Symphony Plus as application for power plants

AC500 Subproject

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BACHELOR'S THESIS

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ABSTRACT

This thesis work is in its entirety a project consisting of two parts made to study and evaluate the functionality of the S + Operations in combination with the AC500 PLC. This thesis covers the part of the AC500 PLC, developed by ABB.

It provides information on programming of a demo process and the applications associated with the AC500 that are used to achieve a functioning demo process. The demo process is used to test the functionality in combination with S + Operations while evaluating the features and characteristics of the PLC. The Water & Wastewater library is used to provide extended programming content for the demo solution. The actual programming is done in PS501 Engineering Tool.

A comparison with another system is made to weigh characteristics and solutions against each other. The comparison is made on the basis of a system overview from an engine power plant. A solution with AC500 as an application in a power plant is presented and discussed based on the comparison.

The end result is a working demo process that is controlled using the AC500 in combination with S+ Operations, which was also considered to be an overall flexible solution. From the demo process it is possible to continue to develop and test the functionality with AC500.

Language: english Keywords: AC500, PLC

EXAMENSARBETE

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ABSTRAKT

Detta examensarbete är i sin helhet ett projekt bestående av två delar, utförda för att studera och evaluera funktionaliteten vid S+ Operations i kombination med AC500. Detta examensarbete omfattar delen för PLC:n AC500, utvecklad av ABB.

Det ges information om programmering av en demoprocess och de tillämpningar som i samband med AC500 används för att uppnå en fungerande process. Demoprocessen används för att testa funktionaliteten i kombination med S+ Operations, men samtidigt evaluera de olika funktionerna och egenskaperna av PLC:n. Water & Wastewater biblioteket används vid programmeringen av demoprocessen, men för själva programmeringen av PLC:n används PS501 Engineering tool.

En jämförelse med ett annat system görs för att väga egenskaper och lösningar mot varandra. Jämförelsen görs på basis av en systemöversikt från ett kraftverk. Av evaluationen och jämförelsen presenteras möjligheter till lösningar med AC500 som tillämpning i ett kraftverk

Slutresultatet är en fungerande demoprocess som styrs med hjälp av AC500 i kombination med S+ Operations med god funktionalitet. Från demoprocessen är det möjligt att fortsätta vidareutveckla och testa funktionaliteten med AC500.

Språk: engelska   Nyckelord: AC500, PLC

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PLC	Programmable Logic Controller
CPU	Central Processing Unit
CRC	Cyclic Redundancy check
CBP	Control Builder Plus
ST	Structured Text
IL	Instruction List
LD	Ladder Diagram
FBD	Function Block Diagram
SCL	Structure Control Language
CPU	Central Processing Unit
PMU	Power Monitoring Unit
AVR	Automatic Voltage Regulator

I would like to thank Mr. Ronnie Sundsten at Novia University of Applied Sciences and Mr. Frank Redlig at ABB, who have been my supervisors during this thesis work. They have provided me with guidance and support throughout this project.

1. Introduction

This Bachelor's thesis is conducted on behalf of the ABB Power Generation department in Vaasa. I have been given the task to participate in research on Symphony+ operations in combination with AC500 as a solution for engine power plants. This thesis focuses on AC500, and describes all essential parts necessary to know for readers to understand the outcome and discussion of this thesis. Mr. Anton Wargh is responsible for the S+ operations part of this investigation.

1.1 Target

The purpose of this thesis is to investigate Symphony Plus Operations in combination with AC500, using the Water & Wastewater library, as a solution for power plants. This thesis focuses on AC500 and the goal has been to develop a demo solution of a watertank process, where the functionality of the AC500 can be tested and further developed. This has been done through research, consultation with experts and tests done with the Demo solution. This solution will be an example of how to configure AC500 for establishing a connection between S+ Operations and AC500 using OPC. It is also used to determine the possible area of use for the AC500 in power plants and compare it to existing solutions and thereby determine advantages and disadvantages as well as potential improvement areas regarding S+ Operations in combination with AC500, and with AC500 in general.

2. ABB

ABB is globally known for being leaders in power and automation tecchnologies. Currently ABB is based in Zurich, Switzerland, but the company is active in approximately 100 countries, with about 150 000 employees.

The company's current form was created in 1988 and comprises five divisions that are in turn organized in relation to the customers and industries that are being served. This form was established through a merger between ASEA and BBC, which are both electrical companies established before the 20th century and are responsible for innovative solutions in areas like turbines, transformers, switchgears, robots etc. [6]

2.1 In Finland

ABB in Finland can be found in over 30 locations with about 5500 employees. ABB is also one of Finland's biggest employer in the industry sector with a revenue of 2,3 billion euro of which 184 million is used on research and development.

The ABB organisation in Finland consists of Discrete Automation and Motion, Low Power Products, Process Automation, Power Systems and Power Products, and their respective sub-units.[2]

2.2 Power Generation

Power Generation is a part of the ABB Power Systems division, which consists of Power Generation, Substations and Network Management. The Power Generations unit focuses on planning and delivering power plants as turnkey solutions. The Power Generation unit in Finland is located in Vaasa and specializes in gas, gas turbine, hydro, thermal and nuclear power plants. The hydropower unit has its biggest focus is the Nordic countries.[1]

3. Programmable Logic Controllers

The AC500 is a PLC (Programmable logic controller) and therefore it is necessary to know the basics of the functionality of the PLC to be able to understand later chapters of this thesis. The features and functions of newer PLCs have changed since the literature references for this chapter were written, but the principle of the PLC is generally the same.

3.1 History

Programmable logic controllers, or PLCs as they are referred to in the industry, have since 1969 become the most popular mean of controlling machinery and plant operations. These small logics would replace long cabinets of relays and wiring that were used earlier. Microprocessors have been used as the brain of the PLC since around 1974 and from that evolved together with the advances in the electronics industry to provide powerful and reliable PLCs.[13]

3.2 Functionality

The PLC system consists of a CPU which contains the microprocessor that interprets the input signals and, according to programs stored in its memory it carries out control actions that communicate descisions as signals to the outputs. To have an interface between the system and the outside world the PLC needs an input and output section, where it receives information from external devices and also communicates it back to external devices. For the PLC to have an understanding of what to do it needs a programming device and a memory unit. The programming device is used for inserting the project specific program into the memory unit of the PLC. The memory unit is then used by the microprocessor for control actions, also input and output data are stored in this area. Lastly, a power supply is needed for the processor and interface modules. [9]

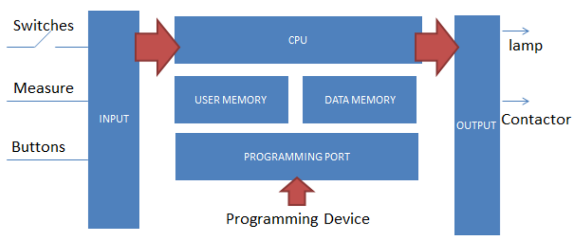


Figure 3.1: *PLC functionality*

4. CS31

This chapter describes the features of the communication protocol CS31 with AC500 using RS458 as a transmission medium. This bus protocol was developed by ABB in 1989 and is widely used in AC500 solutions. It is provided as an onboard interface with most AC500 CPUs. This chapter should give the reader an input in bus characteristics that will be necessary to know to fully understand later chapters.

4.1 Technical data

The CS31 bus uses mostly RS485 (twisted pair, with shield) for communication, but can be used with fiber optic cables (requiring a converter) or contact lines and slip rings. It should be noted that bus characteristics may differ from RS485 when using other types of transmission mediums. There is a limit of 31 modules that can function as slaves on the bus. The master handles communication with slaves using polling, which means that it sends a request to the slave and receives a response. The maximal length of a busline is 500m, or with repeaters it can extend to 2000m. The baudrate used is 187,5 kB/s with an 8-bit CRC appended to each telegram. This enables process input/output data to be written and read. [10]

4.2 In practice

In practice when the AC500 PLC is used as a CS31 Master, the busline is connected on COM1 interface of the PLC terminal base as seen in the following pictures. These configurations may differ from module to module, but these are taken from those used in chapter 9 and are very general. [5]

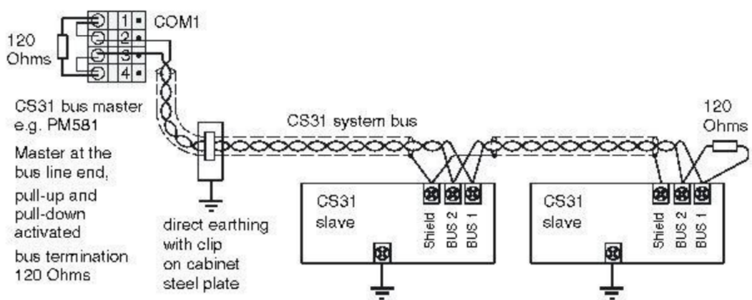


Figure 4.1: *Overview of bus topology in practice [5]*

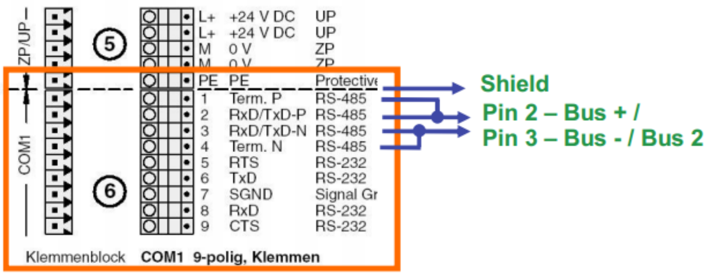
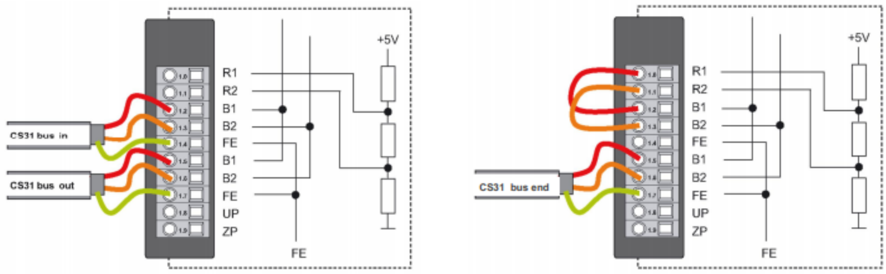


Figure 4.2: *Connecting bus on AC500 terminal base [5]*



(a) *middle of bus* **(b)** *end of bus*

Figure 4.3: *CS31 module connection [5]*

4.3 Restrictions

One mentionable restriction when using the CS31 protocol is in decentralized systems with the slave module. The Slave module can be viewed as a cluster with multiple attached I/O modules. The maximum amount of I/O modules connected to a slave module depends on the used CS31 bus module. The different bus modules may be specified for a given number of I/O module extensions, and a cluster with maximal configuration, which is a CS31 module with the maximum amount of I/O modules attached, can occupy two addresses. This means that if the first CS31 bus module is located at address 2, then the following has to be set at address 4.

However, getting maximal configuration on a CS31 cluster does not necessarily mean that all I/O module slots are used. This occurs when I/O modules exceed the amount of digital or analog subscribers. This can either be manually counted or viewed using a tool like Control Builder Plus. These restrictions may differ from module to module.[5]

5. AC500

This chapter describes the features and benefits of the ABB AC500 PLC. To prove the goal of this thesis it is crucial to be familiar with the AC500 PLC, and therefore it is a necessary part to include. The chapter describes the basics of the AC500 that are needed to fully understand later chapters. Some references where AC500 have been used are also shown and discussed to give a better grasp of an example area of use. The AC500 series can be found with different special features such as:

- AC500 - With or without internal Ethernet coupler.
- AC500 eCo - Budget PLC.
- AC500 S - Offers safety features for critical applications.
- AC500 XC - Offers state of the art technology for extreme conditions.

This chapter focuses on the AC500 with internal Ethernet coupler.[4]

5.1 Introduction

The AC500 PLC and the whole AC500 family consist of modules that are easily combined and scaled to fit descriptions given by customers. There are always expansions made throughout the lifetime of power plants and other plant industries. Most AC500 CPU modules are installed on the same terminal base, so when upgrading, only the CPU module has to be replaced for a more powerful version. This leads to minimal maintenance and downtime.

Figure 5.1: *AC500 [8]*

AC500 offers high availability, which can be described as warm standby redundancy without cycle synchronization (Software-layer redundany). This is discussed and described further in chapters 10 and 11. All AC500 CPU modules offer a display for setting mostly communication addresses but also different start-up modes. Errors and diagnostics are shown on the display allowing fast troubleshooting.[4]

5.2 Overview

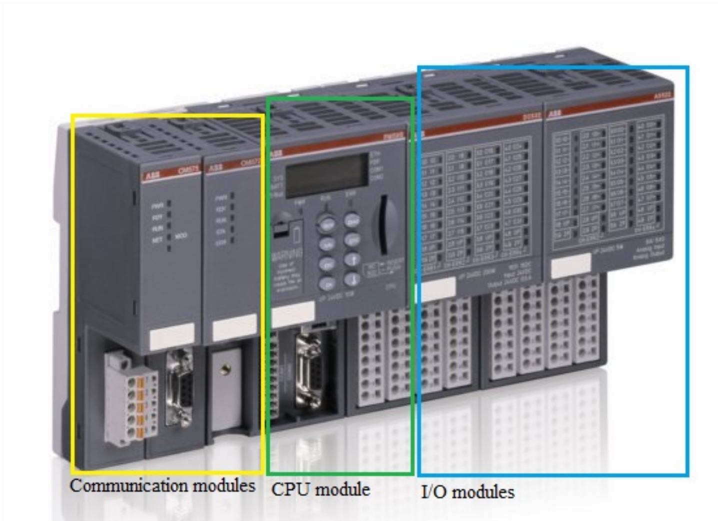


Figure 5.2: *AC500 Centralized system [7]*

AC500 as a centralized system offers very efficient scalability of projects and ease of use. As seen in figure 5.2, the green highlighted module refers to the CPU unit. The CPU unit itself as seen in figure 5.1 has to be mounted on a terminal base and supplied with 24VDC(figure 5.3 Power). The terminal bases for CPU units can have one, two or four slots for communication modules to be mounted on. All modules have to be mounted on terminal bases. Centralized I/O modules are connected with the CPU module through connectors on the terminal base.

Communication interfaces for the AC500 is possible using common open industrial networks via Ethernet, PROFINET, EtherCAT, ARCNET, Profibus, CANopen, DeviceNet, Modbus and CS31.

Using a centralized I/O rack, the maximum amount of modules supported by AC500 is ten. The amount of decentralized I/O racks is restricted by the used fieldbus type. The AC500 does not support hot swap when replacing I/O modules.

A lithium battery and SD-memory card are not supplied with the CPU and does not need to be used. It is however a recommended solution to use both a lithium battery and an SD-memory card. The lithium battery is used for saving RAM content and as a back-up for the real-time clock. The SD-memory card is used for updating CPU firmware, storing user programs and as a back-up of user data.

AC500 modules offer Ethernet communication with TCP/IP and UDP/IP protocols through the internal Ethernet coupler and the RJ45 connector located on the terminal base. These can be used simultaneously.[4]

5.3 Technical data and features

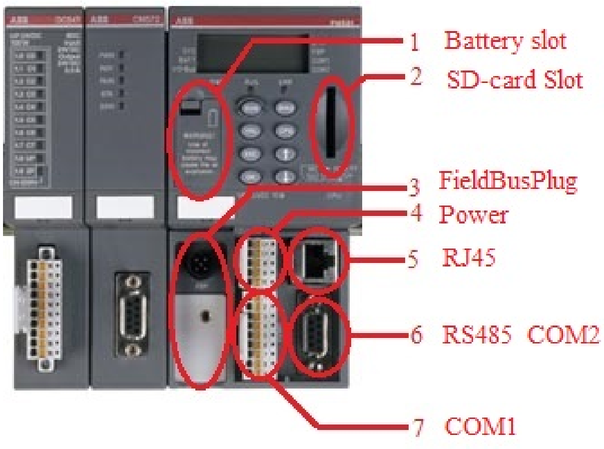


Figure 5.3: *AC500 Terminal base and CPU*

- 1. Battery Slot
  - Save RAM content
  - Back-up real-time clock
- 2. SD-Card Slot
  - Back-up user data
  - Store user programs
- 3. FieldBusPlug
  - Profibus DP (slave)
  - CanOpen (slave)
  - DeviceNET (slave)
- 5. Ethernet RJ45
  - Programming
  - Internet Protocols (webserver, FTP, e-mail,time sync, etc.),
  - IEC 60870-5-104
- 6. COM 2 - serial
  - Programming
  - ASCII protocol
  - MODBUS-RTU (master or slave)
- 7. COM 1 - Spring terminal
  - Programming
  - CS31 Bus (master)
  - ASCII protocol
  - MODBUS-RTU (master or slave)

All CPUs of the AC500 family are equipped with the same features, but with an exception for some models like PM572 and PM582 that don't offer *Web server's data for user RAM disc* . PM592-ETH, which is the most powerful module, is the only CPU offering *User flashdisc*, stated in technical documents as *4GB Flash nonremovable* used for Data-storage, program access or FTP functions. The amounts of integrated memory and process time are features that improve when changing from an inferior to superior CPU.[4]

The following comparison is done between AC500 and Siemens S7 CPUs with values gathered from their respective data sheets. An "average" model from each vendor was chosen as well as one of the more powerful versions.

	ABB AC500		Siemens S7	
	PM583-ETH	PM592-ETH	CPU315-2	CPU416-5H
CPU process time				
bit	0,05 µs	0,002 µs	0,05 µs	0,0125 µs
word	0,06 µs	0,004 µs	0,09 µs	0,0125 µs
fixed point	not stated	not stated	0,12 µs	0,0125 µs
floating point	0,5 µs	0,004 µs	0,45 µs	0,025 µs

Figure 5.4: *CPU processing time comparison [4, 15, 14]*

As seen in the figure above, the processing times for PM583-ETH and CPU3125-2 show minimal differences when compared, whereas the PM592-ETH from ABB is multiple times faster than the others. The CPU416-5H, which is a powerful Siemens CPU, does not reach the same processing time as the PM592-ETH, but exceeds the other ABB and Siemens CPU multiple times.

A memory comparison is made using the same devices. The memory type is stated differently from both vendors. In ABB data sheets stated as *Integrated User Data Memory* is compared to in Siemens data sheets stated as *Integrated (for data)* for work memory size. Load memory is stated in ABB data sheets as *Memory Size User Program* and in Siemens *integrated (for program)*.

	ABB AC500		Siemens S7	
	PM583-ETH	PM592-ETH	CPU315-2	CPU416-5H
Memory				
Work memory	1024 kB	4096 kB	384 kB	6 Mbyte
Load memory	1024 kB	5632 kB	pluggable MMC	10 Mbyte

Figure 5.5: *Load and work memory comparison. (observe different symbols of measure)[4, 15, 14]*

As seen in the figure above, again the same proportions of difference can be noted. It should be noted that the memory size used for CPU416-5H is the integrated value and can be expanded using a RAM memory card up to 64 Mbyte.

5.4 References

The AC500 family is a fairly "new" line of PLCs on the market and has therefore not been used in such a large scale as PLCs that have a longer product history, which due to their time on the market have established bigger "communities" for knowledge and support. Taking this into consideration it can be assumed that ABB customers should be introduced to a solution using AC500 to prove their features and benefits. This section of references is included to show one area of use where PLCs from the AC500 family have been used by ABB as a new solution or as a replacement for existing solutions. All these references comprise different water and wastewater solutions.

5.4.1 Sewage Treatment Plant, China

- Design Request
  - Full open system, run steadily
  - High control precision
  - Integrate & maintain easily based on module solutions
  - Programmed easily, fit on sequence flow control
- Project Introduction
  - Occupies $< 26km^3$
  - First step 20 km^3/day, in future 40 km^3/day
  - Solve the problem of pollution of industry section and protect water environment.

This was a new solution and based on the design request and the project introduction two AC500 PM581−ETH are used, both with four DI524-32DI, two DC532-24DC and one AI523-16AI. Both PLCs were installed in the power distribution room and communicate with SCADA using Modbus TCP/IP. The AC500 PM581−ETH fulfills high-speed computing requirements of the sewage treatment and the system that is fitted on a sequence flow chart can be developed by engineers using PS501 open programmable environment. It also fulfills the communication equipment and network requirements. Moreover it has passed a variety of international standard certifications considering sewage treatment plant environment.

5.4.2 Desalination Plant, Israel

- Design Request
  - Energy saving solution.
  - Multicontrol PLCs for reverse osmosis desalination process.
- Project Introduction
  - Older Plant controlled by Modicon PLCs with redundatn CPUs, bus lines
  - Desalination facility utilizes Reverse Osmosis
  - It will produce 100 million m^3 fresh water per year

In this project AC500 was used as a replacement for an old design and based on the new design request and project introduction, the project realization involve 120 $\times$ AC500 PLCs, AC drives and a solution based on Microsoft Dot Net and XML technology. One of the challenges was to use relatively independent PLC groups with separate PLCs for each task instead of using a small amount of PLCs with redundant CPU and bus lines. Competitive pricing position, energy savings and reduced maintenance costs are beneficial to the customer as well as improved membrane life thanks to pressure regulation.

5.4.3 Water Reuse Treatment Plant, China

- Design Request
  - Communication
  - Stability
  - Compatibility
- Project Introduction
  - Wastewater treatment for economic development area
  - Former existing solution: Siemens S7-300

Based on the design request and project introduction, the project configuration consists of two different stations. The PLC main station with a PM581 CPU and several I/O modules, which is used to coordinate to remote station controllers and the Chemical Dosing Station. These are linked by industrial switches for high speed data exchange on site. There are totally 6 remote stations equipped with a PM581 CPU and several I/O modules. The benefits for the customer are flexible options for communication integration with Phase I Siemens system, as well as a common programming environment - PS501. The use of CS31 bus for decentralization is another of the technical benefits.

5.5 Summary

The previous section is gathered from ABB AC500 success stories and these three were picked to display that AC500 has been successfully used as a "new" solution in projects, as well as a replacement for an existing control system and that it has been implemented to coexist with a former existing control system. They are shown as descriptions of those projects, but the whole project consisting of all details can be found at http://www150.abb.com/spaces/PLC-and-automation-Marketing-Team-Space/SitePages/References-and-SuccessStories-INTERNAL.aspx. This is an internal ABB database for information that cannot be accessed without access permission.

6. PS501 Engineering Tool

PS501 Engineering Tool is the ABB AC500 vendor-specific configuration tool with a range of different functions. This chapter gives an explanation of the two main parts of the PS501 Engineering Tool, which are Control Builder Plus and CoDeSys. They will to some extent be compared to other programming and configuration tools. Since the PS501 Engineering Tool is the programming environment for the AC500, it is necessary to know the overall basic parts of it to be able to fully understand later chapters. The current version of PS501 Engineering tool is version 2.3.0.

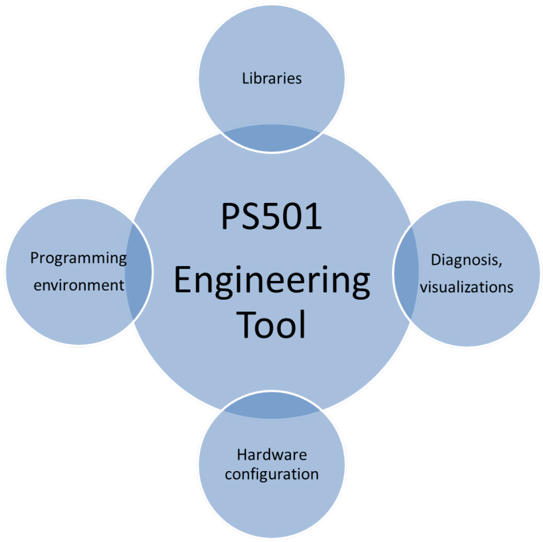


Figure 6.1: *PS501 Engineering Tool*

6.1 Control Builder Plus

Control Builder Plus is the vendor-specific part of the PS501 Engineering tool suite, and can be referred to as CBP. CBP is the starting point when configuring a new project. CBP handles all hardware configuration and to some point also the bus and Ethernet configuration of the project. These hardware configurations of used modules are sent to CoDeSys for finalization in the program.

6.1.1 Hardware configuration

All CPUs, I/O modules, interface and fieldbus modules are added into CBP to provide the user with an overview from the device tree. From the device tree the user can add or delete modules, but there is no graphical overview of the communication nor the system.

6.1.2 Parametrization

Configuration of hardware modules is done through parametrization. From here the user can choose specific configuration outcomes and solutions. Here all hardware settings are set for the different modules, such as mappings of I/O channels that are sent to CoDeSys and are a crucial part of the system functionality. Also IP addresses and module adresses have to be set according to hardware setup for the correct functionality. All parameters and settings for respective module are accessible by doubleclicking on them.

6.1.3 Diagnostics

When using diagnostics in CBP the following can be monitored: CPU Diagnostics, CPU statistics, Version information and PLC Browser. Also input values can be viewed live from CBP as well as communication module and fieldbus diagnostics.

From the different diagnostics it is easy to monitor cycle times, load on buses and CPUs which makes maintenance and troubleshooting much easier.

6.2 CoDeSys

CoDeSys itself is free to download programming environment developed by a German company called 3S-Smart Software Solutions. CoDeSys licenses are free of charge. This chapter only discusses CoDeSys version 2.3, as it is the version included in PS501.

6.2.1 Languages

CoDeSys offers programming in all five IEC 61131-3 languages, which include Instruction List, Structured Text, Ladder diagram, Function block diagram and Sequential function chart. Beyond that it also offers programming in a language called Continuous function chart, which is not defined as an IEC standard.

Structured Control Language, which is used by Siemens, cannot be used when programming in CoDeSys, but SCL is based on Structured Text so the similarities when programming are noticeable. Using IEC 61131-3 languages when programming is beneficial because it allows third party tools and module access as well as an easier integration with other systems.
[11]

6.2.2 Programming

CoDeSys itself is hardware independent so the capabilities when creating programs are endless. Learning the programming environment in CoDeSys may have a steep learning curve since it differs very much from e.g. Simatic manager, which is a widely used programming environment from Siemens.

Since CoDeSys by itself is hardware independent it needs to know the configuration of the project-specific hardware and its attributes, especially for the PLC. When using AC500 it is gathered from Control builder plus into CoDeSys as a Target file. This is needed for the software when using hardware specific blocks and different hardware diagnostics.

The main components when programming in CoDeSys is Program Organization Unit (POU), Data types, Visualizations and resources. POU consists of all functions, function blocks and programs. The data types section makes it possible to create your own data types such as structs and references etc. along the standard data types. Visualization is for making HMI visualizations, or if the PLC supports web visualization (visualization on webserver) or target visualization (visualization directly on PLC display). In resources, the configuration and organization of the project are found, e.g. global variables, task configuration, Library manager etc.

Program execution in CoDeSys is performed through task configuration, which can be found under resources tab. From the task configuration different forms of tasktypes such as cyclic with interval time, freewheeling and triggered by event or external event can be made and have to be set with a priority. Those programs made under POU can then be appended in the task. There are restrictions on PLCs regarding how many tasks can be used. Both PM583-ETH and PM592-ETH can have a maximum of 16 tasks, whereas for example PM573-ETH can only handle a maximum of three tasks.

6.3 CoDeSys with other brands

There is a large number of PLC manufacturers that offer programming with IEC 61131, but the cross compatibility is lost because there is to my knowledge no standards for import and export of programs or projects. There are only ”guidelines” written as standards for the program-code itself. This means that when making a program in for example FBD it follows IEC 61131-3 standards and is compatible to some extent with other platforms and programming environment, but since there are no standards for exporting and importing files, they cannot be shared between vendors. [12]

Some manufacturers that offer CoDeSys for their modular PLCs are Berghof, Eaton, Festo , Hitachi, Mitsubishi, Schneider, WAGO etc. The whole list can be found at CoDeSys.com . Just like AC500 has a specific target file, most of these also have a vendor-specific part creating a Target file specific to their own platform. If the project only consists of basic functions and function blocks that don't need the information about the PLC, that program can be used on multiple platforms. [16]

When using CoDeSys for programming an extension of function blocks with OSCAT library is very useful (*http://www.oscat.de/*). This is a hardware independent IEC 61131-1 library provided license free. Since it is open source it offers great flexibility and includes over 800 library modules.

7. Water & Wastewater

This chapter describes the functionality of ABB Water & Wastewater library and the library in combination with S+ operations. The library has been developed by ABB for the purpose of giving standard solutions for waste and wastewater applications. A license must be ordered and requested via ABB when included and used in CoDeSys. The Water & Wastewater library is used in this thesis because of its current content of function blocks. This is explained in the Water & Wasterwater chapter and also used in later chapters.
The current library version is V1.0, but the Water & Wastewater library V1.1 is planned to launch in 2014.

7.1 Functionality

When trying to understand the functionality of the Water & Wastewater library one must first understand the basic PLC project structure. Many PLC systems as well as AC500 systems provide diagnostic information of the hardware layer that is nearly impossible to make use of in user applications. When using ABB AC500 systems, projects are separated in two main parts, which are hardware configuration and user application. With the Water & Wastewater library it is possible to create a program called HW_PRG between hardware and user application. HW_PRG is where pre-made function blocks for S500 I/O modules with their individual configuration and mappings are called, as seen in figure 7.1.

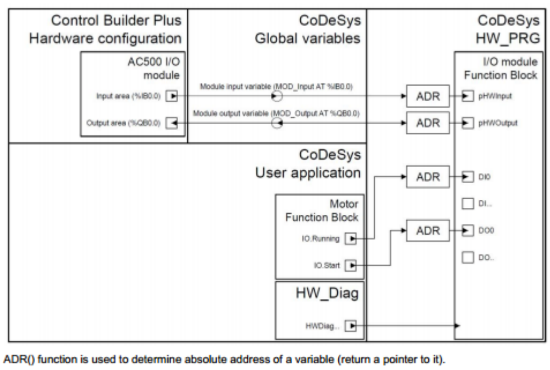


Figure 7.1: *Structure [3]*

This program is not included in Task configuration but instead called through the main program with a function called HW_Diag, which is included in the library. Calling HW_Diag is necessary for the functionality of the library and should be included in a cyclic manner.
HW_diag is protected in the library with a nowrite flag and can therefore not be changed by the user. Instead HW_PRG must be made as a program containing those hardware configurations that are specific to the project. HW_Diag uses HW_PRG as a reference

when refreshing IO data and passing diagnostic messages.
For example: When using the default program PLC_PRG and appending it to a cyclic task it is possible to call HW_Diag simply by calling HW_Diag() in PLC_PRG. This means that the diagnostic function HW_Diag is called every PLC cycle through PLC_PRG, and HW_PRG is therefore not necessary to append in task configuration. Following the guidelines given for HW_Diag, input/output processing and diagnostic reset is executed in HW_PRG as:

```
IF HW_Diag.HWCallTask=1 OR HW_Diag.HWCallTask=2 OR
 (HW_Diag.HWCallTask=3 AND (HW_Diag.HWDiagStart OR HW_Diag.HWDiagEnd)) THEN
 (* Processing of Input/Output or global diagnostic buffer shift *)
 (* For update of I/O, modules have to be listed here *)
 Module1();
 Module2();
 END_IF;
```

The second part of HW_Diag is diagnostic processing. Function blocks for I/O modules have no information of where they are located on the I/O bus or fieldbus, so the program has to be made so that it passes the diagnostic message to the right function block. Diagnostic messages can then be read from the outputs of HW_Diag.

```
IF HW_Diag.HWCallTask=3 THEN
 (* Modules are called periodically to process errors. This is based on their posit
 IF HW_Diag.HWDiagComp=14 THEN (* I/O bus *)
 CASE HW_Diag.HWDiagDev OF
 1: (* Module number one on I/O rack *)
 Module1();
 2: (* Module number two on I/O rack *)
 Module2();
 ELSE
 ; (* Non-recognizable module *)
 END_CASE;
 ELSE
 ; (* Non-recognizable module *)
 END_CASE;
END_IF
```

7.2 Function blocks

The Function blocks in the Water & Wastewater library can be sorted into four different groups depending on the functionality.

- Device control blocks

  FB_Motor1_1, FB_Motor2_1, FB_Valve1_1 FB_Valve2_1, FB_Transmitter1_1

- Application logic blocks

  FB_Alarm1_1, FB_AlternationTime1, FB_AlterationPri2_1, FB_LimitControl1_1, FB_LimitControl2_1, FB_Actuator1_1

- Real time function blocks

  FB_TimeData1, FB_OperatingData1_1, FB_Accumulator1_1

- Calculation blocks

  FB_Weir1_1, FB_Inflow1_1

All these blocks have an application interface and an HMI interface. Device control blocks have an additional hardware interface since they are connected to the hardware layer. The function blocks under device control blocks also have a first scan behavior because of this. This ensures a smooth transition when the program is updated by giving the hardware layer time to read the hardware inputs and outputs and update correct IO variables. This delay occurs because block outputs are not updated and I/O signals are ignored for the first cycle.[3]

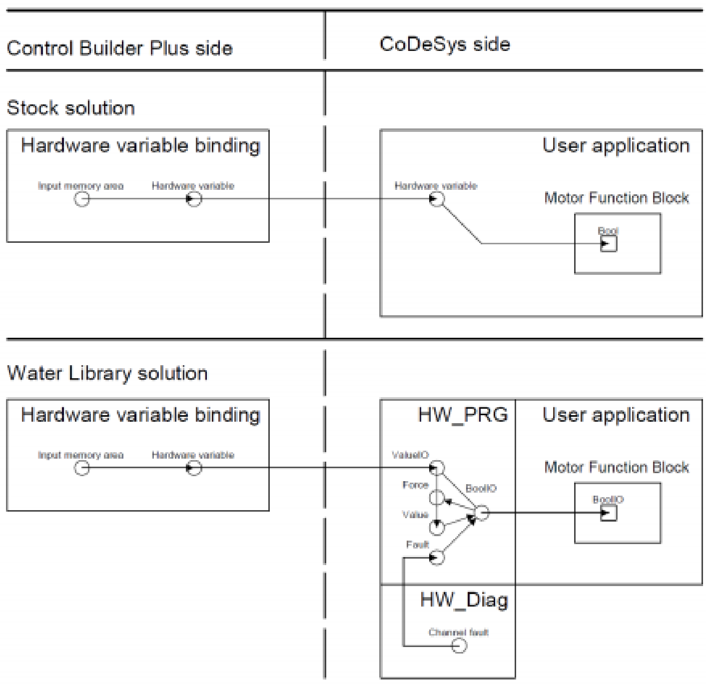


Figure 7.2: *Functionality of the hardware interface. [3]*

7.2.1 Hardware interface

As mentioned before, hardware interface is only present in those function blocks that are meant to be connected to the hardware layer. This interface interacts between the function blocks and the I/O modules of the PLC as seen in figure 7.2. The data types used for this interface are marked with an IO_ prefix followed by the name.[3]

7.2.2 Application interface

Application interface is present in all Water & Wastewater function blocks. Application interface variables are used to connect to other parts of the program. Input variables of the application interface can be changed from both inside and outside the block. Output variables of the application interface can be used directly as inputs to other blocks or copied to other variables.

Output variables cannot be changed from outside the block, nor can they be accessed from HMI or SCADA.[3]

7.2.3 HMI interface

HMI interface is present in all Water & Wastewater library function blocks that have to be accessed from S+ operations. HMI variables are divided into read-only and writable variables. Read-only variables are in general marked with an SO_ prefix and writable with an IP_ prefix, e.g. in FB_Transmitter1_1, the HMI.SO_value which is the output value from the block can only be read and displayed on the HMI, but HMI.CONF.IP_LimAHH which is the level of the HH-alarm can be set from S+ operations.
Device control blocks can also be accessed from S+ operations in such a way that protection is bypassed allowing writing directly to PLC outputs. This has to be done with careful consideration.[3]

7.2.4 FB_Motor1_1

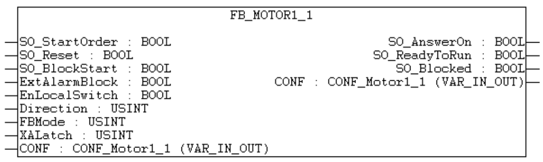


Figure 7.3: *FB_Motor1_1 [3]*

This function block can be used when a motor or similar device has to be controlled using only one activation signal and one feedback signal. [3]

7.2.5 FB_Motor2_1

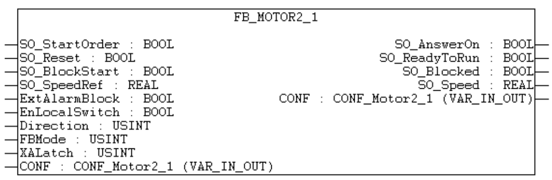


Figure 7.4: *FB_Motor2_1 [3]*

This function block can be used when a motor or similar device has to be controlled using analog speed control. [3]

7.2.6 FB_Valve1_1

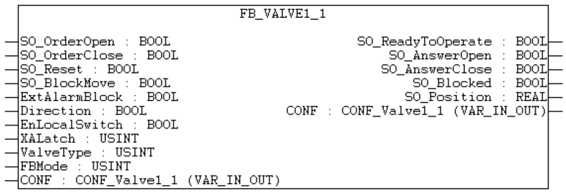


Figure 7.5: *FB_Valve1_1 [3]*

This function block can be used when a valve has to be controlled using activation signals in both directions and feedback from both directions. This valveblock can be set from e.g. alarm outputs or other BOOL type variables. The operating time of the valve can be set and valve position can be monitored from that. [3]

7.2.7 FB_Valve2_1

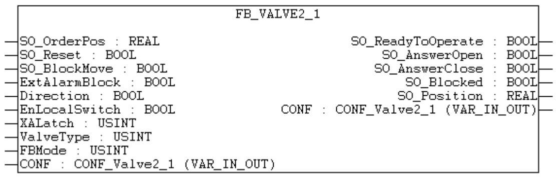


Figure 7.6: *FB_Valve2_1 [3]*

This function block can be used when a valve has to be controlled using analog value as setpoint for the valve, and analog feedback from the valve. This block can e.g. be operated with a controller output ordering the position of the valve.[3]

7.2.8 FB_Transmitter1_1

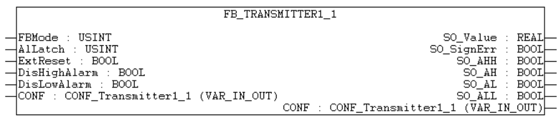


Figure 7.7: *FB_Transmitter1_1 [3]*

This function block is used when evaluating an analog signal. It has a hardware interface where it handles both analog and digital input. The type of variable into the hardware interface of the block is REALIO or BOOLIO. This means that it has to be connected to the hardware layer and cannot be used with another type of variable as input signal.

When the block is in normal operation and has a value from e.g. an analog input, the value is passed to both application and HMI interfaces. Scaling of the signal is done inside the block. [3]

7.2.9 FB_Alarm1_1

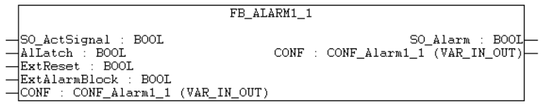


Figure 7.8: *FB_Alarm1_1 [3]*

This function block monitors a BOOL variable and if a TRUE edge occurs for a longer time than the configurated DelayOn, an output alarm signal is set to TRUE. This block can be used to monitor fire alarms, level switches, door alarms etc. [3]

7.2.10 FB_AlternationTime1

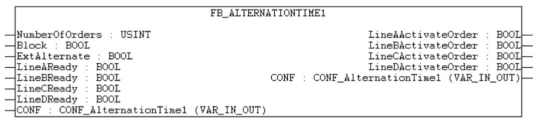


Figure 7.9: *FB_AlternationTime1 [3]*

This function block can handle four objects. The functionality of the block is to alternate between the four objects. The longest running one is stopped first and the one being stopped for the longest time is next to start.[3]

7.2.11 FB_AlterationPri2_1

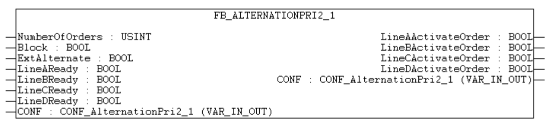


Figure 7.10: *FB_AlternationPri2_1 [3]*

This function block can handle four objects. The functionality of the block is to alternate between the four objects. Unlike FB_AlternationTime1 this function block uses a priority list when alternating between objects. The possibilities are:

- Choice 1: LineA – LineB – LineC – LineD
- Choice 2: LineB – LineC – LineD – LineA
- Choice 3: LineC – LineD – LineA – LineB
- Choice 4: LineD – LineA – LineB – LineC

[3]

7.2.12 FB_LimitControl1_1

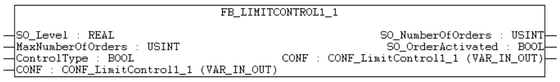


Figure 7.11: *FB_LimitControl1_1 [3]*

This function block monitors a reference value of type REAL. This value is measured against a maximum of four different limits to which output is set, which makes it suitable for different types of reservoirs, tanks, etc.[3]

7.2.13 FB_LimitControl2_1

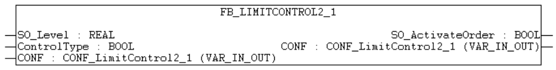


Figure 7.12: *FB_LimitControl2_1 [3]*

This function block monitors a reference value of type REAL and, when the configurated limit value IP_LimStart is exceeded, the output BOOL is set to TRUE. This function block can be connected directly to start/stop of motors and valves.[3]

7.2.14 FB_Actuator1_1

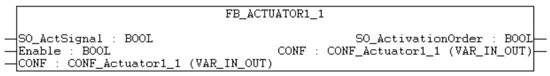


Figure 7.13: *FB_Actuator1_1 [3]*

This function block works as a counter, monitoring the rising edge of a BOOL type signal. When exceeding the pre-configured number of pulses, the output signal is set to TRUE.[3]

7.2.15 FB_TimeData1

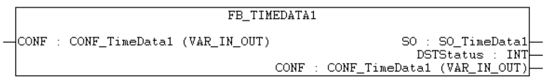


Figure 7.14: *FB_TimeData1 [3]*

This function block handles system time and provides time information for the other blocks of the real time clock function block group. The internal clock of the PLC is used for calculating the local time and daylight savings.[3]

7.2.16 FB_OperatingData1_1

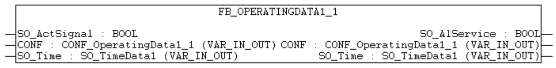


Figure 7.15: *FB_OperatingData1_1 [3]*

This function block is used for calculating operating data for certain devices. It monitors a BOOL type signal and while the signal is TRUE it uses FB_Timedata1 to calculate operating data. Runtime data, time to service etc. are obtained with this function block.[3]

7.2.17 FB_Accumulator1_1

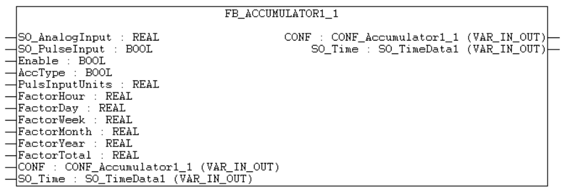


Figure 7.16: *FB_Accumulator1_1 [3]*

This function block is used for calculating different types of quantities. For example energy or water comsumption can be calculated on timebase using FB_Timedata1. The pulse mode or analog mode can be used based on preference.[3]

7.2.18 FB_Weir1_1

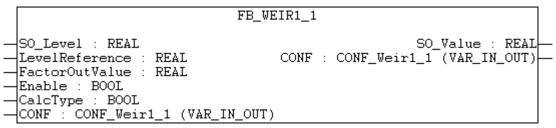


Figure 7.17: *FB_Weir_1 [3]*

This function block calculates the flow in rectangular and triangular weirs. The weir is divided into ten segments. Data on volume and height of the individual segments has to be configured for the right functionality of the block. [3]

7.2.19 FB_Inflow1_1

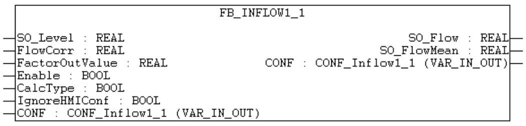


Figure 7.18: *FB_Inflow1_1 [3]*

This function block calculates the flow into or out from a tank. The functionality is similar to FB_Weir1_1 and the tank has to be divided into ten segments.Data on volume and height of the individual segments has to be configured for the right functionality of the block. [3]

7.3 Implementation

As of today the Water & Wastewater library consists of earlier listed function blocks, but for this thesis I was also able to try the PID controller function block, which is planned to be launched in Water & Wastewater V1.1 later this year. It had the necessary interfaces to function with S+ operations . These function blocks cover almost all critical blocks used for Project X, which is discussed in Chapter 8. An exception is the function block for breakers which cannot be found in Water & Wastewater, but can be developed based on a requirement specification and included in the library in the future. Symphony Plus Water Automation department in Sweden is responsible for updates of the library.

The function blocks are easily implemented in CoDeSys from where they can be utilized from S+ operations after they are downloaded on the PLC. This is a part that is described by Mr.Anton Wargh in his thesis - *Symphony plus as application for power plants - S+ operations subproject.*

8. Project X - Using AC500

This chapter is an essential part of the thesis, as it shows how an existing system solution could be solved using AC500. The layout is from an engine power plant in Liberia using a Siemens solution. This chapter gives a clear view of the advantages and disadvantages of the different system solutions. PLC program sizes and programming environment advantages and disadvantages are not addressed in this chapter. The full system overview can be seen in Appendix 1.

8.1 Introduction

The engine power plant is a 20MW Power Plant with the configuration of 5 Diesel engines at 4,164 MW a piece, located in Liberia (Personal communication 26.03.2014). I believe there have been som changes in the system overview since the revision used for this thesis work. This should not be of any concern, since the overall solutions are more relevant than the specific solution for this project.

8.2 Communication

This section describes different types of communication protocols used, based on the layout. They are compared to those available with the AC500.

8.2.1 Siemens

For the Siemens solution the different communication types used are listed in figure 8.1. On panel-level, Ethernet is used to communicate both inside and outside the panels via switches. Profibus is used to communicate to remote stations and it is also used to achieve redundancy to remote stations, and via Y-link to singular devices. Communication to relays is done with Modbus TCP in this case, instead of the widely used IEC 61850 standard.

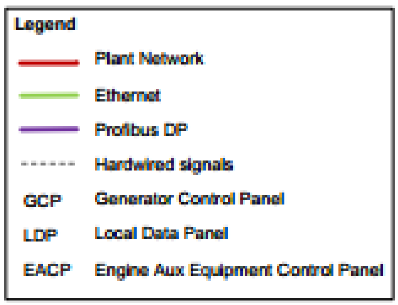


Figure 8.1: *Communication*

8.2.2 ABB

For the ABB solution, Ethernet can be used in the same way as in the Siemens solution, but instead of Profibus a solution using CS31 is mandatory for achieving high availability. Redundancy on device level is not manageable because of the lack of an Y-link. Both TCP and UDP can be utilized at the same time, offering both fast transmission and a more reliable transmission. Communication to relays can be achieved with Modbus TCP or using IEC 60870-5-104 depending on device support.

8.3 Common Control Panel

The common control panel is the "main" panel of the plant. It is also the most critical panel and has to be kept running for the functionality of the power plant.

8.3.1 Siemens

For the CCP (central control panel) two S7-400 H type PLCs are used to handle all communication and program operations. Synchronization between the two redundant PLCs is achieved through Siemens communication. The redundancy is used for remote I/Os and motor control devices, e.g. Simocode, which is used to give more control over different motors located on the plant. The redundancy is synchronized continuously using Siemens' own internal communication via an optical fiber.

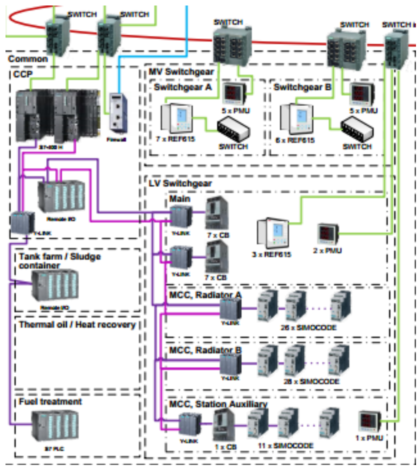


Figure 8.2: *Common Control Panel*

8.3.2 ABB

AC500 cannot be used in this case, as the high availability solution using CS31-buses will cause problems because of its restrictions on the ratio between nodes and bandwidth (about 60 nodes in this case). Instead, using the AC800 PLC for the common control panel in this case could be a more efficient solution to maintain redundancy in the system. Communication to AC500 in other panels can be achieved using Modbus TCP or Profibus, as well as a working communication with S+ operations using Ethernet. The AC800 is a PLC developed by ABB, but this will not be discussed any further in this thesis.

8.4 Generator Control Panel 1-5

There is one Generator Control Panel per engine in the power plant. They are not as critical as the Common Control Panel because the plant can even function with one engine faulting.

8.4.1 Siemens

For the GCP (Generator Control Panel) an S7-400 PLC is used to handle communication and program operations. GCPs in this case are installed with PMUs and protection relays and communication to these are achieved using standard Modbus TCP. The generator protection relay is connected directly to operator stations. There is no redundancy in the GCP panels, and communication to Remote I/O stations is done with Profibus. The AVR (Automatic Voltage Regulator) is connected only to other AVRs in this case. A viscosimeter used to measure the viscosity in fluids is connected via a switch and converter (Modbus TCP/ RS485).

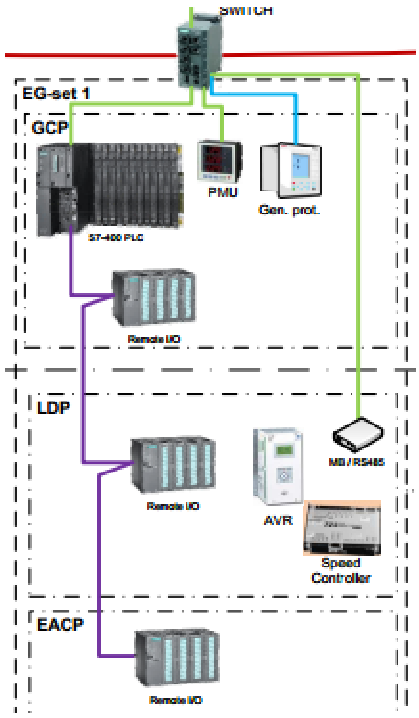


Figure 8.3: *Engine panels 1-5*

8.4.2 ABB

The AC500 is a suitable solution for the Generator Control Panels thanks to the lack of redundancy in those panels. Profibus can be used in the same way as for the Siemens solution. For communication to PMU and relays, AC500 supports IEC standard 60870-5-104 and Modbus TCP. This could also be solved using another fieldbus, e.g. Profinet which would support a ring type topology if necessary. Using the AC500 as a Profibus or Profinet master is achieved by using separate communication modules. The viscosimeter could be used via the same type of solution via a switch and a converter.

8.5 HMI

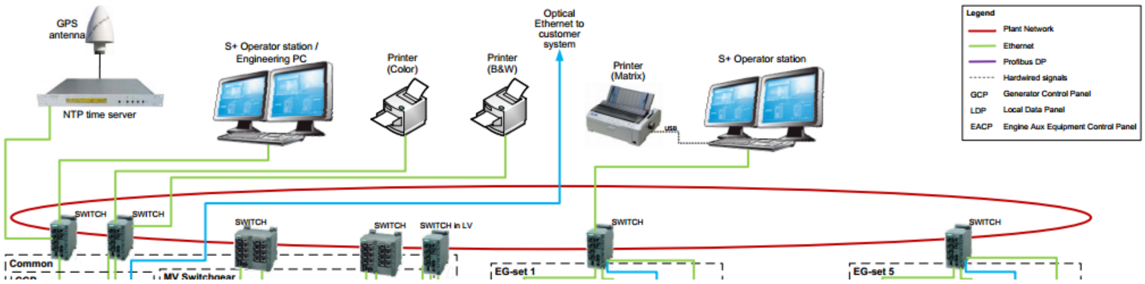


Figure 8.4: *Engine power plant operator stations*

This part is explained in Mr.Anton Wargh's subproject on S+ operations, but some aspects are worth mentioning in this part as well.

8.5.1 Siemens

The solution shown in Figure 8.4 was in this case changed to a Siemens solution, using WinCC SCADA.

8.5.2 ABB

This could be solved by using OPC server and S+ operations. The benefits of this solution are presented in the thesis conducted by Mr.Anton Wargh and are discussed more thoroughly there, so readers should refer to this document.

8.6 Summary

This chapter gives a direct input for the reader to see the current capabilities of the AC500. There are some aspects of the AC500 that could be improved to make it more suitable for this area of use. These aspects are discussed in chapters 10 and 11 where it is directly weighed against the Siemens PLCs, using information from experience gathered during this thesis work and inputs from specialists and co-workers.

9. Creating a Project

This chapter describes the overall making of a project using PS501. This project is going to be connected with S+ operations. It is based on the demo setup made by me and Mr.Anton Wargh to test the usability and functionality of AC500 in combination with S+ operations. The steps are explained in an "overall" type of way instead of a step by step way, because the overall configuration is more relevant than program-specific settings and configurations. The project can be seen in Appendix 2.

9.1 Project

The target with the demo solution is to determine the functionality of the AC500 PLC. It was therefore necessary to get a hardware setup providing those functions that are mostly used in e.g. power plant projects. The focus was on performance, redundancy, communication and I/O modules consisting of both digital and analog inputs and outputs, with support for thermocouple. The hardware modules chosen for this were:

- 2 X PM590-ETH CPU
- AX522 - Analog input/output module, 8AI/8AO, PT100.
- AI531 - Analog input module, 8AI, thermocouple.
- CI590 - High availability, CS31, 16DC
- Ethernet switch

9.2 Overview

Mr.Anton Wargh and I chose to make the demo solution based on a watertank process. The watertank process itself is a simple type of process consisting of mainly tanks and valves, but can be expanded to use almost all function blocks included in the Water & Wastewater library. Since it is a demo solution intended to be shown and displayed, the watertank solution is a good solution based on its simplicity.
The functionality of the watertank process is based on two different water tanks. These tanks have a continuous flow between them from tank 1 to tank 2. The level in Tank 1 is regulated by its inflow through a valve that is operated by a PID controller. The level in tank 2 is only regulated if the level reaches a high limit, leading to a drain-valve opening and triggering an outflow from tank 2. If the limit reaches a high-high limit, not only does the drain-valve of tank 2 open, but a pump starts to run which then increases the outflow of the tank. The operating data for the pump is calculated as well as the outflow quantity.

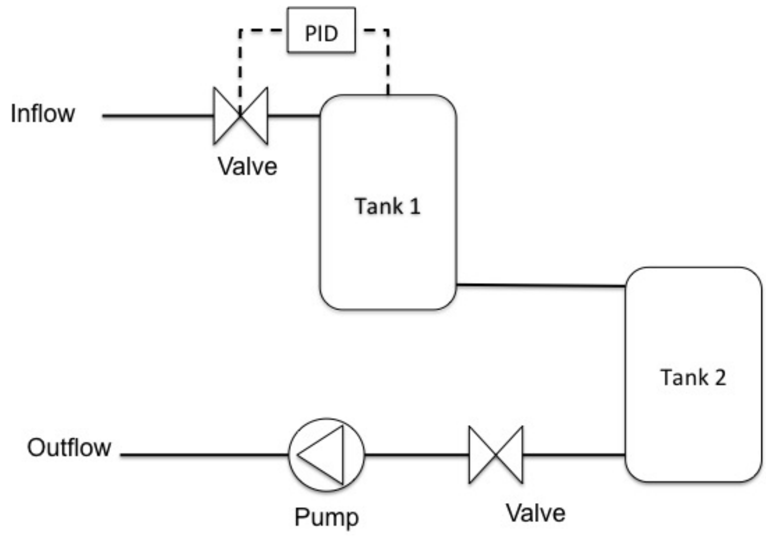


Figure 9.1: *Watertank process*

9.3 Hardware installation

It is easiest to start with mounting of all modules on their respective terminal bases. The terminal bases are easily locked on a DIN-rail, but the order in which the I/O modules are mounted has to be noted if the hardware is not present during the hardware configuration in Control Builder Plus. This has to be noted because it has to comply with the configuration in Control Builder Plus. Since this is a decentralized system, power supply is needed for both "clusters".

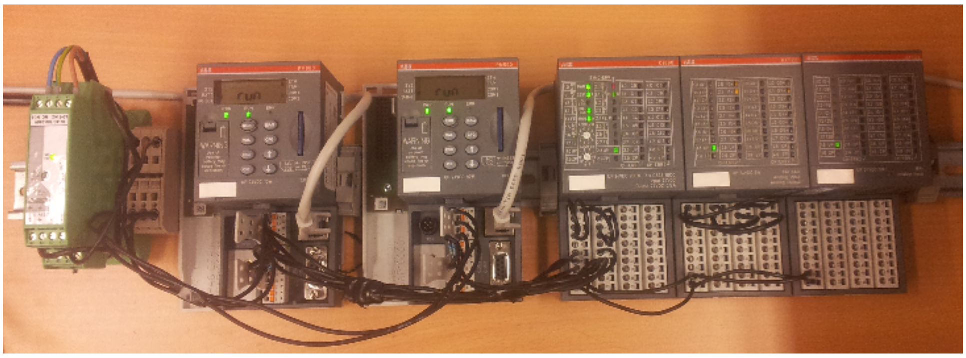


Figure 9.2: *Hardware installation*

9.4 Communication protocols

The communication protocols used in this project are:

- CS31 bus for high availability
- Ethernet for programming and for communication to S+ workstation
- Modbus TCP for testing functionality

- UDP/IP communication between CPUs

The CS31 bus that is used in this project to achieve high availability has to be connected from the COM1 port on both CPU modules to the CI590 high availability module. End terminators are default for the CI590 module, but on the COM1 port of both CPUs an 120Ω resistor has to be added for the bus to function properly. This can be verified by measuring the resistance over the bus with a multimeter. The multimeter should show a resistance of 60Ω. Two rotary switches are located on the CI590 module for setting the address of the module. This address has to comply with the configuration in both Control Builder Plus and CoDeSys.

Ethernet communication is used for programming the PLCs and for being able to go online and monitor the functionality in CoDeSys. Connection to S+ operations is also achieved using Ethernet. When having multiple computers and PLCs connected to the same network, it is crucial to avoid IP-conflicts by choosing different static IP-addresses. The IP-addresses of the two PLCs can be set either from the display or through Control Builder Plus. Communication parameters are then set to either of those addresses depending on the desired PLC to connect to.

Modbus TCP was used in this project to test its functionality and load on CPU. There are hardware independent Modbus function blocks in CoDeSys that were used for this. In Control Builder Plus the onboard Ethernet coupler has to be configured for this by adding Modbus TCP/IP server/client. Read and write of registers was tested by using a secondary laptop running a Modbus server simulator. The Modbus program was appended to a 10ms cyclic task and recorded a polling interval of $\tilde{2}0$ms in the Modbus server simulator.

UDP/IP is used for data transfer between PLCs. It is used with high availability for the communication between CPUs. Modbus TCP can also be used for this and is a more reliable way, because TCP has checksums and uses resending to assure stable data transaction. With UDP this cannot be achieved on the same level, but it is a faster type of communication.

9.5 Hardware configuration

Hardware configuration is done in Control Builder Plus. To be able to start the hardware configuration, specifications should be known. There are ways to change the hardware configuration if modules are replaced after the configuration is done, but then those changes have to be downloaded into CoDeSys from Control Builder Plus.
The hardware configuration begins with naming of a new project and saving it. One can choose to start a new *AC500 project* or just *new project*, but by choosing *AC500 project* the CPU can be chosen directly from the *AC500 project* window. Though two CPU modules of the same type are used in this project, only one has to be added to the project tree. This is because high availability needs to have the same project configuration to function properly. Therefore the same project configuration is downloaded into both CPUs with the exception of individual IP-address configuration. The IP-address

is set to 192.168.0.10 as default, but can be changed from the display of the CPU module, in Control Builder Plus under tools/IP-Configuration or from IP_Settings located in the Project tree. When using the last mentioned it should be known that it overwrites both display and IP-Configuration tool data. In this project the AC500 web server is tested, so under IP_setting in tab *Extended settings* the option *Web server active* is checked.

Since this project uses a decentralized I/O rack, the I/O modules should not be added directly to the CPU module like in centralized extension, but under the used communication interface module. Interfaces, located as one of the main "branches" of the project tree displays onboard interfaces that can be used. These have to be configured for the bus protocol used, and for this project, the *CS31 - bus* is chosen on COM1. The parameter *operating mode* is default set to master and therefore it does not need to be changed. When the bus protocol is chosen for respective interface, modules that are connected to the interfaces should be added as devices under that interface. For this project the CI590 module is added under the earlier configured COM1 interface, and I/O modules are then added onto the CI590 module. The address chosen from the rotary switch that is physically located on the CI590 module has to comply with the parameter module address on the CI590 module in Control Builder Plus.

As mentioned before, I/O modules are added to the CI590 module in this project. Like all other modules in hardware configuration they are added from an ABB vendor specific device list. I/O modules have to be added in Control Builder Plus in the same order that they are physically installed on the DIN-rail, for the correct functionality. The I/O module configuration is critical for the functionality of the project, because the mappings, which are the variables names, addresses, channels and types, are exported to CoDeSys to achieve the use of *I/O* modules in the program.

Only those variables that are configured with names are exported to CoDeSys. The configuration of the channels also has to be done in Control Builder Plus. This is dependent on the module used, but for this project 0..20mA was chosen for all active channels, since two analog inputs and two analog outputs are used.
Under branch Onboard_Ethernet in the project tree, UDP data exchange, Modbus server and Modbus client are added. When these configurations are done, configuration data and mapping data are exported to CoDeSys by doubleclicking on source code file.

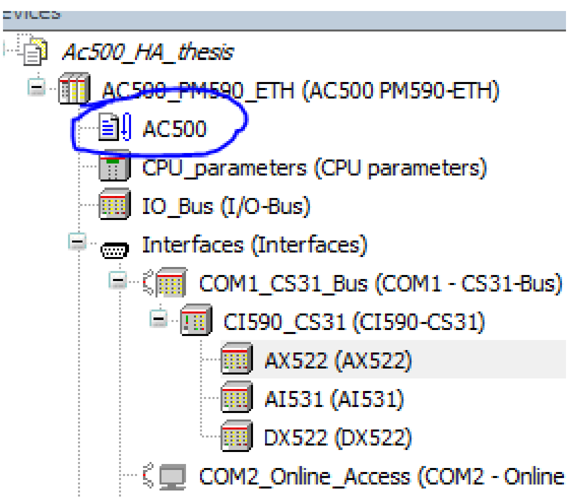


Figure 9.3: *Opening CoDeSys*

9.6 Software Configuration

CoDeSys opens with an empty program called PLC_PRG located in the POU tab. This project uses multiple Water & Wastewater function blocks, thus the library has to be added. For the library to function properly the option "Replace constants" has to be checked. This option can be found under *Project/Option/Build*.

The mapping variables are imported to CoDeSys and can be seen in Resources tab under *Global variables/Interfaces/COM_CS31_Bus/CI590_CS31*. To make use of these variables a program called HW_PRG is made. Here both I/O modules are implemented using their specific function blocks from the Water & Wastewater library. HW_PRG for this project is structured based on guidelines in document *2VAA002998* with a few modifications. Structured text is used because it allows for easier and faster coding.

```
    module1.pHWInput:=ADR(in0);
    module1.pHWOutput:=ADR(out0);


 (*  I/O bus module 01 application connections  *)


    module1.AI0:=ADR(level.IO.IO_Value);
    module1.AO0:=ADR(Watertank.value_outWord1);
    module1.AI1:=ADR(level2.IO.IO_Value);
    module1.AO1:=ADR(Watertank.value_outWord2);
(*  Analooginputs unused  *)
(*  module1.AI1:=;
    module1.AI2:=;
    module1.AI3:=;
    module1.AI4:=;
    module1.AI5:=;
    module1.AI6:=;
    module1.AI7:=;*)
```

Figure 9.4: *I/O setting in HW_PRG*

PLC_PRG is used in this project as a "main" program where first scan behavior and HW_Diag both are executed. Going to Resources tab and by opening Task configuration a cyclic 50 ms task is created and PLC_PRG is appended to that task.

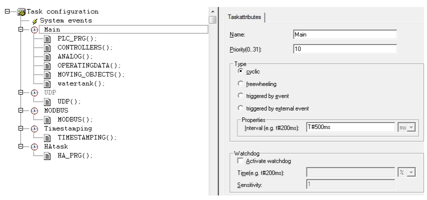
```
(* Obligatory FUNCTION call FOR HW_Diag *)
HW_Diag();

(*Calling CPU diagnostics used in visualization*)
CPU(EN:=TRUE , DONE=> , ERR=> , ERNO=> );



(*First scan extra behaviours*)
IF FirstScan THEN
controller.InitmodeReset:=FALSE;
FirstScan:=FALSE;
END_IF
```

(a) *Programcode*



(b) *Task Configuration*

Figure 9.5: *PLC_PRG*

The high availability configuration requires an additional library called HA_CS31_AC500_V23. HA_PRG and CALLBACK_STOP are programs added to POU for high availability. Callback stop, which is the mandatory name for the program, calls function HA_CS31_CALLBACK_STOP intended to detect CPU stop event.

System events

Name	Description	called POU
☐ start	Called when program starts	
☑ stop	Called when program stops	callback_stop
☐ before_reset	Called before reset takes place	
☐ after_reset	Called after reset took place	
☐ shutdown	Called before shutdown is performed	

Figure 9.6: *Calling CALLBACK_STOP using system task configuration*

This program is called from Task configuration under System events by checking *stop* and typing the program name under the column *called POU*. Another program called

HA_PRG is made containing HA_Diag and HAcontrol which are the diagnostic block and the block handling the high availability switchover. This program is appended in a cyclic task of 20ms called HAtask.

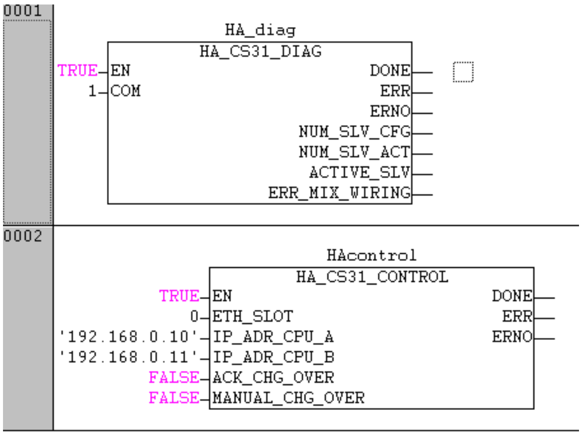


Figure 9.7: *High availability function blocks*

The Modbus communication was solved by using function blocks called ETH_MOD_MAST in a program called MODBUS. This program was also appended in a Task of 10ms called MODBUS. Modbus was tested using a second laptop running Modbus server simulator, where the polling time and register set and read were monitored.

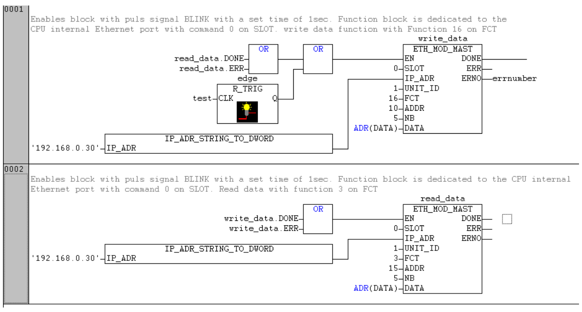


Figure 9.8: *Modbus function blocks*

The rest of the programs implement mostly function blocks from Water & Wastewater. These were made to control the process tank level using values from the program called watertank, consisting of calculations that simulate inflow or outflow of a watertank. Since no real process tank was used, the simulated level calculated in the watertank was set to the first analog output of module AX522. This had to be done because the signal used in FB_Transmitter1_1 has to be RealIO. That is accomplished by wiring the first analog output to the first analog input, thus making it possible to use FB_Transmitter1_1. Parameters have to be set for the outgoing signal or else the module function block will get an error because of the lack of maximum and minimum values.

```
0020    AnalogSignal1_par: SignalParReal:=(MinVal:=0,MaxVal:=100,Unit:='%');
```

Figure 9.9: *Analog signal scale configuration values*

The analog input is then used in FB_Transmitter1_1 and scaled as 0..100. This signal is used for the PID controller block in the program CONTROLLERS. The valves and motor blocks are located in the program called MOVING_OBJECTS.

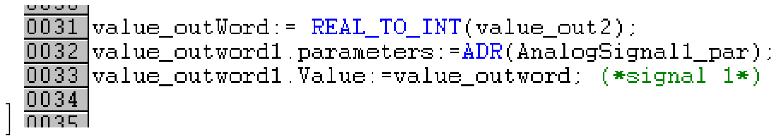
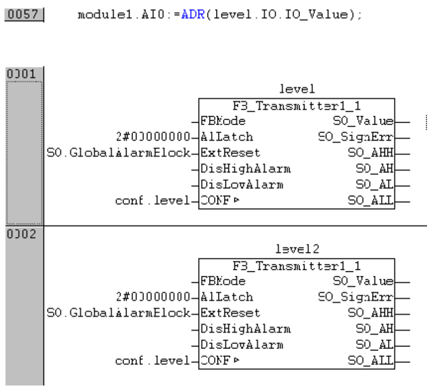
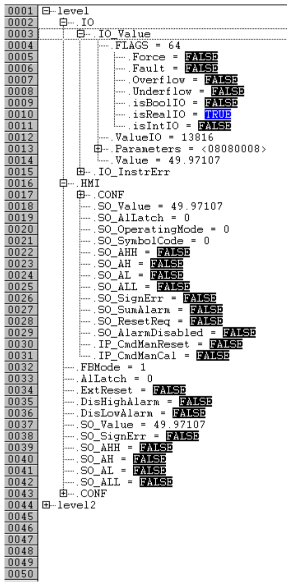


Figure 9.10: *Scale configuration to signal*



(a) *offline view*



(b) *Online view*

Figure 9.11: *Transmitter block*

The Water & Wastewater function blocks need to have an IN_OUT type variable containing a specific configuration for certain constants e.g. scaling values for the transmitter block. These values are saved in a Global variable file under resources tab. Since these values are configuration values and therefore need to be persistent, they are saved as VAR_GLOBAL RETAIN PERSISTENT. These values are then loaded into the struct CONF_var under Data types tab, from where they can be called to function blocks with configuration values.

As the web server option was checked already in Control Builder Plus, the only thing that needs to be done is to open target settings under resources tab, under which Visualization "Use 8.3 file format" and "Web visualization" have to be checked. In this project the CPU load is visualized as a web server and is accessable by IPaddressofCPU/webvisu in Internet explorer.

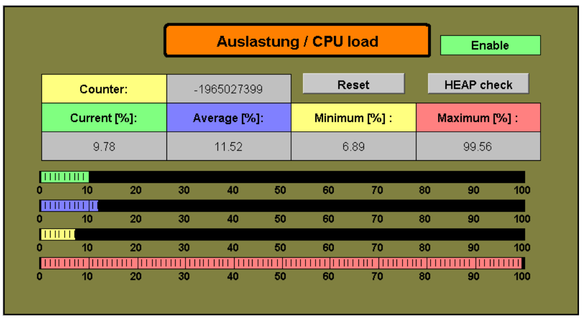


Figure 9.12: *Web visualization of CPU load*

9.7 Summary

This chapter has given an understanding of the overall configuration of the demo solution from where the results shown in chapter 10 are determined. To establish a working communication with S+ operations symbol files had to be loaded into the PLC as well as loaded into S+ operations. These had to be up-to-date for the communication to work.

10. Results

The demo solution for investigating S+ operations in combination with AC500 was made according to Chapter 9. As a result of the demo solution Mr.Anton Wargh and I were able to determine the functionality of S+ operations in combination with AC500, and AC500 in general.

Despite the fact that the whole program size is relatively small it was interesting to see that the cycle time was not reduced even though I was running Demo, Modbus and HA programs at the same time on minimal task cycle times, trying to stress the PLC. This was observed from the Modbus server simulation software polling time and Control Builder Plus diagnostics.

High availability was tested with functional switchover between the two CPUs. However, since the demo process and its values are calculated, instead of using "real" inputs some values tend to keep counting beyond their limits. This is because both programs run simultaneously and calculate tank volumes and levels instead of using "real" process values. It was easy to work with and configure the CS31 bus, but unfortunately it was the only bus tested with AC500. However, since AC500 supports multiple bus-types and these hold international standards, using them should not be harder than with the CS31 bus. CS31 was the only bus supported with high availability.

At first it was difficult to understand the functionality of the Water & Wastewater library with all the different layers. After understanding the connection between these layers and the other attributes of the library, I came to the conclusion that it is a very efficient way of handling function blocks, especially when they have to be connected to some form of HMI. The current selection of function blocks worked as they were intended. The Preliminary PID-function block felt a bit unfinished but could be used in S+ operations, and also the application functionality worked well for the purpose in the demo solution.

There was no standard Timestamping solution for the AC500, but Mr.Mika Kuukasjärvi had programmed a function block for timestamping earlier, which I was able to try. It was only tested on an application level, since no form of function to link the timestamps further was found in the function block. My supervisor Mr.Frank Redlig and I decided that programming such a link fell outside the target of this thesis.

Overall we made a working demo solution from where the earlier mentioned aspects could be determined. Using Control Builder Plus and CoDeSys has a steep learning curve, and since CoDeSys is basically a "freeware" from the beginning it didn't feel like it had the same standard of usability as proprietary branded programs. Function blocks were used in S+ operations from where Mr.Anton Wargh could operate Water

& Wastewater function blocks, but variables that I made to determine which CPU was master for the high availability switchover in the OPC server was something we did not get to function properly. Timestamping was the only critical feature that we didn't get to function between AC500 and S+ Operations. Mr.Anton Wargh describes some aspects of the timestamping from an OPC and S+ operations point of view in his thesis.

As a result of the comparison in Project X to determine advantages and disadvantages I was able to determine that the current features of the AC500 could not be used for a common control panel with the specifications of Project X. This is because high availability is only supported using the CS31 bus, and the amount of nodes in Project X (≈ 60) exceeds the amount of nodes that can be used with CS31 (31). The other features of AC500 should suffice based on the specification from the layout of Project X.

On the other hand, when analyzing the generator control panels that don't need redundancy, AC500 could be a possible solution. This is based on technical specifications that have been compared as well as supported protocols and network types. As a conclusion the AC800 could be used for the common control panels until a solution for high availability with AC500 that meets all the specifications is developed. On generator control panels AC500 could be a possible solution for this specification.

As a conclusion, assuming a realization of power plant projects using AC500 in the future, areas of improvement should include AC500, the Water & Wastewater library and CoDeSys. AC500 high availability should have a comprehensive and practical solution to achieve communication to third party modules and devices. Timestamping should be developed to a fully functional solution that can be used in engine plant projects. The Water & Wastewater library could be updated according to different plant specifications to improve the extent of the library. CoDeSys usability should be improved by investigating the abilities of the SFC and CFC languages for sequential programs and also the use of project templates in CoDeSys.

11. Discussion

This thesis work covers a wide area, including PLCs, networks, Programming, implementation, power plant and water treatment plant configurations. Since it is also part of a two-part project investigating S+ operations in combination with AC500, me and Mr.Anton Wargh who was in charge of the second part, had to have meetings at regular intervals to determine where we were and how we would continue from that. We had both made similar timetables so we would be able to keep the same pace and be able to achieve the target more easily.

I also had regular follow-ups with Mr.Frank Redlig about the progress and he explained aspects of power plants and their PLC system layouts in general. He also helped with providing information and useful contacts for the AC500.
Because I was conducting this thesis work on behalf of ABB Power Generation I had good and modern equipment available as well as large databases of information. But regarding examples and guides on AC500 it was hard to find useful information. The most difficult thing was to find good information and guides on PS501, which really slowed down the progress.

The time spent on the project during autumn/winter of 2013 was very limited because of a hectic school schedule, but I was able to intensify the time at the beginning of 2014. In the beginning when I was learning to use both CoDeSys and Control Builder I had to use evenings and weekends to do this, which slowed down the process. If I was to conduct this project work again, I would try to order components at an earlier stage and also try to have more structure in the way we tested the demo solution.
Narrowing down the written part was difficult since it involved a wide area. I tried to include all those parts that are necessary to get an overall picture of both the demo solution and Project X to be able to understand the results.

It is going to be interesting to see the outcome of this work. I think the AC500 PLC has great potential for power plant implementation when some of the features such as eg. high availability has been improved. With the shown interest from domestic sales and R&D looking for a pilot project, I think improvements and support could be accelerated if it were to be realized.

Mr. Frank Redlig and I discussed the solution using Siemens, to where he pointed out that synchronization between CPUs put a huge load on them, because of all the communication running and the heavy synchronization communication, which leads to slower cycle times. Using AC500 with faster process time and high availability could be a better solution. This depends on requirements on the redundancy from customers, since high availability is a software-layer redundancy and has a switchover time of a multiple number of cycles. I have been in contact with Mr.Mika Kuukasjärvi from domestic sales, stated as a PLC specialist. He told me about a PROFINET solution that is going to be launched at the end of next year or beginning of 2016. This solution will support High availability to redundant PROFINET IO-devices. Currently the only supported solution is CS31, to which only AC500 I/Os can be connected. The Profinet solution should have a wider device support compared to CS31.

Communication to relays was in this case using Modbus TCP, which is supported by AC500, but according to Mr. Frank Redlig communication to relays is often achieved using IEC standard 61850. This again, according to Mr. Mika Kuukasjärvi, cannot be used with AC500, but instead it can be achieved using supported IEC standard 60870-5-104. Devices that support this standard are unknown.

When I was in contact with Mr. Mika Kuukasjärvi to verify the solution of chapter 8, he pointed out an interest from domestic sales when I attached a system layout from Project X. He mentioned that if the high availability is the only thing preventing this from realization, it could probably be accelerated to a solution from R&D because they are looking for pilot projects. Considering the improvement areas mentioned in chapter 10, a form of workgroup consisting of Water & Wastewater library personnel and e.g. Mr. Mika Kuukasjärvi as an ABB PLC specialist as well as personnel from Power generation in Vasa would give a wider area of inputs for a more complete project solution.

A solution for the timestamping could also possibly be achieved by this workgroup. Possibly by using Mr.Mika Kuukasjärvi's timestamp block linked to an OPC server and if necessary, interfaces to S+ operations. Using it in CoDeSys, appended to a triggered-by-event type of task, it could possibly be triggered on I/O-level in combination with Water & Wastewater library.

There was no complete comparison made on price differences when using the AC500. My own opinion is that a solution using AC500 would reduce costs, both regarding hardware and software, considering that the program environment is based on CoDeSys and also that the AC500 PLC has a lower cost in general.

This is based on a rough comparison on prices between a Siemens bundle set consisting of two pieces of CPU416-5H with racks, synch-modules and backup batteries (a listing price of about 21200 €) and the ABB PM592-ETH module as a high availability setup consisting of two pieces of PM592-ETH with terminal bases (a listing price of about 8000 €). Even on a more basic level when comparing Siemens CPU315-2 and ABB PM583-ETH, the result is the same, as the Siemens CPU315-2 has a listing price of about 1950 €and the PM583-ETH about 1250 €. It would be interesting to see such a comparison on a project-level, comparing the costs of program environments and their licenses as well as hardware modules.

I have learned a lot during the time I have spent on this thesis. Both theoretically and practically in areas such as PLCs, programming, hardware testing and implementation and power plant technology overall. Considering this I feel like I now have a better understanding of power plants in general and their critical parts. I believe I have improved my skills when working in a group and also when consulting others for getting other points of view, and maybe a better solution in the end.

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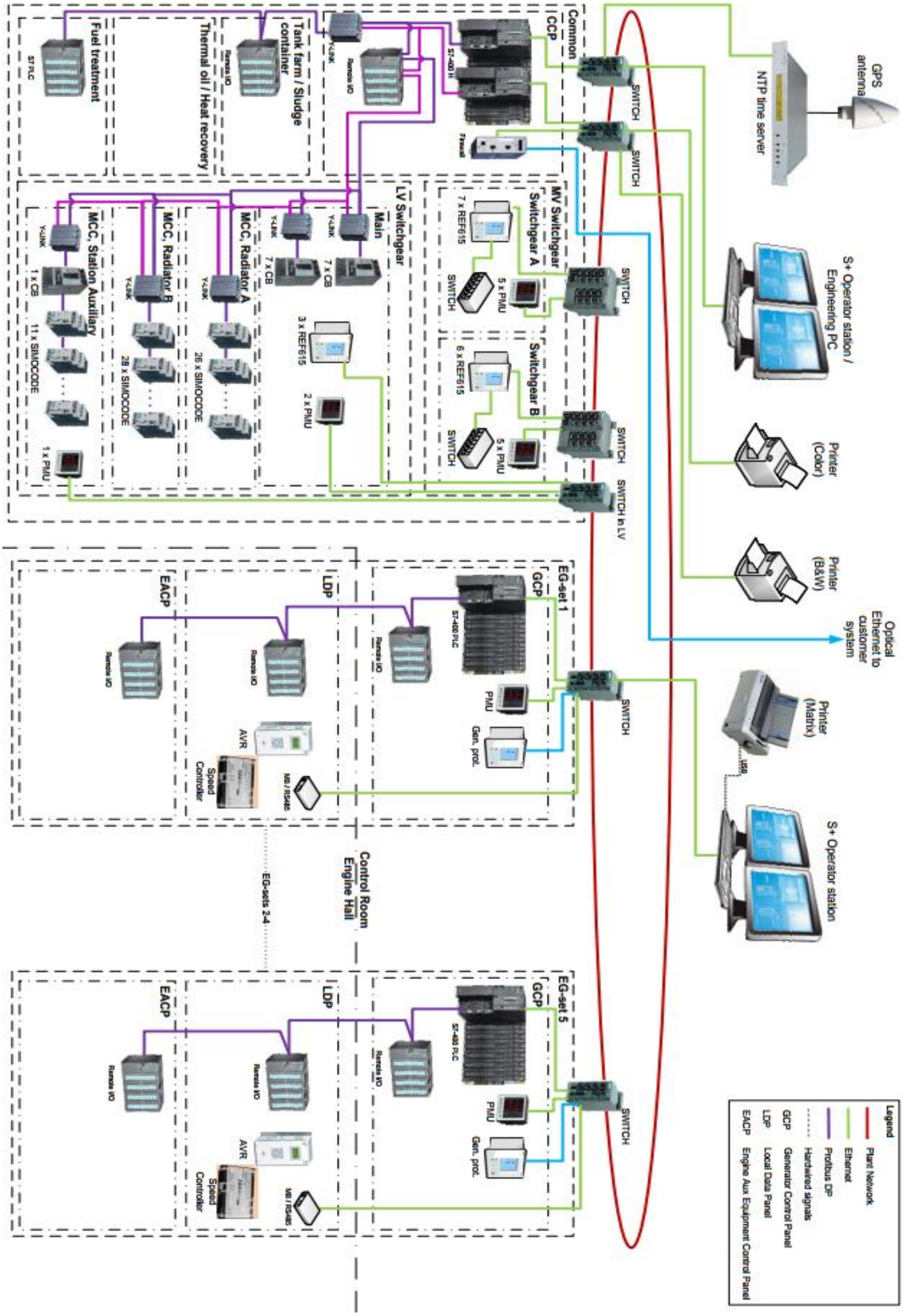

GPS antenna
NTP time server
S+ Operator station / Engineering PC
Printer (Color)
Printer (B&W)
Optical Ethernet to customer system
Printer (Matrix)
S+ Operator station
Common
CCP
S7-400 H
Remote I/O
Firewall
SWITCH
Tank farm / Sludge container
Thermal oil / Heat recovery
Fuel treatment
S7 PLC
MV Switchgear
Switchgear A
7 x REF615
5 x PMU
Switchgear B
6 x REF615
LV Switchgear
Main
7 x CB
3 x REF615
2 x PMU
MCC, Radiator A
26 x SIMOCODE
MCC, Radiator B
28 x SIMOCODE
MCC, Station Auxiliary
1 x CB
11 x SIMOCODE
1 x PMU
Y-LINK
SWITCH in LV
EG-set 1
GCP
S7-400 PLC
PMU
Gen. prot.
LDP
AVR
Speed Controller
MB / RS485
EACP
Control Room
Engine Hall
EG-sets 2-4
EG-set 5
Legend
Plant Network
Ethernet
Profibus DP
Hardwired signals
GCP Generator Control Panel
LDP Local Data Panel
EACP Engine Aux Equipment Control Panel

Filename:	AC500.AC500PRO
Directory:	C:\Users\FIDAHUM\Desktop\Thesis\CBP_project_files\Ac500_First_program\Ac50
Change date:	2.1.14 17:05:06 / V2.3
Title:	Demo process
Author:	Daniel Hummel
Version:	V1.0
Description:	Watertank process with AC500 in combination with S+ Operations

ANALOG (PRG-FBD)

```
PROGRAM ANALOG
VAR_EXTERNAL
    level:FB_Transmitter1_1;        (*Level In Tank*)
    level2:FB_Transmitter1_1;           (*Level In Tank2*)

END_VAR
```

0001

Analog in 1, Tank 1

```
                                level
                         FB_Transmitter1_1
                       -FBMode          SO_Value-
           2#00000000-AlLatch         SO_SignErr-
SO.GlobalAlarmBlock-ExtReset          SO_AHH-
                       -DisHighAlarm     SO_AH-
                       -DisLowAlarm      SO_AL-
            conf.level-CONF ▷            SO_ALL-
```

0002

Analog in 2, Tank 2

```
                                level2
                         FB_Transmitter1_1
                       -FBMode          SO_Value-
           2#00000000-AlLatch         SO_SignErr-
SO.GlobalAlarmBlock-ExtReset          SO_AHH-
                       -DisHighAlarm     SO_AH-
                       -DisLowAlarm      SO_AL-
            conf.level-CONF ▷            SO_ALL-
```

CALLBACK_STOP (PRG-ST)

```
PROGRAM CALLBACK_STOP
VAR_EXTERNAL
    dwEvent: DINT;
    dwFilter: DINT;
    dwOwner: DINT;

END_VAR
```

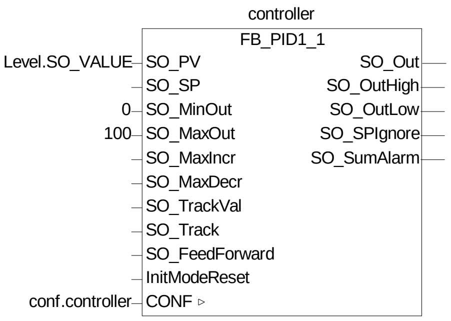
```
(*Mandatory name for Program*)
HA_CS31_CALLBACK_STOP(dwEvent, dwFilter, dwOwner);
```

CONTROLLERS (PRG-FBD)

```
PROGRAM CONTROLLERS

VAR_EXTERNAL
    controller:FB_PID1_1;
END_VAR
```

0001

PID controller Tank 1



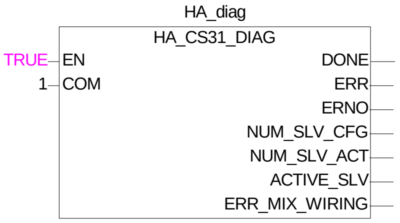
0002

HA_PRG (PRG-FBD)

```
PROGRAM HA_PRG


VAR
      HA_diag: HA_CS31_DIAG;
      HAcontrol: HA_CS31_CONTROL;
      hacontrol_man_change:BOOL:=FALSE;
      hacontrol_ackn:BOOL:=FALSE;
      hacs31_sync_EN: BOOL:= TRUE;
      HA_sync: HA_CS31_DATA_SYNC;
END_VAR
```

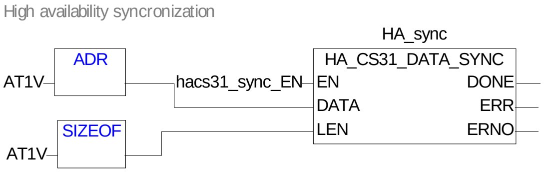
0001

High availability diagnostics



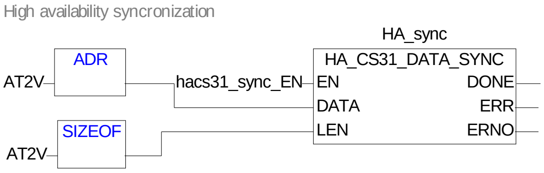
0002

High availability syncronization



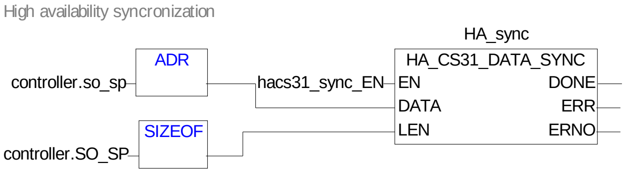
0003

High availability syncronization



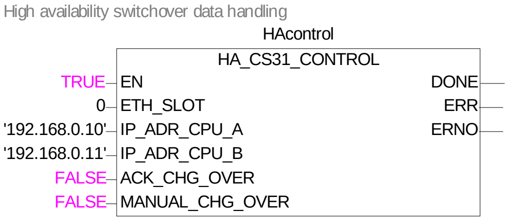
0004

High availability syncronization



0005

High availability switchover data handling



HW_PRG (PRG-ST)

```
PROGRAM HW_PRG



VAR
 HWOnlineChangeCount_old:USINT:=0;

      module1:HW_MOD_AX522; (*S500 I/O module*)
      module2:HW_MOD_AI531; (*S500 I/O module*)
      test:REAL:=100;

END_VAR





VAR_EXTERNAL
      (*Value_outWord: INT;*)
      HWOnlineChangeCount:USINT:=10;  (*  Increased +10 with each online change  *)

END_VAR
```

```
IF HW_Diag.HWCallTask=1 OR HW_Diag.HWCallTask=2 OR (HW_Diag.HWCallTask=3 AND ( HW_Diag.HWDiagStart OR HW_Diag.HWDiagEnd)) THEN
      (* Input/Output processing or global diagnostic buffer shift *)
      (* All modules have to be listed here, if they want to update their I/O and diagnostics *)
module1();
module2();
(*END_IF;*)

ELSIF HW_Diag.HWCallTask=3 THEN
      (* Modules are periodically called to process errors, based on their position in the rack *)


            CASE HW_Diag.HWDiagComp OF
            11: (* CS31 *)
            IF HW_Diag.HWDiagMod=31 THEN (* Whole slave station failed *)
                        IF HW_Diag.HWDiagDev=1 THEN (*CS31*)
                              module1(ExtAlarm:=TRUE); (* First module on I/O rack *)
                              module2(ExtAlarm:=TRUE); (* Second module on I/O rack *)

                  ELSE;   (*CS31*)(* Unrecognized station on bus *)


                        END_IF;

                  END_IF;
            ELSE;
             (* Unrecognized component *)
            END_CASE;
ELSE
 ; (* Wrong call *)
END_IF;

IF HWOnlineChangeCount<>HWOnlineChangeCount_old THEN
  HWOnlineChangeCount_old:=HWOnlineChangeCount;


  (*  Only variable connections to HW and Application here    *)
  (*  Calling modules should be done further down the program   *)

  (*  I/O bus module 01 HW configuration  *)
  (*module1.InvertIn:=2#00000000;*)
  (* module1.InvertOut:=2#00000000;*)

      module1.pHWInput:=ADR(in0);
      (*module1.pHWInput:=ADR(in0);*)
      module1.pHWOutput:=ADR(out0);
      (*module1.pHWOutput:=ADR(out1);*)

  (*  I/O bus module 01 application connections  *)


      module1.AI0:=ADR(level.IO.IO_Value); (*Input to Transmitter block*)
      module1.AO0:=ADR(Watertank.value_outWord1); (*Output to Analog I/O module*)
```

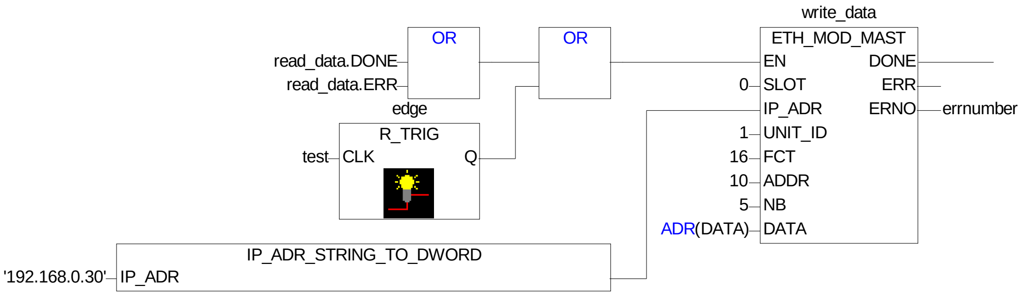
```
     module1.AI1:=ADR(level2.IO.IO_Value); (*Input to Transmitter block*)
     module1.AO1:=ADR(Watertank.value_outWord2); (*Output to analog I/O module*)
(*  Analooginputs unused  *)
(*   module1.AI1:=;
     module1.AI2:=;
     module1.AI3:=;
     module1.AI4:=;
     module1.AI5:=;
     module1.AI6:=;
     module1.AI7:=;*)



  (*  Digital outputs *)

  (* Unused I/O
     MOD01.DO0:=ADR();
     MOD01.DO1:=;
     MOD01.DO2:=;
     MOD01.DO3:=;
     MOD01.DO4:=;
     MOD01.DO5:=;
     MOD01.DO6:=;
     MOD01.DO7:=;
  *)

  (*  I/O bus module 02 HW configuration*)
  (*module2.pHWInput:=ADR(%%%%%%);*)

  (*  I/O bus module 02 application connections  *)
  (*  Analog inputs  *)

  (* Unused I/O
  module2.AI0:=ADR();
  module2.AI1:=;
  module2.AI2:=;
  module2.AI3:=;
  module2.AI4:=;
  module2.AI5:=;
  module2.AI6:=;
  module2.AI7:=;
  module2.AI8:=;
  module2.AI9:=;
  module2.AI10:=;
  module2.AI11:=;
  module2.AI12:=;
  module2.AI13:=;
  module2.AI14:=;
  module2.AI15:=;
  *)

END_IF;
```

MODBUS (PRG-FBD)

```
PROGRAM MODBUS
VAR
    write_data:ETH_MOD_MAST;
    read_data:ETH_MOD_MAST;
    edge:R_TRIG; (*Temporary solution, doesnt need to be used*)

    errnumber AT %MD0.0 : WORD;

    DATA AT %MW0.0 : DWORD;
    test:BOOL:=TRUE;


END_VAR
```

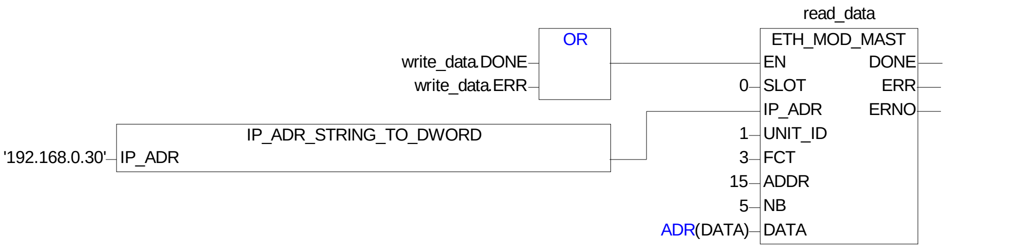
0001

Enables block with puls signal BLINK with a set time of 1sec. Function block is dedicated to the CPU internal Ethernet port with command 0 on SLOT. write d



0002

Enables block with puls signal BLINK with a set time of 1sec. Function block is dedicated to the CPU internal Ethernet port with command 0 on SLOT. Read d

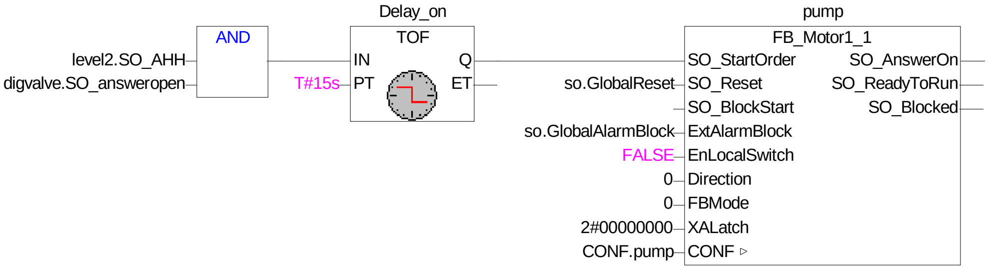


MOVING_OBJECTS (PRG-FBD)

```
PROGRAM MOVING_OBJECTS
VAR_EXTERNAL
      pump:FB_Motor1_1;
      digvalve:FB_Valve1_1;
      valve:FB_Valve2_1;
END_VAR
VAR
      mcount AT %MW0.0 : UINT;
      Tank1level:REAL;
      Delay_on: TOF;
      Delay_onvalve: TOF;
END_VAR
```

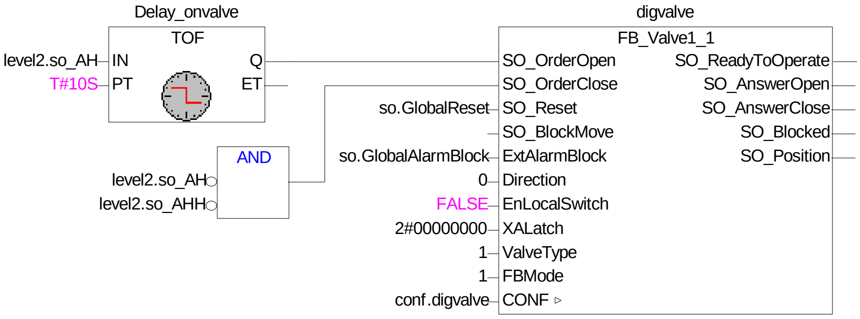
0001

The pump used in in the demo solution to flush Tank 2 when high-high-alarm level is reached

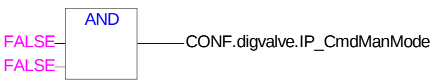


0002

Digital valve to flush Tank 2

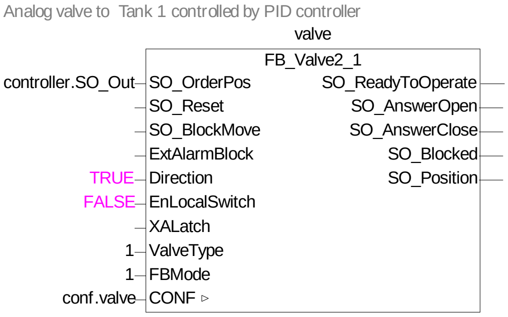


0003

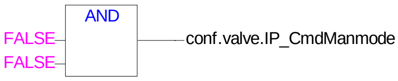


0004

Analog valve to Tank 1 controlled by PID controller



0005

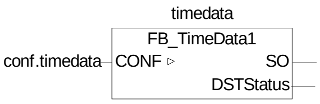


OPERATINGDATA (PRG-FBD)

```
PROGRAM OPERATINGDATA

VAR_EXTERNAL
    motor_data:FB_OperatingData1_1;
    timedata:FB_TimeData1;
    Waterout: FB_Accumulator1_1;
END_VAR
VAR

END_VAR
```

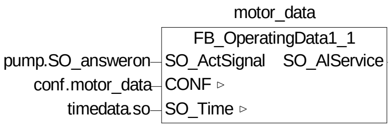
0001

Time data that is used



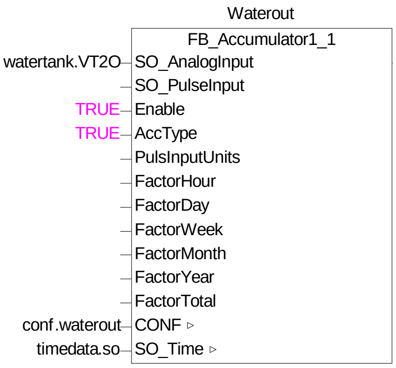
0002

Runtime data and time to service for pump



0003

Used to measure quantity of water flushed from Tank 2



PLC_PRG (PRG-ST)

```
PROGRAM PLC_PRG

    VAR_EXTERNAL
    SystemClock:FB_TimeData1;    (* System time handling *)
    controller:FB_PID1_1;
    AT1V: REAL;
END_VAR

VAR
{flag noread,nowrite on}
    FirstScan:BOOL:=TRUE;
    PLC_Master: BOOL;

END_VAR {flag off}
```

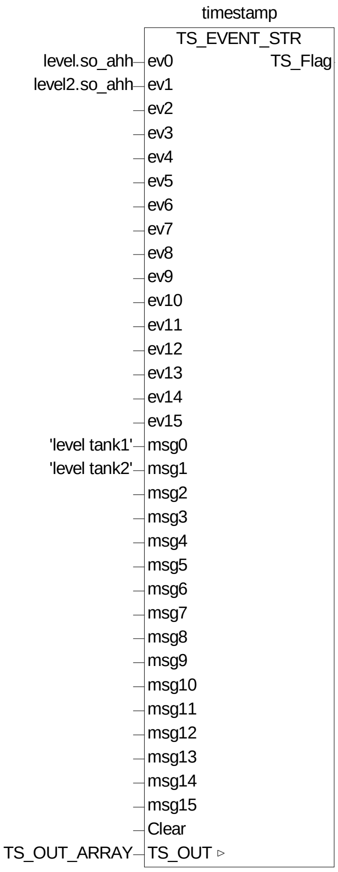
```
(* Obligatory FUNCTION call FOR HW_Diag *)


(*Determine Master PLC for OPC server*)
IF fG_HA_PRIMARY THEN
HW_Diag( );
PLC_Master:= TRUE;
END_IF

(*Calling CPU diagnostics used in visualization*)
CPU(EN:=TRUE , DONE=> , ERR=> , ERNO=> );

(* Handling configuration variables *)

(*First scan extra behaviours*)
IF FirstScan THEN
controller.InitmodeReset:=FALSE;
AT1V:=3000;
(*CONF.controller.IP_CmdManOut:=FALSE;*)
FirstScan:=FALSE;
END_IF
```

TIMESTAMPING (PRG-FBD)

```
PROGRAM TIMESTAMPING
VAR
    TS_OUT_ARRAY: ARRAY [0..99] OF TS_DATA_STR;
END_VAR
VAR_EXTERNAL
    timestamp:TS_EVENT_STR;
END_VAR
```

0001

Timestamp block, only used to test functionality in application.



watertank (PRG-ST)

```
PROGRAM watertank
VAR_EXTERNAL
      AT1V: REAL; (*Actual Tank 1 Value*) (*Is set 3000litre volume on first scan*)
      AT2V: REAL; (*Actual Tank 2 Value*)
END_VAR

VAR
      AnalogSignal_par: SignalParReal:=(MinVal:=0,MaxVal:=100,Unit:='%'); (* parametersettings of analog signal*)
      value_outWord1: REALIO; (*Analog signal to output 1*)
      value_outWord2: REALIO; (*Analog signal to output 2*)

      CIF:  REAL:= 150;     (* Constant IN Flow Tank 1, 100litre *)
      CV1:  REAL:=-500;    (*correction value if over 10000*)
      CV2:  REAL:= 500;    (*correction value if under 0*)



      MT1V: REAL:=10000; (*Max value in Tank*)
      VT1I: REAL; (*Value Tank 1 IN *)
      VT2I: REAL; (*Value Tank 2 IN*)
      (*fbt:  REAL:= 60; constant flow between tanks, 60 litre*)
      VT1O :REAL; (*Value Tank 1 OUT*)
      MVT1O :REAL:= 150; (*MAX Value Tank 1 OUT*)
      VT2O :REAL:= 10; (*Value Tank 2 OUT*)
      PO:REAL:=0; (*PUMP ON = Flow increase*)


      VR: REAL;(*Relative tank volume*)
      IVR: REAL;
END_VAR
```

```
(*-----------------------------------INFLOW CALCULATIONS FOR TANK 1-----------------------*)

IF AT1V < 10000 AND AT1V > 0 THEN

      VT1I := (Valve.so_position/100) * CIF; (*Regulated inflow based on constant inflow of 150litres*)

            ELSIF AT1V > 10000  THEN
                  REPEAT AT1V:=AT1V+CV1; UNTIL AT1V < 5000 END_REPEAT; (*correct value if it floats past limits. IN CASE SYNC IS DISRUPTED*)
            ELSIF at1v <0 THEN
                  REPEAT AT1V:=AT1V+CV2; UNTIL AT1V > 5000 END_REPEAT; (*correct value if it floats past limits. IN CASE SYNC IS DISRUPTED*)
            ELSE;

 END_IF;
VR:= (AT1V/MT1V);
IVR := (1-VR);
VT1O := MVT1O * (1-(IVR*IVR));

AT1V := AT1V + VT1I - VT1O;


value_outword1.parameters:=ADR(AnalogSignal_par);
value_outword1.Value:=AT1V*0.01;

(*-----------------------------------INFLOW CALCULATIONS FOR TANK 2-----------------------*)

IF AT2V <= 10000 AND AT2V >= 0 THEN

      VT2I := VT1O;



            ELSIF AT2V > 10000  THEN
                  REPEAT AT2V:=AT2V+CV1; UNTIL AT2V < 5000 END_REPEAT; (*correct value if it floats past limits. IN CASE SYNC IS DISRUPTED*)
            ELSIF at2v <0 THEN
                  REPEAT AT2V:=AT2V+CV2; UNTIL AT2V > 5000 END_REPEAT; (*correct value if it floats past limits. IN CASE SYNC IS DISRUPTED*)

            ELSE;
 END_IF;

IF pump.so_answeron = TRUE AND digvalve.so_answeropen = TRUE THEN
PO:= 100;
VT2O:=100;
ELSIF pump.so_answeron = FALSE AND digvalve.so_answeropen = TRUE THEN
VT2O:=100;
```

```
PO:=0;
ELSE
VT2O:=0;
PO:=0;
END_IF;

AT2V := AT2V + VT2I - VT2O - PO;
value_outword2.parameters:=ADR(AnalogSignal_par);
value_outword2.Value:=AT2V * 0.01;


(*--------------------------------LEVEL MANIPULATION-----------------------------------------------------------*)
                    (* These are set to manipulate values and keep the level moving*)

(*Limitcontroller on Tank 1*)
tankcritical(
      SO_Level:=AT1V/100 ,
      ControlType:=FALSE ,
      CONF:= conf.tankcritical,
      SO_ActivateOrder=> );
(*Limitcontroller on Tank 2*)
tankcritical2(
      SO_Level:=AT2V/100 ,
      ControlType:=FALSE ,
      CONF:= conf.tankcritical,
      SO_ActivateOrder=> );
```

Conf_app

```
TYPE Conf_app :
STRUCT



    GlobalAlarmBlockResetHour: UINT:=24; (* Hour for resetting GlobalAlarmBlock, <0 AND >23 turns off automatic disabling *)
END_STRUCT
END_TYPE
```

CONF_var

```
TYPE CONF_var :
STRUCT
    App:CONF_App;
    pump:CONF_Motor1_1;
    level:CONF_Transmitter1_1;
    level2:CONF_Transmitter1_1;
    motor_data:CONF_operatingdata1_1;
    timedata:CONF_TimeData1;
    controller:CONF_PID1_1;
    digvalve:CONF_Valve1_1;
    valve:CONF_Valve2_1;
    SystemClock:CONF_timedata1;
    tankcritical:CONF_LimitControl2_1;
    Waterout: CONF_Accumulator1_1;
END_STRUCT
END_TYPE
```

HMI_Var

```
TYPE HMI_Var :
STRUCT
    App:CONF_App;
    IP_CmdGlobalAlarmBlock: BOOL; (* Global blocking of alarms *)
    IP_CmdGlobalReset: BOOL; (* Global reset of latched alarms *)
    IP_CmdAckPresence: BOOL; (* Acknowledge station presence *)
END_STRUCT
END_TYPE
```

IO_Var

```
TYPE IO_Var :
STRUCT
    GlobalResetButton: BoolIO; (* Global reset of latched alarms *)
END_STRUCT
END_TYPE
```

REC_buffer

```
TYPE REC_buffer :
STRUCT
    DATArecieved:INT;
END_STRUCT
END_TYPE
```

SEND_buffer

```
TYPE SEND_buffer :
STRUCT
    Value:INT;
END_STRUCT
END_TYPE
```

SO_var

```
TYPE SO_var :
STRUCT
    GlobalReset:BOOL;
    GlobalAlarmBlock:BOOL;
END_STRUCT
END_TYPE
```

module1_Module_Mapping

```
VAR_GLOBAL
	in0 AT %IW502 : INT; (* Analog input 0 *)
	in1 AT %IW503 : INT; (* Analog input 1 *)
	in2 AT %IW504 : INT; (* Analog input 2 *)
	in3 AT %IW505 : INT; (* Analog input 3 *)
	in4 AT %IW506 : INT; (* Analog input 4 *)
	in5 AT %IW507 : INT; (* Analog input 5 *)
	in6 AT %IW508 : INT; (* Analog input 6 *)
	in7 AT %IW509 : INT; (* Analog input 7 *)
	out0 AT %QW502 : INT;	(* Analog output 0 *)
	out1 AT %QW503 : INT;	(* Analog output 1 *)
END_VAR
```

module1_Module_Mapping_1

```
VAR_GLOBAL
	in0 AT %IW502 : INT; (* Analog input 0 *)
	in1 AT %IW503 : INT; (* Analog input 1 *)
	in2 AT %IW504 : INT; (* Analog input 2 *)
	in3 AT %IW505 : INT; (* Analog input 3 *)
	in4 AT %IW506 : INT; (* Analog input 4 *)
	in5 AT %IW507 : INT; (* Analog input 5 *)
	in6 AT %IW508 : INT; (* Analog input 6 *)
	in7 AT %IW509 : INT; (* Analog input 7 *)
	out0 AT %QW502 : INT;	(* Analog output 0 *)
	out1 AT %QW503 : INT;	(* Analog output 1 *)
END_VAR
```

module2_Module_Mapping

```
VAR_GLOBAL
	in2_1 AT %IW510 : INT;	(* Analog input 0 *)
END_VAR
```

module2_Module_Mapping_1

```
VAR_GLOBAL
	in2_1 AT %IW510 : INT;	(* Analog input 0 *)
END_VAR
```

Global_Variables

```
VAR_GLOBAL

(* MOVING_OBJECTS *)
	pump:FB_Motor1_1;				(*Starts pump in Tank 2*)
	digvalve:FB_Valve1_1;				(*outflow valve tank2*)
	valve:FB_Valve2_1;				(*inflow valve Tank 1*)


(*CONTROLLER*)
	controller:FB_PID1_1;				(*PID, valve*)

(*OPERATINGDATA*)
	motor_data:FB_OperatingData1_1;		(*run time counter for pump*)
	timedata:FB_TimeData1;				(*TIME*)
	Waterout: FB_Accumulator1_1;			(*waterquantity*)
(* ANALOG *)
	level:FB_Transmitter1_1;			(*Level In Tank*)
	level2:FB_Transmitter1_1;			(*Level In Tank2*)


(* PLC_PRG *)
	SystemClock:FB_TimeData1;			(*Timedata*)


(*TIMESTAMPING*)
	timestamp:TS_EVENT_STR;				(*Timestamping*)

(*watertank*)
	tankcritical:FB_LimitControl2_1;	(**)
	tankcritical2:FB_LimitControl2_1;	(**)
	Value_outWord: INT;				(**)
```

```
    Value_outWord2: INT;            (**)

    dwEvent: DINT;
    dwFilter: DINT;
    dwOwner: DINT;

    DATA AT %MW0.0 : DWORD;
    OPClive AT %MW1.0: DWORD;
    AT1V: REAL;
    AT2V: REAL;



END_VAR
```

Global_Variables_CONF

```
VAR_GLOBAL
    SO:SO_var;

END_VAR

VAR_GLOBAL RETAIN PERSISTENT

    CONF:CONF_var:=(





                Level:=(                    (* Level in the tank *)
                    IP_LimAHH:=80,                  (* Limit HH-Alarm *)
                    IP_LimAH:=60,               (* Limit H-Alarm *)
                    IP_LimAL:=40,               (* Limit L-Alarm *)
                    IP_LimALL:=20,              (* Limit LL-Alarm *)
                    IP_Hysteresis:=0.2,     (* Hysteresis in measuring unit *)



                    IO_Value_par:=(         (* Signal parameters for analog input *)
                        MaxVal:=100.0,          (*Max value*)
                        MinVal:=0.0,            (*Min Value*)
                        Unit:='m')),        (*Unit of the signal*)

                tankcritical:=(
                    IP_LimStart:=65.0,
                    IP_Hysteresis:=0),



                motor_data:=(
                    (*IP_CmdManResRnt:= FALSE,      Reset accumulated runtime       *)
                    (*IP_CmdManResCnt:=FALSE,       Reset accumulated number of activations         *)
                    (*IP_CmdManResSrv:=FALSE,       Reset service required and time before service*)
                    IP_AccRntTot:=1000,         (*Acc. time total               *)
                    IP_AccCntTot:=1000),        (*Acc. activations total        *)

                controller:=(
                    IP_Out:= 20,                (*REAL;  PID output, can be changed in manual out mode *)
                    IP_SP:=50,                  (* SetPoint, sent to the PID *)
                    IP_Gain:=0.75,              (* Gain coefficient for the PID *)
                    IP_TI:=1,                   (* Integral coefficient for the PID [sec] *)
                    IP_TD:=0,                   (* Differential coefficient for the PID [sec] *)
                    IP_MaxDeviation:=0,     (* Alarm if SP and PV differ more than this value; 0=disable alarm *)
                    IP_MinDerivative:=0,    (* Alarm if PV derivative is less than this value; 0=ignore this condition *)
                    IP_AFilterTime:=5,          (* Timeout before alarm is raised *)
                    IP_CmdManOut:=FALSE,            (* Activate output manual override *)
                    IP_CmdManSP:=FALSE,         (* Activate SP manual override *)
                    IP_CmdOutLim:=FALSE),       (* Limit Out change rate in ManOut and Track modes *)


                valve:=(
                    IP_TravelTime:=10,
                    IP_CmdManMode:=FALSE),          (* Command Auto (0) / Manuell (1) *)

```

```
            digvalve:=(
                IP_AcofTime:=10,            (* Limit switch timeout *)
                IP_TravelTime:=10,          (* Open<>Close travel time *)
                IP_CmdManMode:=FALSE,           (* Command Auto (0) / Manuell (1) *)
                IP_CmdManBlock:=FALSE)          (* Command manual blocking valve *)

            );



END_VAR
```

Variable_Configuration

```
VAR_CONFIG
END_VAR
```

SPC_Bit_Enum

```
VAR_GLOBAL CONSTANT
    {flag noread, nowrite on}
    (*Configuration bit enumeration*)

    Force:INT:= 0; (* Stop copy form Value to ValueIO *)
    Fault:INT:= 1; (*   Module fault, copy stopped *)
    Value:INT:= 2; (* Value to application *)
    ValueIO:INT:= 3; (* Value in hardware *)

    Overflow:INT:= 2; (* ValueIO above max*)
    Underflow:INT:= 3;      (* ValueIO below max *)

    isBoolIO:INT:= 5; (*true=This variable is BoolIO type*)
    isRealIO:INT:= 6; (*true=This variable is RealIO type*)
    isIntIO:INT:= 7; (*true=This variable is IntIO type*)

    (* HW_Diag bit enumerations *)
    IOBusFail: INT:= 0;     (* General I/O bus error *)
    IOBusWarn: INT:= 1; (* I/O bus subunit error *)
    IntEthFail: INT:= 2;     (* General Internal Ethernet error *)
    IntEthWarn: INT:= 3; (* Internal Ethernet subunit error *)
    IntCOM1Fail: INT:= 4;(* General Internal COM port 1 error *)
    IntCOM1Warn: INT:= 5;    (* Internal COM port 1 subunit error *)
    IntCOM2Fail: INT:= 6;(* General Internal COM port 2 error *)
    IntCOM2Warn: INT:= 7;    (* Internal COM port 2 subunit error *)
    ExtCI1Fail: INT:= 8;     (* General External Communications Interface 1 error *)
    ExtCI1Warn: INT:= 9; (* External Communications Interface 1 subunit error *)
    ExtCI2Fail: INT:= 10;  (* General External Communications Interface 2 error *)
    ExtCI2Warn: INT:= 11;      (* External Communications Interface 2 subunit error *)
    ExtCI3Fail: INT:= 12;  (* General External Communications Interface 3 error *)
    ExtCI3Warn: INT:= 13;      (* External Communications Interface 3 subunit error *)
    ExtCI4Fail: INT:= 14;  (* General External Communications Interface 4 error *)
    ExtCI4Warn: INT:= 15;      (* External Communications Interface 4 subunit error *)
    SO_BatteryAlarm:INT:= 16; (* PLC CPU Battery is not OK *)
    {flag off}
END_VAR
```

SPC_Global_Constant

```
VAR_GLOBAL CONSTANT
    (***Visualization constants***)
    SecondToHourFactor: REAL := 0.000277777777777778;

    (***Visualization color constants***)
    VisuColorBackground: DINT:= 16#FFFFFF;
    VisuColorAlarmMain: DINT:= 16#0000C8;
    VisuColorAlarmAux: DINT:= 16#80FFFF;
    VisuColorActiveMain: DINT:= 16#004000;
    VisuColorActiveAux: DINT:= 16#008000;
    VisuColorInactive: DINT:= 16#C0C0C0;
    VisuColorForce: DINT:= 16#00FFFF;
```

```
    VisuColorOPMode: DINT:= 16#0000FF;
    VisuColorNavButton: DINT:= 16#C0C0C0;
    VisuColorButton: DINT:= 16#F0F0F0;
    VisuColorButtonPressed: DINT:= 16#F3F3F3;
    VisuColorFont: DINT:= 16#000000;
    VisuColorFrame: DINT:= 16#000000;

    (***Time constants***)
    TimeConfTimeZone: SINT:= 1; (* Local timezone (1 = GMT+01:00) *)
    TimeConfDSTMode: USINT:= 1; (* Daylight saving mode: 0=no DST; 1=European DST; 2=North American DST; 3=Custom Table*)
    (* EU GMT+1 Table *)
    TimeConfDSTStart1: DT:= DT#2014-03-30-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd1: DT:=  DT#2014-10-26-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart2: DT:= DT#2015-03-29-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd2: DT:=  DT#2015-10-25-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart3: DT:= DT#2016-03-27-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd3: DT:=  DT#2016-10-30-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart4: DT:= DT#2017-03-26-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd4: DT:=  DT#2017-10-29-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart5: DT:= DT#2018-03-25-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd5: DT:=  DT#2018-10-28-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart6: DT:= DT#2019-03-31-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd6: DT:=  DT#2019-10-27-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart7: DT:= DT#2020-03-29-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd7: DT:=  DT#2020-10-25-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart8: DT:= DT#2021-03-28-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd8: DT:=  DT#2021-10-31-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart9: DT:= DT#2022-03-27-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd9: DT:=  DT#2022-10-30-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart10: DT:=DT#2023-03-26-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd10: DT:=      DT#2023-10-29-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart11: DT:=DT#2024-03-31-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd11: DT:=DT#2024-10-27-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart12: DT:=DT#2025-03-30-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd12: DT:=      DT#2025-10-26-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart13: DT:=DT#2026-03-29-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd13: DT:=      DT#2026-10-25-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart14: DT:=DT#2027-03-28-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd14: DT:=      DT#2027-10-31-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart15: DT:=DT#2028-03-26-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd15: DT:=      DT#2028-10-29-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
    TimeConfDSTStart16: DT:=DT#2029-03-25-02:00:00; (* Custom Daylight saving period start, local time *)
    TimeConfDSTEnd16: DT:=      DT#2029-10-28-03:00:00; (* Custom Daylight saving period end, local time, including DST *)
{library private}
    TimeConfDSTNoEntries: USINT:=16; (* Number of entries in DST table *)
{library public}

    (***Signal limit constants***)
    OverflowLimit: INT:=31795; (* Overflow warning limit for analog signals *)
    UnderflowNorm: INT:=-3456; (* Underflow warning limit for analog signals *)
    UnderflowExt: INT:=-31795; (* Underflow warning limit for analog signals *)

(*  Since signal limits are digital, they correspond to different actual measured values, depending on the selected signal range.
    The following table is for reference only, consult specific I/O module documentation for precise range data.

                    Value   4..20mA     0..20mA     0..10V  -10..10V
    OverflowLimit   31795   22.5mA 23mA   11.5V    11.5V
    UnderflowNorm   -3456   2mA         -           -1.25V  -1.25V
    UnderflowExt -31795  -          -           -           -11.5V
*)
END_VAR
```

SPC_Global_Persist_Var

```
VAR_GLOBAL PERSISTENT
    HWEnableSimulation:BOOL:=FALSE; (* Swithes all blocks to FBMode=0 *)
END_VAR
```

SPC_Global_Var

```
{nonpersistent}
{library public}
VAR_GLOBAL

    HWOnlineChangeCount:USINT:=10;      (*    Increased +10 with each online change   *)
```

```
    HWOnlineChangeCallbackRunning:BOOL:=FALSE;   (*Online change callback has been started*)

    HWInputCallbackWatchdog:USINT:=0;   (*0:Stopped, 1:Set by Callback, 2:Set by SPCControl*)
    HWOutputCallbackWatchdog:USINT:=0; (*0:Stopped, 1:Set by Callback, 2:Set by SPCControl*)

    {library private}{flag noread, nowrite on}
    (* 0-100% RealIO parameters, normal range, available for signals that do not require scaling *)
    ZeroHundredNormFixedPar:SignalParReal:=(MaxVal:=100, MinVal:=0, Unit:='%', ExtendedRange:=FALSE);
    (* 0-100% RealIO parameters, extended range, available for signals that do not require scaling *)
    ZeroHundredExtFixedPar:SignalParReal:=(MaxVal:=100, MinVal:=0, Unit:='%', ExtendedRange:=TRUE);
    {flag off}
END_VAR
```

Global_Variables

```
VAR_GLOBAL
END_VAR
```

Globale_Variablen

```
VAR_GLOBAL
END_VAR
```

GL_AC500_Diagnosis

```
VAR_GLOBAL
    CPU         : CPU_LOAD;      (* structure of CPU load variables *)
    diagCPU     : CPU_DIAG;      (* structure of CPU diagnosis variables *)
    diagCS31    : CS31_DIAG;     (* structure of CS31 diagnosis variables *)
    diagFBP : FBP_DIAG;      (* structure of FBP diagnosis variables *)

END_VAR
```

GL_Diag_Constant

```
VAR_GLOBAL CONSTANT
    (* Error numbers for all diag function blocks *)
    wERNO_SIMULATION_MODE : WORD := 16#50FF;

END_VAR
```

Globale_Variablen

```
VAR_GLOBAL
END_VAR
```

GL_Diag_Constant

```
VAR_GLOBAL CONSTANT
    (* Error numbers for all diag function blocks *)
    wERNO_SIMULATION_MODE_EXT : WORD := 16#50FF;
END_VAR
```

Globale_Variablen

```
VAR_GLOBAL
END_VAR
```

LIBRARY_VERSION_INFORMATION

```
VAR_GLOBAL
(*****************************************************************************************************
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* production, use or disclosure to third parties without express authority
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*****************************************************************************************************

LIBRARY: Ethernet_AC500_V10

DESCRIPTION:

FBs to use Ethernet on AC500

```

```
RESTRICTIONS: Just be used in ABB AC500-PLCs

*************************************************************************************************
DATE:           2012-03-08
MODIFIED:
                    2012-03-08  Added datatype ETH_MOD_FCT22 and ETH_MOD_FCT23

*************************************************************************************************)
END_VAR
```

Global_Variables

```
VAR_GLOBAL

END_VAR
```

HA_Global

```
VAR_GLOBAL CONSTANT
    (* HA specific error codes*)
    wHA_ER_WRONG_COM:                   WORD    := 16#2001;     (* Wrong COM Number at the COM Input *)
    wHA_ER_WRONG_NO_CS31_PROTOCOL:      WORD    := 16#3003;     (* No CS31 Protocol on COM *)
    wHA_ER_CI590_CFG_NOT_COMPLETE:      WORD    := 16#3029;     (* CI590 Slave configuration not complete *)
    wHA_ER_ALL_CI590_NOT_ACTIVE:        WORD    := 16#1021;     (* All the CI590 configured are not active *)
    wHA_ER_CI590_Cross_Wiring:          WORD    := 16#2029;     (* CI590 Slaves in Bus1 and Bus2 are Mix wired *)
    wHA_ER_CS31_CI590_CFG_ERROR:        WORD    := 16#201C;     (* The number CI590 Configured on both CPUs are not s
    wHA_ER_REMOTE_CI590_FAILURE:        WORD    := 16#1029;     (*Remote CI590 Failure*)
    wHA_ER_OWN_CI590_FAILURE:           WORD    := 16#1021;     (*CI590 Failure is own bus*)
    wHA_ER_NO_ETHERNET_LINK:            WORD    := 16#2013;     (*No Ethernet Link*)
    wHA_ER_CS31_MASTER_CROSS_WIRE:      WORD    := 16#2029;     (* CS31 Master Cross Wired *)
    wHA_ER_CS31_BUS_FAILURE:            WORD    := 16#2005;     (* CS31 BUS Faliure *)
    wHA_ER_Remote_CPU_Failure:          WORD    := 16#101B;     (*Remote CPU Failure*)
    wHA_ER_Remote_CS31_BUS_Failure:     WORD    := 16#201B;     (*Remote CS31 Bus (Master) Failure*)
    wHA_ERNO_COUPLER_CONFI:             WORD    := 16#6076;     (* coupler configuration for the sync connection is invalid *)
    wHA_ERNO_TBL_OVERFLOW:              WORD    := 16#2022;     (* HA data reference table is full *)
    wHA_ERNO_TBL_DIFFERENT:             WORD    :=16#2022;      (* HA data reference tables are different *)
    (* HA specific constants*)
    bHA_FRAME_TYPE_STATUS:              BYTE    := 16#42;       (* HA status farme *)
    bHA_FRAME_TYPE_STATUS_DATA:         BYTE    := 16#DD;       (* HA status and data farme *)
    uiHA_MaxBufferSize:                 UINT    := 1400;        (* HA Sync max Frame size *)
    uiHA_MaxSyncEntries:                UINT    := 256;         (* Total size of the sync entry array NoSyncFBPins* MaxSync
    HA_MAX_DATA_IN_ETH_FRAME:           UINT    := 1336;        (* Ethernet Frame Length - Size of Header *)
    uiDelay_LineB_init_Prim:            UINT    := 1500;        (*Number of cycle delay before declaring the Line B as Pri
    uiDelay_CI590_err:                  UINT    := 25;          (*Number of cycle delay before declaring the CI590 Failur
    MaxDelayData:                       BYTE    := 5;           (*Max number of cycles for data update*)
    uiSync_Cycle:                       UINT    := 6;           (* Number of cycle delay before acknowledge signal is
    (*    FRABB - A.M      - HA_SyncArray control Items*)
    uiFilterTimeHASyncArrayInit:        UINT    := 200;         (*Number of cycles to wait before calculating HA_SyncAr
END_VAR
```

HA_Global_Variables

```
VAR_GLOBAL
    fG_HA_PRIMARY:          BOOL        := 0;           (* State of the AC500 CPU    (FALSE -> PM acts as Secondary, TRUE-> PM acts as PRIMARY)
    fG_HA_PM1_PRIMARY:  BOOL        := FALSE;   (* Indication of primary PM, TRUE ->  PM1 / IP1 acts as PRIMARY *)
    fG_HA_CPU_STOP:         BOOL        :=FALSE;    (*IF TRUE -> Indicates the CPU in STOP MODE*)
    (* HA error infomation *)
    fG_HA_Err:              BOOL        := FALSE;   (* HA error state *)
    wG_HA_ErNo:             WORD  := 0;         (* HA error code *)
    bitG_Data_ERR:          BOOL        := FALSE;   (* HA data sync error state *)
    wG_Data_ERNO:               WORD  := 0;         (* HA data error sync code *)
    (* HA synchronization link configuration *)
    dwG_HA_OwnIP:               DWORD       := 0;           (* own IP address on sync link connection *)
    dwG_HA_OtherIP:         DWORD       := 0;           (* other PMs  IP address on sync link connection *)
    bG_HA_Slot:                 BYTE        := 0;           (* slot of interface to sync link connection *)
    (*OPC Server connection check*)
    dwG_HA_ServerAlive:         DWORD:=0;       (* Life counter incremented by OPC server *)
    byLastDataDelay:        BYTE        :=0;
    bitRefreshDataDelay:   BOOL        := FALSE;
    byCntDataDelay:         BYTE        :=0;
    wETH_Life:              WORD;                   (* Ethernet Life Count *)
    dwHATimersBaseTime : DWORD;
END_VAR
```

```
{library private}

VAR_GLOBAL
    uiHASyncArrayIndex:     UINT        := 0;
    HASyncArray:                ARRAY[0..uiHA_MaxSyncEntries] OF strHA_SYNC_DATA;
    stHA_CS31_State:        strHA_CS31_STATE;
    stHA_VISU_DATA:         strHA_VISU_DATA;
END_VAR
```

HA_VERSION_INFORMATION

```
VAR_GLOBAL
(**********************************************************************************************
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**********************************************************************************************
*
* DESCRIPTION:
*
* BASIC FBs, structures and visualizations for AC500 PLCs
*
* RESTRICTIONS: may just be used in  ABB AC500-PLCs
*
*
**********************************************************************************************
* AUTHOR:       ABB Automation Products GmbH
* DATE:             2009-06-09
* MODIFIED:         2009-06-09      V1.3        Released
                    2010-10-27      V2.0        Released
                    2013-04-12      V2.3        Updated 'CS31_AC500_V10' library reference to 'CS31_AC500_V20' in library manager

**********************************************************************************************)

{library private}
(* detailed history for internal use *)
(* ------------------------------------------ *)

(* MODIFIED:        2009-06-09      V1.3        released
                    2010-10-27      V2.0        Updated HA_CS31_CONTROL block
                                                        -Added new variables and logic for common base time management
                    2012-07-31      V2.2         HA_CS31_CALLBACK_STOP is updated as a Function with below input variables
                                                        -dwEvent,dwFilter,dwOwner.;
                                                        -Program is added with a line, 'fG_HA_PM1_PRIMARY    := FALSE;'
                                                    Updated HA_Global_Variables by removing flag no write
                                                    Updated HA_CS31_CONTROL block by below change
                                                        -Removed logic to enable function block DIAG_EVENT and changed to EN = TRUE.
                    2013-04-12      V2.3        Updated 'CS31_AC500_V10' library reference to 'CS31_AC500_V20' in library manager
                                                    Added global variable for HA version information
                                                    Added project information in project Info.





**********************************************************************************************)

END_VAR
```

Globale_Variablen

```
VAR_GLOBAL
END_VAR
```

LIBRARY_VERSION_INFORMATION

```
VAR_GLOBAL
(**********************************************************************************************
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**********************************************************************************************

LIBRARY: SysInt_AC500_V10
```

```

DESCRIPTION:

Common library  for the AC500 system

RESTRICTIONS: Just be used in ABB AC500-PLCs

****************************************************************************************************
DATE:           2012-03-20
MODIFIED:
                    2012-03-20 V1.0.0      Added function block IO_PROD_ENTRY_READ
                                                and  a  datatype for internal use only zSYSINT_IO_PROD_DATA_TYPE
                    2012-04-04 V1.1.0      Added function block PM_INFO, IO_MODULE_INFO_EXT, a  datatype for internal use only zRTS_VERSI
                                                and done some error correction of IO_MODULE_INFO
                    2012-06-22 V1.2.0      Added function blocks DPRAM_SM5XX_REC and DPRAM_SM5XX_SEND
                    2013-04-09 V1.3.0      Added function block BOOTPRG_HASH_INFO

****************************************************************************************************)
END_VAR
```

Globale_Variablen

0001	VAR_GLOBAL
0002	END_VAR

Globale_Variablen

0001	VAR_GLOBAL
0002	END_VAR

Globale_Variablen

0001	VAR_GLOBAL
0002	END_VAR

Globale_Variablen

0001	VAR_GLOBAL
0002	END_VAR

Globale_Variablen

0001	VAR_GLOBAL
0002	END_VAR

Globale_Variablen

0001	VAR_GLOBAL
0002	END_VAR

Globale_Variablen

0001	VAR_GLOBAL
0002	END_VAR

Globale_Variablen

0001	VAR_GLOBAL
0002	END_VAR

Globale_Variablen

0001	VAR_GLOBAL
0002	END_VAR

Alarm configuration

- Alarm configuration
  - Alarm classes
  - System

PLC Configuration

*AC500 CPU (Id.: 5107)
Node number: -1
Input address: %IB0
Output address: %QB0
Diagnostic address: %MB0
Download: 1
AutoAdr: 1
Parameter:
Datei: FlexConf.ini

Sampling Trace

No trace loaded

Task configuration

```
Task configuration
    System events
    Main (PRIORITY := 10, INTERVAL := T#500ms)
        PLC_PRG();
        CONTROLLERS();
        ANALOG();
        OPERATINGDATA();
        MOVING_OBJECTS();
        watertank();
    UDP (PRIORITY := 10, INTERVAL := T#1s0ms)
        UDP();
    MODBUS (PRIORITY := 10, INTERVAL := T#500ms)
        MODBUS();
    Timestamping (PRIORITY := 10, INTERVAL := T#500ms)
        TIMESTAMPING();
    HAtask (PRIORITY := 10, INTERVAL := T#20ms)
        HA_PRG();
```

Notepad

Watch- and Recipe Manager

Standard
Watch0

0001	MODBUS.errnumber
0002	

Workspace

Parameter Manager

0001	Parameter-Manager
0002	==============