...*
VAR_INPUT	**in_nWarmup**	UDINT	*Warmup time [sec]*
VAR_INPUT	**in_bLogExtTime**	BOOL	*If TRUE, use external time in event logs. Default...*
VAR_INPUT	**in_bLog**	BOOL	*If TRUE, log events. Default TRUE.*

3.2.3 Signal Mapping

The figure below shows the TwinCAT view of the *FB_LAMP* I/O variables that are available for mapping to physical signals, i.e. ports of I/O terminals.

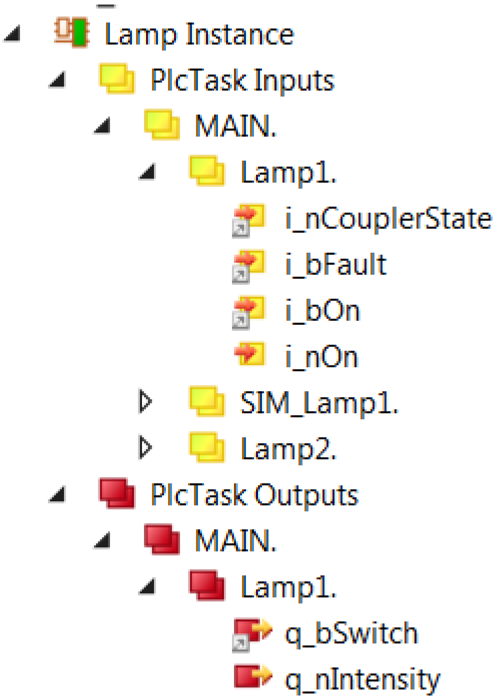


Fig. 3.1: Example of FB_LAMP input/output signals.

The table below describes each mapping variable.

Variable	Port Type	Optional Mapping	Description
i_nCouplerState	UINT	No	Mapped to the ‘state’ of the coupler that hosts I/O terminals. If the terminals span over more than one coupler, it is recommended to select the ‘state’ of the last coupler that hosts a lamp signal.
i_bFault	Digital In	Yes	Does not have to be mapped if ‘fault’ signal is ignored, i.e. does not exist.
i_bOn	Digital In	No	Mapped to the Lamp status (ON/OFF) digital input signal.
i_nOn	Analog In	Yes	Analog feedback signal. Has to be mapped only if analog feedback is used.
q_bSwitch	Digital Out	No	Mapped to the Lamp control digital output signal.
q_nIntensity	Analog Out	Yes	Mapped to the Lamp intensity analog output signal (if exists).

3.2.4 GUI Template

The Lamp Library provides a template GUI to control instances of *FB_LAMP*. Applications can easily deploy an instance of this GUI by setting the GUI reference to the particular instance of *FB_LAMP*, as shown below.

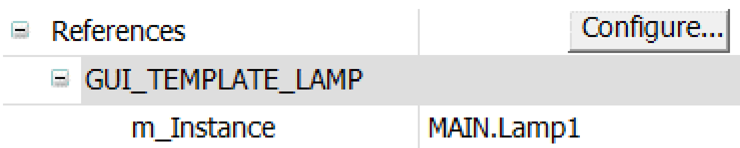


Fig. 3.2: Instantiation of GUI_TEMPLATE_LAMP for Lamp1

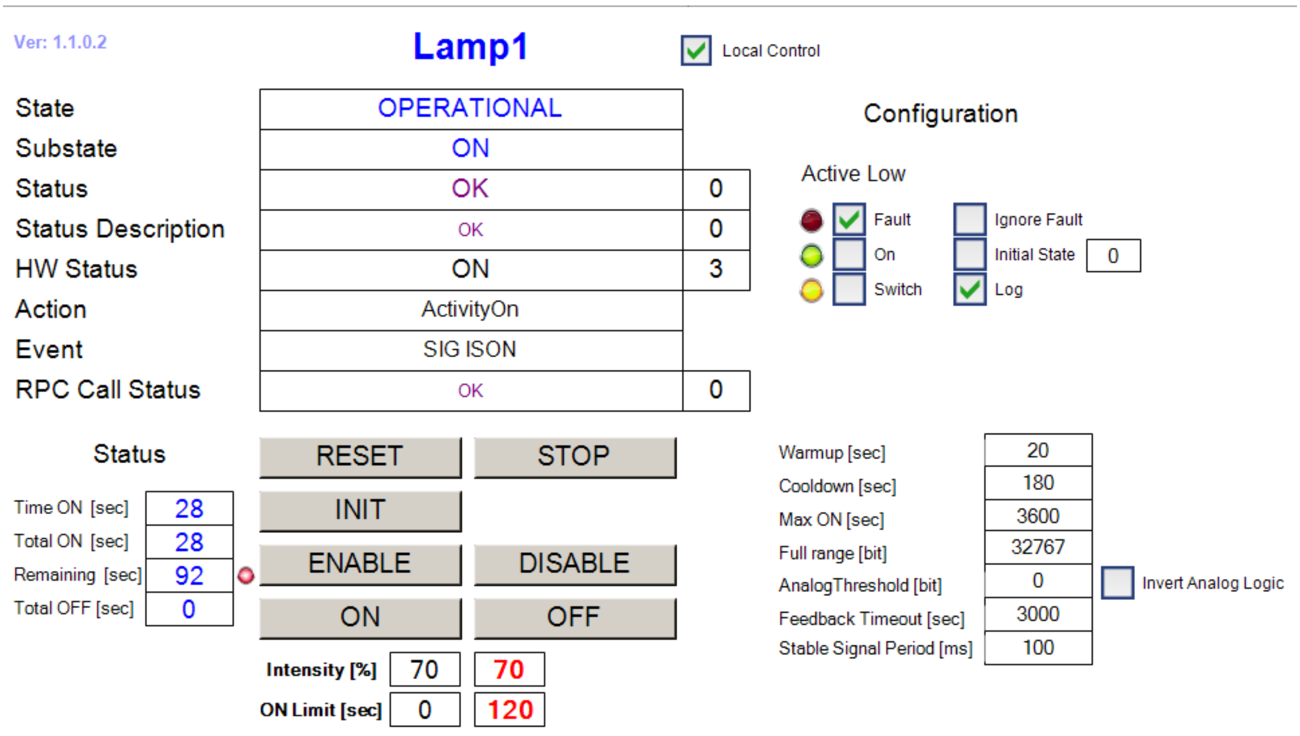


Fig. 3.3: FB_LAMP HMI for Local Control.

3.2.5 Lamp specific RPC Methods

- RPC_Off() Turn lamp OFF
- RPC_On() Turn lamp ON

3.2.6 Lamp Simulator

The function block *FB_SIM_LAMP* implements the lamp simulator on the PLC. The simulator has the address of the lamp instance as the only input parameter. The following code shows how the simulator is declared and executed:

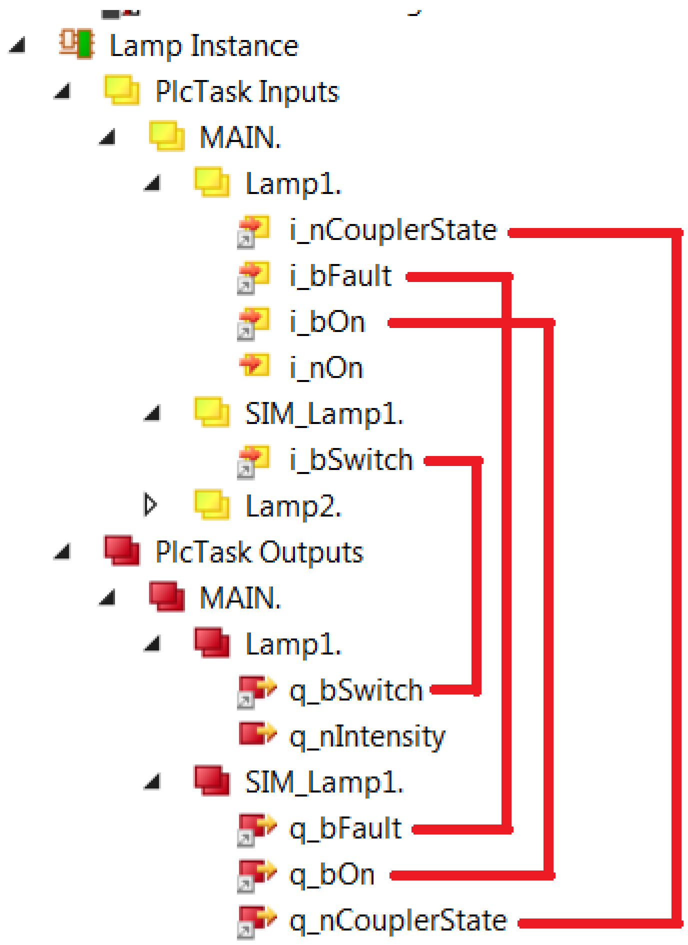
Declaration:

```
{attribute 'OPC.UA.DA':='1'}

Lamp1: FB_LAMP; // Simulated lamp

{attribute 'OPC.UA.DA':='1'}

SIM_Lamp: FB_SIM_LAMP; // Lamp simulator
```

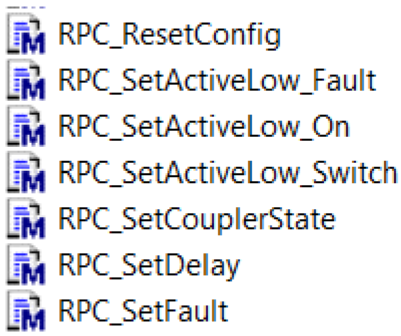
Execution:

```
Lamp1(in_sName:='Lamp1', in_bActiveLowFault:=TRUE);

SIM_Lamp(ptrDev:=ADR(Lamp1));
```

Simulator Mapping



Simulator RPC Methods

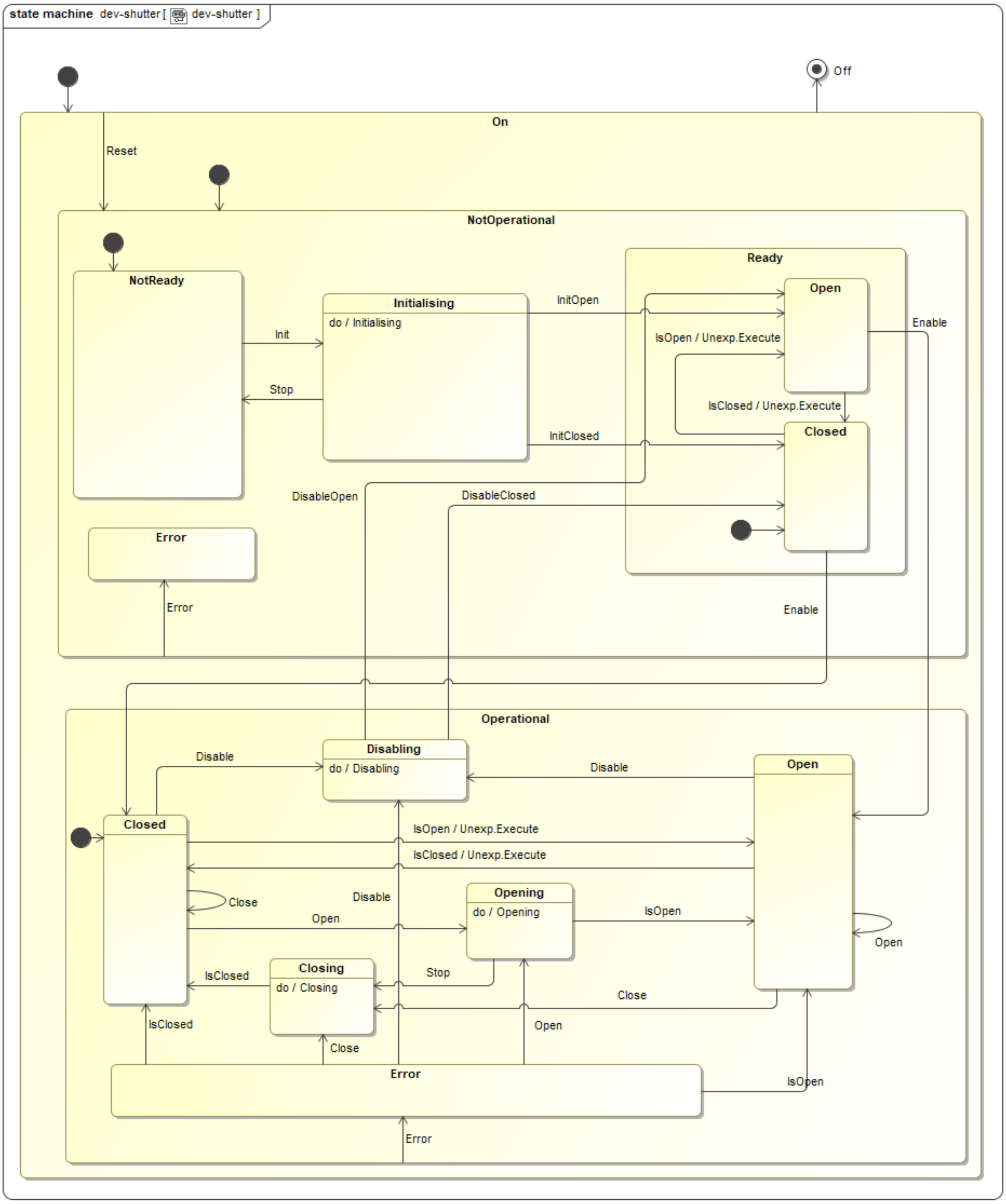


3.3 Shutter Library (shutter.library)

FB_SHUTTER is the TwinCAT PLC Function Block for the low level control of the standard shutter device.

3.3.1 State Machine

The state machine of the shutter controller is shown below. The main operational states are *Open*, *Closed*, *Opening* and *Closing*.


state machine dev-shutter [dev-shutter]
Off
On
Reset
NotOperational
NotReady
Initialising
do / Initialising
Init
Stop
InitOpen
InitClosed
Ready
Open
Closed
IsOpen / Unexp.Execute
IsClosed / Unexp.Execute
Enable
DisableOpen
DisableClosed
Error
Error
Enable
Operational
Disabling
do / Disabling
Disable
Disable
Closed
Open
IsOpen / Unexp.Execute
IsClosed / Unexp.Execute
Close
Disable
Open
Opening
do / Opening
IsOpen
Open
Closing
do / Closing
IsClosed
Stop
Close
Open
IsClosed
Close
Error
IsOpen
Error

3.3.2 Input parameters

FUNCTION_BLOCK FB_SHUTTER_BASE

VAR_INPUT	**in_sName**	STRING	*Instance name*
VAR_INPUT	**in_bActiveLowClosed**	BOOL	*If TRUE, the CLOSED signal is Active Low, default FALSE*
VAR_INPUT	**in_bActiveLowFault**	BOOL	*If TRUE, the FAULT signal is Active Low, default FALSE*
VAR_INPUT	**in_bActiveLowOpen**	BOOL	*If TRUE, the OPEN signal is Active Low, default FALSE*
VAR_INPUT	**in_bActiveLowSwitch**	BOOL	*If TRUE, the SWITCH signal is Active Low, default FALSE*
VAR_INPUT	**in_bIgnoreClosed**	BOOL	*If TRUE, the CLOSED signal is Ignored, default FALSE*
VAR_INPUT	**in_bIgnoreFault**	BOOL	*If TRUE, the FAULT signal is Ignored, default FALSE*
VAR_INPUT	**in_bIgnoreOpen**	BOOL	*If TRUE, the OPEN signal is Ignored, default FALSE*
VAR_INPUT	**in_bInitialState**	BOOL	*Default shutter position is FALSE/CLOSED*
VAR_INPUT	**in_nTimeout**	UDINT	*Timeout for OPEN/CLOSE transitions [msec], default 3000 ms*
VAR_INPUT	**in_bLogExtTime**	BOOL	*If TRUE, use external time in event logs. Default FALSE.*
VAR_INPUT	**in_bLog**	BOOL	*If TRUE, log events. Default TRUE.*

3.3.3 Signal Mapping

The figure below shows the TwinCAT view of the *FB_SHUTTER* I/O variables that are available for mapping to physical signals, i.e. ports of I/O terminals.

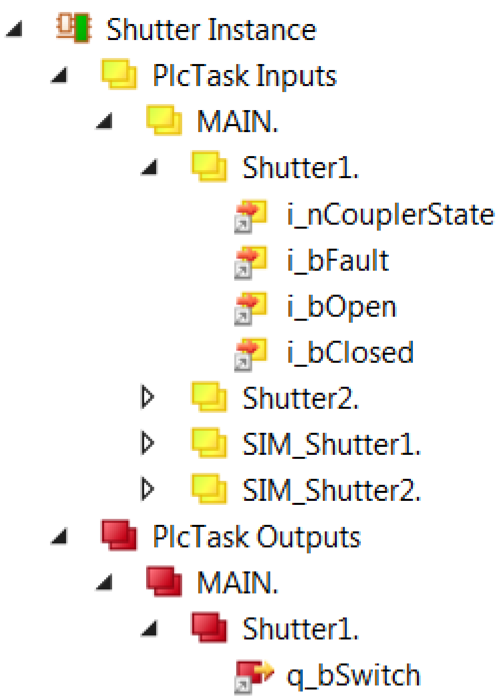


Figure 4: Example of FB_SHUTTER input/output signals.

The table below describes each mapping variable.

Variable	Port Type	Optional	Description
i_nCouplerState	**UINT**	**No**	**Mapped to the 'state' of the coupler that hosts I/O terminals. If the terminals span over more than one coupler, it is recommended to select the 'state' of the last coupler that hosts a shutter signal.**
i_bFault	**Digital In**	**Yes**	**Does not have to be mapped if 'fault' signal is ignored, i.e. does not exist.**
i_bOpen	**Digital IN**	**No**	**Mapped to the Shutter 'open' digital input signal.**
i_bClosed	**Digital IN**	**No**	**Mapped to the Shutter 'closed' digital input signal.**
q_bSwitch	**Digital Out**	**No**	**Mapped to the Shutter control digital output signal.**

3.3.4 GUI Template

The Shutter Library provides a template GUI to control instances of *FB_SHUTTER*. Applications can easily deploy an instance of this GUI by setting the GUI reference to the particular instance of *FB_SHUTTER*, as shown below.

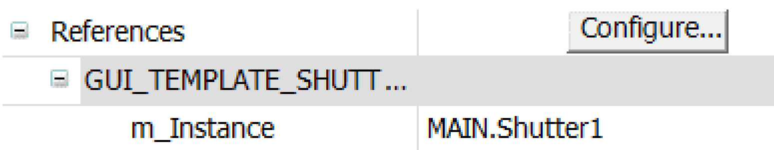


Figure 5: Instantiation of GUI_TEMPLATE_SHUTTER for Shutter1

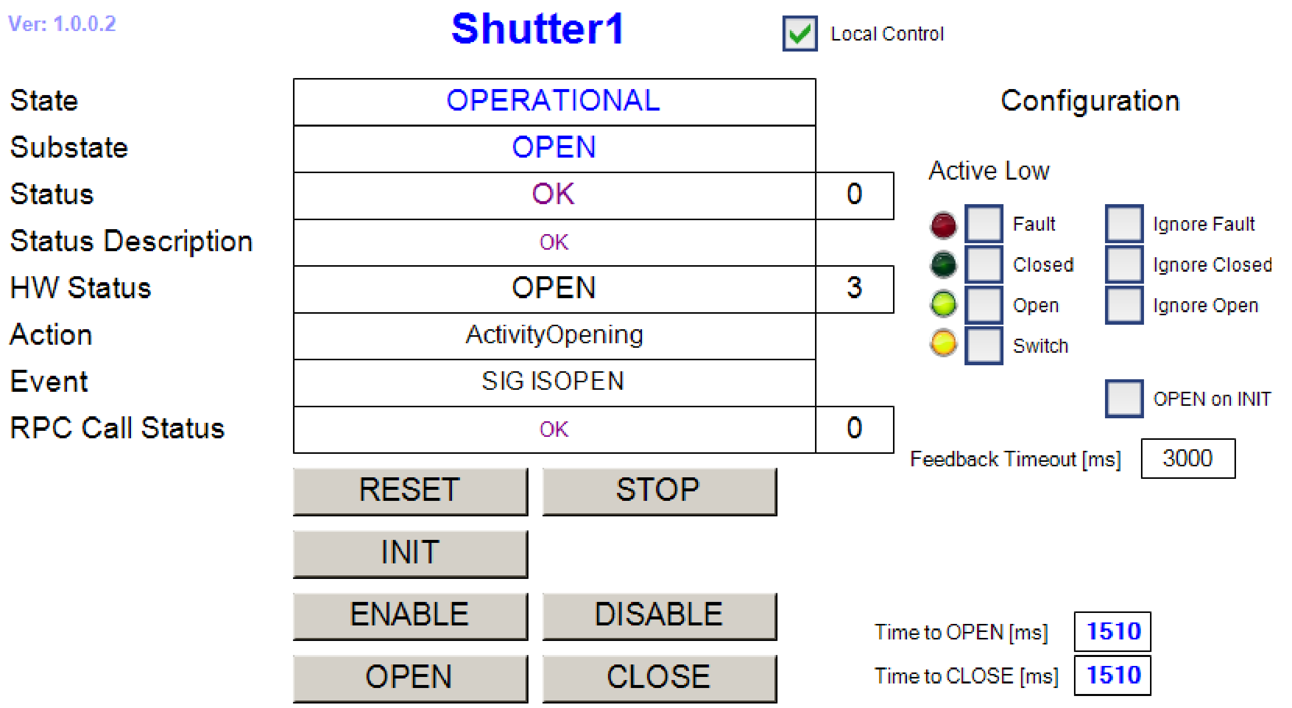


Figure 6: FB_SHUTTER HMI for Local Control.

3.3.5 Shutter specific RPC Methods

- RPC_Close() Close shutter
- RPC_Open() Open Shutter

3.3.6 Shutter Simulator

The function block *FB_SIM_SHUTTER* implements the shutter simulator on the PLC. The simulator has the address of the shutter instance as the only input parameter. The following code shows how the simulator is declared and executed:

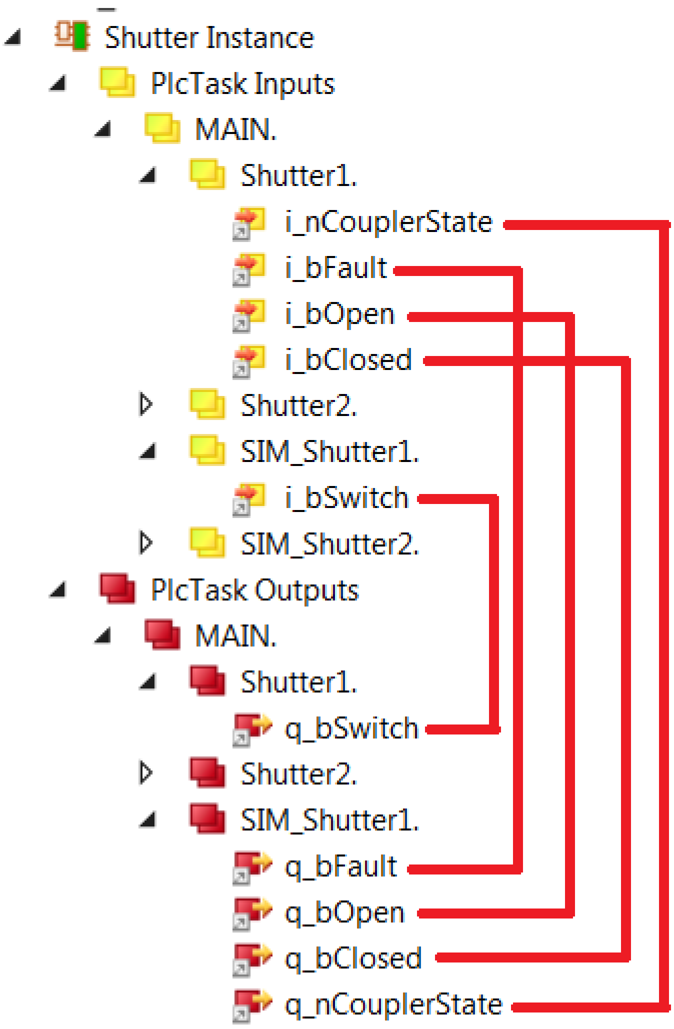
Declaration:

```
{attribute 'OPC.UA.DA':='1'}

Shutter1: FB_SHUTTER;

{attribute 'OPC.UA.DA':='1'}

SIM_Shutter1: FB_SIM_SHUTTER;
```

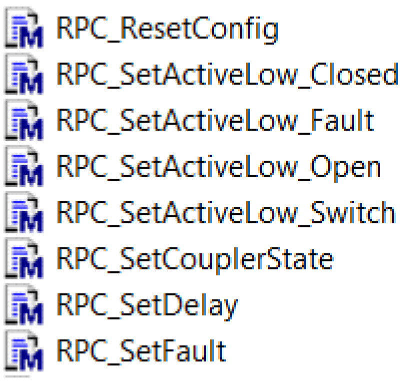
Execution:

```
Shutter1(in_sName:='Shutter1', in_bActiveLowOpen:=TRUE, in_
↪bActiveLowClosed:=TRUE);

SIM_Shutter1(ptrDev := ADR(Shutter1));
```

Simulator Mapping



Simulator RPC Methods



3.4 Time Library (timer.library)

FB_TIME is the ESO PLC Function Block that provides time services to other components running within the PLC, e.g. computation of absolute time. This FB delivers the time by combining an external offset together with the time delivered by the EtherCAT DC clock. This offset may come from different sources: PTP, NTP or a simulated one.

Note: The FB_TIME in FCF version 4.0 supports NTP. NTP is now provided as part of the TwinCAT Corrected Timestamps[10]. The NTP client inside the TwinCAT is available only in build 4024 or above. To use NTP in the FB_TIME requires to have the NTP added to the project.

3.4.1 Input parameters

The FB_TIME does not have input parameters.

3.4.2 Signal Mapping using EL6688 terminal

The *FB_TIME* defines a number of mappings that are needed to do the correct computation of the time. Most of these mappings come from the EL6688 terminal. If this terminal is not available in the HW configuration, the *FB_TIME* could still be used using NTP or simulating a particular time in the PLC.

The table below describes each mapping variable.

[10] https://infosys.beckhoff.com/content/1033/corrected_timestamps/index.html

Variable	Port Type	Optional Mapping	Description
i_inTime	ULINT	No	Mapped to the EL6688 internal time stamp
i_exTime	ULINT	No	Mapped to the EL6688 external time stamp
i_dc2TcOffset	LINT	No	Mapped to the EtherCAT Dc2TcOffet
i_dc2ExtOffset	LINT	Yes	Mapped to the EtherCAT Dc2ExtOffset
i_extDevNotConnected	BOOL	No	Mapped to the EL6688 External device not connected
i_syncMode	UINT	Yes	Mapped to the EL6688 Sync mode
i_AdsAddr	AMSADDR	No	Mapped to the EL6688 ADS address
q_timeInfo	T_TIME_INFO	Yes	Delivers the actual absolute time (DC) and mode

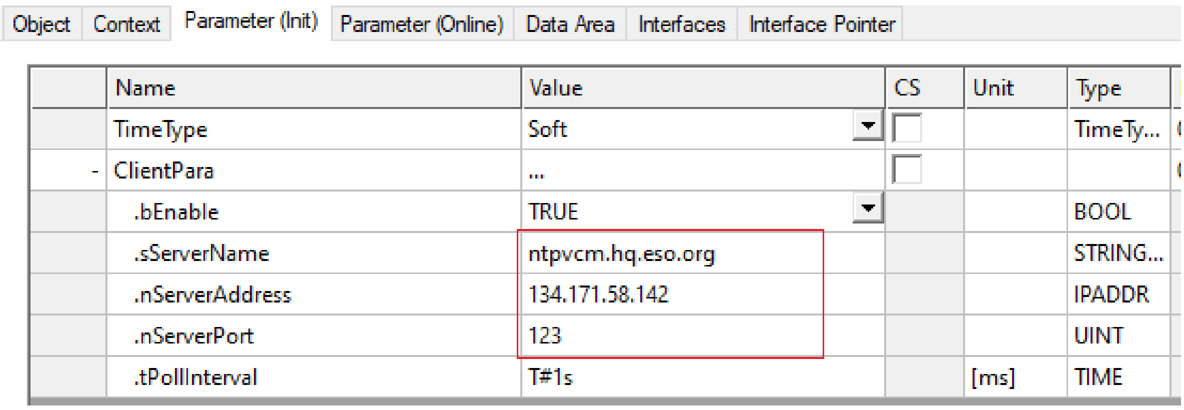
3.4.3 Signal Mapping using NTP

Warning: The precision provided by NTP might be not good enough for tracking axes therefore it is recommended to use PTP for those cases.

When using *FB_TIME* together with NTP, the source of the time offset comes from the TcNtpExternalProvider module that should be configured in the project prior to use the FB_TIME. For more details, refer to the TwinCAT documentation[11].

Once the TcNtpExternalProvider has been added to the project, it shall be configured by defining the server name, IP and port.

[11] https://infosys.beckhoff.com/english.php?content=../content/1033/corrected_timestamps/6326712203.html&id=



Object | Context | Parameter (Init) | Parameter (Online) | Data Area | Interfaces | Interface Pointer

	Name	Value	CS	Unit	Type
	TimeType	Soft			TimeTy...
-	ClientPara	...			
	.bEnable	TRUE			BOOL
	.sServerName	ntpvcm.hq.eso.org			STRING...
	.nServerAddress	134.171.58.142			IPADDR
	.nServerPort	123			UINT
	.tPollInterval	T#1s		[ms]	TIME

Fig. 3.4: TcNtpExternalProvider: Sample configuration.

The *FB_TIME* defines some specifics parameters for NTP. The table below describes each mapping variable.

Variable	Port Type	Optional Mapping	Description
i_exNtpExtTime	**LINT**	**No**	**Mapped to the NTP external time**
i_exNtpSysTime	**LINT**	**No**	**Mapped to the NTP system time**
i_exNtpExtOffset	**LINT**	**No**	**Mapped to the NTP offset time**
i_NtpConnected	**BOOL**	**No**	**Mapped to the NTP diagnostic flag**
i_exNtpSynchronized	**BOOL**	**Yes**	**Mapped to the NT{ diagnostic flag**
q_timeInfo	**T_TIME_INFO**	**Yes**	**Delivers the actual absolute time (DC) and mode**

The mapping between the NTP and the FB_TIME instance is shown in the folling figure:

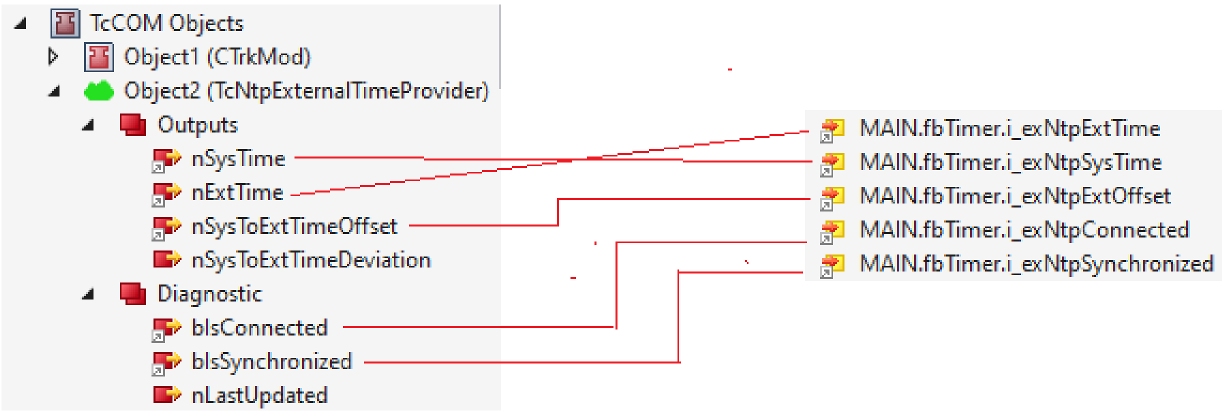


Fig. 3.5: FB_TIME: NTP mapping.

3.4.4 GUI Template

As for other PLC libraries, the *timer.library* provides a template GUI *GUI_TEMPLATE_TIME* for control of *FB_TIME* instances. Applications can easily deploy an instance of this GUI by setting the GUI references to the particular instance of *FB_TIME* and its name.

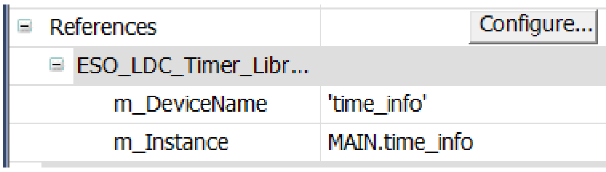


Fig. 3.6: Instantiation of GUI_TEMPLATE_TIME for time_info instance

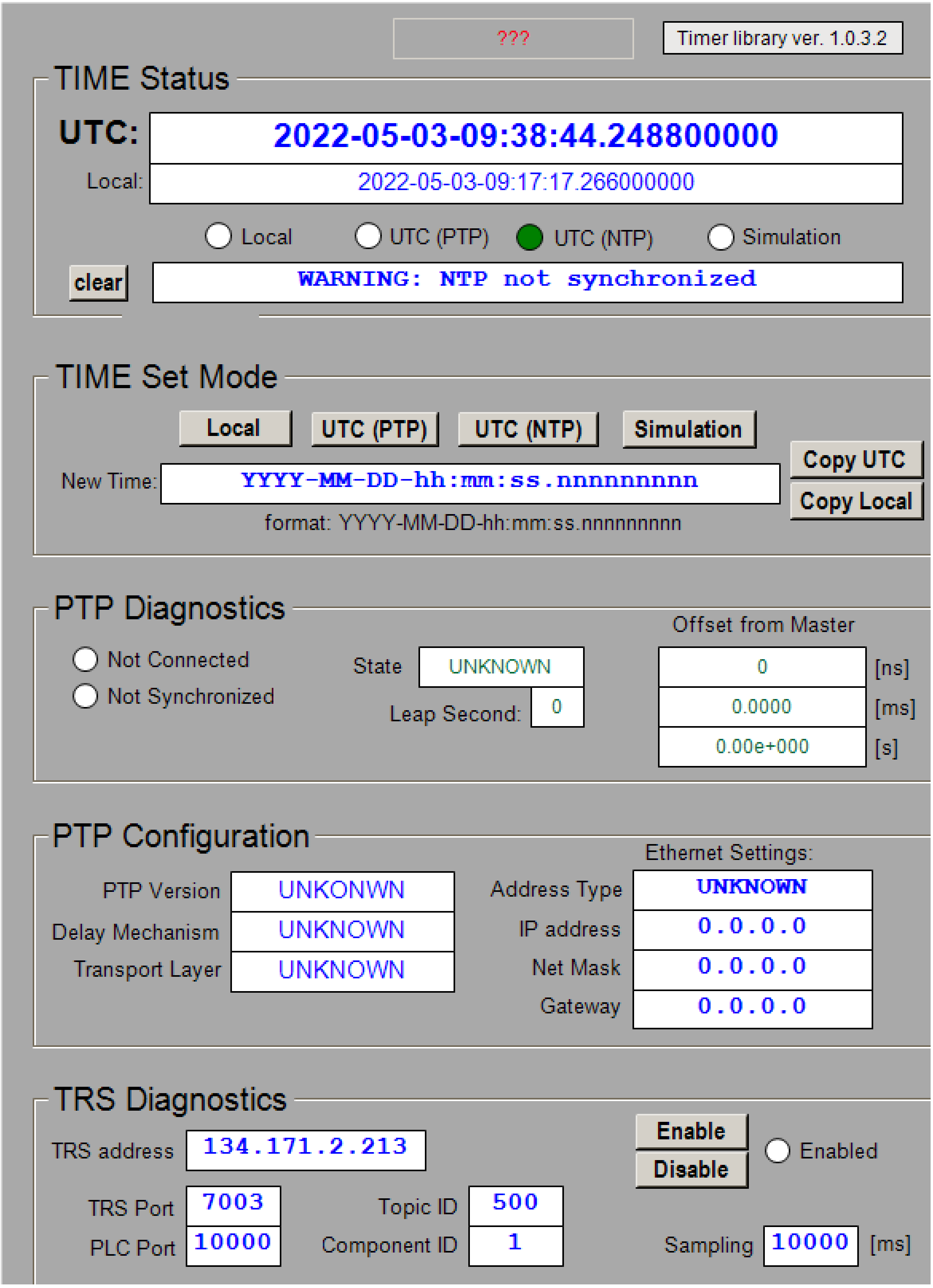


Fig. 3.7: FB_TIME HMI for Local Control.

The user has a choice of three time signals:

Time Signal	Description
UTC(PTP)	**Time signal coming from the IEEE1588 PTP server. This is the default time signal.**
UTC(NTP)	**Time signal coming from the TC NTP Client.**
Local	**Local time of the Beckhoff IPC.**
Simulated	**Simulated time. This is the perfect tool for testing SW for specific date and time.**

The GUI instance shown on the screenshot above, the time is obtained from the TwinCAT NTP client. In case it would be needed, the time can be also simulated.

The two buttons *Copy UTC* and *Copy Local* are used to copy UTC or Local time string into the entry field for simulated time, avoiding unnecessary typing.

In *UTC* mode, if the time signal gets lost, the time will automatically switch to *Local* mode.

3.4.5 Time specific RPC Methods

- RPC_GetMode() Get actual time mode: Local, UTC or Simulation.
- RPC_SetMode() Set new time mode (Local, UTC or Simulation).
- RPC_GetUTC() Obtain the actual absolute time and mode.
- RPC_SetTime(string) Set a user defined time (only works in Simulation mode).

Note: By downloading a new new version of the PLC project, the FB_TIME might switch automatically to local time. To avoid this, applications shall force the setting to be NTP time within the projects (SetMode(E_TIME_MODE.UTC_NTP)).

3.5 Motor Library (motor.library)

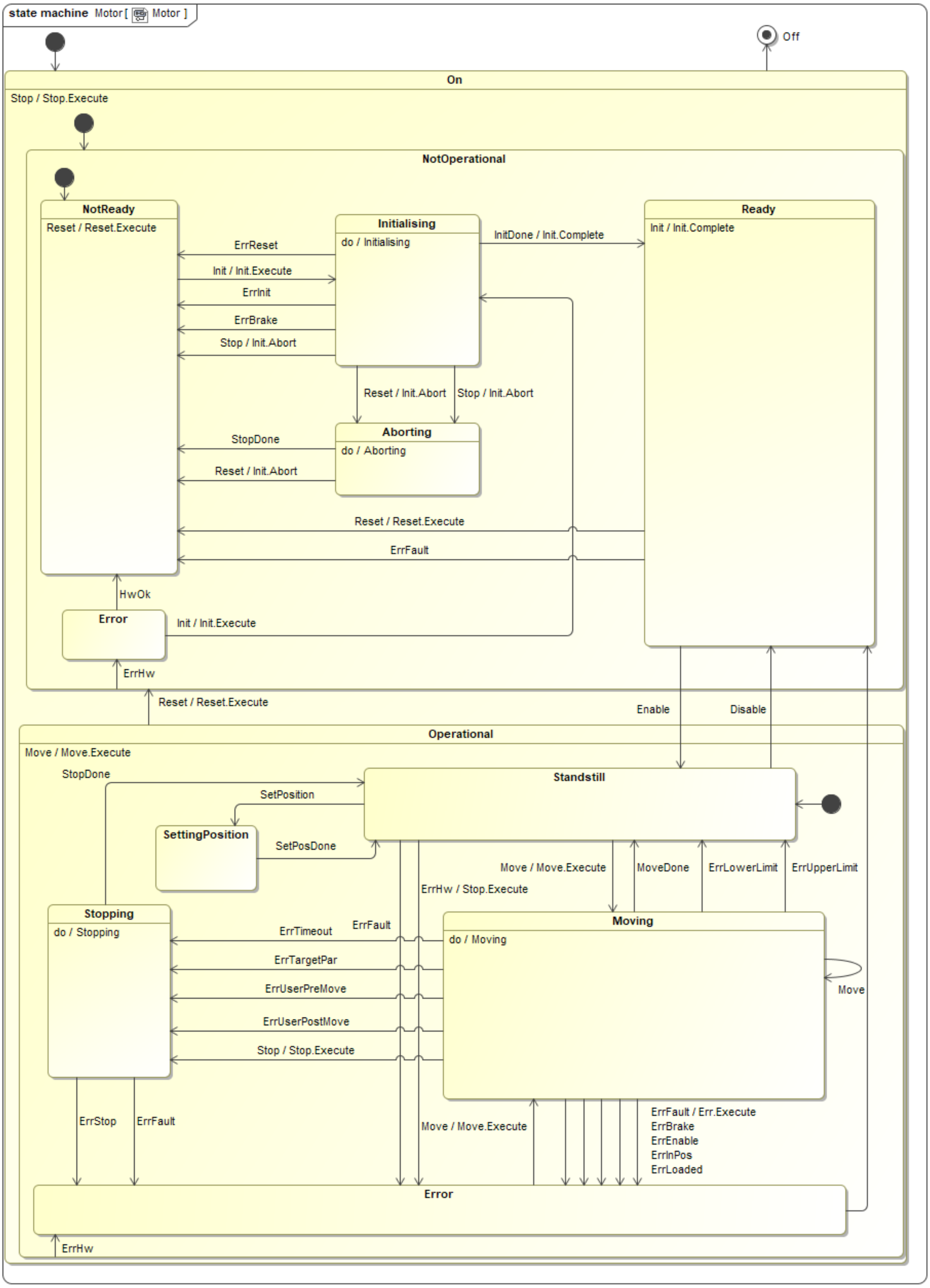
Note: **Important note**: The cycle time of the task (e.g. *PlcTask*) that executes an instance of any FB delivered in motor.library that controls motors, i.e. *FB_MOTOR*, *FB_MA_ADC*, *FB_MA_DROT*, etc, must be the same or longer than the cycle time of the *NC-Task 1 SAF* task. In other words, the instance of these FBs must not be executed faster than the *NC-Task 1 SAF* task. Otherwise, there could be some synchronization problems, in particular when exiting tracking mode.

Note that the default cycle time of the *NC-Task 1 SAF* task is 2 ms. Therefore, if for example the *PlcTask* cycle time is set to 1 ms, the *NC-Task 1 SAF* task cycle time has to be set to the same value.

FB_MOTOR is the TwinCAT PLC Function Block used to operate motors. The library is based on the Beckhoff *MC* Library that is in turn *PLCOpen MC compliant*. This means that it should be possible to use the library for control of any type of motor, including brushless motors, under the condition that the motor controller is fully EtherCAT certified and PLCOpen MC compliant. So far, stepper, DC, BLDC (brushless DC) and synchronous motors have been successfully tested with the library.

3.5.1 State Machine

The state machine of the motor controller is shown below. The main operational states are *Standstill*, *Moving* and *Stopping*.


state machine Motor [Motor]
Off
On
Stop / Stop.Execute
NotOperational
NotReady
Reset / Reset.Execute
Initialising
do / Initialising
InitDone / Init.Complete
Ready
Init / Init.Complete
ErrReset
Init / Init.Execute
ErrInit
ErrBrake
Stop / Init.Abort
Reset / Init.Abort
Stop / Init.Abort
Aborting
do / Aborting
StopDone
Reset / Init.Abort
Reset / Reset.Execute
ErrFault
HwOk
Error
Init / Init.Execute
ErrHw
Reset / Reset.Execute
Enable
Disable
Operational
Move / Move.Execute
StopDone
Standstill
SetPosition
SettingPosition
SetPosDone
Move / Move.Execute
MoveDone
ErrLowerLimit
ErrUpperLimit
ErrHw / Stop.Execute
Stopping
do / Stopping
ErrTimeout
ErrFault
Moving
do / Moving
ErrTargetPar
ErrUserPreMove
ErrUserPostMove
Stop / Stop.Execute
Move
ErrStop
ErrFault
Move / Move.Execute
ErrFault / Err.Execute
ErrBrake
ErrEnable
ErrInPos
ErrLoaded
Error
ErrHw

3.5.2 Usage of NOVRAM

Note: **Important note**: If the motor is configured to use NOVRAM, the configuration of the motor is copied into NOVRAM on every **successful** INIT of the motor. If the INIT fails, the NOVRAM doesn't get updated.

NOVRAM is used to store and keep the configuration of the motor. The configuration of the motor is copied into the NOVRAM on every successful INIT of the motor. On power cycle of the PLC, the configuration of the motor is read from the NOVRAM during the first PLC cycle. As a general rule, only PLCs with NOVRAM should be used for motor control applications, e.g. CX-2030 that comes with 128 kB of NOVRAM. PLCs without NOVRAM can still be used for motor control applications but the configuration will be lost on every power cycle of the PLC. These applications have to rely on the higher level software that has to download the configuration after each power cycle. The other option is to hard-code the configuration in the PLC application itself.

3.5.3 Input parameters

```
FUNCTION_BLOCK FB_MOTOR

VAR_INPUT   sName            STRING   Default Motor name
VAR_INPUT   nNOVRAM_DevId    UDINT    NOVRAM device ID - normally 4
VAR_INPUT   nNOVRAM_Offset   UDINT    NOVRAM offset where motor configuration is stored
```

FB_MOTOR has three input parameters. Apart from the standard sName parameter for the name, i.e. the label, of the motor instance, there are two additional parameters related to the usage of the NOVRAM.

Parameter	Type	Description
sName	STRING	Motor instance name/label
nNOVRAM_DevId	UDINT	NOVRAM Device ID. For PLCs without NOVRAM, this parameter should be set to zero or not given at all.
nNOVRAM_Offset	UDINT	Offset in bytes in NOVRAM. A motor instance needs about 500 bytes for configuration data. For simplicity it is recommended to increment offsets by 1000 for each motor. Therefore, the first motor will have the offset of zero, second of 1000, third of 2000, etc. For PLCs without NOVRAM, this parameter should be set to zero or not given at all.

The following example shows the usage of NOVRAM. It is very important to note that the entered value for the parameter nNOVRAM_DevId matches the value of the NOV-DP-RAM device. In this example the value is 4.

In case that the NOVRAM is not used, the *Motor1* instance would not have any NOVRAM related parameters and the code would look like this:

```
Motor1(sName:='Motor1');
```

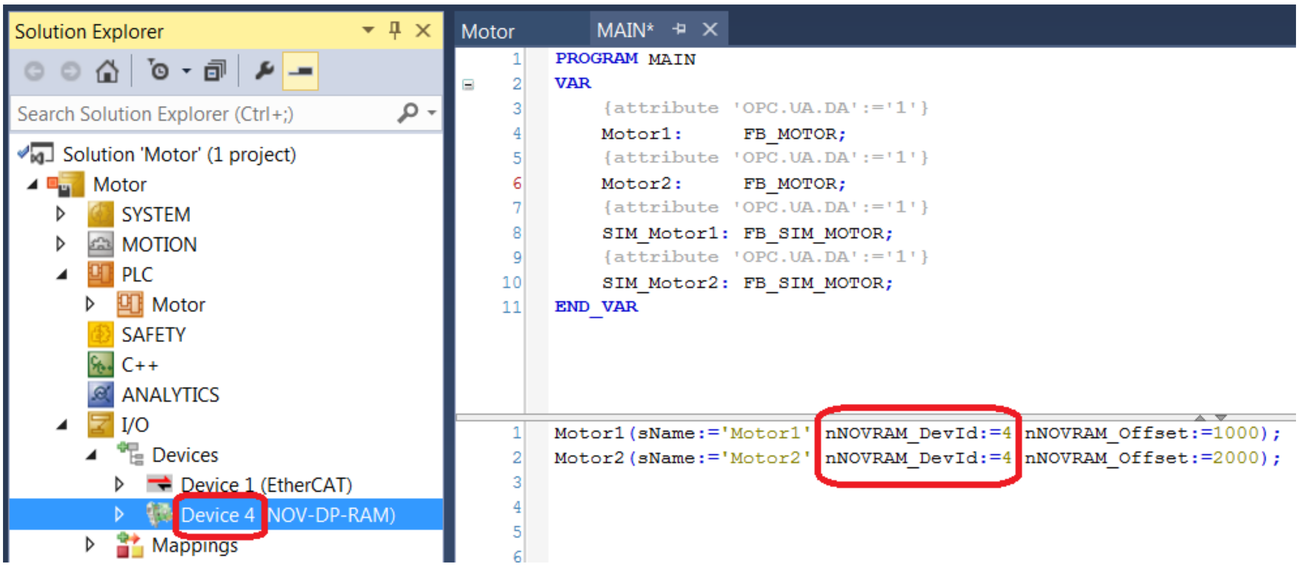


Figure 7: Application example for using NOVRAM with FB_MOTOR.

3.5.4 Signal Mapping

Figure 8 shows the TwinCAT view of the *FB_MOTOR* I/O variables that are available for mapping to physical signals, i.e. ports of I/O terminals or NC structures.

The mapping is quite different from other devices. Specific to motors, for each Axis (i.e. motor) there are two links to be established from the Axes/<Motor> Settings:

1. *Link To I/O...* This is the link between the Axis and the motor controller terminal, e.g. EL7041, that controls it.
2. *Link To PLC...* This is the link between the Axis and the motor instance in the *MAIN* program, e.g. *Motor1*. This link sets all the mappings for the two complex structures *NcToPlc* (input) and *PlcToNc* (output) and the user should not touch it afterwards.

The mapping parameters are described in the table below.

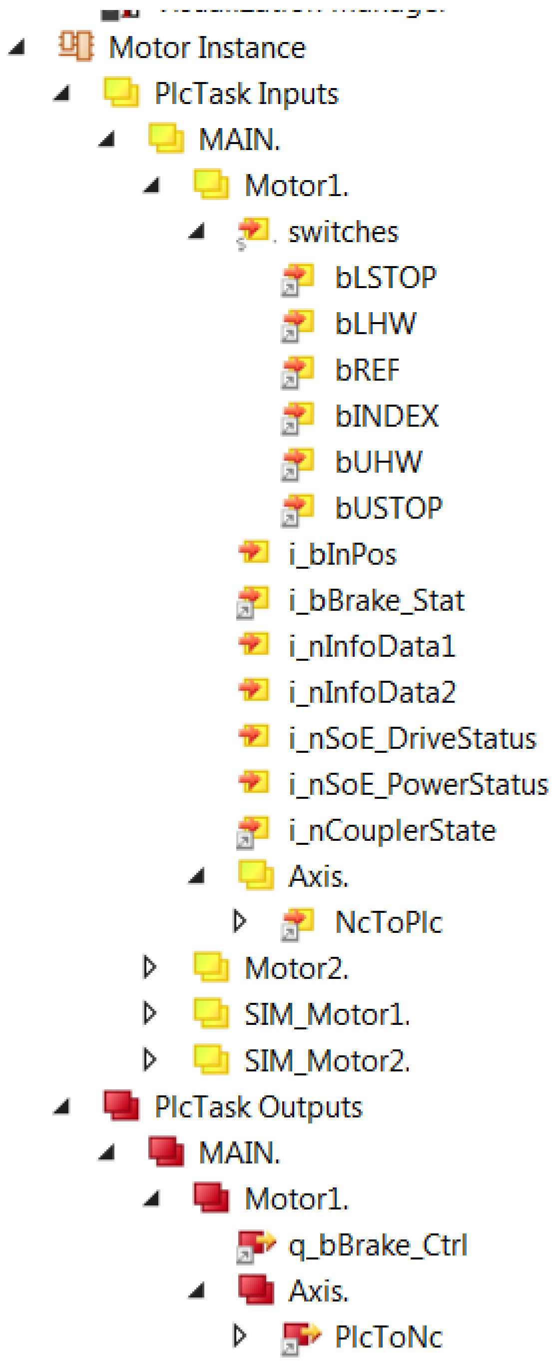


Figure 8: Example of FB_MOTOR input/output signals.

Variable	Port Type	Optional	Description
switches	Digital In	Yes	There are six variables to be linked to various limit and reference switches, depending on the HW configuration; upper and lower Stop and HW limits, Reference and Index switch. Switches can be linked to any binary signal (BOOL). Normally the signals are coming from digital inputs but they could also be linked to variables of type BOOL in some special applications, i.e. digitizing of analog position sensors.
i_bInPos	Digital In	Yes	Signal of the In-Position switch. In some applications with stepper motors without feedback (cryogenic environment) a switch is used to confirm that the motor is in correct position.
i_bBrakeStat	Digital In	Yes	Status of the brake feedback signal.
i_nInfoData1/2	INT	Yes	Two freely selectable signed integers to be link to any variable of the same type, e.g. motor controller output current.
i_nSoE_DriveStatus	UINT	Yes	Serco Drive (e.g. AX5000) Status, not used with CoE drives.
i_nSoE_PowerStatus	UINT	Yes	Serco Drive (e.g. AX5000) Power Status, not used with CoE drives.
i_nCouplerState	UINT	No	Mapped to the 'state' of the coupler that hosts I/O terminals. If the terminals span over more than one coupler, it is recommended to select the 'state' of the last coupler that hosts a shutter signal.
NcToPlc	Struct In	No	Internal MC structure of type MC.NCTOPLC_AXIS_REF. Automatically linked from "Link To PLC".
q_bBrake_Ctrl	Digital Out	Yes	Brake control digital output signal. Active low!
PlcToNc	Struct Out	No	Internal MC structure of type MC.PLCTONC_AXIS_REF. Automatically linked from "Link To PLC".

3.5.5 GUI Templates

The Motion Library provides two template GUIs intended for configuration and control of motor instances of FB_MOTOR respectively. Applications can easily deploy instances of the GUIs by setting the GUI references to the particular instance of FB_MOTOR_CONTROL, as shown below for the case of the configuration GUI.

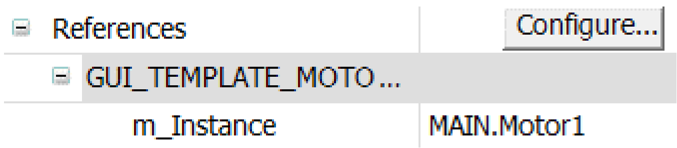


Figure 9: Instantiation of GUI_TEMPLATE_MOTOR_CONFIG for Motor1

From the Configuration GUI, shown in Figure 10, it is very simple to set axis type, define INIT sequence, select user defined methods to be executed, set the active low parameters for each switch, as well as to configure brakes, define timeouts, software limits and backlash compensation.

Once the motor is successfully initialised, the complete configuration will be stored in NOVRAM.

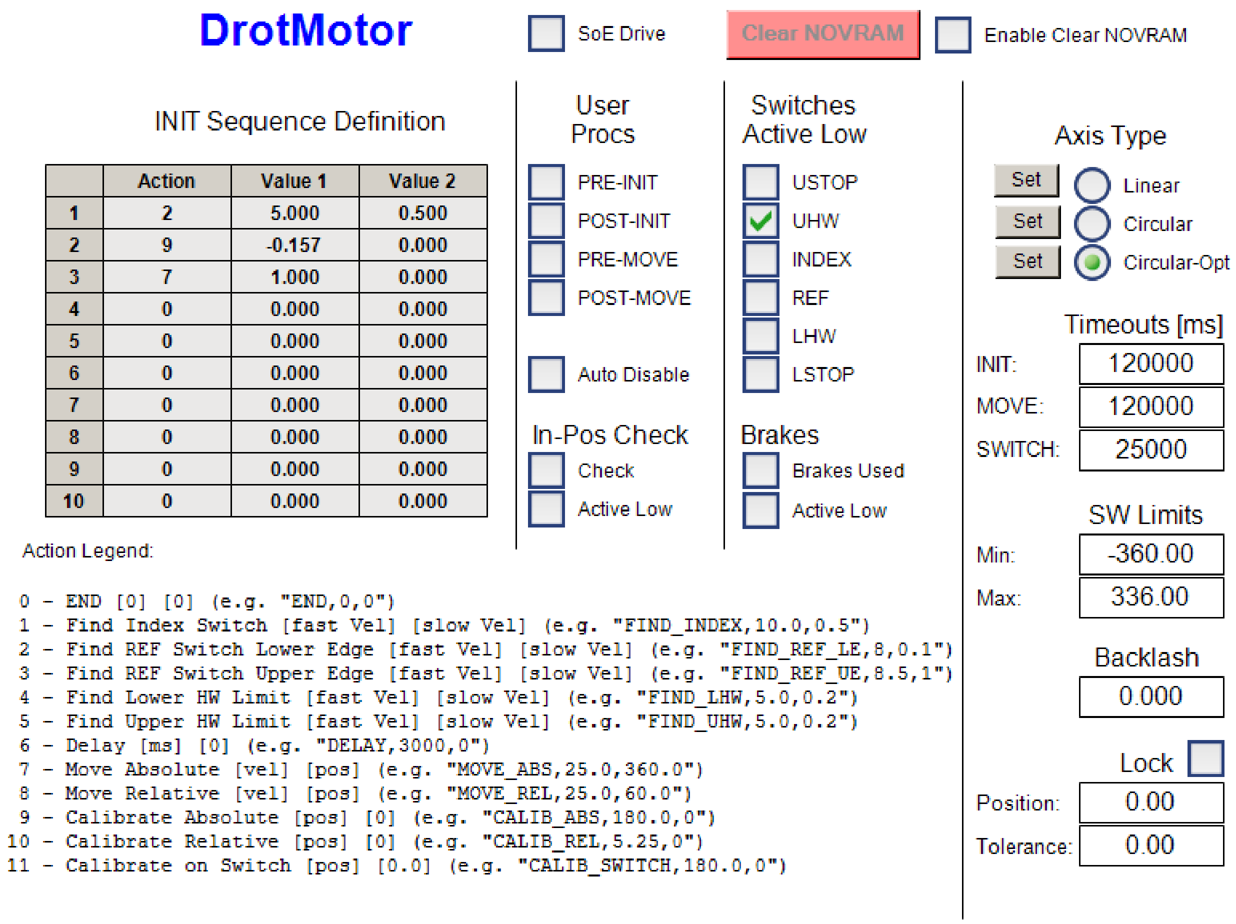


Figure 10: FB_MOTOR HMI for motor configuration.

From the Control GUI, shown in Figure 11, it is possible to perform basic control operations on the motor.

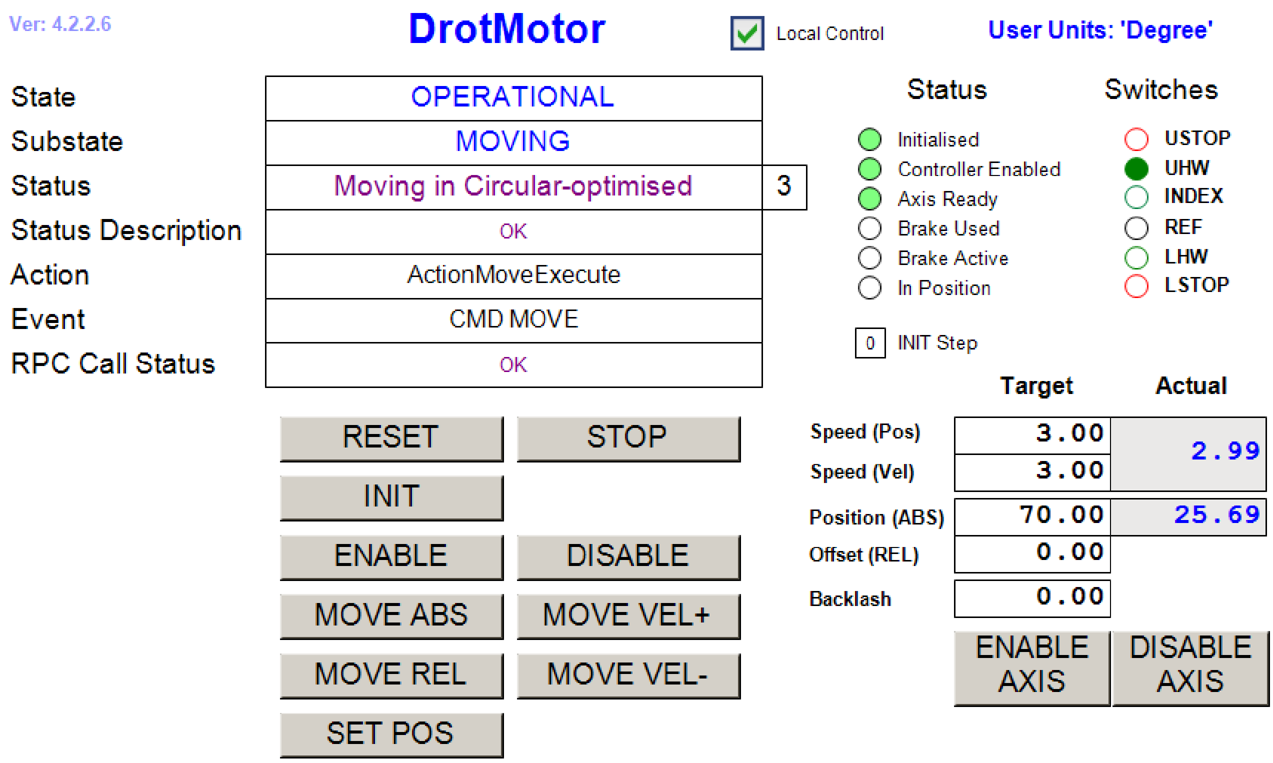


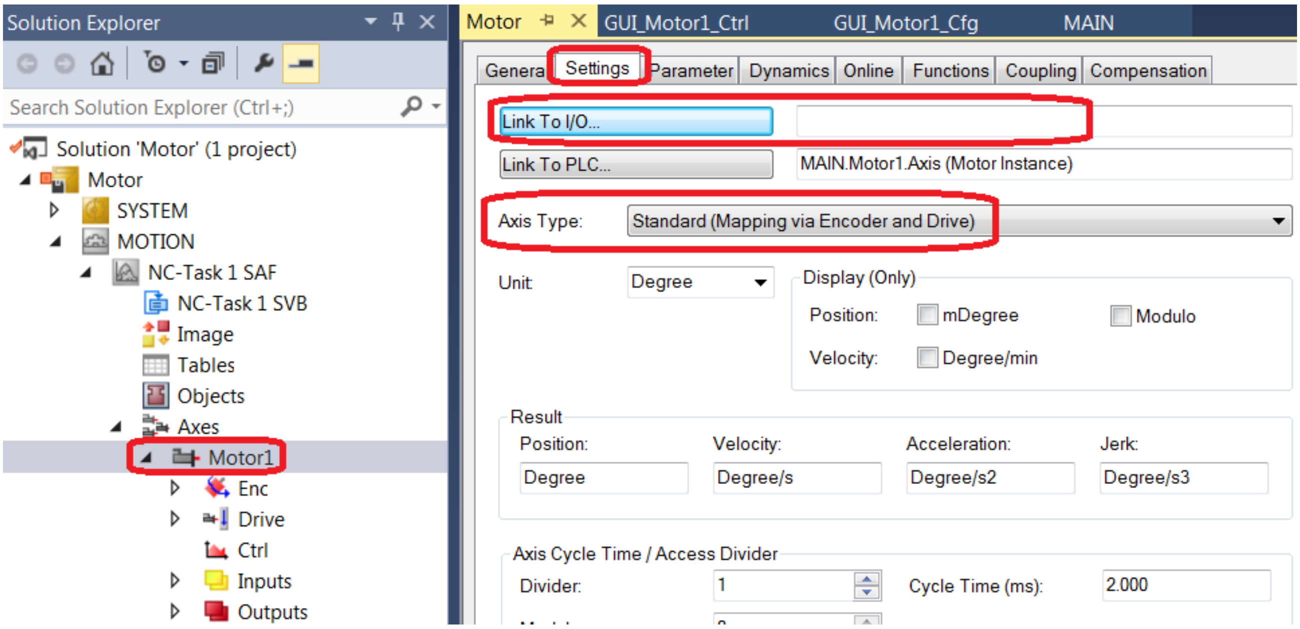
Figure 11: FB_MOTOR HMI for Local Control.

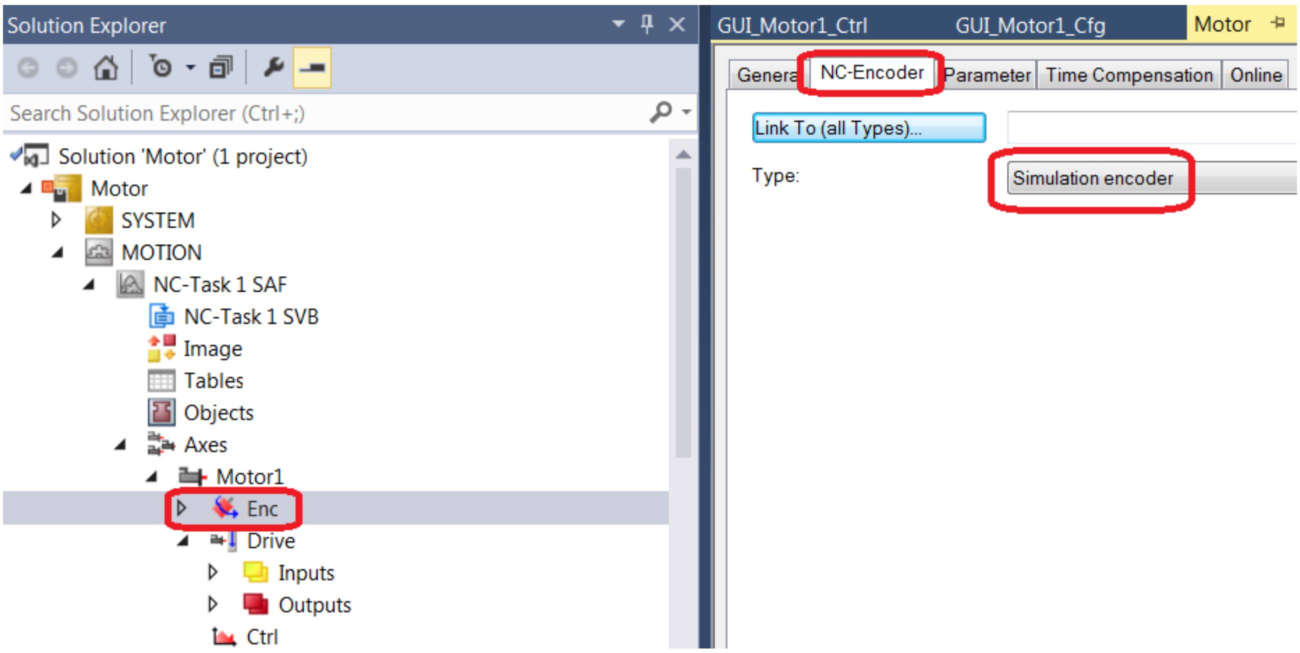
3.5.6 Motor specific RPC Methods

- RPC_MoveAbs() Move to absolute position
- RPC_MoveRel() Move relative to current position
- RPC_MoveVel() Move in velocity

3.5.7 Motor Simulator

Note: Important note: In order to use the motor simulator, the Axis has to be modified. The Axis Type has to be set to *Standard (Mapping via Encoder and Drive)* and the *Link to I/O. . .* should be left empty. The Axis Encoder has to be configured as *Simulation encoder*. See screen shots below.





The function block *FB_SIM_MOTOR* implements the motor simulator on the PLC. The input parameter of the simulator are addresses of the motor instance configuration and status structures. The following code shows how the simulator is declared and executed:

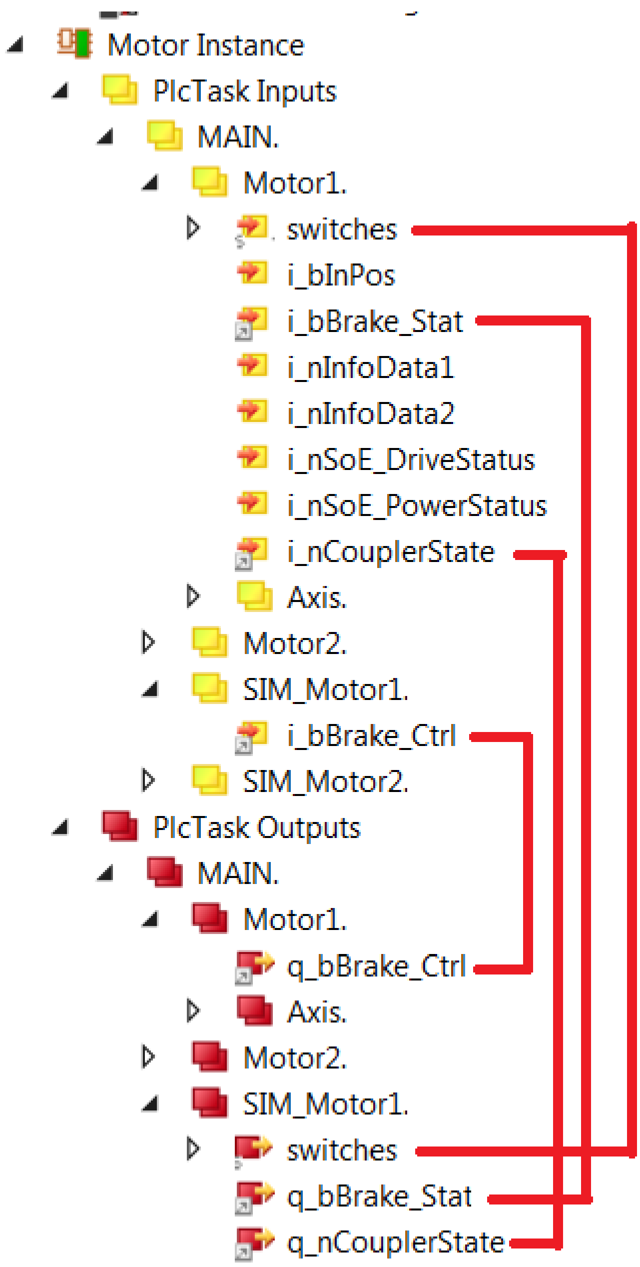
Declaration:

```
{attribute 'OPC.UA.DA':='1'}

Motor1: FB_MOTOR;

{attribute 'OPC.UA.DA':='1'}

SIM_Motor1: FB_SIM_MOTOR;
```

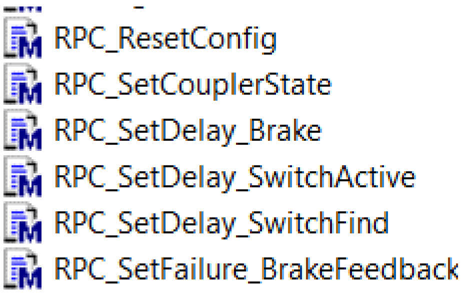
Execution:

```
Motor1(sName:='Motor1', nNOVRAM_DevId:=0);

SIM_Motor1 (ptrCfg:=ADR(Motor1.cfg), ptrStat:=ADR(Motor1.stat));
```

Simulator Mapping

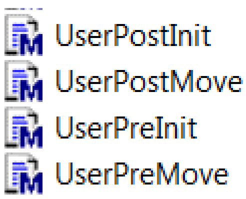


Simulator RPC Methods



3.5.8 User Defined Methods

The functionality of *FB_MOTOR* can be extended by user defined Pre- and Post INIT and MOVE methods. *FB_MOTOR* already includes the four dummy methods (see below) that only add a delay of three seconds during the execution. However, the dummy implementation can be a good starting point when overloading these methods for specific implementations in FBs that extend the *FB_MOTOR* functionality.



3.6 CCS Library (ccslib.library)

This is a small PLC library that provides some convenient Function Blocks to facilitate sending and receiving MUDPI packets as well as a function to receive the CCS data supporting linear interpolation.

> **Warning:** The ccslib library requires the TwinCAT TCP/IP (TF6311) to send MUDPI data through the network. To learn how to configure the Beckhoff TF6311, please refer to the TwinCAT documentation[12].

[12] https://infosys.beckhoff.com/english.php?content=../content/1033/TF6311_Tc3_TcpUDP/index.html&id=

3.7 CCS Simulator (ccssim.library)

Tracking devices require information from CCS to be able to compute the corrections to be applied to the actuators. This information will be delivered from CCS but in the meantime, FCF includes a utility that enable a simple way to validate tracking without the CCS infrastructure. It is a dummy FB (*FB_CCS_SIM*) that can be edited to define the telescope coordinates, environmental conditions and other parameters needed by a couple of C++ modules computing the tracking data.

The ccssim Library includes two C++ modules that work together to compute the tracking data:

- TrkParams
- TrkModule

The trkParams computes the parameters used by the slalib library and it does not require to be executed at a fast rate. The trkModule is the one computing the tracking data and it should be configured to run in a task running faster than the trkParams. It is suggested to use isolated CPU cores in order to maximize performance, as shown in the figure below where one CPU core is dedicated to the more demanding tasks.

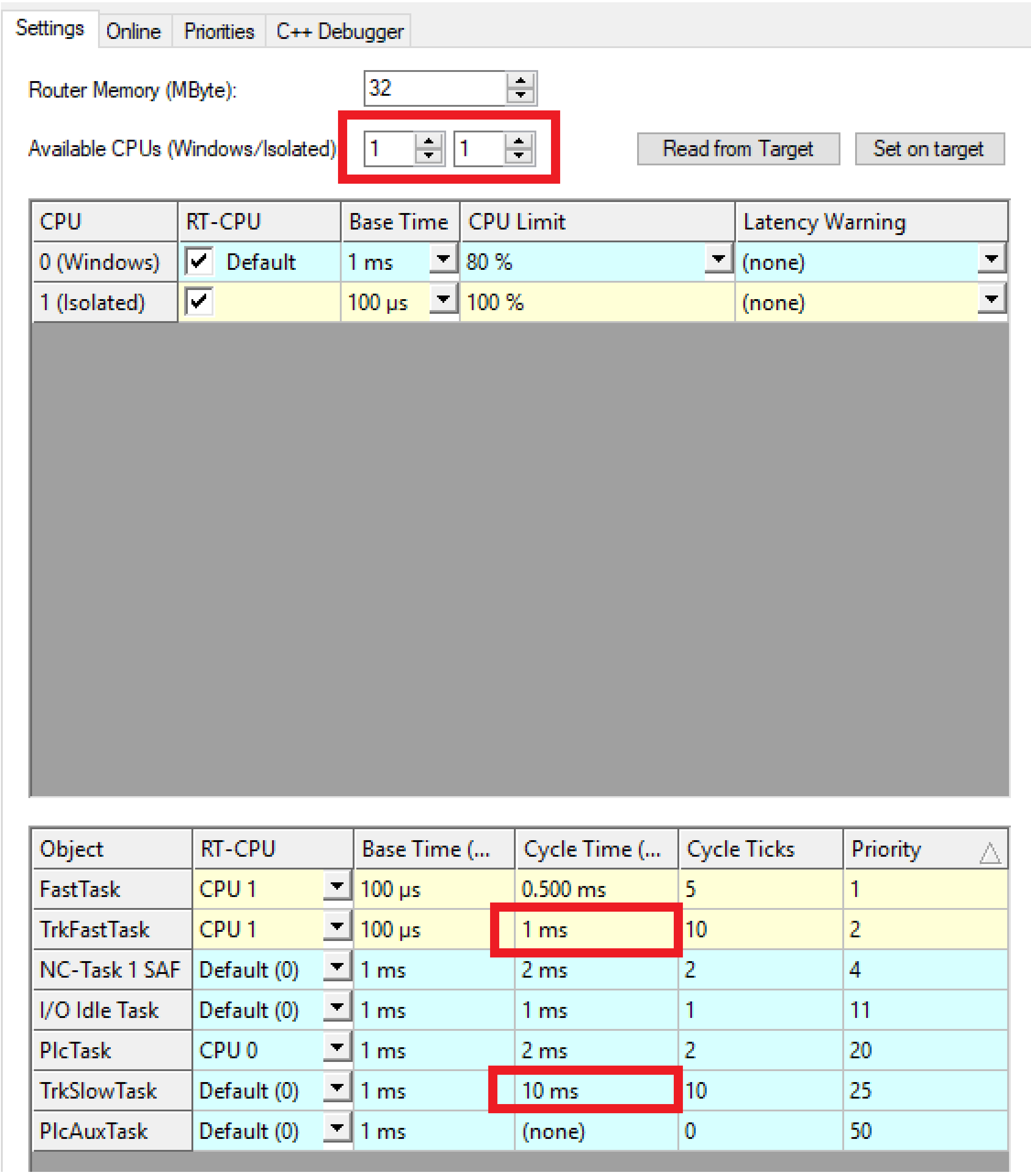


Fig. 3.8: Suggestion for PLC CPU assignments for C++ modules supporting the ccssim library.

Note: This library has been updated in FCF version 4 to send the tracking data via MUDPI protocol. This is achieved by having a dedicated task running at 20Hz and sending the CCS data using UDP (MUDPI).

The ccssim library requires the ccslib library which provides the methods to encode and decode

MUDPI and the timer library to deliver the absolute time.

Note: An sample project implementing a CCS receiver can be found in the ifw-resources project.

3.7.1 Input parameters

The *FB_CCS_SIM* does not have input parameters.

3.7.2 Signal Mapping

Figure below shows an example of the mapping related to the CCS Simulator (ccs_sim). It relates to the C++ modules, an instance to the FB_TIME (time_info) and a tracking device such a the derotator (drot).

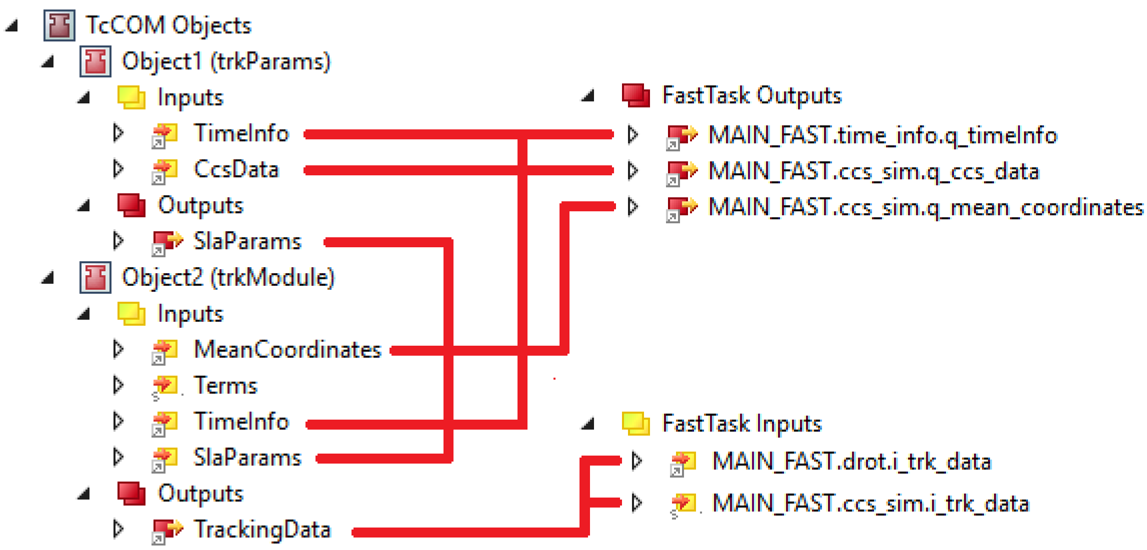


Fig. 3.9: Example of the *FB_CCS_SIM* mapping.

The specific mapping parameters of CCS Simulator are described in the table below.

Variable	Port Type	Optional Mapping	Description
i_trk_data	**PointingKernel**	**No**	**Structure delivered by the C++ Module**
q_ccs_data	**CcsData**	**No**	**Structure containing the complete CCS data**
q_mudpi_cfg	**T_MUDPI_CFG**	**No**	**Structure containing MUDPI configuration**
q_mean_coordinates	**TrkMeanCoordinates**	**No**	**Structure containing the MEAN coordinates**
q_timeinfo	**TimeInfo**	**No**	**Structure containing the time information**

3.7.3 GUI Template

As for the other FBs, the ccsim Library provides a template GUI to control the *FB_CCS_SIM*. Applications can easily deploy an instance of this GUI to control their own time function block by setting the GUI references to the particular instance of the *FB_CCS_SIM*. However applications can use directly the project included in the ccssim library.

Instantiation of GUI_TEMPLATE_CCS_SIM for ccs_sim

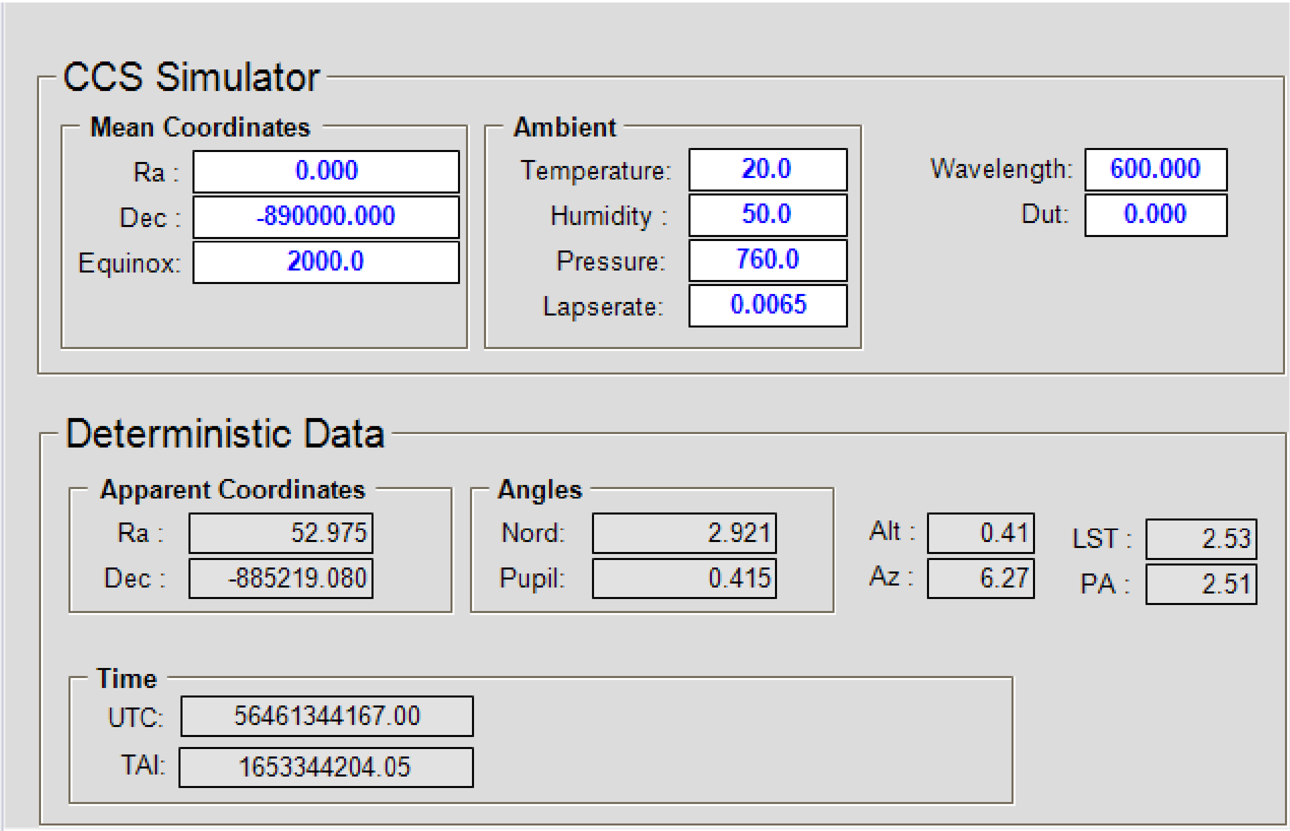


Fig. 3.10: *FB_CCS_SIM* HMI for Local Control.

3.7.4 CCS_SIM specific RPC Methods

RPC_SetCoordinates() This RPC allows the user to change RA,DEC and EQUINOX via OPCUA.

3.8 Drot Controller (motor.library)

FB_MA_DROT is the TwinCAT PLC Function Block used to operate a derotator. The FB encapsulates the motion control functionality using a composition of a motor device together with the functionality to derive the next motor position using the field rotation obtained from CCS.

Note: All the functionalities provided for a normal motor device are available as well for the derotator.

3.8.1 Input parameters

FB_MA_DROT has four input parameters. Apart from the standard sName parameter for the name, i.e. the label, of the derotator instance, there are three additional parameters used by the motor used internally by the derotator.

Parameter	Type	Description
sName	**STRING**	**Drot instance name/label**
sMotorName	**STRING**	**Motor instance name/label**
nNOVRAM_DevId	**UDINT**	**NOVRAM Device ID. For PLCs without NOVRAM, this parameter should be set to zero or not given at all.**
nNOVRAM_Offset	**UDINT**	**Offset in bytes in NOVRAM. A motor instance needs about 500 bytes for configuration data. For simplicity it is recommended to increment offsets by 1000 for each motor. Therefore, the first motor will have the offset of zero, second of 1000, third of 2000, etc. For PLCs without NOVRAM, this parameter should be set to zero or not given at all.**

Note: The usage of NOVRAM follows the same guidelines as for a FB_MOTOR.

In case that the NOVRAM is not used, the *Drot1* instance would not have any parameters and the code would look like this:

```
Motor1(sName:='Drot1', sMotorName:= 'Drot1Motor');
```

3.8.2 Signal Mapping

The mapping includes all the mapping of a motor plus the specific mapping of the derotator.

Specific to the internal derotator motor, there are two links to be established from the Axes/<Motor> Settings:

1. *Link To I/O...* This is the link between the Axis and the motor controller terminal, e.g. EL7041, that controls it.
2. *Link To PLC...* This is the link between the Axis and the motor instance in the *MAIN* program, e.g. *drot1.motor*. This link sets all the mappings for the two complex structures *NcToPlc* (input) and *PlcToNc* (output) and the user should not touch it afterwards.

The description of the standard motor mapping can be found here *motor-signal-mapping*

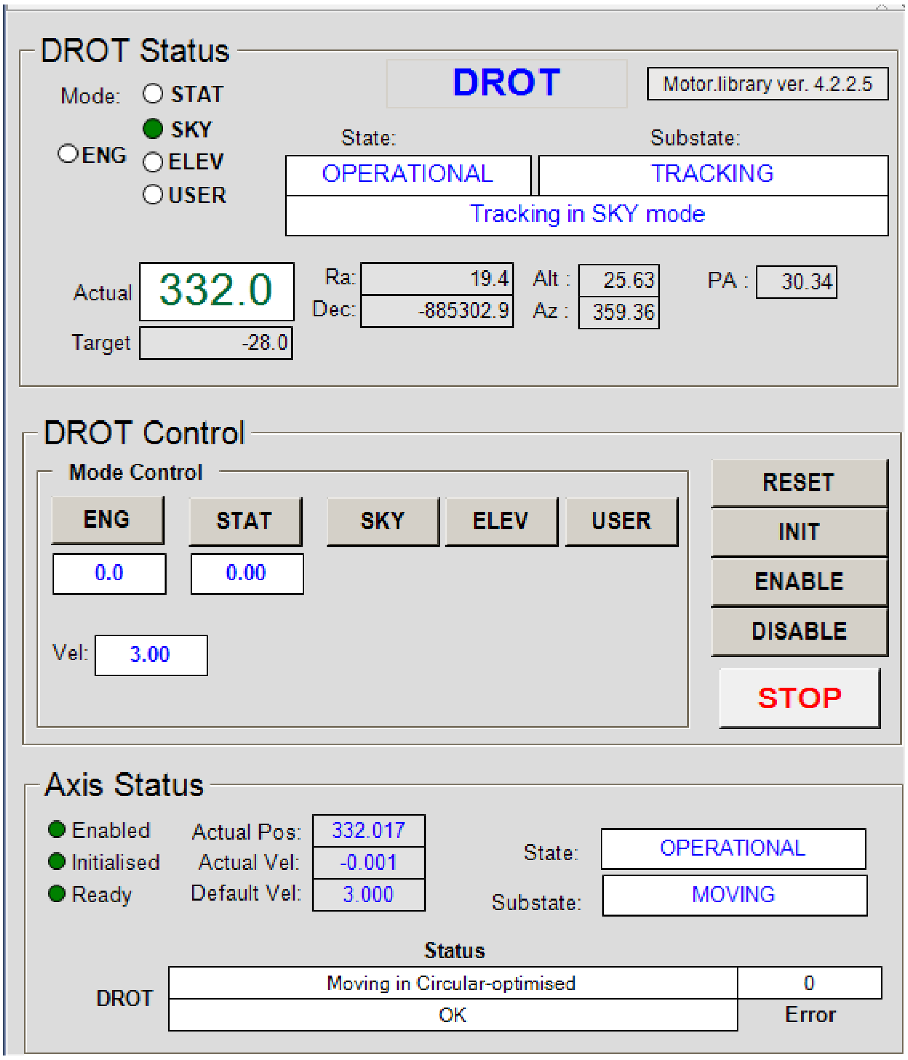
The additional derotator mapping parameters are described in the table below.

Variable	Port Type	Optional	Description
i_trk_data	**Struct In**	**No**	**Tracking data got from CCS.**
i_ccs_data	**Struct In**	**Yes**	**CCS Simulation data**

Warning: The above mapping table does not include the standard motor mapping.

3.8.3 GUI Templates

The Motion Library provides one template GUI intended for the control of instances of FB_MA_DROT. Applications can easily deploy instances of the GUI by setting the GUI reference to the particular instance of FB_MA_DROT.



FB_MA_DROT HMI for Local Control

From the Derotator Control GUI, shown above, it is possible to perform basic control operations on the Derotator. The GUI also shows the status of the subordinated motor.

Note: It is possible to create dedicated control and configuration GUIs for the derotator subordinated motor as for any other motor device.

3.8.4 Derotator specific RPC Methods

RPC name	Parameters	Description
RPC_MoveAngle()	in_lrAngle	Move the derotator to a particular position angle.
RPC_StartTrack()	in_mode in_angle	Start derotator tracking.
RPC_StopTrack()		Stop derotator tracking.

3.8.5 Derotator Simulator

Derotator does not have a dedicated simulator. Motor simulator shall be used to simulate derotator behaviour.

Declaration:

```
{attribute 'OPC.UA.DA':='1'}
drot:        FB_MA_DROT;
{attribute 'OPC.UA.DA':='1'}
sim_drot:    FB_SIM_MOTOR;
```

Execution:

```
drot(sName:='DROT', sMotorName:='DrotMotor', nNOVRAM_DevId:=0);
sim_drot(ptrCfg:=ADR(drot.motor.cfg), ptrStat:=ADR(drot.motor.stat));
```

3.8.6 User Defined Methods

Derotator user defined functions are the same as for the Motor.

3.9 ADC Controller (motor.library)

FB_MA_ADC is the TwinCAT PLC Function Block used to operate a ADC. The FB encapsulates the motion control functionality using a composition of two internal motors (motor1 and motor2).

Note: All the functionalities provided for a normal motor device are available as well for the internal ADC motors.

3.9.1 Input parameters

FUNCTION_BLOCK FB_MA_ADC
eso ldc motor library, 4.2.0.1 (eso)

VAR_INPUT	**sMotorAdc1**	STRING	*Default Motor name*
VAR_INPUT	**sMotorAdc2**	STRING	*Default Motor name*
VAR_INPUT	**nNOVRAM_DevId**	UDINT	*NOVRAM device ID - normally 4*
VAR_INPUT	**nNOVRAM_Offset1**	UDINT	*NOVRAM offset where ADC motor1 configuration is stored*
VAR_INPUT	**nNOVRAM_Offset2**	UDINT	*NOVRAM offset where ADC motor2 configuration is stored*

FB_MA_ADC has five input parameters as shown in figure above.

Note: The usage of NOVRAM follows the same guidelines as for *FB_MOTOR*.

3.9.2 Signal Mapping

The mapping includes all the mapping of the two internal motors plus the specific mapping of the ADC.

Specific to the internal ADC motors, there are two links to be established from each of the Axes/<Motor> Settings:

1. *Link To I/O...* This is the link between the Axis and the motor controller terminal, e.g. EL7041, that controls it.
2. *Link To PLC...* This is the link between the Axis and the motor instance in the *MAIN* program, e.g. *drot1.motor*. This link sets all the mappings for the two complex structures *NcToPlc* (input) and *PlcToNc* (output) and the user should not touch it afterwards.

The description of each standard motor mapping can be found here *motor-signal-mapping*

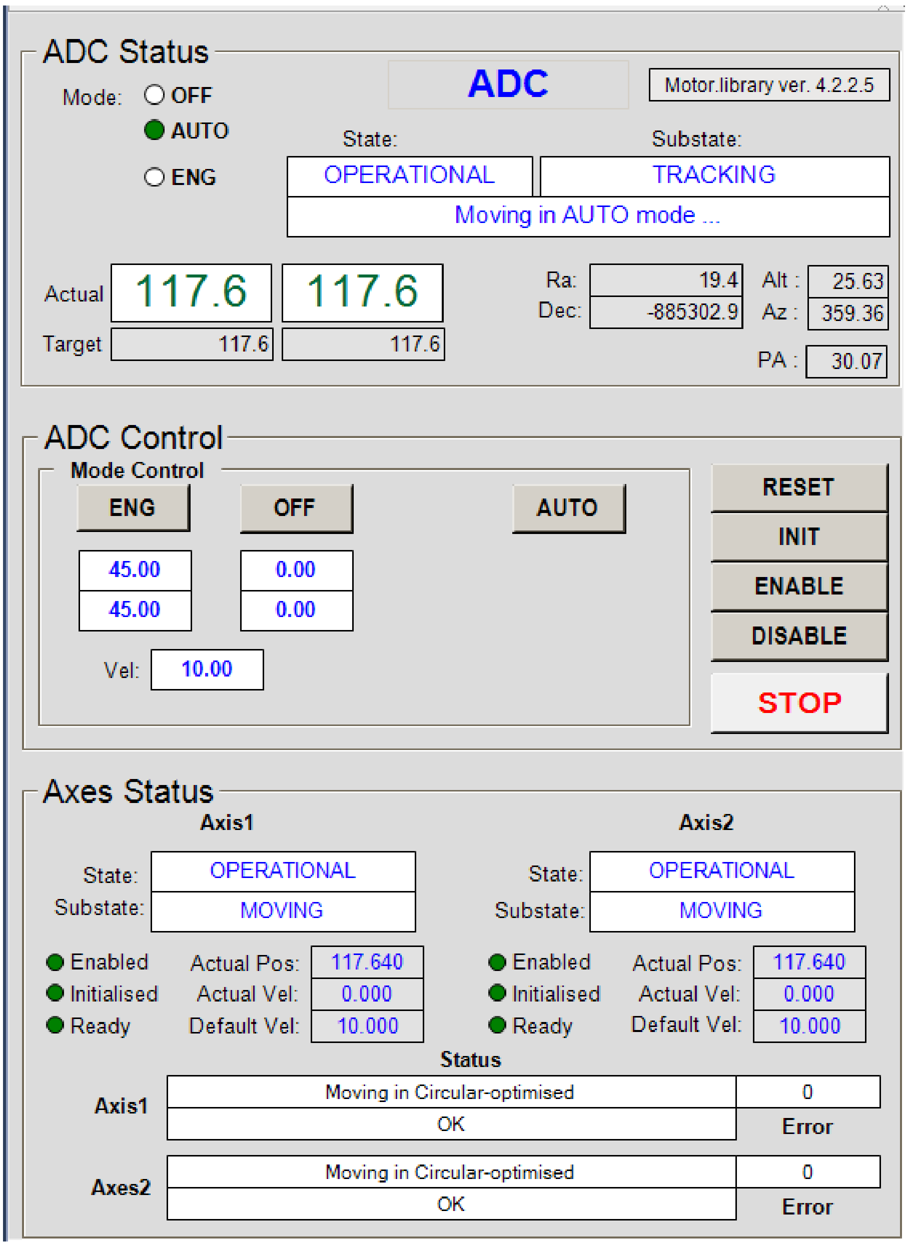
The additional ADC mapping parameters are described in the table below.

Variable	Port Type	Optional	Description
i_trk_data	Struct In	No	Tracking data got from CCS.
i_ccs_data	Struct In	Yes	CCS Simulation data

Warning: The above mapping table does not include the mapping for the two internal motors.

3.9.3 GUI Templates

The Motion Library provides one template GUI intended for the control of instances of FB_MA_ADC. Applications can easily deploy instances of the GUI by setting the GUI reference to the particular instance of FB_MA_ADC.



FB_MA_ADC HMI for Local Control

From the ADC Control GUI, shown on above, it is possible to perform basic control operations on the ADC. The GUI also shows the status of the subordinated motors.

Note: It is possible to create dedicated control and configuration GUIs for the ADC subordinated motors as for any other motor device.

3.9.4 ADC specific RPC Methods

RPC name	Parameters	Description
RPC_MoveAngle()	**in_lrAngle**	**Move the ADC to a particular position angle.**
RPC_StartTrack()	**in_angle**	**Start ADC tracking.**
RPC_StopTrack()		**Stop ADC tracking.**

3.9.5 ADC Simulator

ADC does not have a dedicated simulator. Motor simulator shall be used to simulate the behaviour of the two internal motors.

Declaration:

```
{attribute 'OPC.UA.DA':='1'}
adc:        FB_MA_ADC;

{attribute 'OPC.UA.DA':='1'}
sim_adc1:    FB_SIM_MOTOR;

{attribute 'OPC.UA.DA':='1'}
sim_adc2:    FB_SIM_MOTOR;
```

Execution:

```
adc(sName             := 'ADC',
    sMotorAdc1        := 'AdcMotor1',
    sMotorAdc2        := 'AdcMotor2',
    nNOVRAM_DevId     := 4,
    nNOVRAM_Offset1   := 3000,
    nNOVRAM_Offset2   := 4000);

sim_adc1(ptrCfg:=ADR(adc.motor1.cfg), ptrStat:=ADR(adc.motor1.stat));
sim_adc2(ptrCfg:=ADR(adc.motor2.cfg), ptrStat:=ADR(adc.motor2.stat));
```

3.9.6 User Defined Methods

No user defined functions are provided by the ADC.

3.10 I/O Device Library (ioDev.library)

Note: The most common data type for analog signals is INT (16-bit signed). However, some I/O terminals, e.g. *EL3692*, can provide readings in user units of type REAL (FLOAT). *ioDev.library* supports both types of analog inputs.

---

ioDev.library contains a number of FBs for handling analog (INT and REAL) and digital sensors and I/O devices. In addition, it provides FB methods for scaling of signals in order to work directly in user units (temperatures, pressures, etc), instead of displaying pure voltages that cannot be easily interpreted by the user before they are scaled at the WS level. Simulators for analog and digital signals are also provided. They might be of great help at the early stages of projects when sensors are not available yet or for testing of out-of-range conditions.

The library provides a Function Block called *FB_IODEV_BASE* that has to be extended and customised by the user by adding input and output signals to the status and control structures. A number of I/O and Sensor FB examples that extend the *FB_IODEV_BASE* functionality can be found in the Examples directory. Example FBs with the string '_USER_CONFIG' in their name provide examples of user defined configuration, i.e. signal scaling, that is implemented in the *M_UserConfigure()* method. In addition to the extension of the FB functionality, the user has to extend the definition of the status *T_IODEV_STAT* and the control *T_IODEV_CTRL* structure (if any) by adding arrays of specific input and output signals.

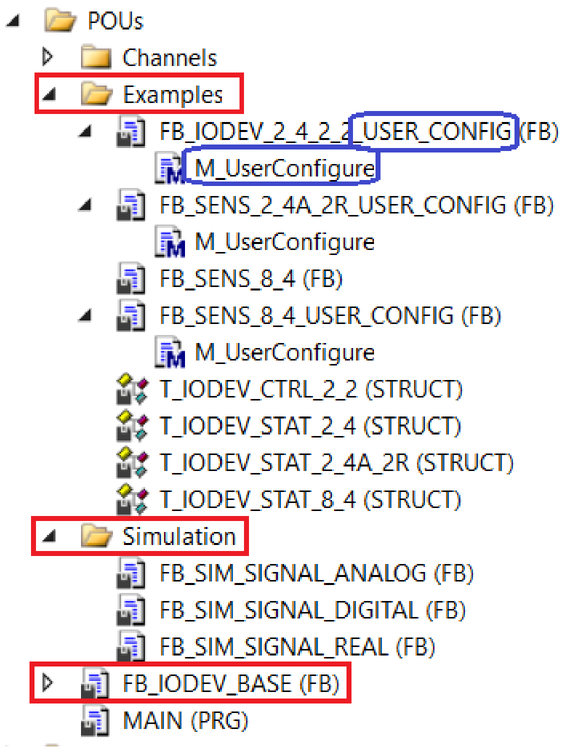
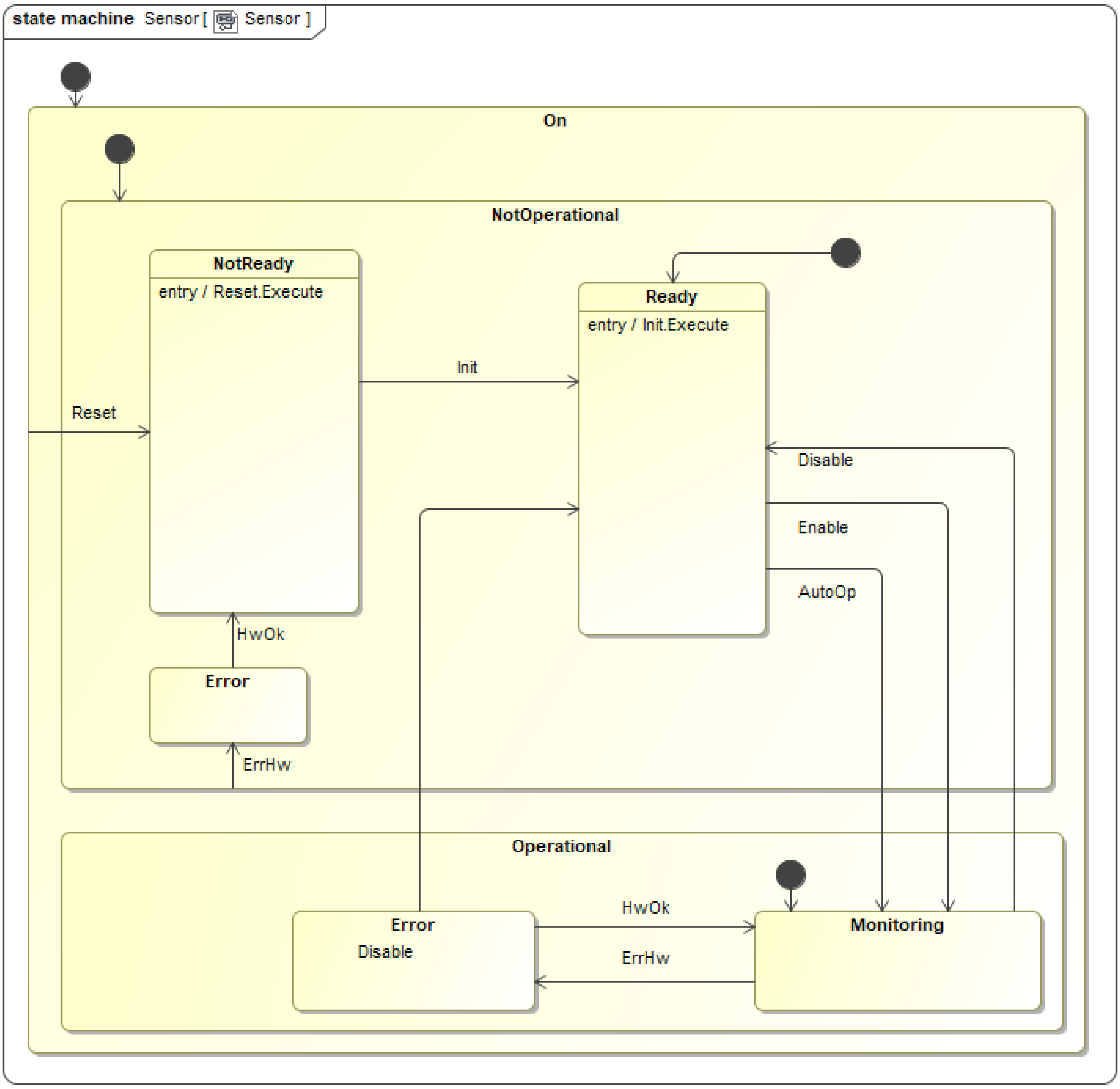


Fig. 3.11: Overview of *ioDev.library*

3.10.1 State Machine of Sensor

Sensor is a special case of the I/O Device that doesn't have any outputs. The state machine of the sensor controller is shown below. The main operational state is *Monitoring*.



Note: All I/O devices start monitoring in the *NotOp/Ready* state.

3.10.2 Input parameters

```
FUNCTION_BLOCK FB_IODEV_BASE

VAR_INPUT   in_sName         STRING   Instance name
VAR_INPUT   in_bAutoOp       BOOL     If TRUE, go automatically to OPERATIONAL state. Default FALSE.
VAR_INPUT   in_bUserConfig   BOOL     If TRUE, configuration in M_UserConfigure() is used. Default FALSE.
```

3.10.3 User Customisation

As previously stated, the Function Block *FB_IODEV_BASE* provides all methods to handle I/O signals but no signals are defined. The FB has to be extended by the user by adding required I/O signals. The customisation process will be described through examples.

Example 1: I/O Device with User Defined Scaling

The FB *FB_IODEV_2_4_2_2_USER_CONFIG* is an example of the I/O device that handles 2 DI, 4 AI, 2 DO and 2 AO, with the user defined scaling.

The following steps have to be done:

- Extend the *T_IODEV_STAT* structure by adding arrays of input signals. The new structure is called *T_IODEV_STAT_2_4*, meaning 2 digital inputs and 4 analog inputs.

```
// EXAMPLE: Extension of T_IODEV_STAT with 2 DI and 4 AI.
//          Used in FB_IODEV_2_4_2_2_USER_CONFIG.
TYPE T_IODEV_STAT_2_4 EXTENDS T_IODEV_STAT :
STRUCT
    //
    // Signals, inputs.
    //
    arrDI:  ARRAY [0..1] OF FB_IODEV_CH_DIG_IN;     // 2 digital inputs
    arrAI:  ARRAY [0..3] OF FB_IODEV_CH_ANLG_IN;    // 4 analog inputs
END_STRUCT
END_TYPE
```

- Extend the *T_IODEV_CTRL* structure by adding arrays of output signals. The new structure is called *T_IODEV_CTRL_2_2*, meaning 2 digital outputs and 2 analog outputs.

```
// EXAMPLE: Extension of T_IODEV_CTRL with 2 DO and 2 AO.
//          Used in FB_IODEV_2_4_2_2_USER_CONFIG.
TYPE T_IODEV_CTRL_2_2 EXTENDS T_IODEV_CTRL :
STRUCT
    // Signals, Outputs
    arrDO:  ARRAY [0..1] OF FB_IODEV_CH_DIG_OUT;    // 2 digital outputs
    arrAO:  ARRAY [0..1] OF FB_IODEV_CH_ANLG_OUT;   // 2 analog outputs
END_STRUCT
END_TYPE
```

- Define signal scaling for both inputs and outputs in the *M_UserConfigure()* method.

FB_IODEV_2_4_2_2_...IG.M_UserConfigure

```
METHOD M_UserConfigure
VAR_INPUT
END_VAR
```

```
// TODO_USER
//
// Example implementation.
// Hard code any signal configuration.
//

// Configuration parameter cfg.bUserConfig defines if
// the hard-coded configuration below should be used or
// the signals will be configured from the WS.

//
// Digital signals
//
// Digital inputs (defined in stat structure T_IODEV_STAT_CUSTOM)
// Signal DI[0] is a door open signal
// Signal DI[1] is a light switch signal
stat.arrDI[0].M_Configure('CLOSED', 'OPEN');
stat.arrDI[1].M_Configure('OFF',    'ON');

// Digital outputs (defined in ctrl structure T_IODEV_CTRL_CUSTOM)
// Signal DO[0] is a pure digital signal without user defined labels
// Signal DO[1] is a light switch signal that is controlled by setting User labels 'OFF' and 'ON'.
ctrl.arrDO[0].M_Configure(CONVERSION_IODEV_NONE,    '0',    '1');
ctrl.arrDO[1].M_Configure(CONVERSION_IODEV_DIGITAL, 'OFF',  'ON');


//
// Analog signals
//
// Analog inputs (defined in stat structure T_IODEV_STAT_CUSTOM)
stat.arrAI[0].M_Configure(CONVERSION_IODEV_NONE,      0.0,   0.0, 0.0);
stat.arrAI[1].M_Configure(CONVERSION_IODEV_LINEAR,    2.0,   1.0, 0.0);
stat.arrAI[2].M_Configure(CONVERSION_IODEV_QUADRATIC, 2.0,   1.0, 5.0);
// Edwards pressure guage
// P =10^(1.5*V - 12)     [mbar]
// 16-bit A/D converter, +=10V, e.g. EL3102.
// 1V = 2^16/10/2 = 3276.8 bit
// P = 10^(1.5*V - 12) = 10^(1.5/3276.8*bit - 12) = 10^(0.000457763*bit - 12)
stat.arrAI[3].M_Configure(CONVERSION_IODEV_EXP10,   0.000457763, -12.0, 0.0);

//
// Analog outputs (defined in ctrl structure T_IODEV_CTRL_CUSTOM)
ctrl.arrAO[0].M_Configure(CONVERSION_IODEV_NONE,    0.0,   0.0, 0.0);   // No conversion
ctrl.arrAO[1].M_Configure(CONVERSION_IODEV_LINEAR,  0.1,   0.0, 0.0);   // out = User/10
```

- Extend the functionality of *FB_IODEV_BASE* in newly created FB *FB_IODEV_2_4_2_2_USER_CONFIG*.

  The code below shows all that the user has to do in order to define an FB that extends the functionality of *FB_IODEV_BASE*. The following has to be done in the FB:

  – In the declaration of FB *FB_IODEV_2_4_2_2_USER_CONFIG*, add *ctrl* and *stat* structures. They should be of type *T_IODEV_CTRL_2_2* and *T_IODEV_STAT_2_4*, respectively.

  – Set references to *ctrl* and *stat* structures.

- Set the number of existing I/O signals.
- Set the pointers to the first item of each signal array.
- Execute the code of the base (SUPER) FB.

```
// EXAMPLE: Customised FB_IODEV_BASE for 2 DI, 4 AI, 2 DO and 2 AO.
//          Overloaded M_UserConfigure() method for User Configuration of channels.
FUNCTION_BLOCK FB_IODEV_2_4_2_2_USER_CONFIG EXTENDS FB_IODEV_BASE
VAR_INPUT
END_VAR
VAR_OUTPUT
END_VAR
VAR
    // Control parameters that EXTEND T_IODEV_CTRL
    {attribute 'OPC.UA.DA' := '1'}
    ctrl:    T_IODEV_CTRL_2_2;
    // Status parameters that EXTEND T_IODEV_STAT
    {attribute 'OPC.UA.DA' := '1'}
    {attribute 'OPC.UA.DA.Access' := '1'}
    stat:    T_IODEV_STAT_2_4;
END_VAR
```

```
//
//
// Set References
RefCtrl REF=ctrl;
RefStat REF=stat;

// Set number of channels for each type.
// Default values are set to zero.
// Set whatever is not zero, i.e. whatever is defined.
// WARNING: The values MUST match the sizes of corresponding arrays above !!!
//
cfg.nNum_DI     :=  2;  // Number of digital INPUT signals, arrDI:  ARRAY [0..1]
cfg.nNum_AI     :=  4;  // Number of analog INPUT signals,  arrAI:  ARRAY [0..3]
//cfg.nNum_DisI :=  0;  // Number of discrete INPUT signals
//cfg.nNum_TI   :=  0;  // Number of text INPUT signals

cfg.nNum_DO     :=  2;  // Number of digital OUTPUT signals, arrDO: ARRAY [0..1]
cfg.nNum_AO     :=  2;  // Number of analog OUTPUT signals,  arrAO: ARRAY [0..1]
//cfg.nNum_DisO :=  0;  // Number of discrete OUTPUT signals
//cfg.nNum_TO   :=  0;  // Number of text OUTPUT signals

//
// Set pointers for EXISTING arrays ONLY, e.g. arrDI, arrAI, etc.
//
pArrDI   := ADR(stat.arrDI[0]);
pArrAI   := ADR(stat.arrAI[0]);
pArrDO   := ADR(ctrl.arrDO[0]);
pArrAO   := ADR(ctrl.arrAO[0]);

//
// Execute the base class object FB_IODEV_BASE
//
SUPER^();
```

Example 2: Sensor Device without User Defined Scaling

The Function Block *FB_SENS_8_4* is an example of a sensor device for 8 digital and 4 analog input signals. The corresponding status data structure is called *T_IODEV_STAT_8_4*. Since there are no output signals, the standard control structure *T_IODEV_CTRL* is used. In this example user scaling is not used, so the scaling is supposed to be done on the WS.

The following steps have to be done:

- Extend the *T_IODEV_STAT* structure by adding arrays of input signals. The new structure is called *T_IODEV_STAT_8_4*, meaning 8 digital inputs and 4 analog inputs.

```
// EXAMPLE: Extension of T_IODEV_STAT with 8 DI and 4 AI.
//          Used in FB_SENS_8_4.
TYPE T_IODEV_STAT_8_4 EXTENDS T_IODEV_STAT :
STRUCT
    //
    // Signals, inputs.
    //
    arrDI:  ARRAY [0..7] OF FB_IODEV_CH_DIG_IN;     // 8 digital inputs
    arrAI:  ARRAY [0..3] OF FB_IODEV_CH_ANLG_IN;    // 4 analog inputs
END_STRUCT
END_TYPE
```

- Create a Function Block called *FB_SENS_8_4* and extend the functionality of *FB_IODEV_BASE*, as shown below.

  The code below shows all that the user has to do in order to define an FB that extends the functionality of *FB_IODEV_BASE*. The following has to be done in the FB:

  - In the declaration of *FB_SENS_8_4*, add *ctrl* and *stat* structures. Since this is a pure sensor, the standard *ctrl* structure of type *T_IODEV_CTRL* is used. The *stat* structure is declared as *T_IODEV_STAT_8_4*.
  - Set references to *ctrl* and *stat* structures.
  - Set the number of existing input signals.
  - Set the pointers to the first item of each signal array.
  - Execute the code of the base (SUPER) FB.

FB_SENS_8_4

```
// EXAMPLE: FB for SENSORS with 8 DI and 4 AI
FUNCTION_BLOCK FB_SENS_8_4 EXTENDS FB_IODEV_BASE
VAR_INPUT
END_VAR
VAR_OUTPUT
END_VAR
VAR
    // Control parameters as defined in T_IODEV_CTRL.
    // For sensors use the base control structure T_IODEV_CTRL.
    {attribute 'OPC.UA.DA' := '1'}
    ctrl:    T_IODEV_CTRL;
    // Status parameters that EXTEND T_IODEV_STAT
    {attribute 'OPC.UA.DA' := '1'}
    {attribute 'OPC.UA.DA.Access' := '1'}
    stat:    T_IODEV_STAT_8_4;
END_VAR
```

```
//
// TODO_USER
//
//
// Set References
RefCtrl REF=ctrl;
RefStat REF=stat;

// Set number of channels for each type.
// Default values are set to zero.
// Set whatever is not zero, i.e. whatever is defined.
// WARNING: The values MUST match the sizes of corresponding arrays above !!!
//
cfg.nNum_DI     :=  8;  // Number of digital INPUT signals, arrDI:  ARRAY [0..7]
cfg.nNum_AI     :=  4;  // Number of analog INPUT signals,  arrAI:  ARRAY [0..3]

//
// Set pointers for EXISTING arrays ONLY, e.g. arrDI, arrAI, etc.
//
pArrDI  := ADR(stat.arrDI[0]);
pArrAI  := ADR(stat.arrAI[0]);

//
// Execute the base class object FB_IODEV_BASE
//
SUPER^();
```

3.10.4 Signal Mapping

As an example, the figure below shows the TwinCAT view of the *FB_IODEV_2_4_2_2_USER_CONFIG* I/O variables that are available for mapping to physical signals, i.e. ports of analog and digital I/O terminals.

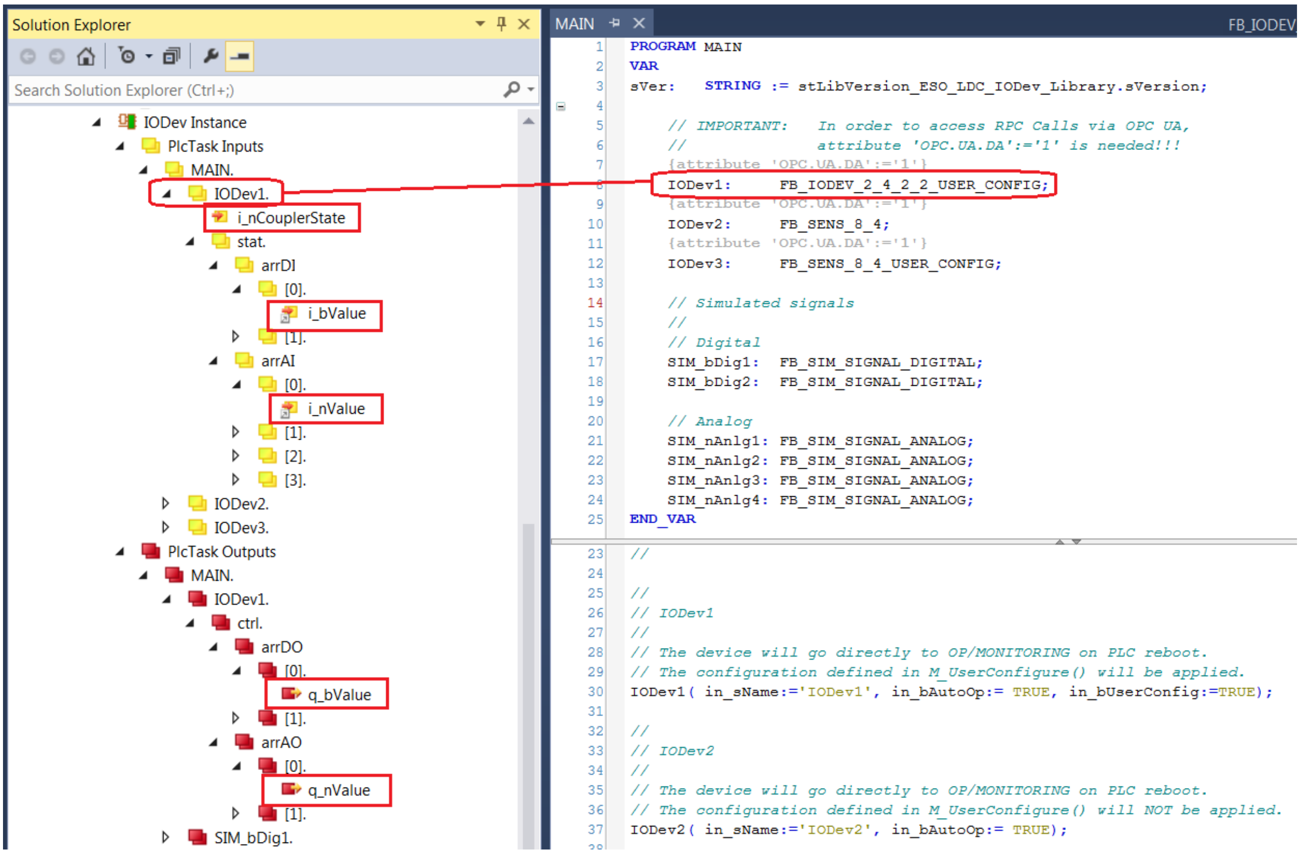


Figure 12: Example of a FB_IODEV_2_4_2_2_USER_CONFIG signals.

The table below describes each mapping variable.

Variable	Port Type	Optional	Description
i_nCouplerState	UINT	No	Mapped to the 'state' of the coupler that hosts I/O terminals. If the terminals span over more than one coupler, it is recommended to select the 'state' of the last coupler that hosts a shutter signal.
arrDI[i].i_bValue	BOOL	Yes	Array of digital input signals
arrAI[i].i_nValue	INT	Yes	Array of analog input signals
arrDO[i].q_bValue	BOOL	Yes	Array of digital output signals
arrAO[i].q_nValue	INT	Yes	Array of analog output signals

3.10.5 GUI Template

The *IODev* Library provides a template GUI *GUI_TEMPLATE_IODEV* for the *FB_IODEV_BASE* FB. The GUI can be also used for the Function Blocks that extend the *FB_IODEV_BASE* functionality. Applications can easily deploy an instance of this GUI by setting the GUI references to the particular instance of the FB, as shown below.

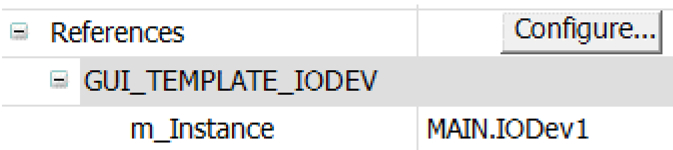


Fig. 3.12: Instantiation of GUI_TEMPLATE_IODEV for IODev1

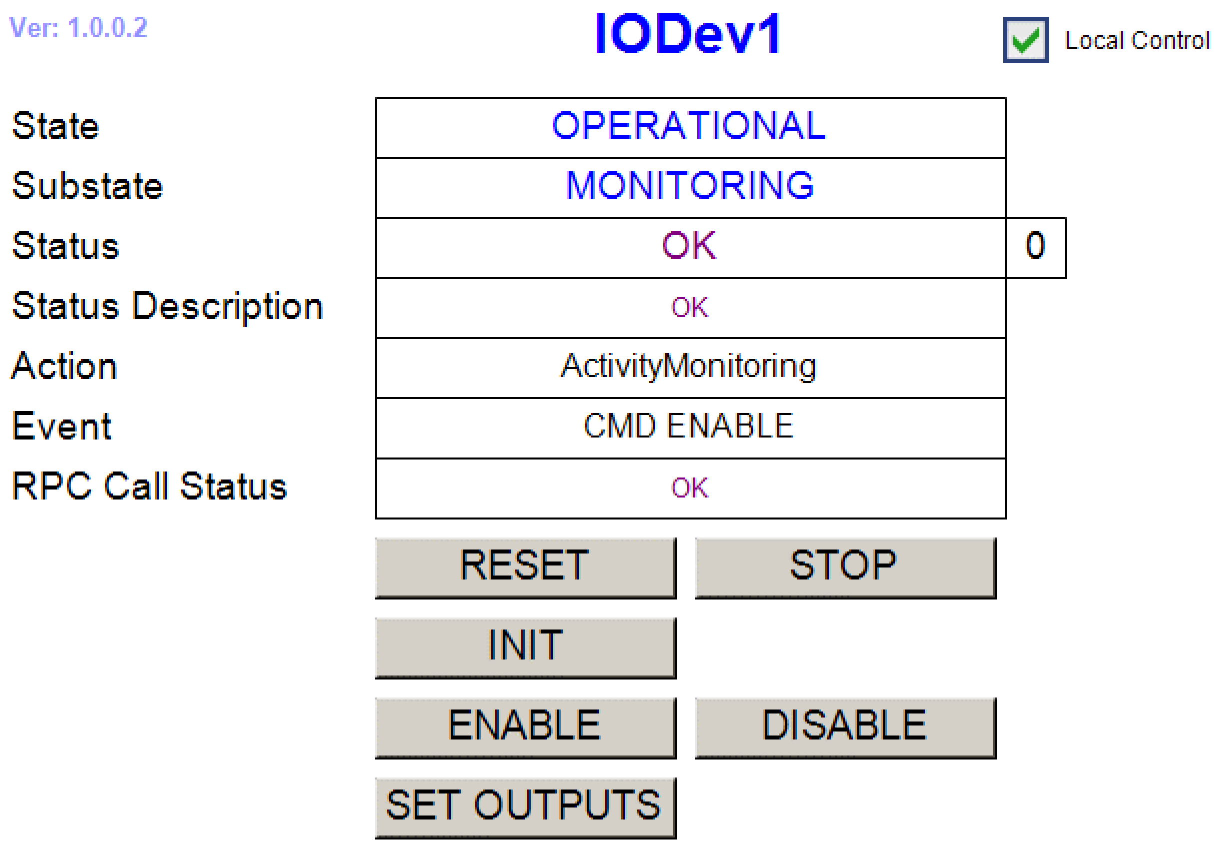


Fig. 3.13: FB_IODEV_BASE HMI for Local Control.

3.10.6 IODev specific RPC Methods

- RPC_SetOutputs() Activate *IODev* outputs (not used with pure sensors)

3.10.7 Signal Simulators

The *ioDev.library* provides individual analog and digital signal simulators. This means that if the user wants to simulate all signals of a sensor with eight digital and four analog signals, for example, he will have to instantiate eight digital and four analog signal simulators. However, for testing purposes it might be needed to simulate just a few signals. Time parameters are given in milliseconds.

The function blocks *FB_SIM_SIGNAL_ANALOG* and *FB_SIM_SIGNAL_REAL* implement simulated analog sinusoidal signals of type INT and REAL, respectively. The input parameters are the same for both FBs:

FUNCTION_BLOCK FB_SIM_SIGNAL_ANALOG

VAR_INPUT	**in_nPeriod**	DINT	*Period for signal to go o-max-0*
VAR_INPUT	**in_nScale**	LREAL	*Scale of the output*
VAR_INPUT	**in_nOffset**	INT	*Offset of the output*

The function block *FB_SIM_SIGNAL_DIGITAL* implements a simulated digital signal. The input parameters are:

FUNCTION_BLOCK FB_SIM_SIGNAL_DIGITAL

VAR_INPUT	**in_nPeriodLow**	DINT	*Period for signal = FALSE*
VAR_INPUT	**in_nPeriodHigh**	DINT	*Period for signal = TRUE*

The following source code example is the Program MAIN that is delivered with the library. The code shows how to configure sensors as well as simulators whose outputs could be mapped to sensor input variables.

Declaration:

```
// IMPORTANT: In order to access RPC Calls via OPC UA,
//             attribute 'OPC.UA.DA':='1' is needed!!!
{attribute 'OPC.UA.DA':='1'}
IODev1:      FB_IODEV_2_4_2_2_USER_CONFIG;
{attribute 'OPC.UA.DA':='1'}
IODev2:      FB_SENS_8_4;
{attribute 'OPC.UA.DA':='1'}
IODev3:      FB_SENS_8_4_USER_CONFIG;
{attribute 'OPC.UA.DA':='1'}
IODev4:      FB_SENS_2_4A_2R_USER_CONFIG;

// Simulated signals
//
// Digital
SIM_bDig1:   FB_SIM_SIGNAL_DIGITAL;
SIM_bDig2:   FB_SIM_SIGNAL_DIGITAL;

// Analog
SIM_nAnlg1: FB_SIM_SIGNAL_ANALOG;
SIM_nAnlg2: FB_SIM_SIGNAL_ANALOG;
SIM_nAnlg3: FB_SIM_SIGNAL_ANALOG;
SIM_nAnlg4: FB_SIM_SIGNAL_ANALOG;

SIM_rAnlg1: FB_SIM_SIGNAL_REAL;
SIM_rAnlg2: FB_SIM_SIGNAL_REAL;
```

Execution:

```
//
// Simulated signals
//
SIM_bDig1(in_nPeriodLow:=5000, in_nPeriodHigh:=2000);
SIM_bDig2(in_nPeriodLow:=2000, in_nPeriodHigh:=4000);

SIM_nAnlg1(in_nPeriod:=10000, in_nScale:=10000.0, in_nOffset:=0);
SIM_nAnlg2(in_nPeriod:=10000, in_nScale:=100.0,   in_nOffset:=5000);
SIM_nAnlg3(in_nPeriod:=10000, in_nScale:=10.0,    in_nOffset:=1000);

// Simulation of Edwards pressure guage
// Vary input from 4.5 to 5.0 V
// 16-bit A/D converter, +=10V, e.g. EL3102.
// 1V = 2^16/10/2 = 3276.8 bit
// 4.5 to 5.0 V ==> 4.5*3276.8 to 5.0*3276.8 bit ==> 14745 to 16384
// in_nScale = (16384 - 14745) / 2 = 819.5
// in_nOffset = 14745 + 819.5 = 15564.5
SIM_nAnlg4(in_nPeriod:=30000, in_nScale:=819.5, in_nOffset:=15564);


SIM_rAnlg1(in_nPeriod:=20000, in_nScale:=1000.0, in_nOffset:=1000.0);
SIM_rAnlg2(in_nPeriod:=10000, in_nScale:=100.0,  in_nOffset:=0.0);


//
// Real devices
//

//
// IODev1
//
// The device will go directly to OP/MONITORING on PLC reboot.
// The configuration defined in M_UserConfigure() will be applied.
IODev1(in_sName:='IODev1', in_bAutoOp:= TRUE, in_bUserConfig:=TRUE);

//
// IODev2
//
// The device will go directly to OP/MONITORING on PLC reboot.
// The configuration defined in M_UserConfigure() will NOT be applied.
IODev2(in_sName:='IODev2', in_bAutoOp:= TRUE);

//
// IODev3
//
// The device will go directly to OP/MONITORING on PLC reboot.
// The configuration defined in M_UserConfigure() will be applied.
IODev3(in_sName:='IODev3', in_bAutoOp:= TRUE, in_bUserConfig:=TRUE);

//
```

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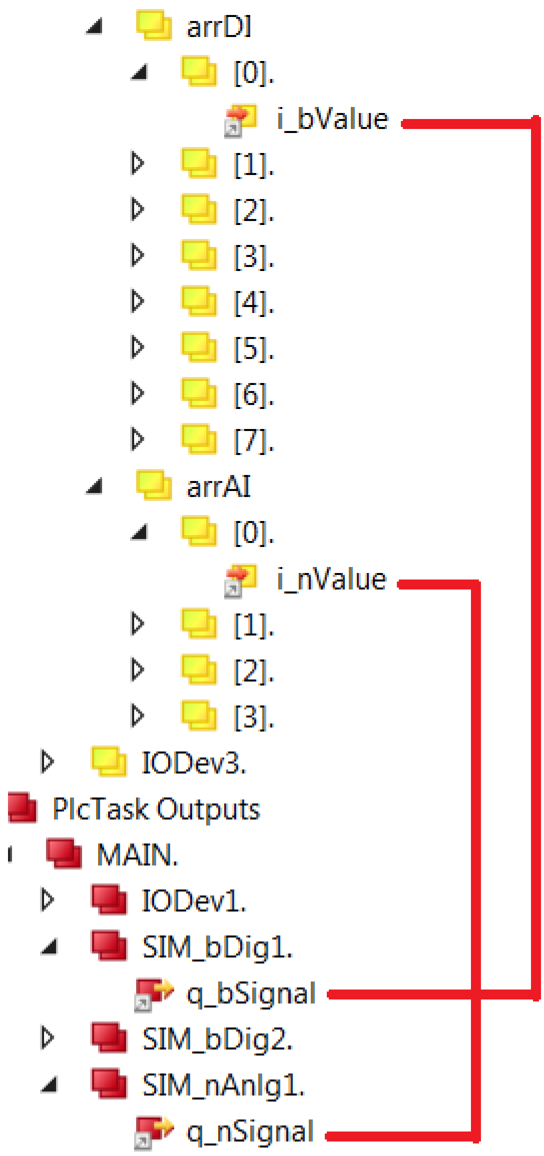
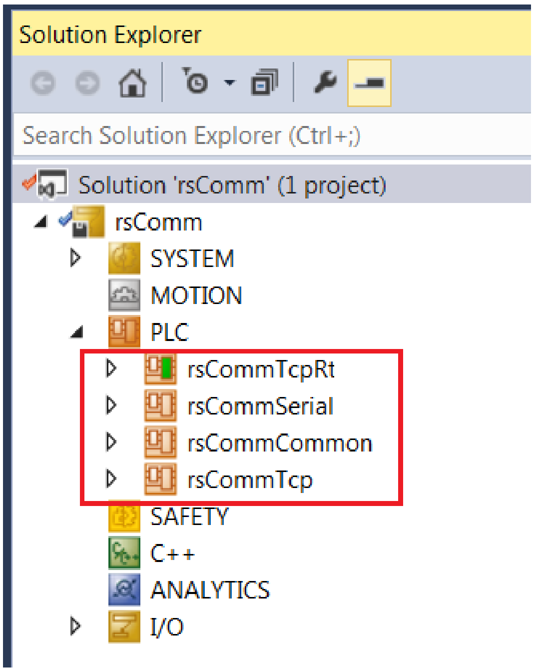
```
// IODev4
//
// The device will go directly to OP/MONITORING on PLC reboot.
// The configuration defined in M_UserConfigure() will be applied.
IODev4(in_sName:='IODev4', in_bAutoOp:= TRUE, in_bUserConfig:=TRUE);
```

Simulator Mapping

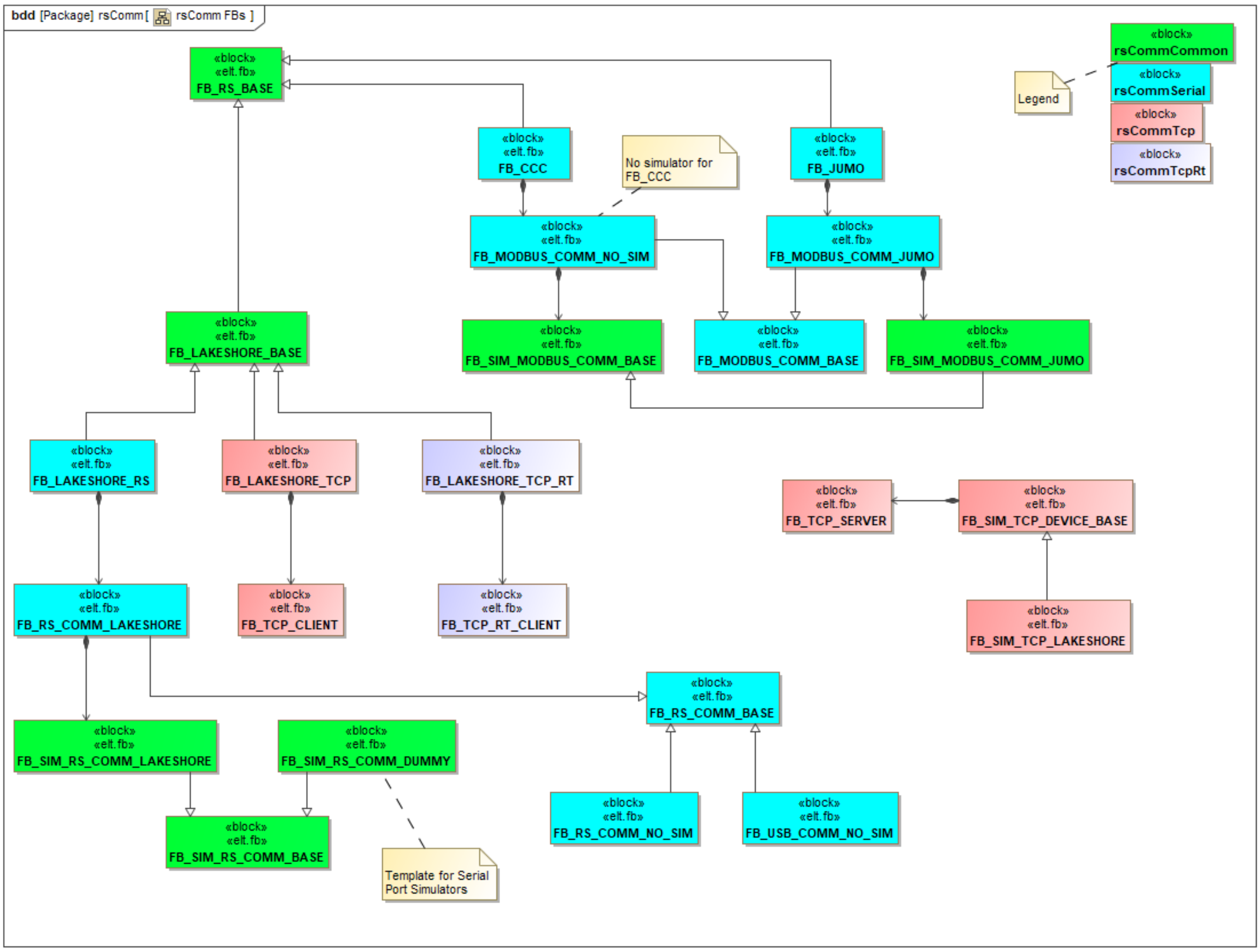


3.11 Communication Libraries (rsComm*.library)

Module *rsComm* contains PLC libraries for communication via serial port, Ethernet Tcp and Ethernet Tcp RT (Ethernet Tcp Real-Time). The libraries are delivered under separate PLC projects as part of the *rsComm* TwinCAT solution. The reason for this is that each communication protocol requires a separate license, so the functionality is provided per license. The four PLC projects are shown in the figure below.



The overview of all Function Blocks is shown in the figure below. The FBs are color-coded in order to indicate the corresponding PLC project they belong to.

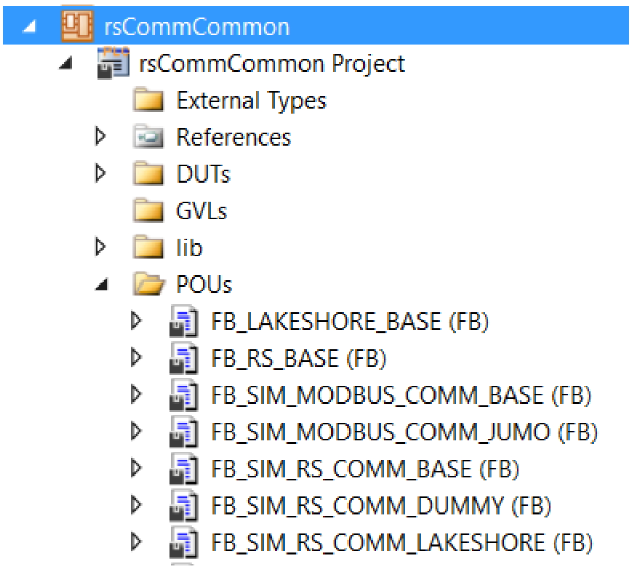


The following table gives the overview of the libraries.

Library	Description
rsCommCommon	Common library that has to be included in every project using rsComm* libraries
rsCommSerial	Serial port communication and modbus RTU
rsCommTcp	TCP/IP communication via EtherCAT switch ports EL6601 and EL6614
rsCommTcpRt	TCP/IP Real-Time communication via CX2500-0060

3.11.1 rsCommCommon.library

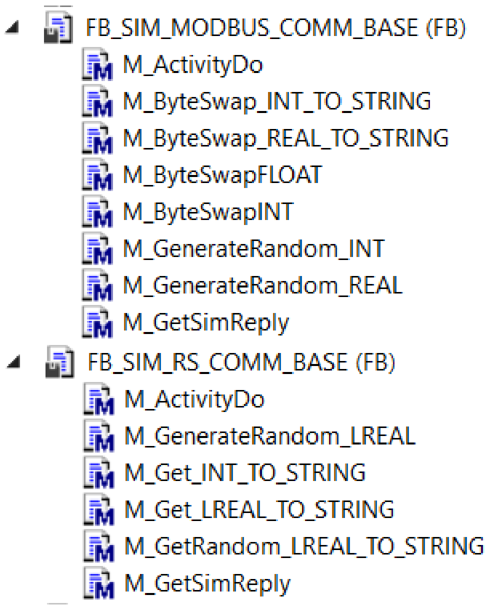
This is the common library that has to be included under *References* in all projects that use other *rsComm** libraries. This library does not require any license. The Function Block FB_RS_BASE provides the common state machine for all controllers. All *rsComm* PLC controllers, Serial, Tcp and TcpRt, extend the functionality of this FB.



The overview of FBs is given in the following table.

Function Block	Description
FB_RS_BASE	Base FB for all rsComm controllers.
FB_LAKESHORE_BASE	Base FB for all Lakeshore controllers, regardless of the comm interface.
FB_SIM_MODBUS_COMM_BASE	Base FB for MODBUS simulation.
FB_SIM_MODBUS_COMM_JUMO	JUMO MODBUS simulator.
FB_SIM_RS_COMM_BASE	Base FB for RS-232/422/485 simulation.
FB_SIM_RS_COMM_DUMMY	Example of RS comm simulator implementation.
FB_SIM_RS_COMM_LAKESHORE	RS based comm simulator for Lakeshores with serial port, i.e. models 218 & 340.

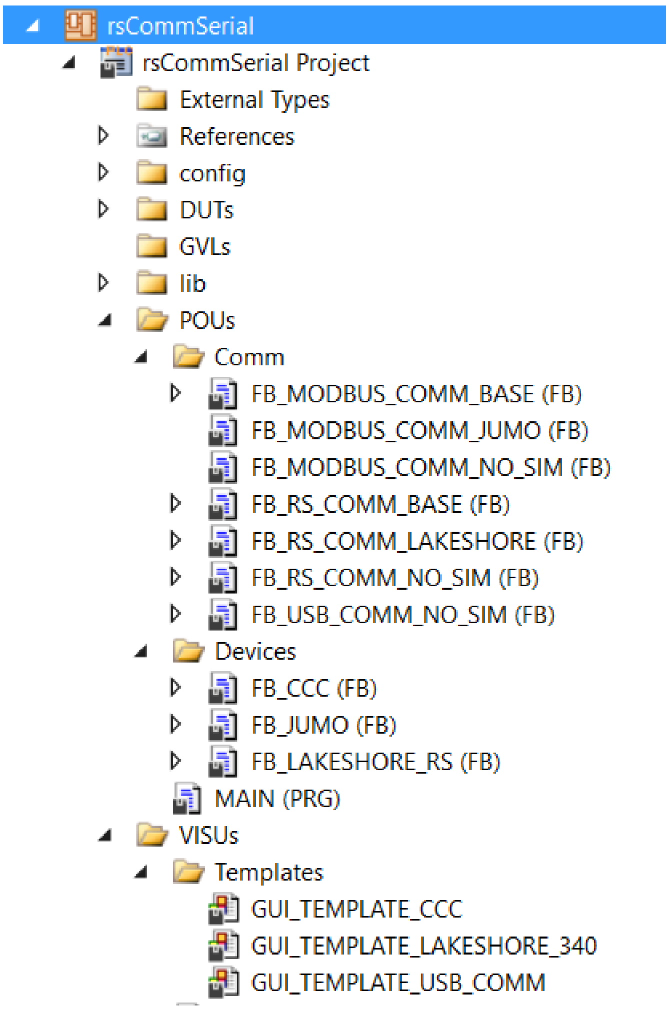
There are two base FBs for RS comm simulation, FB_SIM_MODBUS_COMM_BASE and FB_SIM_RS_COMM_BASE. Their main purpose is to provide methods that generate simulated replies that include the reply terminators as well. The replies could have fixed values as well as simulated variations. The methods are shown on the following figure.



There are two methods, *M_GetSimReply()* and *M_ActivityDo()*, that should be customised for a particular simulator, e.g. for a Lakeshore 340 simulator. *M_GetSimReply()* should construct a reply based on the command. *M_ActivityDo()* might be used to provide more realistic behaviour, e.g. to simulate a Lakeshore warm-up ramp. For more info, please see method *M_GetSimReply()* of FB_SIM_RS_COMM_LAKESHORE.

3.11.2 rsCommSerial.library

This library handles communication via serial line, e.g. via EL6001. In addition to the FBs handling ASCII serial (RS-232/422/485) and modbus RTU communication protocols, it provides controllers for the standard equipment used at ESO that have the serial port interface, like the Lakeshore 340 temperature controller or the ESO Cabinet Cooling Controller.

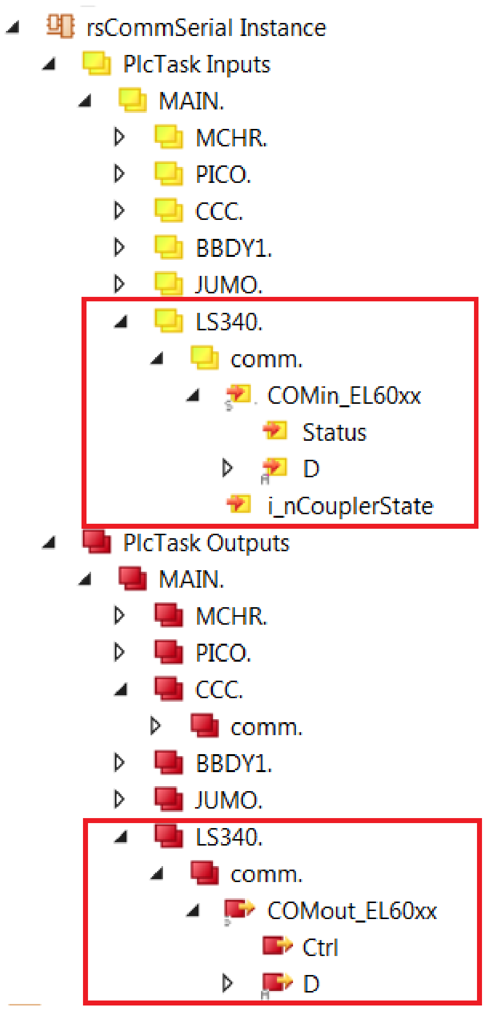


The overview of FBs is given in the table below.

Function Block	Description
FB_MODBUS_COMM_BASE	Base FB for generic modbus RTU communication driver via serial port.
FB_MODBUS_COMM_JUMO	Modbus RTU communication driver customised for JUMO simulation.
FB_MODBUS_COMM_NO_SIM	Modbus RTU communication driver without any simulator
FB_RS_COMM_BASE	Base FB for generic RS-232/422/485 communication driver.
FB_RS_COMM_LAKESHORE	RS-232/422/485 communication driver customised for Lakeshore simulation.
FB_RS_COMM_NO_SIM	Generic RS-232/422/485 communication driver without a simulator.
FB_USB_COMM_NO_SIM	Generic USB communication driver without a simulator.
FB_CCC	Driver for ESO standard Cabinet Cooling Controller with RS-232 interface.
FB_JUMO	JUMO driver with modbus RTU interface.
FB_LAKESHORE_RS	Lakeshore driver for devices with serial port, i.e. models 218 & 340.

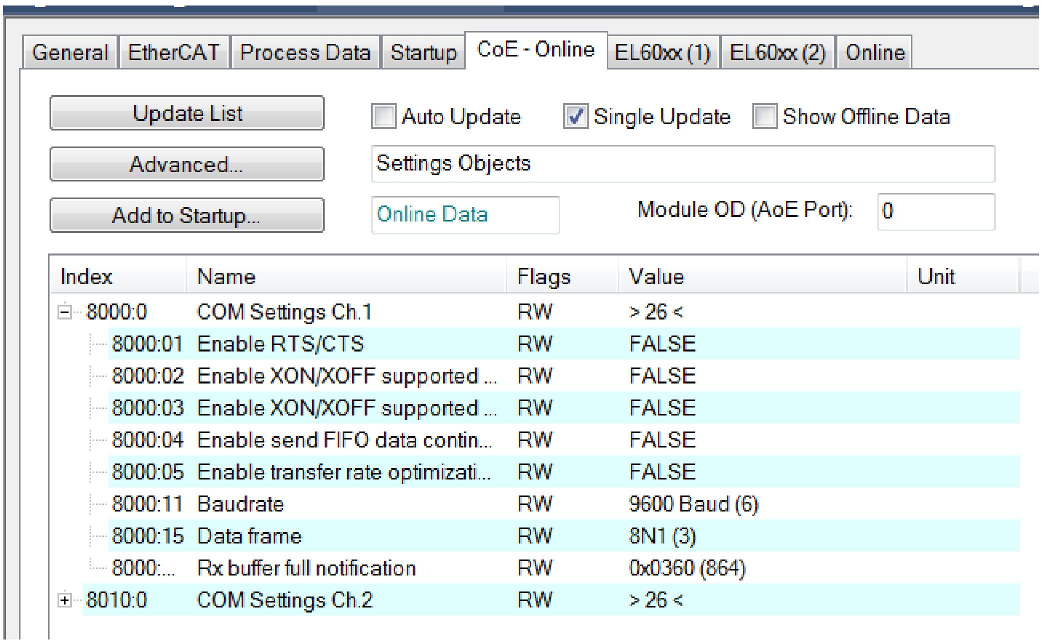
Signal Mapping

Apart from the common *i_nCouplerState* input parameter that has to be mapped to any of the State variables on the PLC, the mapping has to be done for input and output parameters of the serial port.



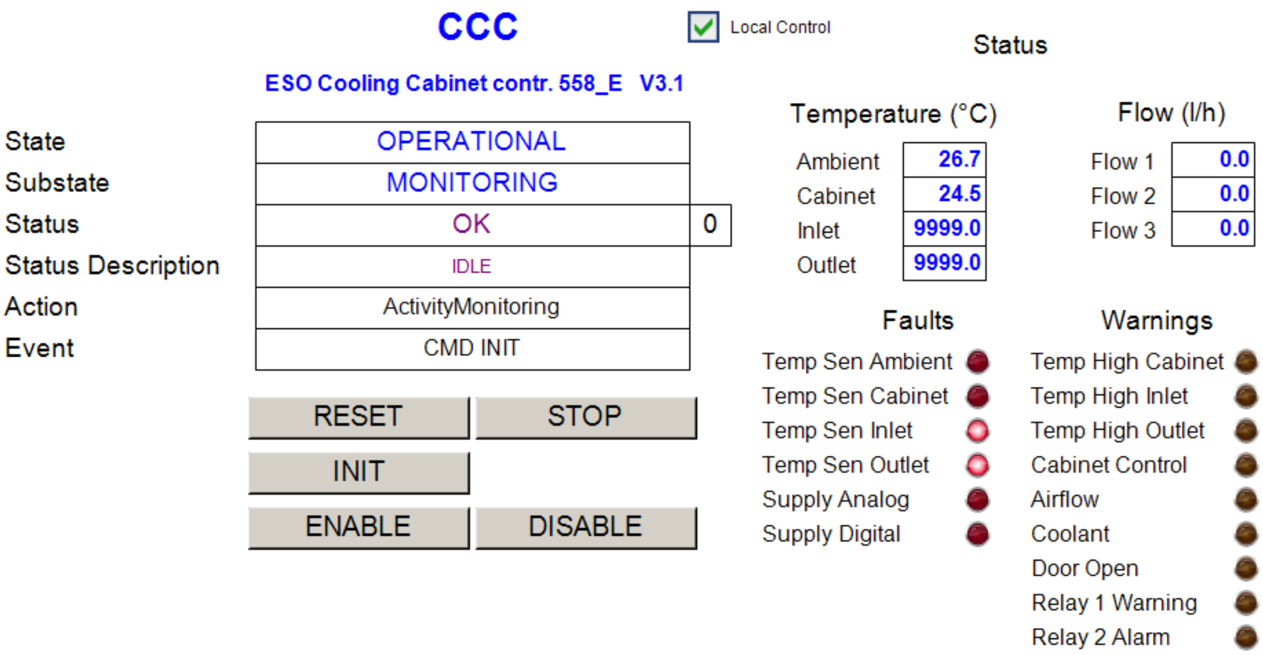
The serial port communication parameters, like baud rate, etc, have to be configured via the CoE interface.

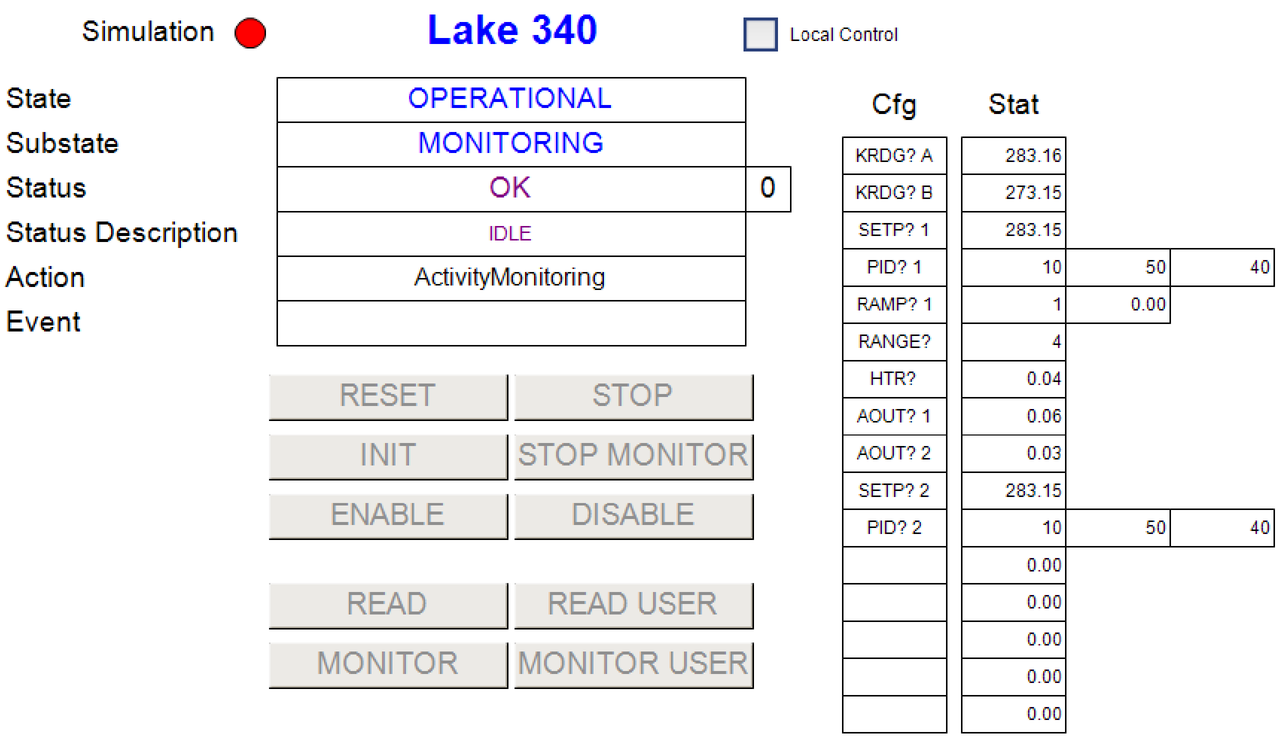
The default CoE configuration for the Lakeshore 340 is given below.



GUI Templates

GUI templates for the ESO Cabinet Cooling Controller and the Lakeshore 340 temperature controller are provided.





Example code

The following code handles an ESO Cabinet Cooling Controller, a JUMO controller and a Lakeshore 340.

```
PROGRAM MAIN
VAR
        // ESO Cabinet Cooling Controller (RS-232 interface)
        {attribute 'OPC.UA.DA' := '1'}
        CCC:        FB_CCC;

        // JUMO Controller (modnus RTU via Serial)
        {attribute 'OPC.UA.DA' := '1'}
        JUMO:       FB_JUMO;

        // Lakeshore 340 (RS-232 interface)
        {attribute 'OPC.UA.DA' := '1'}
        LS340:      FB_LAKESHORE_RS;

END_VAR
```

```
CCC(in_sName:='CCC', in_nPeriod := 1200);

JUMO(in_sName:='JUMO',in_nPeriod:=1000);    // Read all JUMOs every second
```

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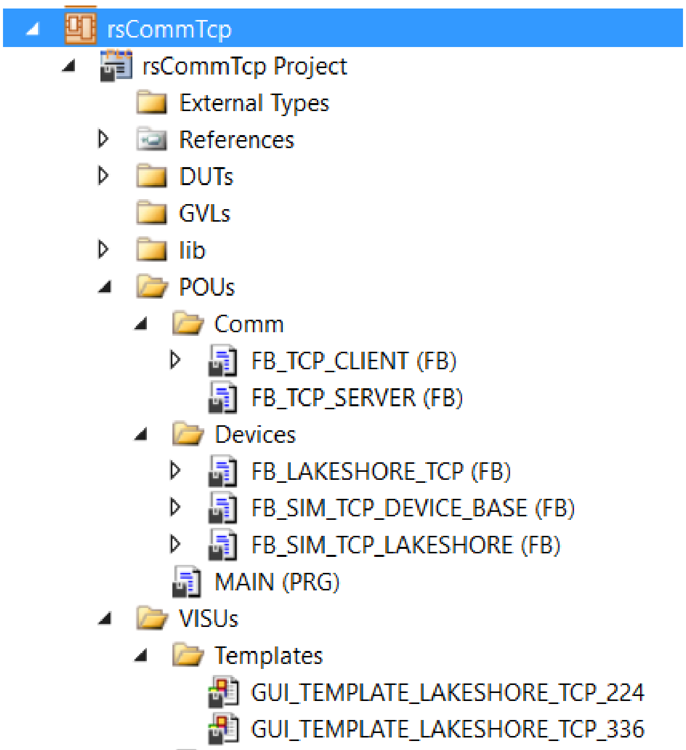
```
LS340(
    in_bSimulation          := FALSE,
    in_sName                := 'Lake 340',
    in_nModel               := 340,
    in_bAutoMonitor         := TRUE,
    in_sCmdSuffix             := '$0D$0A',
    in_sReplySuffix           := '$0D$0A',
    in_nPeriod              := 1700);
```

3.11.3 rsCommTcp.library

Note: Usage of the rsCommTcp.library in combination with the EtherCAT switch ports EL6601 and EL6614 is the preferred option over the usage of the CX2500-0060 Realtime network adapter (see rsCommTcpRt.library).

This library handles the TCP/IP communication via EtherCAT switch ports EL6601 and EL6614. It can be used to communicate with devices equipment with the Ethernet port, e.g. the Lakeshore 336 temperature controller. It requires the TF6310 TCP/IP license. In addition, the TF6310 function Windows driver has to be installed on the PLC. The IP address of the switch has to match the subnet of the device connected to it. For more info about installation and licensing consult Beckhoff documentation.

The library provides generic TCP/IP drivers for TCP clients (FB_TCP_CLIENT) and servers (FB_TCP_SERVER). Device PLC controllers are based on FB_TCP_CLIENT, while FB_TCP_SERVER is used only for simulators.

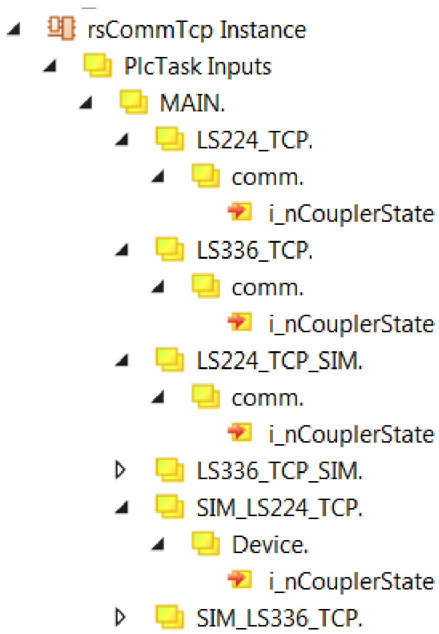


The overview of FBs is given in the table below.

Function Block	Description
FB_TCP_CLIENT	Generic TCP/IP Client driver. This is the base FB for Tcp based controllers.
FB_TCP_SERVER	Generic TCP/IP Server driver. This is the base FB for the communication part of Tcp based simulators.
FB_LAKESHORE_TCP	Lakeshore driver for devices with Ethernet port, i.e. models 224 & 336.
FB_SIM_TCP_DEVICE_BASE	Generic TCP/IP device simulator that uses FB_TCP_SERVER for communication.
FB_SIM_TCP_LAKESHORE	TCP/IP device simulator for Lakeshore models 224 & 336.

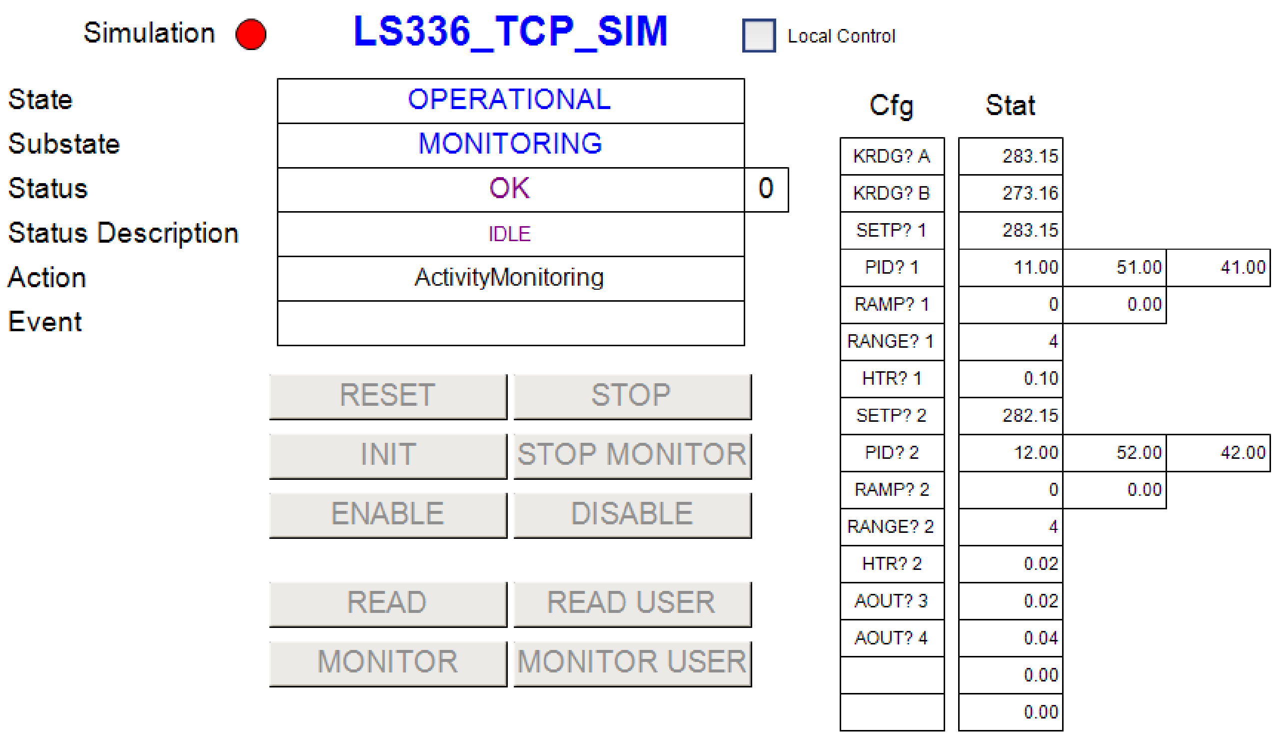
Signal Mapping

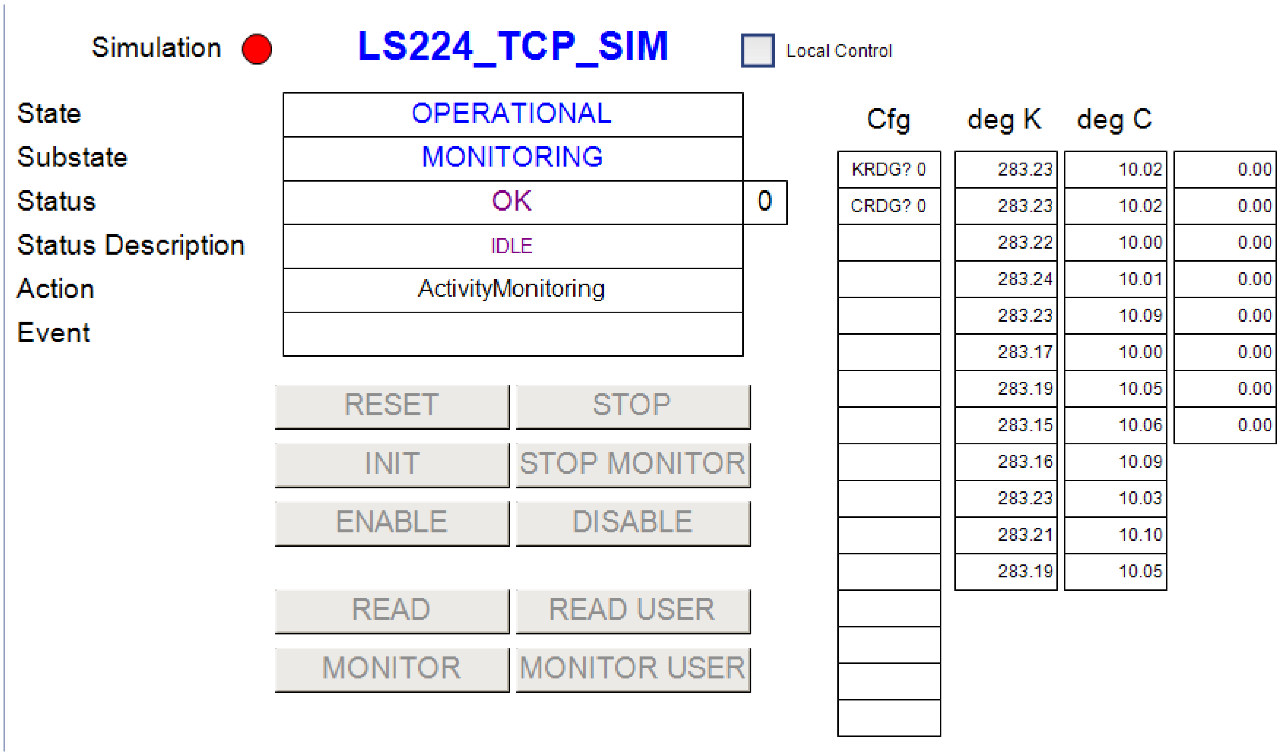
Devices and simulators have only a single input parameter (*i_nCouplerState*) to be mapped to any of the State variables on the PLC.



GUI Templates

GUI templates for the Lakeshore 336 and 224 temperature controller/monitor are provided.


Simulation
LS336_TCP_SIM
Local Control
State
OPERATIONAL
Substate
MONITORING
Status
OK
0
Status Description
IDLE
Action
ActivityMonitoring
Event
RESET
STOP
INIT
STOP MONITOR
ENABLE
DISABLE
READ
READ USER
MONITOR
MONITOR USER
Cfg
Stat
KRDG? A 283.15
KRDG? B 273.16
SETP? 1 283.15
PID? 1 11.00 51.00 41.00
RAMP? 1 0 0.00
RANGE? 1 4
HTR? 1 0.10
SETP? 2 282.15
PID? 2 12.00 52.00 42.00
RAMP? 2 0 0.00
RANGE? 2 4
HTR? 2 0.02
AOUT? 3 0.02
AOUT? 4 0.04
0.00
0.00


Simulation
LS224_TCP_SIM
Local Control
State
OPERATIONAL
Substate
MONITORING
Status
OK
0
Status Description
IDLE
Action
ActivityMonitoring
Event
RESET
STOP
INIT
STOP MONITOR
ENABLE
DISABLE
READ
READ USER
MONITOR
MONITOR USER
Cfg
deg K
deg C
KRDG? 0 283.23 10.02 0.00
CRDG? 0 283.23 10.02 0.00
283.22 10.00 0.00
283.24 10.01 0.00
283.23 10.09 0.00
283.17 10.00 0.00
283.19 10.05 0.00
283.15 10.06 0.00
283.16 10.09
283.23 10.03
283.21 10.10
283.19 10.05

Example code

The following code handles two real Lakeshore devices (224 and 336) and two additional Lakeshore devices that are connected to simulators. It is important to note that the devices that use simulators have to use the IP address '127.0.0.1'. Also, the port numbers of the device and the simulator have to match.

```
PROGRAM MAIN
VAR
    // Lakeshore 224 (Ethernet interface)
    {attribute 'OPC.UA.DA' := '1'}
    LS224_TCP:      FB_LAKESHORE_TCP;                // LakeShore based on FB_TCP_
↪CLIENT

    // Lakeshore 336 (Ethernet interface)
    {attribute 'OPC.UA.DA' := '1'}
    LS336_TCP:      FB_LAKESHORE_TCP;                // LakeShore based on FB_TCP_
↪CLIENT


    // Lakeshores to be simulated
    {attribute 'OPC.UA.DA' := '1'}
    LS224_TCP_SIM: FB_LAKESHORE_TCP;                 // LakeShore based on FB_TCP_
↪CLIENT
    {attribute 'OPC.UA.DA' := '1'}
    LS336_TCP_SIM: FB_LAKESHORE_TCP;                 // LakeShore based on FB_TCP_
↪CLIENT

    // Simulators
    SIM_LS224_TCP: FB_SIM_TCP_LAKESHORE;             // LakeShore SIM based on FB_
↪TCP_SERVER
    SIM_LS336_TCP: FB_SIM_TCP_LAKESHORE;             // LakeShore SIM based on FB_
↪TCP_SERVER


END_VAR
```

```
// Lakeshore 224
LS224_TCP(
    in_sName              := 'LS224_TCP',
    in_nModel             := 224,
    in_nPeriod            := 1500,
    in_sCmdSuffix           := '$0D$0A',
    in_sReplySuffix         := '$0D$0A',
    in_sDeviceTcpIpAdr    := '192.168.0.12',
    in_nDeviceTcpPort     := 7777);

// Lakeshore 336
LS336_TCP(
```

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```
    in_sName              := 'LS336_TCP',
    in_nModel             := 336,
    in_nPeriod            := 1000,
    in_sCmdSuffix           := '$0A',
    in_sReplySuffix         := '$0A',
    in_sDeviceTcpIpAdr    := '192.168.0.80',
    in_nDeviceTcpPort     := 7777);

// Dummy Lakeshore 224
// in_bSimulation:= TRUE means that it communicates with a simulator.
// If the simulator is running on the same PLC, in_sDeviceTcpIpAdr:='127.0.0.1'.
// in_nDeviceTcpPort has to match simulator's in_nTcpPort.
// See SIM_LS224_TCP.
LS224_TCP_SIM(
    in_bSimulation        := TRUE,
    in_sName              := 'LS224_TCP_SIM',
    in_nModel             := 224,
    in_nPeriod            := 1500,
    in_sCmdSuffix           := '$0D$0A',
    in_sReplySuffix         := '$0D$0A',
    in_sDeviceTcpIpAdr    := '127.0.0.1',
    in_nDeviceTcpPort     := 8888);

// Dummy Lakeshore 336
// in_bSimulation:= TRUE means that it communicates with a simulator.
// If the simulator is running on the same PLC, in_sDeviceTcpIpAdr:='127.0.0.1'.
// in_nDeviceTcpPort has to match simulator's in_nTcpPort.
// See SIM_LS336_TCP.
LS336_TCP_SIM(
    in_bSimulation        := TRUE,
    in_sName              := 'LS336_TCP_SIM',
    in_nModel             := 336,
    in_nPeriod            := 1000,
    in_sCmdSuffix           := '$0A',
    in_sReplySuffix         := '$0A',
    in_sDeviceTcpIpAdr    := '127.0.0.1',
    in_nDeviceTcpPort     := 7777);


// Lakeshore simulators
SIM_LS224_TCP(
    in_bSimulation        := TRUE,
    in_bEnable            := TRUE,
    in_nModel             := 224,
    in_sReplySuffix         := '$0D$0A',
    in_sTcpIpAdr          := '127.0.0.1',
    in_nTcpPort           := 8888);

SIM_LS336_TCP(
```

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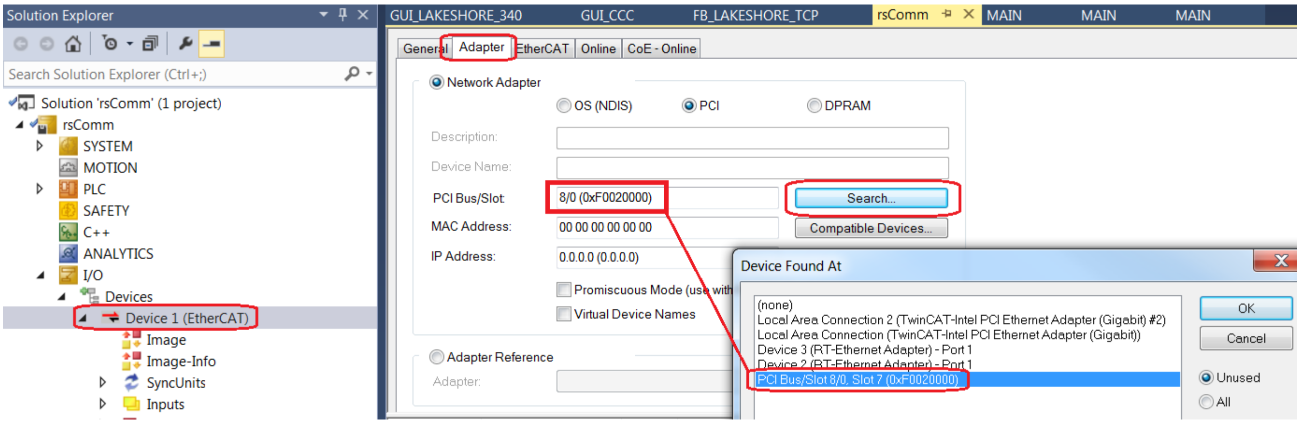
```
    in_bSimulation          := TRUE,
    in_bEnable              := TRUE,
    in_nModel               := 336,
    in_sReplySuffix           := '$0A',
    in_sTcpIpAdr            := '127.0.0.1',
    in_nTcpPort             := 7777);
```

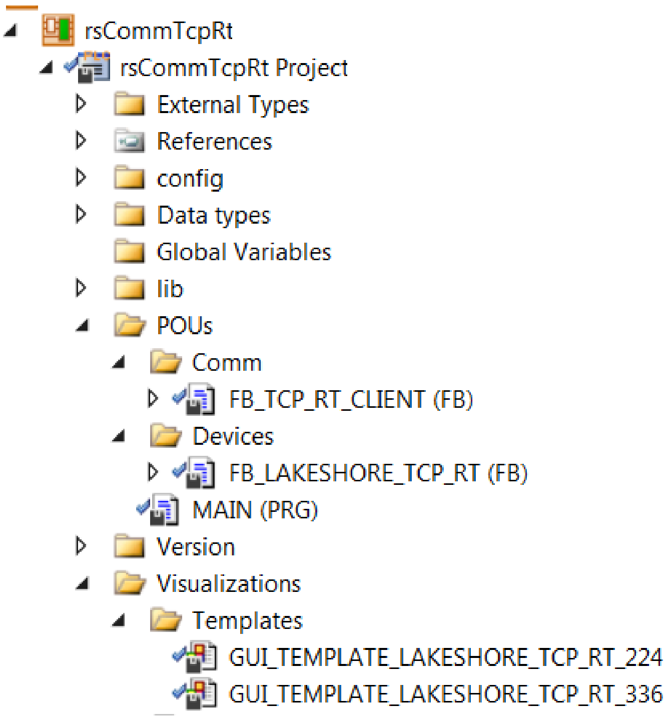
3.11.4 rsCommTcpRt.library

This library handles the TCP/UDP communication via CX2500-0060 system module that provides two independent Gbit Ethernet interfaces to the CX2000 family of PLCs, e.g. to the CX2030. The library can be used to communicate with devices equipment with the Ethernet port, e.g. the Lakeshore 336 temperature controller. It requires the TF6311 TC3 TCP/UDP Realtime license. The IP address of the switch has to match the subnet of the device connected to it. For more info about installation and licensing, consult Beckhoff documentation.

Warning: If the CX2500-0060 system module is installed, the PCI Bus address of the EtherCAT Device will be changed from the default 4/0 (0xF0020000) to 8/0 (0xF0020000), and an attempt to download an existing project will result in a failure message that is impossible to understand. For new projects the system will recognise the address automatically, while for the existing ones the new address has to be set by pressing the 'Search. . . ' button and selecting the only available PCI Bus address, as seen on the figure below.



The library provides a generic TCP/UDP RT driver for TCP RT clients (FB_TCP_RT_CLIENT) that is used in PLC controllers for the equipment with the Ethernet interface, e.g. the Lakeshore 336.

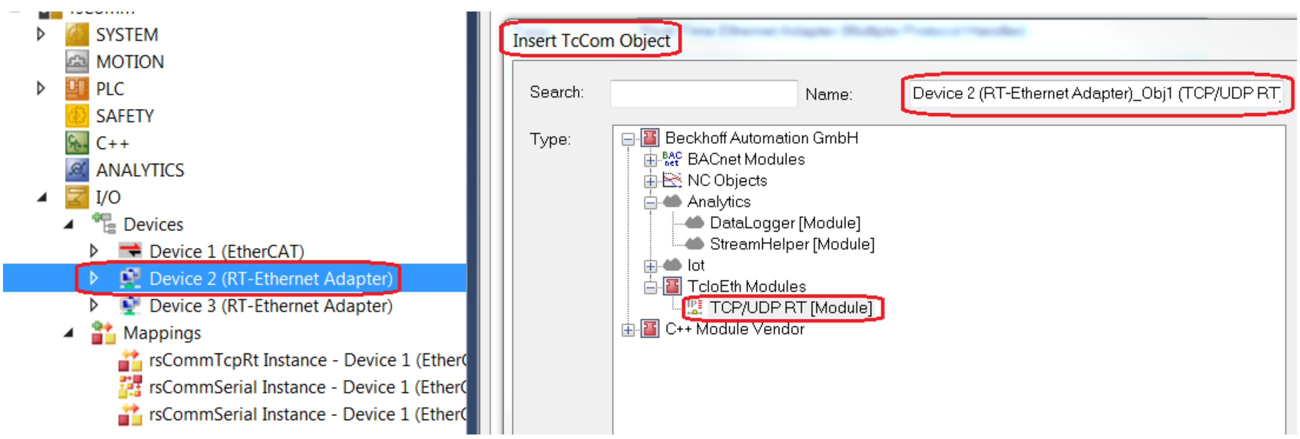


The overview of FBs is given in the table below.

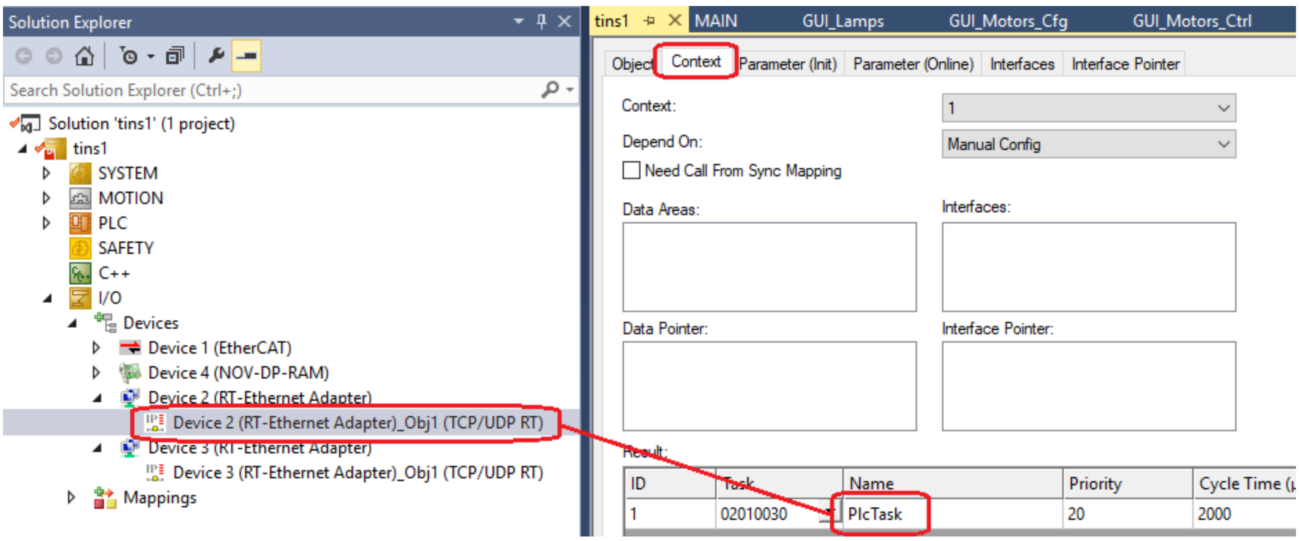
Function Block	Description
FB_TCP_RT_CLIENT	**Generic TCP/UDP RT Client driver.**
FB_LAKESHORE_TCP_RT	**Lakeshore driver for devices with Ethernet port, i.e. models 224 & 336.**

Adapter Configuration

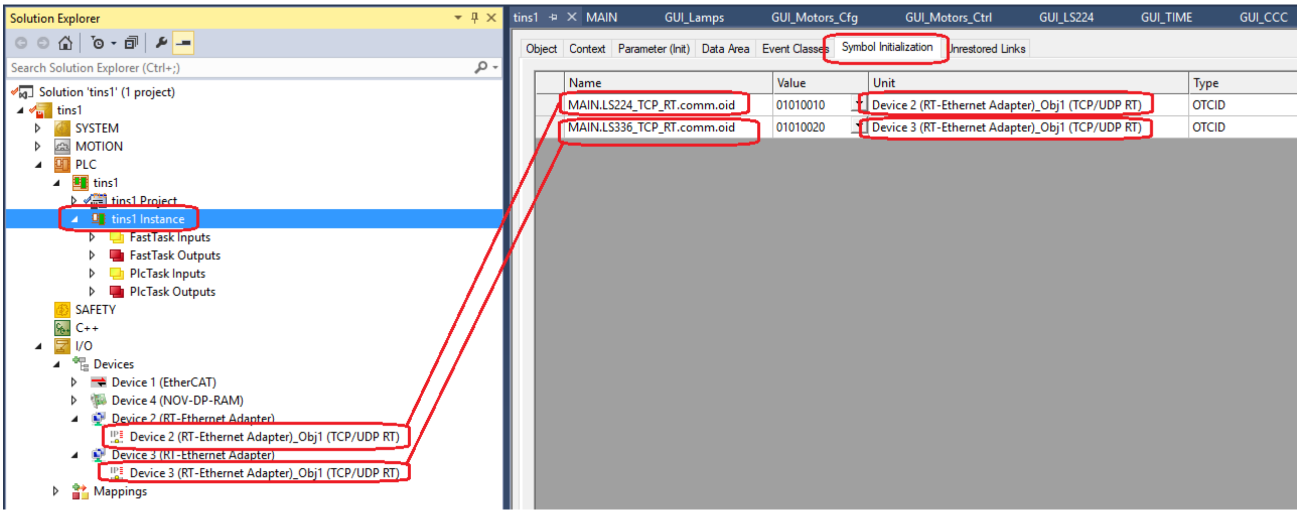
The CX2500-0060 system module is not part of the EtherCAT network and there is no ‘clasical’ EtherCAT I/O mapping. Each network port has to be added manually under the I/O Devices as an RT-Ethernet Adapter. Then, an Object of type TCP/UDP RT, that can be found under Beckhoff/TcIoEth Modules, has to be added to the adaptor, e.g. Device 2 (RT-Ethernet Adapter)_Obj1 (TCP/UDP RT).



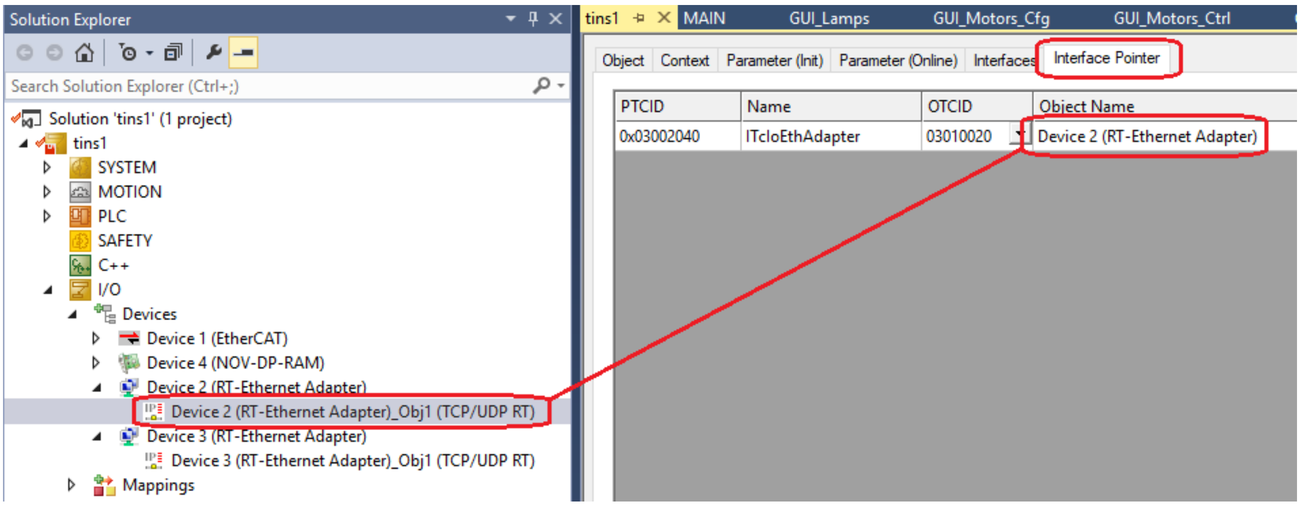
The Context of the Object is the PLC Task where an instance of the devices, e.g. MAIN.LS224_TCP_RT, will be running.



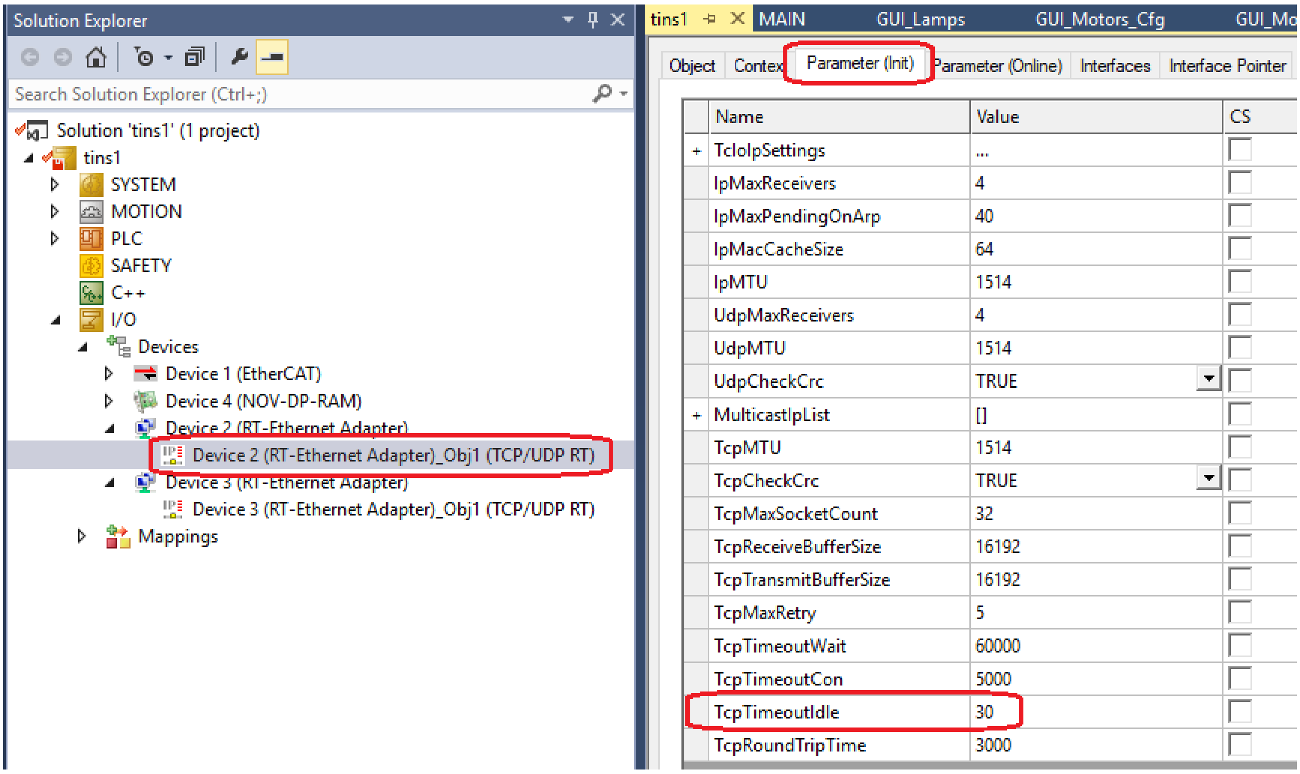
In the ‘Symbol Initialisation’ the Object has to be linked to the device instance.



The ‘Interface Pointer’ has to be set to the Device Object.



In the case of a Lakeshore device connected to the RT-EthernetAdapter Object, the TcpTimeoutIdle, that can be found under ‘Parameter (Init)’, has to be set to 30 ms. This is a Lakeshore specific setting.



GUI Templates

GUI templates for the Lakeshore 336 and 224 temperature controller/monitor are provided. See the corresponding section for Lakeshore TCP devices. The GUIs look the same.

Example code

The following code handles two Lakeshore devices (224 and 336).

```
PROGRAM MAIN
VAR
        //
        // Tcp RT interface functions
        //
        // Lakeshore 224 (Ethernet TCP Realtime interface)
        {attribute 'OPC.UA.DA' := '1'}
        LS224_TCP_RT:   FB_LAKESHORE_TCP_RT;        // LakeShore based on FB_TCP_
↪RT_CLIENT

        // Lakeshore 336 (Ethernet TCP Realtime interface)
        {attribute 'OPC.UA.DA' := '1'}
        LS336_TCP_RT:   FB_LAKESHORE_TCP_RT;        // LakeShore based on FB_TCP_
↪RT_CLIENT
```

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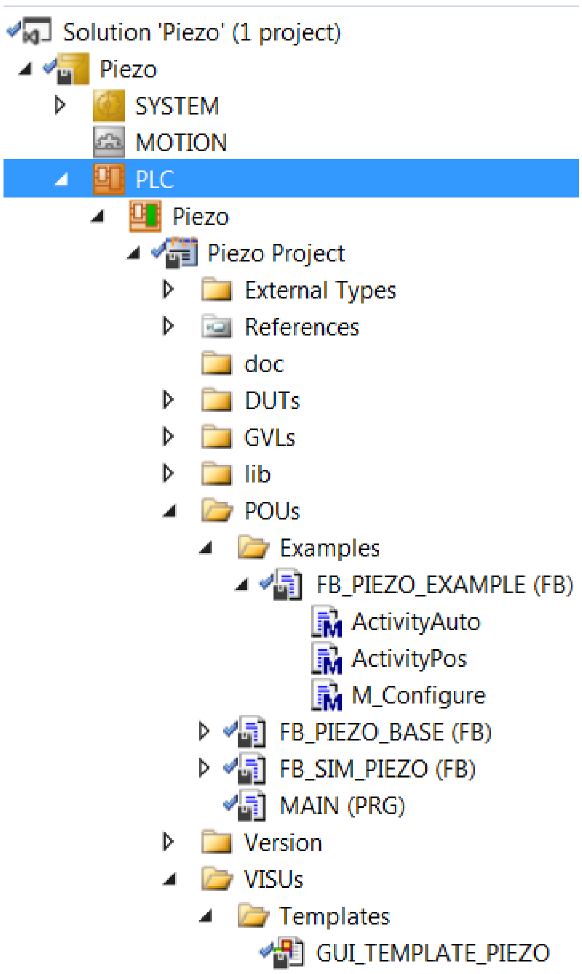
```
END_VAR
```

```
//
// Tcp RT interface functions
//

// Read every 2000 ms
// Command terminator for Lakeshore 224 is '$0D$0A'
LS224_TCP_RT(
    in_sName              := 'LS224_TCP_RT',
    in_nModel             := 224,
    in_sCmdSuffix           := '$0D$0A',
    in_sDeviceTcpIpAdr    := '192.168.0.12',
    in_nDeviceTcpPort     := 7777,
    in_nPeriod            := 2000);

// Read every 1000 ms
// Command terminator for Lakeshore 336 is '$0A'
LS336_TCP_RT(
    in_sName              := 'LS336_TCP_RT',
    in_nModel             := 336,
    in_sCmdSuffix           := '$0A',
    in_sDeviceTcpIpAdr    := '192.168.0.80',
    in_nDeviceTcpPort     := 7777,
    in_nPeriod            := 1000);
```

3.12 Piezo Library (piezo.library)

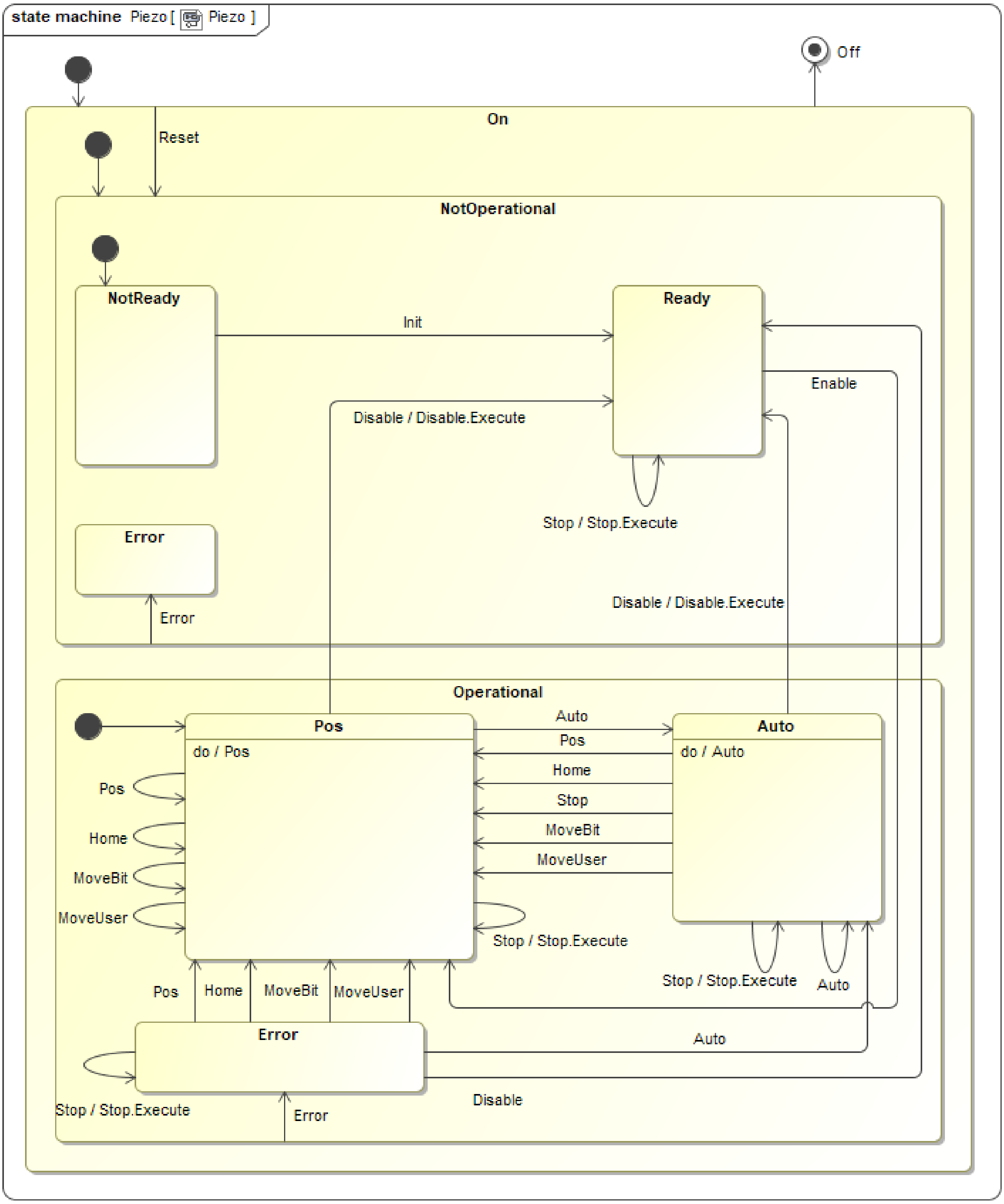
The *piezo.library* provides a generic PLC Piezo controller *FB FB_PIEZO_BASE* that has to be customised (extended) by the user. Up to three output control signals of type INT are supported (configurable). The example FB called *FB_PIEZO_EXAMPLE* shows how this customisation could be done.

The figure below shows what is delivered in the library.



3.12.1 State Machine

The state machine of the piezo controller is shown below. The main operational states are *Pos* (stationary) and *Auto* (user-defined closed loop).


state machine Piezo [Piezo]
Off
On
Reset
NotOperational
NotReady
Ready
Init
Enable
Disable / Disable.Execute
Stop / Stop.Execute
Error
Error
Disable / Disable.Execute
Operational
Pos
do / Pos
Auto
do / Auto
Auto
Pos
Home
Stop
MoveBit
MoveUser
Pos
Home
MoveBit
MoveUser
Stop / Stop.Execute
Stop / Stop.Execute
Auto
Pos
Home
MoveBit
MoveUser
Error
Auto
Disable
Stop / Stop.Execute
Error

3.12.2 Input parameters

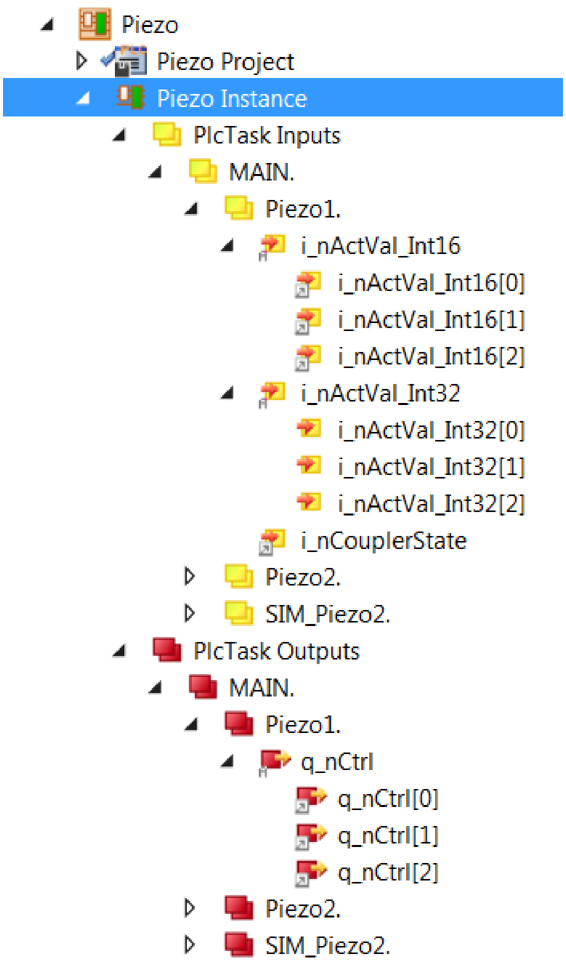
FUNCTION_BLOCK FB_PIEZO_BASE

VAR_INPUT	**in_sName**	STRING	*Instance name. Default 'Piezo'.*
VAR_INPUT	**in_nNumAxes**	INT	*Max 3 axes*
VAR_INPUT	**in_nMaxOn**	DINT	*Maximum time for Piezo to be active [sec].*

3.12.3 Signal Mapping

The figure below shows the TwinCAT view of the *FB_PIEZO_BASE* I/O variables that are available for mapping to physical signals, i.e. ports of I/O terminals.

There are two arrays for the feedback signals, one of type INT and the other one of type DINT. Any of them can be used in the customised application. There is an array for the control output signals of type INT.

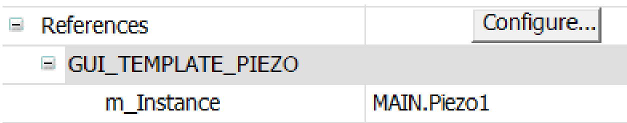


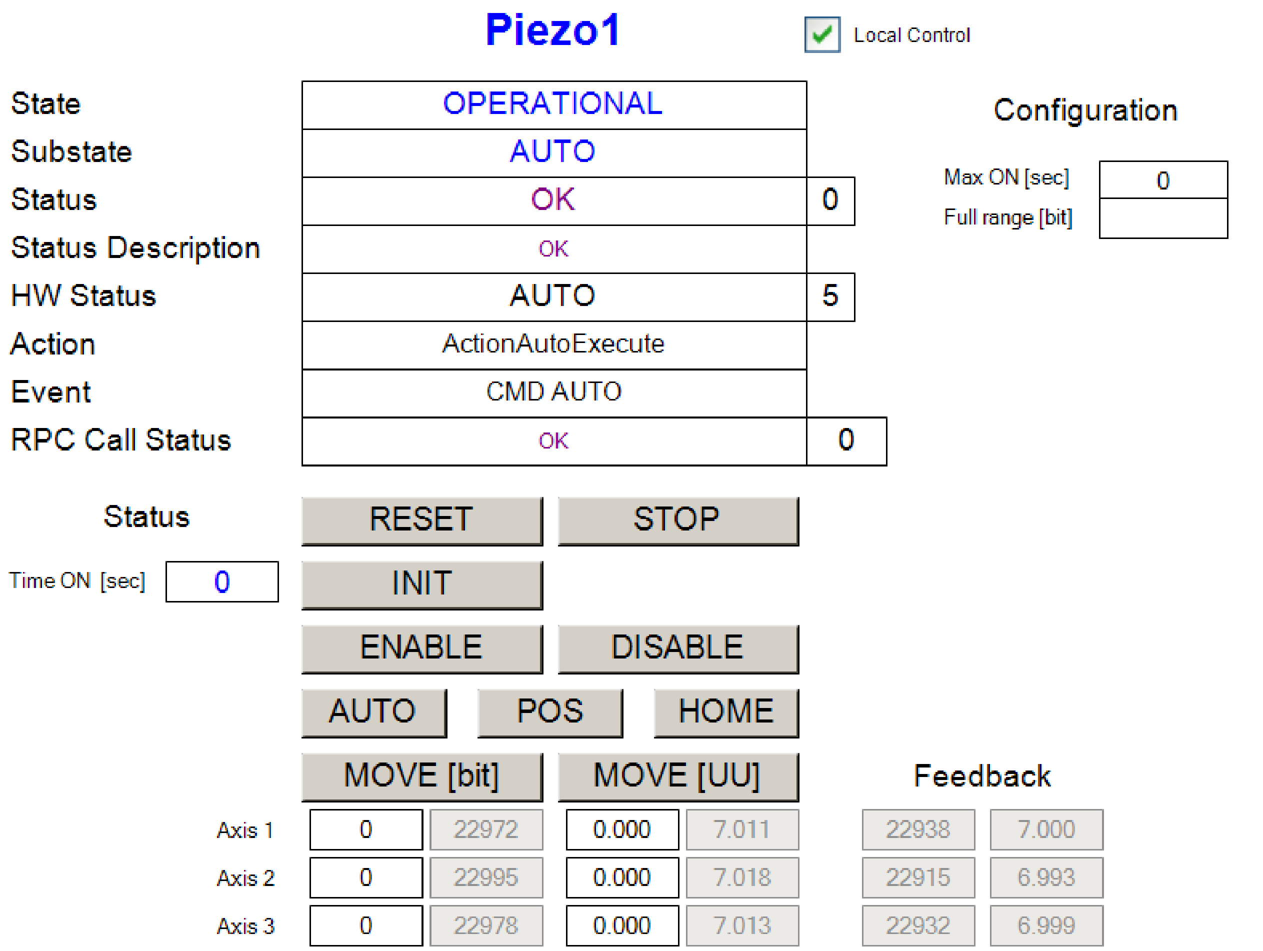
The table below describes each mapping variable.

Variable	Port Type	Optional Mapping	Description
i_nCouplerState	UINT	No	Mapped to the 'state' of the coupler that hosts I/O terminals. If the terminals span over more than one coupler, it is recommended to select the 'state' of the last coupler that hosts a lamp signal.
i_nActVal_Int16	INT	Yes	Array [0..2] of feedback signals of type INT
i_nActVal_Int32	DINT	Yes	Array [0..2] of feedback signals of type DINT
q_nCtrl	INT	No	Array [0..2] of control output signals of type INT

3.12.4 GUI Template

The *piezo.library* provides a template GUI called *GUI_TEMPLATE_PIEZO* for the control of Piezo devices. Applications can easily deploy an instance of this GUI by setting the GUI references to a particular instance, as shown below.





3.12.5 Piezo specific RPC Methods

Method	Description
RPC_Auto	Start Automatic Loop. The user has to overload method ActivityAuto()
RPC_Home	Move piezos to Home position
RPC_MoveBit	Move piezos to positions given in [bit]
RPC_MoveUser	Move piezos to positions given in user units [UU]
RPC_Pos	Keep the piezos where they are (default behaviour). This might mean to stop the Auto loop. The user can overload this method.

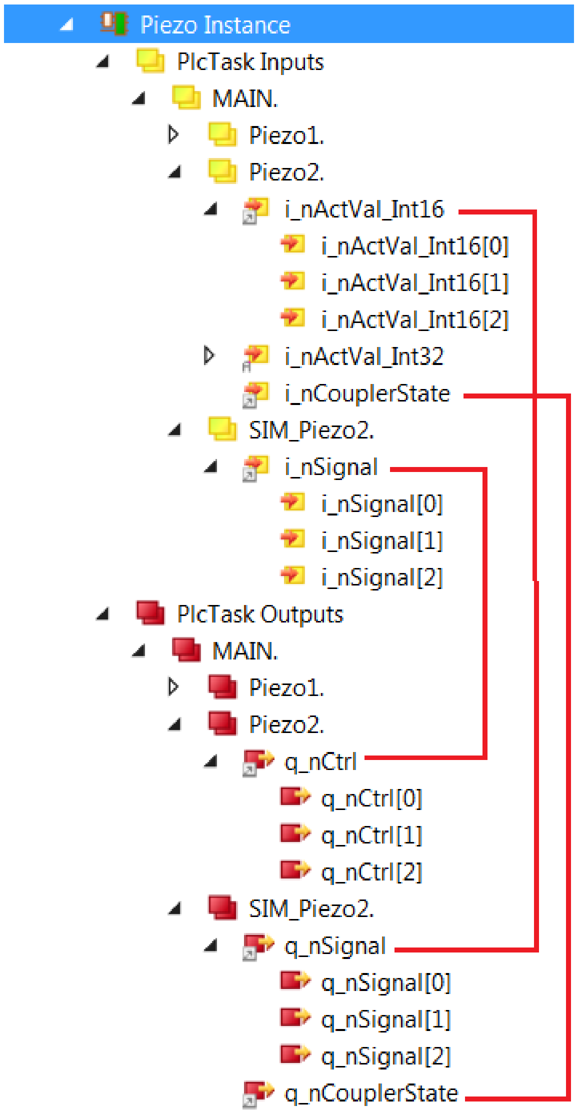
3.12.6 Piezo Simulator

The function block *FB_SIM_PIEZO* implements the piezo simulator on the PLC. The FB doesn't have any input parameter. The simulator takes the real piezo device control outputs and generate its own feedback output signals by adding sine wave offsets. The simulator output feedback is mapped to the feedback inputs of the simulated device. The sine wave is fully configurable (amplitude and cycle period).

3.12.7 Piezo Simulator RPC Methods

Method	Description
RPC_ResetConfig	**Reset simulator configuration to its default.**
RPC_SetCouplerState	**Set coupler state. Any value other than 8 would cause a failure of the simulated device.**
RPC_SetMaxError	**Set Maximal Simulated feedback offset [bit] and the Period for complete sine wave offset cycle [msec]**

3.12.8 Simulator Mapping



3.12.9 Sample Code

The following code represent a real Piezo controller (*Piezo1*) and a piezo controller (*Piezo2*) that is connected to a simulator (*SIM_Piezo2*). The mapping is shown in the *Simulator Mapping* section.

```
PROGRAM MAIN
VAR

        {attribute 'OPC.UA.DA':='1'}
        Piezo1:      FB_PIEZO_EXAMPLE;       // Piezo #1
        {attribute 'OPC.UA.DA':='1'}
```

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```
        Piezo2:      FB_PIEZO_EXAMPLE;        // Piezo #2

        {attribute 'OPC.UA.DA':='1'}
        SIM_Piezo2: FB_SIM_PIEZO;             // Simulator for Piezo #2

END_VAR
```

```
Piezo1(in_sName:='Piezo1', in_nNumAxes:=3);

Piezo2(in_sName:='Piezo2', in_nNumAxes:=3);

SIM_Piezo2();
```

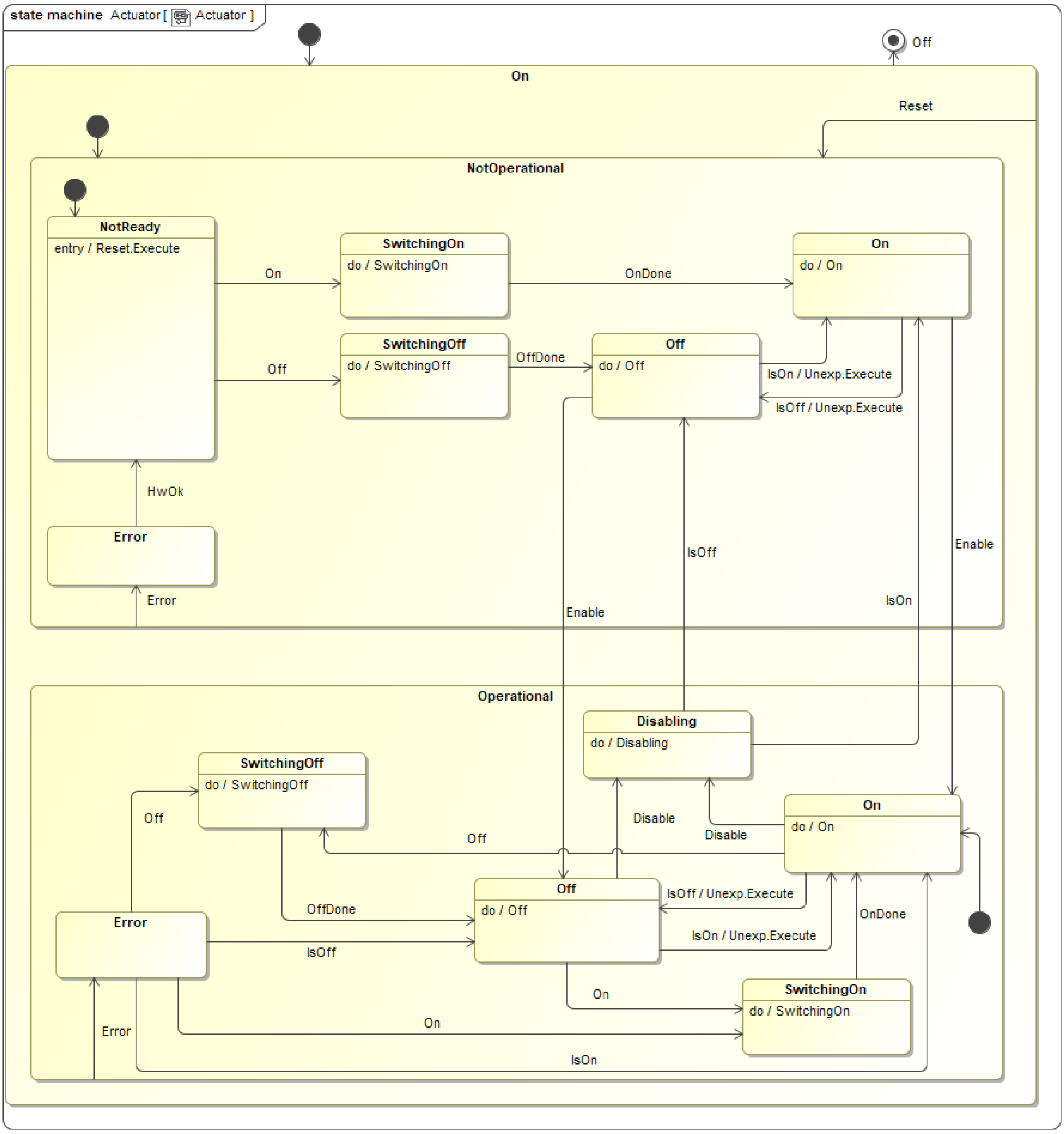
3.13 Actuator Library (actuator.library)

FB_ACTUATOR is the TwinCAT PLC Function Block for the low level control of actuators. The most common use of this FB is for power control.

The functionality is very similar to the one of *FB_LAMP* with an important difference that the HW state (On/Off) of the actuator is not affected by the state change of the controller (NOT_OP/OPERATIONAL). The HW state can only be changed in OPERATIONAL state using ON and OFF commands. An actuator can be configured to go ON on PLC reboot or on RESET of the controller. The configuration is set with the input parameter *in_bInitialState*.

3.13.1 State Machine

The state machine of the actuator controller is shown below. The main operational states are *On*, *Off*, *Switching On* and *Switching Off*.


state machine Actuator [Actuator]
Off
On
Reset
NotOperational
NotReady
entry / Reset.Execute
On
SwitchingOn
do / SwitchingOn
OnDone
On
do / On
Off
SwitchingOff
do / SwitchingOff
OffDone
Off
do / Off
IsOn / Unexp.Execute
IsOff / Unexp.Execute
HwOk
Error
Error
IsOff
Enable
IsOn
Enable
Operational
Disabling
do / Disabling
SwitchingOff
do / SwitchingOff
Off
Off
Disable
Disable
On
do / On
Off
do / Off
OffDone
IsOff / Unexp.Execute
OnDone
IsOn / Unexp.Execute
Error
IsOff
On
SwitchingOn
do / SwitchingOn
On
Error
IsOn

3.13.2 Input parameters

```
FUNCTION_BLOCK FB_ACTUATOR

VAR_INPUT  in_sName              STRING  Default device name
VAR_INPUT  in_bActiveLowOn       BOOL    If TRUE, On signal is Active Low. Default FALSE.
VAR_INPUT  in_bActiveLowSwitch   BOOL    If TRUE, Switch ctrl signal is Active Low. Default FALSE.
VAR_INPUT  in_bAutoOp            BOOL    If TRUE, go automatically to OPERATIONAL state. Default FALSE.
VAR_INPUT  in_bInitialState      BOOL    Default power state is OFF (FALSE).
VAR_INPUT  in_bInvertAnalog      BOOL    If TRUE, analog feedback is active if signal < nAnalogThreshold. Default FALSE.
VAR_INPUT  in_nAnalogThreshold   DINT    Analog feedback signal threshold [bits]. Used if <>0. Default 0, i.e. not used.
VAR_INPUT  in_nMaxOn             UDINT   Maximum time for power to be ON [sec]. Default 0, no limit.
VAR_INPUT  in_nSigStablePeriod   UDINT   Signal is stable if it has been constant for so long [msec]. Default 200 ms.
VAR_INPUT  in_nTimeout           UDINT   Timeout for state transitions [msec]. Default 5000 ms (5 sec).
```

3.13.3 Signal Mapping

The figure below shows the TwinCAT view of the *FB_ACTUATOR* I/O variables that are available for mapping to physical signals, i.e. ports of I/O terminals.

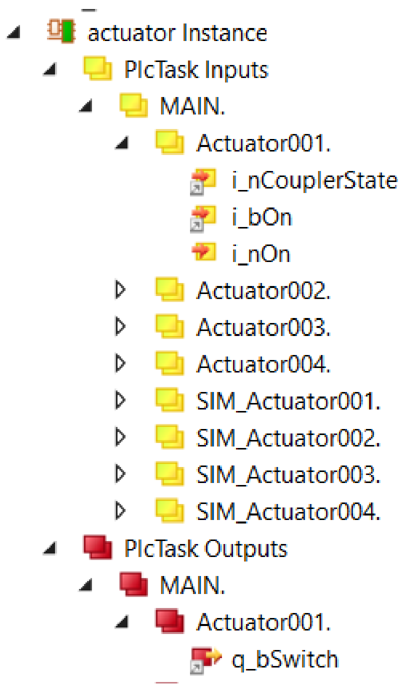


Fig. 3.14: Example of FB_ACTUATOR input/output signals.

The table below describes each mapping variable.

Variable	Port Type	Optional Mapping	Description
i_nCouplerState	UINT	No	Mapped to the 'state' of the coupler that hosts I/O terminals. If the terminals span over more than one coupler, it is recommended to select the 'state' of the last coupler that hosts an actuator signal.
i_bOn	Digital In	No	Mapped to the Actuator status (ON/OFF) digital input signal.
i_nOn	Analog In	Yes	Analog feedback signal. Has to be mapped only if analog feedback is used.
q_bSwitch	Digital Out	No	Mapped to the Actuator control digital output signal.

3.13.4 GUI Template

The Actuator Library provides a template GUI to control instances of *FB_ACTUATOR*. Applications can easily deploy an instance of this GUI to control their own actuator function blocks by setting the GUI references to the particular instance of *FB_ACTUATOR*, as shown below.

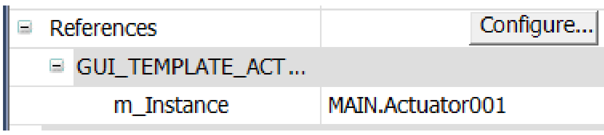


Fig. 3.15: Instantiation of GUI_TEMPLATE_ACTUATOR for Actuator001

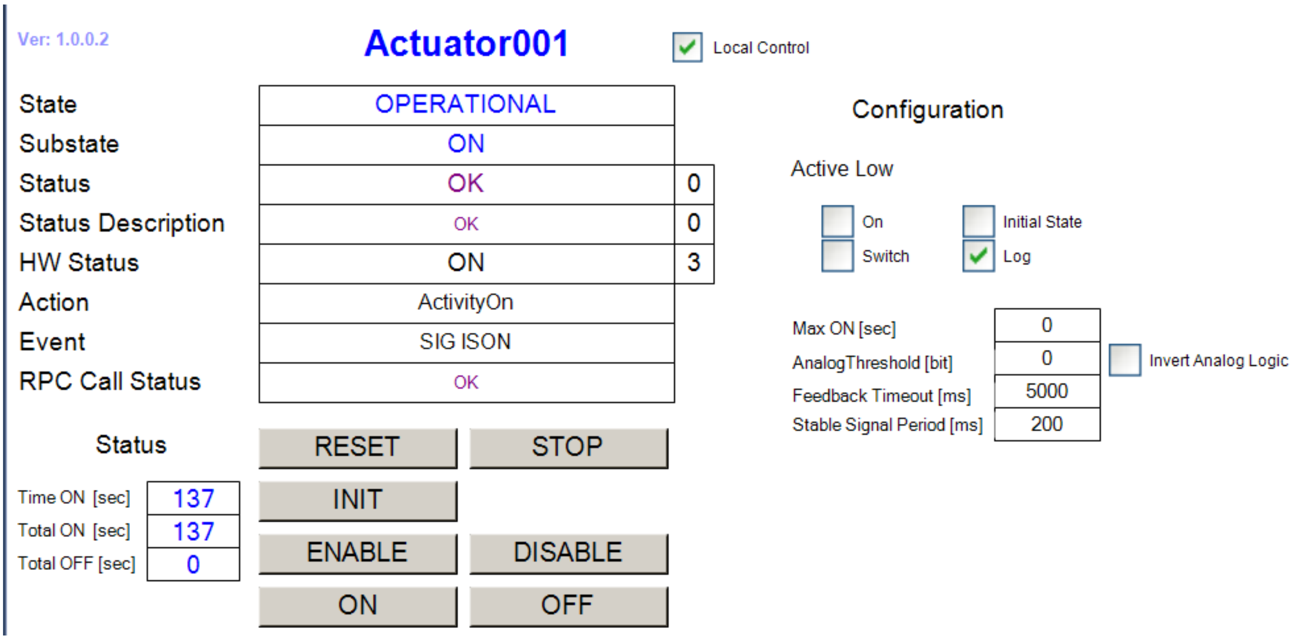


Fig. 3.16: FB_ACTUATOR HMI for Local Control.

3.13.5 Actuator specific RPC Methods

- RPC_Off() Turn actuator OFF
- RPC_On() Turn actuator ON

3.13.6 Actuator Simulator

The function block *FB_SIM_ACTUATOR* implements the actuator simulator on the PLC. The simulator has the address of the actuator instance as the only input parameter. The following code shows how the simulator is declared and executed:

Declaration:

```
{attribute 'OPC.UA.DA':='1'}
Actuator001:         FB_ACTUATOR;     // Simulated power

{attribute 'OPC.UA.DA':='1'}
SIM_Actuator001:     FB_SIM_ACTUATOR;
```

Execution:

```
// Actuator001 configuration:
// - Go to  OPERATIONAL on PLC reboot
// - Initial state is OFF
```

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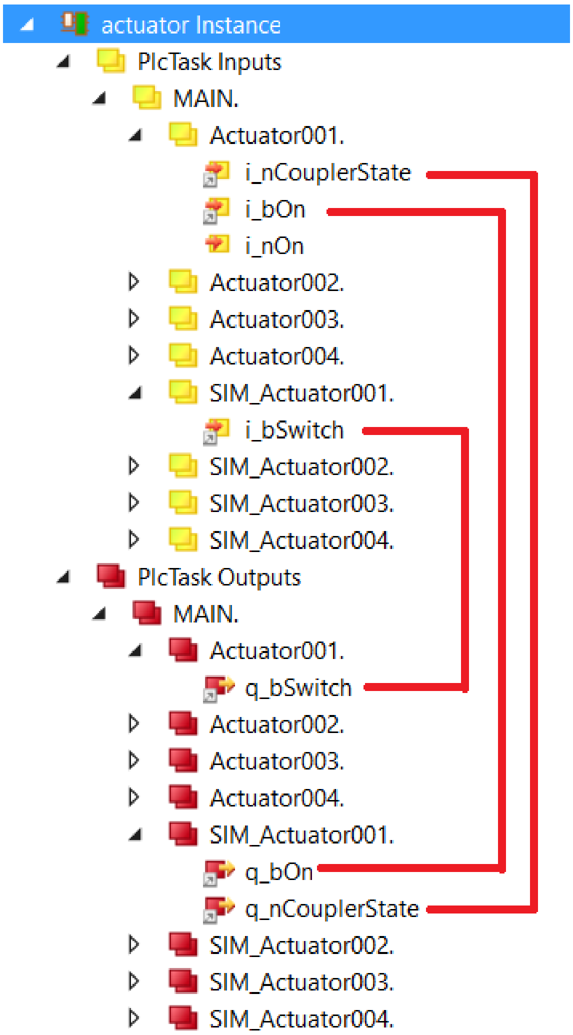
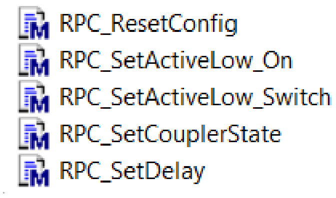
```
Actuator001(in_sName:='Actuator001', in_bAutoOp:=TRUE,in_bInitialState:=FALSE);

// Actuator001 Simulator
SIM_Actuator001(ptrDev:=ADR(Actuator001));
```

Simulator Mapping



Simulator RPC Methods



4 Creating PLC Applications with MakeTcProject Utility

A Windows utility called *MakeTcProject.exe* is provided for automatic creation of TwinCAT projects with a selectable number of available FCF controllers. For example, with this utility the user could automatically build a PLC application for four lamps, three shutters, two motors and two actuators. The utility generates a fully operational project that includes the selected number of devices/controllers and their simulators, i.e. every device is simulated at the PLC level. Without any modification, the project can directly run on the development PC in *Local* mode or be deployed to a PLC.

The utility is recommended to be used as the starting point for creating PLC applications since it creates all necessary PLC tasks, Function Block instances, GUIs and establishes I/O links. The utility is also very useful at early stages of instrument projects when HW is not yet available, since it makes it possible to test the complete control system as if the HW were present. Once a particular piece of HW gets available, the corresponding simulator part should be removed from the project and the function block I/O variables linked to the real system I/O instead of the simulator.

Note: **Important note**: The generated PLC application uses PLC simulators, so it can run on both the PC in *Local* mode or on the PLC target without the need for any hardware. However, once the HW is available, the PLC signal mapping has to be adjusted accordingly. From the Device Manager point of view that runs on the WS, it *believes* that it controls the real HW.

The Windows executable *MakeTcProject.exe* is located in the *<ifw-ll>/tools/twincat/makeTcProject* directory, where *<ifw-ll>* is the directory on the Windows PC where the tar file of the component *ifw-ll* has been checked out from the ESO Gitlab site IFW-LL release 2.0.0[13]. There is no need to install the executable but it is important to note that it has to be executed from this directory because it uses a relative path to find required resources. Note that *MakeTcProject.exe* is a Windows program and it has to be executed from the *Command Prompt* (*cmd*) application. The target PLC configuration is defined in the corresponding configuration file *MakeTcProject.cfg* that is also located in the *<ifw-ll>/tools/twincat/makeTcProject* directory.

The FCF PLC binaries (libraries and modules) are located in the SVN repository tag under *http://svnhq9.hq.eso.org/p9/tags/EELT/ICS/PLC/2.0.0*. The complete directory has to be checked out to a local directory on the TwinCAT development PC. Prior to building the PLC application, the *MakeTcProject.exe* utility installs the PLC binaries in the TwinCAT Library Repository from that directory.

[13] https://gitlab.eso.org/ifw/ifw-ll/-/releases

4.1 Configuration File MakeTcProject.cfg

The configuration file sets all parameters needed by the utility, including the Visual Studio version, the location of PLC binaries, the TwinCAT output project name and the type and the number of controllers to include in the application.

The following table describes each entry in the configuration file.

Parameter	Values	Default	Description
VisualStudio	2013, 2017, etc	2013	Version of Visual Studio to use. This version has to be already installed.
Binaries		C:\Temp\PLC	Directory where the PLC binaries are checked out.
Project		plcprj	TwinCAT project name.
Lamps	0, 1, etc	1	Number of Lamps to generate.
Shutters	0, 1, etc	1	Number of Shutters to generate.
Motors	0, 1, etc	1	Number of Motors to generate.
Piezos	0, 1, etc	1	Number of Piezos to generate.
Actuators	0, 1, etc	1	Number of Actuators to generate.
ADC	yes | no	yes	If yes, ADC instance will be generated. Note that an ADC instance includes two prism motors (mult-axis).
DROT	yes | no	yes	If yes, DROT instance will be generated.
IODEV	yes | no	yes	If yes, two example instances of IODEV will be generated, one for a sensor and one for an I/O device.

4.2 Utility Specifics

- Generated projects are saved in the *C:\Temp\Solutions* directory. It is not possible to change the destination directory.
- The resulting PLC application is not optimized for the usage of CPU cores of multi-core CPUs. All PLC tasks are configured to run on Core0 and other cores, if exist, are not used. It is the responsibility of the user to optimize the PLC application by activating available isolated cores and moving tasks from one core to the other.
- Generated instances of controllers/devices will be named <device>xxx, e.g. Motor001, Motor002, etc. The user will have to rename (refactor) them to, e.g. Filter1, Mirror1, etc.
- There utility will generate only one GUI per controller type using the following convention: GUI_<device>001, e.g. GUI_Lamp001. The user will have to rename (refactor) them to, e.g. GUI_Neon, GUI_ThArg, etc.

4.3 Summary of Main Steps

The following is the summary of the required steps to build and customize the PLC application.

1. Retrieve the FCF SW from GIT and SVN repositories.
2. Edit file MakeTcProject.cfg to match the system configuration and the PLC project.
3. Build the PLC application.
4. Open the PLC application with TwinCAT, rebuild it and run it in *Local* mode on the PLC.
5. Refactor the PLC application by renaming the controller instances and GUIs.
6. Rebuild the PLC application and deploy it to the PLC.
7. Test the devices in PLC simulation.
8. Once the HW is available, scan the PLC HW and map the controller I/O signals to the real HW I/O.

In this example we assume the following:

- VisualStudio 2013 is the version to be used for building the PLC application. The specified version, together with the Beckhoff TwinCAT SW has to be already installed on the Windows PC.
- The tar file of the component *ifw-ll* has been checked out from the ESO Gitlab site and extracted into the *D:\GIT\ifw-ll* directory on the Windows PC, so the utility and the configuration file can be found in the *D:\GIT\ifw-ll\tools\twincat\makeTcProject* directory.
- The PLC binaries are checked out from the SVN repository under *http://svnhq9.hq.eso.org/p9/tags/EELT/ICS/PLC/2.0.0* into the *C:\Temp\PLC* directory.

4.4 Building PLC Application

This section describes, step-by-step, the process of building the PLC application.

The procedure is the following:

1. Check-out the *IFW-LL release 2.0.0* tar file and extract it into the *D:\GIT\ifw-ll* directory on the Windows PC.
2. SVN check out the binaries tag *http://svnhq9.hq.eso.org/p9/tags/EELT/ICS/PLC/2.0.0* to *C:\Temp\PLC*.
3. Edit file *MakePlcProject.cfg* in *D:\GIT\ifw-ll\tools\twincat\makeTcProject* and adjust the number of instances for each type of controller. The example below shows the default configuration - one of each controller.

```
D:\GIT\ifw-ll\tools\twincat\makeTcProject>type MakeTcProject.cfg
VisualStudio: 2013
```

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```
Binaries: C:\Temp\PLC
Project: plcprj
Lamps: 1
Shutters: 1
Motors: 1
ADC: yes
DROT: yes
IODEV: yes
Piezos: 1
Actuators: 1
```

4. Open a *cmd* terminal and CD to the *D:\GIT\ifw-ll\tools\twincat\makeTcProject* directory.
5. Run *MakeTcProject.exe*. The created TwinCAT project will be saved in the *C:\Temp\Solutions* directory. The output will look like this:

```
D:\GIT\ifw-ll\tools\twincat\makeTcProject>MakeTcProject.exe
MakeTcProject $Id: Program.cs 332694 2020-05-20 21:22:51Z wpirani $
INFO:
Visual Studio = '2013'
Binaries = C:\Temp\PLC
Project = 'plcprj'
Motors = 1
Lamps = 1
Shutters = 1
DROT = True
ADC = True
IODev = True
Piezos = 1
Actuators = 1
Trying to lunch Visual Studio 2013...
Creating empty project...
Adding module trkParams with GUID {15952e35-5679-4d71-9f28-196df14bbd2e}
Adding module trkModule with GUID {6f6a340e-378a-4fe4-ab0d-f15c12dfef0c}
Populating project...
Adding libraries...
Copying required libraries to System repository...
        C:\Temp\PLC\Libraries\actuator.library
        C:\Temp\PLC\Libraries\IODev.library
        C:\Temp\PLC\Libraries\Lamp.library
        C:\Temp\PLC\Libraries\Motor.library
        C:\Temp\PLC\Libraries\Mudpi.library
        C:\Temp\PLC\Libraries\Piezo.library
        C:\Temp\PLC\Libraries\plctpl.library
        C:\Temp\PLC\Libraries\rsCommCommon.library
        C:\Temp\PLC\Libraries\rsCommSerial.library
        C:\Temp\PLC\Libraries\rsCommTcp.library
        C:\Temp\PLC\Libraries\rsCommTcpRt.library
        C:\Temp\PLC\Libraries\Shutter.library
```

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```
        C:\Temp\PLC\Libraries\Switch.library
        C:\Temp\PLC\Libraries\timer.library
Adding required libraries to this project...
Importing VISUs...
Importing: GUI_CCS_SIM.TcVIS from ..\..\..\controllers\motor\Motor\VISUs\
↪Tracking\
Importing: GUI_time_info.TcVIS from ..\..\..\controllers\timer\timer\timer\
↪VISUs\
Importing: GUI_MA_ADC.TcVIS from ..\..\..\controllers\motor\Motor\VISUs\
↪Tracking\
Importing: GUI_MA_DROT.TcVIS from ..\..\..\controllers\motor\Motor\VISUs\
↪Tracking\
Importing: GUI_Lamp001.TcVIS from ..\..\..\controllers\lamp\Lamp\Lamp\VISUs\
Importing: GUI_Motor001_Cfg.TcVIS from ..\..\..\controllers\motor\Motor\
↪VISUs\Motor\
Importing: GUI_Motor001_Ctrl.TcVIS from ..\..\..\controllers\motor\Motor\
↪VISUs\Motor\
Importing: GUI_Shutter001.TcVIS from ..\..\..\controllers\shutter\Shutter\
↪Shutter\VISUs\
Importing: GUI_IODev001.TcVIS from ..\..\..\controllers\ioDev\IODev\IODev\
↪VISUs\
Importing: GUI_Piezo001.TcVIS from ..\..\..\controllers\piezo\Piezo\Piezo\
↪VISUs\
Importing: GUI_Actuator001.TcVIS from ..\..\..\controllers\actuator\
↪actuator\actuator\VISUs\
Fixing references for: C:\temp\Solutions\plcprj\plcprj\VISUs\GUI_CCS_SIM.
↪TcVIS
Fixing references for: C:\temp\Solutions\plcprj\plcprj\VISUs\GUI_time_info.
↪TcVIS
Fixing references for: C:\temp\Solutions\plcprj\plcprj\VISUs\GUI_MA_ADC.
↪TcVIS
Fixing references for: C:\temp\Solutions\plcprj\plcprj\VISUs\GUI_MA_DROT.
↪TcVIS
Fixing references for: C:\temp\Solutions\plcprj\plcprj\VISUs\GUI_Lamp001.
↪TcVIS
Fixing references for: C:\temp\Solutions\plcprj\plcprj\VISUs\GUI_Motor001_
↪Cfg.TcVIS
Fixing references for: C:\temp\Solutions\plcprj\plcprj\VISUs\GUI_Motor001_
↪Ctrl.TcVIS
Fixing references for: C:\temp\Solutions\plcprj\plcprj\VISUs\GUI_Shutter001.
↪TcVIS
Fixing references for: C:\temp\Solutions\plcprj\plcprj\VISUs\GUI_IODev001.
↪TcVIS
Fixing references for: C:\temp\Solutions\plcprj\plcprj\VISUs\GUI_Piezo001.
↪TcVIS
Fixing references for: C:\temp\Solutions\plcprj\plcprj\VISUs\GUI_
↪Actuator001.TcVIS
Building project...
Linking variables...
```

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```
Fixing C:\temp\Solutions\plcprj\plcprj\PlcTask.TcTTO...
All done!
```

4.5 Testing PLC Application on Windows PC

In this step, the PLC application is open with the TwinCAT IDE and the application is run on the development Windows PC in *Local* mode. Each device can be tested using the generated GUIs.

1. In the Windows Explorer, go to the *C:\Temp\Solutions\plcprj* directory and double-click on *plcprj.sln*. This will start the TwinCAT IDE and open the newly created project.
2. From the *BUILD* pull-down menu, click on *Rebuild Solution*.
3. From the *TWINCAT* pull-down menu, click on *Activate Configuration*. Confirm with 'OK'. When asked "*Restart TwinCAT System in Run Mode*", confirm with *OK*.
4. From the *PLC* pull-down menu, click on *Login*. Confirm with 'OK'.
5. In the TwinCAT *Solution Explorer* window on the left, go to the *VISUs* directory and start the GUIs by double-clicking on each of them. Test each device.

4.6 Customizing PLC Application to match Instrument Project

In this step, the user has to rename (refactor) the instances of controllers/devices in order to match the Instrument SW configuration. Please note that the *Refactor* feature in the TwinCAT IDE is a very powerful, quick and safe tool for renaming all instances of a certain string in the PLC project.

For example, the following renaming will be done in the project:

- Refactor Lamp001 to ThArg.
- Refactor Motor001 to Filter1.
- Refactor Actuator001 to CamPower.
- Rename GUI_Lamp001 to GUI_ThArg.
- etc, etc

4.7 PLC Application deployment to PLC

In this step, the PLC will be deployed to the real PLC with a given name and IP address. From the TwinCAT IDE, the user has to choose the target PLC system. This can be done only if the current target is *Local*.

The procedure is the following:

1. Logout by clicking on the *PLC* pull-down menu and selecting *Logout*.

2. Ensure that the current target system is *<Local>*.
3. Click on *<Local>* and select *Choose Target System. . .* .
4. From the *Choose Target System*, select *Search (Ethernet). . .* .
5. In the *Enter Host Name / IP* field, write the PLC name or the IP and press *Enter*.
6. Select the PLC from the available list and press *Add Route* to connect to the PLC.

After the connection with the PLC has been established, the PLC application can be downloaded to the PLC and tested in simulation.

Once the HW is available, the I/O links with the simulators should be cleared and the mapping should be done with the real HW I/O instead. Unused simulators should be removed from the project.

5 Client Application

The client application (*fcfClient*) is a simple utility allowing to send commands to the *Device Manager* from the command line. In this context we use the words commands and events as synonyms. The fcfClient uses the standard interface module `stdif` and the application interface module `fcfif` to compose the payload of the messages. The *fcfClient* sends the messages using CII MAL request/reply.

```
$ fcfClient <serviceURI> <command> ["<parameters>"]

Where
      <serviceURI> destination of the command (e.g. zpb.rr://127.0.0.1:12081)
      <command>    command to be sent to the server (e.g. Init)
      <parameters> optional parameters of the command.
```

Warning: The URI shall not contain the '/' at the end otherwise the client will hang trying to connect to a non existing server.

5.1 List of Commands

The commands (events) currently supported by the *fcfClient* utility are:

Table 5.1: Client commands

Command	Parameters
Init	“”
Enable	“”
Disable	“”
GetState	“”
GetStatus	“”
Setup	“”
Recover	“”
Reset	“”
GetConfig	“”
DevNames	“”
DevInfo	“”
DevConfig	“<device id>”
DevStatus	“[<device id1>, . . . ,<device idn>]”
SetLogLevel	“<ERROR|INFO|DEBUG|TRACE>”
Simulate	“<device id1>, . . . ,[<device idn>]”
StopSim	“<device id1>, . . . ,[<device idn>]”
Ignore	“<device id1>, . . . ,[<device idn>]”
StopIgn	“<device id1>, . . . ,[<device idn>]”
HwInit	“<device id1>, . . . ,[<device idn>]”
HwEnable	“<device id1>, . . . ,[<device idn>]”
HwDisable	“<device id1>, . . . ,[<device idn>]”
HwReset	“<device id1>, . . . ,[<device idn>]”
StartDaq	“<daq id>”
StopDaq	“<daq id>”
Exit	“”

Warning: Due to the upgrade to CII, the payload of the SETUP command cannot be defined through a JSON file. For sending SETUP and other commands is better to use the Python interface.

Note: The HW commands like HwInit or HwEnable control the state of the controller associated to the device.

5.1.1 Examples

Note: The following examples assume the server is listening for incoming events under the URI zpb.rr://127.0.0.1:12081 in the local host.

Enabling debug level in the server

```
$ fcfClient zpb.rr://127.0.0.1:12081  SetLogLevel "DEBUG"
```

Initialising the server

```
$ fcfClient zpb.rr://127.0.0.1:12081  Init ""
```

Moving the server to Operational state

```
$ fcfClient zpb.rr://127.0.0.1:12081  Enable ""
```

Executing a *Setup* command from the command line

This is not possible in this version using fcfClient utility. Please use the FCF Shell instead.

6 FCF Shell (CLI)

The FCF provides an experimental command shell with commands aiming to simplify the interaction with the Device Manager. The FCF shell can be invoked issuing the command `fcfcli`. The FCF Shell is based on a generic asynchronous shell that it is included in the IFW core libraries.

6.1 Command Line Parameters

The fcfcli offers few command line parameters. If no parameters are specified, the fcfcli will use the default name services and use nomad/consul to obtain the correct IP and port numbers of the Device Manager. The fcfcli shell commands are not necessary using the same names as the MAL interfaces with the purpose to shorten the commands names. This is also because the name of the commands are the name of the class methods in Python. Commands are asynchronous so the shell can continue being used while the answer from the previous command is not yet received.

Parameter	optional	Description
–uri	no	if the URI is specified, the supcli will use it to connect to the server
–name	no	When using nomad, one could specify the name of the service instead of the URI
–module	yes	Custom interface library
–class_name	yes	Custom command class name
–timeout	yes	Timeout for CII MAL requests in ms
–log_level	yes	log level (ERROR, INFO, DEBUG)
–help	yes	Show the usage message

Warning: The fcfcli shell assumes NOMAD/CONSUL services are up and running. If this is not the case then –uri parameter shall be used instead of –name.

Note: The fcfcli shell was created for the Device Manager but since it uses the standard interface, it can be used for any server implementing this interface, although only for the standard events like init, enable, disable, etc.

```
fcfcli --uri zpb.rr://134.171.3.48:30269
fcfSh>?
reply> = Available command list:
 - abortdaq
 - close
 - daqstatus
 - devconfig
```

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```
- devinfo
- devnames
- devstatus
- devstatus_regex
- devtype
...
...
- stopdaq
- switch_off
- switch_on
```

6.2 Shell History

The FCF shells keeps its own history file under $HOME/.fcfSh.txt. The history can be accessed using the arrows keys.

6.3 Shell Completion

The FCF shell provides a completion capability for the supported commands using the Tab key.

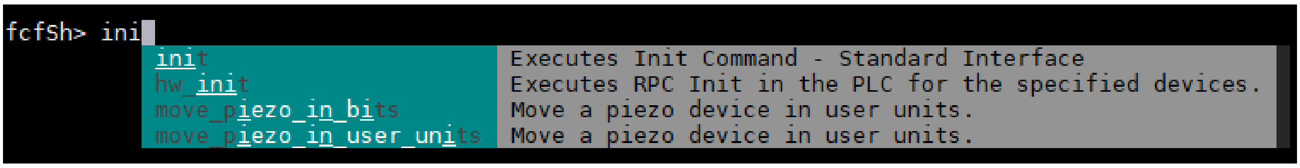

Fig. 6.1: FCF Shell command completion.

The shell completion also gives information about the parameters of each command.

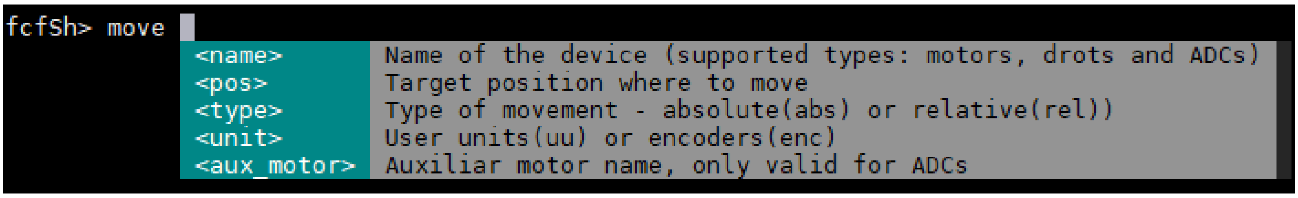

Fig. 6.2: FCF Shell online help of command parameters.

6.4 Supported Shell Commands

Command	Parameters	Description
init		sends the init (stdif) event to the connected server.
enable		sends the enable (stdif) event to the connected server.
disable		sends the disable (stdif) event to the connected server.
reset		sends the reset (stdif) event to the connected server.
stop		sends the stop (stdif) event to the connected server.
recover		sends the recover (fcfif) event to the connected server.
hw_init	<argv>	sends the init directly to the device controllers. The parameter is a variable list of devices.
hw_enable	<argv>	sends the enable directly to the device controllers. The parameter is a variable list of devices.
hw_disable	<argv>	sends the disable directly to the device controllers. The parameter is a variable list of devices.
hw_reset	<argv>	sends the reset directly to the device controllers. The parameter is a variable list of devices.
help		print the list of supported commands
startdaq	<daqid>	Start DAQ acquisition
abortdaq	<daqid>	Abort DAQ acquisition
daqstatus	<daqid>	Get DAQ acquisition status
stopdaq	<daqid>	Stop DAQ acquisition
devnames		Get the list of devices managed by the server
devinfo		Get the list of devices managed by the server with their respective types.
devstatus	<argv>	Get the status of all devices managed by the server.
devstatus_regex	<pattern>	Get the status of all devices managed by the server and it applies a filter using regular expressions. The output to be included in the reply is the one matching the pattern.
devconfig	<device>	Get the actual configuration of a device (yaml formatting)
devtype	<device>	Get the associated type of the device
simulate	<device>	sends the simulate event to the connected server
stop_simulate	<device>	sends the stopsim event to the connected server
ignore	<device>	sends the ignore event to the connected server
stop_ignore	<device>	sends the stopign event to the connected server
setup_json_file	<file>	The setup commands uses a JSON file to set run-time parameters. The contents of the JSON file shall match the defined schema.

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Table 6.1 – continued from previous page

Command	Parameters	Description
setup_json_string	<JSON string>	The setup commands uses a JSON format to set run-time parameters. The JSON string shall match the defined schema.
setup_spf	<string>	The setup commands uses a simple format to specify the parameters to be changed. Examples: setup_spf 'shutter1:action=”OPEN”' setup_spf 'lamp1:action=”ON”, actuator1:action=”OFF”'
state		sends the GetState (stdif) event to the connected server
status		sends the GetStatus (stdif) event to the connected server
get_config		Get the server configuration (yaml formatting)
close	<shutter device>	It closes a shutter
open	<shutter device>	It opens a shutter
switch_on	<lamp device>	It switch on a lamp or an actuator device
switch_of	<lamp device>	It switch off a lamp or an actuator device
move	<motor>,<pos> [,<type>] [,<unit>] [,<aux_motor>]	It moves a motor to a target position
move_by_name	<motor>,<name>	It moves a motor using a named position
move_by_speed	<motor>,<speed>	It moves a motor in speed
move_by_angle	<motor>,<angle>	It moves a drot by position angle
start_track	<device>,<mode>	It start tracking for using a given mode
stop _track	<device>	It stops tracking
ctrl-d		Stop the shell

6.4.1 using devnames command

```
fcsSh> devnames
reply> = shutter1, lamp1, motor1, drot1, adc1, piezo1
OK
```

6.4.2 using devstatus command

```
fcsSh> devstatus lamp1
reply> = ['lamp1.lcs.state = Operational', 'lamp1.lcs.substate = On', 'lamp1.lcs.
↪intensity = 0.000000', '', 'OK']
fcsSh>
```

6.4.3 using devstatus_regex command

```
fcsSh> devstatus_regex lamp1\.
reply> = lamp1.lcs.state = Operational
lamp1.lcs.substate = Off
lamp1.lcs.intensity = 0.000000

fcsSh>
```

Note: The dot character shall be escaped for the python regular expression matching.

6.4.4 using switch_off command

```
fcsSh> switch_off lamp1
fcsSh> reply> = OK setup completed.
fcsSh>
```

6.4.5 using move command

```
fcsSh> move motor1,50
fcsSh> reply> = OK setup completed.
fcsSh>
```

6.4.6 using setup command

This example uses a test JSON file (test.json).

```
[{
"id": "shutter1", "param": {
    "shutter": {
            "action": "OPEN"
            }
    }
```

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```
},
{
"id": "lamp1", "param": {
    "lamp": {
            "action": "OFF"
            }
    }
},
{
"id": "motor1", "param": {
    "motor": {
        "action": "MOVE_ABS",
        "pos": 50,
        "unit": "UU"
            }
    }
}]
```

```
fcsSh> setup_json_file test.json
fcsSh> reply> = OK setup completed.
fcsSh>
```

```
fcsSh> setup_json_string '[{"id": "shutter1", "param": { "shutter": {"action":
↪"OPEN"}}}]'
fcsSh> reply> = OK setup completed.
fcsSh>
```

```
fcsSh> setup_spf 'shutter1:action="OPEN"'
fcsSh> reply> = OK setup completed.
fcsSh>
```

6.4.7 using DAQ commands

These commands are the implementation of the metadaq interface. For more information, please refer to the ECS Metadaq interface module. These commands shall be executed in sequence. First the start and then the stop.

Note: The FCF requires to be in operational to handle the DAQ commands.

Warning: The FCF requires that the DATAROOT variable is defined to properly create the metadaq files.

```
fcsSh> startdaq science
fcsSh> reply> = science
fcsSh>
```

```
fcfSh> daqstatus science
reply> = id: science
state: DaqState.Acquiring
files: ['/scratch/DATAROOT/fcs1_science_start.fits']
keywords:
fcsSh>
```

```
fcfSh> stopdaq science
reply> = id: science
files: ['/scratch/DATAROOT/fcs1_science_start.fits', '/scratch/DATAROOT/fcs1_
↪science_stop.fits']
keywords:
fcsSh>
```

These FIT files shall be created on disk and they shall contain the FCF metadata information

```
fcfSh> daqstatus science
reply> = id: science
state: DaqState.Succeeded
files: ['/scratch/DATAROOT/fcs1_science_start.fits', '/scratch/DATAROOT/fcs1_
↪science_stop.fits']
keywords:
fcsSh>
```

Note: The FCF python library converts the output from the metadaq commands to strings such that the users can easily understand it from a shell.

7 FCF Python Client Library

It is possible to communicate with the *Device Manager* through clients developed in Python. The FCF provides a library that simplifies the interaction with the Device Manager (`clib`). This is probably the more flexible way to interact with the Device Manager. The clib encapsulates the creation of the payload for the Setup command by providing predefined methods.

Users might want to interact directly with the server through the FCF ICD binding methods. This is, of course possible, but it is outside the scope of this library.

Note: This Python client library was added in version 2.

7.1 Error Handling

The `clib` reports as a RuntimeError exceptions that may be delivered by the Device Manager.

7.2 Classes

The `clib` library provides internal classes to build the buffer for each device. In addition, this library provides one class that encapsulates the user interface with the DeviceManager. This class is the DevmgrCommand class. The `clib` also provides an asynchronous version of the same class (DevmgrAsyncCommands) which does exactly the same but it implements coroutines.

7.2.1 DevmgrCommand

The constructor of the DevmgrCommand class support four parameters: uri, timeout, and setup_obj.

Parameter	Description
uri	This is URI of the device manger.
timeout	The timeout is optional and has a default of one minute, expressed in milliseconds. default: 60000[ms]
setup_obj	Dedicated setup object used when sending setup of multiple devices. By using a custom setup buffer object, users can implement more complex setups. default: None

Unless the setup_obj is provided, the class handles an internal buffer object that is used to build the payload of the Setup command. Each time the command is executed, the buffer is reset. The user can add multiple device settings into the internal buffer before executing the setup command.

The methods names of the class are shown in the tables below. They try to be self explanatory.

7.2.2 Public Methods for building Setup Payload

Method	parameters
close	device (string)
open	device (string)
switch_on	device (string), intensity (float) and timer (integer).
switch_off	None
move	device (string), position (float), type (string), unit (string) and aux_motor (string)
move_by_name	device (string), namepos (string)
move_by_speed	device (string), speed (float)
move_by_posangle	device (string), angle (float) ONLY for derotators.
start_track	device (string), mode (string)
stop_track	device (string)
move_piezo_in_user_units	device (string)
move_piezo_in_bits	device (string)
setup_spf	spf_buffer (string), keep (bool)
setup_json_file	json_file (string), keep (bool)
setup_json_string	json_str (string), keep (bool)

7.2.3 Methods for Command Interface

Method	parameters
devstatus	device list (argv)
devstatus_regex	pattern (string)
devconfig	device (string)
devnames	None
devinfo	None
devtype	device (string)
ignore	device list (argv)
simulate	device list (argv)
stop_ignore	device list (argv)
stop_simulate	device list (argv)
hw_init	device list (argv)
hw_enable	device list (argv)
hw_disable	device list (argv)
hw_reset	device list (argv)
state	None
status	None
get_config	None
init	None
enable	None
recover	None
disable	None
reset	None
stop	None
startdaq	id (string)
stopdaq	id (string)
abortdaq	id (string)
daqstatus	id (string)
setloglevel	level (string), logger (string)

7.3 Examples

7.3.1 Retrieving the Status

```
import ifw.fcf.clib.devmgr_commands as fcs

uri = "zpb.rr://127.0.0.1:12081"
fcsif = fcs.DevMgrCommands(uri)
print(fcsif.devstatus())
```

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```
['shutter1.simulated = true', 'shutter1.lcs.state = Undefined', 'shutter1.lcs.
↪substate = Undefined',
'lamp1.simulated = true', 'lamp1.lcs.state = Undefined', 'lamp1.lcs.substate =␣
↪Undefined',
'lamp1.lcs.intensity = 0.000000', 'motor1.simulated = true', 'motor1.lcs.state =␣
↪Undefined',
'motor1.lcs.substate = Undefined', 'motor1.lcs.pos_target = 0.000000',
'motor1.lcs.pos_actual = 0.000000', 'motor1.lcs.vel_actual = 0.000000',
'motor1.lcs.axis_enable = false', "motor1.pos_actual_name = ''",
'motor1.pos_enc = -2147483648', '', 'OK']
```

7.3.2 Executing a single *Setup*

```
import ifw.fcf.clib.devmgr_commands as fcs

uri = "zpb.rr://127.0.0.1:12081"
fcsif = fcs.DevMgrCommands(uri)
# Move single motor1 to absolute position 100 in user units
# Fill the internal setup buffer
fcsif.move("motor1", 100)
```

7.3.3 Using a custom buffer object

```
import ifw.fcf.clib.devmgr_commands as fcs
import ifw.fcf.clib.setup_buffer as sbuf

uri = "zpb.rr://127.0.0.1:12081"
fcsif = fcs.DevMgrCommands(uri)
buffer = sbuf.SetupBuffer(fcsif._cii)
buffer.add_shutter_open("shutter1")
buffer.add_lamp_switch_on_with_intensity("lamp1", 50)

# Performs the setup with the custom buffer object
fcsif._setup(buffer)
```

7.3.4 Using a custom buffer object with JSON files and SPF strings

In this case, it is loaded first a JSON file with the initial settings. Then, one setting is overwritten. At last, one additional setting is added to the buffer before it is sent to the server.

```
import ifw.fcf.clib.devmgr_commands as fcs
import ifw.fcf.clib.setup_buffer as sbuf

```

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```
uri = "zpb.rr://127.0.0.1:12081"
fcsif = fcs.DevMgrCommands(uri)

# Get list of devices and their types from the server. This is needed when using␣
↪SPF format
# and custom setup buffers.
fcsif._init_devtype()

# initialise setup buffer object
buffer = sbuf.SetupBuffer(fcsif._cii)

# Load json file
buffer.add_json_file(myfile.json)

# Overwrite some contents using SPF
buffer.add_spf_string('motor1:action="MOVE_ABS",motor1:pos=30', fcsif._devtypes)

# extending the buffer with a new setting using SPF
buffer.add_spf_string('actuator1:action="ON"', fcsif._devtypes)

# Convert from JSON to CII
buffer.json2object()

# Performs the setup with the custom buffer object
fcsif._setup(buffer)
```

8 JSON Schema

JSON is used to compose the payload of the setup command. To minimize possible errors, the client python library validates the payload against a defined schema before sending the command to the server. The FCF provides a schema that covers all standard devices. Instrument implementing custom devices shall extend this schema definition.


```
{
  "$schema": "http://json-schema.org/draft-07/schema#",
  "type": "object",
  "title": "FCF schema",
  "type": "array",
  "items": {
    "type": "object",
    "properties": {
      "id": {
        "type": "string",
        "description": "device identifier."
      },
      "param": {
        "$ref": "#/definitions/param"
      }
    }
  },
  "definitions": {
    "param": {
      "type": "object",
      "properties": {
        "shutter": {
          "$ref": "#/definitions/shutter"
        },
        "actuator": {
          "$ref": "#/definitions/actuator"
        },
        "lamp": {
          "$ref": "#/definitions/lamp"
        },
        "motor": {
          "$ref": "#/definitions/motor"
        },
        "drot": {
          "$ref": "#/definitions/drot"
        },
        "adc": {
          "$ref": "#/definitions/adc"
        },
        "piezo": {
          "$ref": "#/definitions/piezo"
        }
```


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```
      },
      "oneOf": [
                { "required":
                     [ "shutter" ] },
                { "required":
                     [ "actuator" ] },
                { "required":
                     [ "lamp" ] },
                { "required":
                     [ "motor" ] },
                { "required":
                     [ "drot" ] },
                { "required":
                     [ "adc" ] },
                { "required":
                     [ "piezo" ] }
                ]
    },
    "shutter": {
      "type": "object",
      "properties": {
        "action": {
          "type": "string",
          "enum": ["OPEN", "CLOSE"],
          "description": "Shutter action."
        }
      },
       "required": ["action"]
    },
     "actuator": {
      "type": "object",
      "properties": {
        "action": {
          "type": "string",
          "enum": ["ON", "OFF"],
          "description": "Actuator action."
        }
      },
       "required": ["action"]
    },
    "lamp": {
      "type": "object",
      "properties": {
        "action": {
          "type": "string",
          "enum": ["ON", "OFF"],
          "description": "Lamp action."
        },
        "intensity": {
```


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```
          "type": "number",
          "minimum": 1,
          "maximum": 100,
          "description": "Lamp intensity."
        },
        "time": {
          "type": "integer",
          "minimum": 1,
          "description": "Lamp timer."
        }
      },
      "required": ["action"],
      "additionalProperties": false
    },
    "motor": {
      "type": "object",
      "properties": {
        "action": {
          "type": "string",
          "enum": ["MOVE_ABS", "MOVE_REL", "MOVE_BY_NAME", "MOVE_BY_SPEED"],
          "description": "Motor action."
        },
        "pos": {
          "type": "number",
          "description": "Motor position in user units."
        },
        "enc": {
          "type": "integer",
          "description": "Motor position in encoders."
        },
        "unit": {
          "type": "string",
          "enum": ["UU", "ENC"],
          "description": "Motor position unit."
        },
        "name": {
          "type": "string",
          "description": "Motor named position."
        },
        "speed": {
          "type": "number",
          "description": "Motor speed."
        }
      },
      "required": ["action"]
    },
    "drot": {
       "allOf": [{ "$ref": "#/definitions/motor" }],
      "properties": {
```

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```
        "action": {
          "type": "string",
          "enum": ["MOVE_ABS", "MOVE_REL", "MOVE_BY_NAME", "MOVE_BY_SPEED",
↪"MOVE_BY_POSANG", "START_TRACK", "STOP_TRACK"],
          "description": "Drot action."
        },
        "posang": {
          "type": "number",
          "description": "Motor position angle."
        },
         "mode": {
          "type": "string",
          "enum": ["ENG", "STAT", "SKY", "ELEV", "USER"],
          "description": "Drot mode."
        }
      },
      "required": ["action","mode"]
    },
    "adc": {
      "allOf": [{ "$ref": "#/definitions/motor" }],
      "properties": {
        "action": {
          "type": "string",
          "enum": ["MOVE_ABS", "MOVE_REL", "MOVE_BY_NAME", "MOVE_BY_SPEED",
↪"MOVE_BY_POSANG", "START_TRACK", "STOP_TRACK"],
          "description": "Adc action."
        },
        "posang": {
          "type": "number",
          "description": "Motor position angle."
        },
        "axis": {
          "type": "string",
          "enum": ["ADC1", "ADC2"],
          "description": "Adc axis."
        },
         "mode": {
          "type": "string",
          "enum": ["ENG", "OFF", "AUTO"],
          "description": "Adc mode."
        }
      },
      "required": ["action","mode"]
    },
    "piezo": {
      "type": "object",
      "properties": {
        "action": {
          "type": "string",
```

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```
          "enum": ["SET_AUTO", "SET_POS", "SET_HOME", "MOVE_ALL_BITS", "MOVE_ALL_
↪POS"],
          "description": "Piezo action."
        },
        "pos1": {
          "type": "number",
          "description": "Piezo position 1 in volts."
        },
        "pos2": {
          "type": "number",
          "description": "Piezo position 2 in volts."
        },
        "pos3": {
          "type": "number",
          "description": "Piezo position 3 in volts."
        },
        "bit1": {
          "type": "integer",
          "description": "Piezo position 1 in bits."
        },
        "bit2": {
          "type": "integer",
          "description": "Piezo position 2 in bits."
        },
        "bit3": {
          "type": "integer",
          "description": "Piezo position 3 in bits."
        }
      },
      "required": ["action"]
    }
  }
}
```

9 Simple Parameter Format (SPF)

This is a custom format used to express the parameters for the setup command in an easy a simple way for users. You can include multiple parameters for one or more devices. The FCF client library will take this format and translate it to JSON internally to be able to check whether the syntax is correct before submitting the command to the server.

The format has the following syntax:

```
<device>:<parameter>=<value>[,<device>:<parameter>=<value>]...[,<device>:
↪<parameter>=<value>]
```

The FCF client library provides a method where you can setup the FCF using a string with this format (setup_spf). For more information, see client interface description above.

```
fcsSh> setup_spf 'shutter1:action="OPEN",lamp1:action="ON",lamp1:intensity=80'
fcsSh> reply> = OK setup completed.
fcsSh>
```

Note: The parameter for the setup_spf command shall be enclosed as string (‘’) to avoid issues parsing the commas.

10 Device Simulator

The FCF SDK provides a small Python base application to implement Device Simulators on the WS, for short: DevSim. These Device Simulators emulate the PLC sufficiently well to be able to carry out the basic operations of the device. This makes it possible to carry out a integration test of the instrument software, without the availability of a 'physical' PLC or HW. This is useful, e.g. for autonomous tests, running during in Jenkins, and, of course, during development, where it may be more efficient to test/debug against a local process, rather than a PLC; maybe a PLC is not even always available.

The FCF Device Simulators implement the same state machine as is implemented on the PLC. Moreover the OPC UA interface (namespace), is the same, at least for what concerns the nodes, essential for controlling and monitoring the PLC device from the FCF Device Manager.

The Device Simulators load the SCXML state machine model and the OPC UA namespace profile at start-up and configures themselves accordingly.

It is possible to implement customised business logic for each Device Simulator, to achieve a simulation, accurate enough to do the development and test of the WS Device Manager.

For each Special Device, implemented for an instrument, an FCF Device Simulator shall be provided, in addition to the WS Device Manager and PLC device code.

It may be useful, to start the implementation of a new device by implementing **first** the Device Simulator, and **then** use this during the implementation of the Device Manager, because it is easier to control a local application than an application running on a PLC and some device operations may be executed faster by the Device Simulator compared to executing them on the PLC.

The following standard Device Simulators are provided:

- Actuator
- ADC
- CCC
- DROT
- Lamp
- Motor
- Piezo
- Sensor
- Shutter

If support for new types of devices is added, the associated Device Simulators will be provided.

10.1 Device Simulator - Command Line Options

A Device Simulator accepts the following command line options (example):

```
$ fcfDevsimShutter --help
usage: fcfDevsimShutter [-h] --port PORT --cfg CFG [--use-ext-ip]
                        [--log-level LOG_LEVEL]
                        [--log-file LOG_FILE] [--verbose]

Device Workstation Simulator

optional arguments:
  -h, --help            show this help message and exit
  --port PORT           server port number
  --cfg CFG             configuration
  --use-ext-ip          use the external IP address of deployment host
  --log-level LOG_LEVEL
                        set log level (CRITICAL, ERROR, WARNING, INFO, DEBUG)
  --log-file LOG_FILE   log output file
  --verbose             output log on stdout
```

Option: "cfg":

YAML based configuration. The general part and specific part for each DevSim is described below.

Option: "use-ext-ip":

By default, a Device Simulator uses the loop-back IP address (127.0.0.1). This means that is it only possible to reach it from within the local host. To make the Device Simulator available on the network, use this option to make it serve on the external IP address.

10.2 Device Simulator - Base Application

A Device Simulator is derived from the base class fcf_devsim_lib.device_simulator_base.DeviceSimulatorBase[14]

At this point, there is no way to generate the Python source files for a Device Simulators, so the files must be prepared by hand. It is suggested to copy the source files of one of the existing Device Simulators, and adapt them.

As example, the Lamp Device Simulator could be used. It is structured such that there is a library part, which could be re-used to implement other Device Simulators, with similar properties and the specific part, which is also the deployment module:

[14] https://gitlab.eso.org/ifw/ifw-fcf/-/blob/master/devsim/lib/src/fcf_devsim_lib/device_simulator_base.py

- Lamp DevSim Defines[15].
- Lamp DevSim Library[16].
- Standard Lamp DevSim Deployment Module[17].

10.3 Generation of the SCXML State Machine Model

At this point in time, there is no way to share the same SXCML definition between the PLC and the associated DevSim. The SCXML state chart can be generated from the MagicDraw state machine chart, in which the proper COMODO stereotypes have been applied. For instructions for how to create the SCXML definition, using MagicDraw and COMODO, consult the RAD User Manual. Alternatively, the SCXML state chart document, can be created by hand, by means of a text editor or an XML editor. An example of the SCXML chart for the Lamp Device can be accessed here[18] (generated from the MagicDraw model, using COMODO).

10.4 Generation of the OPC UA Namespace Profile

To facilitate generating the OPC UA XML namespace profile, a simpler and more compact format has been defined, based on YAML. An example of such a (source) YAML Namespace Definition can be accessed here: Standard Lamp Device YAML Namespace Definition[19].

Although the format of the YAML Namespace Definition is self-explicatory, here a few comments:

Left/right Columns:

The right column as an 'internal name', which may be used internally in the implementation of the Device Simulator code, but not necesarily. The right column is the name in the PLC namespace, the HW address. It is possible to define a specific data type for a name, by adding it in parentheses after the name, e.g. "StatCounter: stat.nCounter(UInt32)" (see list of supported types below). Default mapping of data types:

- "b<name>" -> Boolean.
- "n<name>" -> Int32.
- "lr<name>" -> Float.
- "s<name>" -> String.

The complete path is created by prepending "MAIN." + <device name>, e.g. "Lamp1" + the HW address. An example of a complete name, as generated in the OPC UA namespace profile is, e.g.:

[15] https://gitlab.eso.org/ifw/ifw-fcf/-/blob/master/devsim/lamp/src/fcf_devsim_lamp/defines.py
[16] https://gitlab.eso.org/ifw/ifw-fcf/-/blob/master/devsim/lamp/src/fcf_devsim_lamp/lamp.py
[17] https://gitlab.eso.org/ifw/ifw-fcf/-/blob/master/devsim/lamp/src/fcfDevsimLamp.py
[18] https://gitlab.eso.org/ifw/ifw-fcf/-/blob/master/devsim/lamp/resource/config/fcf/devsim/lamp/lamp.scxml.xml
[19] https://gitlab.eso.org/ifw/ifw-fcf/-/blob/master/devsim/lamp/resource/config/fcf/devsim/lamp/lamp.namespace.yaml

“ns=4;s=MAIN.Shutter1.stat.sStatus”

The “ns=4” indicates OPC UA namespace 4. For the moment, the convention is to use namespace 4. The “s=” that it is a string node ID, as opposed to an integer node ID. The “MAIN” is a convention, decided for the ELT ICS PLC code. Both namespace and the “MAIN” prefix may be made configurable, if necessary.

RPC Method Calls:

RPC method calls are defined as:

Rpc<Operation>: rpc.<Operation>([I:<Variable>(<type>)][,] O:<Variable>(<type>)])

whereby “I:” means input variable and “O:”, imaginatively, output value. The following types are supported:

- Boolean
- SByte
- Byte
- Int16
- UInt16
- Int32
- UInt32
- Int64
- UInt64
- Float
- Double
- String
- DateTime
- ByteString

The “coreGenOpcuaProfile” tool, is invoked as follows on the YAML Namespace Definition:

```
$ coreGenOpcuaProfile --device Shutter3 --name-mapping shutte.namespace.yaml
<?xml version="1.0" encoding="utf-8"?>
<UANodeSet xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
           xmlns:uax="http://opcfoundation.org/UA/2008/02/Types.xsd"
           xmlns="http://opcfoundation.org/UA/2011/03/UANodeSet.xsd"
           xmlns:xsd="http://www.w3.org/2001/XMLSchema">
```

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```
<NamespaceUris>
  <Uri>http://www.eso.org/xmlShutter3/</Uri>
</NamespaceUris>

<UAObject NodeId="ns=1;s=PLC1" BrowseName="1:PLC1">
  <DisplayName>PLC1</DisplayName>
  <References>
    <Reference ReferenceType="HasTypeDefinition">i=58</Reference>
    <Reference ReferenceType="Organizes">ns=4;i=20737</Reference>
    <Reference ReferenceType="Organizes" IsForward="false">i=85</Reference>
  </References>
</UAObject>
...
```

The output can be piped into a file, used as part of the configuration for the Device Simulator.

Note: DevSim provides a mechanism to generate the OPC UA namespace on-the-fly, in memory, directly from the source YAML definition. This is the recommended way of achieving the OPC UA namespace to automatically use the latest version and to avoid one configuration file (of which there are many. . .).

10.4.1 Example

```
$ fcfDevsimShutter --port 7677 --cfg config/fcf/devsim/shutter/shutter1.cfg.yaml␣
↪--use-ext-ip --log-level DEBUG --verbose
2018-12-04 12:31:52.821:INFO:DevSim:MainThread:deviceSimulatorBase:557:execute:␣
↪Setting up OPC UA server ...
Listening on 134.171.2.213:7577
2018-12-04 12:31:54.411:INFO:DevSim:MainThread:deviceSimulatorBase:567:execute:␣
↪Setting up OPC UA server - done
2018-12-04 12:31:54.411:INFO:DevSim:MainThread:deviceSimulatorBase:574:execute:␣
↪Loading configuration: fcf/devsim/devsimShutter/shutter1.yaml
2018-12-04 12:31:54.413:INFO:DevSim:MainThread:deviceSimulatorBase:578:execute:␣
↪Loading OPC UA namespace definition: fcf/devsim/devsimShutter/
↪shutter1Namespace.xml
2018-12-04 12:31:54.484:INFO:DevSim:MainThread:deviceSimulatorBase:582:execute:␣
↪Parsing OPC UA node info
2018-12-04 12:31:54.639:INFO:DevSim:MainThread:deviceSimulatorBase:442:set_node_
↪permissions_: Setting node permissions
2018-12-04 12:31:54.667:INFO:DevSim:MainThread:deviceSimulatorBase:454:install_
↪data_ch_subscr_: Installing data change subscription handlers
2018-12-04 12:31:54.670:INFO:DevSim:MainThread:deviceSimulatorBase:464:install_
↪rpc_methods_: Installing RPC method handlers
2018-12-04 12:31:54.670:INFO:DevSim:MainThread:deviceSimulatorBase:472:install_
↪rpc_methods_: Installing RPC method handler for: self.RPC_GetNamespace
```

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```
...
2018-12-04 12:31:54.673:INFO:DevSim:MainThread:deviceSimulatorBase:472:install_
↪rpc_methods_: Installing RPC method handler for: self.RPC_Init
2018-12-04 12:31:54.673:INFO:DevSim:MainThread:deviceSimulatorBase:499:gen_opcua_
↪state_node_ids_: Generating OPC UA state machine node IDs
2018-12-04 12:31:54.673:INFO:DevSim:MainThread:deviceSimulatorBase:145:init_
↪device_parameters_: Initializing device parameters
2018-12-04 12:31:54.676:INFO:DevSim:MainThread:deviceSimulatorBase:593:execute:␣
↪SCXML state machine model: fcf/devsim/devsimShutter/scxmlShutter.xml
2018-12-04 12:31:54.676:INFO:DevSim:MainThread:stateMachine:62:__init__: Loading␣
↪SCXML model: fcf/devsim/devsimShutter/scxmlShutter.xml
2018-12-04 12:31:54.682:INFO:DevSim:MainThread:stateMachine:73:__init__: Status:
2018-12-04 12:31:54.682:INFO:DevSim:MainThread:deviceSimulatorBase:598:execute:␣
↪Serving ...
2018-12-04 12:31:54.683:INFO:DevSim:MainThread:stateMachine:86:run: Starting␣
↪execution of /home/jknudstr/ROOTS/INTROOT_eltdev26/resource/config/fcf/devsim/
↪devsimShutter/scxmlShutter.xml
2018-12-04 12:31:54.685:INFO:DevSim:MainThread:stateMachine:91:run: Status: On␣
↪On::NotOperational On::NotOperational::NotReady
```

After generating the SCXML definition and OPC UA XML Profile, it is possible to start up the Device Server and connect to the Device Simulator OPC UA server and execute e.g. the provided RPC calls and read/write variables, e.g.:

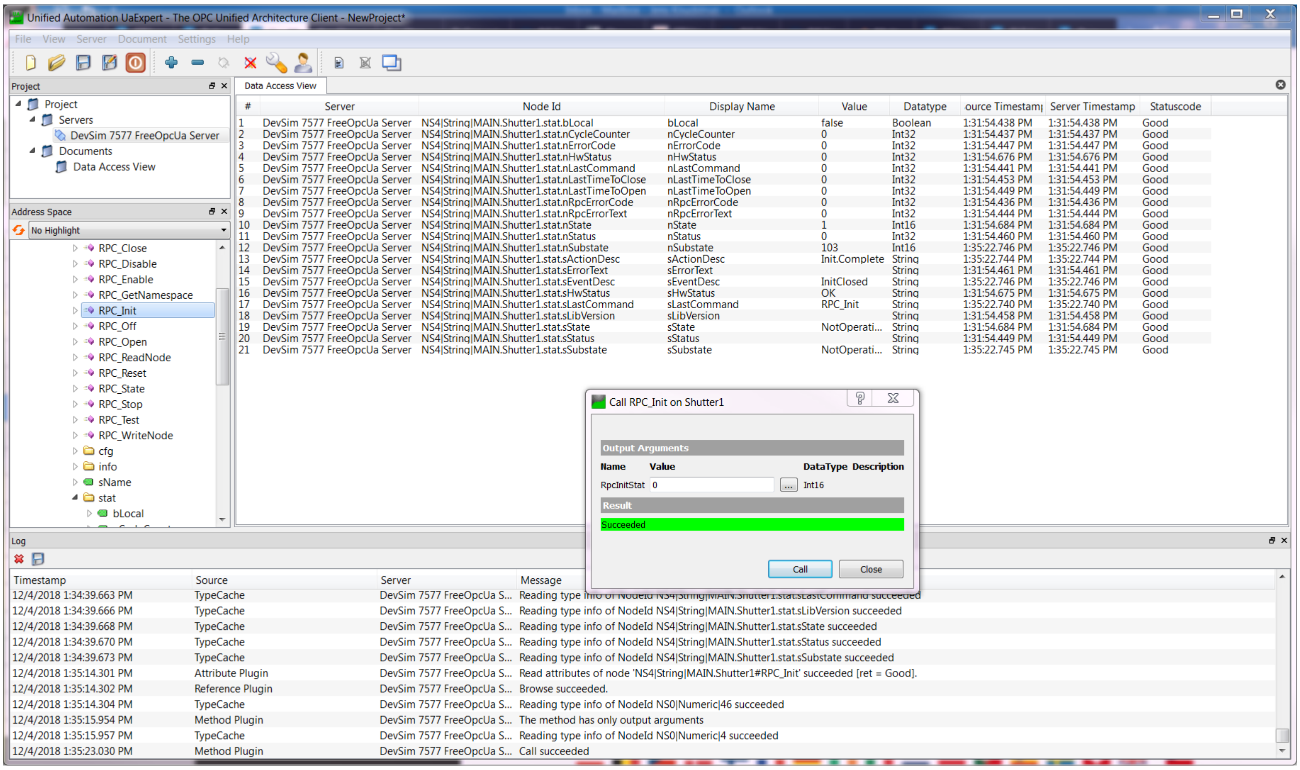

Fig. 10.1: Shutter Device Namespace in UaExpert

10.5 Device Simulators for Standard Devices

This section provides specific details about the various Device Simulators provided for Standard Devices.

Since the Device Simulators are used to emulate the PLC Controllers, they implement the same behavior and therefore, their behavior is described in the PLC section of the FCF user manual and not repeated here. Here only specific properties of the Device Simulators are mentioned.

The following common configuration parameters are supported by all Device Simulators:

Parameter	Type	Description
DeviceName	String	Name of device, e.g. "Lamp1". Needed if the OPC UA namespace is generated from the OPC UA namespace source YAML document.
OpcUaProfile	String	Name of OPC UA Profile XML document, e.g. "config/devsim/lamp/lamp1.namespace.xml" or the OPC UA namespace YAML source definition (preferred option).
StateMachineScxml	String	Name of SCXML definition (document), e.g. "config/fcf/devsim/lamp/lamp.scxml.xml".
CfgSimAcceleration	Float	Factor, which can be used to tune the execution speed of actions in the Device Simulator, globally.
AutoEnterOp	Boolean	Enter Operational State automatically when starting up.
CfgSimDelay	Float	General delay that can be applied when a delay is needed to make the simulation more realistic [s].
CfgLocal	Boolean	Device simulator will emulate Localo Mode at start-up if True.
UpdateFrequency	Float	Frequency for the internal simulation loop (thread) in Hz. Default value is 10 Hz.

Note: In general the Device Simulators do not support 'engineering mode', but are mostly dedicated for the 'common usage', e.g. from Sequencer Templates and standard operation of the instrument software. This means that many 'low level/engineering parameters' and RPC calls are not supported.

10.5.1 ADC Device Simulator

The state machine of the ADC Device Simulator is the same as for the (Standard PLC ADC Device (tracking devices)).

The ADC Device Simulator defines the following configuration parameters:

Parameter	Type	Description
CfgMotor1	String	Configuration for the Motor DevSim for axis 1, e.g. "config/fcf/devsim/adc/adc1Motor1.cfg.yaml".
CfgMotor2	String	Configuration for the Motor DevSim for axis 2.
Motor1Step	Float	Factor applied when calculating the next position for axis 1 for each simulated cycle of the ADC. The higher this factor, the faster the motor moves.
Motor2Step	Float	Factor applied when calculating the next position for axis 2 for each simulated cycle of the ADC. The higher this factor, the faster the motor moves.

Note: The ADC Device Simulator does not support 'engineering mode' and can therefore not be used together with the FCF Python Motor GUI ("pymotgui"). In particular, the following RPC calls are not supported: RPC_MoveAbs, RPC_MoveAngle, RPC_MoveRel, RPC_MoveVel.

10.5.2 DROT Device Simulator

The state machine of the DROT Device Simulator is the same as for the (Standard PLC DROT Device (tracking devices)).

The DROT Device Simulator defines the following configuration parameters:

Parameter	Type	Description
CfgMotor	String	Configuration for the Motor DevSim for internally controlled axis, e.g. "config/fcf/devsim/drot/drot1Motor.cfg.yaml".
MotorStep	Float	Factor applied when calculating the next position for axis for each simulated cycle of the DROT. The higher this factor, the faster the motor moves.

Note: The DROT Device Simulator does not support 'engineering mode' and can therefore not be used together with the FCF Python Motor GUI ("pymotgui"). In particular, the following RPC calls are not supported: RPC_MoveAbs, RPC_MoveAngle, RPC_MoveRel, RPC_MoveVel.

10.5.3 Lamp Device Simulator

The state machine of the Lamp Device Simulator is the same as for the (Standard PLC Lamp Device).

The Lamp Device Simulator defines the following configuration parameters:

Parameter	Type	Description
SimInitTime	Float	Time to spend for the initialisation [s].
CfgCoolDown	Float	Time to spend for the cool-down [s].
CfgInitialState	Boolean	Initial state to assume after enabling the device (True = On).
CfgMaxOn	Float	Maximum time the lamp is allowed to remain switched on [s].
CfgWarmUp	Float	Time spent for the warm-up phase [s].

10.5.4 Motor Device Simulator

The state machine of the Motor Device Simulator is the same as for the (Standard PLC Motor Device).

The Motor Device Simulator defines the following configuration parameters:

Parameter	Type	Description
CfgVelocityError	Float	Simulated error in % to be applied to the simulated velocity.
CfgSimPosError	Float	Simulated positioning error in % to be applied to the simulated position.
CfgSimTolerance	Float	Tolerance to apply for considering simuilated position on target [UU].
CfgSimulated-StartPos	Float	Start position of motor after start-up of application.
CfgScaleFactor	Float	Scale factor to apply for converting between UU and encoder values [UU/enc]
CfgMinPosition	Float	Minimum position [UU].
CfgMaxPosition	Float	Maximum position [UU].
CfgTimeoutInit	Float	Timeout applied during initialisation [s].
CfgTimeoutMove	Float	Timeout applied while moving simulated axis [s].
CfgTime-outSwitch	Float	Timeout applied while moving simulated axis [s].
CfgDisableAfter-Move	Boolean	Disable the current on the simulated axis after completion of a movement.
CfgLocal	Boolean	Indicates Local Mode if True.
CfgDefaultVeloc-ity	Float	Default velocity to apply, e.g. during initialisation [UU/s].

10.5.5 Sensor Device Simulator

The Sensor Device Simulator defines the following configuration parameters:

Parameter	Type	Description
DiCh<i>Value	Boolean	Initial or static value of signal of given channel.
DiCh<i>Function	String	Function, with parameters to be invoked. For now only a square wave generator is provided "di_square_wave(period hi[s], period lo[s])".
AiCh<i>Value	Double	Initial or static user value of signal of given channel.
AiCh<i>Function	String	Function, with parameters to be invoked. For now only a sine wave generator is provided "ai_sine_wave(period[s], scale, offset)".

Note: More simulation functions may be added on request. A future extension may be to allow user provided simulation function on a plug-in basis.

10.5.6 Shutter Device Simulator

The state machine of the Shutter Device Simulator is the same as for the (Standard PLC Shutter Device).

The Shutter Device Simulator defines the following configuration parameters:

Parameter	Type	Description
CfgInitialState	Boolean	Initial state to assume after enabling the device (True = Open).

10.5.7 Piezo Device Simulator

The state machine of the Piezo Device Simulator is the same as for the (Standard PLC Piezo Device).

The Piezo Device Simulator defines the following configuration parameters:

Parameter	Type	Description
CfgInitialState	Boolean	Initial state to assume after enabling the device (True = Open).

10.5.8 Actuator Device Simulator

The state machine of the Actuator Device Simulator is the same as for the (Standard PLC Actuator Device).

The Actuator Device Simulator defines the following configuration parameters:

Parameter	Type	Description
CfgInitialState	Boolean	Initial state to assume after enabling the device (True = Open).

10.5.9 CCC Device Simulator

The CCC (Cabinet Cooling Controller) Device Simulator is a special one since it mimics the contents of the address space embedded in the ESO controller.

The CCC Device Simulator does not define any configuration parameter.

10.6 Developing a Device Simulator

The steps to implement a Device Simulator is as follows:

1. Generate the code of the Device Simulator from the template provided by FCF DevSim (see instructions below).
2. Define the state machine, generate the SCXML state chart document (see instructions above).
3. Define the namespace and OPC UA profile for the Device Simulator (see instructions above).
4. Adopt the code generated in step 1. according to the specific Device Simulator state machine and business logic (see instructions below).
5. Implement the necssary integration test cases to verify the basic functioning of the Device Simulator.

Note, it is important that the Device Simulator developed, emulates the PLC Controller relatively well for it to have a realistic behaviour.

It may not be necessary to implement all features of the PLC Controller, but the features needed to be able to execute the instrument integration tests, and to execute the Templates, both in simulation mode, without the availability of any hardware, shall be provided by the Device Simulator.

10.6.1 Generate the Code of the Device Simulator

The steps to generate the basic code are shown below. After generating the code, it will be necessary to adapt the specific code manually. The template provided is based on the Lamp Device Simulator described elsewhere in this document. After having generated the code for the new Device Simulator, a new instance of the Lamp Device Simulator is obtained as starting point for the development.

The steps to generate the basic code for the new Device Simulator are:

1. Enter the folder in the instrument source tree where the Device Simulator WTOOLS module shall be located.
2. Invoke Cookiecutter on the DevSim template.
3. Add the new Device Simulator module in the “wscript” file, found at the same level, if needed.
4. Build and install the instrument software.
5. Execute the generated Device Simulator.

6. Connect with an OPC UA client, e.g. UA Expert to verify that the Device Simulator is functioning properly.

In the following a live example of how to generate the code, is shown.

```
$ cookiecutter <path to ifw-hl>/fcf/devsim/templates/devsim_tpl/
device_name [device]: mydev
Device_name [Device]: Mydev
package_name [pkg]: mypkg
device_description [This the description of my device]: This is a test Device␣
↪Simulator

$ find mydev/
mydev/
mydev/resource
mydev/resource/config
mydev/resource/config/mypkg
mydev/resource/config/mypkg/devsim
mydev/resource/config/mypkg/devsim/mydev
mydev/resource/config/mypkg/devsim/mydev/mydev.scxml.xml
mydev/resource/config/mypkg/devsim/mydev/mydev1.yaml
mydev/resource/config/mypkg/devsim/mydev/mydev1Namespace.xml
mydev/resource/config/mypkg/devsim/mydev/mydevNamespace.yaml
mydev/src
mydev/src/mypkgDevsimMydev
mydev/src/mypkgDevsimMydev/__init__.py
mydev/src/mypkgDevsimMydev/devsimMydev.py
mydev/src/mypkgDevsimMydev/mydevDefines.py
mydev/src/mypkgDevsimMydev.py
mydev/wscript

# Add "mydev" in the "wscript" file at the same level as the "mydev" module.

$ mypkgDevsimMydev --port 7777 --cfg mypkg/devsim/mydev/mydev1.yaml --use-ext-ip␣
↪--log-level INFO --verbose
2020-02-04 11:53:49.780:INFO:SmOpcUaSrv:MainThread:serverBase:501:execute:␣
↪Setting up OPC UA server ...
Endpoints other than open requested but private key and certificate are not set.
Listening on 134.171.2.213:7777
2020-02-04 11:53:50.955:INFO:SmOpcUaSrv:MainThread:serverBase:512:execute:␣
↪Setting up OPC UA server - done
2020-02-04 11:53:50.955:INFO:SmOpcUaSrv:MainThread:serverBase:519:execute:␣
↪Loading configuration: /home/jknudstr/ROOTS/INTROOT_eltdev26/resource/config/
↪mypkg/devsim/mydev/mydev1.yaml
2020-02-04 11:53:50.957:INFO:SmOpcUaSrv:MainThread:serverBase:524:execute:␣
↪Loading OPC UA namespace definition: mypkg/devsim/mydev/mydev1Namespace.xml
#...
2020-02-04 11:53:51.
↪116:INFO:SmOpcUaSrv:MainThread:mypkgDevsimMydev:34:initialise: Initialising␣
↪Device Simulator
2020-02-04 11:53:51.116:INFO:SmOpcUaSrv:MainThread:devsimMydev:286:initialise:␣
↪Initialising Device Simulator
```

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```
2020-02-04 11:53:51.117:INFO:SmOpcUaSrv:MainThread:devsimMydev:305:initialise:␣
↪Local Mode is: False
2020-02-04 11:53:51.118:INFO:SmOpcUaSrv:MainThread:serverBase:124:initialise:␣
↪Initialising server
2020-02-04 11:53:51.119:INFO:SmOpcUaSrv:MainThread:serverBase:540:execute: SCXML␣
↪state machine model: mypkg/devsim/mydev/mydev.scxml.xml
2020-02-04 11:53:51.125:INFO:SmOpcUaSrv:MainThread:serverBase:545:execute: Time␣
↪for initialising: 1.346s
2020-02-04 11:53:51.125:INFO:SmOpcUaSrv:MainThread:serverBase:546:execute:␣
↪Serving ...
```

Connect to Device Simulator e.g. vie UAExpert. Read/write nodes, execute RPC calls:

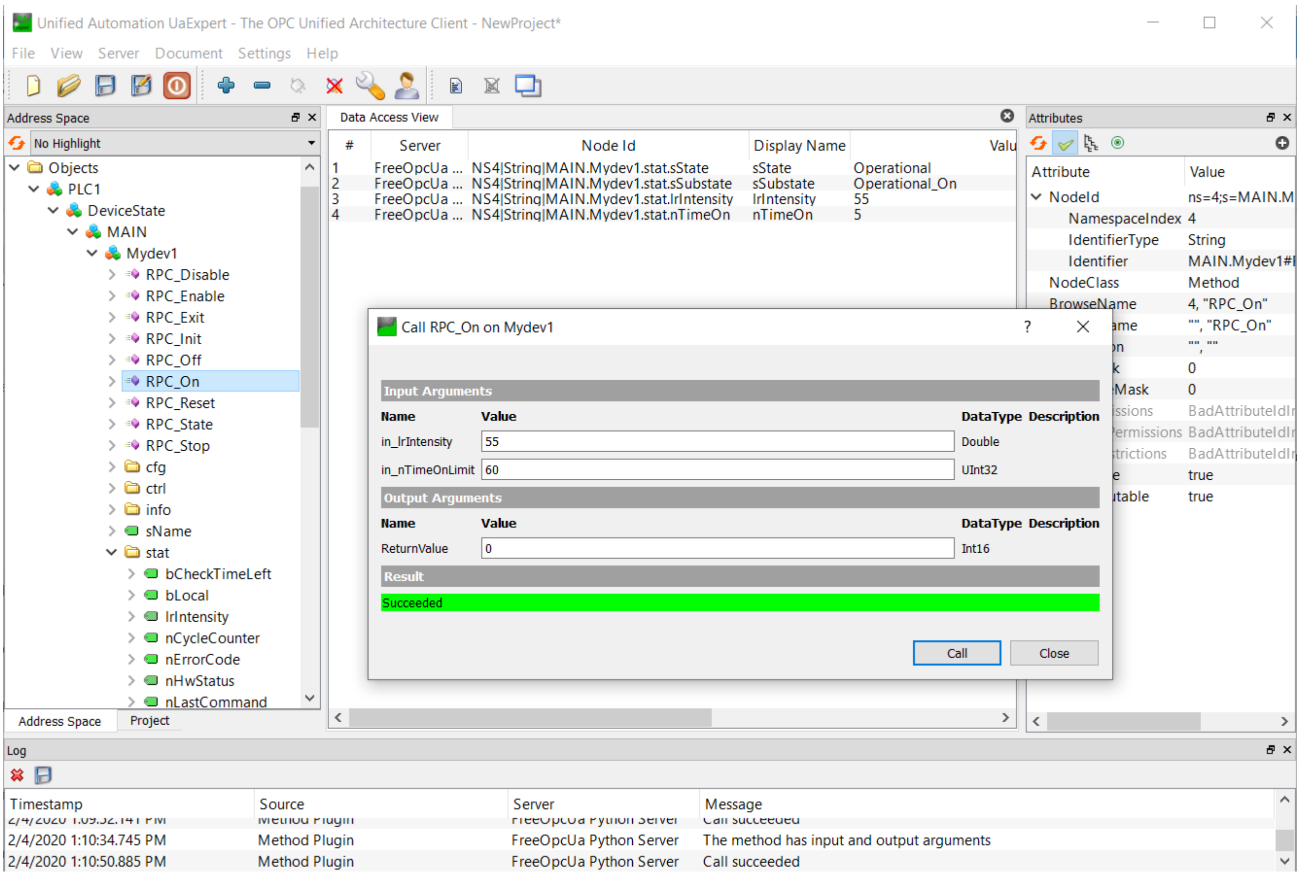

Fig. 10.2: Namespace of generated Device Simulator in UaExpert.

Note, the name “<device>1”, here “Mydev1” is merely a default name. However, often multiple instances of a device will be named e.g. “Motor1”, “Motor2”, etc. This is not a prerequisite though, and a free name may be chosen.

To do this, a new OPC UA Profile, here “mydev/resource/config/mypkg/devsim/mydev/mydev1.namespace.xml”, must be generated for each instance of the new Device Simulator deployed if a pre-generated OPC

UA namespace is used. It is possible to change the name in the OPC UA Profile using the tool “tooReplace”. It is recommended to reference the OPC UA source namespace (YAML) from the DevSim configuration, if possible.

In addition a configuration shall be prepared (here “mydev/resource/config/mypkg/devsim/mydev/mydev1.yaml”)

10.6.2 Adapt the Generated Code of the Device Simulator

In this section some guidelines for implementing the specific code of the new Device Simulator are provided.

When executing Cookiecutter, the following Python source files are generated:

1. A source file containing constant declarations, mostly the constants defined in the PLC code (here “mydev/src/mypkgDevsimMydev/defines.py”).
2. The actual Device Simulator source code (various classes implementing the logic of the simulator; here “mydev/src/mypkgDevsimMydev/mydev.py”).
3. The instantiation of the Device Simulator, generating the executable (here “mydev/src/mypkgDevsimMydev.py”).

In the following the source files mentioned in the points 2. and 3. above are described in more details.

Device Simulator Class File (here “mydev/src/mypkgDevsimMydev/devsimMydev.py”):

The Device Simulator Class file contains the following main parts:

1. The classes implementing the Activities of the State Machine Chart. These are running in threads in the simulator. Example “Class ActivityInitialising()”.
2. The Action Manager Class (“class ActionMgr”), which defines the actions implemented by the Device Simulator and creates and registers the Activity Classes in the SCXML Engine.
3. The Device Simulator Class implementing the logic of the simulator. In the example above “class DevsimMydev()”. This shall be derived from the base class “devsimBase.DeviceSimulatorBase”. The Device Simulator Class provides the following methods to initialise the simulator and implementing the behaviour:

   3.1. The constructor defining basic properties of the simulator, defining a mapping between the textual and numerical representation of the states defined and defining/instantiating/initialising other members of the simulator class.

   3.2. An “initialise()” method which starts the Simulation Thread (see below) and sets initial valus for various parameters in the OPC UA namespace, either from the configuration or constant values.

   3.3. The Simulation Thread (“sim_thr_user()”), which can be used to implement dynamic behaviour of the simulator, e.g. for a tracking device, simulating that it is tracking.

   3.4. A callback function, which is invoked when changes are introduced in the OCP UA namespace in the simulator (“data_change_handler()”).

3.5. The methods implementing the RPC calls of the OPC UA interface.

In order to read and write from/to the internal OPC UA namespace, the methods “<simulator class>.read_node()” and “<simulator class>.write_node()” can be used.

Device Simulator Instantiation (here “mydev/src/mypkgDevsimMydev.py”):

The Device Simulator Instantiation source file contains the main function to start up and execute the simulator server process.

In the template an option is provided to implement specific behaviour at instatiation level. If not used, the class definition contained in the instantiation source file, may be omitted.

11 Engineering Interfaces

11.1 Device Manager GUI

The *Device Manager* provides an engineering interface that enables an easy control and monitor of the devices managed by the server. Each device type has a dedicated widget and the list of widgets is built reading the configuration at startup. Devices can be controlled individually using the *Setup* button within each device widget or collectively using the *Setup* button at the top right of the GUI.

Note: The menu *FCS* enables to control the main states of the server. The server can be also restarted from this menu.

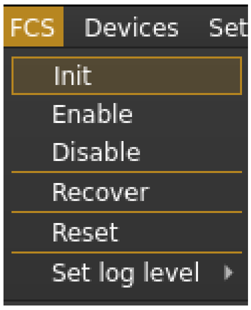

Fig. 11.1: *FCF* menu.

Note: The menu *Devices* enables to control directly one or more device controllers running in the PLC. Devices can be either ignored or simulated as well from this menu.

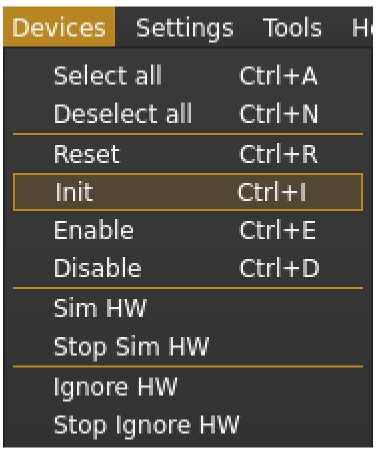

Fig. 11.2: *Devices* menu.

At the bottom, a command window is included reporting the commands sent and the replies received by the GUI.

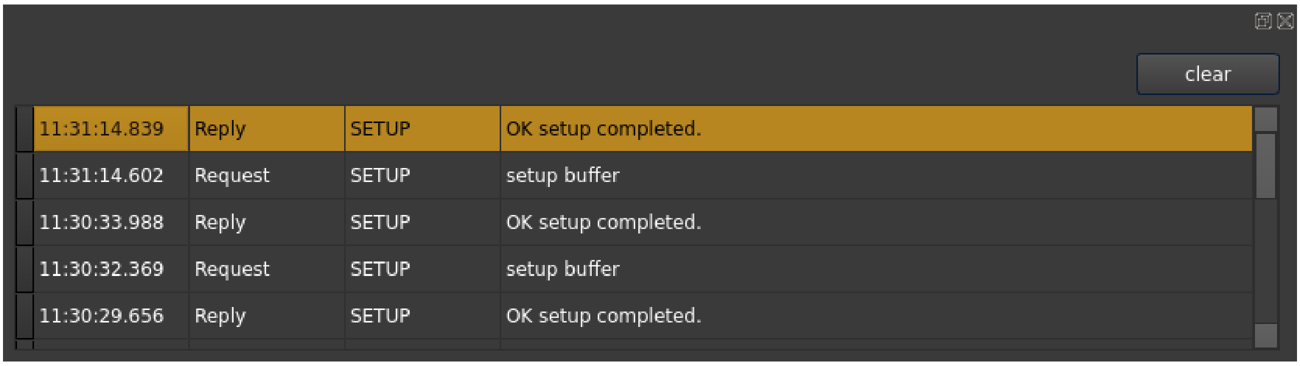

Fig. 11.3: Command window widget.

The GUI does not prevent the execution of parallel *Setup* commands. This is achieved by creating a new thread per each command.

```
$ fcfGui -h
Usage: fcfGui [options]
Description: This is the generic FCF GUI

Options:
-h, --help                                              Displays help on␣
↪commandline options.
-u, --uri <uri>                                         Server URI
-l, --loglevel <ERROR|INFO|DEBUG|TRACE>                 Specify Loglevel
-s, --stylesheet-name <Default||Combinear|Diffnes|Takezo> Specify built-in␣
↪stylesheet
-f, --stylesheet-file <stylesheet>                      Specify stylesheet␣
↪file
-p, --pollinterval <500>                                Specify DB polling␣
↪interval (default 500ms)
```

Warning: The GUI gets the configuration directly from the server at start-up. If the server is not running, the GUI will be blocked until getting a timeout.

An example how to start the `fcfgui` from the command line is shown below.

```
$ fcfGui --uri `geturi fcs-req`
```

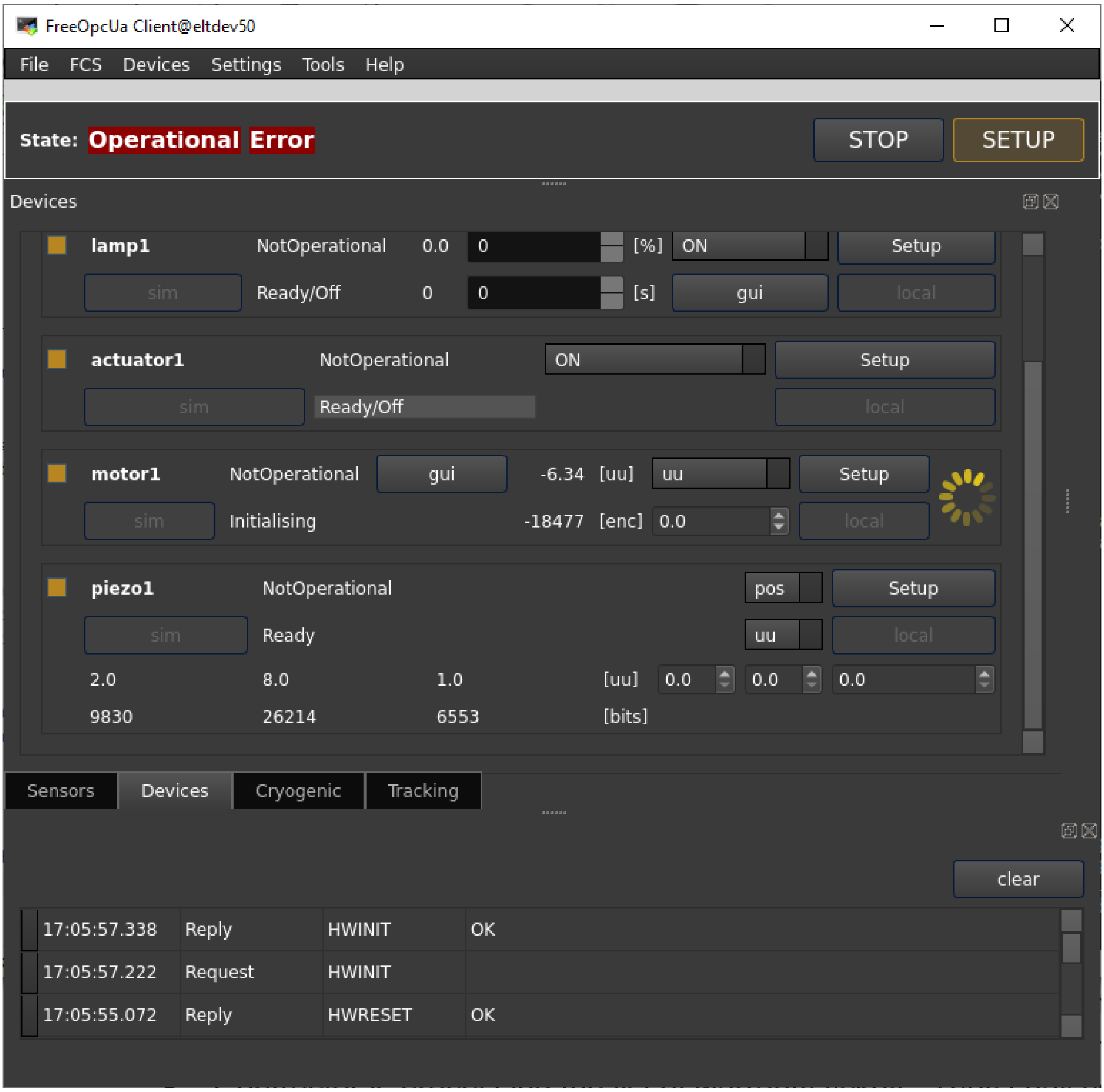

Fig. 11.4: Device Manager Engineering Graphical Interface.

11.1.1 Stylesheets

The GUI in version 4 has been modified to remove most of the hardcoded styles. The look&feel of the GUI can now be defined externally through QT stylesheets. The FCF GUI provides a predefined set of styles that the user could select at the startup through the command option -s. These stylesheets are coming from the site qss-stock (Style Sheets[20]) but they have been slightly modified to include some ESO specifics settings.

THe users can also provide their own QSS files by using the options -f.

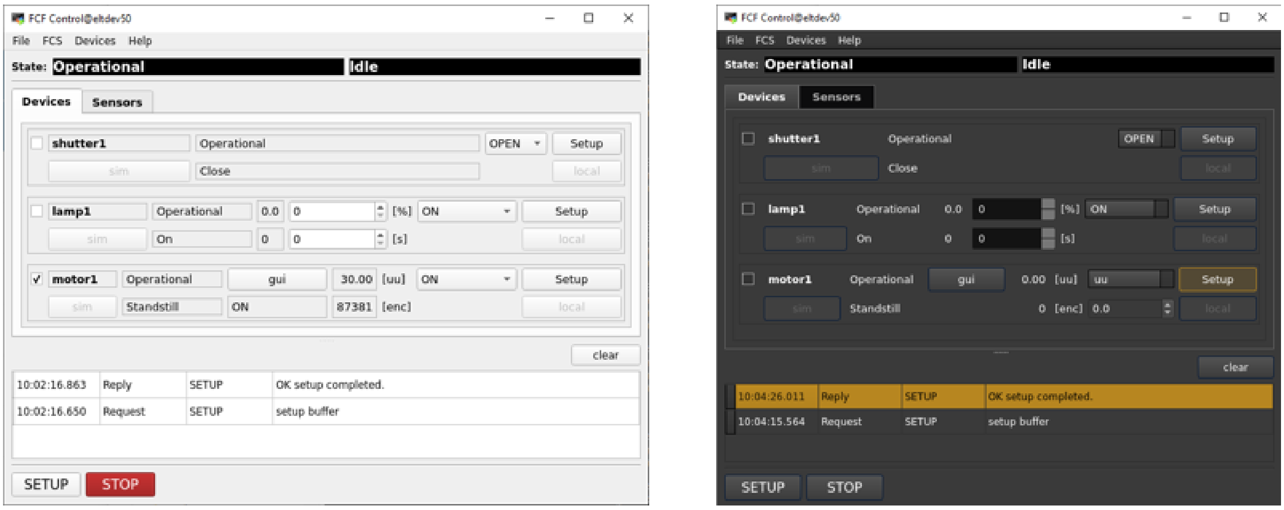

Fig. 11.5: FCS main GUI started with two different styles.

11.1.2 Dock Widgets

The FCF GUI in version 4 has been updated to use of Qt dock widgets. The dock widgets allow the user to arrange the design of the GUI at runtime. Docks widgets can be moved, resized and stacked or even moved outside the main window.

[20] https://qss-stock.devsecstudio.com/

11.1.3 Device Widgets

Device widgets share some common features.

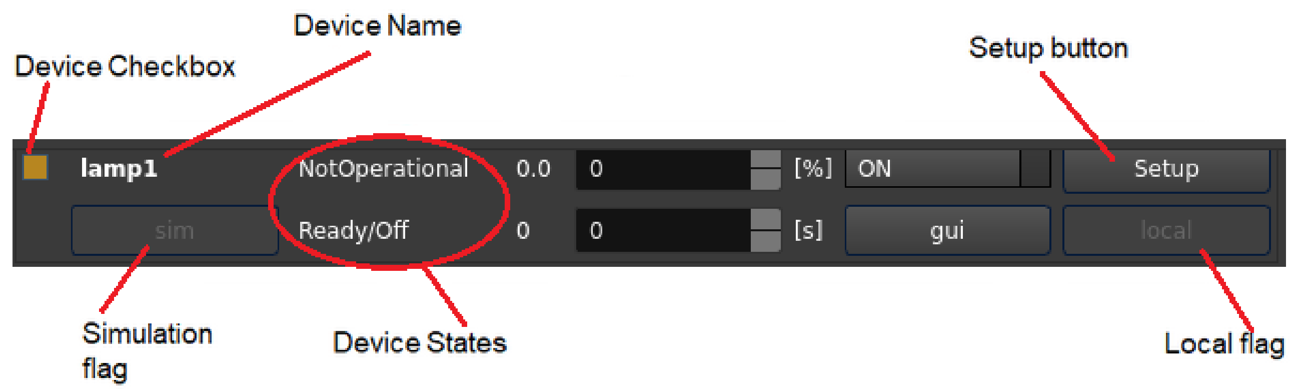

Fig. 11.6: Common Widget Elements.

Selection Check-box

This checkbox shall be used to select/unselect a device. The global Setup button at the bottom is applied only to the selected devices. In the same way, actions in the `Devices` menu are also affecting the selected devices.

Device Name

Here is displayed the name of the device taken from the FCF configuration.

Simulation Flag

This flag indicates when the device is set into simulated. This means that Device Manager will use the simulation address to connect to the device controller.

Local Flag

This flag indicates when the device is set into local mode. Setup actions are rejected by the controllers when they are in local mode.

Device States

These two fields present the state and substate of the controller in the PLC. This information is read by the Device Manager. When Device Manager is not in Ready or Operational state, these values are undefined.

Setup Button

Each device with the exception of sensors can be setup individually from each widget.

Activity Feedback

This is a coloured and spinning feedback allowing the user to have a quick overview of any ongoing activity in the controller associated to the device, for instance if a derotator is tracking, the activity feedback will show it in magenta. This is faster to understand than reading each individual substate. This might be useful during initialisation phase.

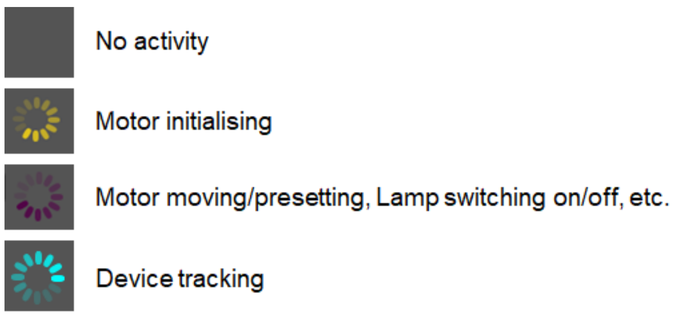

Fig. 11.7: Device activity feedback.

Motor Widget

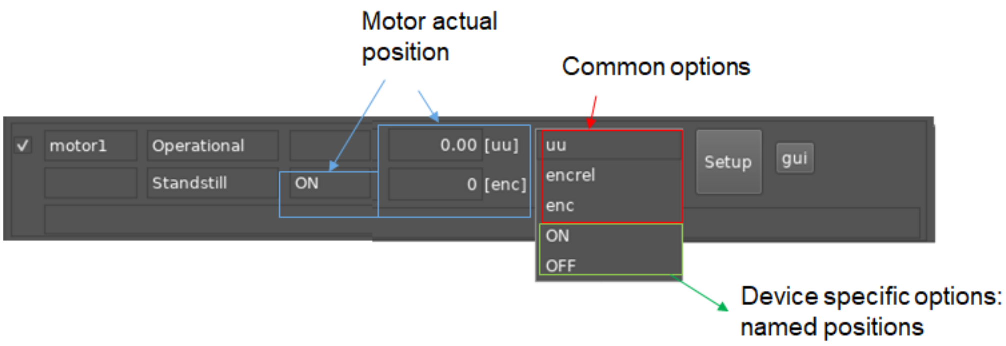

Fig. 11.8: Motor Widget.

The motor widget allows moving a motor in:

1. Absolute user units (uu) and encoders (enc)
2. Relative encoders (encrel)
3. By name positions

Options 1 and 2 are common for all motor widgets while named position (3) may change per motor device. The named positions are read by the widget from the FCF configuration at the startup. The mapping between named positions and user units is done by the Device Manager.

Drot Widget

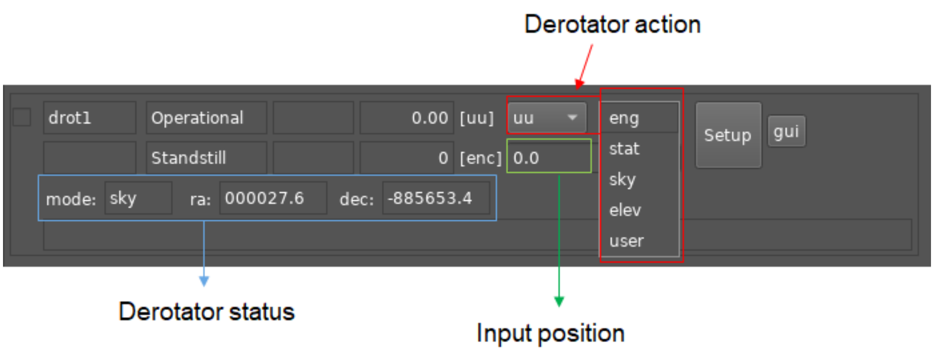

Fig. 11.9: Drot Widget.

The drot widget allows selecting the operation mode and the position angle. There are three tracking modes supported by a drot device: Sky, Elevation (Elev) and User Specific (User). Additionally, a drot device can be controlled as a normal motor by selecting the Engineering mode (eng), this means moving it by user units or encoders.

Adc Widget

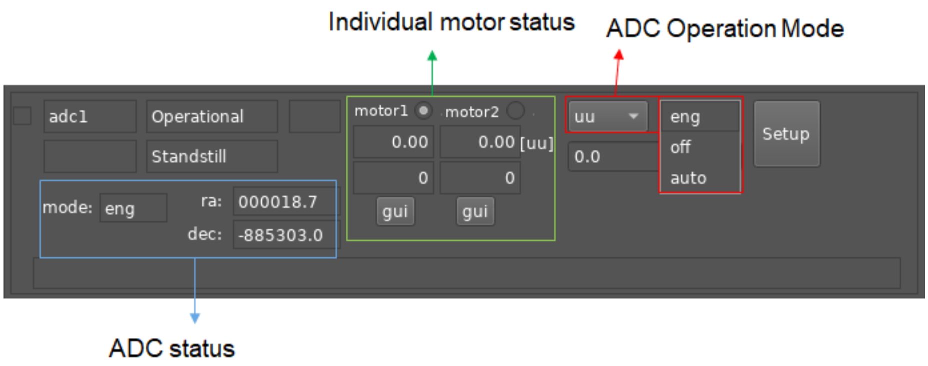

Fig. 11.10: ADC Widget.

The ADC widget allows to control the operation mode of an ADC device. There are two defined modes supported by an ADC: Stationary (off) and Automatic (auto). Additionally, an ADC device can control each individual motor by selecting the Engineering mode (eng). The ADC status reports the actual run-time configuration of the device.

11.2 Motor Engineering GUI

The *Motor* device provides an additional engineering interface offering more details for the control and monitoring of motorized devices (`pymotgui`). With this GUI it is possible to see the motor position or the activation of signals during initialisation. The motor can be controlled in Position or in Velocity mode.

The `pymotgui` can be launched directly from the command line or from each *Motor* widget by pressing the 

button.

```
$ pymotgui
usage: pymotgui [-h] -d DEVICE -a ADDRESS -p PREFIX [-n NS]
            [-l {INFO,DEBUG,ERROR}] [-s STYLERESOURCE] [-f STYLEFILE]

optional arguments:
-h, --help            show this help message and exit
-d DEVICE, --device DEVICE
                      Set motor device.
-a ADDRESS, --address ADDRESS
```

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```
                        Set PLC address, e.g. opc.tcp://134.171.59.98:4840
-p PREFIX, --prefix PREFIX
                        Set motor prefix, e.g. MAIN.Motor1
-n NS, --ns NS          Set OPCUA namespace, e.g. 4
- l {INFO,DEBUG,ERROR}, --loglevel {INFO,DEBUG,ERROR}
                        set the logging level: INFO|DEBUG|ERROR
-s STYLERESOURCE, --styleresource STYLERESOURCE
                        Set stylesheet resource, e.g. mystyle.qss
-f STYLEFILE, --stylefile STYLEFILE
                        Set stylesheet file, e.g. mystyle.qss
```

An example how to start the `pymotgui` from the command line is shown below.

```
$ pymotgui -d motor1 -a opc.tcp://127.0.0.1:7578 -p MAIN.Motor1
```

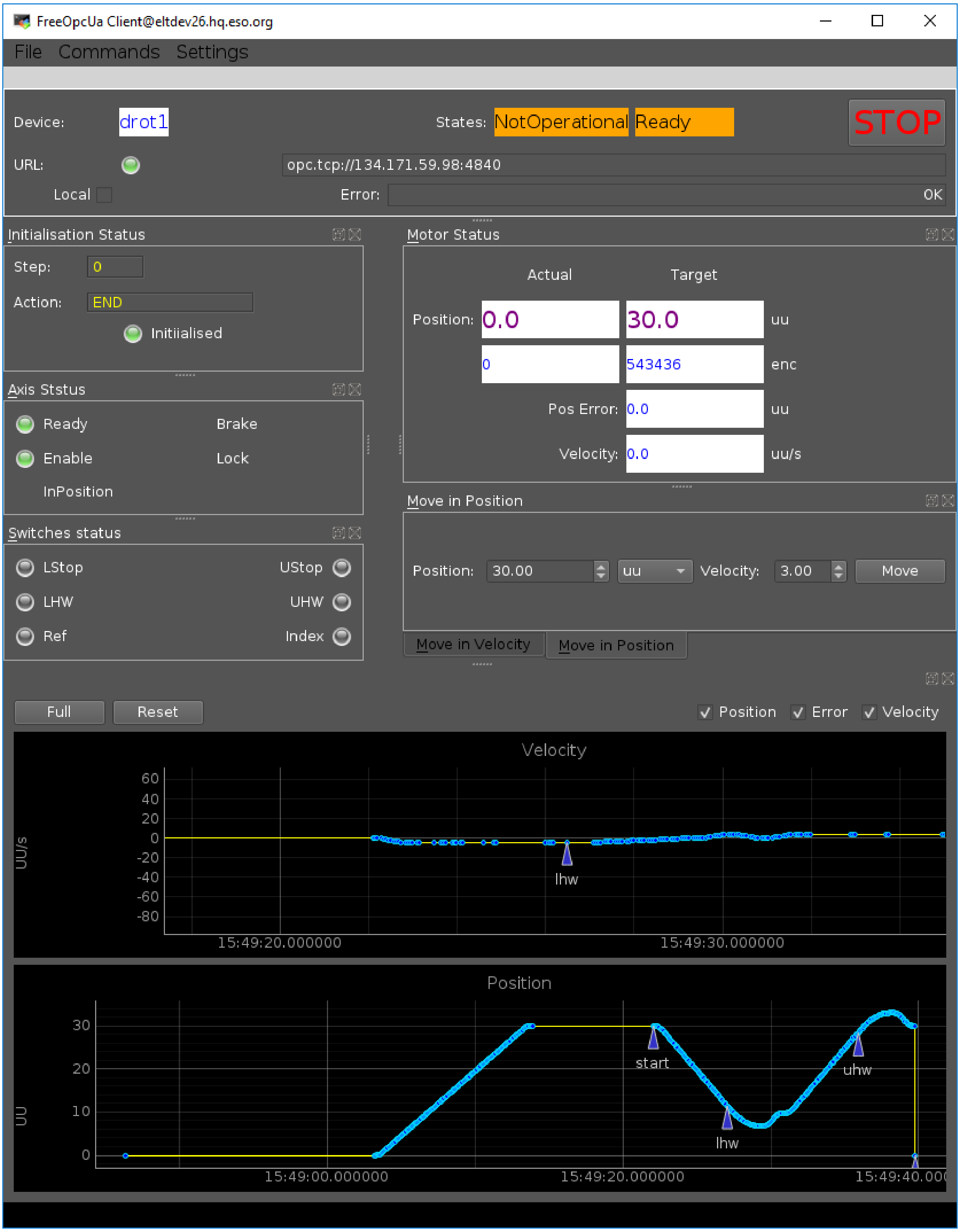

Fig. 11.11: Motor Graphical Interface.

11.2.1 Initialisation Markers

The Motor GUI uses markers to identify the time when motors reach a switch during the initialisation sequence. Two markers indicate the start and the end of the sequence, the others will depend of the switches reached during the sequence, see an example in the image below. In this example it was marked lower and higher hardware limits.

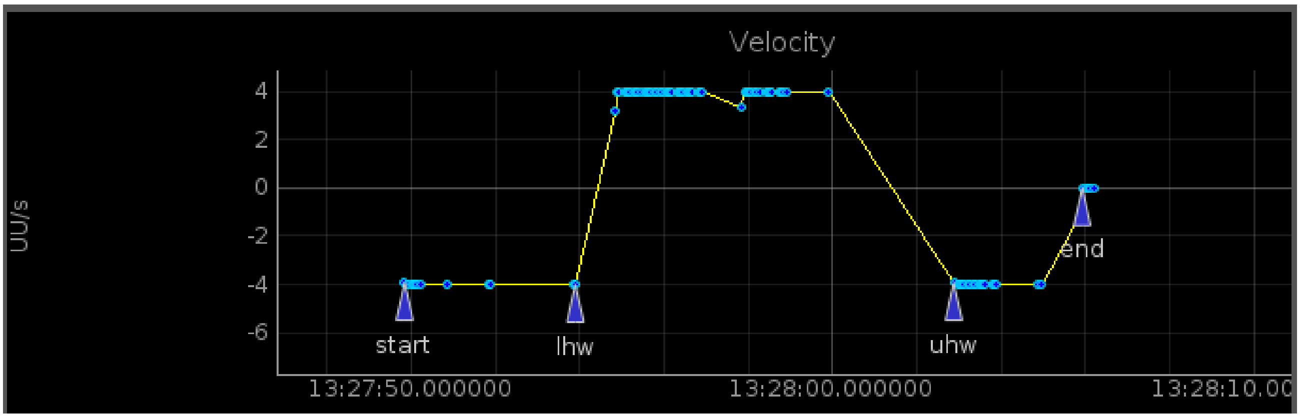

Fig. 11.12: Example of Initialisation Markers.

11.2.2 Exporting Plotting Data

The plotting data can be exported in a PNG or JPG format. This can be achieved by doing the following steps:

- Press mouse right-button and select "Export. . . "
- Select "Image File (PNG,TIF, JPG,.." from Export format and press "Export", see image below.
- Define the name of the file, e.g. myplotdata.png and press "Save".

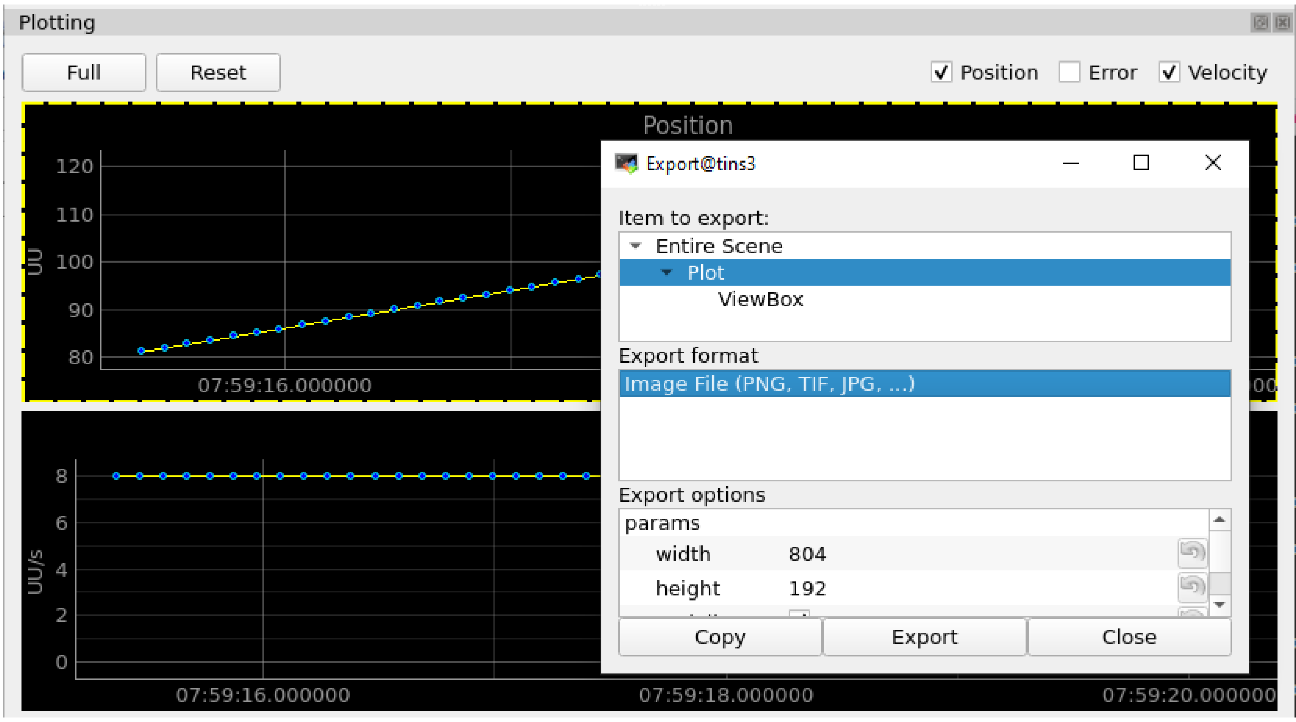

Fig. 11.13: Exporting Plotting Data.

11.3 Lamp Engineering GUI

The *Lamp* device provides an additional engineering interface offering more details for the control and monitoring of lamp devices (`pylampgui`). With this GUI it is possible to see details of the lamp timers or the value of the analog feedback.

The `pylampgui` can be launched directly from the command line or from each *Lamp* widget by pressing the `gui` button.

```
$ pylampgui --help
usage: pylampgui [-h] -d DEVICE -a ADDRESS -p PREFIX [-n NS]
             [-l {INFO,DEBUG,ERROR}] [-s STYLERESOURCE] [-f STYLEFILE]

optional arguments:
 -h, --help            show this help message and exit
-d DEVICE, --device DEVICE
                    Set lamp device.
-a ADDRESS, --address ADDRESS
                    Set PLC address, e.g. opc.tcp://134.171.59.98:4840
-p PREFIX, --prefix PREFIX
                    Set motor prefix, e.g. MAIN.Motor1
-n NS, --ns NS        Set OPCUA namespace, e.g. 4
-l {INFO,DEBUG,ERROR}, --loglevel {INFO,DEBUG,ERROR}
                    set the logging level: INFO|DEBUG|ERROR
```

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```
-s STYLERESOURCE, --styleresource STYLERESOURCE
                    Set stylesheet resource, e.g. mystyle.qss
-f STYLEFILE, --stylefile STYLEFILE
                    Set stylesheet file, e.g. mystyle.qss
```

An example how to start the `pylampgui` from the command line is shown below.

```
$ pylampgui -d lamp1 -a opc.tcp://127.0.0.1:7578 -p MAIN.Lamp1 -s Combinear.qss
```

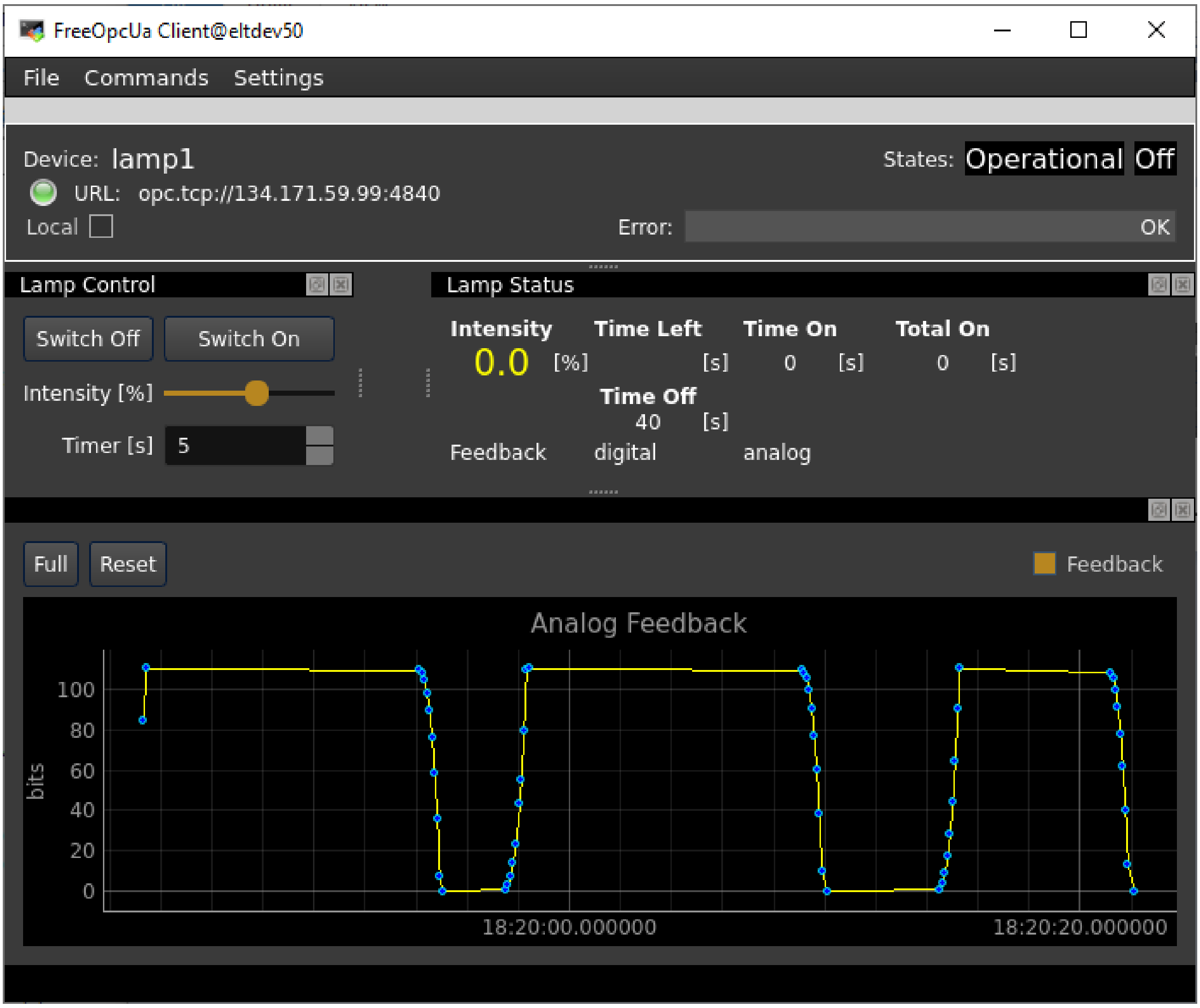

Fig. 11.14: Lamp Graphical Interface.

12 Programming Guide

12.1 Device Manager Extensions

The base classes provided by the FCF already implement large part of the functionality needed to implement the control of devices. However it is always needed to implement specific functionality and this can be achieved by extending basic device classes. This section gives a short overview of the most important aspect for developing custom devices.

Having type safe interfaces, as defined by CII ICD XML, enables to improve runtime robustness of our applications. However it is also makes the extendability harder to achieve. To solve this problem and to provide more flexibility to the developers, custom devices shall use a JSON based encoding for defining the parameters of the Setup command. This payload shall be encapsulated in the Setup command such that standard and custom devices can be managed by the FCF Device Manager.

12.1.1 Device Classes

Every device has a class which is derived from a common device class (fcf::devmgr:common:Device). This common class uses a dedicated configuration object to handle all the device configuration. It also uses a LCS interface object to manage the communication with the device controller running on the PLC.

Applications can create new classes by extending the Device class or by extending existing devices. If no special configuration is needed by the device, then there is no need to use a custom configuration class and it is possible to reuse the common one. The usage of a dedicated LCS interface class is normally needed because every device has a different interface.

12.1.2 Methods

There are few methods to be implemented in the device class to create a new one. The description of the methods are listed in the following table. These methods shall override the parent implementation and they will be called automatically by the device facade in response of the actions triggered by the user.

Method	Description
CreateObjects	Create the instances of the config and LCS interface classes. It writes the initial device configuration into the OLDB.
Setup	Parse the setup parameters and trigger the actions on the PLC. The payload for a custom device is specific and it shall contain a JSON string that have to be parsed by the device. Here the LCS interface class instance is used to interact with the controller.
IsSetupActive	It monitors the action triggered by the Setup to decide when the action has been completed for the device. This information is used by the device facade to return the answer of the setup command to the originator. For instance, if you move a motor to a certain position, it checks if the target position has been achieved. This method is called regularly by the device facade when waiting for the result of the setup command.
UpdateStatus	Get the latest device status received by the device. It also updates the OLDB with the device status data.
Status	Implement specific actions for the GetStatus command. This method adds all the relevant information about the device into the buffer. The buffer delivered by the GetStatus is a composition of all the status information delivered by every device.
Status	Similar to the Status above but specific for the FITS header metadata information.

12.1.3 Device Config

There is no need to use a custom device configuration unless the device has some special parameters. Even if a new devices uses new parameters that need to be downloaded to the PLC, it is possible to do it with the common configuration class (fcf::devmgr:common:DeviceConfig). In the FCF, most of the devices do not implement a dedicated configuration class, e.g. Shutter or Lamp. The DeviceConfig class will automatically download any configuration under `ctrl_config` which uses built-in data types.

12.1.4 LCS Interface

The FCF provides a basic class that implements the common functionality (fcf::devmgr:common:DeviceLcsIf). Custom devices do not require to implement a large and complex LCS interface class . A typical need is the implementation of a new RPC. In such a case, you can just extend the existing class by adding a new method to handle the RPC. An example of an RPC method implementation is show below (from Shutter device).

```
void ShutterLcsIf::Open() {
    LOG4CPLUS_TRACE_METHOD(m_logger,__PRETTY_FUNCTION__);

    fcf::common::VectorVariant attr_list;
```

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```
    std::string obj;
    std::string proc;
    // Get the RPC node id based on the device configuration
    proc = m_config->GetProcId(GetMapValue(fcs::CAT_RPC,
                                           RPC_OPEN));
    // Get the PLC object ID from the configuration
    obj = m_config->GetObjId();
    try {
        LOG4CPLUS_INFO(m_logger, "[" << m_config->GetName() << "] "
                     << "Openning shutter ...");
        // Executes the RPC in this case with an empty attribute vector
        ExecuteRpc(obj, proc, attr_list);
    } catch (std::exception& e) {
        const std::string msg = "[" + m_config->GetName()
            + "] Openning failure: " + e.what();
        LOG4CPLUS_ERROR(m_logger,  msg);
        throw std::runtime_error(msg);
    }
}
```

The DeviceLcsIf class monitors (via OPCUA subscriptions) some basic status parameters from the device controller. These parameters are: state,substate,local and error. These parameters can be extended by modifying the internal map node. The map is a pair including the name of the attribute (coming from the mapping file) and an identifier. See the example below for the lamp device. The class will automatically create a subscription for these attributes.

```
const std::vector <std::pair<std::string, unsigned int>> subscription_vector = {
  {CI_STAT_INTENSITY, STAT_INTENSITY},
  {CI_STAT_TIME_LEFT, STAT_TIME_LEFT},
  {CI_STAT_ANALOG_FEEDBACK, STAT_ANALOG_FEEDBACK},
  {CI_STAT_ON_ANALOG, STAT_ON_ANALOG},
  {CI_STAT_ON_DIGITAL, STAT_ON_DIGITAL},
};

// Build a map with the real OPCUA names.
this->StoreUaNames(subscription_vector);
```

In order to handle the subscription events for new attributes, developers need to implement a Listener method. This method receives the notifications in a vector containing the attributes (OPCUA NodeIds) and their values. They are used to update the internal device status and the OLDB. Here the identifier, e.g. `STAT_INTENSITY` is used to determine which attribute has been modified in the controller (PLC).

```
void  LampLcsIf::Listener(fcf::common::VectorVariant& params) {
    LOG4CPLUS_TRACE_METHOD(m_logger,__PRETTY_FUNCTION__);

    // Process basic attributes in base class
    fcf::devmgr::actuator::ActuatorLcsIf::Listener(params);

```

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```
    try {
        for (auto parIt = params.begin(); parIt != params.end(); parIt++)  {
            LOG4CPLUS_DEBUG(m_logger, "[" << m_config->GetName()
                            << "] Node ID: " << parIt->first);
            LOG4CPLUS_DEBUG(m_logger, "[" << m_config->GetName()
                          << "] Node Value: " << parIt->second);

            // NodeId has a defined format. We need to extract just the address␣
↪space
            // path. For that we use boost:split function.
            // NodeId format: ns=4;s=MAIN.Lamp1.stat.nSubstate
            // We split by '=' char and we take the latest element of the vector.

            std::vector<std::string> tokens;
            boost::split(tokens, parIt->first, boost::is_any_of("="));
            std::string attribute = tokens[tokens.size()-1];

            auto it = m_ua_status_map.find(attribute);
            if (it != m_ua_status_map.end())  {
                LOG4CPLUS_DEBUG(m_logger, "Identifier: " << it->second);
                // Only in case variable is registered in the status map
                switch (it->second) {
                    case STAT_INTENSITY: {
                            // here we obtain the value from the notification.
                            m_intensity = boost::get<double>(parIt->second);
                            // here we prepare the DB attribute name.
                            const std::string attr = m_lcs_prefix +
                            std::string(utils::bat::CONFIG_DB_DELIMITER) + CI_
↪STAT_INTENSITY;
                            // here we update the DB.
                            m_data_ctx.Set(attr,m_intensity);
                        }
                        break;
                    case STAT_TIME_LEFT: {
                            // here we obtain the value
                            m_time_left = boost::get<unsigned int>(parIt->
↪second);
                            // here we prepare the DB attribute name.
                            const std::string attr = m_lcs_prefix +
                            std::string(utils::bat::CONFIG_DB_DELIMITER) + CI_
↪STAT_TIME_LEFT;
                            // here we update the DB.
                            m_data_ctx.Set(attr,m_time_left);
                        }
                        break;
                    ...
                }
            } else {
                LOG4CPLUS_ERROR(m_logger, "Variable not handled, notification␣
↪will be skipped: "
```

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```
                                        << parIt->first);
            }
        }
    } catch (std::exception& e) {
            LOG4CPLUS_ERROR(m_logger, "[" << m_config->GetName()
                          << "] Problem processing event notification: "
                            << e.what());
            m_failure.broadcast();
    } catch (...) {
            LOG4CPLUS_ERROR(m_logger, "[" << m_config->GetName()
                          << "] Unknow error processing notification");
            m_failure.broadcast();
    }

}
```

To simplify adding instrument specific extensions to the Device Manager, The FCF provides a template that can be used as starting point to implement special devices along with some companion modules. Probably the best way to understand how to develop a device is having a look to the existing FCF devices. The simplest one is the Shutter device which is implemented in few lines of code.

12.2 Template

You should create your software based on the provided project template by following the procedure in the Getting Started guide here[21]

12.2.1 Top Directory Structure

```
<root>                  # Generated project directory
├── resource            # directory containing the resources
└── <prefix>-ics        # WAF project
    ├── <component>     # Generated FCS
    ├── seq
    ├── <prefix>stoo
    └── wscript
```

[21] http://www.eso.org/~eltmgr/ICS/documents/IFW_HL/sphinx_doc/html/manuals/ifw/src/docs/guide.html

12.2.2 Component Directory Structure

Here it will be reported the specific parts about FCS in the generated project. The generated structure resembles the structure of the FCF component.

```
<component>
├── devices            # Custom Device
├── devsim             # Simulator for custom device
├── clib               # Custom Python client library
├── cli                # Custom FCS Command Line Interface (CLI)
├── gui                # Custom GUI
├── LCS                # Example PLC Project (VS)
├── server             # Custom server
└── wscript
```

Note: All custom devices shall use the CUSTOM device type of the existing FCF XML interface for the Setup event payload.

12.2.3 Custom Device

The generated code includes the implementation of a dummy custom device that can be used as starting point to develop instrument specific ones. This device contains the intelligence to deserialize the custom setup command payload in method Setup. Users will have to modify this method and method IsSetupActive to adapt to their specific needs.

Warning: The serialization of the setup command for custom devices is done in JSON format. Devices shall parse the JSON serialization to obtain the device parameters. The template provides an example for this.

```
void Mirror::Setup(const std::any& payload) {
    RAD_LOG_TRACE();
    RAD_LOG_INFO() << "Processing Setup command ...";
    if (!m_config->GetIgnored()) {
      auto fcf_vector = std::any_cast<std::vector<std::shared_ptr
↪<fcfif::SetupElem>>>(&payload);
      for (auto it = fcf_vector->begin(); it != fcf_vector->end(); it++) {
           auto setup_elem = *it;
           RAD_LOG_INFO() << "ID: " << setup_elem->getId();
           // ignore other shutters
           if (IsMsgForMe(setup_elem->getId()) != true) {
               continue;
             }
           auto fcs_union = setup_elem->getDevice();
```

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```
            if (fcs_union->getDiscriminator() != ::fcfif::DeviceType::CUSTOM) {
                RAD_LOG_ERROR() << "[" << m_config->GetName() << "] "
                                << "Setup is for me but device type is not␣
↪correct?";
                continue;
              }

            auto custom = fcs_union->getCustom();
          RAD_LOG_DEBUG() << "[" << m_config->GetName() << "] "
                          << "Setup ID: " << setup_elem->getId();
          std::string params = boost::replace_all_copy(custom->getParameters(), "
↪'", "\"");
          RAD_LOG_INFO() << "Setup buffer: " << params;

          //@TODO: Add handling of setup parameters
          EncDec data = nlohmann::json::parse(params);
          // Optional parameter
          RAD_LOG_INFO() << "Action: " << data.get_action();
          if (data.has_piston()) {
              RAD_LOG_INFO() << "Piston: " << data.get_piston();
            }
          RAD_LOG_INFO() << "Tip: " << data.get_tip();
          RAD_LOG_INFO() << "Tilt: " << data.get_tilt();

          if (data.get_action() == "MOVE") {
            m_lcs_if->Ping();
            }
          }
    }
}
```

12.2.4 Custom Simulation

In oder to allow the testing of the dummy device, a device simulator is generated and can be used for testing purposes. The simulator implements the RPC_Ping dummy method used by the custom device as an action of the Setup command.

12.3 Extending JSON schema

In order to validate the setup payload before sending it to the server, applications shall extend the FCF schema for custom devices. We provide an example for this in the template for the Mirror device.

Note: The schema presented in the template is just an example to illustrate how to achieve this. Instrument developers shall define the scheme that better fits the needs of the custom devices. In this case and for simplicity, we are using a flat structure.

```
{
      "type": "object",
      "properties": {
        "action": {
          "type": "string",
          "enum": ["MOVE" ],
          "description": "Mirror action."
        },
        "tip": {
          "type": "number",
          "description": "tip."
        },
        "tilt": {
          "type": "number",
          "description": "tilt."
        },
        "piston": {
          "type": "number",
          "description": "piston."
        }
      },
      "required": ["action","tip","tilt"]
}
```

Applications are required to define their own python library where to compose the FCS schema. This can be achieved by adding the custom device schemas. There are probably different ways to achieve this, we provide an example below where the composition in done in python.

```
""" Load basic schema for all standard devices """
self._schema = json.loads(json_obj.SETUP_SCHEMA)

""" Change the schema to add new device """
""" add the new definition """
self._schema['definitions']['mirror'] = json_obj.load_json_string(SetupBuffer.
↪MIRROR_SCHEMA)
""" add new element the array """
self._schema['definitions']['param']['oneOf'].append(json_obj.load_json_string('{
↪"required": [ "mirror"]}'))
self._schema['definitions']['param']['properties']['mirror'] = json_obj.load_
↪json_string('{"$ref": "#/definitions/mirror"}')
```

13 Getting Started

13.1 Log-in

Login to a standard ELT machine.

13.2 IFW Software

If not yet done, retrieve and install the complete ICS Framework from the ESO RPMs repository. For more details, please have a look to the installation procedure here[22]

You should create your software based on the provided template by following the procedure in the Getting Started guide here[23]

This guide assumes you have followed all the steps in the above guide. The examples assume you selected the instrument as `tins`, the FCS component as `fcs` and the custom device as `mirror`. You can adapt the configuration according to your needs.

13.3 Database Server

The present version of the *Device Manager* uses Redis as the database engine to store run-time configuration (Redis documentation[24]).

The DB server shall be running after following the general Getting Started guide here[25]

The data is stored in the DB using a list of keyword/values. Each keyword has a hierarchical name that helps to idenfify its context, for instance the keys associated to a *Device Manager* start with the <server id> defined in the FCF configuration.

The ELT development environment provides a DB browser tool (dbbroser) that can be used to monitor the database keywords in an easy way similar to the *ccseiDb* tool in the VLT project.

[22] http://www.eso.org/~eltmgr/ICS/documents/IFW_HL/sphinx_doc/html/manuals/ifw/src/docs/installation.html
[23] http://www.eso.org/~eltmgr/ICS/documents/IFW_HL/sphinx_doc/html/manuals/ifw/src/docs/guide.html
[24] https://redis.io/
[25] http://www.eso.org/~eltmgr/ICS/documents/IFW_HL/sphinx_doc/html/manuals/ifw/src/docs/guide.html

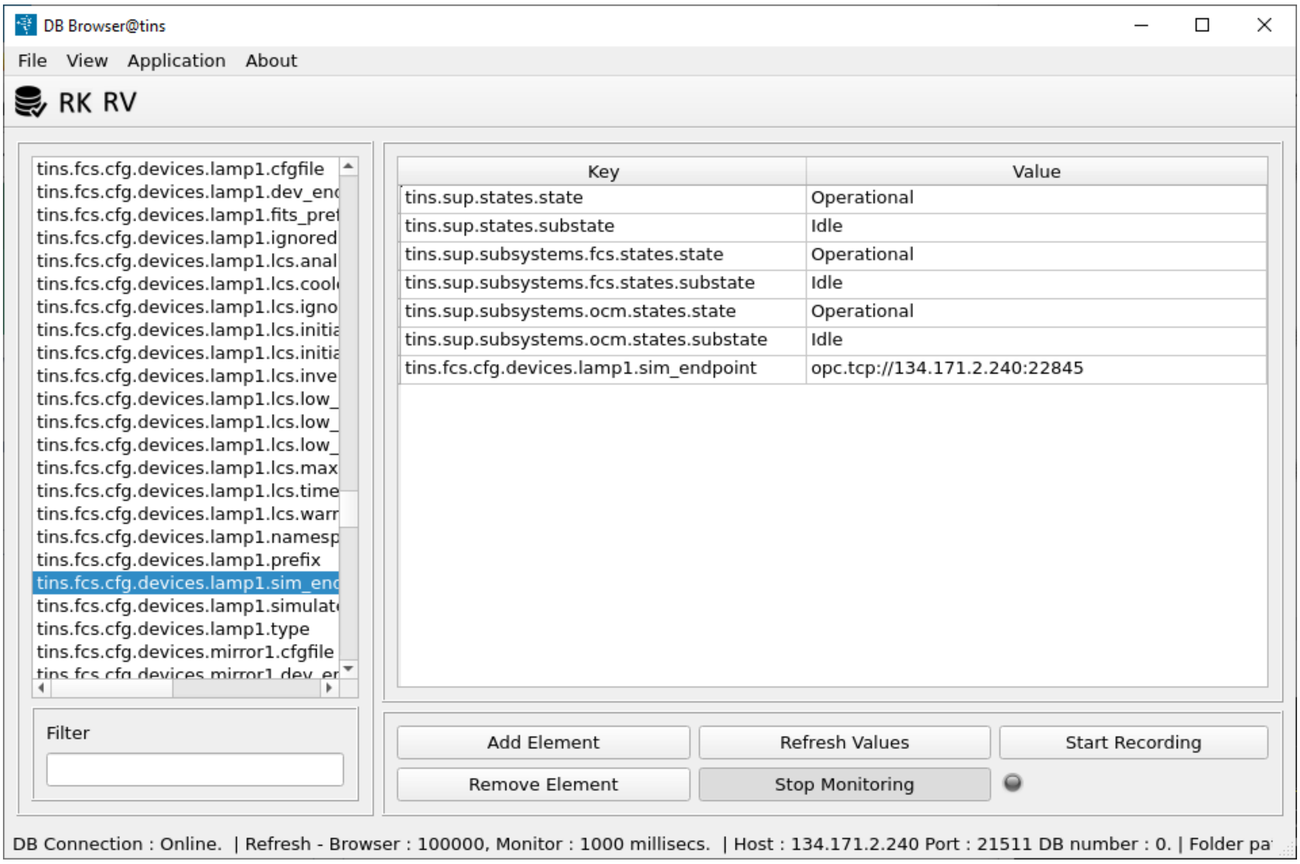

Fig. 13.1: Dbbrowser tool screenshot showing Device Manager attributes.

```
dbbrowser &
```

Note: To get list of attributes in the dbbrowser is needed to configure the connection first. Menu *Application* option *Open*. Consult the dbbrowser User Manual in case of problems.

Note: The attributes will be populated only when the *Device Manager* server is started.

13.4 FCS Configuration

The project template includes a sample of a FCF configuration. The generated directory contains a fully working waf project with a custom device to be used as starting point for the development. After executing the *cookiecutter* command with the provided template, you can build, install and deploy the provided example.

Please follow the instructions in the general Getting Started guide here[26]

The `Device Server` requires a configuration file including all the relevant information for the server. A pre-defined configuration has been created as part of the generation process. This configuration include three standard devices plus a the custom device.

Generated server configuration: <ins id>/resource/nomad/<component>.yml.tpl. This files contains the Nomad tags so it should not be used directly but through a nomad job command.

```
!cfg.include config/fcf/devmgr/definitions/server.yaml:

server: !cfg.type:FcfServer
server_id       : '{{cookiecutter.component_name}}'
{% raw %}
req_endpoint    : "zpb.rr://{{ range service "${component}-req" }}{{ .Address }}:
↪{{ .Port }}{{ end }}/"
pub_endpoint    : "zpb.ps://{{ range service "${component}-pub" }}{{ .Address }}:
↪{{ .Port }}{{ end }}/"
db_endpoint     : "{{ range service "${redis}" }}{{ .Address }}:{{ .Port }}{{␣
↪end }}"
{% endraw %}
db_timeout      : 2000
scxml           : "config/fcf/devmgr/server/sm.xml"
dictionaries    : ['dictionary/dit/stddid/primary.did', 'dictionary/fcf/devmgr/
↪server/fcf.did']
fits_prefix     : "FCS1"
log_properties  : "config/{{cookiecutter.component_name}}/server/log_properties.
↪cfg"
devices         : [
{
name: 'shutter1',
type: Shutter,
cfgfile: "local/shutter1.yaml"
},
{
name: 'lamp1',
type: Lamp,
cfgfile: "local/lamp1.yaml"
},
{
name: 'motor1',
type: Motor,
```

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[26] http://www.eso.org/~eltmgr/ICS/documents/IFW_HL/sphinx_doc/html/manuals/ifw/src/docs/guide.html

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```
cfgfile: "local/motor1.yaml"
},
{
name: '{{cookiecutter.device_name}}1',
type: {{cookiecutter.device_name|capitalize()}},
cfgfile: "local/{{cookiecutter.device_name}}1.yaml"
}
]
```

Note: This configuration shall be adapted to the instrument specific needs.

13.5 Device Manager Logs

```
$ nomad alloc logs -job fcs
```

The output of the server shall be something like the following:

```
2021-04-20T08:19:13.783333   INFO CfgFile - req_endpoint = <zpb.rr://134.171.2.
↪250:24738/>
2021-04-20T08:19:13.783420   INFO CfgFile - db_endpoint = <134.171.2.250:27874>
2021-04-20T08:19:13.783437   INFO CfgFile - pub_endpoint = <zpb.ps://134.171.2.
↪250:21765/>
2021-04-20T08:19:13.783519   INFO CfgFile - Devices: 4
2021-04-20T08:19:13.783535   INFO shutter1
2021-04-20T08:19:13.783552   INFO lamp1
2021-04-20T08:19:13.783566   INFO motor1
2021-04-20T08:19:13.783578   INFO mirror1
2021-04-20T08:19:13.799213   INFO Application fcsDevmgr started.
2021-04-20T08:19:13.817823   INFO PS Endpoint: zpb.ps://134.171.2.250:21765/std/
↪status
2021-04-20T08:19:13.934309   INFO [shutter1] Warning device simulated !
2021-04-20T08:19:13.934391   INFO [shutter1] reading configuration keywords ...
2021-04-20T08:19:13.934943   INFO [shutter1] Publishing Endpoint: zpb.ps://134.
↪171.2.250:21765/shutter1
2021-04-20T08:19:14.074730   INFO [lamp1] Warning device simulated !
2021-04-20T08:19:14.074812   INFO [lamp1] reading configuration keywords ...
2021-04-20T08:19:14.075311   INFO [lamp1] Publishing Endpoint: zpb.ps://134.171.
↪2.250:21765/lamp1
2021-04-20T08:19:14.177424   INFO [motor1] Warning device simulated !
2021-04-20T08:19:14.178016   INFO [motor1] reading init sequence ...
2021-04-20T08:19:14.178057   INFO [motor1] number of init actions: 4
2021-04-20T08:19:14.178197   INFO [motor1] reading name position:motor1
2021-04-20T08:19:14.178222   INFO [motor1] number of named positions: 2
2021-04-20T08:19:14.178308   INFO [motor1] reading named position␣
↪tolerance:motor1
```

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```
2021-04-20T08:19:14.178344   INFO [motor1] named position tolerance: 1
2021-04-20T08:19:14.179338   INFO [motor1] Publishing Endpoint: zpb.ps://134.171.
↪2.250:21765/motor1
2021-04-20T08:19:14.180703   INFO [motor1] Publishing Motor Endpoint: zpb.ps://
↪134.171.2.250:21765/motor1/position
2021-04-20T08:19:14.382390   INFO [mirror1] Warning device simulated !
2021-04-20T08:19:14.382480   INFO [mirror1] reading configuration keywords ...
2021-04-20T08:19:14.382698   INFO [mirror1] Publishing Endpoint: zpb.ps://134.
↪171.2.250:21765/mirror1
```

Note: The server can be started with option -l ERROR to remove the information logs.

13.5.1 Initialising the server

The client application can be used to send commands to the server from the command line:

```
$ fcfClient `geturi fcs-req` GetState ""
```

Note: `geturi` is an utility to compose the expected URI from the name of the registered Consul service.

The reply from the server shall be something like the following:

```
Idle/Operational/On/
```

Besides the above, you can also use the FCF CLI to interact with the server.

```
$ fcscli --name fcs-req
zpb.rr://134.171.2.250:24738
fcsSh> status
```

Note: The fcscli is a custom FCS CLI provided in the template. It already contains the configuration to include the custom FCF python libraries.

13.6 Using the *DeviceManager* GUI

13.6.1 Starting the GUI

```
$ fcsGui --uri `geturi fcs-req` &
```

The sample GUI defines some sections to illustrate how developers can organize the various dock widgets. This is just an example that shall be adapted to the needs of each instrument.

Note: The first time the GUI is started, it might appear too small to display all the information from the device widgets. The user has to resize it and organize the dock widgets accordingly. It is recommended to stack all the dock windows together. This can be done using drag&drop.

Note: If you want to use another style, you can start the GUI with option –stylesheet-name or –stylesheet-file if you have your own style-sheet file.

You can control the devices from the GUI, for instance by selecting the action *OPEN* or *CLOSE* from the shutter widget and then pressing *Setup* button.

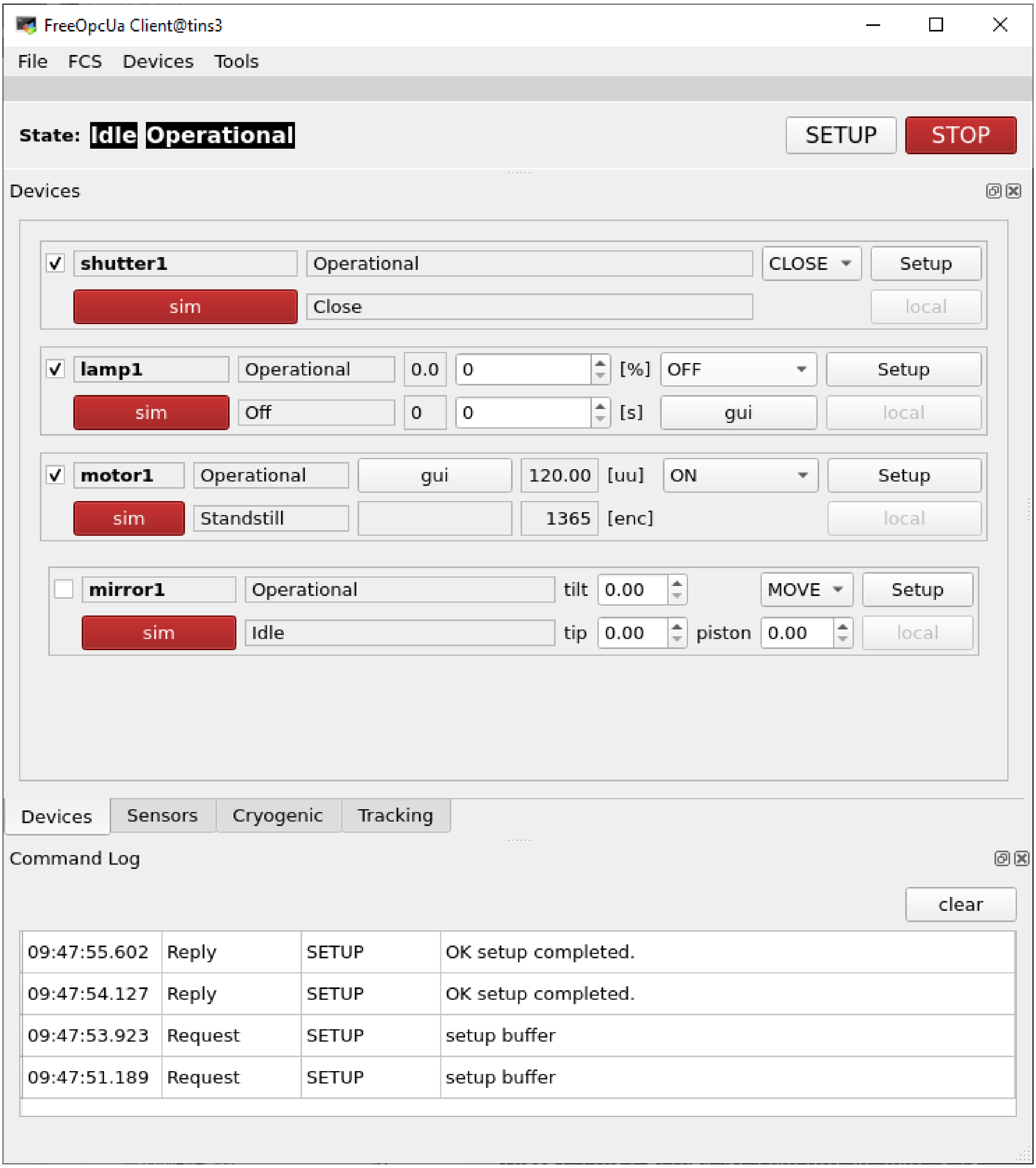

Fig. 13.2: Device Manager Engineering Graphical Interface.

13.7 Using the *Motor Engineering* GUI

13.7.1 Starting the GUI

This GUI can be started from the command line or launched from the *fcfGui* by clicking with the mouse pointer over the small 'gui' button on each motor widget.

```
pymotgui -d motor1 -a opc.tcp://127.0.0.1:7578 -p MAIN.Motor1 &
```

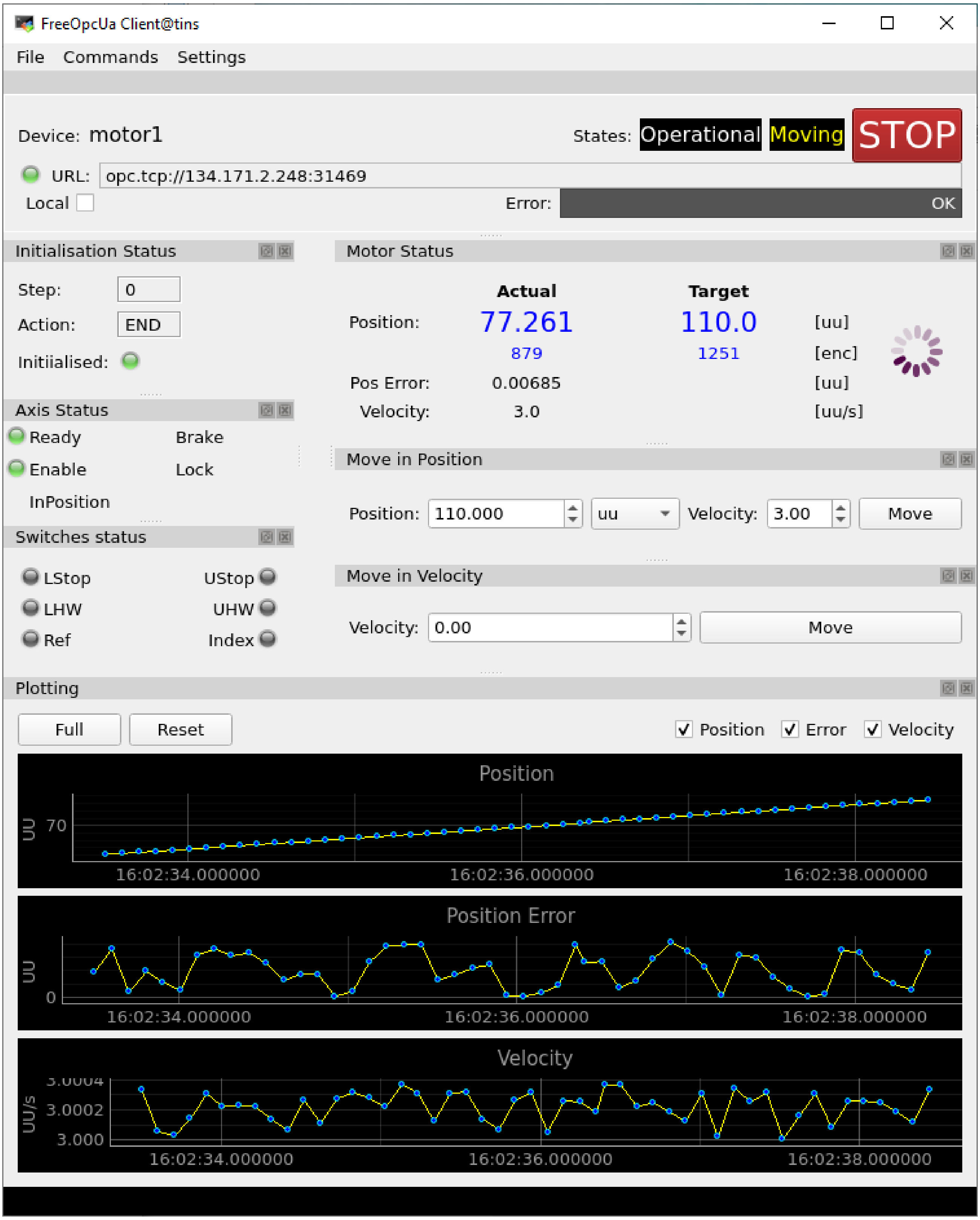

Fig. 13.3: Motor Engineering GUI.

13.7.2 Controlling Custom Device

Warning: The mirror device is a dummy device that is a showcase how to develop custom devices.

The mirror device includes a setup that triggers the execution of a custom RPC in the controller (simulator).

```
$ fcsSh> setup_spf 'mirror1:action="MOVE",mirror1:tip=2.1,mirror1:tilt=4.3'
```

Note: The client library will convert the Simple Parameter Format (SPF) into JSON and check against the defined schema. If the validation is okay, it will send this JSON string to the server which it will pass it to the corresponding device to be processed.

Note: The same you can do from the custom GUI which provides a custom widget for this device.

The reply from the server shall be something like the following:

```
2021-04-20T13:01:55.551216   INFO Started SETUP command
2021-04-20T13:01:55.551443   INFO Processing Setup command ...
2021-04-20T13:01:55.551506   INFO ID: mirror1
2021-04-20T13:01:55.551621   INFO Setup buffer: {"action": "MOVE", "tip": 2.1,
↪"tilt": 4.3}
2021-04-20T13:01:55.552321   INFO Action: MOVE
2021-04-20T13:01:55.552358   INFO Tip: 2.1
2021-04-20T13:01:55.552365   INFO Tilt: 4.3
2021-04-20T13:01:55.552373   INFO [mirror1] Executing RPC_PING ...
2021-04-20T13:01:55.553805   INFO [mirror1] Successful call of Mirror ping:
```

Note: To see the specific logs from the custom device, the logging level shall be specified for that device, e.g. setloglevel INFO,mirror

13.7.3 Forcing a Syntax Error

The custom device defines a sample schema where parameters tip and tilt are mandatory. If a setup is sent with a missing required parameter, this will be detected when validating against the schema, see below.

```
$ fcsSh> setup_spf 'mirror1:action="MOVE", mirror1:tip=3'
'tilt' is a required property

Failed validating 'required' in schema['items']['properties']['param'][
↪'properties']['mirror']:
    {'properties': {'action': {'description': 'Mirror action.',
                               'enum': ['MOVE'],
                               'type': 'string'},
                    'piston': {'description': 'piston.', 'type': 'number'},
                    'tilt': {'description': 'tilt.', 'type': 'number'},
                    'tip': {'description': 'tip.', 'type': 'number'}},
     'required': ['action', 'tip', 'tilt'],
     'type': 'object'}

On instance[0]['param']['mirror']:
    {'action': 'MOVE', 'tip': 3}
JSON data not valid !
ERROR: something went wrong, setup buffer not modified
...
```

13.8 Working with a PLC

The following steps can be done to use the server configuration that was generated with controllers running in a PLC.

Note: The provided PLC project includes the corresponding simulators so hardware is not needed only a bare PLC. All the mapping is pre-configured and the PLC code is generated to match the server configuration (only the three standard devices).

13.8.1 Requirements

- PLC available with required version of TwinCAT run-time and OPC-UA Server.
- Windows development environment with required TwinCAT software installed.
- All ESO PLC libraries installed in the Windows development environment.

1. Load the PLC Project

From a Visual Studio load the PLC project generated. The project can be found in fcs1/LCS/plcprj1.

2. Select Target System

Select the target system, this is the PLC that you want to use.

3. Build the PLC Project

If you have errors, make sure you have all ESO libraries installed.

4. Activate Configuration

This active the project configuration and restart the OPC-UA Server in the PLC.

5. Login to the target system.

This will download the code to the PLC.

6. Update the configuration of each device with the corresponding PLC address (IP).

```
!cfg.include config/fcf/devmgr/definitions/lamp.yaml:

lamp1: !cfg.type:Lamp
identifier: PLC1                              # OPCUA Object Identifier
prefix: MAIN.Lamp1                            # OPCUA attribute prefix
simulated: true
dev_endpoint: undefined                                      # To be set if a␣
↪PLC is available
sim_endpoint: opc.tcp://{{ range service "lamp1sim" }}{{ .Address }}:{{ .Port }}{
↪{ end }}
fits_prefix: "LAMP1"
```

6. Stop the simulation for the devices

```
$ fcfClient `geturi fcs-req` Reset ""
$ fcfClient `geturi fcs-req` StopSim "lamp1, shutter1, motor1"
```

Note: By changing the flag simulated to false in the device configuration it is possible to make this change persistent.

7. Set the server to operational state

```
$ fcfClient `geturi fcs-req` Init ""
$ fcfClient `geturi fcs-req` Enable ""
```

You can now operate the server with devices connected to the PLC controllers.

13.9 Stopping the Software

13.9.1 Stopping the GUI

The menu *File* has an option *Quit*. Please select this option if you want to stop properly the GUIs.

13.9.2 Stopping the Software

You can use the startup/shutdown script provide to stop the whole software. For more details please check the general Getting Started guide here[27]

[27] http://www.eso.org/~eltmgr/ICS/documents/IFW_HL/sphinx_doc/html/manuals/ifw/src/docs/guide.html