UNIVERSITETET I AGDER

Development, Modeling and Simulation of Test Equipment for Subsea Choke Valves

Bjørn Andre Lia

Supervisors
Morten Kjeld Ebbesen
Stig Andre Torkelsen

This Master's Thesis is carried out as a part of the education at the University of Agder and is therefore approved as a part of this education. However, this does not imply that the University answers for the methods that are used or the conclusions that are drawn.

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Faculty of Technology and Science
Department of Engineering Sciences

Abstract

As a step toward being more effective and to improve test procedures, GE Oil & Gas wants to develop a workshop tool to automate the testing of Choke Valves. The Choke Valve Workshop Tool (CVWT) main function is to operate the Hydraulic Stepping Actuator automatically by providing controlled pressure pulses. Electrical and hydraulic equipment will have an interface allowing the test equipment to be connected and used on a wide range of Choke Valves. Test results will be transferred and stored automatically based on current need. A detailed description of the planned CVWT including a complete control system and a Human Machine Interface (HMI) has been developed.

A large variety of modeling and simulation tools are on the market today. This report will concentrate on model development and Software-In-Loop (SIL) testing performed with SimulationX. The control system and the HMI have both been thoroughly tested in a SIL setup. Chosen SIL setup uses the Virtual Machine (VM) package in SimulationX which communicates directly with S7-PLCSIM.

The dynamic model used in the SIL setup is based on a simplified version of the full scale model. The dynamic model replicates the behavior when the Choke Valve is connected to the workshop tool. Some of the parameters used in the model are based on tests results performed in the workshop in Dusavika, Stavanger.

SIL has in this project proven its importance being a less expensive, safer and more time efficient method to verify program code compared to experimental testing and prototyping. The SIL setup is found to be a less complex setup compared to the HIL method currently being lectured at UIA. However, the SIL has restrictions regarding communication protocols that can be used, and also that timers in the PLC are lagging behind compared to real time.

Keywords: Dynamic modeling, Simulation, Software-In-Loop, SimulationX, PLCSIM, WinCC, TIA-Portal

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Finally would i like to thank Thomas Langer and the rest of the employees at ITI-SimulationX for lending me a license to their software. It has been widely used in this thesis and proven to be a user friendly and versatile software.

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Bjørn André Lia ,

Abbrevitions

AISI	American Iron and Steel Institute
API	Application Programming Interface
BDF	Backward Differential Formula
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CE	Conformité Européenne
CIU	Chemical Injection Unit
CPU	Central Processing Unit
CSV	Comma Separated Value
CVWT	Choke Valve Workshop Tool
DB	Data Blocks
DCV	Directional Control Valve
DLL	Dynamic Link Library
FAT	Factory Acceptance Test
FLOPS	Floating Point Operations per Second
FPSO	Floating Production, Storage and Offloading
GE	General Electric
HES	Health Environment and Safety
HIL	Hardware-In-Loop
HMI	Human Machine Interface
HPU	Hydraulic Power Unit
IP	International Protection - Rating
LVDT	Linear Variable Differential Transformer
MCS	Master Control Station
MP	Medium Pressure
MPI	Multi Point Interface
ODE	Ordinary Differential Equations
OLE	Object Linking and Embedding
OPC	OLE-Process Control
PAC	Programmable Automation Controller
PC	Personal Computer
PLC	Programmable Logical Controller
PRV	Pressure Relief Valve
ROV	Remote Operated Vehicle
SCADA	Supervisory Control and Data Acquisition
SCM	Subsea Control Module
SDU	Subsea Distribution Unit
SIL	Software-In-Loop
TCP/IP	Transmission Control Protocol/Internet Protocol
TIA	Totally Integrated Automation
UFDS	Unit Functional Design Specifications
UIA	University of Agder
VM	Virtual Machine
WBS	Work Breakdown Structure
XT	Christmas tree

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Chapter 1

Introduction

1.1 Motivation

The continuous search for more energy globally is leading the oil companies to search for hydrocarbons in deeper water and with longer distances between the well and platform. When the equipment is submerged to depths down to 3000 meters and exposed to wellhead extreme conditions, the importance of having reliable equipment and good test procedures are crucial. The cost of installing and maintaining equipment is high and the consequences of a malfunction part may lead to a severe environmental incident.

GE Oil&Gas as a world leader in advanced Subsea technology, wants to improve the current test procedures for Choke Valves. Currently the test procedures are performed manually with a hand operated Directional Control Valve (DCV), and the test results are logged manually. To reduce test time and perform a more realistic test, which replicates the control signal of the Subsea Control Module (SCM), GE wants a workshop tool that can perform this operation and reading automatically and more accurate. The main goal would be to find a more reliable, better and cheaper way to perform the testing of Choke Valves.

1.2 Objectives

Main objective

The main objective is to design a workshop tool that automates the testing procedures of Choke valves, actuated by a hydraulically powered hydrostep, fail-as is stepping actuator. Test results shall be stored for future use. The layout shall include principle drawing of the chosen design and schematics for electrical and hydraulic circuits. Suitable hydraulic and electrical components shall be selected for the workshop tool.

Secondary objectives

- Develop a simplified dynamic model of the workshop tool in a Computer Aided Engineering (CAE) simulation software.
- Develop a control system for the workshop tool, it shall be user friendly and include an intuitive and easy to use HMI.
- Control system shall be tested towards the model developed in the simulation software for verification. The test shall be performed as a Hardware-In-Loop setup (HIL).
- If time allows a complete assembly of the workshop tool shall be done, and a complete function test of the tool shall be conducted.

As discussed later was the HIL testing replaced with a Software-In-Loop (SIL) test. This led to two additional research questions. Could a SIL-setup replace the HIL, and be used to verify the program code for both the PLC and HMI? What would the main differences be when comparing these methods?

1.3 Report outline

Chapter 2 provides basic information about Subsea oil and gas production.

Chapter 3 gives an overview of the constraints and requirements used in the design process.

Chapter 4 presents the basis of the chosen design and provides arguments for why they were chosen.

Chapter 5 gives an overview of the dynamic model.

Chapter 6 presents how the system was simulated and verified with a SIL simulation.

Chapter 7 presents the conclusion.

Chapter 2

Theoretical Background

2.1 Introduction to Subsea oil and gas production

Figure 2.1 show the main components in Subsea oil and gas production when a Floating Production, Storage and Offloading (FPSO) is used. On board the vessel is the Master Control Station (MCS), Hydraulic Power Unit (HPU) and other equipment, such as Chemical Injection Unit (CIU). A cable called the control umbilical goes from the FPSO down to the Subsea Distribution Unit (SDU), this cable is literally the lifeline connecting the FPSO with the subsea units. The umbilical allows transferring of hydraulic and electrical power, chemicals, communications signals and more to the Subsea installation[1]. The SDU works as a hub, splitting and redistributing umbilical signals to units such as manifolds and Subsea Control Module (SCM) mounted on the Christmas tree (XT).

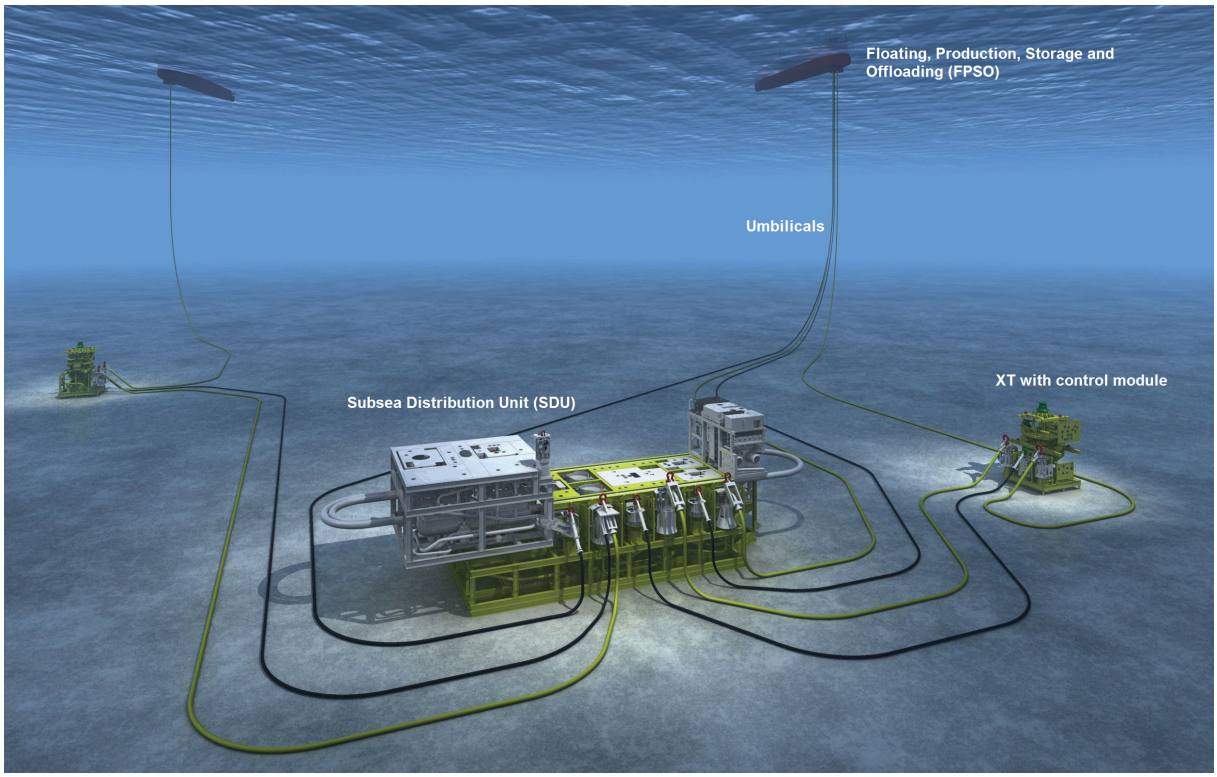


Figure 2.1: Typical Subsea layout[2]

2.2 Christmas tree

In Subsea applications, the term XT refers to an assembly of valves, spools and fittings for an oil well, figure 2.2. Subsea XT are used to monitor and control the production of oil and gas, and is mounted directly on top of the the wellhead. Mounted on the XT is typically the SCM and Choke valves, allowing an operator to remotely control the flow in and out of the well [3].

Figure 2.2: DHXT-SP: Standard Production tree

2.3 Choke valve

Choke valves are mounted on the XT and used for controlling the production flow, injecting gas and fluids, controlling the startup and shutdown and also to reduce flow-line pressure [4]. Opening and closing of the valve is done by a remotely controlled hydraulic stepping actuators. There is one actuator for each of the open and close directions. Return springs are used for exhausting the actuators after each step [5]. The valve is designed in such a way that, if an actuator should fail, it fails-as-is [5]. In addition to the actuators, there is a built in override opportunity to manually operate the valve by Remotely Operated Vehicle (ROV). Most of the Choke valves are designed as insert-retrievable chokes, meaning that the actuator and retention mechanism can be retrieved to the surface if needed, as can be seen in figure 2.3.

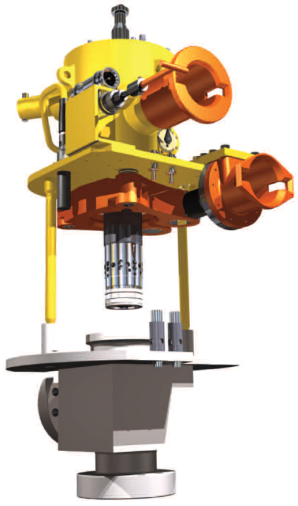
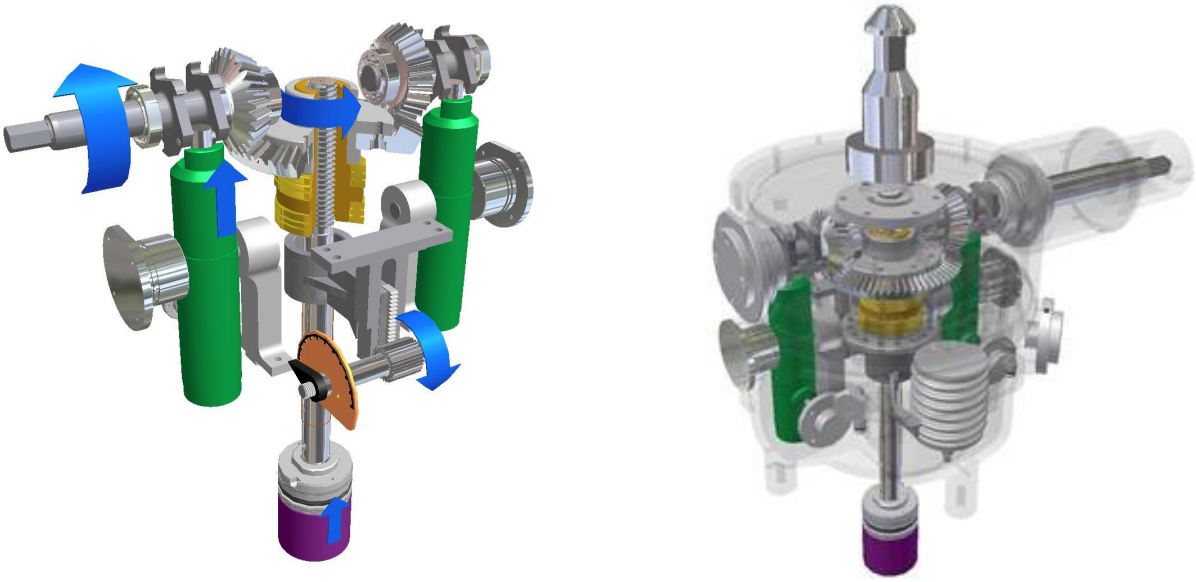


Figure 2.3: Insert retrievable choke [6]

2.3.1 Stepping actuators

Figure 2.4a illustrate the working principle of the stepping actuator. Most hydraulic stepping actuator designs use piston-pawl method and pinion wheels to transmit the rotation to the choke stem [6]. As mentioned in section 2.3, the valves are equipped with to actuators, one for opening (lowering) and one for closing (hoisting). Depending of the valve, approximately 100-200 steps is needed to go from open to closed position, or vice-versa. Figure 2.4b give an example of how the system may look like when it is assembled.



(a) Stepping actuator

(b) Stepping actuator, assembled

Figure 2.4: Working principle of Choke Valve

2.3.2 Position reading

To be able to control the choke valves, feedback on its position is required. The valves are equipped with both Linear Variable Differential Transformer (LVDT) and a visual indicator. The LVDT is an electromechanical transducer which converts linear position into a corresponding electrical signal. The mentioned visual indicator is intended as a backup solution and can be read by a diver or a ROV. It is very important to have accurate position indicators, wrong readings can result in a severe environmental disaster.

Chapter 3

Design of CVWT

In this chapter the restrictions, arguments and requirements that form the basis for the chosen solutions for the CVWT is mentioned. A short presentation of the chosen solutions are given, along with arguments for why these solutions were found to be the best ones. For a complete overview should appendix A, CVWT specification be read prior to this chapter. Chosen solutions are a result of a stepwise approach, fulfilling all of the requirements mentioned in section 3.4 with special focus on public regulations, GE requirements and procedures.

3.1 Current testing procedures

The current test procedure for testing Choke valves is performed by the use of a manually operated directional valve (DCV). To carry out one step is the valve operated and held for 2 seconds, then released for 4 seconds. This is a very time consuming operation, especially since it may be as much as 200 steps from open to closed position. It may take the operator as much as 20 minutes to go from open to closed position, or vice-versa.

During the testing, the operator fills out the forms shown in figure 3.1. The valves are always shipped in middle position and the test procedure divided into three stages. Logged data is the current reading from the electrical position indicator along with the position reading from the visual position indicator.

Equipment used for testing the valve has been listed below. The tool is stored in a pelicase and assembled for each time it is being used.

- Fluke 707EX Instrinsically safe loop calibrator
- Hand operated directional valve
- Hose 3/8 IN,WP 330bar, 1.5m Length
- 4 way ODI Electrical test connector with pigtails
- 1 snaptite SS72N6-6FV 3/8 NPT

OPEN Actual position		FLUKE reading	VPI needle position
%	mA	mA	%
50			
60			
80			
100	20		

CLOSE Actual position		FLUKE reading	VPI needle position
%	mA	mA	%
100	20		
80			
60			
40			
20			
0	4		

OPEN Actual position		FLUKE reading	VPI needle position
%	mA	mA	%
0	4		
20			
40			
50			

Figure 3.1: Logging of test data

3.2 Constraints

Prior to the work of finding a suitable way to automate the test procedure, the constraints in the project was found and evaluated. The most important constraints are summarized below.

- Price - *To reduce cost, used and/or standard parts should be used where it is found to be suitable.*
- Time - *Time available for completing this project is limited, the project period is from 06.01-06.06.2014.*
- Tools - *Software available for carrying out tasks.*
- Technical - *Technical challenges in combinations with lack of knowledge which may affect the wanted result*

3.3 Stakeholder analysis

The main purpose of this analysis is to find the requirements from the different stakeholders. This is done to avoid situations where user requirements keep changing even when system or product development has been started. Stakeholders are defined as people or organizations that have a valid interest in the system, they may be affected by it either directly or indirectly. In this project the stakeholders have been identified as:

- Technicians in the workshop
- Engineering department
- Sales personnel
- Customers
- Laws and regulations affecting the product or it‘s solutions.
- Competitors

A challenge when having many stakeholders is that they may have various self-interests in the product. The developers and end user may have different vocabularies leading to misunderstanding and some stakeholders may believe they are in perfect agreement until the finished product is supplied. The requirements from the stakeholders have therefor been defined as measurable, testable and to some extent traceable. In this project methods like interviews, meetings and also observations in the workshop have been used to reveal the different requirements. The results of this requirement is listed in section 3.4.

3.4 List of Requirements

The list of requirement is used to develop measurable requirements from the stakeholder's analyses. This make it easier to evaluate whether the chosen solution fulfills the requirement or not. The list is divided into two categories, wishes and demands. Only the wishes are evaluated, as demands need to be fulfilled for the solution to be acceptable.

Table 3.1: Requirement list

Demands

1.0 Interface	Choke Valves, Lifting equipment and test facility
1.1 Hydraulic	Different working pressure, max 10000psi (690bar). Flushing loop.
1.2 Electrical	Connect to both 220V and 110V. Connectivity towards different Chokes
1.3 Mechanical	Mobile. Industrial Use.
1.4 Control system	Choke parameters shall be adjustable. Data shall be stored for future use
1.5 Handling	Lifting lugs/points shall be provided if needed
1.6 HES	No risk to health or the environment.
1.7 Certification	CE marking

Wishes

2.0 Temperature	-10 $C^\circ \sim 65\ C^\circ$
2.1 IP-rating	≥ 56
2.2 Quality	$\geq$ 1000 Working hours
2.3 Manual operation	Possible to operate manually
2.4 Noise	$\leq$ 80dB
2.5 Upgrade options	Possible to upgrade controller with extra I/O
2.6 Ergonomic	Operating height 850 ∼1050 [mm]
2.7 Weight	$\leq$ 50 kg
2.8 Size	H=1300 W=1400 D=800 [mm]
2.8 Price	Reuse of old and/or standard parts where possible.

Based on the requirement list, a Unit Functional Design Specifications (UFDS) was created. The aim of this document was to provide detailed information and instructions needed for building the CVWT. The document provides both a functional overview and detailed information about the chosen solution. This document should be read in detail for a complete overview of all the specifications for this tool, appendix A. In chapter 4 are argumentation for the described solutions given.

Chapter 4

Choke Valve Workshop Tool

4.1 Basis of the design

An industrial standard laptop shall be used as an engineering workstation. The laptop shall provide both engineering tool and operator (HMI) software. The HMI allows the operator to control the DCVs, provide the operator with system information and adjust choke parameters. A PLC is chosen as the control unit, and monitors the pressure transducers, positions sensors and also the actuation of the DCVs. The system is designed to operate on three different pressure levels and with an opportunity for the operator to open and close the DCVs individually through the HMI. Result being a flexible, versatile and space efficient tool. Figure 4.1 shows the planed final design for the CVWT

Figure 4.1: Example of layout for the CVWT

4.2 Function Structure

Since most products and machines developed today are based on similar products and already existing technology was the functional structure for the CVWT chosen as a starting point. The overall function of the system was divided into smaller sub-functions. There it was defined what type of building blocks it consisted of and in which way they interacted with each other. Instead of searching for new technology or solutions for the system as a whole, already existing and proven technology were applied for the individual building blocks.

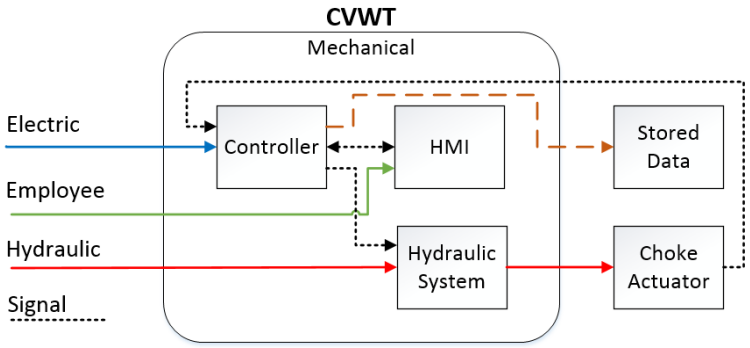


Figure 4.2: Function structure

Figure 4.2 show the function structure for the CVWT. The dotted lines illustrate communication between the different blocks. Each one of the blocks within the CVWT-block can be considered as a design requirement.

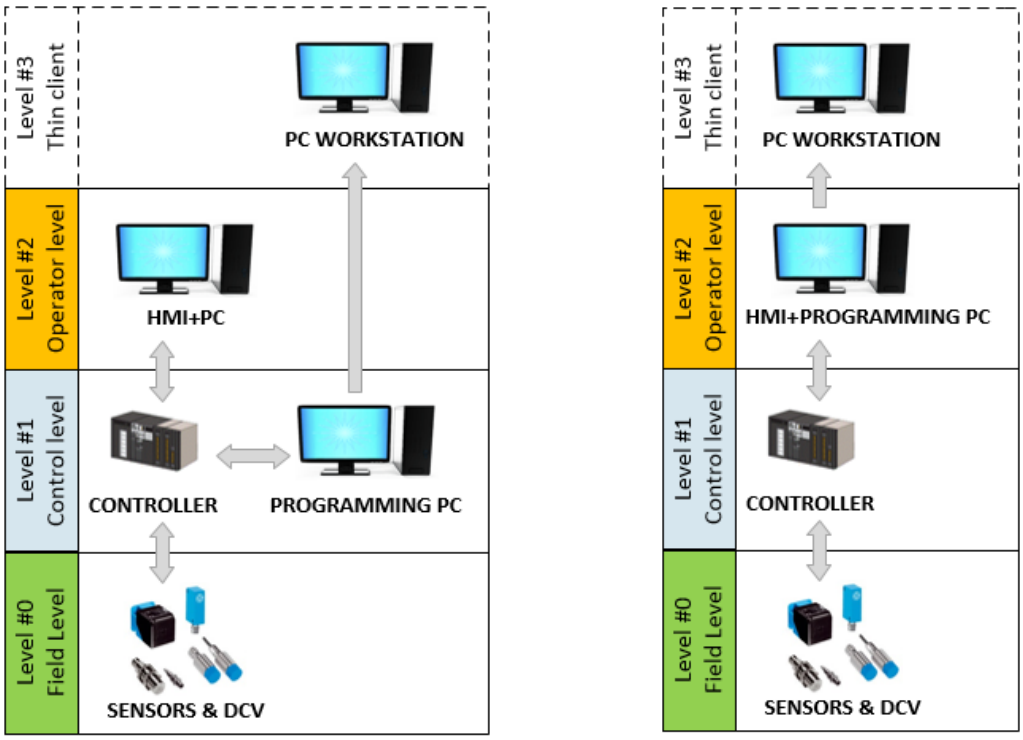
- Controller type
- Human Machine Interface (HMI)
- Hydraulic components
- Mechanical

With the exception of power consumption, the choice of sensors, valves and other hydraulic equipment influence the mechanical design. The blocks that had the biggest influences on the system was considered to be the controller in combination with the HMI. The topology for the system was used as a starting point for the system design.

4.3 Topology

When evaluating the topology for this system, one of the main challenges was that the operator shall be given read and write rights, without been given the access rights to enter the program code. Entering the program code should only be done by authorized personnel. Also, if found necessary in the future shall thin clients be given read access through an Object Linking and Embedding Process Control (OPC) -client. Based on this, two different solutions for the topology was considered, figure 4.3a and 4.3b, standard topology and simplified topology.

In figure 4.3a the programming PC is placed on the control level, and an additional computer is placed on the operator level. This has been proven to be a safe solution since the programming and operating of the system is carried out in different authorization levels on different computers. As stated earlier the system shall also have the opportunity to communicate with thin clients through an OPC- server if found necessary in the future. If the topology shown in figure 4.3a was chosen, the OPC-client could be installed on the programming PC with the result of being a stable and secure system.



(a) Standard topology

(b) Simplified topology

Figure 4.3: Topology

The second solution considered is shown in figure 4.3b, and is a simplified version. By removing the programming PC, and use the same computer for programming as well as HMI, the complexity will be reduced and there will be no need for an additional PC. The same restrictions need to be followed, meaning that the operator are not allowed to enter any program code, just to change the control parameters and make use of process information. If needed the thin clients can be given reading rights through a OPC-client, but all the software must be installed and managed on the same computer on the operator level.

Since this is a stand-alone unit operated by GE-personnel only, it has been discussed, but not found necessary to go for the safer and more complex topology shown in figure 4.3a. It is in general, always a good idea to keep things as simple as possible, and it also applies for this system. The advantage of having a less complex topology, with fewer computers, exceeds by far the advantage of having physically separated the operator and the programming PC. Sufficient security level will be provided by adding password protection to the relevant software. The preferred solution is therefore the topology shown in figure 4.3b, simplified topology.

4.4 Engineering workstation

4.4.1 Controller

Since the controller will be both the heart and mind of the system, it must solve a large variety of different tasks. In addition to controlling the systems in/out-puts it must communicate with the PC on the operator level. It must prevent unsafe operations by handling alarms and unplanned events. It must also be able to capture and store data and all of this in just a few milliseconds.

All of these requirements can be fulfilled with the use of a Programmable Logical Controller (PLC) or Programmable Automation Controllers (PAC). They have both been developed and continuously improved over decades to be able to operate industrial machines, and processes in the best possible way[7]. The main difference between PLC and PAC is that the PAC is capable of handling much more information in a shorter time period. Making the PACs the number one choice to perform and process complex measurements such as analyzing car crashes or explosions. The PLC is on the other hand considered to be relative cheap and robust. A PLC is well-suited for complete plant automation such as flow control, pressure control, level and temperature loops [8].

Based on the requirements for this system, the clear choice is the PLC. It fulfills the requirements of the system since there are no complex calculations, closed loop control or high speed measurements to be monitored. Also, when talking to engineers in GE, it became clear that their preferred solution was a PLC. This is a controller that is widely used within the Oil & Gas industry and the level of expertise is therefore high on this type of controller.

The chosen PLC for this project is the Siemens S7-1511-1- PN, it belongs to the newest S7-1500 series from Siemens and is intended to replace the S7-300 series in the future. This ensures that it will not be an issue to get hold of spare parts, at least for the next two decades. It is a cost efficient choice that is sufficiently fast for this application. It is also flexible, meaning that I/O modules can be replaced and added if needed. The power loss in the PLC is only 5.7 W, and the PLC is delivered without a colling fan. This allows the PLC to be installed in a closed cabinet with International Protection (IP) -rating $\geq$ 56. This reduces the cost since the more expensive PLC‘s specially designed for the industrial environment, does not have to be used. Siemens S7-1511-1-PN uses Profinet which allows for communication rates up to 100 Mbits. Another benefit is that the same power supply can be used for the PLC, sensors and DCV. Only the main plug must be replaced before connecting to either the European or American power grid.

4.4.2 Programming PC and HMI

As described in section 4.3, a Laptop will be used as both the programming PC and HMI. This will reduce the number of components needed and the complexity in the topology will be reduced. Advantages by using a PC-screen as a HMI is that the operator interface is similar to most of the PC based software; you just point and click, meaning that the operator is working in a familiar environment. The operator will also be able to process, and create reports out of the logged system parameters directly from the HMI.

A Simatic Field PG M4 laptop which is a Siemens Certified industrial standard laptop is chosen for this system. This laptop needs the latest standard Siemens operator system and engineering tool to be installed. It must also be delivered with relevant components needed to interface the PLC and other equipment. This to ensure that both the hardware and software interact with each other in the best possible way. If the computer, PLC or software for some reason stop functioning, GE will only have one company to address. In addition to the discussed arguments, is the price found to be significant lower when ordering a complete system instead of buying the components separately. A complete functional, factory acceptance test (FAT) shall be performed by Siemens before the computer and PLC is delivered to GE to ensure that the system works as specified.

The software needed for the system is Totally Integrated Automation (TIA) - portal V.12 with WinCC Advanced and WinCC Advanced RunTime. For the logging of process events will a WinCC Logging RunTime License be needed. WinCC Advanced is a single user system which can be used both as an OPC server and towards an already existing OPC server if found needed in the future. This will allow thin client to be given read rights as discussed in section 4.3.

4.5 Hydraulic

This section should be read in conjunction with appendix B, hydraulic schematic. Maximum operating pressure level in the system it set to be 10000psi. GE procedures requires therefore that the system pressure is designed according to equation 4.1 and that the system shall be prof tested at a pressure level according to equation 4.2.

$$DP = NWP \cdot 1.1 \tag{4.1}$$

$$PTP = DP \cdot 1.5 \tag{4.2}$$

Where:

- NWP = Nominal Working Pressure
- DP= Design Pressure
- PTP= Proof Test Pressure

Reynolds number was used for finding a suitable tube size. During normal operations, it is recommended in GE procedures that linear flow is maintained during normal operations to reduce the power loss in the system, meaning a Reynolds number lower than 2300 for circular tubes. On the other hand the tubing size must be sufficiently small to ensure effective flushing of the hydraulic system. GE procedures recommends a Reynolds number of 4000 when flushing circular tubes. Equation 4.3 was used for calculating the Reynolds number and necessary flow to ensure turbulent flow.

With an expected viscosity of 5 cSt when using the water-based HW443 hydraulic fluid and a fluid velocity of 36 l/min, it was difficult to find a tube size that kept the Reynolds number below 2300 and still keep the tube size within reasonable limits. However, since the total amount of fluid required in one step is only 0.06 l, were the power loses calculated to be so small that this requirements could be ignored, equation 4.4-4.7. Based on the calculations and the requirements for the pressure level, were 3/8" medium pressure cold drawn, seamless grade American Iron and Steel Institute (AISI) 316 stainless steel tubing selected for the tool. All fittings and output connectors shall be 3/8" medium pressure (MP) and output connectors shall be bulkhead mounted.

$$Re = \frac{\mathrm{v} \cdot d}{v} \tag{4.3}$$

$$P = \Delta p \cdot Q \tag{4.4}$$

$$\Delta p = \lambda \cdot \frac{l}{d_i} \cdot \rho \cdot \frac{\mathrm{v}^2}{2} \tag{4.5}$$

$$\lambda = \frac{0.316}{Re^{0.25}} \qquad if\ Re > 2300 \tag{4.6}$$

$$\lambda = \frac{64}{Re} \qquad if\ Re < 2300 \tag{4.7}$$

Where:

- Re= Reynolds number [-]
- v= Speed of the fluid $[m/s]$
- v= Kinematic viscosity $[m^2/s]$
- P= Power loss $[Nm/s]$
- Δp= Pressure loss in tubing $[N/m^2]$
- Q= Flow $[m^3/s]$
- λ= Friction coefficient [-]

- l= Length of tubing $[m]$
- d_i=Tubing inner diameter $[m]$
- ρ= Fluid density $[kg/m^3]$

One important demand for the CVWT was that is should be able to operate on different pressure levels. This is solved by using three pressure relief valves (PRV) adjusted for different pressure levels and isolated by needle valves. In case the operator forgets to open, or opens the wrong needle valve when operating the CVWT at low pressures an alarm will be given to the operator and also prevent the DCV from opening. A needle valve is mounted on the supply port as an extra safety precaution, the same valve will be used for slow and controlled filling of the system. In addition are check valves with crack pressure of 0.5-1 bar mounted on the supply and return port since the system shall be stored, filled with hydraulic fluid.

Hydraulic gauges and pressure transducers shall be mounted on block and bleed valves, providing the system with sufficient bleeding point and also making calibration of the sensors easier. Chosen gauges shall be able to handle the continuous pulsation in the system, caused by the stepping. Due to the rapid closing of the DCV valves were calculations done to determine whether or not shock absorbers should be installed. Calculations showed that the pressure only increased with approximately 13-15 bar in the worst case when the valve closes as rapid as 100ms and with a tube length of 3 meters. In the data sheet for the valve is 100ms stated to be the minimum energizing time. Joukowsky's estimate of maximum occurring pressure surge were used for calculating the pressure shock, equation 4.8-4.11 [9].

$$\Delta p_s = \rho \cdot a \cdot \Delta \mathrm{v} \cdot \frac{t}{T} \qquad if\ T > t \tag{4.8}$$

$$\Delta p_s = \rho \cdot a \cdot \Delta \mathrm{v} \qquad if\ T < t \tag{4.9}$$

$$a = \frac{1}{\sqrt{\rho \cdot \left(\frac{1}{\beta} + \frac{d_i}{E \cdot e}\right)}} \tag{4.10}$$

$$t = \frac{2 \cdot l}{a} \tag{4.11}$$

Where:

- Δp_s= Pressure schok $[N/m^2]$
- ρ= Density $[kg/m^3]$
- a= Velocity of the pressure wave propagation [m/s]
- Δv = Change of the fluid speed [m/s]
- t=reflection time [s]
- T=Closing time of valve [s]
- β=Compression modulus of the fluid $[N/m^2]$
- d_i=Tubing inner diameter $[m]$
- E=Modulus of elasity of the pipe line $[N/m^2]$
- e= Wall thickness of pipe line [m]
- l=Length of pipe line [m]

To reduce cost and make the test conditions regarding flow and pressure as similar as possible to the subsea conditions, the same valve was used on the SCM and the CVWT. This is a valve developed for and by GE, designed especially for harsh conditions. It is a monostable 3/2-way DCV which is design to operate 400000 cycles at 5000 psi or 40000 cycles at 10000 psi. The DCV shall be mounted on a GE manifold designed especially for testing valves. As recommended in the compendium; Hydraulic components and system is the ports on the manifold and tubing of the same size[10]. As already mentioned; the GE procedures requires that a flushing loop shall be installed on the testing equipment. In addition to needle valves for flushing, a bypass loop for the DCV has been added since the DCV valves will be dismounted when flushing.

According to GE test procedures a pressure drop test must be performed on the choke valves before they are approved for subsea use. To be able to perform this test are two needle valves mounted so that the pressure gauges and transducers can be isolated from the DCV. Eventual pressure drop can be monitored and logged. The Choke Valve will be pressurized with an open/close function in the HMI.

4.6 Mechanical

A conceptual drawing of the portable trolley created in SolidWorks can be seen in appendix A. The trolley is recommended build out of 45x45mm Bosch Rexroth aluminum strut profiles. Another supplier may be chosen if it is found beneficial. One of the major benefits with this type of aluminum profiles is that it requires no welding, the profiles are easily bolted together with custom made brackets. This reduces the time spent on construction and thereby the cost. Other reasons for choosing this strut profiles is its light weight and corrosion-free surface.

The aluminum frame that make up the trolley shall work as a mechanical protection for the hydraulic and electrical equipment. Nothing of this equipment shall therefore be mounted in such a way that it can be damaged with normal handling and storing. All of the hydraulic and electrical equipment shall be bulkhead mounted. A cover in Plexiglas supported by gas springs shall be mounted as extra protection over the laptop.

In accordance with the Health Safety and Environment (HSE) requirements in GE, a drip tray is installed under the hydraulic component to reduce the risk of spilling. The CVWT is designed in such a way that the number of loose parts is reduced a minimum. Parts like dust caps, locking pins etc. shall be fixed to the trolley by use of wire. Since all lifting lugs and equipment need to be certified is the trolley designed with forklift pockets to reduce cost.

Chapter 5

Dynamic modeling

5.1 Introduction

A simplified dynamic model of the workshop tool in a CAE simulation software was developed in line with the objectives defined. The main purpose of the dynamic model is to confirm that the PLC and HMI program works as predicted, and not necessarily describe the system response as accurate as possible. However, it would be an advantage if the dynamic model is reflecting the real system as accurate as possible. The challenge has been to develop a adequately detailed model without superfluous features. In this section, the modeling of the CVWT and the Choke Valve is presented. The hydraulic system and its components are presented and also the analysis and calculation behind the development of the dynamic model is described.

5.2 Modeling and simulation

Modelling and simulation of a physical system has a lot of advantages. It is used for optimization of system performance, reduce cost and failure rate, experimenting and reconfiguration, and to prevent under or over-utilization of resources. This is very valuable, since it is often impossible, too expensive or impractical to do in the real system [12].

SimulationX was chosen for the development of the dynamic model. It is a versatile software used for simulation of physical systems by engineers in most industries. It has an grafical user interface with drag and drop functions and also a good library of pre-engineered models. Via c-code export can SimulationX models be directly integrated into NI's LabVIEW or other graphical design platforms used when performing a HIL test[11]. SimulationX also provide the opportunity to perform SIL test, by connecting to virtual machines such as Siemens S7-PLCSIM directly without the need of exporting files or to connect to OPC-servers.

In this report SIL testing are referred to as tests conducted using only software simulations of system physics and embedded control routines. HIL testing refers to tests that include some hardware components.

5.3 System overview

In figure 5.1, a schematic drawing of the mechanical parts is given. As illustrated, hydraulic pressure is applied to either one of the two spring return cylinders, which connects with the respective camshaft. The bevel pinion gear fixed to the cam shaft arrangement rotates the central gear, this rotary action is converted to a linear motion by the Acme thread. The stem-plug assembly has an anti-rotation arrangement to prevent it from rotating, allowing it to travel in a linear way only. Each stroke of the hydraulic cylinder allows the plug to open or close in incremental steps Hydraulic pressure is applied to the cylinders by the use of two 3/2-way DCV.

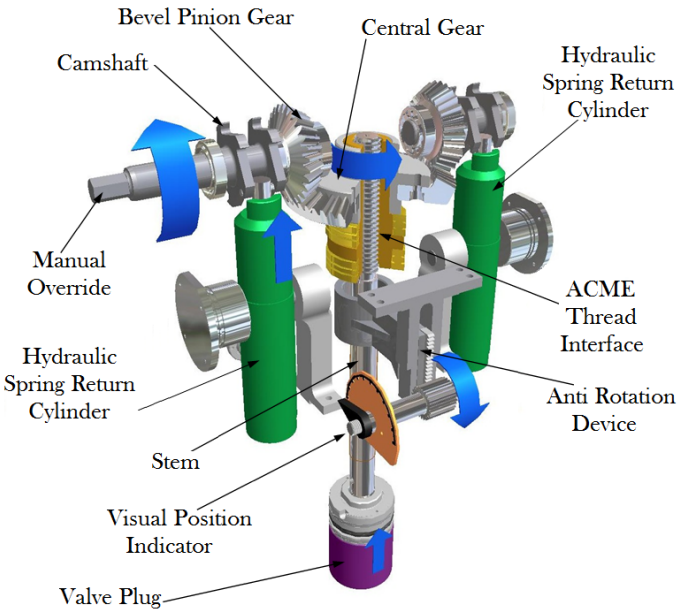


Figure 5.1: Working principle of Choke Valve

Figure 5.2 shows a model of the Choke Valve and CVWT when combined into a system, it consist of a cylinder with the corresponding forces acting on it, components replicating the tubing, control valves and a HPU. This simplified model is based on the hydraulic schematic shown in appendix B and figure 5.1 showing the working principle of the Choke Valve.

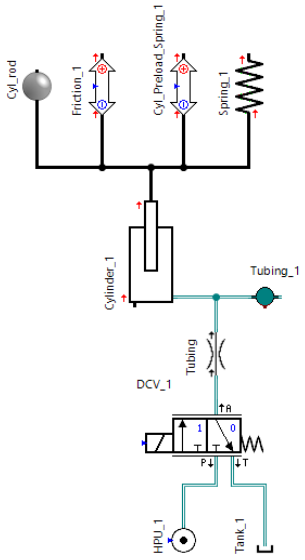


Figure 5.2: System overview

5.3.1 Cylinder

Some simplifications must be applied when converting physical systems into a dynamic model. In this model the leakage from the cylinder and the valve have not been considered, they are evaluated to be small and insignificant for the overall response of the system. Also, the computation time in SimulationX is strongly affected when such parameters are added. Piston behavior determines the overall system response, and is therefore a very essential part in the dynamic model. The free body diagram shown below, figure 5.3 describes the forces acting on the pistons in each of the two cylinders.

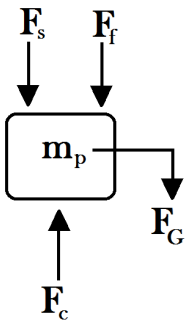


Figure 5.3: Forces acting on the piston

Spring forces is calculated with, equations 5.1. Spring stifness was found in the data sheet for the Choke Valve. Pressure force changes with the changing pressure in the cylinder and was calculated with equation 5.2. No accurate data on the mass of the piston was found so an estimate was done with equation 5.3.

$$F_s = x \cdot k \tag{5.1}$$

$$F_c = p_c \cdot A_c \tag{5.2}$$

$$m_p = \rho \cdot V \tag{5.3}$$

Where:

- k=Spring stiffness [N/m]
- F_s=Spring force [N]
- x=Piston position [m]
- F_c=Pressure force [N]
- p_c=Pressure in the cylinder [Pa]
- A_c=Piston area [m^2]
- m_p=Mass of piston [kg]
- ρ=Density [kg/m^3]
- V=Pistom volum [m^3]

Instead of estimating the friction coefficient and calculating the friction force, the friction force was measured based on tests done in the workshop. Torque needed for turning the camshaft in atmospheric pressure was converted into force with equation 5.4. The friction force acting on the cylinder was found to be approximately 790 N when the cylinder is extracting. This force corresponds to the entire friction force from the camshaft to the Acme tread.

For modeling the friction force were the model shown in equation 5.5 used. This model are using the hyperbolic tangent function which gives a smooth transition around zero relative velocity. One of the main

disadvantage with the tanh-friction model is that it does not return any friction force at zero relative velocity which is contrary to what is normally the case, figure 5.4 [13]. Despite of this is the model found to be satisfying, especially since it prevents unwanted oscillations caused by models that have discontinuity around zero relative velocity such as the Stribeck friction model, figure 5.5 [13]. The equation is velocity dependent and works as a damper and reduces the amount of high frequency transients in the system as shown in figure 5.7.

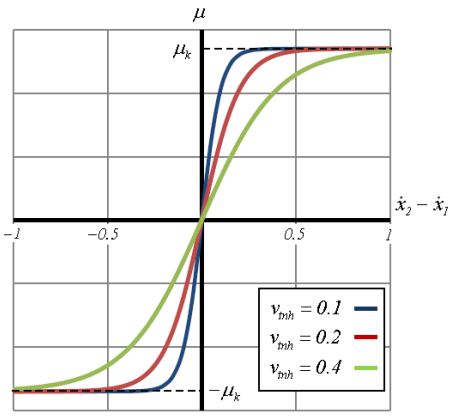


Figure 5.4: Influence of v_{tnh} on the tanh friction model [13]

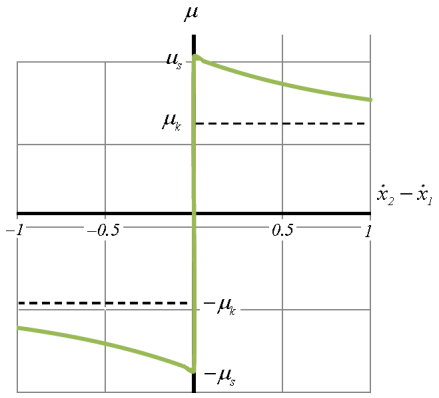


Figure 5.5: Typical Stribeck friction model

$$F_f = \frac{M_f}{r_c} \tag{5.4}$$

$$F_{fmod} = F_f \cdot tanh\left(\frac{v_{cyl}}{v_{tnh}}\right) \tag{5.5}$$

Where:

- F_f=Friction force [N]
- M_f=Friction torque [Nm]
- r_c=Camshaft radius [m]
- F_{fmod}=Firction force modeled [N]
- v_{cyl}=Velocity of cylinder piston[m/s]
- v_{tnh}=Describing the slope of the friction model [m/s]

The friction is different when the cylinder is extracting and retracting. When retracting, only the sliding rings and seals in the cylinder is creating friction force. Unfortunately, no good data was found to describe this force accurate, but a friction force giving a peak value of approximately 200 N gave the result shown on top of the next page, figure 5.6 and 5.7. This value is of course way above the actual friction force in a real life system, but as shown, the difference from the model without any friction force and the one with is only 10ms. So it all comes down to a trade-off between accurate modeling and reduced computation time. Green graph is the system response without the friction force, and the red is when the friction force is applied.

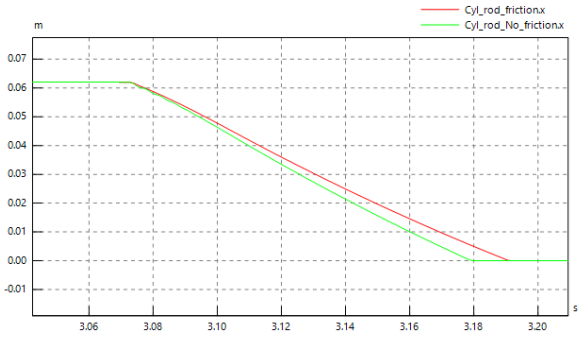


Figure 5.6: Piston position

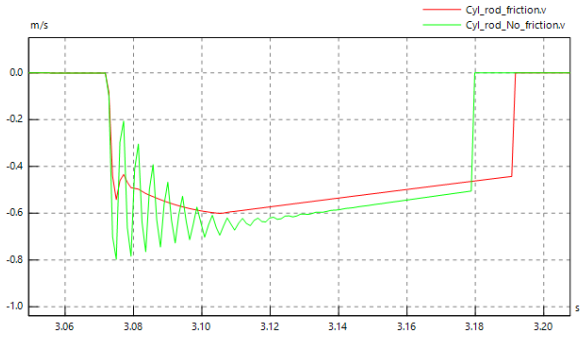


Figure 5.7: Piston velocity

5.3.2 Tubing

Dimensioning of the hydraulic tubing based on the Reynold number was discussed in section 4.5, a tubing size of 3/8" was found to be suitable for the CVWT. Modeled volume is calculated with equation 5.6. Restrictions regarding the tube dimension are modeled as a nozzle with diameter similar to the inner diameter of the tube.

$$V_0 = \frac{\pi \cdot d_i^2 \cdot l}{4} \tag{5.6}$$

Where:

- V_0=Total tubing volume $[m^3]$
- d_i=Inner diameter of the tube $[m^2]$
- l=Total length of tubing [m]

In steady state analysis is it common to consider the fluid as incompressible. However no liquid is fully incompressible and this has therefore been taken into account. Bulk modulus is the property that describes the stiffness of a fluid. If a fluid has a high bulk modulus, then it is difficult to compress (similar to spring stiffness). The relationship between volume, pressure and bulk modulus is shown in equation 5.7

$$\Delta p = \frac{\beta_f \cdot \Delta V}{V_0} \tag{5.7}$$

Where:

- Δp=Pressure change$[Pa]$
- β_f=Bulk modulus$[Pa]$
- ΔV=Change in volume $[m^3]$
- V_0=Volume corresponding to initial pressure $[m^3]$

Just like the density, are the bulk modulus and the compressibility functions of temperature and pressure [10]. In real life systems air bubbles are entrapped in the hydraulic fluid, this may have a strong effect on the effective stiffness of the hydraulic fluid. However if the air is dissolved in the fluid the change in stiffens is minor [10]. As shown in the figure 5.8, the change in stiffness is dramatic for small pressure levels, but decreases rapidly with increasing pressure. The higher the air content the spongier the system becomes (lower bulk modulus), result being a system with low response time.

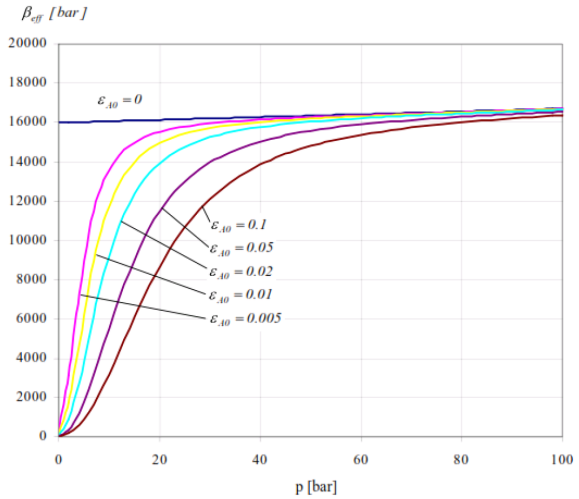


Figure 5.8: Variation of effective stiffness of fluid-air mix at 40°C [10]

SimulationX has a library of predefined hydraulic fluids. Water-based HM433 have been selected with a corresponding bulk modulus of approximately $3.2e^9$ Pa. This is the same hydraulic fluid as they use both in the workshop and in most of the subsea installations. The effect that the fluid-air mixture has on the system has not been taken into account in the dynamic modeling. There are two main reasons for this, the working pressure is minimum 100 bar and the second reason is that the number and complexity in the number of calculations needed is significantly reduced.

5.3.3 Directional Control Valve

The same type of DCVs as used on the SCM, is being used on the CVWT. This is a custom made valve developed for and by GE. It is modeled with the use of the pre-defined 3/2way proportional directional control valve in the SimulationX library. Valve properties were found in a test report. An excerpt of the test result is presented in the table 5.1. The flow coefficient is a coefficient that is widely accepted by industry for comparing valve capacities and sizing, and describes how efficient a device allows a fluid to flow [14]. It can be calculated with equation 5.8.

Table 5.1: Flow coefficient

Supply to function		
Differential pressure [bar]	Flow $[m^3/hour]$	K_v
31.92	0.7313	0.13

Function to return		
Differential pressure [bar]	Flow $[m^3/hour]$	K_v
38.44	0.9426	0.15

$$K_v = Q \cdot \sqrt{\frac{SG}{\Delta P}} \tag{5.8}$$

Where:

- K_v=Flow coefficient$[m^3/hour]$
- Q=Flow$[m^3/hour]$
- SG=Specific gravity $[bar]$

- ΔP=Pressure drop [bar]

SimulationX use the second order differential equation, 5.9 ,for describing the spool dynamic of the valve. No detailed information were found for the natural frequency or the damping ratio. Only the minimum energizing time of 100ms where specified. By experimenting where values of 5 Hz and a damping ratio of 0.7 found to give satisfying results, figure 5.9. Green line represent the input signal to the valve and the red line represent y_s.

$$y_s = \tau^2 \cdot \ddot{y}_{rel} + 2 \cdot D \cdot \tau \cdot \dot{y}_{rel} + y_{rel} \tag{5.9}$$

$$\tau = \frac{1}{2 \cdot \pi \cdot f_o} \tag{5.10}$$

Where:

- y_s=Stroke signal
- y_{rel}=Relative valve stroke
- f_o=Undamped natural frequency [Hz]
- D=Damping ratio [-]

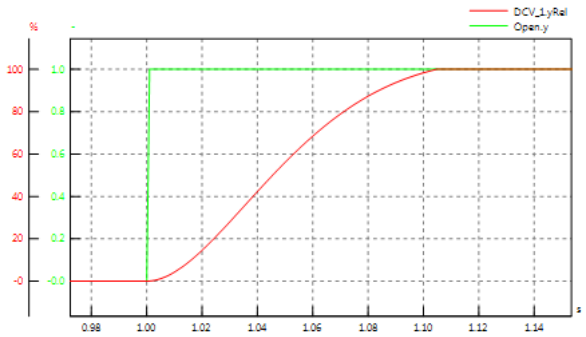


Figure 5.9: Spool response versus time.

5.3.4 Hydraulic Power Unit

The HPU is modeled as a constant pressure source. Amount of fluid needed to actuate the cylinder is only 60cc for each step, approximately every sixth second. Pressure loss due to actuation of the DCV‘s is therefore considered to be negligible.

5.4 Ordinary Differential Equation - solver

As mentioned, the developed model is planed on being used in a HIL setup. This sets major requirements for the Ordinary Differential Equation (ODE) - solver. When running the model in SimulationX, offline solvers with variable step size can be used. This allows the computer to use the necessary time and to reduce the time steps if needed to be able to calculate the ODE's, this is beneficial when analyzing complex models such as stiff systems with high frequency oscillations and corresponding high derivatives as shown in figure 5.10a and 5.10b. However when compiling the model into a Dynamic Link Library (DLL) - file, SimulationX automatically use a fixed-step ODE solver [15]. This is done to ensure determinism when the model is run in real time. Fixed time-step solvers with large time-steps may yield very inaccurate results because it has to predict the future. Reducing the time step may improve the accuracy but may also affect the computation time. It is important that the computer manage to do all of the computations within the time frame defined by the fixed-step solver, figure 5.10c. Failing to do so will result in inaccurate results, and in worst case, cause the model to crash.

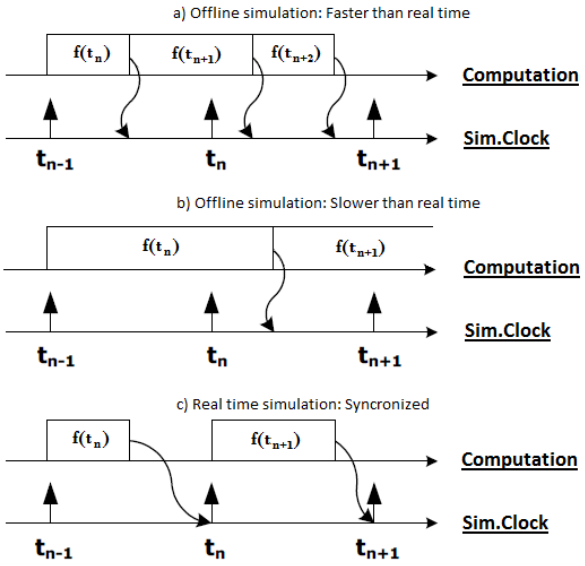


Figure 5.10: Offline versus real time simulation

5.4.1 Time step

Finding a suitable time step can be demanding since it depends on the complexity of the model and the computer processor. An estimate of minimum time step can be given by taking the number of required floating point operations per second (FLOPS) and divide it on available FLOPS, equation 5.11.

$$h_{min} \geq \frac{n_{FLOPS}}{\text{available FLOPS}} \tag{5.11}$$

Where:

- h_{min} = Minimum time step
- n_{FLOPS} = Number of required floating point operations per second
- $availableFLOPS$ = Number of available floating point operations per second

This method requires that the computer is benchmark tested for actual performance since there is no good way to calculate this [16]. Another method described in the next section has therefore been used instead.

5.5 Simplification

In an attempt to increase the time steps and be able to use the model with a fixed time step solver, the following method was used. First the system was modeled without any concerns regarding the limitations from the solver. The performance and behavior of the system response was recorded and replicated with a smaller model without the complexity, caused by the high frequency oscillations and corresponding derivatives.

Cylinder and the corresponding forces acting on it, along with the tubing restrictions etc. was replaced by equations 5.12 and a volume element. Some of the DCV parameters had to be modified to be able to replicate the behavior. This allowed time steps as large as 1ms be used and still give the approximately same results, figure 5.11. Red line represent the simplified model and the green line (almost completely concealed behind the red line) represent the model before the simplification.

$$x_{sp} = s_c \cdot \frac{p_t}{p_s} \tag{5.12}$$

Where:

- x_{sp}= Calculated piston position [m]
- s_c=Stroke length of cylinder [m]
- p_t =Pressure in the volume element [Pa]
- p_s =Pressure source [Pa]

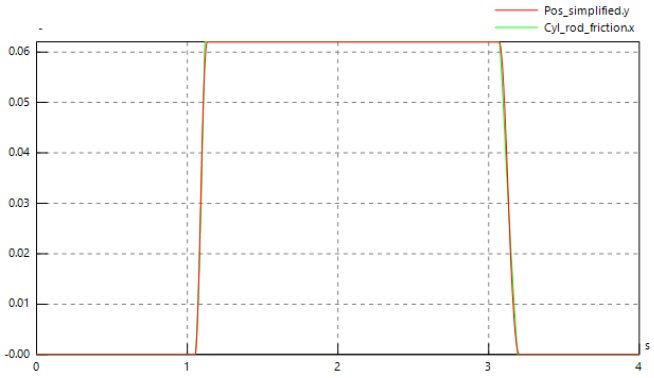


Figure 5.11: System behavior before and after simplification

Despite that this simplified model can not describe the actual behavior of the system accurate; this model was found to be satisfying, especially since the model primarily is going to be used for testing the PLC and HMI program code. Figure 5.12 show the model after it was simplified.

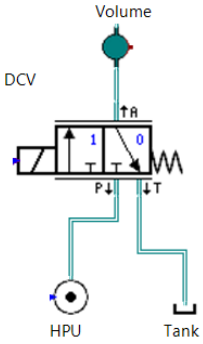


Figure 5.12: Simplified model

Chapter 6

System Simulation and Verification

6.1 Human-machine interface

HMI equipment provides a control and visualization interface between a human and a process, machine, application or appliance. HMIs spans from the simplest text based displays, too advanced graphical operator panels such as Supervisory Control and Data Acquisition (SCADA) and web-based HMI Solutions. In section 6.2, a presentation of the HMI developed for the CVWT in the software SIMATIC WinCC 7.2 is given. Through the different operator screens the operator is given the opportunity to control, monitor, diagnose and operate the CVWT.

6.2 Control panel

People in general have a tendency to be skeptical when they are faced with new technology, so to develop an orderly, clear and easy-to-use HMI has been a priority. The layout is based on an existing workshop tools, used for testing DCV valves. By using a familiar layout and by using the same commands as found in most PC-based software, point and click, should the technicians be able to operate the CVWT in a safe and secure way, even with a minimum of experience. It has also been taken into consideration that this tool is developed for a company with roots worldwide, with different culture and technical experience.

To reduce the workload and level of stress, the amount of information given to the operator during stepping is deliberately kept at a minimum All information given to the operator is in English and the background color used is mainly different shades of gray to create a relaxing and calm feeling. Since bright colors have a tendency to draw our attention, this is only used to separate the different sensors in the trend graphs and to illustrate whether the DCVs are opened or closed. To improve the readability of the HMI, a copy of the hydraulic schematic have been used to illustrate were the sensors and DCVs are mounted. The same schematic, with corresponding valve numbers are planned to be presented on the front panel of the CVWT.

Figure 6.1 shows main screen where the operator is given the opportunity to operate the CVWT in the following way:

- Pressing DCV1 or DCV2, forcing the respective DCV valve to open.
- Step the valve a fixed number of steps. First enter a desired number of steps that the operator would like the Choke valve to step, and then press the STEP OPEN or STEP CLOSE button.
- Go to an absolute position. First enter desired position in % OPEN and then press the ABS POSITION button.
- Stepping a desired number of cycles is possible with the STEP CYCLE button.

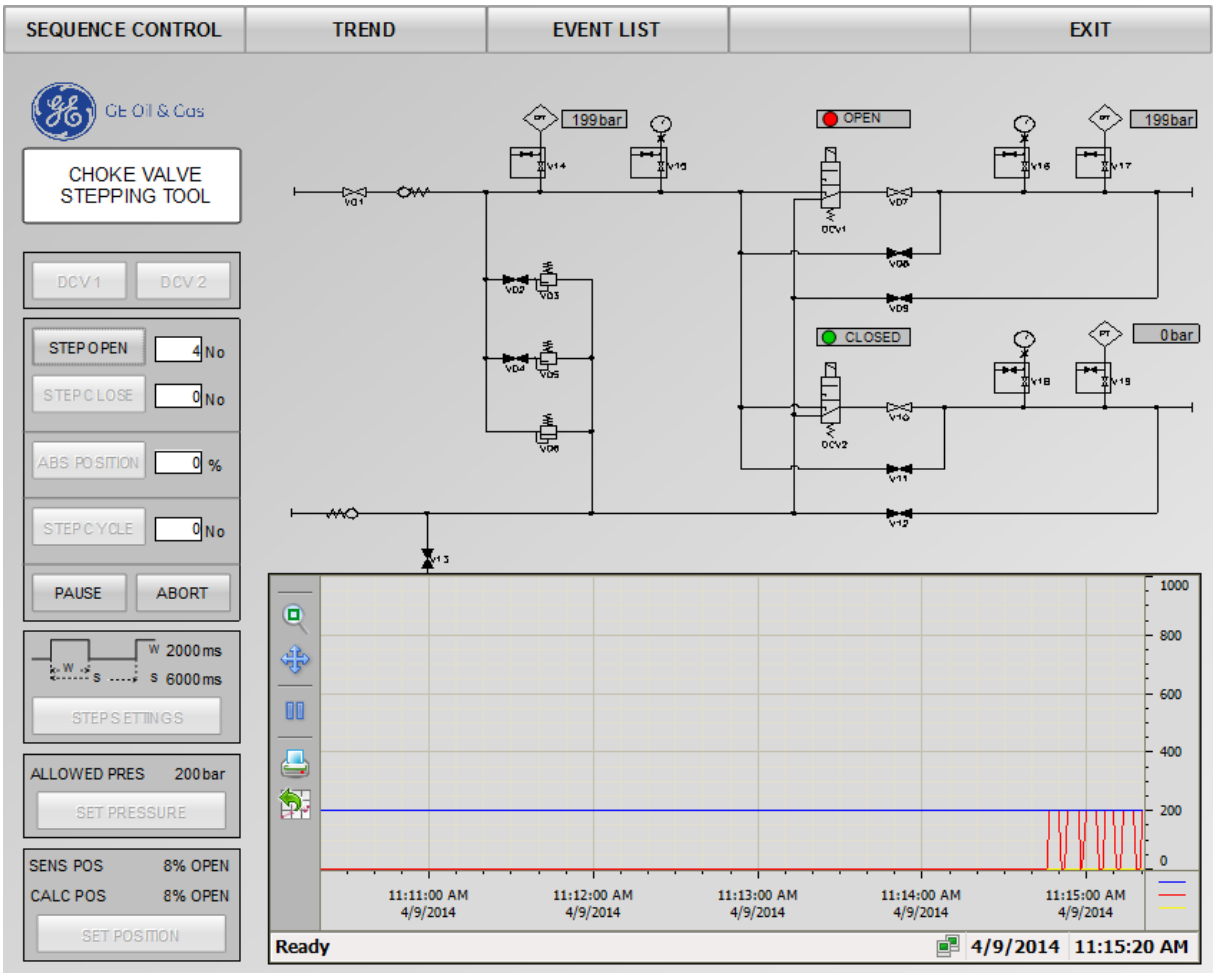
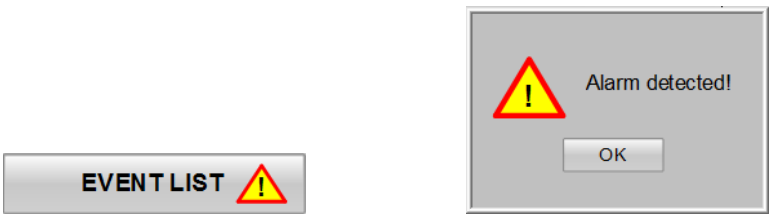


Figure 6.1: HMI layout, Step close sequence

As shown in figure 6.1, an interlock function is added when a step sequence is activated. This prevents the operator from starting a new sequence until the first one is completed and to alter any of the step settings. Any time during a sequence, the PAUSE or ABORT button can be pressed. The pause function temporarily stops the sequence and by pressing the same button once more, the stepping is resumed. If the step sequence is paused, the interlock on the settings is removed. By pressing the ABORT button, the sequence is terminated and input data regarding number of steps, desired position or number of cycles reset to zero. An emergency button is mounted on the trolley and if operated it will give the same response as by pressing the ABORT button. An alarm will then be given to the operator, as shown in figure 6.2b. It will not be possible to start any new sequence as long as the emergency button is pressed.

To alert the operator that an alarm is detected, is a warning symbol on the EVENT LIST button, figure 6.2a, and a pop up window as shown in figure 6.2b displayed when an alarm is present. To prevent the; Alarm detected window from popping up every time a new alarm is present, and to cause unnecessary stress for the operator, the code is written in such a way that the operator must go to the EVENT LIST window and see the current alarms before the window in figure 6.2b can be shown again. The different alarm codes are discussed on page 30.



(a) Alarm present (b) Alarm detected

Figure 6.2: Alarm

In addition to the alarms an additional safety feature is added to prevent the operator from starting a sequence when the supply pressure is above the allowed limit. As mentioned in section 4.5, the CVWT is designed in such a way that it should be able to operate on three different pressure levels. This is done by opening and closing the needle valves in front of the pressure relief valves. If someone accidentally forgets to open the correct valve and the pressure goes above the allowed limit plus deviation, shown in figure 6.3, an alarm will go off. The current sequence is stopped and it will not be possible to start any new sequence before the pressure is either lowered or the limit is changed. An alarm is also shown if the pressure goes below the allowed limit minus deviation.

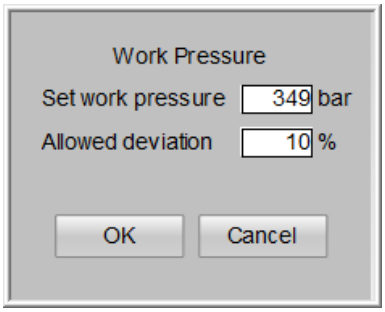


Figure 6.3: Dialog window, pressure settings

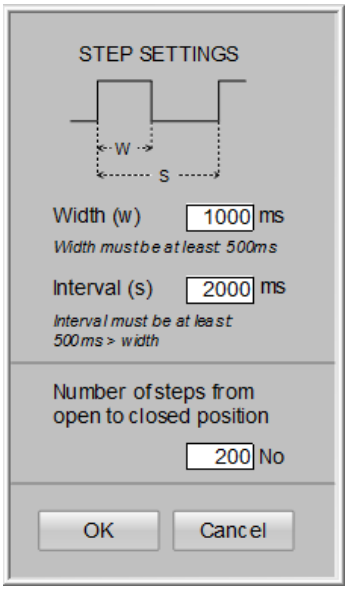


Figure 6.4: Step settings

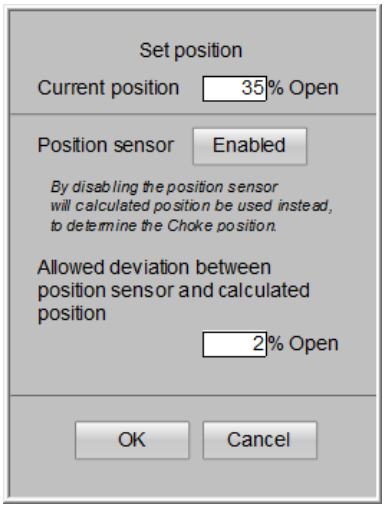


Figure 6.5: Position settings

In the step settings window, shown in figure 6.4, is the operator given the opportunity to change the width and the interval length of the step along, with the number of step required to go from open to closed position or vice versa. In the Position settings window, figure 6.5, can the current position of the choke be entered; this position is used when calculating the position. If for some reason the position sensor should not be used, or the choke valve being tested is not equipped with a position sensor, this sensor can be disabled. Then the calculated position will be used instead to determine the current position of the choke. An alarm will be given

to the operator if the position sensor is enabled and the deviation between the calculated and the measured position is higher than allowed.

In the trend window the default settings is set to show the previous fifteen minutes, this time range can be adjusted to be as high as 14 days or as low as a few seconds. It is also possible to zoom in on areas and to pause the trend graph from updating. Which trends to display is chosen with the dialog box shown in 6.6. Trends can be exported to a Comma Separated Value (CSV) - file with the dialog box shown in figure 6.7 or printed directly as shown in the trend window.

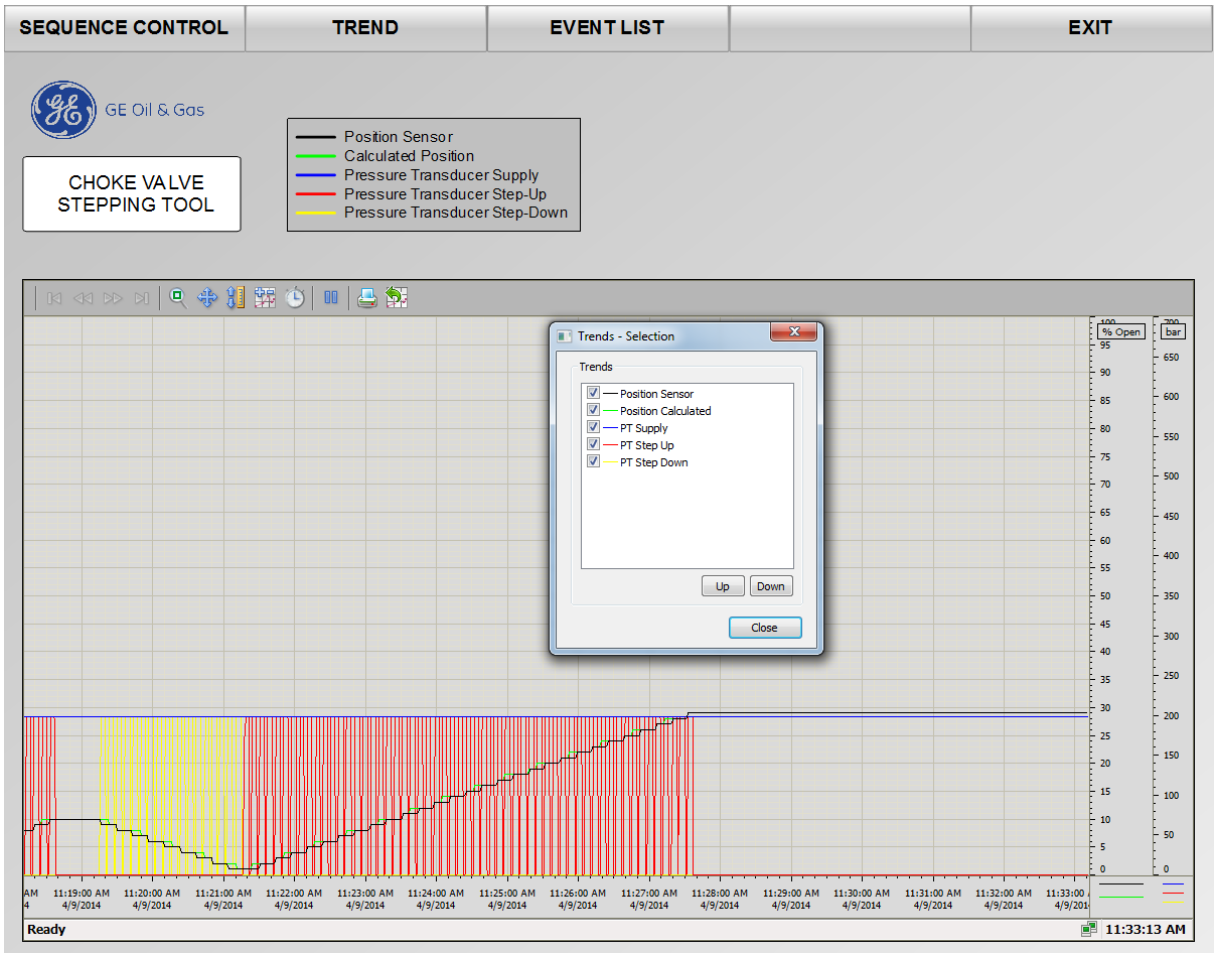


Figure 6.6: HMI layout, Trend window with Trend selection window opened

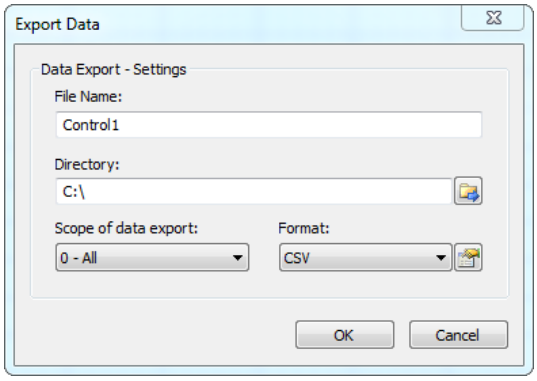
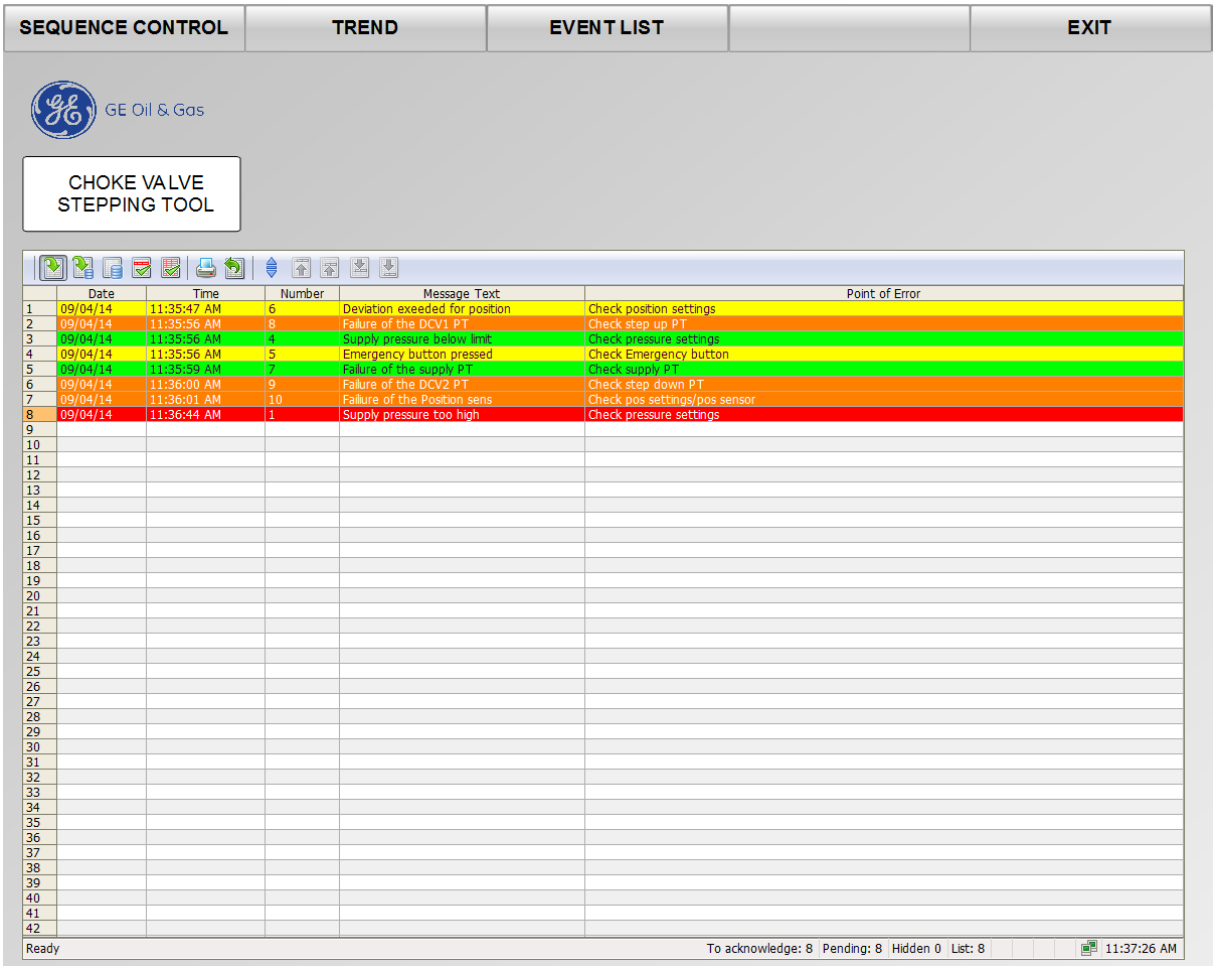


Figure 6.7: Export data

In the event window the alarms and warnings are shown. Depending on whether it is an alarm, warning or failure, and also whether it is still present or not, the background color of the message will change. Table 6.1 shows the color code and their corresponding category. Table 6.2 shows the different events that are being monitored and to which category they belong to.



	Date	Time	Number	Message Text	Point of Error
1	09/04/14	11:35:47 AM	6	Deviation exeeded for position	Check position settings
2	09/04/14	11:35:56 AM	8	Failure of the DCV1 PT	Check step up PT
3	09/04/14	11:35:56 AM	4	Supply pressure below limit	Check pressure settings
4	09/04/14	11:35:56 AM	5	Emergency button pressed	Check Emergency button
5	09/04/14	11:35:59 AM	7	Failure of the supply PT	Check supply PT
6	09/04/14	11:36:00 AM	9	Failure of the DCV2 PT	Check step down PT
7	09/04/14	11:36:01 AM	10	Failure of the Position sens	Check pos settings/pos sensor
8	09/04/14	11:36:44 AM	1	Supply pressure too high	Check pressure settings
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Figure 6.8: HMI layout, Event list

The operator is presented with a short description of the error; message text, and also a description of where the fault has been detected; point of error. The 1000 last events are logged. In the same way as the trend graphs could the event history also be exported, either by use of a CSV file or printed out. The time frame can be altered to a specific period if desired.

Table 6.1: Event type

Alarm	Failure	Warning
Came in	Came in	Came in
Went out	Went out	Went out
Acknowledged	Acknowledged	Acknowledged

Table 6.2: Operator messages

Alarm	
Message text	Point of error
Supply pressure to high	Check pressure settings
High pressure detected at DCV1	Check DCV1 and/or PT at DCV1
High pressure detected at DCV2	Check DCV1 and/or PT at DCV2
Failure	
Message text	Point of error
Failure of supply PT	Check supply PT
Failure of the DCV1 PT	Check step up PT
Failure of the DCV2 PT	Check step down PT
Failure of the position sensor	Check pos settings/pos sensor
Warning	
Message text	Point of error
Supply pressure below limit	Check pressure settings
Emergency button pressed	Check Emergency button
Deviation exceeded for position	Check pressure settings

6.3 Programmable Logical Controller

Due to lack of time, GE decided to not acquire the PLC at the present time. The procurement of parts for assembling the trolley would be done as a whole to reduce cost and save time. A PLC-simulator was therefor used instead for functional testing. Simatic S7-PLCSIM allows simulations to be carried out in the same manner as with a real controller. This meant that a HIL setup no longer was possible, alternative ways to perform the test without a physical PLC were evaluated. The chosen solution was; Virtual Machine (VM) from ITI SimulationX, in a SIL setup. This user package combines all aspects of the interaction between PLCSIM and a virtual plant model, and enables testing in real time [17]. This topic is discussed further in section 6.4.

The PLCSIM have the opportunity to simulate the communication via Multi Point Interface (MPI), PROFIBUS DP and Transmission Control Protocol/Internet Protocol (TCP/IP), the VM on the other hand requires that the MPI communication is being used. This communications method require that all the process tags used by the HMI and SimulationX, not directly connected to the input/output must be, assigned in data blocks (DB) instead of tag tables. Since the PLC, described in the CVWT specification, does not have MPI connections were the PLC used for simulation changed, from IM151-8 PN/DP to 314C-2DP, the two PLC‘s have approximately the same CPU power.

Tag acquisition between the PLC and WinCC is typically performed every 250-500-1000 ms, this means that the amount of information going to/from the PLC is very high every second, since all the tags must be transferred at the same time. To reduce this load on the communication were a hysteresis function in WinCC used, giving the tags a small offset between each other. This scattered the load and reduced the cycle time.

In addition to the information being sent and received from the HMI, is the communication with the SimulationX also affecting the cycle time. After every scan cycle of the PLC, the collected data will be exchanged between the simulators. Process-Image input is read from SimulationX and the Process-Image output is written to SimulationX, as illustrated in figure 6.9 [18].

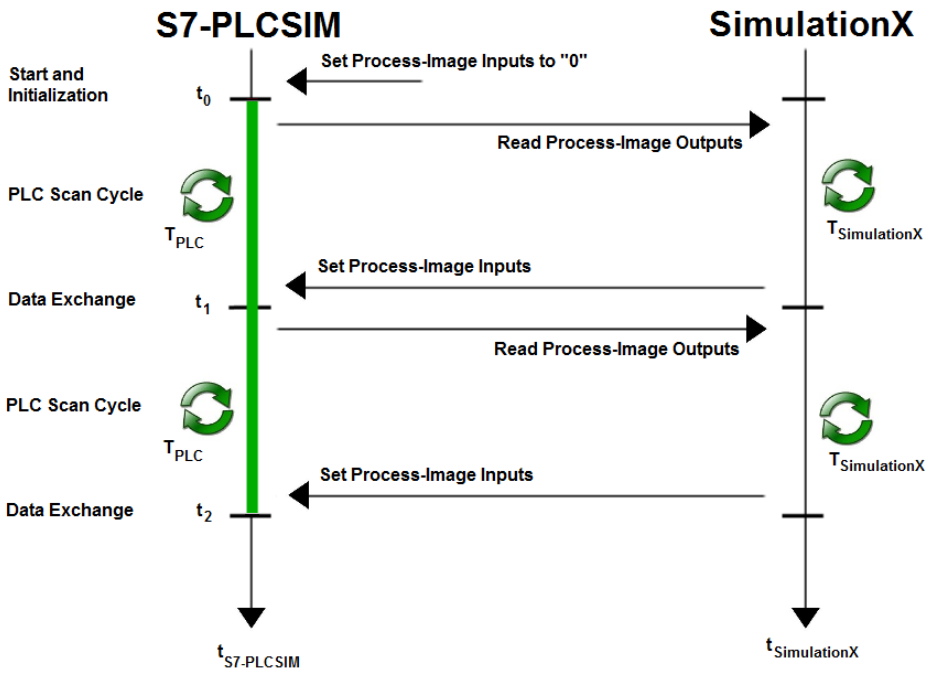


Figure 6.9: Data exchange between PLCSIM and SimulationX [18]

PLC code and Work Breakdown Structure (WBS) can be seen in appendix C. Function blocks have been used when found suitable, particularly when the program code can be reused. The program code does not contain any closed control loop. All of the code is therefore placed in OB1 since there is no need for a fixed cycle time. Requirements for the cycle time is reduced to the desired accuracy in the system. No clear target have been set for the accuracy but with a typical step cycle of 2 seconds hold and 4 seconds release, is the accuracy better than 2.2%, and likely to be in the range of 0.5%. Figure 6.10 shows the cycle times of the PLCSIM.

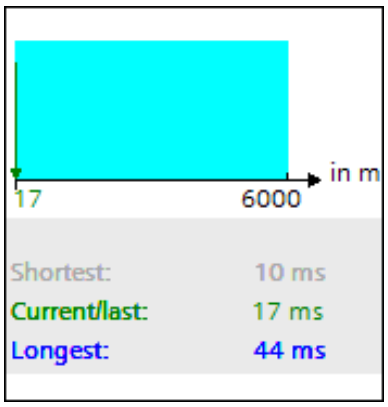


Figure 6.10: Cycle time of the PLCSIM

6.4 SIL

Since no physical PLC was available for HIL testing, an alternative with a SIL setup was used instead. Both of these methods have in common that they use, preferably a physically correct simulation model which is linked to the program code. Replacing a physical installation by a VM or plant has several advantages, such as;

- Early detection of bugs and design flaws in the control software
- Reduced cost. No need for equipment, resources or a set-up area
- Controller design can be started early, in parallel with mechanical/hydraulic design
- Little effort for constructional changes
- Prevention of real hardware losses through software errors or performing critical operations
- Likely and unlikely scenarios can be simulated. (e.g. sensor failure and redundancy)

In this project, SIL have been used for verifying the program code in both the TIA-portal (used to program the PLC) and the WinCC (used to program the HMI). There was some uncertainty whether WinCC could be included in the SIL setup, but tests showed that as long as the virtual MPI connection was being used, WinCC could be included.

All software has been installed on the same computer in a 32 bit version of Windows 7, Professional. Figure 6.11 shows the SIL setup and how the virtual communication works. Figure 6.12 shows the SIL setup during a test. As mentioned in section 6.3 the process values between SimulationX and PLCSIM is updated every time the PLC cycle finish. Update between the PLCSIM and WinCC is tag dependent, typically every 250ms, 500ms and 1000ms.

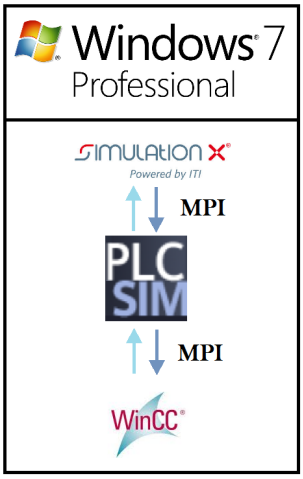


Figure 6.11: SIL setup

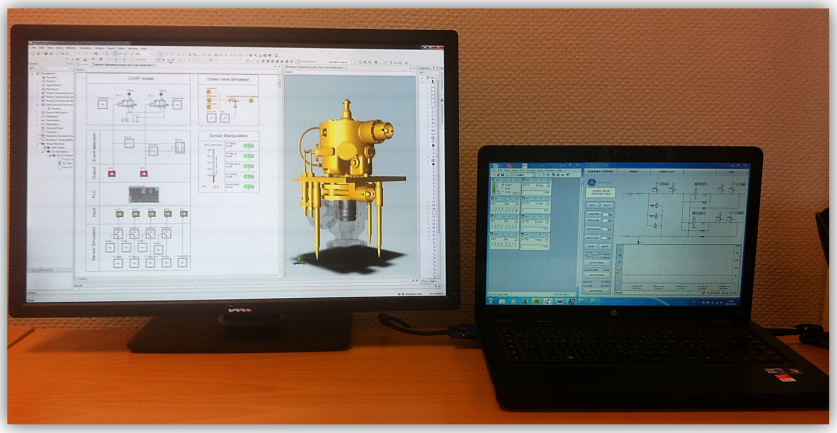


Figure 6.12: SIL setup during a test

One advantage when running the SIL setup with SimulationX, is that there are no restrictions regarding the solver. However, since this is a real time setup, as discussed in section 5.4, is it important that SimulationX manage to perform all the calculations within the time step of the solver to prevent the model from crashing. The Backward Differential Formula (BDF) solver were used. This solver is well suited for stiff systems and have good stability properties which allow larger steps to be possible compared with explicit methods [19]. In compliance with the general rule, that states that the real time targets should have a cycle time with a ratio of 10 or more, were the solver allowed to use time steps up to 1ms, equation 6.1.

As mentioned earlier, should the dynamic model be as simple as possible in its mathematical description, but still be able to simulate the dynamic behavior of the model, with sufficient account taken to all of the controlled variables [20]. Since a fixed time step solver no longer had to be used, were an attempt to use the

complete model as shown in figure 5.2 performed. It became too complex and caused SimulationX to crash. The simplified model were therefore used instead to represent the open/close directions of the choke valve, figure 6.13 The model shown in figure 6.13 is connected to the PLC-Image outputs, figure 6.14

$$R = \frac{PLC_C}{RT_C} \tag{6.1}$$

Where:

- R=Ratio
- PLC_C=Cycle time of the Programmable Logical Controller
- RT_C=Cycle time of the Real-Time target

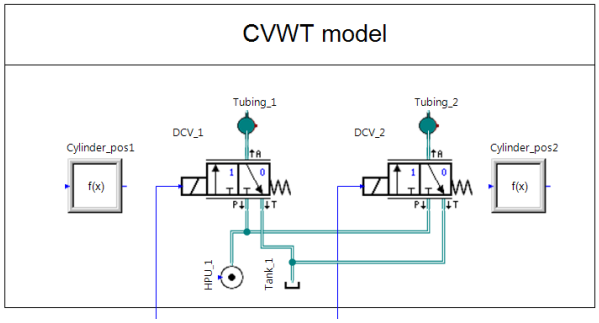


Figure 6.13: Simplified model used in SIL testing

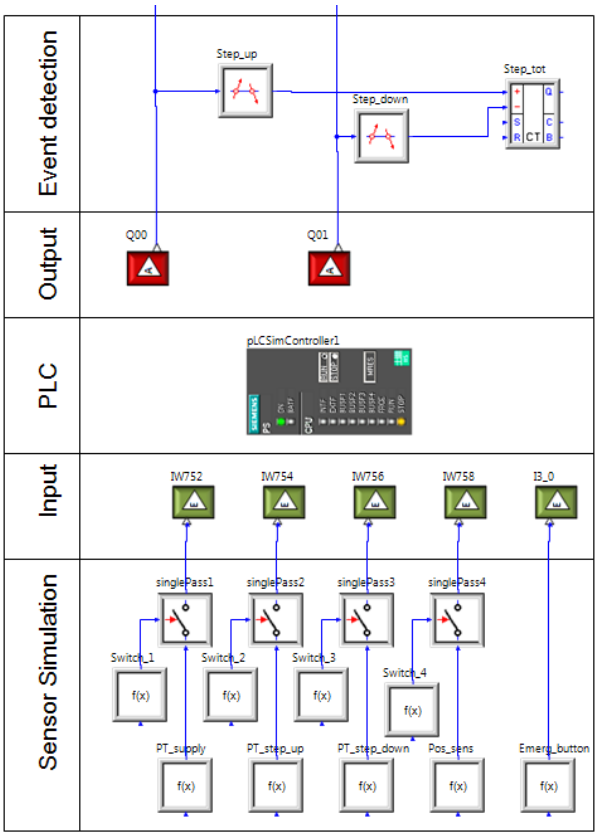


Figure 6.14: PLCSIM interface

On a physical PLC, the analog signal of 4-20mA from the sensors will be converted into a signed Word consisting of 16 bits. A signed 16 bit Word have a process value range of $2^{15} = 32767$. This is the maximum process value from the sensor. The last bit is used to decide whether the value is positive or negative. The process value is typically divided over a sensor range of 0-21mA, valid range for the sensor is therefore as shown in figure 6.15.

All the sensors with exception of the emergency stop are represented as mathematical functions based on the results from the dynamic model, equation 6.2. When converted back from a sensor value to a process value is equation 6.3 used. To simulate sensor failure have switches been connected to the sensors. The outputs from the PLC-Image have been wired to a counter for calculating the choke position as shown in figure 6.14.

$$S_V = \frac{P_V \cdot (S_{Rmax} - S_{Rmin})}{P_R} + S_R min \tag{6.2}$$

$$P_V = \frac{P_R \cdot (S_V - S_{Rmin})}{S_{Rmax} - S_{Rmin}} \tag{6.3}$$

Where:

- S_V=Sensor value
- P_V=Process value
- P_R=Process range
- S_{Rmax}=Sensor value at 20mA
- S_{Rmin}=Sensor value at 4mA

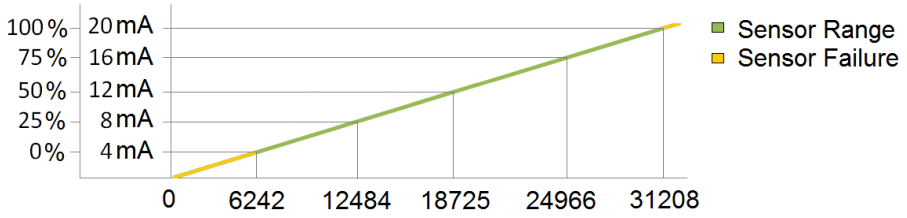


Figure 6.15: Sensor Range

The panel shown in figure 6.16 has been used for simulating sensor failures and changes the pressure in the system.

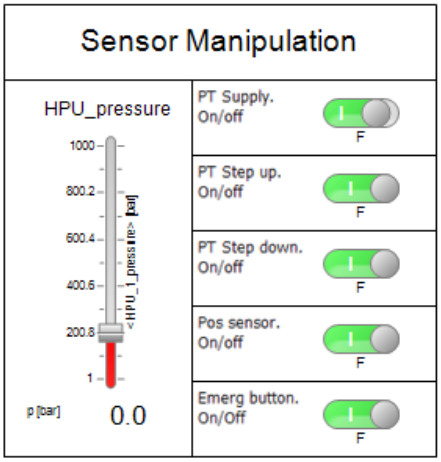
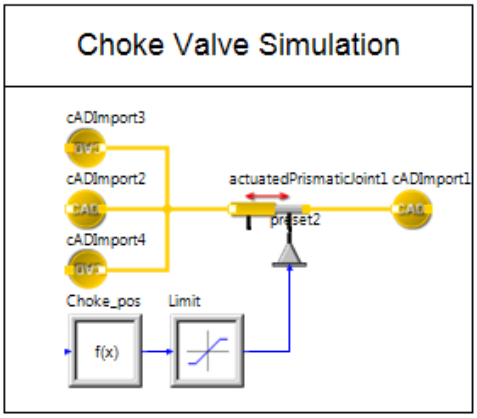
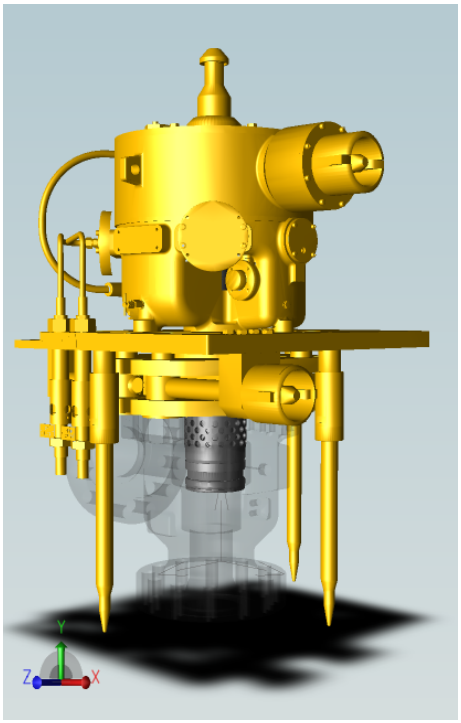


Figure 6.16: Sensor manipulation

Based on a Computer Aided Design (CAD) - model, a dynamic 3D model was created to simulate the stem position relative to the choke body. Figure 6.17a shows how the simplified dynamic model has been developed. A prismatic joint is connected to a preset, which creates a linear motion to the stem. Choke positions is as previous mentioned, calculated based on number of steps. Figure 6.17b shows a 3D model of the choke body and the stem.



(a) SimulationX code



(b) Dynamic Choke Valve

Figure 6.17: Dynamic 3D model

Using a SIL setup to perform this type of test proved to be a good alternative. The setup time is low, and changes in the dynamic model is easily carried out. Alarms and warnings were easily simulated by manipulating the sensor in SimulationX, and the communication between the different softwares worked as predicted.

6.5 SIL vs HIL

There are many different ways to perform both a SIL and HIL test. In this section a comparison of the SIL setup described in section 6.4, and a HIL setup, which is the method currently used and taught at University of Agder is performed. The HIL setup requires that you first develop and test the dynamic model in for instance SimulationX, then export it as a DLL file before it is imported in LabVIEW. The computer with the dynamic model is now used only to run the Real-Time-target. Another computer is used to monitor and control the process values, figure 6.18. Both of the computers are connected to the PLC via TCP/IP.

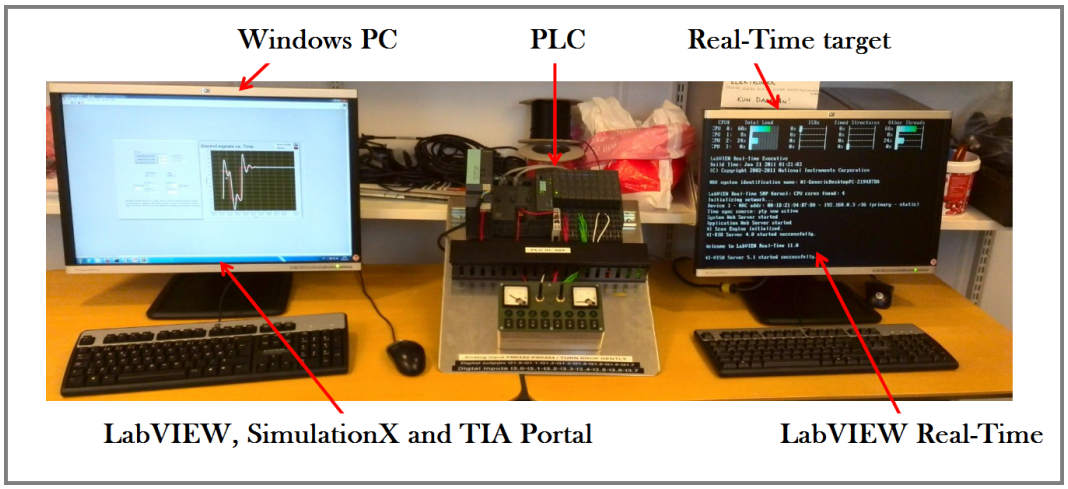


Figure 6.18: HIL setup beeing used at UIA [21]

In many ways, the mentioned SIL and HIL setups are similar. Both use a mathematical dynamic model suitable for testing in real time. The main advantage with a SIL setup is the level of complexity, and derby also the setup time. Compared to the SIL setup, were everything can be monitored and run on the same computer, the HIL setup, with two computers and a PLC is a time consuming and more advanced setup.

Other disadvantages with the HIL is that, if a change in the dynamic model is done, a new DLL file have to be created and transferred into the Real-Time target. Also the restriction of having to use a fixed time step solver could be a drawback, especially when working with stiff models with high derivatives.

The user interface for LabVIEW, does not give any clear message to the user whether or not it actually manage to perform the calculations within the time step. In worst case, if the model does not crash, the user may be given what seems to be just some random numbers. These numbers are actually the results from the calculations at the point when LabVIEW runs out of time. This is not a big problem as long as the user is aware of it and the values are far from what is expected. Compared to SimulationX, are the user given a warning and/or error message.

The advantages of using HIL are among other, that a more realistic time response in the communication between the PLC and Real-Time target can be achieved. Despite that the PLC simulator should have the same CPU power as the physical PLC, is it difficult to determine. This is typically parameters that can be both hard to measure and also to determine whether or not they have any influence on the results.

Another important issue is that there are nothing in the Application Programming Interface (API) to PLC-sim, which allows SimulationX to exchange time or to draw a baseline for the timing of the co-simulation. S7-PLCSIM performs consecutively single scans during cosimulation. This influence the timers in the PLC and correct timing can therefore not be ensured. An article from 2011 [22] states that this is because SimulationX is running in simulation time whereas the PLCsim is running in Real-Time. Therefor is the synchronization of time required, so that the PLC‘s timers are synchronized at the beginning of each PLC cycle. Hence the progression of timers is no longer related to real time but depend only on the simulation time [22]. The theory was confirmed by experimenting with the cycle time for exchanging data between the PLCsim and SimulationX.

With a update time of 10ms a delay of approximately 6 s/min was detected on the timers in the PLC, compared to the simulated time. When this was adjusted to 100 ms the delay was reduced to only 2 s/min. This is not an issue for the program code in this case, but is absolutely an item to be taken into consideration when evaluating which setup to use. A walk around could be to slow down the synchronization. If using a scale factor on the simulation time, it would be possible to decelerate SimulationX. Result being that the delay is eliminated.

SIL testing can not replace HIL testing completely, and none of them can never replace a final Factory Acceptance Test (FAT). But should rather be viewed as a valuable addition to the development process, a tool to reduce time and cost and to improve quality and accuracy. SIL should be considered as a valuable addition during the design and development of the program code. There are some limitations for what you can achieve in a SIL setup, but this can still be found to be adequate in many cases. It is fast and easy to set up, modifications to the code or model can be done quickly, and the need for expensive software is reduced. HIL is suitable to get more realistic results regarding the time response in the communication, compiler and processor of the PC.

Chapter 7

Conclusion and further work

The main objective of the project was to design a workshop tool that automates the testing procedures of Choke Valves. As a result, a Unit Functional Design Specification was created. This document is developed according to GE regulations and with focus on costs and quality, appendix A. This document describes in detail the chosen solutions for the CVWT and is written in a way so that it can be used in a procurement phase of the tool. The document describes everything from tubing size, which software to use, throughout to the mechanical details such as placement of forklift pockets. Due to the time frame, the procurement of parts and assembling of the CVWT were not carried out. Sketches of a suggestion for the final layout of the tool along with electrical and hydraulic schematic can be sen in appendix B. Program code for the PLC and HMI has been developed and thoroughly tested in a SIL setup.

A complete model of how the CVWT would behave when it is connected to the Choke Valve is developed. The model became too complex to be run in real time, regardless of the solver being used, so the model was simplified. The system response was almost identical and found to be sufficient, since the main goal with the model was to use it for testing the control system and the HMI.

The HMI is PC based with point and click commands and based on a existing tool in the workshop, used for testing valves, which ensures that the technicians find the screens user friendly and intuitive. All information is presented in English. Trend graphs show the history of pressure being supplied to the choke along with its position. Data is logged and can be exported either as CSV file or printed directly as displayed in the HMI.

One sub objective stated that; a HIL test shall be used for testing the control system and the HMI. Since no PLC was available to perform the HIL test, a SIL test was performed instead. The model was run in SimulationX and through a virtual interface where the communication established to the PLCsim and WinCC. This setup was used to verify that both the program code in the PLC and HMI worked as predicted. Alarms and warnings were simulated by manipulating sensor values in SimulationX. Using a SIL setup to perform this type of tests proved to be a good alternative, the setup time is reduce and so is the need for expensive software. SIL-based testing can not replace the HIL test completely, but should be viewed as a valuable addition, especially to the development process of a control system. The main differences found is that the SIL is less complex, but the synchronization of time in SimulationX and PLCSIM causes the timers in the PLC to lag behind.

A further study evaluating how accurate the dynamic model is compared to the physical setup would be very interesting. Also to benchmark the SIL and the HIL setup, for instance in a closed control loop could possibly reveal other differences than described in this report. Due to time limitations this has not been a part of this project.

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Appendices

Appendix A

Choke Valve Workshop Toll - Unit Functional Design Specifications

Procedure : XXXXXX
Revision : NC
Rev Date :27/05/2014

CHOKE VALVE
WORKSHOP TOOL
Specifications

Rev	Date	Description	Complied By	Approved By
NC	06.03.2014	Choke Valve Workshop Tool	B.A.Lia	

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1. INTRODUCTION

1.1 SCOPE

This document describes the functional requirements for the Choke Valve Workshop Tool (hereafter referred to as the CVWT). The tool is to be used when testing Choke Valves with Hydraulic Stepping Actuators.

1.2 PURPOSE

The purpose of this document is to describe the design requirements for the CVWT. This document specifies the design basis, functional requirements, testing requirements and documentation requirements for the CVWT.

1.3 DESCRIPTION

The CVWT main function is to operate the Hydraulic Stepping Actuator automatically by providing controlled pressure pulses. Electrical and hydraulic equipment will have interface which allow the test equipment to be connected and used on a wide range of choke valves. Test results are to be stored.

1.4 ABBREVIATIONS

- AI Analogue Input
- BOM Bill Of Material
- CVWT Choke Valve Workshop Tool
- DCV Directional Control valve
- DI Digital input
- DO Digital Output
- HMI Human Machine Interface
- LVDT Linear variable Differential Transformer
- OPC Object Linking and Embedding for Process Control
- PLC Programmable Logical Controller
- PN Part Number
- RMS Rotary Magnetic Sensor
- ROV Remote Operated Vehicle
- SN Serial Number
- WBS Work Breakdown Structure

1.5 STANDARDS

• ASTM A.269	General Service Stainless Steel Tubing
• 97/23/EC	Pressure Equipment Directive
• 2006/42/EC	Directive on machinery
• SAE AS 4059	Cleanliness Requirements for Parts Used in Hydraulic Systems

1.6 GE DOCUMENTS

• QP 444	Preparation of Functional Design Specifications
• BIQ-20000-00-300 Rev D	System Software Requirements Specification
• S39600-004-00-311	HCV - Subsea Hydraulic Choke Valve Application Datasheet
• N142665-100	ABB WORKSTATION FUNCTIONAL DESIGN REQUIREMENTS
• COP 2003 equipment.	Safety in the design and use of hydraulic
• COP 2019	Selection of Preferred Components
• COP 2021 regulations	Compliance with pressure systems safety 2000 No.128
• COP 2005	Cleanliness Requirements for hydraulic Circuits
• ENGVGC 1.01	Prof testing of hydraulic equipment

2. FUNCTIONAL REQUIREMENTS

2.1 GENERAL

The Choke is operated through a Hydraulic Stepping Actuator. The Actuator has two cylinders, one for opening and one for closing. Pressure of 5,000psi is supplied to the respective cylinder in controlled hydraulic pulses to provide stepping actuation of the choke stem. The length of the pressure pulses and the number of step required for opening/closing the valve are determined by choke type, these parameters must therefore be adjustable. Typically the Stepping Actuators requires 2.0 second pressure pulse followed by 4.0 second vent, which makes one step. Depending on the Choke Valve type, the number of steps required for opening and closing the valve will vary, typically it will be in the range of 100-200 steps. Stem position is measured with LVDT (Linear Variable Differential Transformer) or RMS (Rotary Magnetic Sensor). Supply is 24v DC and output is 4-20mA. Choke valves are also equipped with a visual indicator intended as a backup solution. Manual over-ride shaft is also provided on actuator for ROV over-ride operation.

2.2 BASIS OF DESIGN

An industrial standard certified laptop is to be used as an engineering workstation. This laptop shall provide both engineering tool and operator (HMI) software. The PLC shall monitor pressure transducers and positions sensors and through a HMI allow the operator to control DCV and give feedback on system parameters. All of the equipment is to be mounted into a mobile trolley.

3. FUNCTIONS

Figure 1 shows the function structure for the workshop tool. The tool can be divided into three main functions.

- Engineering workstation
  - Controller (PLC)
  - Human Machine Interface (HMI)
- Hydraulic system (DCV, pressure sensors, gauge etc.)
- Mechanical design (Trolley)

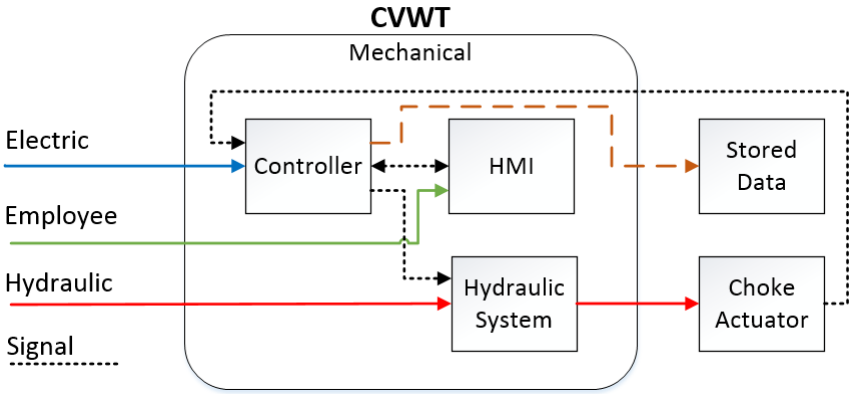


Figure 1 Function Structure

3.1 TOPOLOGY

Various activities and permissions will be determined by the access level to the logged-on user. Four types of user levels are defined. This determines the level of control and security for which the system should handle.

The operator is allowed to read process information and write control parameters from/to the controller. Only authorized personnel will be given rights to change the program code.

The engineering workstation shall be suitable for installing and running an OPC-client, allowing thin clients to be given read access if it is found necessary in the future. Figure 2 shows the system topology, whit the different levels.

- Thin Client
- Operator level
- Control level
- Field level

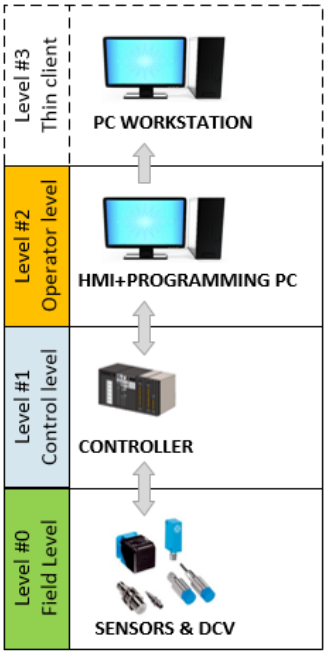


Figure 2 Topology

3.2 CONTROLLER FUNCTION

Based on operator commands can the controller regulate the hydraulic pulses being sent to the Choke Valve. Minor calculations must be performed by the controller, such as choke valve position based on number of hydraulic pulses. The PLC must monitor and convert the 4-20mA signals from the two pressure transducers and the position sensor. If the emergency button is pressed, no signal shall be sent to the DCV before the emergency button is reset.
Table 1 shows the components that are to be connected to the PLC.

Table 1 CVWT – Sensor/DCV

Description - Sensors	**Interface**	**Type**
Production Choke Position Indicator	4-20mA	0-100%
High Pressure Transmitter - Open	4-20mA	0-1000 bar
High Pressure Transmitter -Close	4-20mA	0-1000 bar
High Pressure Transmitter - Supply	4-20mA	0-1000 bar
Emergency stop		NC
Description - DCV	**Interface**	**Type**
Directional Control Valves 3/2 NC	24 VDC	NO
Directional Control Valves 3/2 NC	24 VDC	NO

In appendix B are a schematic layout of the electrically components.

3.3 HMI FUNCTION

The operator can select to operate the choke in several ways; either move the choke a number of steps, move to an absolute position or just open/close the valve. At any given time will the operator have the opportunity to end the stepping by pressing a stop button on the HMI. User interface shall be intuitive and easy to use.

Before operating the CVWT the operator must be able to set the working pressure for the test and/or the relevant Choke valve size. Information such as PN, SN Date and WBS shall be registered before a test is carried out.

Whenever a choke is operated, the HMI shall display the position that the PLC calculates the choke to be in along with the measured position. Trend graphs shall be applied where applicable. The parameters for calculating the valve position must be made possible to alter since this is a valve dependent parameter. When position sensor is in end positions (4 and 20mA) shall a maximum of three additional step pulses be performed before the stepping stop as a safety percussion.

Clicking on a configure button on the Choke Operate Display, shall display the choke configure window from which it shall be possible to provide a minimum of these options, but not limited to:

Set Configuration Parameters for the Choke such as:

- Actual position. (Start position)
- Pulse Width (hydraulic pulse time, 1-10 sec.)
- Pulse Period (time between each step)
- Number of step (1-500) One step = One ON Pulse + One OFF Pulse
- Number of Cycles (1-1000) One cycle = OPEN–CLOSE–OPEN
- Max allowed difference between Calculated Position and Sensor Position (Default value of 10%)
- Select the size of the increment which is applied to the choke position when the +/- buttons are pressed
- Modify parameters for calculating the position

The HMI shall be able to manage alarms and events such as:

- Wrong pressure detected (Low/High)
- Lack of pressure after operating DCV (No stepping)
- Sensor failure
- Emergency stop

3.3.1 History Logging

A historical log shall be provided on the Engineering workstation of test and sensors data for a period of min. 14 days. The HMI shall provide the facility to display the event log on the screen and to save the information to a DVDRW drive or USB-stick. Data shall be stored as a .CSV file so that it may be displayed later in Excel and graphically trended. Table 2 shows the actions that shall be recorded.

Table 2 Action History

Action	Recording Frequency
Choke Step Open Command	On Event
Choke Step Close Command	On Event
Choke Move To position Command	On Event
Choke Sensor Position	On Change
Choke Calculated Position	On Change
Emergency stop button	On Change
Pressure transducer - Close	On Change
Pressure transducer – Open	On Change

The engineering workstation shall also include the ability to exchange process information through software clients like OPC if found necessary in the future.

3.4 HYDRAULIC FUNCTION

This section should be read in conjunction with appendix B, hydraulic schematic. On signal from the PLC shall the mono stable 3/2 way DCV valves open and close. This will result in stepping of the Choke Valve. Three pressure relief valves are mounted so the hydraulic system can be used for different pressure levels. Pressure transducers and gauges are mounted on the open, close and supply line. Manually operated valves are mounted to be able to isolating the pressure lines and for flushing the system. In and out going hydraulic connections are to be bulkhead mounted on the trolley.

3.5 MECHANICAL FUNCTION

The main frame should be a mobile trolley, suitable for industrial use. When the CVWT is not being used, all of the hydraulic and electrical equipment must fit within the main frame of the trolley. Appendix B shows a suggestion for the layout of the trolley.

4. INTERFACE REQUIREMENTS

4.1 MECHANICAL

If weight exceeds 25 kg, it must be prepared for handling with forklift and/or lifting lugs. Necessary lifting lugs/points must be design at the same time as the tool.

4.2 HYDRAULIC

- 1 - HP supply
- 2 - HP Control outputs
- 1 - Return line

4.3 ELECTRICAL

CVWT shall provide the ability to connect to electrical power in both 220 volts and 110 volts power grid. Connectivity towards the LVDT sensor on the Choke Valve.

5. ENVIRONMENTAL CONSTRAINTS

The CVWT shall be designed to accommodate the following

5.1 OPERATORS

The CVWT are to be used mainly by technicians in the workshop. Number of working hours for the tool is estimated to be 14 hour/month.

5.2 DESIGN LIFE

CVWT shall be designed for a service life of 25 years.

5.3 OPERATING ENVIRONMENT

Operating temperature:	5 to +40
Storage temperature:	-20 to +65
Relative humidity:	up to 80%, non-condensing
Exposure:	Dust and sprays of water

5.4 SHOCK AND VIBRATION

Since the CVWT will be subjected, at least to the shock and vibration caused by transportation and handling shall it be designed to withstand 5g at 5Hz, in all directions. Hydraulic gauges must be designed to cope with the pulsation in the system.

5.5 EARTHING

Practical all mechanical components forming the CVWT must be mechanically earthed either by earthing strap or by component to component electrical continuity connection. This shall be achieved through the component fasteners by removing protective coatings from under bolt heads and nuts and/or threads, and coating with copper slip. Continuity between electrical and mechanical components must be provided.

5.6 MATERIAL SELECTION

The design shall, wherever possible, use tried and tested components and materials, field proven in a similar capacity and environment. Non-field proven components and materials shall be identified and the basis of their qualification for use shall be stated.
All parts wetted by the system hydraulic fluids shall be made from 316 stainless steel.
All materials, including gaskets shall be compatible with the system hydraulic fluid SAE AS4059 Class 6 B-F or better.

6. DESIGN CONSTRAINTS

6.1 MECHANICAL

The trolley shall be produced in a non-corrosive material or be fully coated or painted. It is desirable but not mandatory that the trolley is produced in 45x45mm strut aluminium profiles from Bosch Rexroth. It is essential that the equipment should be safe and without health risk when used, but also safe to build and maintain. Hydraulic interface connections on the trolley shall be bulkhead mounted.

6.2 HYDRAULIC

Hydraulic supply and return lines shall be clearly identified, and include suitable bleed points to allow air or fluid to be bled from the system. Selected gauges must handle the continuous pulsation in the system. Table 3 shows the pressure levels in the system. All tubing shall be 3/8" medium pressure (minimum of 10,000 psi rated) cold drawn, seamless grade AISI 316 stainless steel, ASTM A.269. All fittings and output connectors shall be 3/8" Autoclave type MP and output connectors shall be bulkhead mounted. Another supplier may be chosen if quality and price is found to be beneficial.

Table 3 Maximum System pressure

Maximum Working Pressure	Design Pressure	Proof Test Pressure
10,000psi (690bar)	11,000psi (759 bar)	16,500psi (1138 bar)

6.2.1 Equipment

Table 4 Hydraulic BOM

Item.No	Description	Part No.	Qty
1.1	GE-DCV 10,000psi mono stable 3/2	742-4001-00	2
1.2	GE-Hydraulic Test Manifold	S91557	2
1.3	Tee 3/8"		23
1.4	Bulkhead Coupling 3/8" MP		4
1.5	Check valve 3/8" MP with crack pressure of 0.5-1 bar.		2
1.6	Needle valve 3/8" MP		10
1.7	Block and bleed needle valves 3/8" MP		6
1.8	Pressure Transducers 0-1000bar 4-20mA		3
1.9	Industrial Gauge 0-1000 bar ø100mm		3
1.10	Pressure Relief valve 0-600 bar		2
1.11	Pressure Relief valve 300-1200 bar		1

Table 4, Hydraulic BOM must be considered as a recommendation only. Adjustments to the BOM may be necessary, depending on the final layout. A combined Pressure transducer and Gauge may be used if found beneficial.

6.2.2 Hydraulic Cleanliness

When assembling and maintaining the CVWT, care must be taken to ensure that all non-metallic components (including sealants) used in the system are compatible with the system fluid. Deterioration of seals can lead to leakages and the contamination of system fluid, with a subsequent reduction in system performance and operating life. PTFE tape shall not be used. Avoid welding and grinding on assembled components.
The system fluid used on the CVWT shall be flushed to NAS 1638 class 6 or better. The hydraulic fluid must be the same type as used in the relevant project.
The equipment assembly shall minimise dead legs and crevices in which dirt and scale can be trapped. Flushing of the system shall be performed before use and the fluid examined to ensure that the required level of cleanliness is achieved.

6.3 ENGINEERING WORKSTATION

The engineering workstation shall consist of a Siemens industrial standard certified laptop including latest standard operator system as well as relevant components needed to interface the PLC and equipment (communication modules, routers, interconnecting cables etc.). The engineering workstation shall operate as a combined engineering tool and operator station. Both functions shall be available in separate windows, the engineering tool shall be password protected.

6.3.1 Equipment

Table 5 Electric BOM

Item.No	Description	Part No.	Qty
2.1	Adaptor North American		1
2.2	Adaptor UK		1
2.3	Adaptor European		1
2.4	Junction 3-Way IEC		1
2.5	Power Supply Unit Field PG M4		1
2.6	Simatic Field PG M4		1
2.6.1	SIMATIC STEP-7 TIA portal Professional V.12		1
2.6.2	WinCC Advanced		1
2.6.3	WinCC Advanced Runtime		1
2.6.4	WinCC Logging RunTime License		1
2.7	Load current supply, PM 190W 120/230V AC	6EP1333-4BA00	1

2.8	CPU 1511-1 PN	6ES7511-1AK00-0AB0	1
2.9	Digital output, DQ 8x24VDC/2A HF	6ES7522-1BF00-0AB0	1
2.10	Digital input DI 16x24VDC HF	6ES7521-1BH00-0AB0	1
2.11	Analog input AI 8xU/I/RTD/TC ST	6ES7531-7KF00-0AB0	1
2.12	Electrical Distribution Box >IP56		1
2.13	GE-Emergency Stop	CR104PBM01R5CA2	1
2.14	4-Pin Tronic test connector 14-28VDC 4-20mA		1

Table 5, Electric BOM must be considered as a recommendation only. Different material and/or supplier may be chosen if price or quality is found to be better elsewhere. Adjustments to the BOM may be necessary, depending on the final layout.

6.4 GENERAL ACCESS

Particular attention shall be made during design to the need for access for manufacturing and assembly. Consideration shall also be given to ensure that CVWT can be maintained and that individual components can be accessed and replaced in a safe and expedient manner.

6.5 SIZE WEIGHT AND NOISE

The following are targets for the unit

Height: < 1300 mm
Width: < 1400 mm
Depth: <800 mm
Weight: <50 kg
Noise <83dB

6.6 INSTALLATION

The CVWT shall be a free-standing unit and designed to be stable, without being fixed down or physically attached in any way. All parts shall remain inside the boundaries of main frame when it is not being used, this is to avoid any impact damage during lifting and handling.

7. CERTIFICATION REQUIREMENTS

7.1 TYPES OF CERTIFICATE

The following certification, where applicable, will be required to demonstrate that the equipment is fit for purpose:

- Certificates of Conformity for Bought Out Components
- Materials Certificates
- Pressure Test Certificates
- Valid Certificate of examination. (See code of Practice COP 2021)

7.2 CE MARKING AND SAFETY CERTIFICATE

The equipment and/or assembly fall below the limits of classification of compliance with the Pressure Equipment Directive 97/23/EC and Machinery Equipment Directive 2006/42/EC, and must be designed and manufactured in accordance with sound engineering practice. Individual components of CVWT shall bear CE marking. CE marking on CVWT is required.

8. DOCUMENTATION

Following Documents shall be provided with CVWT:

- Declaration of Conformity
- Equipment description
- Bill of Materials (BOM)
- Hydraulic Schematic
- Electrical Schematic
- CVWT detailed drawing with bill of materials
- Operation and Handling Instructions
- Document containing software and programming password, licenses etc.
- Maintenance Manual
- Datasheets
- Certificates, Section 7.1
- FAT report
- Functional Testing Verification

9. HEALTH, SAFETY & ENVIRONMENT (HSE)

9.1 GENERAL

Health and Safety are prime considerations during the design, construction, testing, transportation and use of this Equipment.

9.2 CONSTRUCTION

The equipment will be designed so that it can be lifted and moved safely. Consideration shall be given to the requirements for handling components into place manually or with the aid of lifting equipment. Where components are too heavy for manual lifting, provision shall be made for lifting aids.

9.3 TRANSPORTATION

The requirements for transportation must be considered during the design of the equipment and any special safety equipment (e.g. steadying supports to make the unit stable) must be designed at the same time as the design of the equipment.

9.4 USE

The equipment shall be designed to be safe in use and shall be laid out in a logical and ergonomic order for ease of use and safety in operation.

9.5 ENVIRONMENTAL EFFECTS

The effect that the equipment has on the environment during its manufacture, test and service shall be considered during design. Bad effects shall be identified and negated where

possible, or mitigated in a way that minimises harm to the environment. Water traps that may promote corrosion should be avoided.

10. FUNCTION AND PRESSURE TESTING

10.1 HYDROSTATIC PRESSURE TEST

The CVWT tubing is to be subject to a hydrostatic pressure test at the hydraulic system design pressure x 1.5, with those components and devices which cannot withstand being subjected to this pressure, isolated. The maximum allowable pressure drop shall be 2% of the starting pressure over duration of 30 minutes.

10.2 LEAK TEST

Carry out a 15-minute duration leak test at normal system working pressure plus 10% (design pressure) with the system complete. No visible leaks are permitted.

10.3 FUNCTIONAL TESTING

Full functional testing of the CVWT shall be performed after completion.

11. APPENDIX

11.1 APPENDIX A

11.1.1 Design & Operating Parameters of 5K Hydraulic stepping Actuator

Actuator Manufacturer	GE Vetco Gray	
Actuator Part Number	A103591-47	
Design Type	Stepping Actuator	
Maximum Output Torque	TBD	
API PSL Level	3	
API Material Class	N/A	
API Temperature Rating	-10C^{o} to 65C^{o}	
Full Stroke Definition	4 Inch	
Hydraulic Cylinders		
Number of Cylinders	2	
Volume	60 cc/Cylinder	
Pressure Rating	5,000 psi	
Type of Local Position Indicator	% Open / % Close	
Manual Override		
ROV Assist or Diver Assist	ROV Assist	
Maximum Input Torque	390 ft-lbs	(Maximum Input Torque)
	(450 ft-lbs	(Absolute Maximum Torque only to be used in breakout situations)
Direction to Open	Anti-clockwise	
ROV Torque Receptacle & Over-ride Shaft	Class IV	
Number of Turns to Open or Close the Choke	36	
Number of Steps fully Open to fully close Position	178 steps	
Water Depth Rating	8988 ft (2740m)	
Type of Volume Compensation Device	Bladder units	
RMS Position Feedback Device		
Supply	24v DC	
Output	4 – 20 mA	

11.1.2 Design and Operating Parameters of 8 INCH Subsea Choke

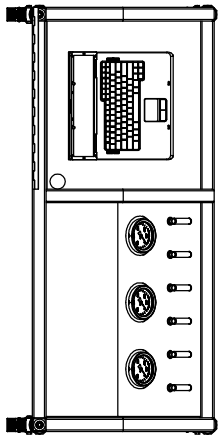
Manufacturer	GE Vetco Gray
Model number	A115062-1
Maximum Pressure Rating	7,500 psi
Maximum Orifice Size	8 inch
Temperature Rating	
Maximum	150 °C (300°F)
Minimum	-46°C (-50°F)
API PSL Level	3G
API Material Class	HH
Type of Choke	Adjustable Choke Prep. For Hydraulic Actuator.
End Connections	
Size and Pressure Rating (API)	12M 82R VG HUBS
API Ring Gasket Size	82 VG Seal
Type of Operation	ROV
ROV Torque Receptacle & Over-ride Shaft	Class IV
External Pressure Rating	4,000psi
Water Depth Rating	8988 ft (2740m)
Maximum Flow Rate	730 Cv

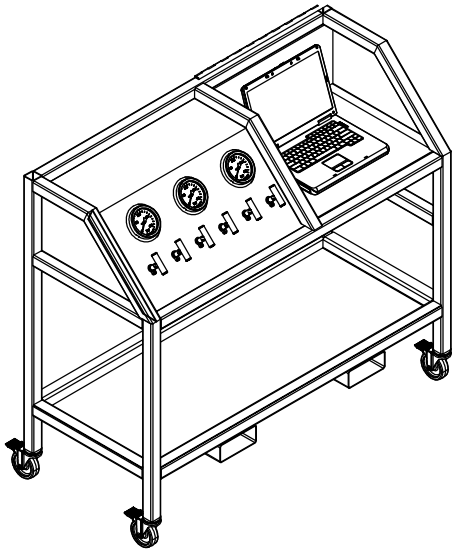
11.2 APPENDIX B

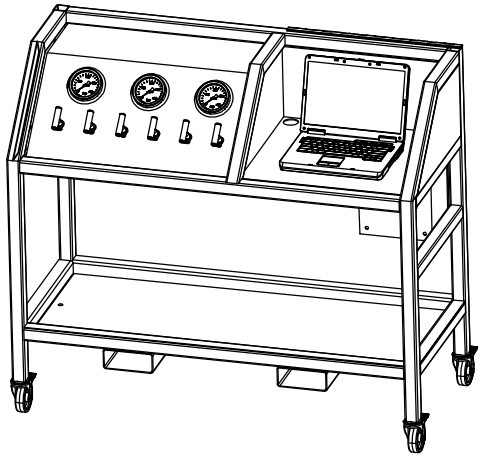
- Electric schematic
- Hydraulic schematic
- Trolley Layout

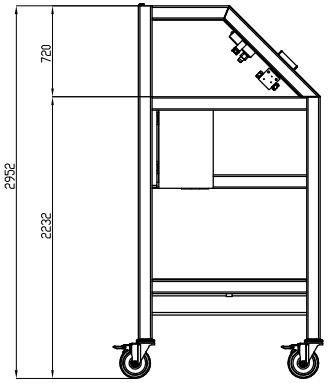
Appendix B

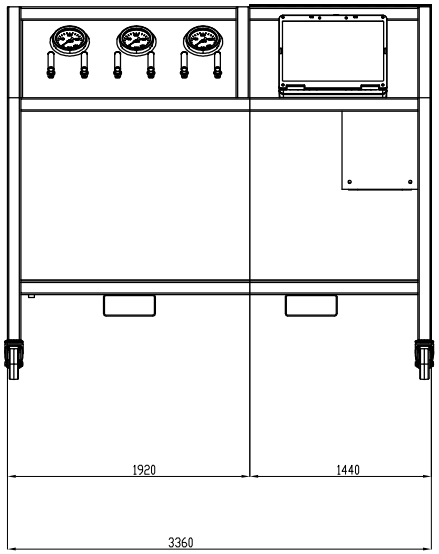
Schematics and Drawings











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THIRD ANGLE PROJECTION

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SCALE U.O.S

EST WEIGHT (kg)

DO NOT SCALE DRAWING

UNLESS OTHERWISE STATED
DIMENSIONS ARE IN MILLIMETRES
MACHINE SURFACE FINISH 1.6 Ra
TOLERANCES :-
0 ±1
0.0 ±0.3
0.00 ±0.13
ANGLES ±0.5°
FABRICATIONS ±2
INTERNAL RADS 1 MAX

CONCENTRICITY
POSITION
SYMMETRY
STRAIGHTNESS
PARALLELISM
PERPENDICULARITY
FLATNESS
CIRCULARITY

GE
Oil & Gas

Sothammergeilen 1, Dusavika, Norway

DRAWN BY BAL

DATE DRAWN 03/02/14

DRAWING TITLE CHOKE VALVE WORKSHOP TOOL TROLLEY LAYOUT

DRAWING No. XXXXXXXX

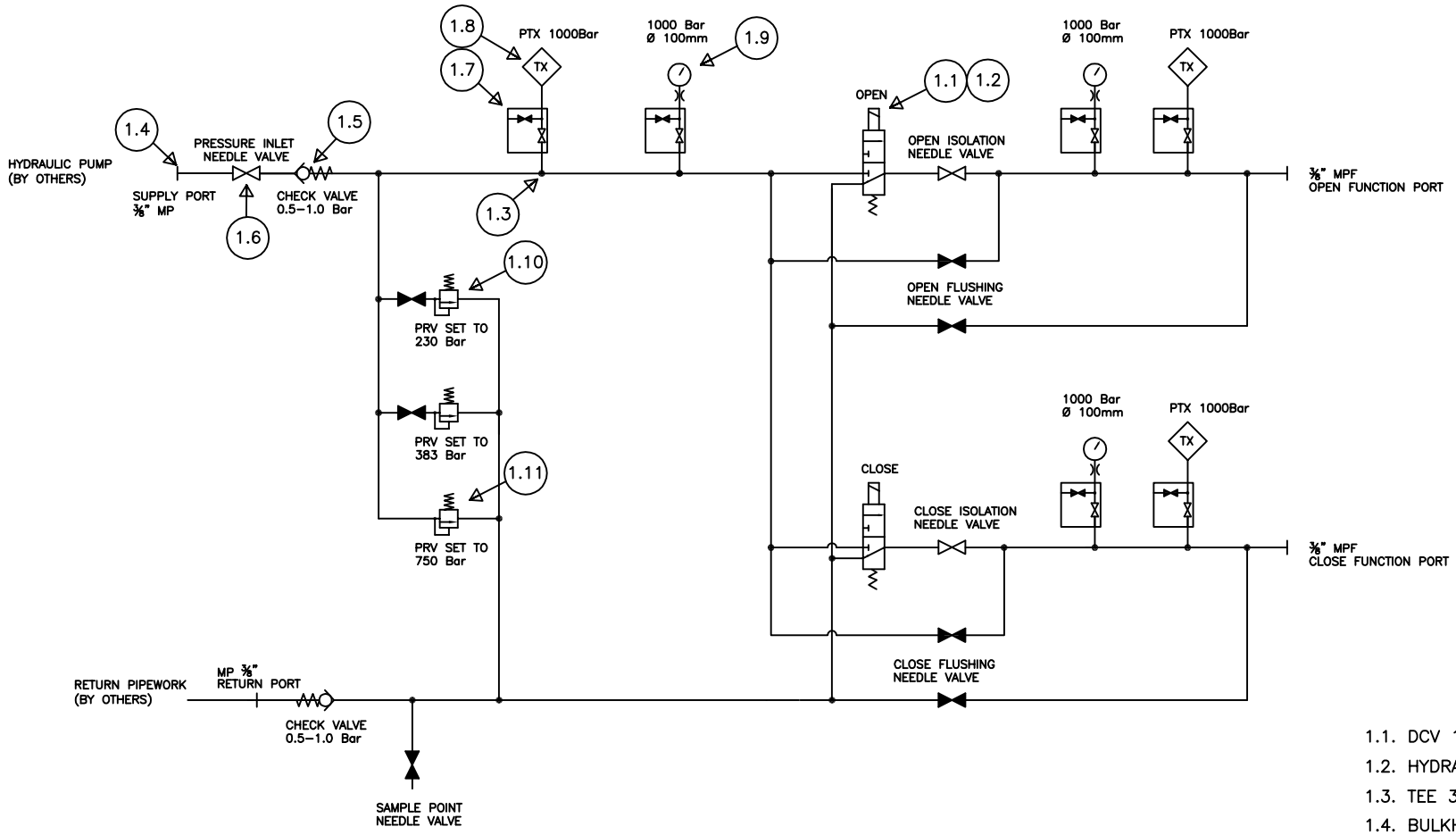
DRG REV A

PART No. XXXXXX

SHT 01 OF 01 SHTS

A 1

FILE NAME Hydraulic_schematic.DWG



1.1. DCV 10,000psi MONO STABLE 3/2
1.2. HYDRAULIC MANIFOLD
1.3. TEE 3/8" MP
1.4. BULKHEAD COUPLING 3/8" MP
1.5. CHECK VALVE 3/8" MP
1.6. NEEDLE VALVE 3/8" MP
1.7. BLOCK AND BLEED VALVES 3/8 MP
1.8. PRESSURE TRANSDUCERS 4–20mA
1.9. INDUSTRIAL GAUGE 1000bar
1.10. PRESSURE RELIEF VALVE 0–600bar
1.11. PRESSURE RELIEF VALVE 300–1000bar

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SCALE U.O.S
EST WEIGHT (kg)
DO NOT SCALE DRAWING

UNLESS OTHERWISE STATED
DIMENSIONS ARE IN MILLIMETRES
MACHINE SURFACE FINISH 1.6 Ra
TOLERANCES :–
0 ±1
0.0 ±0.3
0.00 ±0.13
ANGLES ±0.5°
FABRICATIONS ±2
INTERNAL RADS 1 MAX

CONCENTRICITY
POSITION
SYMMETRY
STRAIGHTNESS
PARALLELISM
PERPENDICULARITY
FLATNESS
CIRCULARITY

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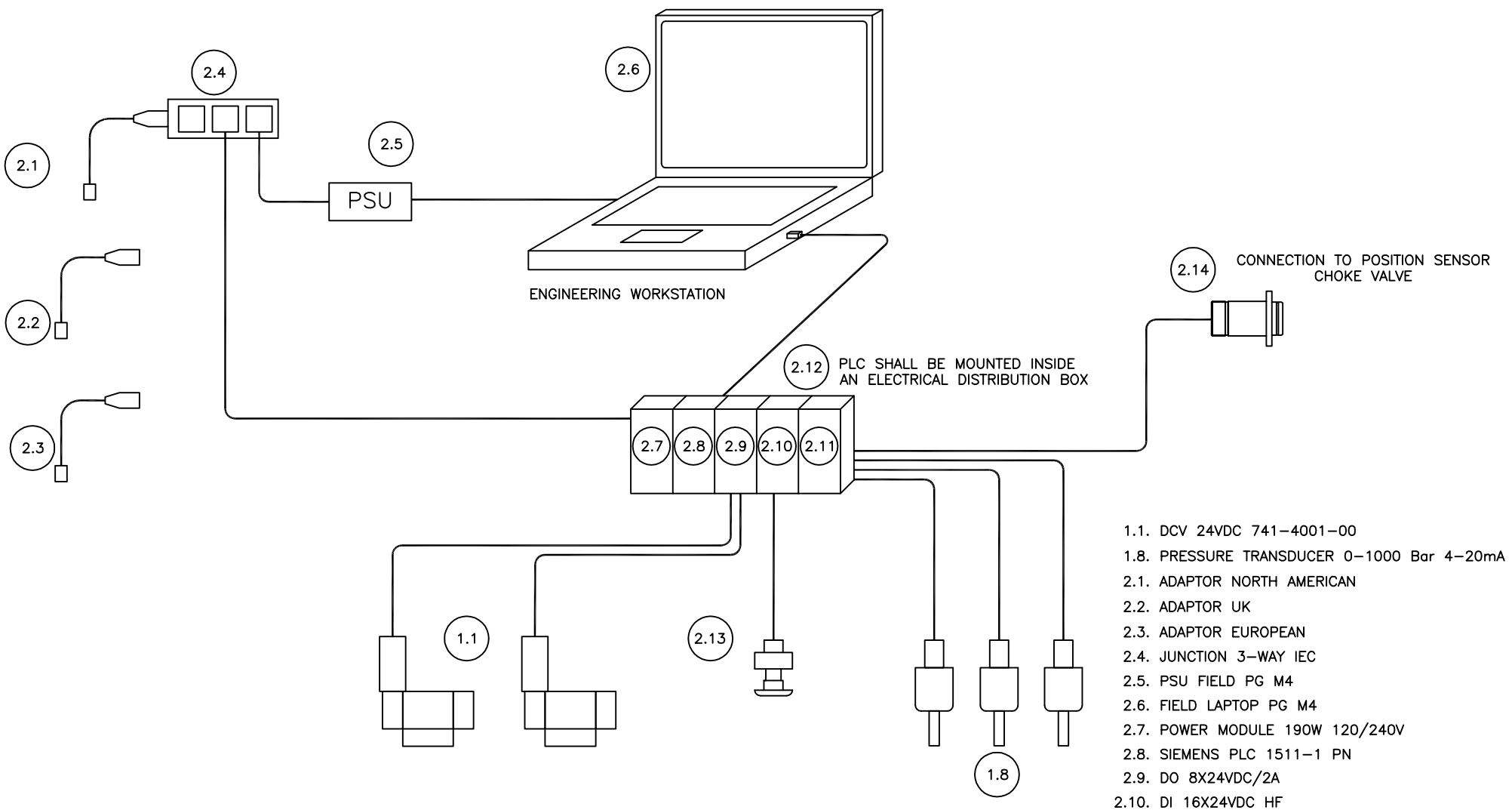
Sothammergeilen 1, Dusavika, Norway

DRAWN BY BAL
DATE DRAWN 03/02/14

DRAWING TITLE: CHOKE VALVE WORKSHOP TOOL HYDRAULIC SCHEMATIC
DRAWING No. XXXXXXXX
DRG REV A
PART No. XXXXXX
SHT 01 OF 01 SHTS
A 1

FILE NAME Hydraulic_schematic.DWG



1.1. DCV 24VDC 741–4001–00
1.8. PRESSURE TRANSDUCER 0–1000 Bar 4–20mA
2.1. ADAPTOR NORTH AMERICAN
2.2. ADAPTOR UK
2.3. ADAPTOR EUROPEAN
2.4. JUNCTION 3–WAY IEC
2.5. PSU FIELD PG M4
2.6. FIELD LAPTOP PG M4
2.7. POWER MODULE 190W 120/240V
2.8. SIEMENS PLC 1511–1 PN
2.9. DO 8X24VDC/2A
2.10. DI 16X24VDC HF
2.11. AI 8XU/I/RTD/TC ST
2.12. ELECTRICAL DISTRIBUTION BOX >IP56
2.13. EMERGENCY STOP
2.14. 4–PIN TRONIC 14–28VDC 4–20mA

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EST WEIGHT (kg)
DO NOT SCALE DRAWING

UNLESS OTHERWISE STATED
DIMENSIONS ARE IN MILLIMETRES
MACHINE SURFACE FINISH 1.6 Ra
TOLERANCES :–
0 ±1
0.0 ±0.3
0.00 ±0.13
ANGLES ±0.5°
FABRICATIONS ±2
INTERNAL RADS 1 MAX

CONCENTRICITY
POSITION
SYMMETRY
STRAIGHTNESS
PARALLELISM
PERPENDICULARITY
FLATNESS
CIRCULARITY

GE
Oil & Gas
Sothammergeilen 1, Dusavika, Norway

DRAWN BY BAL
DATE DRAWN 02/02/14

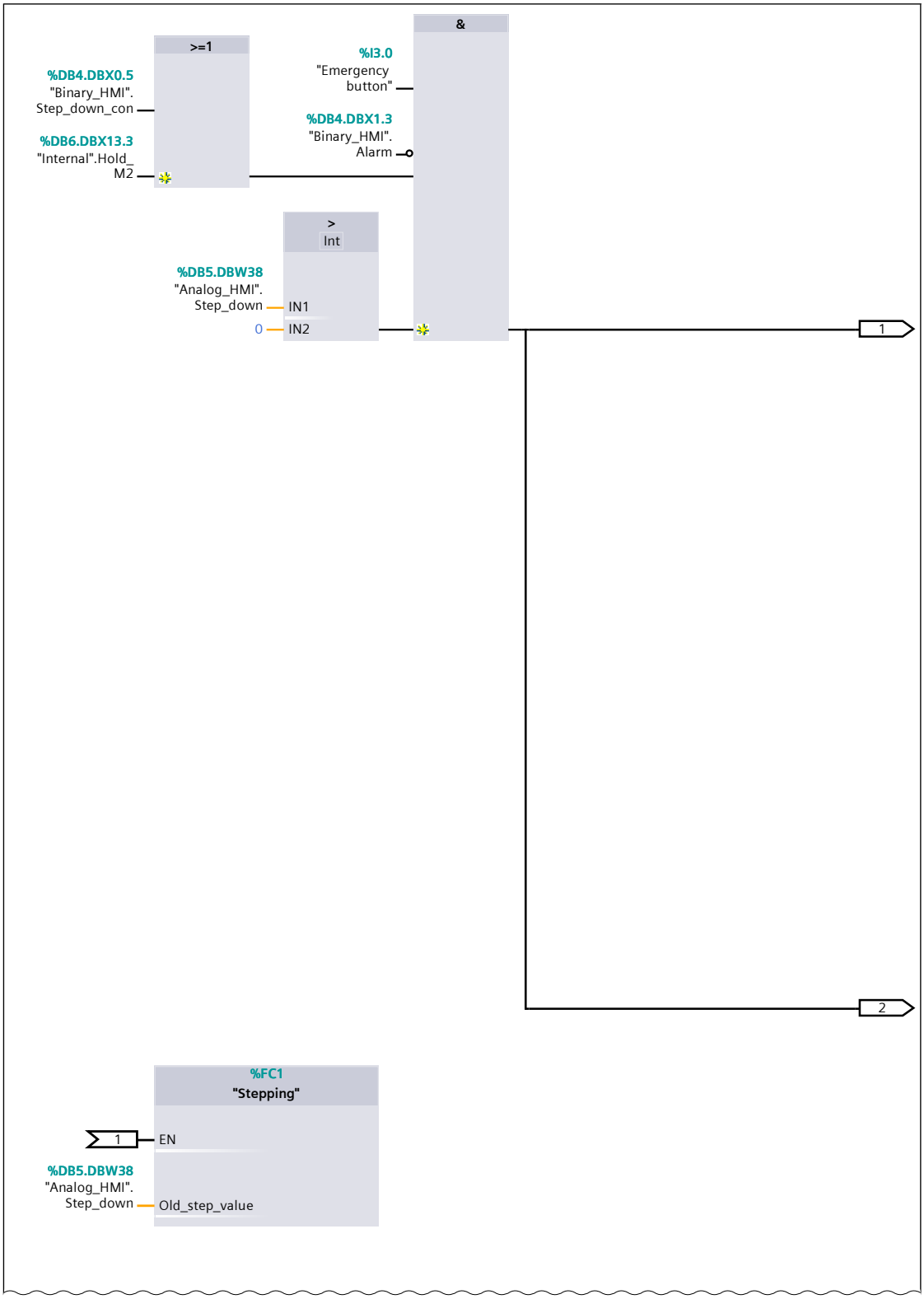
DRAWING TITLE: CHOKE VALVE WORKSHOP TOOL
ELECTRICAL SCHEMATIC
DRAWING No. XXXXXX
DRG REV NC
PART No. XXXXXX
SHT 01 OF 01 SHTS
A 1

FILE NAME Electric_schematic.DWG

Appendix C

PLC program

Network 14: Step_down (1.1 / 2.1)



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 10

Network 14: Step_down (2.1 / 2.1)

1.1 (page 1 - 10)

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 11

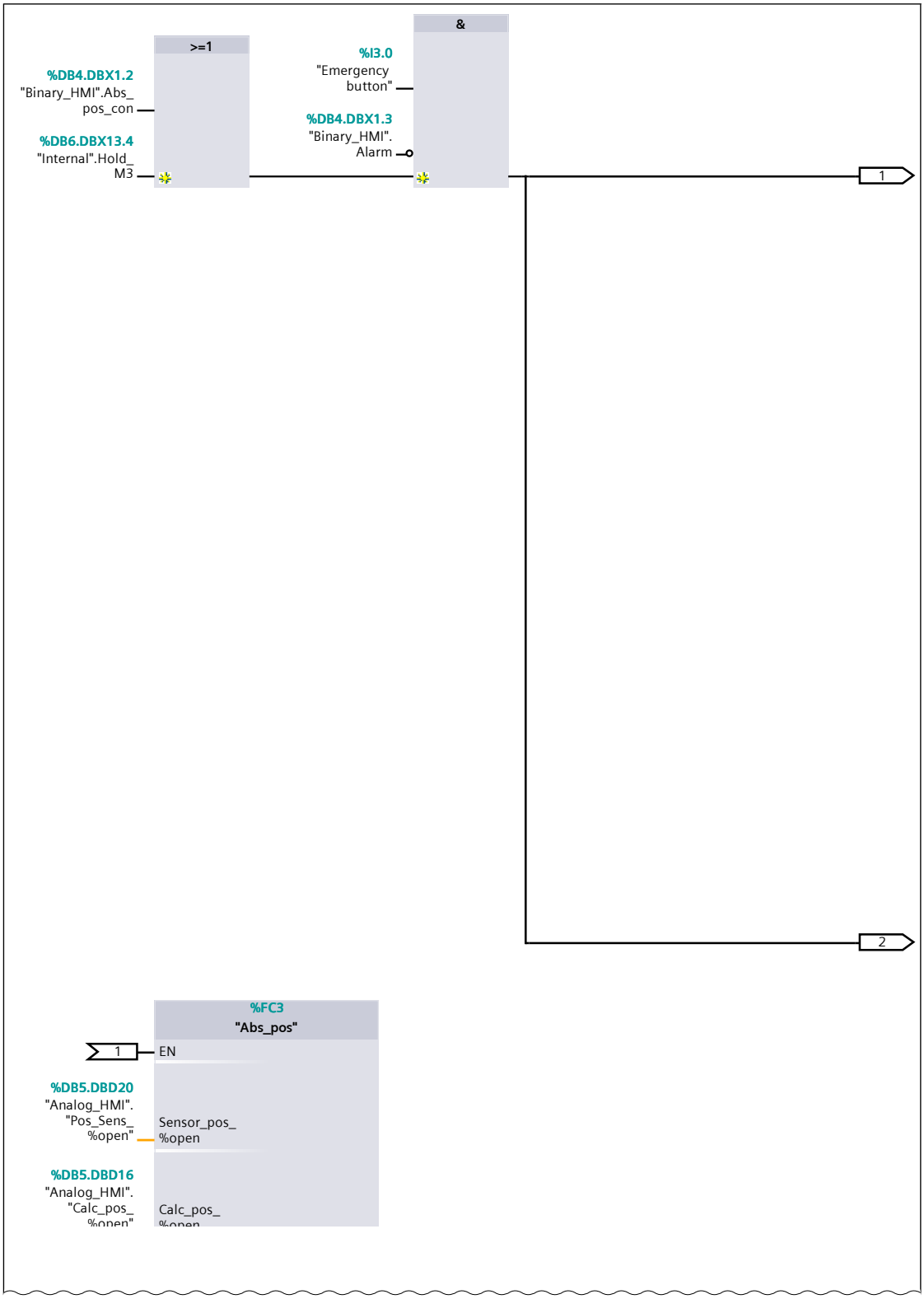
1 2 3 4

A B C D E F

Network 15: Absolute position

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 12

Network 15: Absolute position (1.1 / 2.1)



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 13

Network 15: Absolute position (2.1 / 2.1)

1.1 (page 1 - 13)

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 14

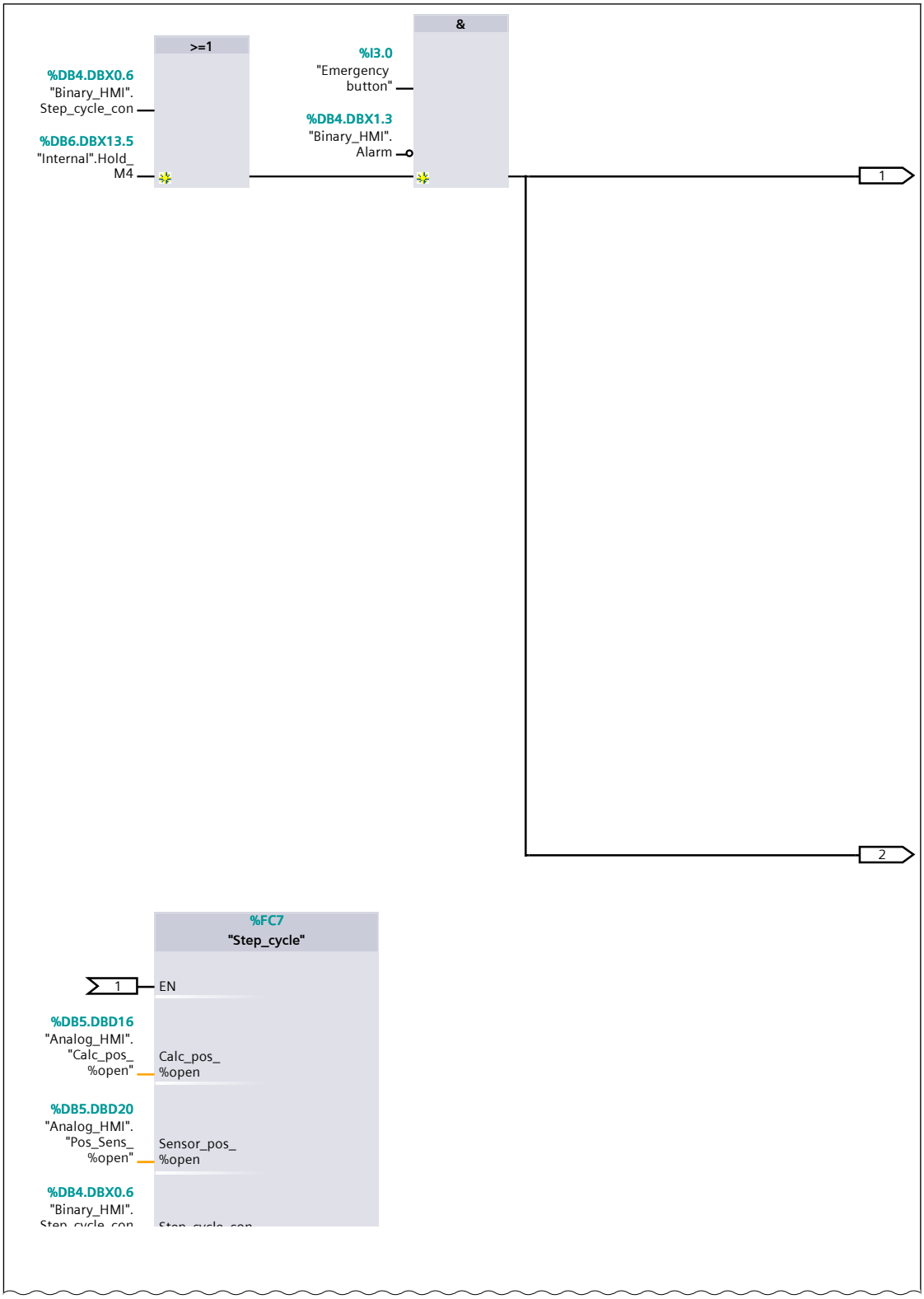
1 2 3 4

A B C D E F

Network 16: Step_cycle

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete \PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 15

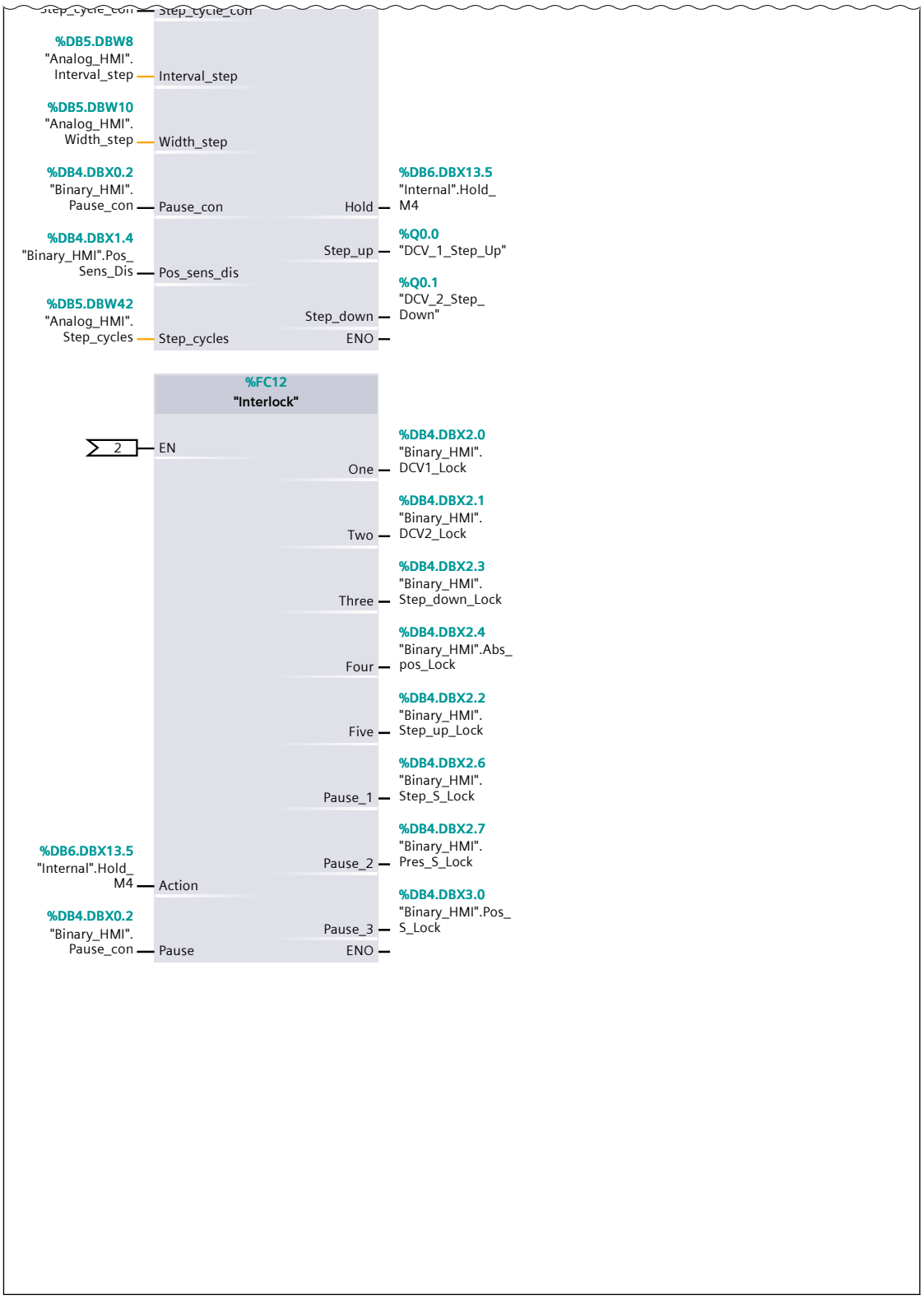
Network 16: Step_cycle (1.1 / 2.1)



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 16

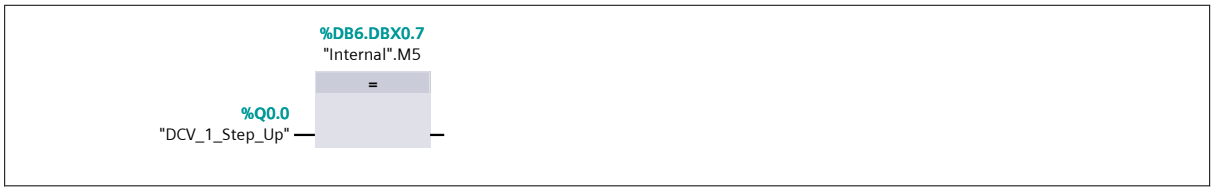
Network 16: Step_cycle (2.1 / 2.1)

1.1 (page 1 - 16)

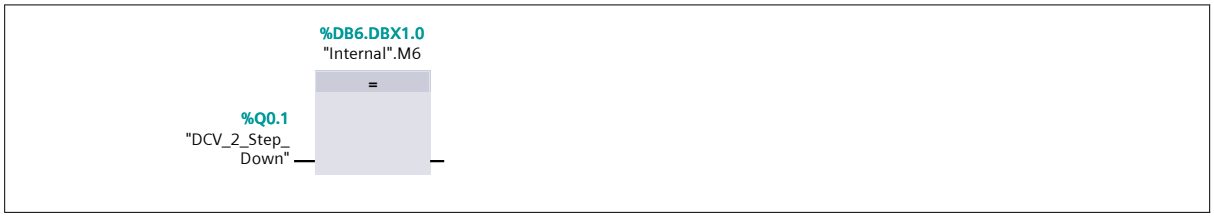


Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 17

Network 17: Create a DB value for the FC to read



Network 18: Create a DB value for the FC to read



Network 19: Alarm Warnings

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 18

Network 20: Setting Alarm Window in WinCC

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 19

Program blocks

CVWT [OB1]

CVWT Properties			
General			
Name	CVWT	**Number**	1
Type	OB	**Language**	FBD
Information			
Title	"Main Program Sweep (Cycle)"	**Author**	
Comment		**Family**	
Version	1.0	**User-defined ID**	

Name	Data type	Offset
Temp		

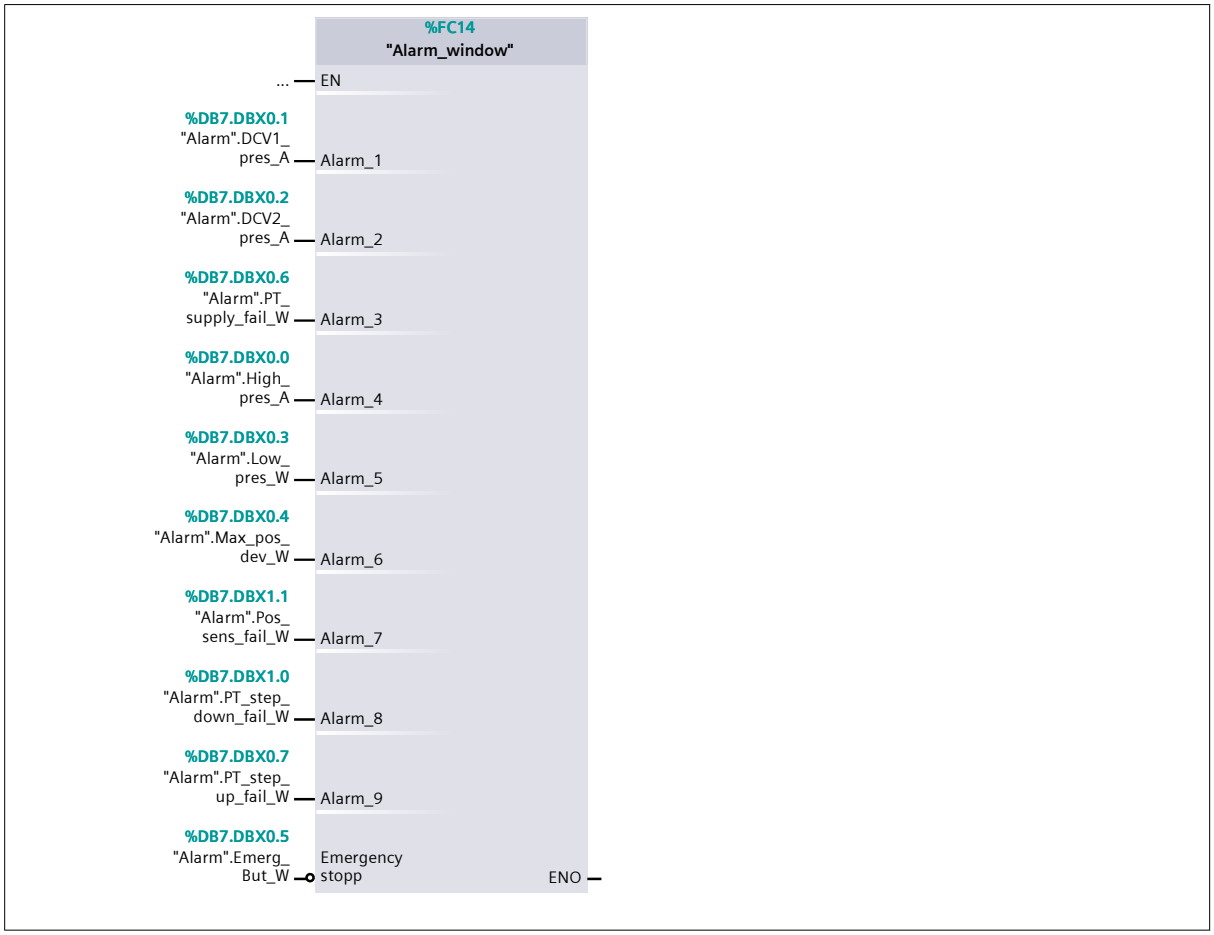
Network 1: Convert PT supply to bar

Network 2: Convert PT step up to bar

Network 3: Convert PT step down to bar

Network 4: Calculated pos

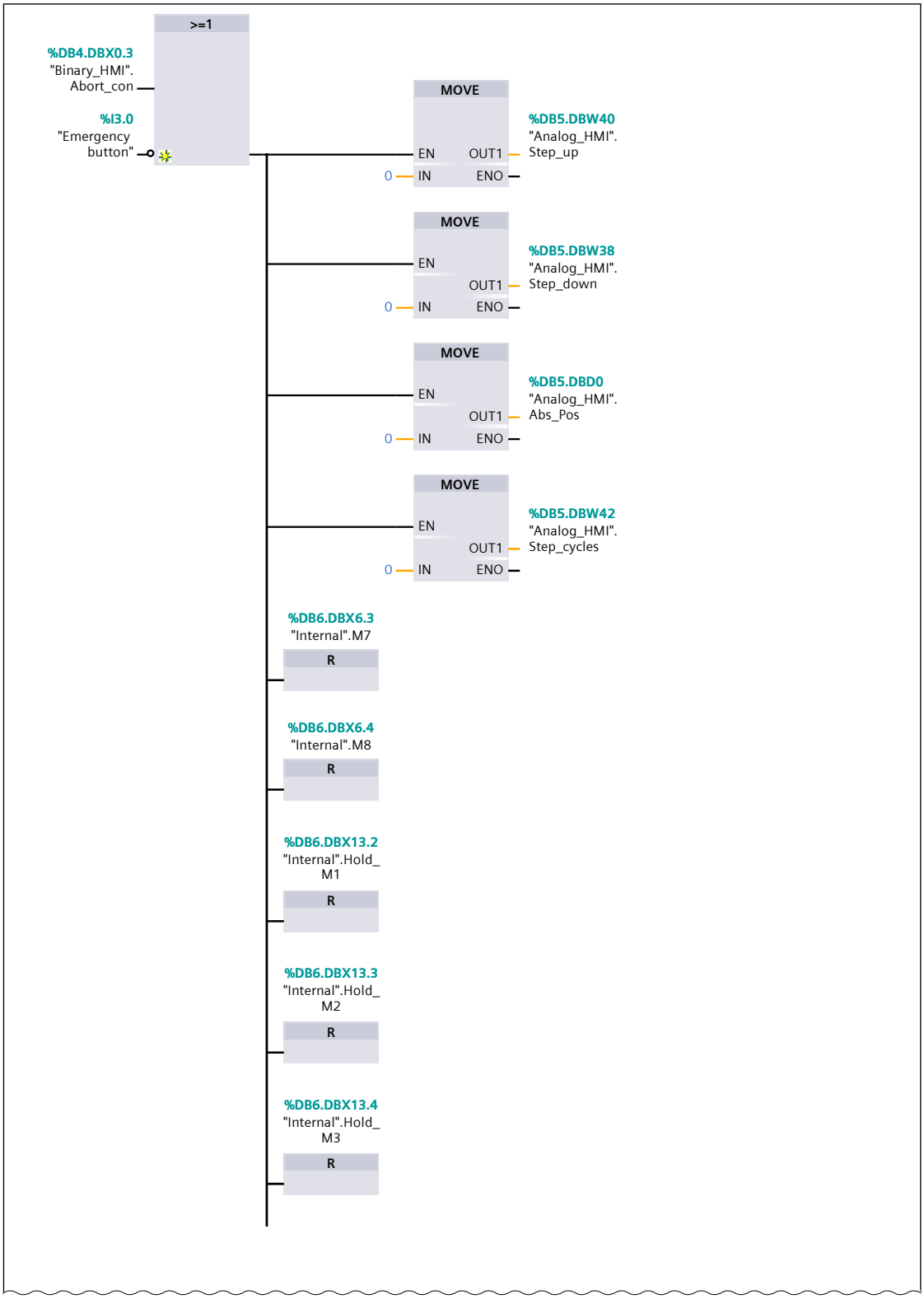
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 1



Network 21: Abort or Emergency button

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 20

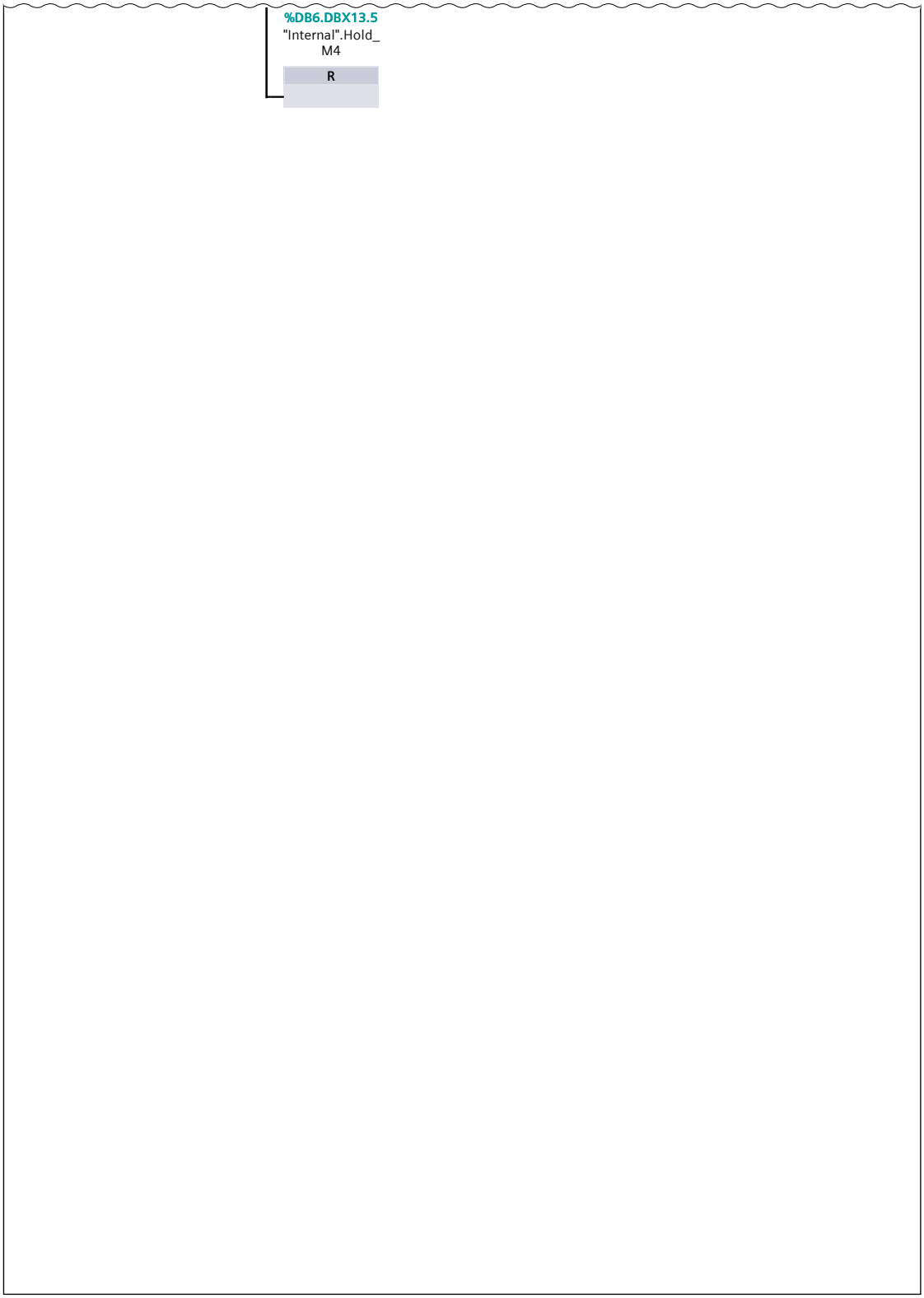
Network 21: Abort or Emergency button (1.1 / 2.1)



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete \PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 21

Network 21: Abort or Emergency button (2.1 / 2.1)

1.1 (page 1 - 21)



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete \PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 22

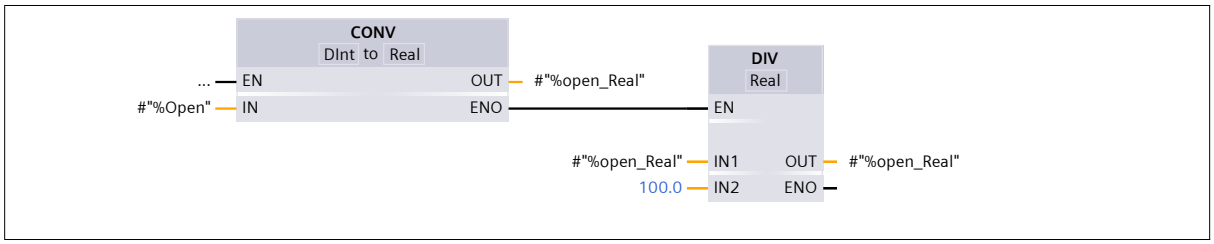
Program blocks

%open2step [FC4]

%open2step Properties			
General			
Name	%open2step	**Number**	4
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Offset
▼ Input		
%Open	DInt	
No_steps_open2close	DInt	
▼ Output		
Steps	DInt	
InOut		
▼ Temp		
%open_Real	Real	
No_steps_Real	Real	
▼ Return		
Ret_Val	Void	

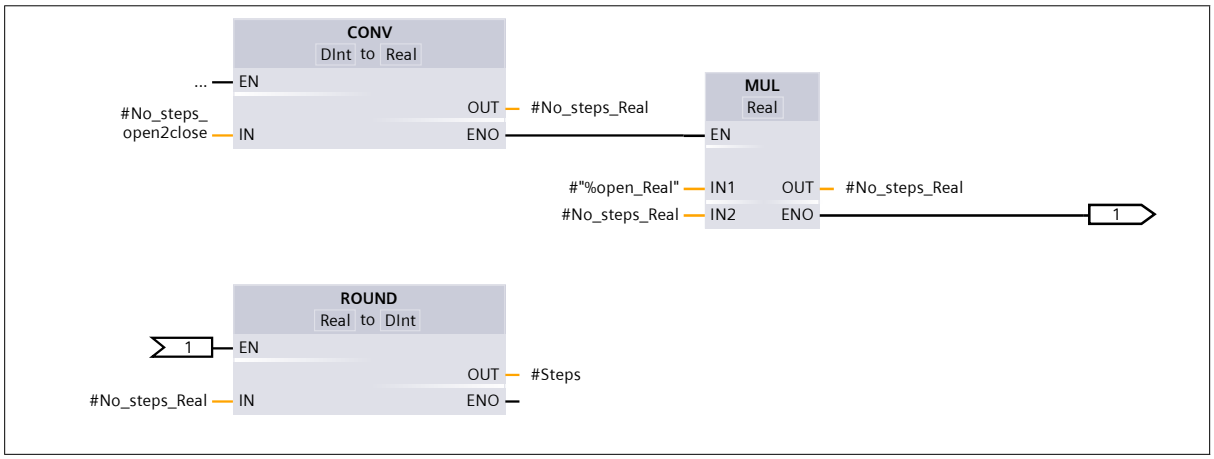
Network 1:



Network 2:

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 2 - 1

Network 2:



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 2 - 2

Program blocks

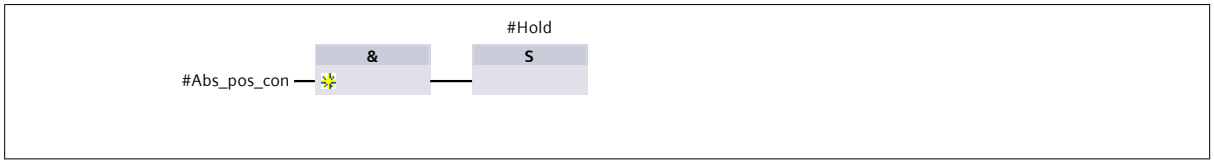
Abs_pos [FC3]

Abs_pos Properties			
General			
Name	Abs_pos	**Number**	3
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

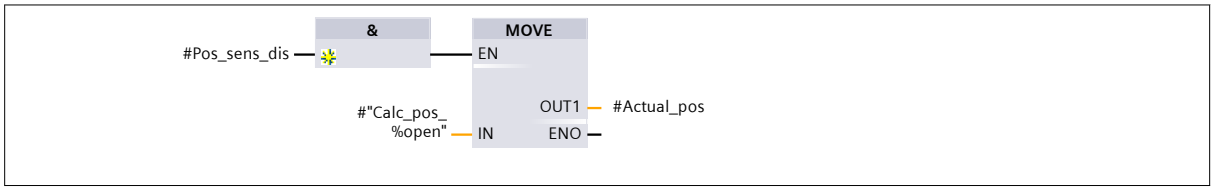
Name	Data type	Offset
▼ Input		
Sensor_pos_%open	DInt	
Calc_pos_%open	DInt	
Abs_pos_con	Bool	
Pos_sens_dis	Bool	
Interval	Int	
Width	Int	
Pause	Bool	
Steps_open2_close	DInt	
▼ Output		
Hold	Bool	
Step_up	Bool	
Step_down	Bool	
▼ InOut		
Abs_pos	DInt	
▼ Temp		
Actual_pos	DInt	
Interval_sub	Int	
Time_interval	Time	
Time_width	Time	
M1	Bool	
M2	Bool	
Step	Bool	
Absolute deviation	DInt	
Step_down_deviation	DInt	
Step_up_deviation	DInt	
Range	DInt	
▼ Return		
Ret_Val	Void	

Network 1: Hold

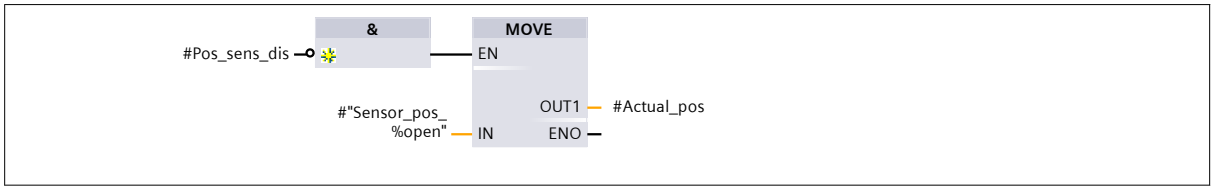
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 3 - 1



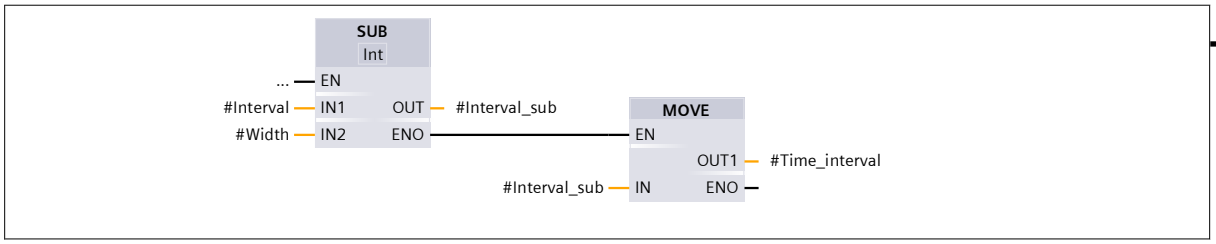
Network 2: Use calculated pos or sensor pos



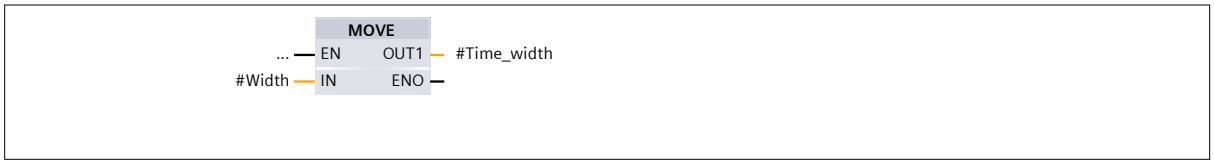
Network 3: Calculated pos or sensor pos



Network 4: finding interval time and converting from int2time

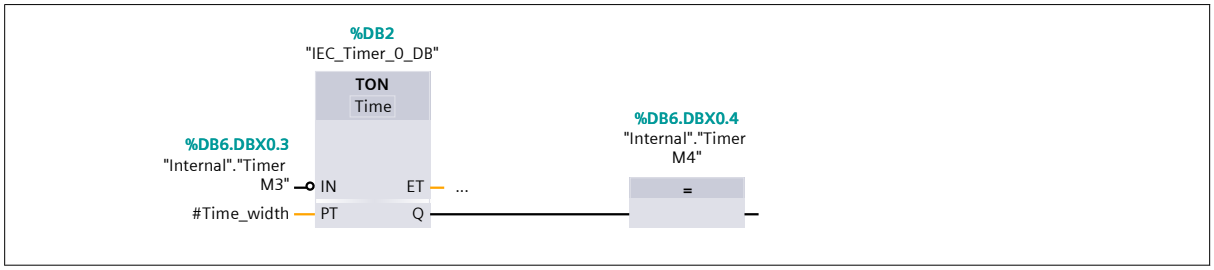


Network 5: Converting from int2time

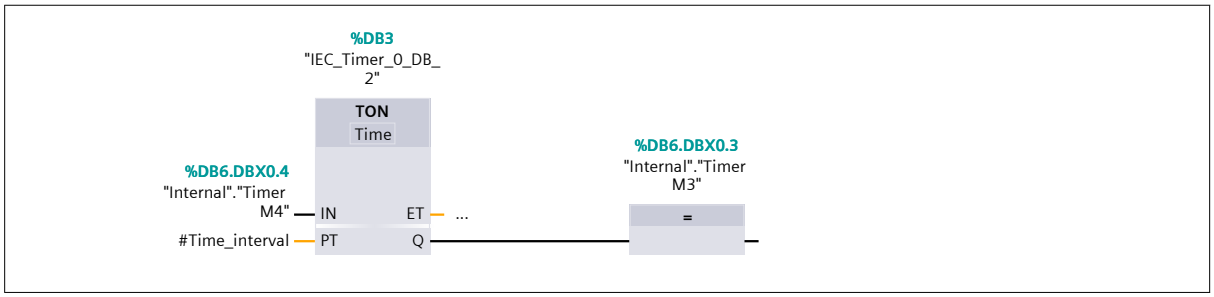


Network 6: Step Width

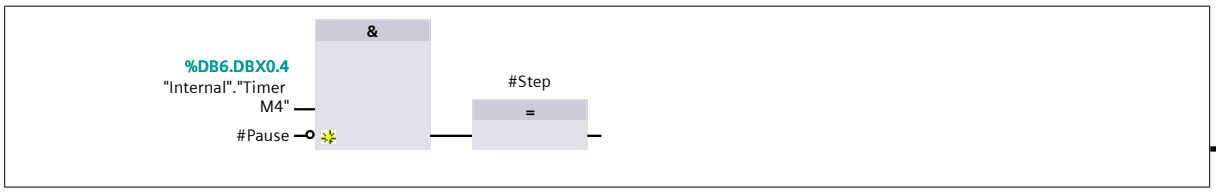
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 3 - 2



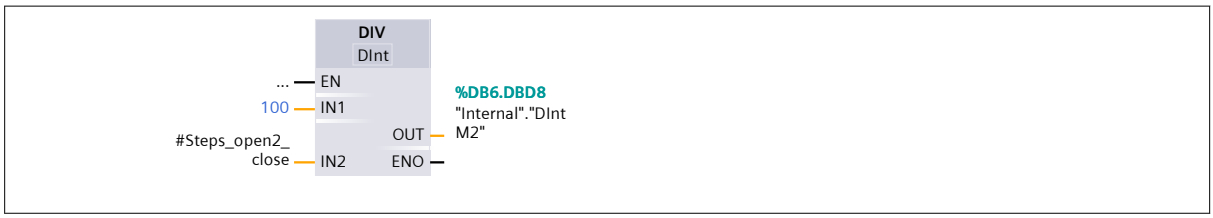
Network 7: Step Interval



Network 8: Pause function

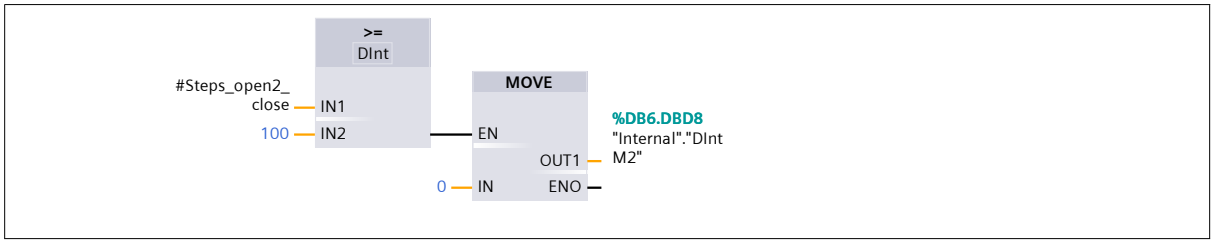


Network 9: Sett range for allowed deviation to absolute position

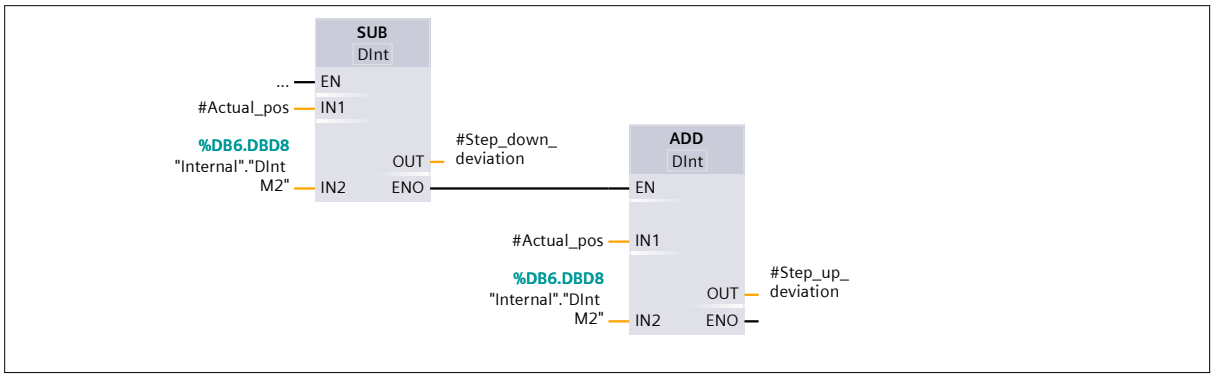


Network 10: Sett range for allowed deviation, put to zero if above 100 step

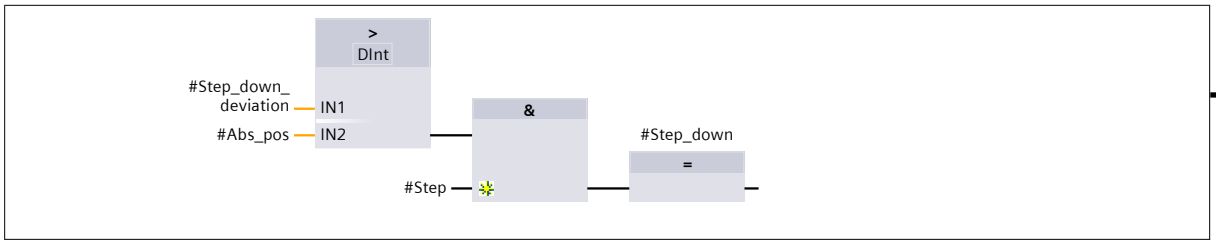
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 3 - 3



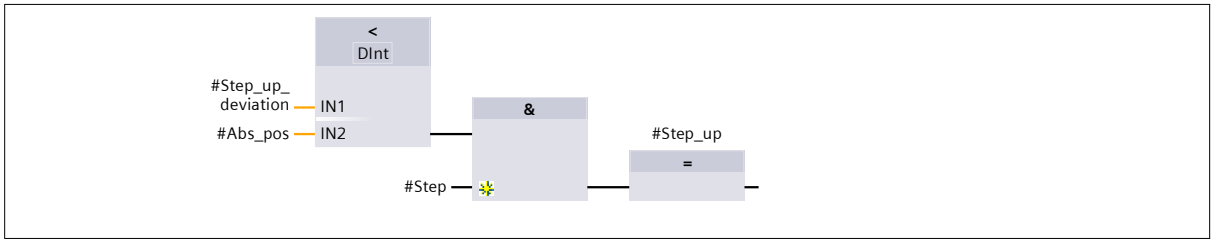
Network 11: Add and sub the allowed deviation



Network 12: step down

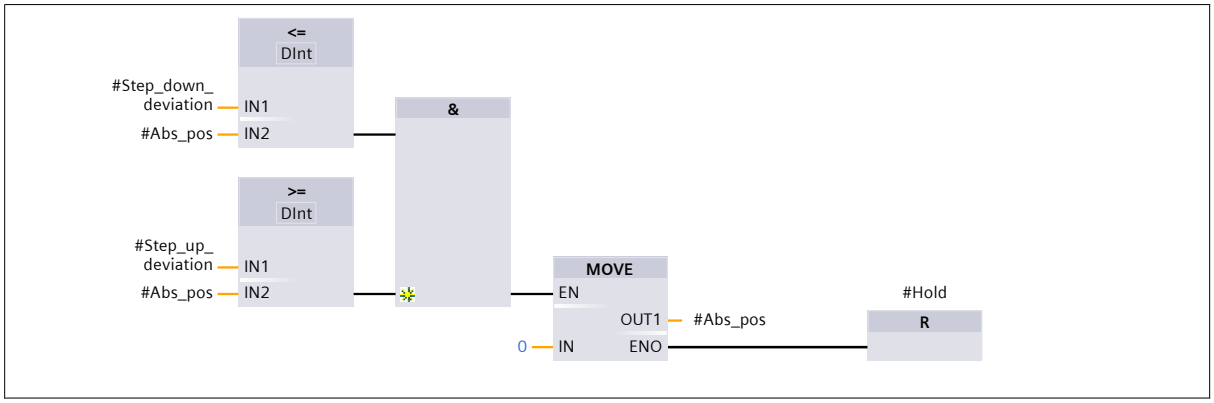


Network 13: Step up



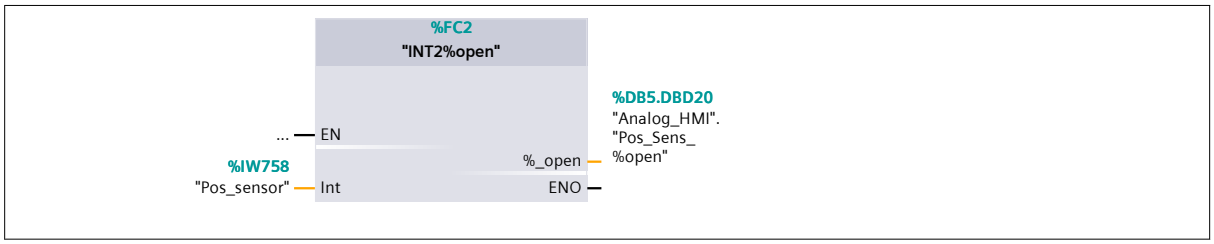
Network 14: Stop stepping if within range

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 3 - 4



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 3 - 5

Network 5: Sensor position



Network 6: Step settings

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 2

Program blocks

Alarm_Events [FC13]

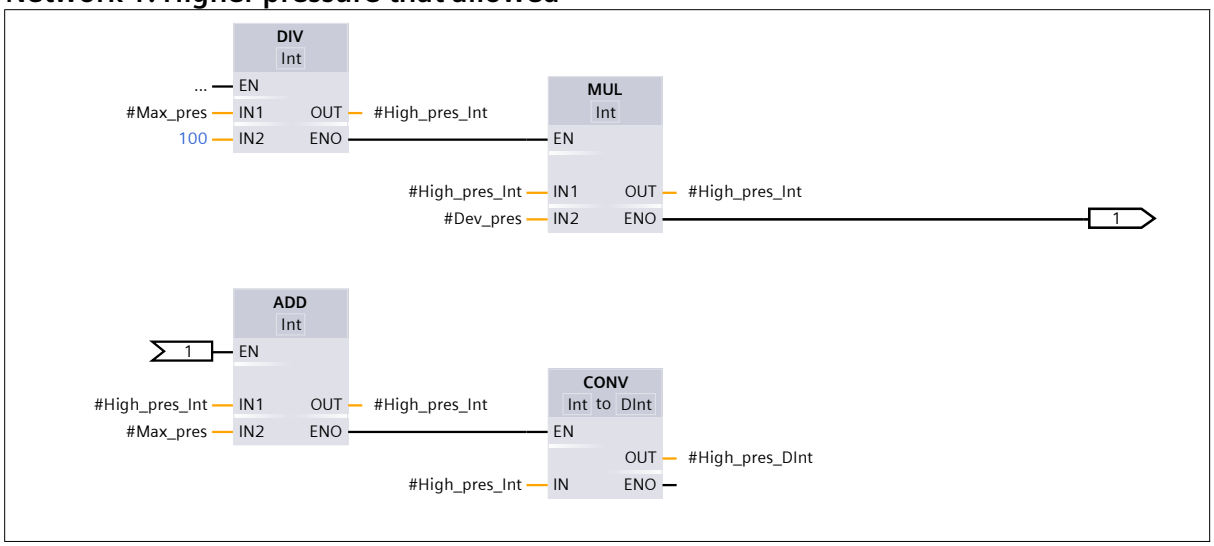
Alarm_Events Properties			
General			
Name	Alarm_Events	**Number**	13
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Offset
▼ Input		
Max_pres	Int	
Dev_pres	Int	
PT_supply_bar	DInt	
Step_con	Bool	
PT_step_up_bar	DInt	
PT_step_down_bar	DInt	
Calc_pos_%open	DInt	
Dev_pos	DInt	
Pos_sens_%open	DInt	
Pos_sens_dis	Bool	
PT_supply_PLC	Int	
PT_step_up_PLC	Int	
PT_step_down_PLC	Int	
Pos_sens_PLC	Int	
Emerg_But	Bool	
▼ Output		
High_pres_A	Bool	
DCV1_pres_A	Bool	
DCV2_pres_A	Bool	
Low_pres_W	Bool	
Max_pos_dev_W	Bool	
PT_supply_fail_W	Bool	
PT_step_up_fail_W	Bool	
PT_step_down_fail_W	Bool	
Pos_sens_fail_W	Bool	
Emerg_But_W	Bool	
InOut		
▼ Temp		
High_pres_Int	Int	
High_pres_DInt	DInt	
Low_pres_Int	Int	
Low_pres_DInt	DInt	

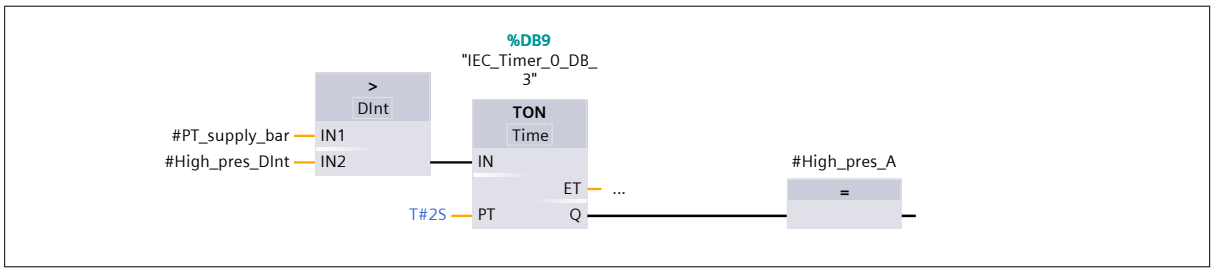
Name	Data type	Offset
High_pos_dev_DInt	DInt	
Low_pos_dev_DInt	DInt	
Return		
Ret_Val	Void	

Network 1: Higher pressure that allowed

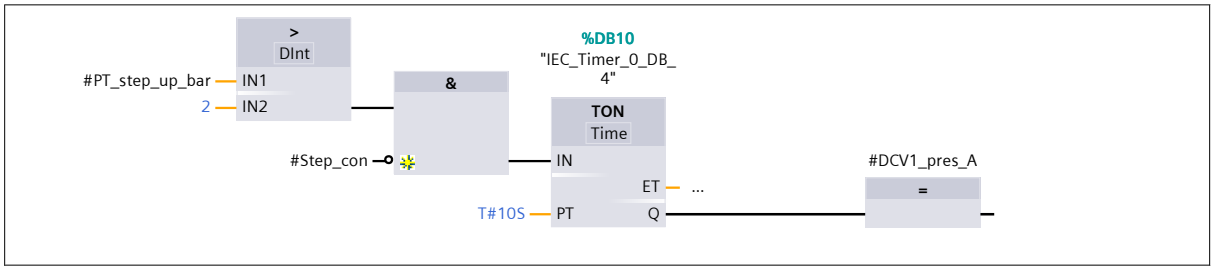
Network 1: Higher pressure that allowed



Network 2: Higher pressure that allowed

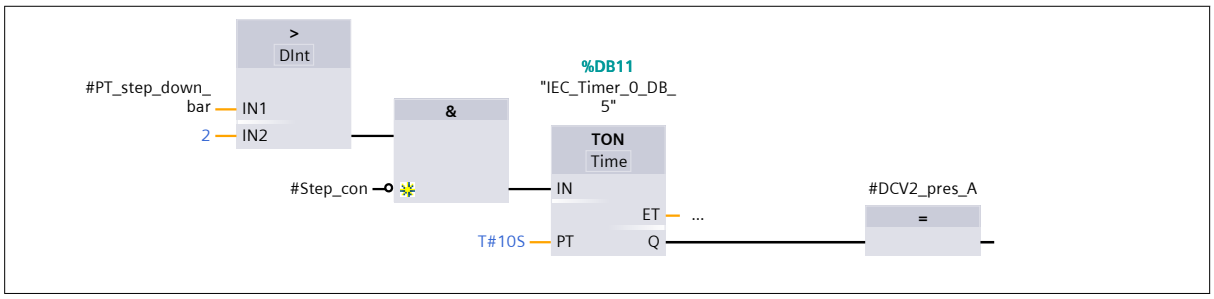


Network 3: High pressure detected after DCV1 is closed



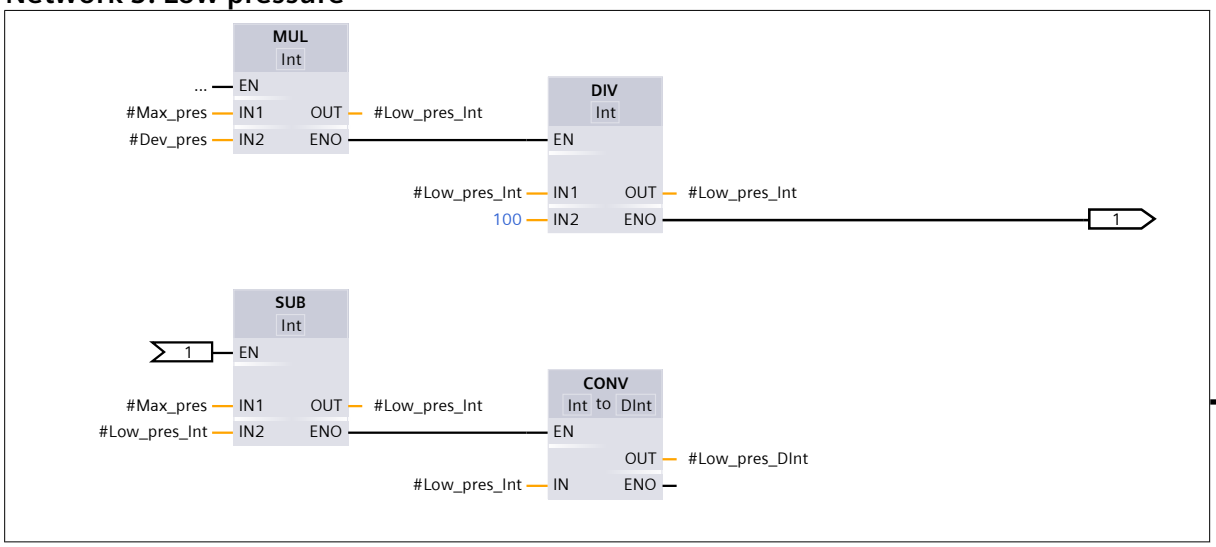
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 4 - 2

Network 4: High pressure detected after DCV2 is closed

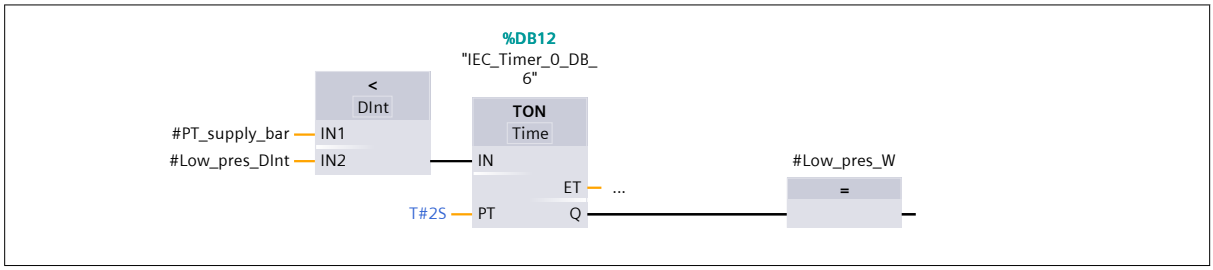


Network 5: Low pressure

Network 5: Low pressure



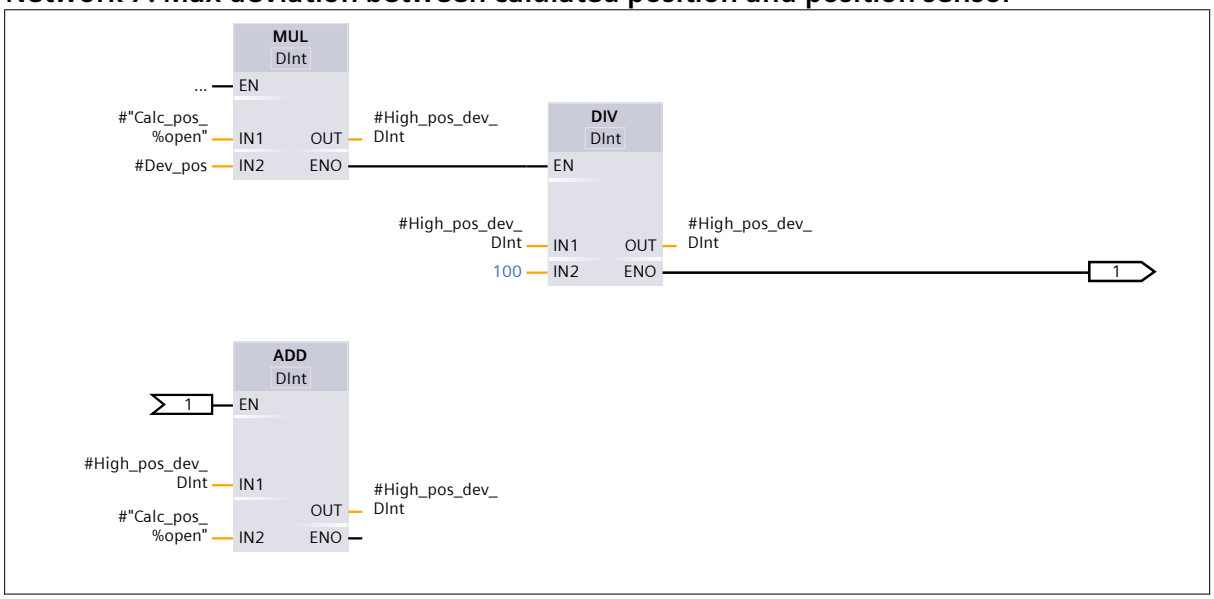
Network 6: Low pressure



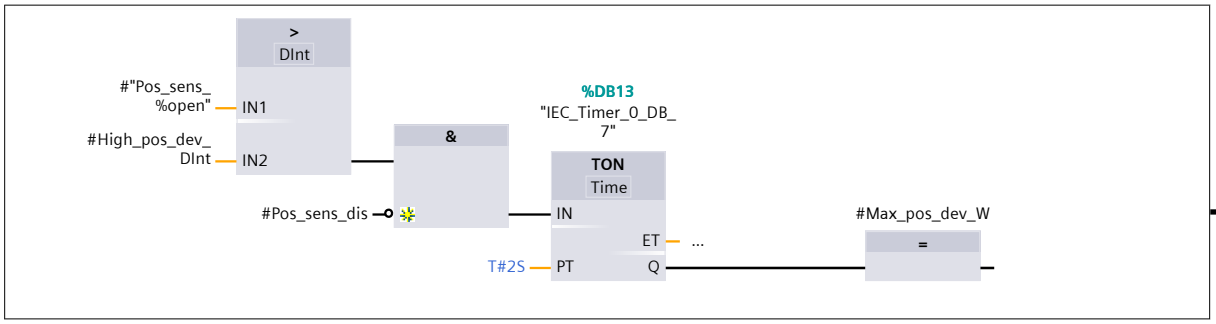
Network 7: Max deviation between calulated position and position sensor

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 4 - 3

Network 7: Max deviation between calulated position and position sensor



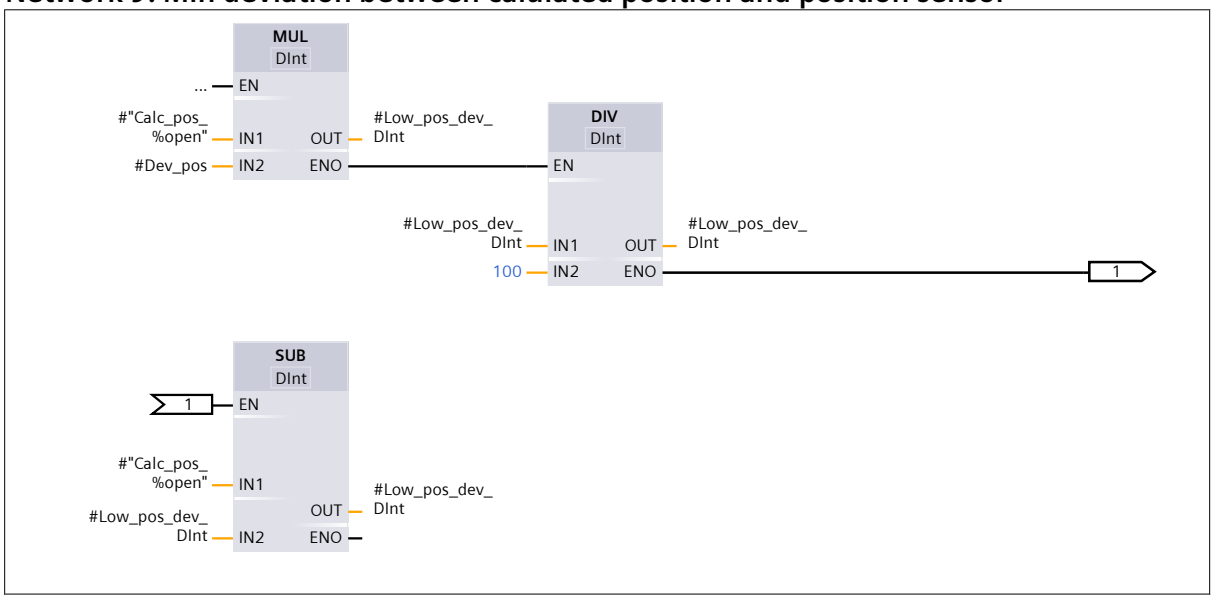
Network 8: Max deviation between calulated position and position sensor



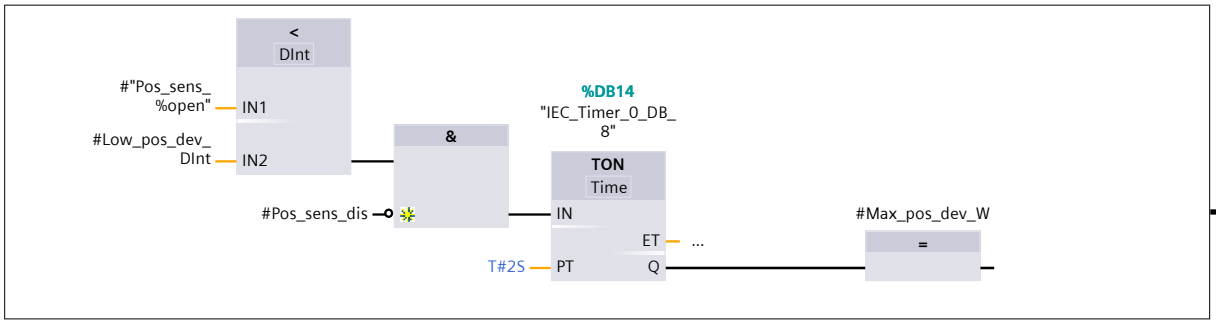
Network 9: Min deviation between calulated position and position sensor

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 4 - 4

Network 9: Min deviation between calulated position and position sensor



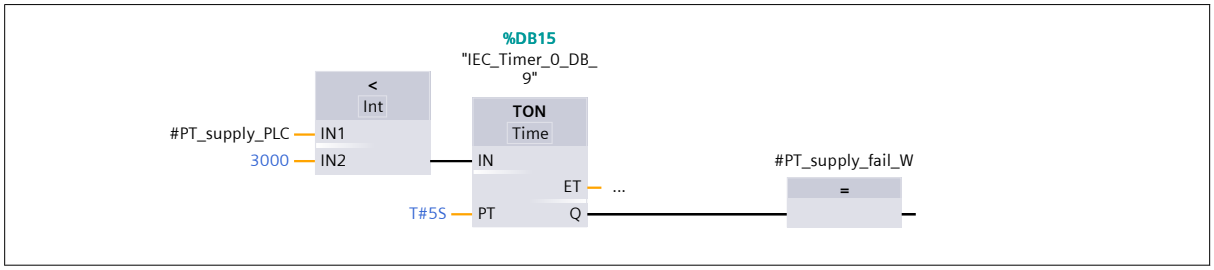
Network 10: Min deviation between calulated position and position sensor



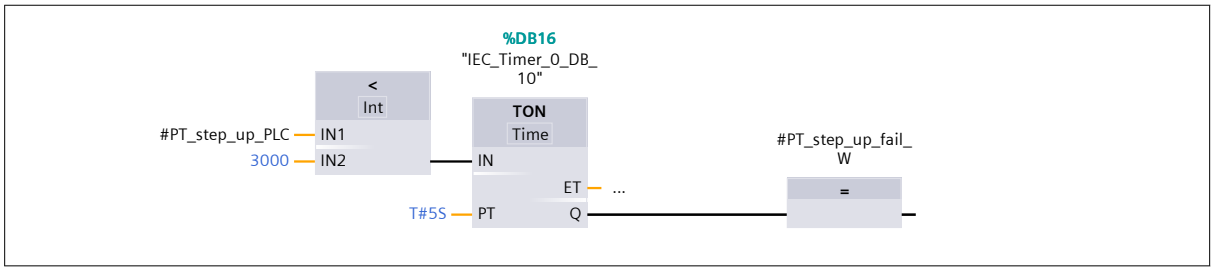
Network 11: Emergency button pressed

Network 12: Supply Sensor failure

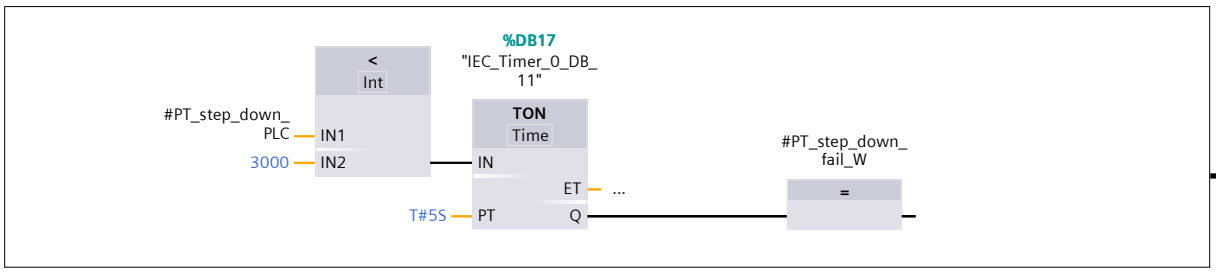
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 4 - 5



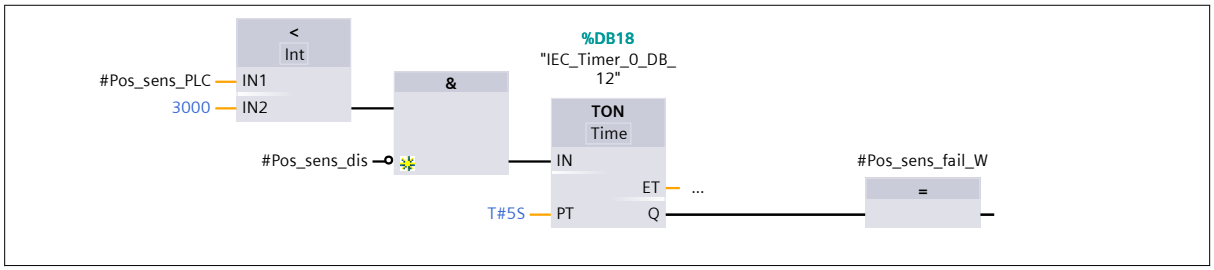
Network 13: Step up sensor failure



Network 14: Step down sensor failure



Network 15: Pos sensor failure



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 4 - 6

Program blocks

Alarm_window [FC14]

Alarm_window Properties			
General			
Name	Alarm_window	**Number**	14
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Offset
▼ Input		
Alarm_1	Bool	
Alarm_2	Bool	
Alarm_3	Bool	
Alarm_4	Bool	
Alarm_5	Bool	
Alarm_6	Bool	
Alarm_7	Bool	
Alarm_8	Bool	
Alarm_9	Bool	
Emergency stopp	Bool	
Output		
InOut		
Temp		
▼ Return		
Ret_Val	Void	

Network 1:

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 5 - 1

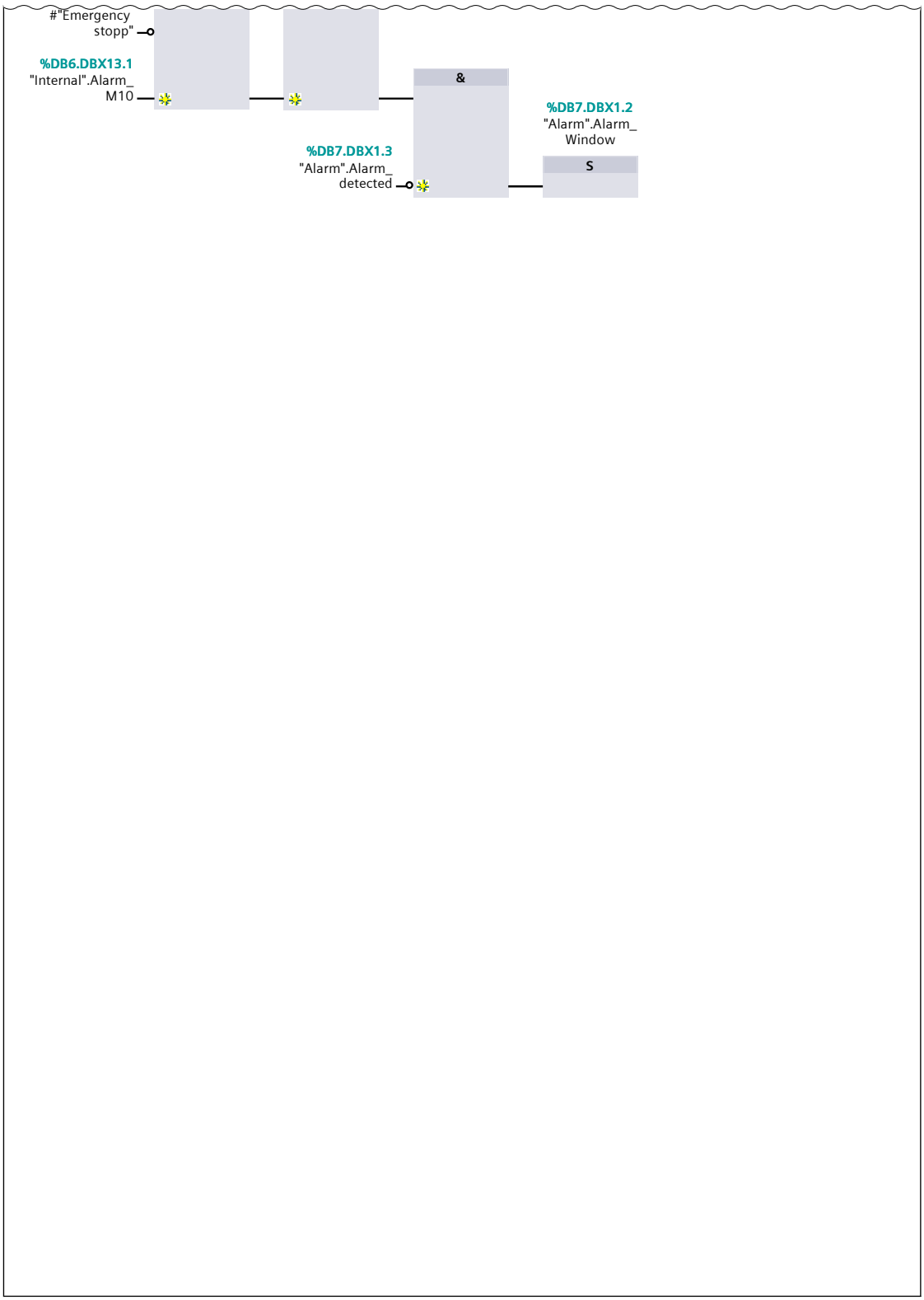
Network 1: (1.1 / 2.1)

2.1 (page 5 - 3)

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 5 - 2

Network 1: (2.1 / 2.1)

1.1 (page 5 - 2)



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete \PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 5 - 3

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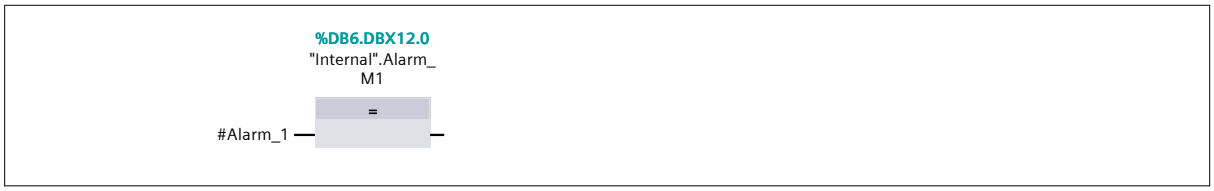
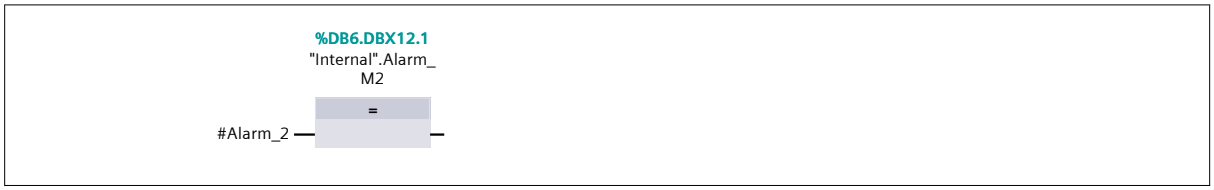
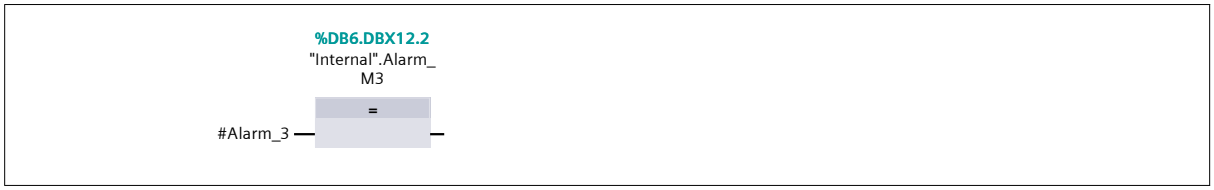
Network 2:



Network 3:

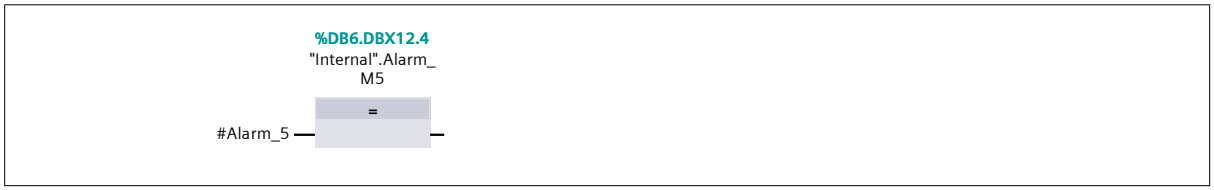


Network 4:



Network 5:

Network 6:



Network 7:

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 5 - 4

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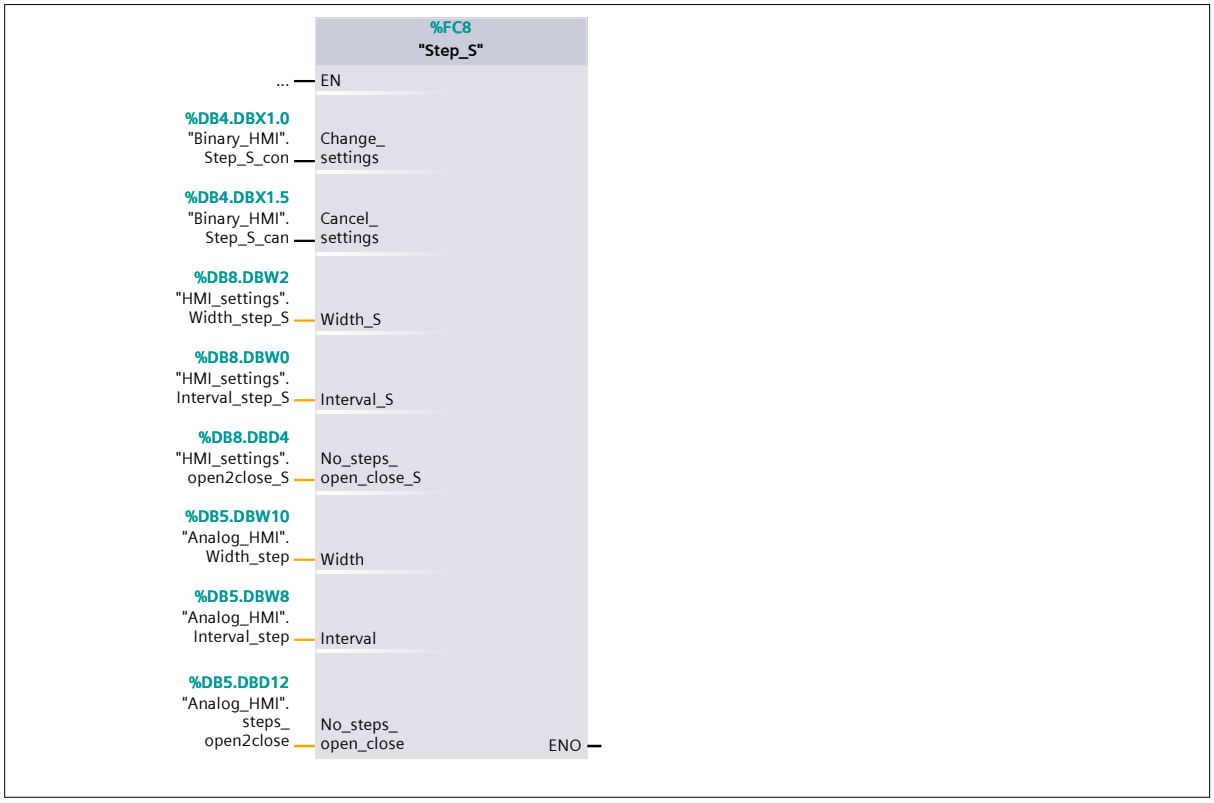
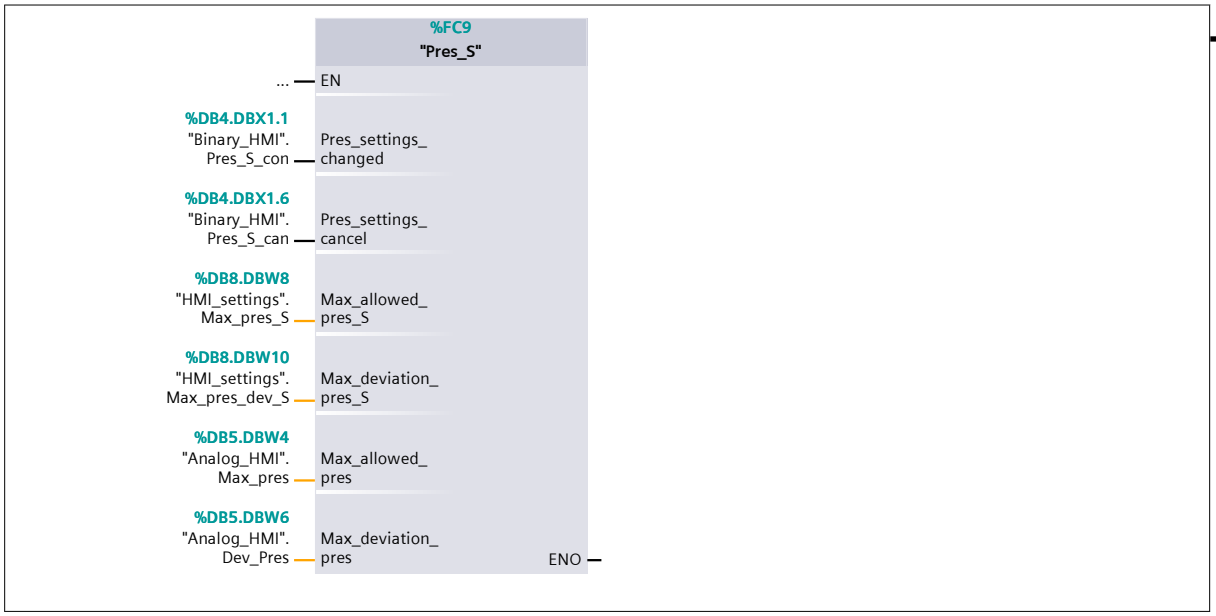
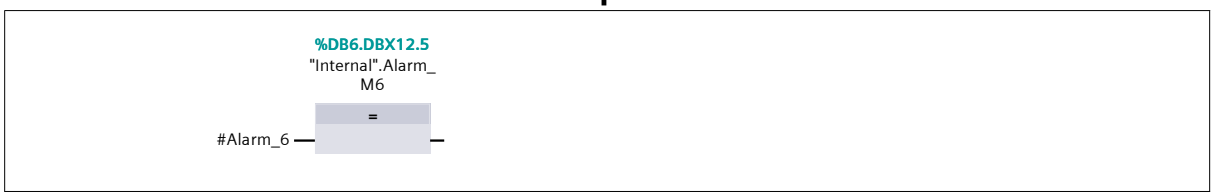


Network 7: Pressure settings



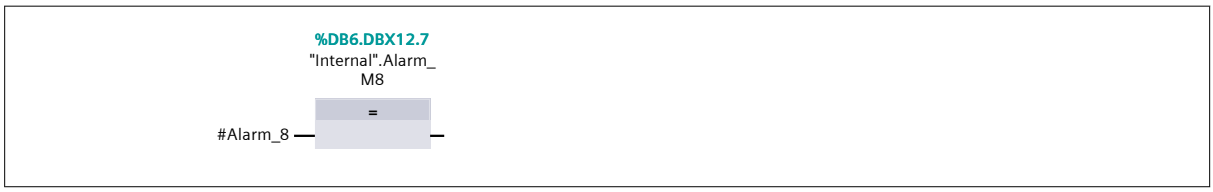
Network 8: Interlock pause button if settings is opened during running mode

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 3

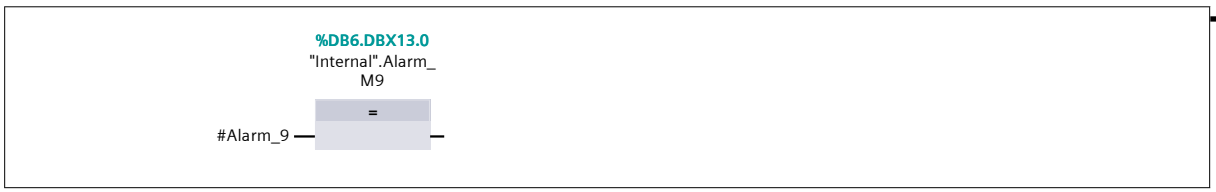


Network 8:

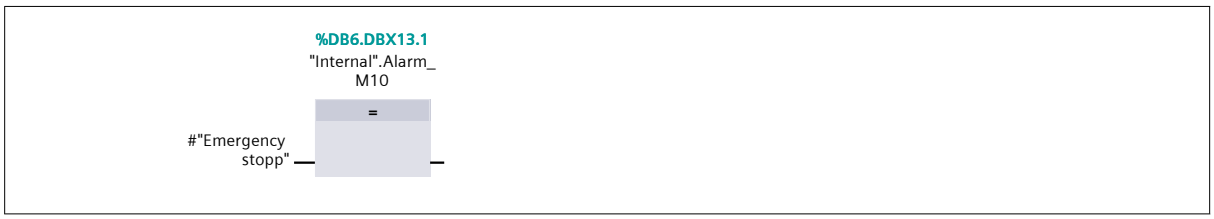
Network 9:



Network 10:

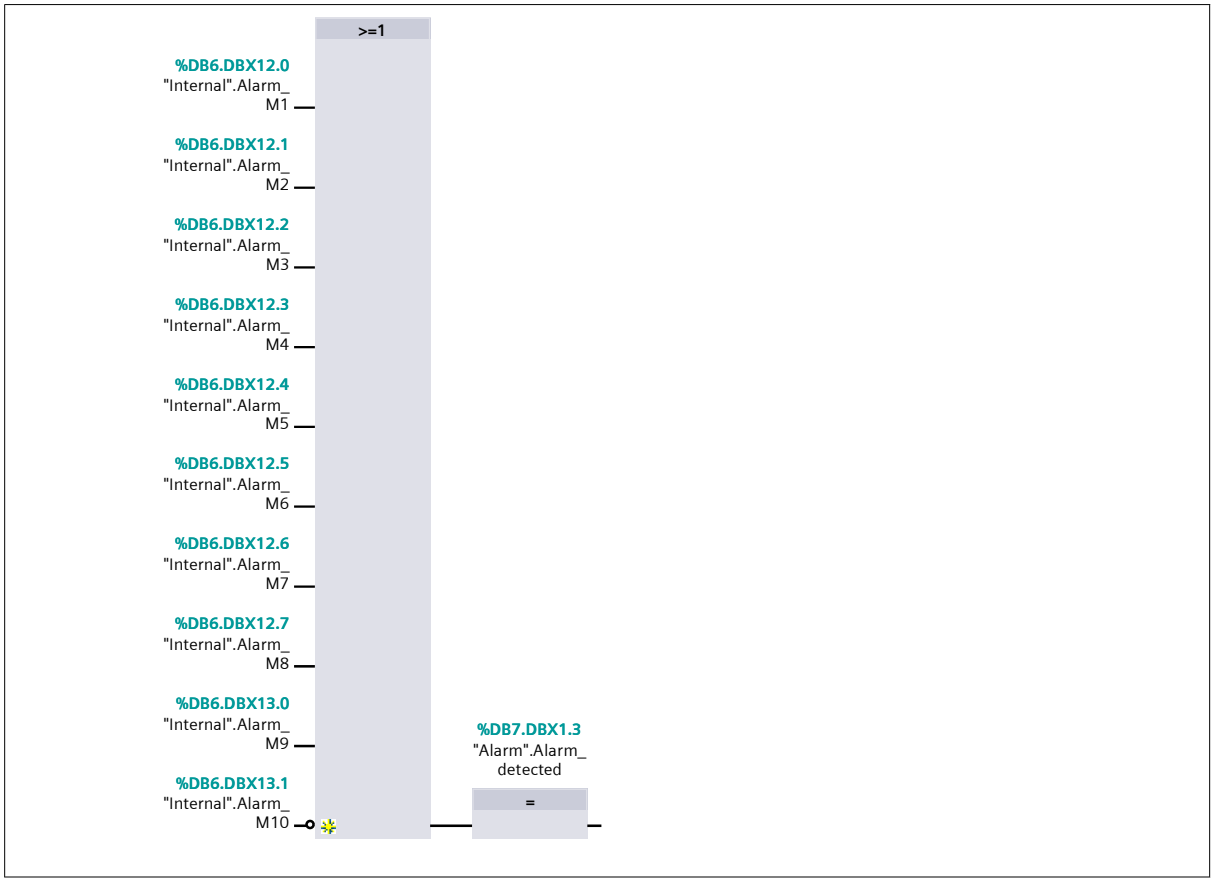


Network 11:



Network 12:

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 5 - 5



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 5 - 6

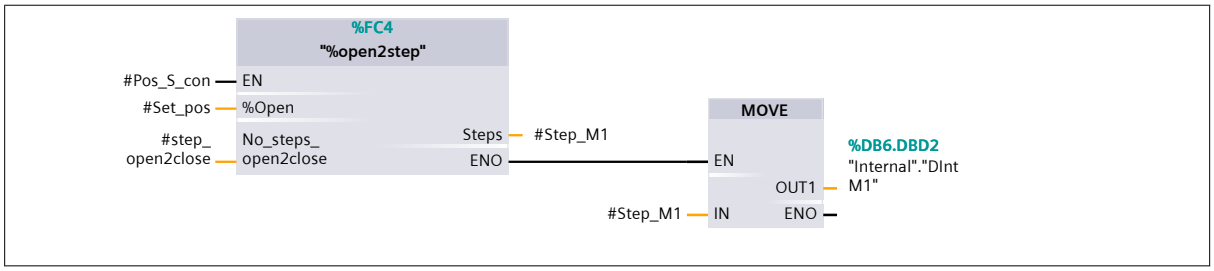
Program blocks

Calc_pos [FC5]

Calc_pos Properties			
General			
Name	Calc_pos	**Number**	5
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

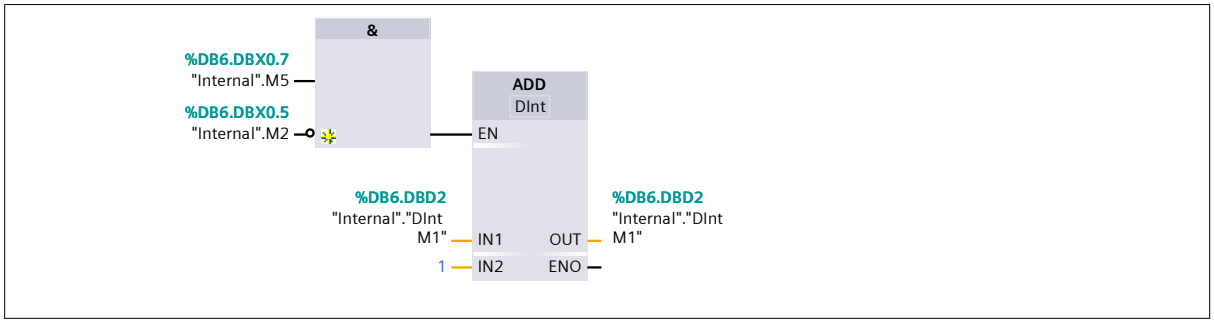
Name	Data type	Offset
Input		
Step_S_con	Bool	
Pos_S_con	Bool	
Set_pos	DInt	
step_open2close	DInt	
Output		
InOut		
Calc_%open	DInt	
Temp		
Step_M1	DInt	
M2	Bool	
Return		
Ret_Val	Void	

Network 1: converting %open to number of steps

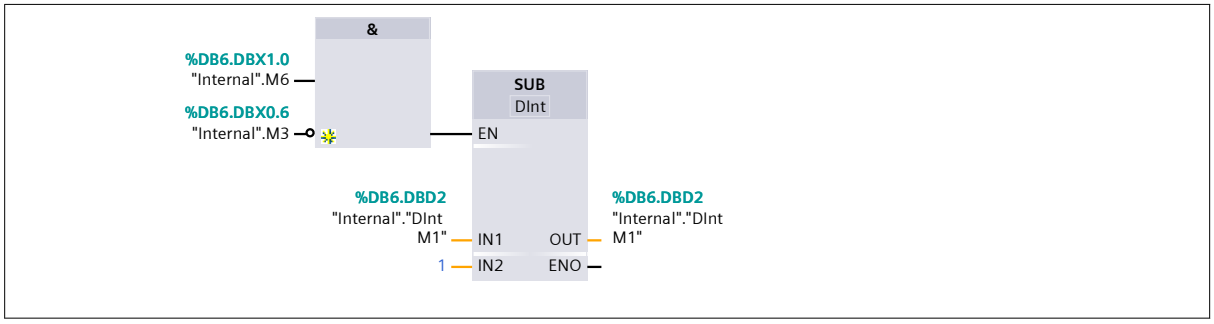


Network 2: Steps_upwards

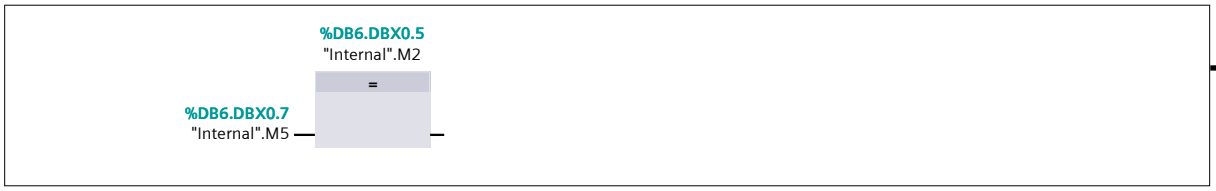
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 6 - 1



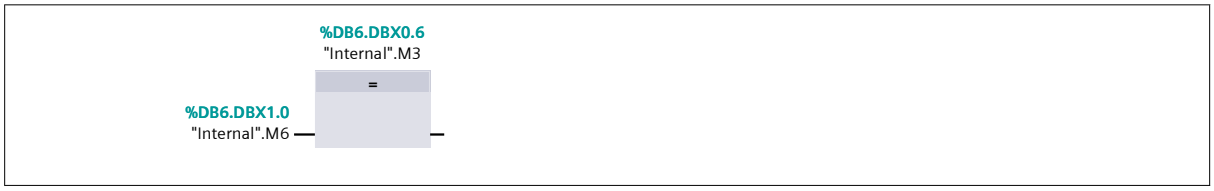
Network 3: Steps_downwords



Network 4: Minne

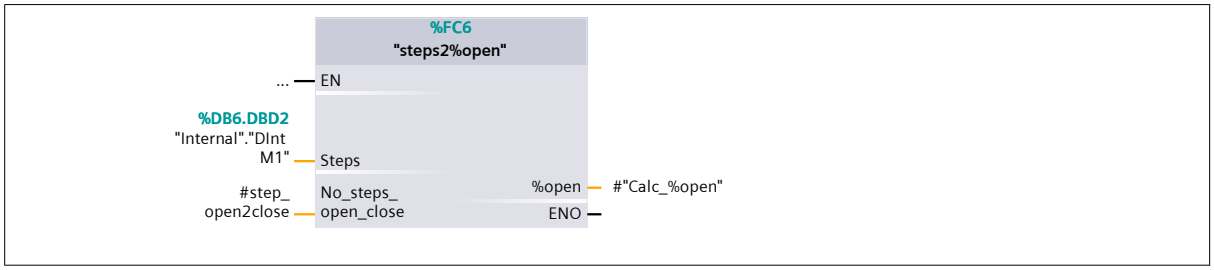


Network 5: Minne

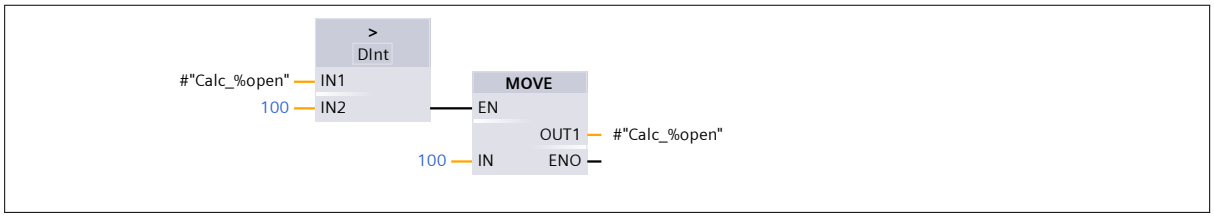


Network 6:

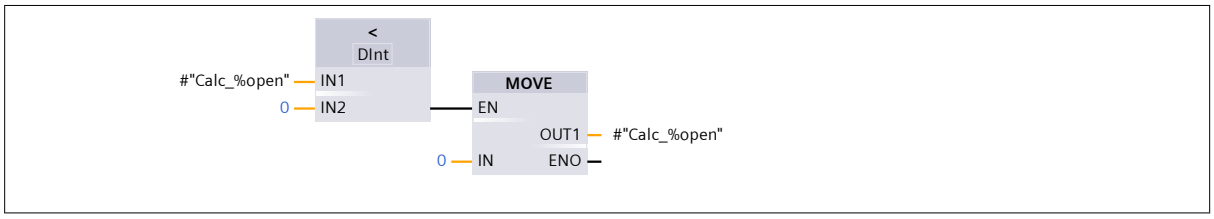
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 6 - 2



Network 7: limit max



Network 8: limit min



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 6 - 3

Program blocks

INT2%open [FC2]

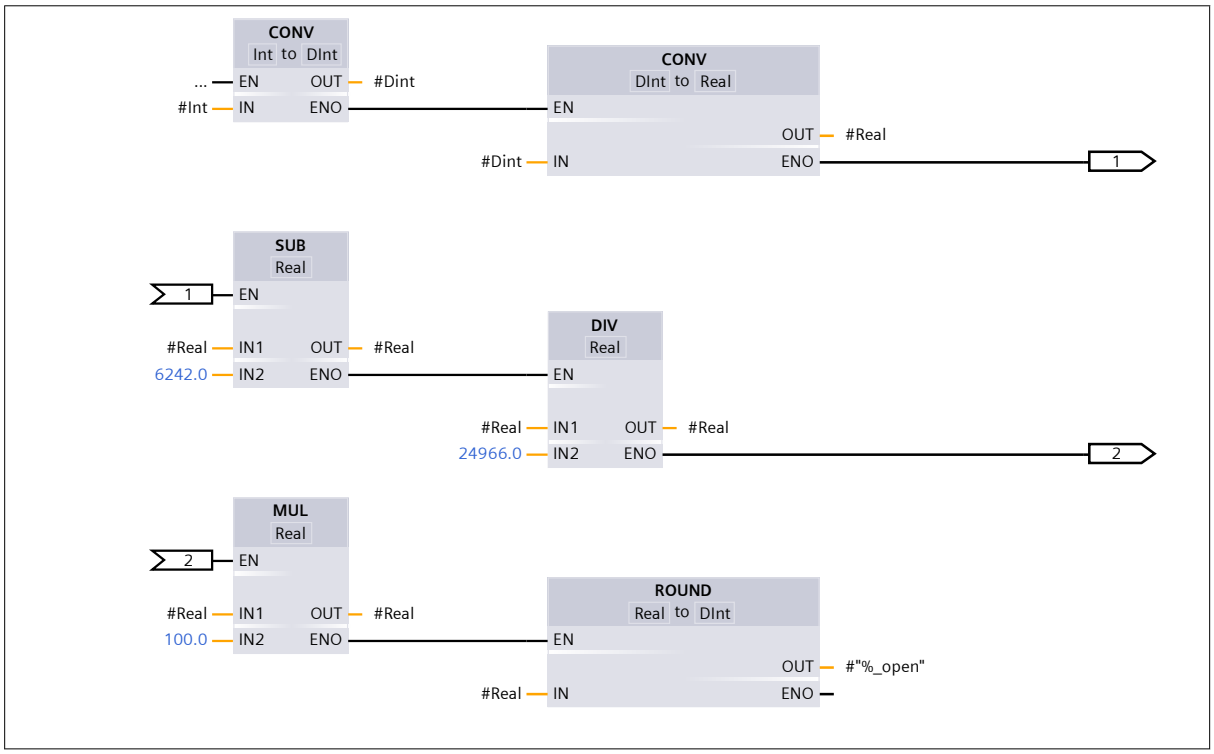
INT2%open Properties			
General			
Name	INT2%open	**Number**	2
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Offset
▼ Input		
Int	Int	
▼ Output		
%_open	DInt	
InOut		
▼ Temp		
Dint	DInt	
Real	Real	
▼ Return		
Ret_Val	Void	

Network 1:

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 7 - 1

Network 1:



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 7 - 2

Program blocks

Int2bar [FC11]

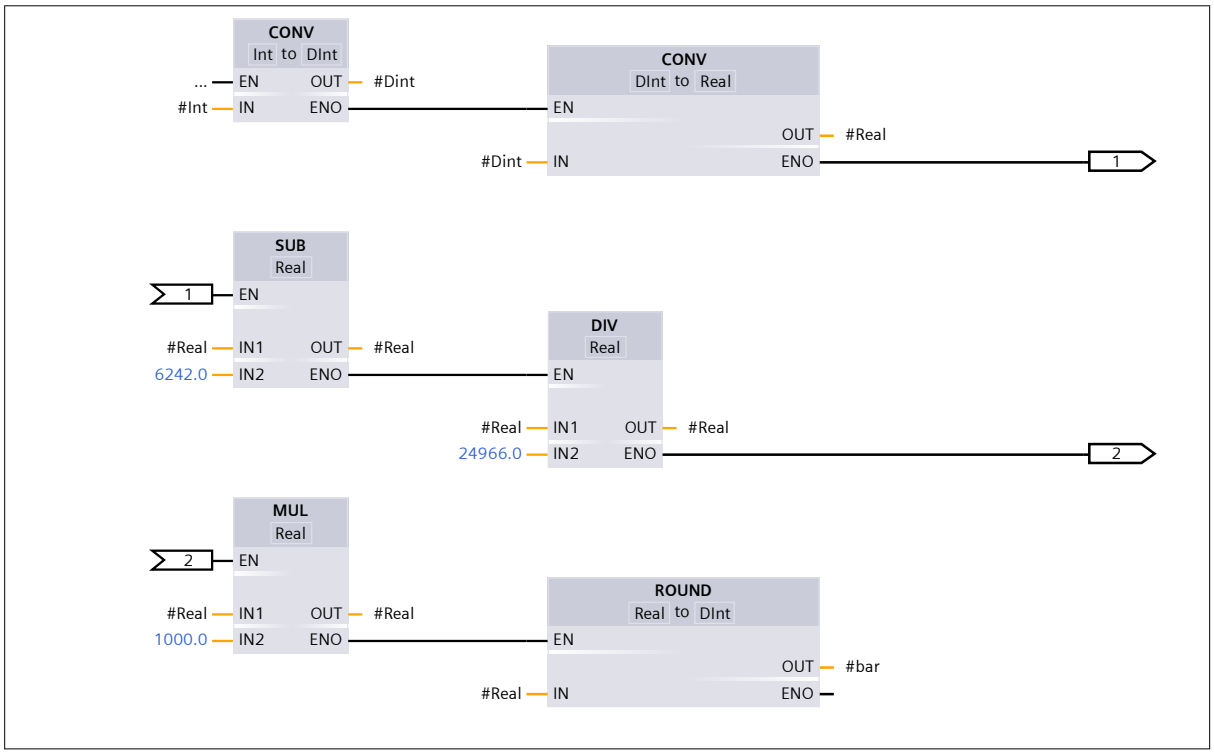
Int2bar Properties			
General			
Name	Int2bar	**Number**	11
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Offset
▼ Input		
Int	Int	
▼ Output		
bar	DInt	
InOut		
▼ Temp		
Dint	DInt	
Real	Real	
▼ Return		
Ret_Val	Void	

Network 1:

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 8 - 1

Network 1:



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 8 - 2

Program blocks

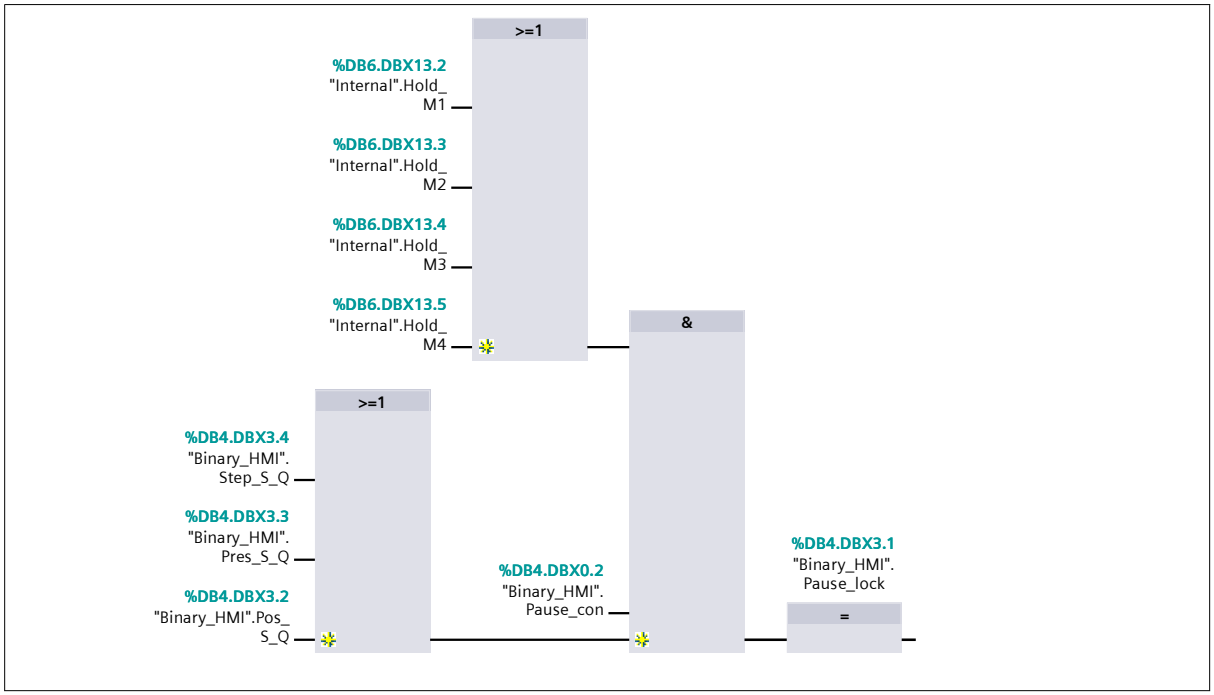
Interlock [FC12]

Interlock Properties			
General			
Name	Interlock	**Number**	12
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Offset
▼ Input		
Action	Bool	
Pause	Bool	
▼ Output		
One	Bool	
Two	Bool	
Three	Bool	
Four	Bool	
Five	Bool	
Pause_1	Bool	
Pause_2	Bool	
Pause_3	Bool	
InOut		
Temp		
▼ Return		
Ret_Val	Void	

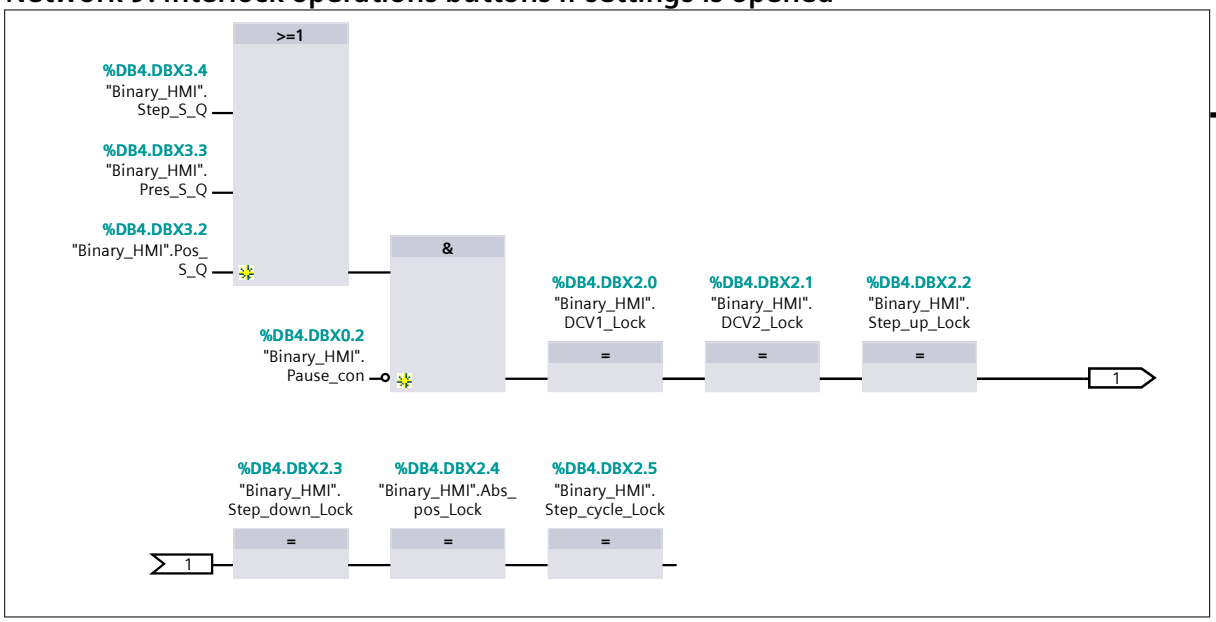
Network 1:

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 9 - 1



Network 9: Interlock operations buttons if settings is opened

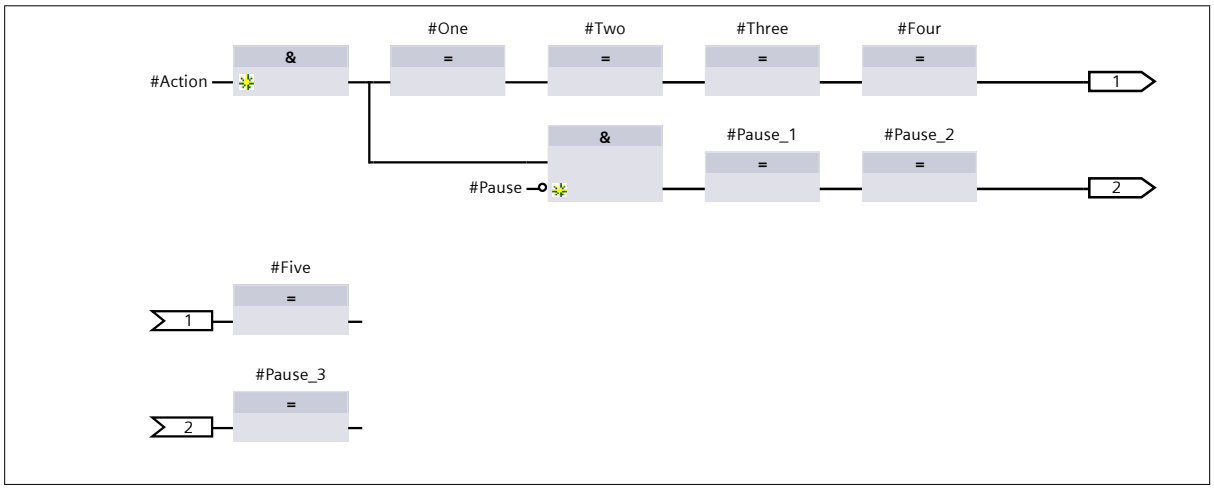
Network 9: Interlock operations buttons if settings is opened



Network 10: Position settings

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 4

Network 1:



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 9 - 2

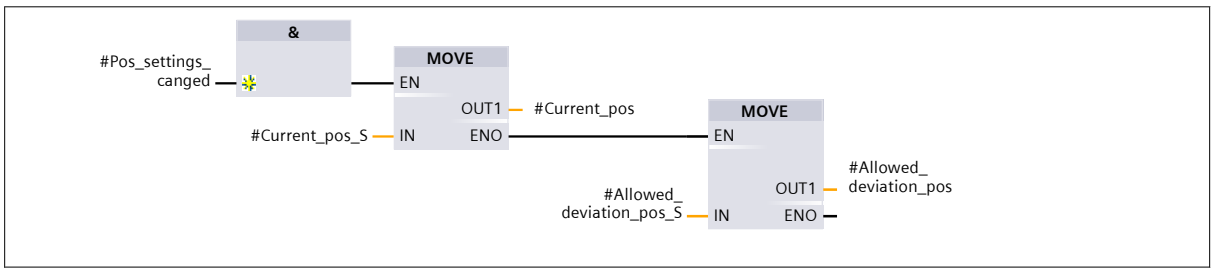
Program blocks

Pos_S [FC10]

Pos_S Properties			
General			
Name	Pos_S	**Number**	10
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

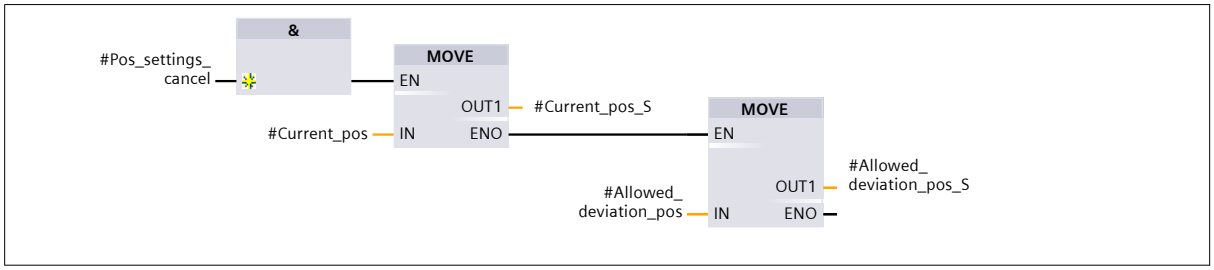
Name	Data type	Offset
▼ Input		
Pos_settings_canged	Bool	
Pos_settings_cancel	Bool	
Output		
▼ InOut		
Current_pos_S	DInt	
Current_pos	DInt	
Allowed_deviation_pos_S	DInt	
Allowed_deviation_pos	DInt	
pos_sensor_disabled_S	Bool	
Pos_sensor_disabled	Bool	
Temp		
▼ Return		
Ret_Val	Void	

Network 1:

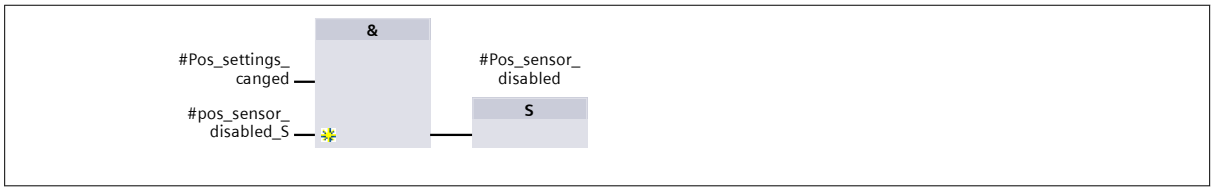


Network 2:

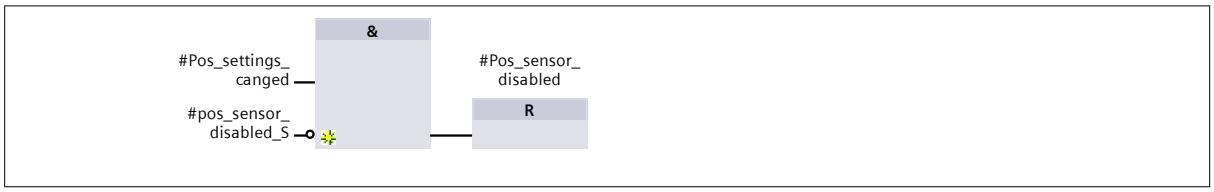
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 10 - 1



Network 3:



Network 4:



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 10 - 2

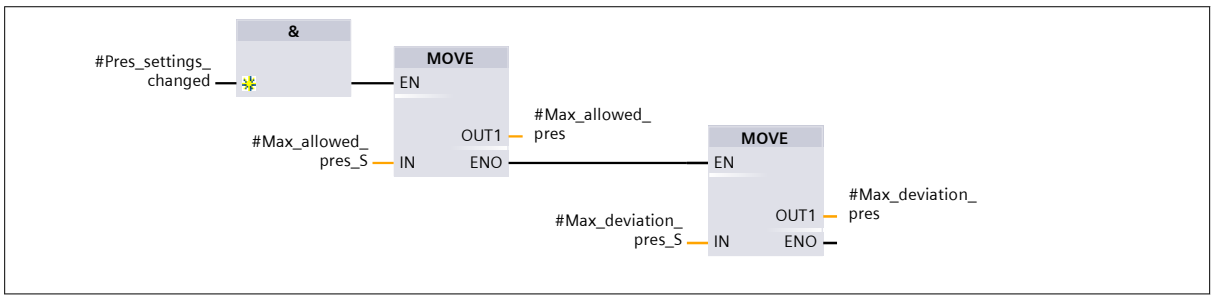
Program blocks

Pres_S [FC9]

Pres_S Properties			
General			
Name	Pres_S	**Number**	9
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

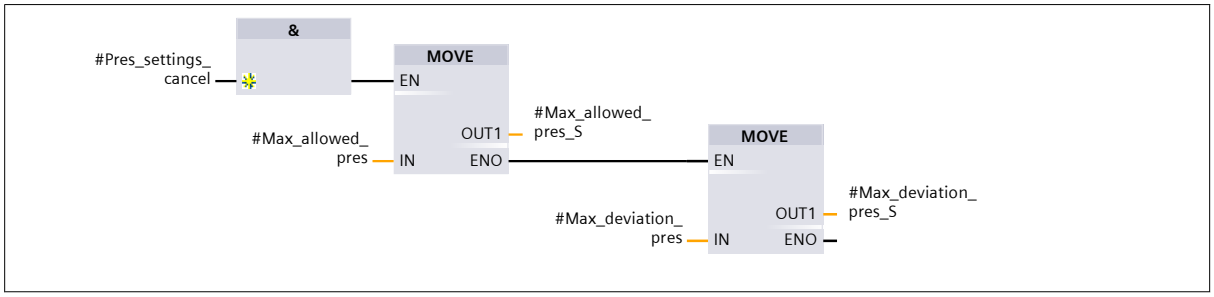
Name	Data type	Offset
▼ Input		
Pres_settings_changed	Bool	
Pres_settings_cancel	Bool	
Output		
▼ InOut		
Max_allowed_pres_S	Int	
Max_deviation_pres_S	Int	
Max_allowed_pres	Int	
Max_deviation_pres	Int	
Temp		
▼ Return		
Ret_Val	Void	

Network 1:



Network 2:

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 11 - 1



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 11 - 2

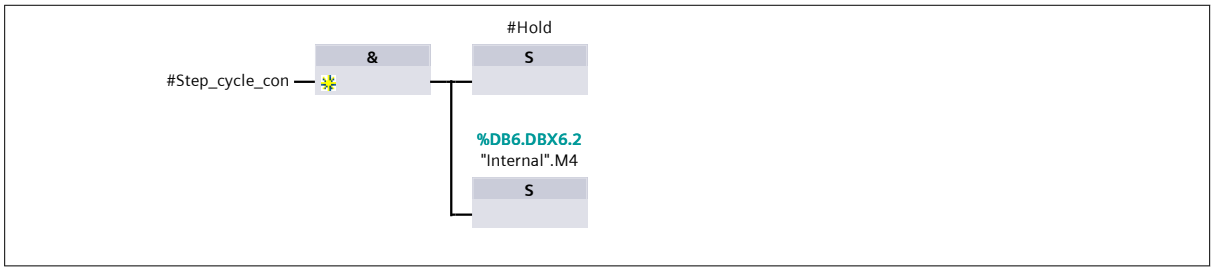
Program blocks

Step_cycle [FC7]

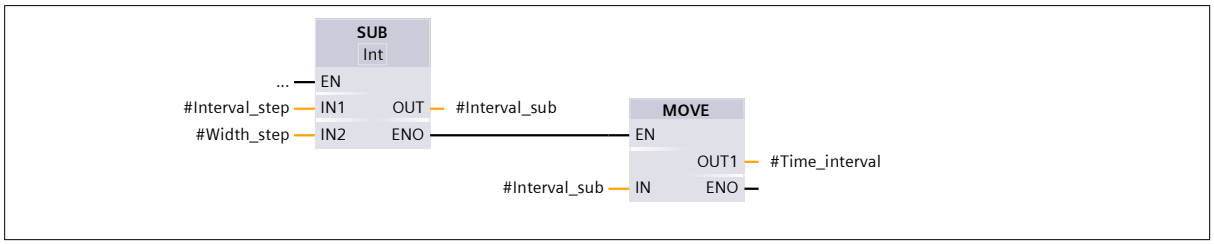
Step_cycle Properties			
General			
Name	Step_cycle	**Number**	7
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Offset
▼ Input		
Calc_pos_%open	DInt	
Sensor_pos_%open	DInt	
Step_cycle_con	Bool	
Interval_step	Int	
Width_step	Int	
Pause_con	Bool	
Pos_sens_dis	Bool	
▼ Output		
Hold	Bool	
Step_up	Bool	
Step_down	Bool	
▼ InOut		
Step_cycles	Int	
▼ Temp		
Actual_pos	DInt	
Interval_sub	Int	
Time_interval	Time	
Time_width	Time	
M1	Bool	
M2	Bool	
Step	Bool	
Closed_pos	Bool	
Open_pos	Bool	
Cycle_no	Int	
Cycle_number	DInt	
Old_closed_pos	Bool	
Desired_cycle no	Int	
Been to zero pos	Bool	
▼ Return		
Ret_Val	Void	

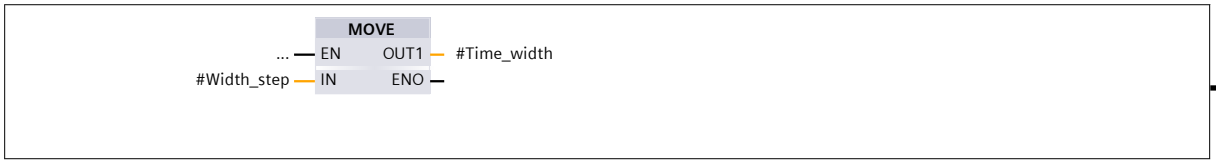
Network 1: Hold



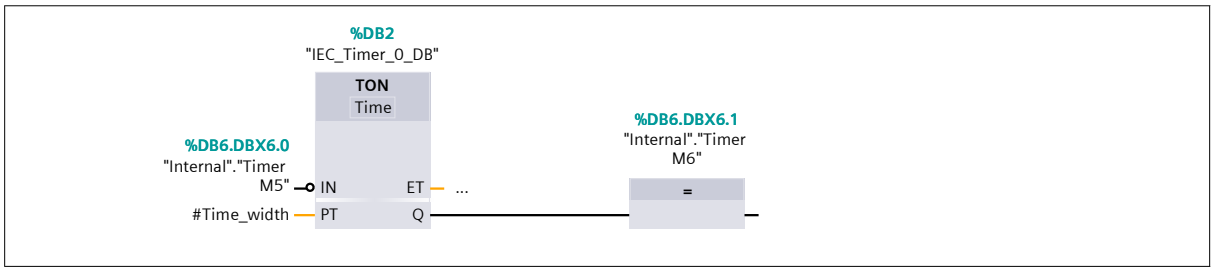
Network 2: finding interval time and converting from int2time



Network 3: Converting from int2time



Network 4: Step Width



Network 5: Step Interval

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
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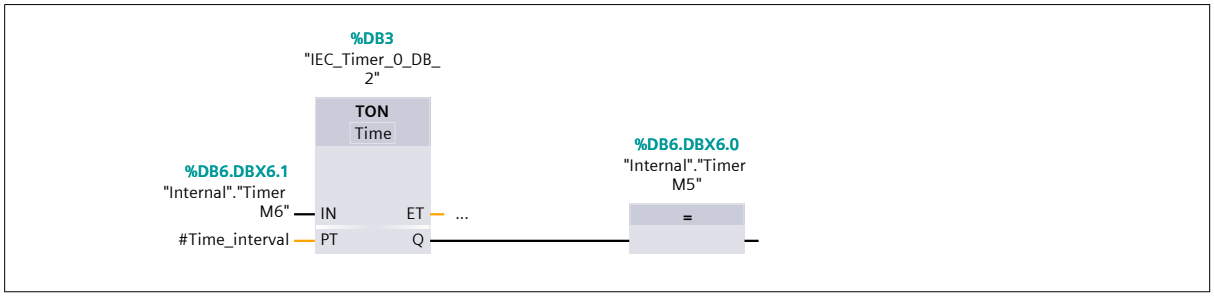
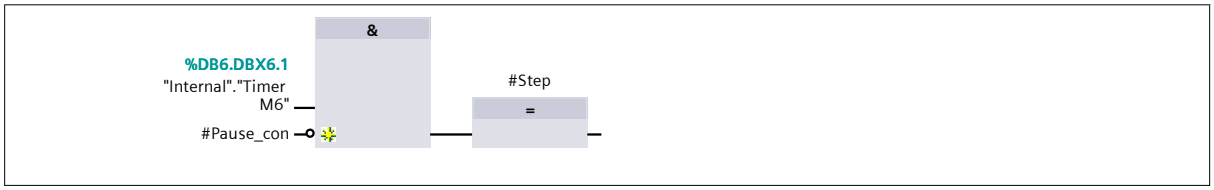
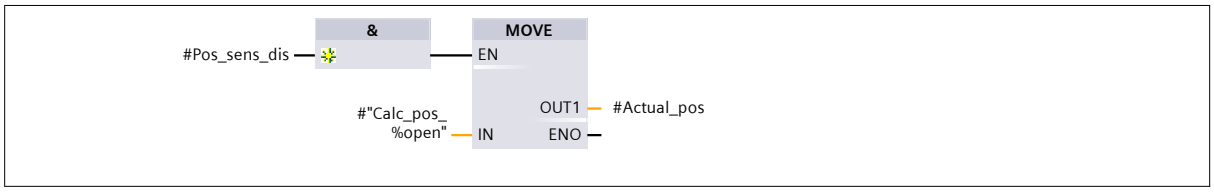


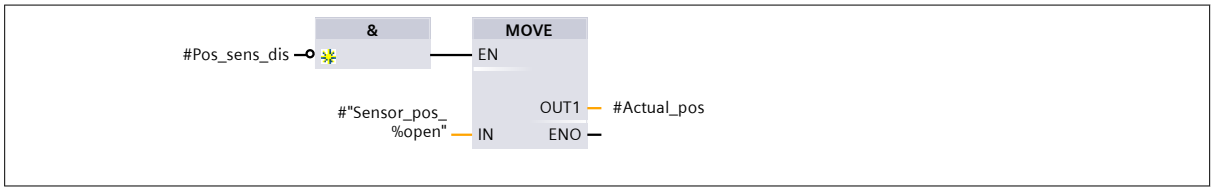
Network 6: Pause function



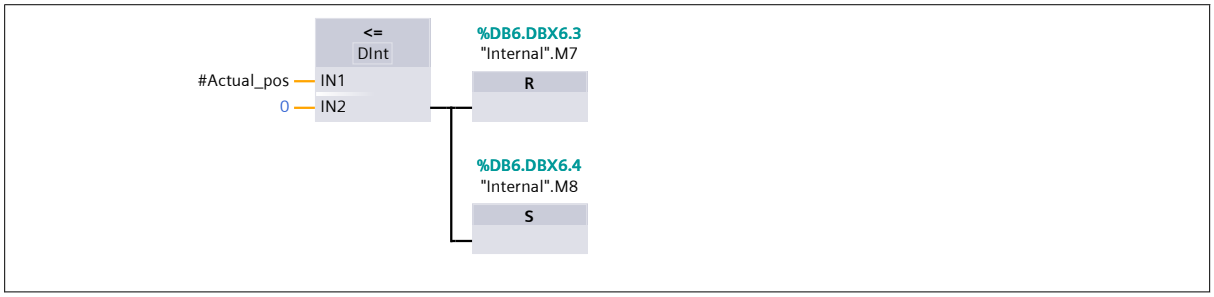
Network 7: Use calculated pos or sensor pos



Network 8: Calculated pos or sensor pos

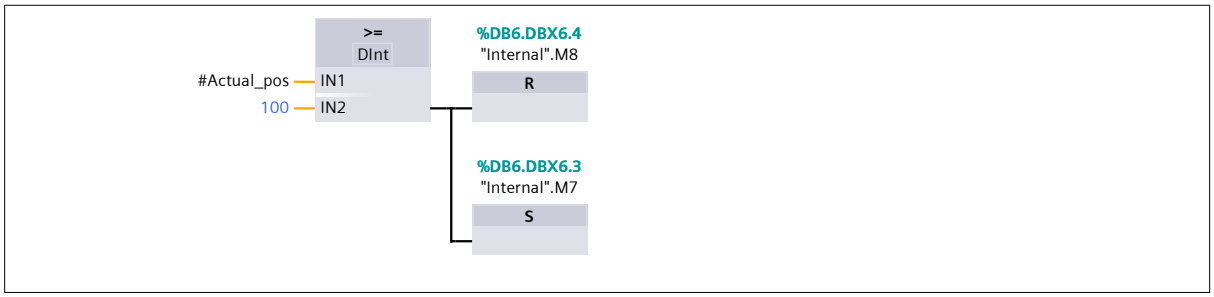


Network 9: Cheking if in zero (start position) position



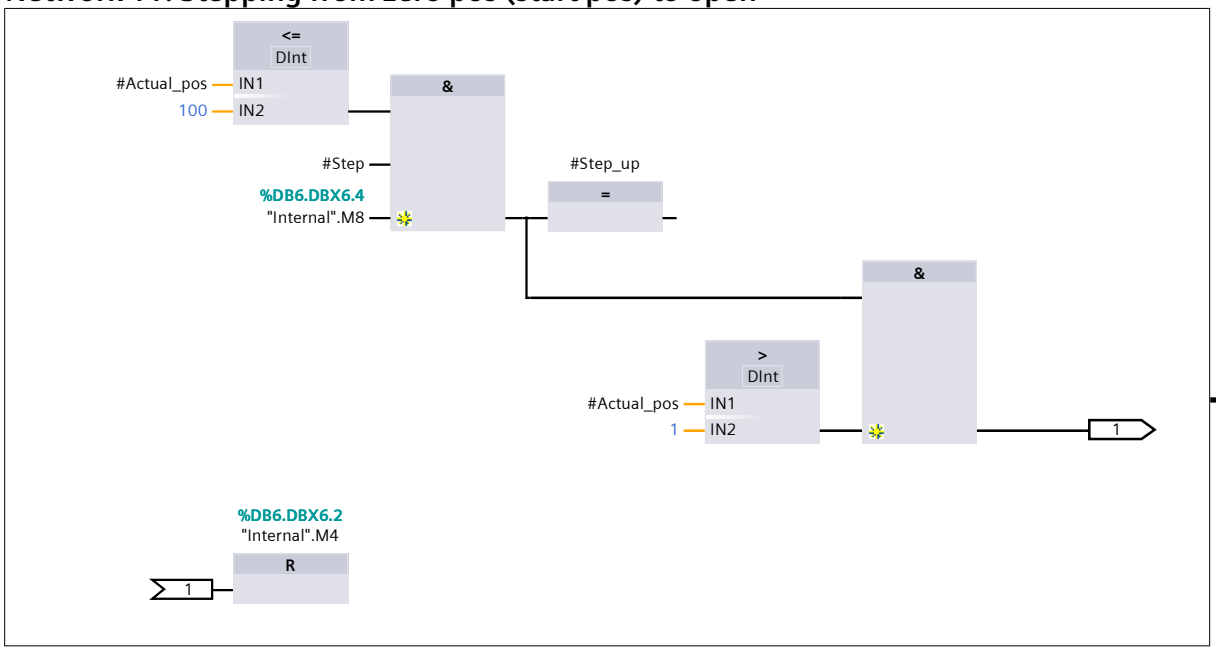
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 12 - 3

Network 10: Cheking if in open position

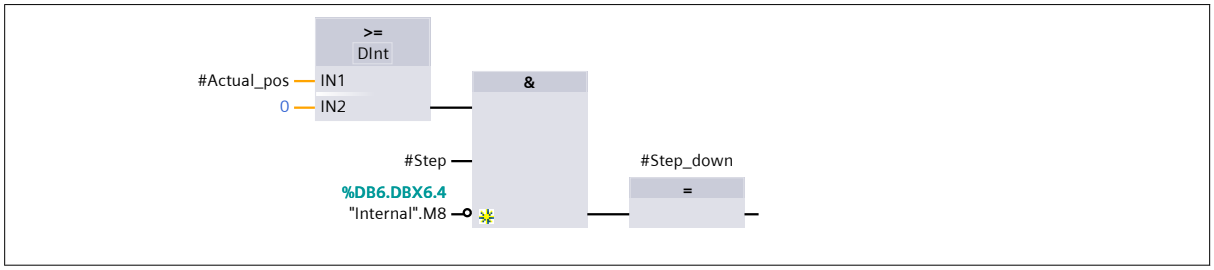


Network 11: Stepping from zero pos (start pos) to open

Network 11: Stepping from zero pos (start pos) to open

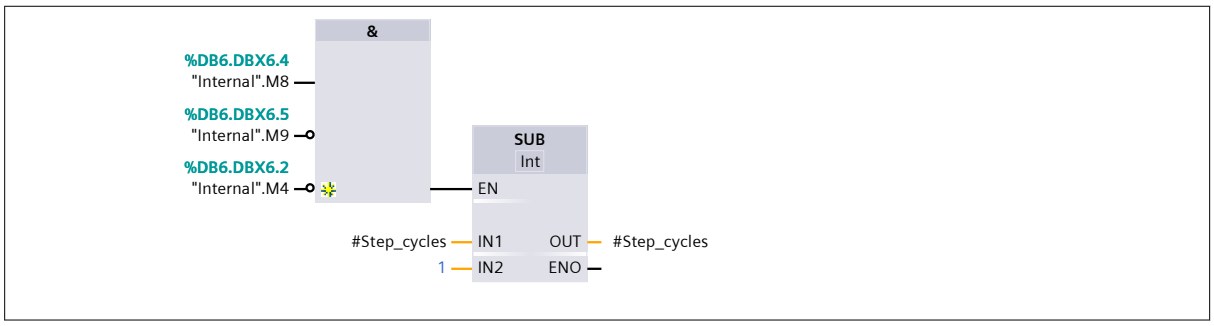


Network 12: Stepping to open to close



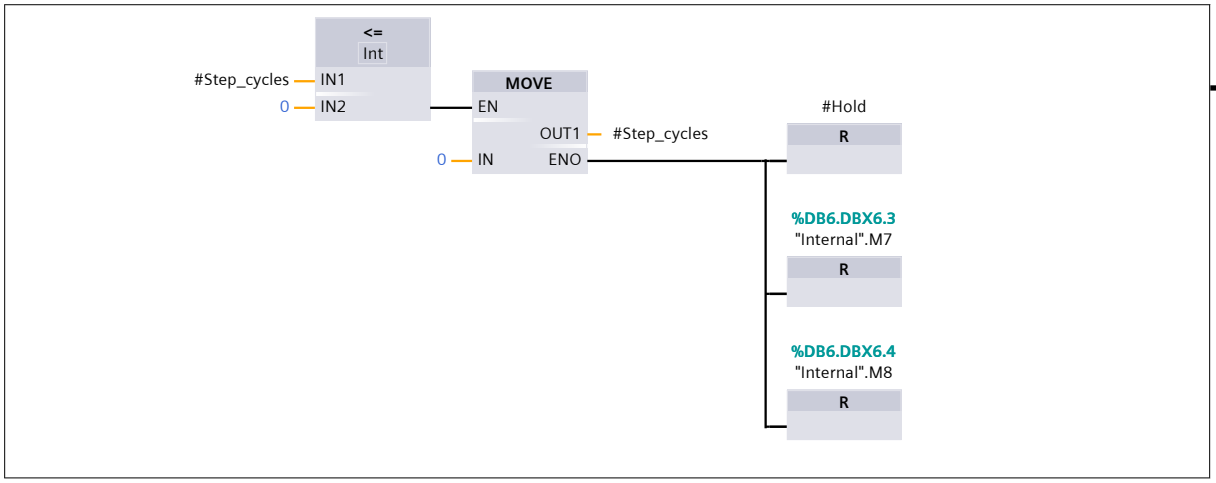
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 12 - 4

Network 13: Counting cycles

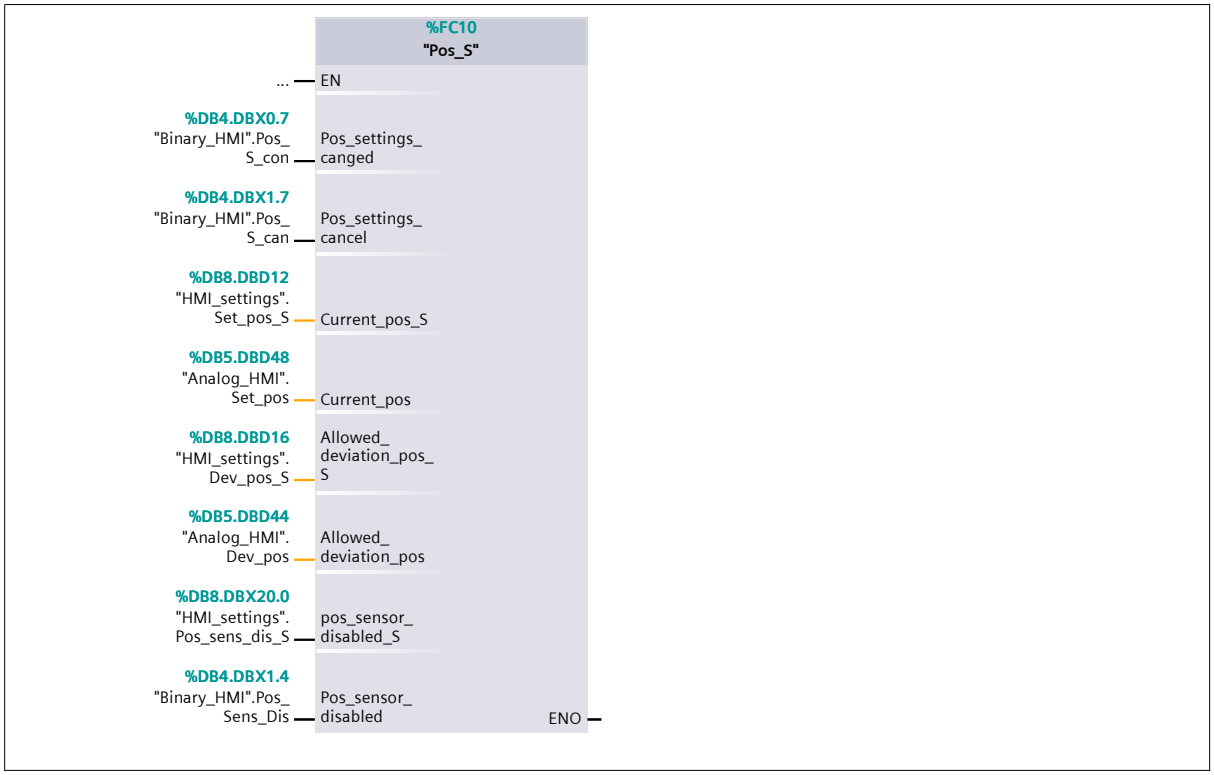


Network 14: Memory

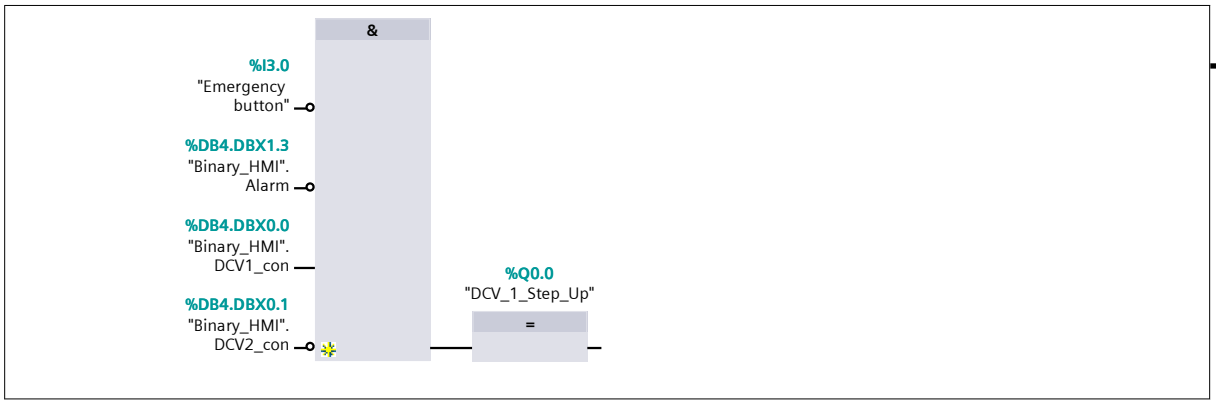
Network 15: Ending cycling



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 12 - 5



Network 11: Open_DCV1_manualy



Network 12: Open_DCV2_manualy

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 5

Program blocks

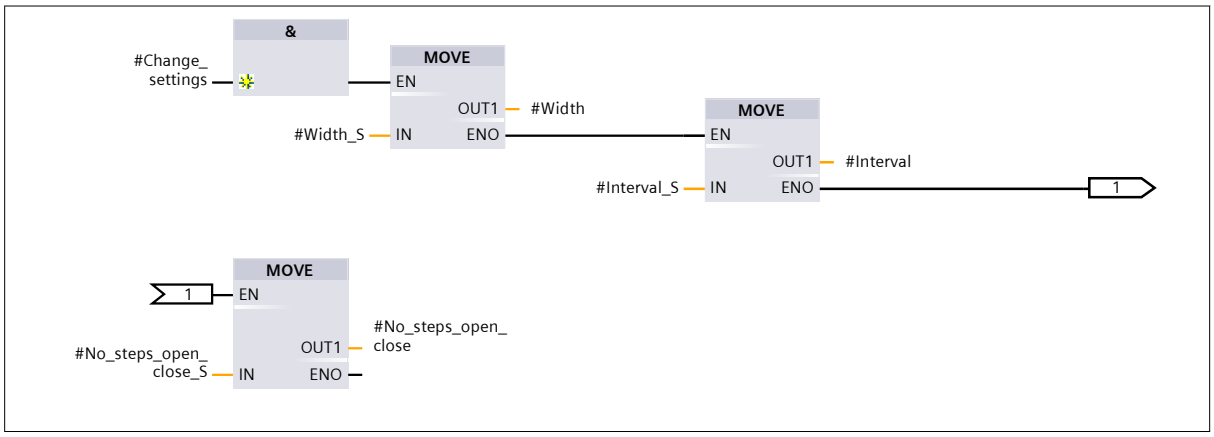
Step_S [FC8]

Step_S Properties			
General			
Name	Step_S	**Number**	8
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Offset
▼ Input		
Change_settings	Bool	
Cancel_settings	Bool	
Output		
▼ InOut		
Width_S	Int	
Interval_S	Int	
No_steps_open_close_S	DInt	
Width	Int	
Interval	Int	
No_steps_open_close	DInt	
Temp		
▼ Return		
Ret_Val	Void	

Network 1:

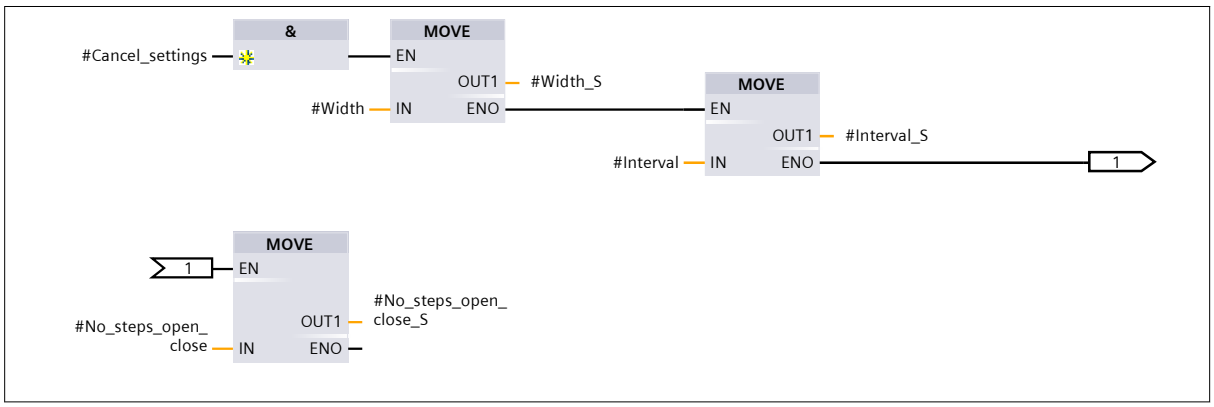
Network 1:



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 13 - 1

Network 2:

Network 2:



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 13 - 2

Program blocks

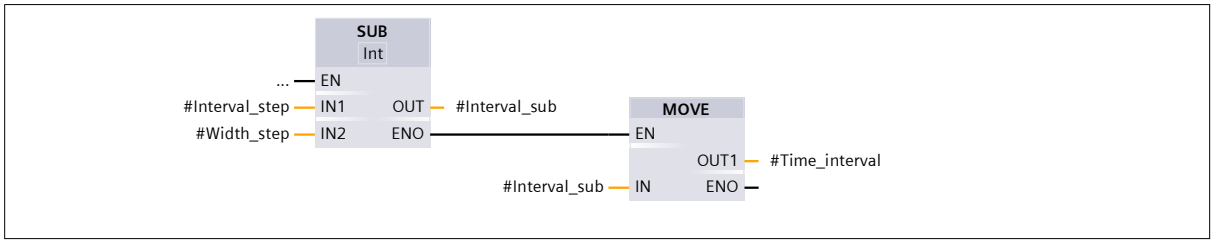
Stepping [FC1]

Stepping Properties			
General			
Name	Stepping	**Number**	1
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

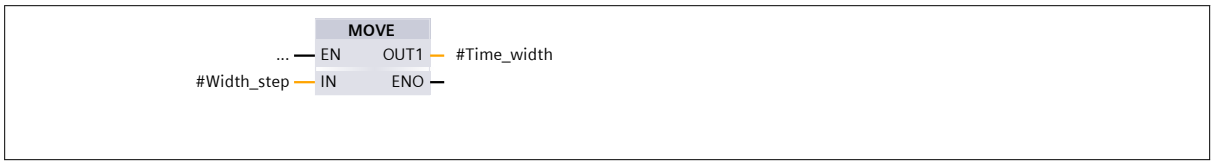
Name	Data type	Offset
▼ Input		
Old_step_value	Int	
Interval_step	Int	
Width_step	Int	
Pause	Bool	
Pos_sens_dis	Bool	
Calc_pos_%open	DInt	
Pos_sens_%open	DInt	
▼ Output		
Step	Bool	
Hold	Bool	
▼ InOut		
New_step_value	Int	
▼ Temp		
M1	Bool	
M3	Bool	
M2	Bool	
Interval_sub	Int	
Time_interval	Time	
M3_old	Bool	
Time_width	Time	
%_open	DInt	
M4	Bool	
▼ Return		
Ret_Val	Void	

Network 1: finding interval time and converting from int2time

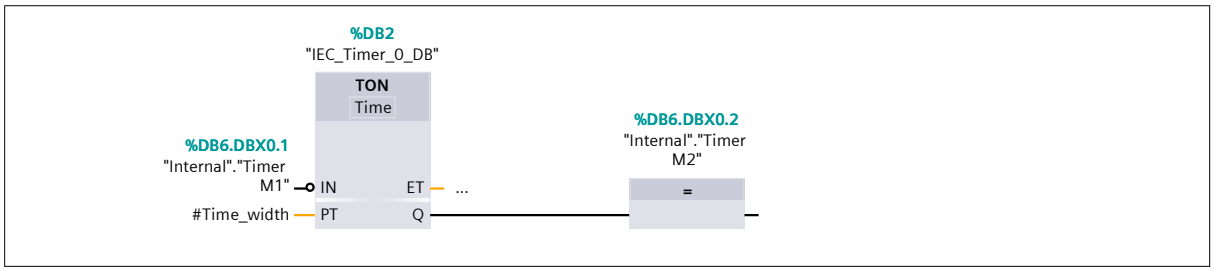
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 14 - 1



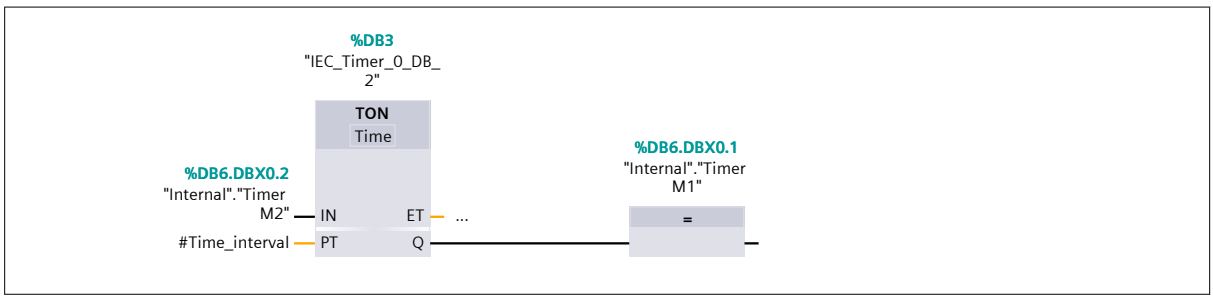
Network 2: Converting from int2time



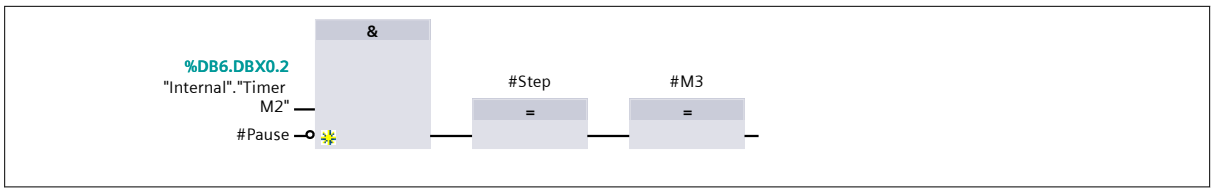
Network 3: Step Width



Network 4: Step Interval

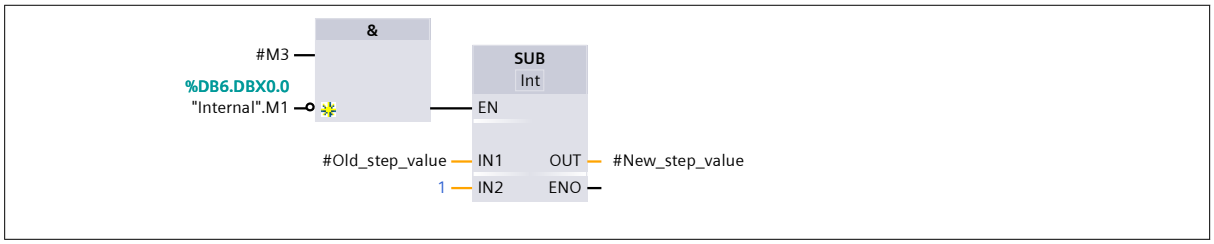


Network 5: Pause function

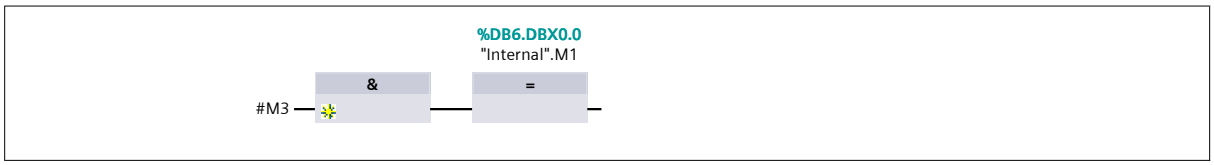


Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 14 - 2

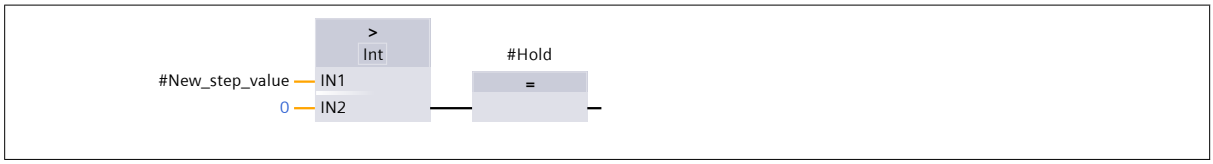
Network 6: Count down when stepping



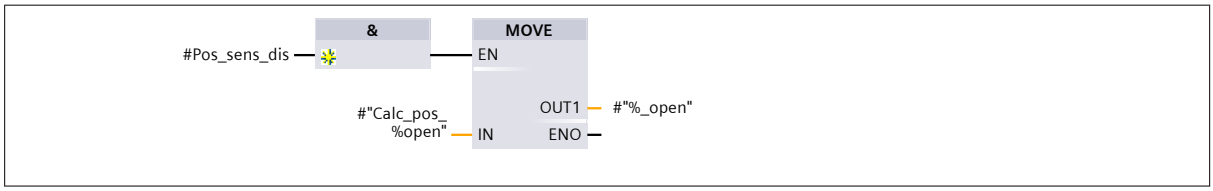
Network 7: Memory for count down



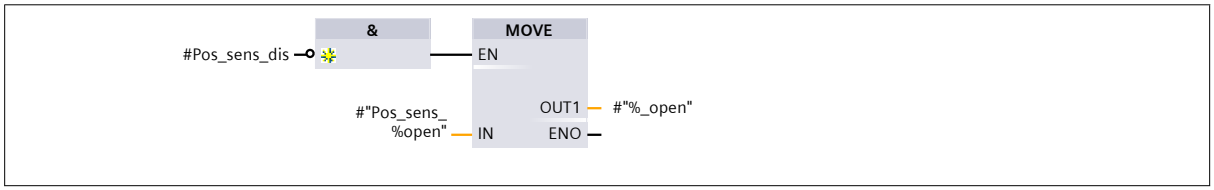
Network 8: Hold bit (Memory)



Network 9: Use calculated pos or sensor pos



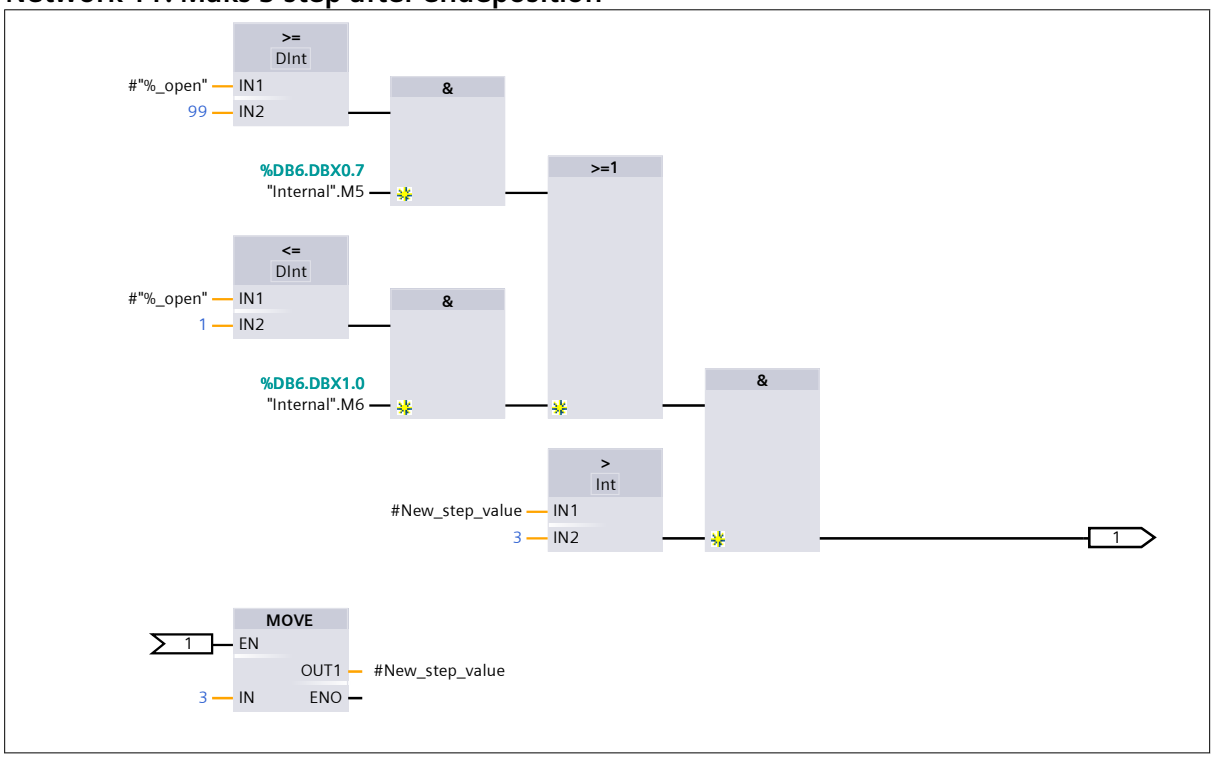
Network 10: Calculated pos or sensor pos



Network 11: Maks 3 step after endeposition

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 14 - 3

Network 11: Maks 3 step after endeposition



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 14 - 4

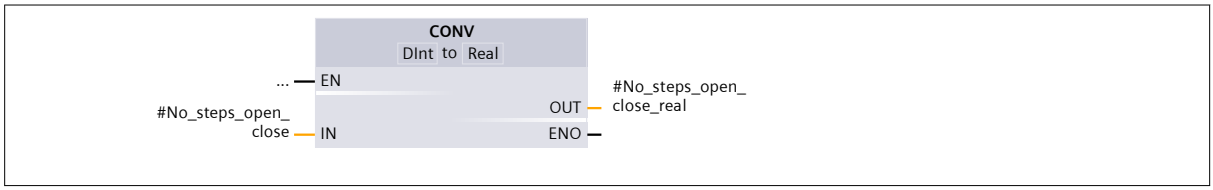
Program blocks

steps2%open [FC6]

steps2%open Properties			
General			
Name	steps2%open	**Number**	6
Type	FC	**Language**	FBD
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Offset
Input		
Steps	DInt	
No_steps_open_close	DInt	
Output		
%open	DInt	
InOut		
Temp		
Steps_real	Real	
No_steps_open_close_real	Real	
%open_real	Real	
Return		
Ret_Val	Void	

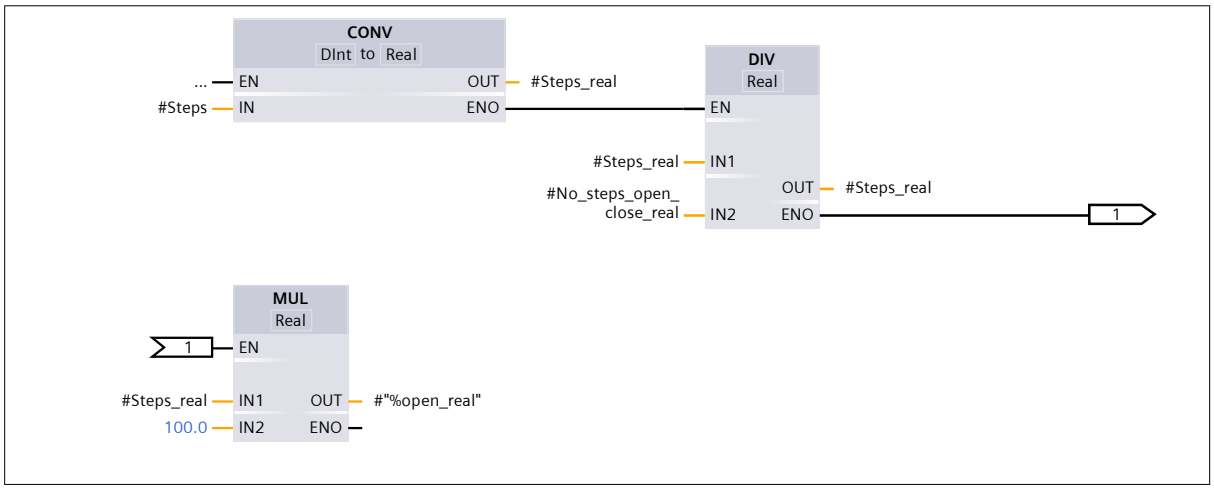
Network 1:



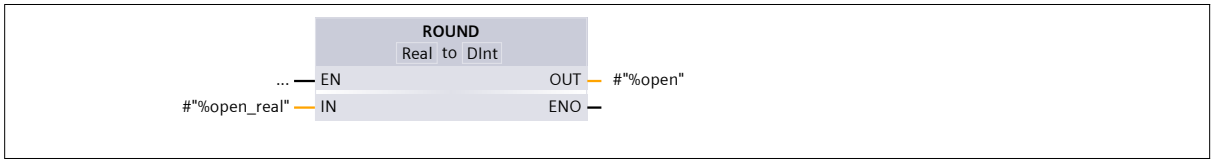
Network 2:

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 15 - 1

Network 2:



Network 3:



Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 15 - 2

Program blocks

Alarm [DB7]

Alarm Properties			
General			
Name	Alarm	**Number**	7
Type	DB	**Language**	DB
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Start value	Retain
▼ Static			
High_pres_A	Bool	false	False
DCV1_pres_A	Bool	false	False
DCV2_pres_A	Bool	false	False
Low_pres_W	Bool	false	False
Max_pos_dev_W	Bool	false	False
Emerg_But_W	Bool	false	False
PT_supply_fail_W	Bool	false	False
PT_step_up_fail_W	Bool	false	False
PT_step_down_fail_W	Bool	false	False
Pos_sens_fail_W	Bool	false	False
Alarm_Window	Bool	false	False
Alarm_detected	Bool	false	False

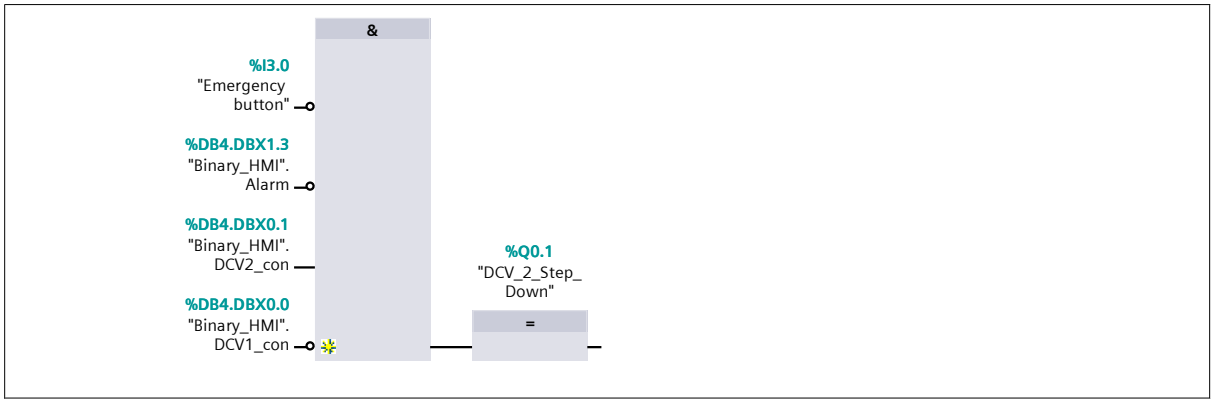
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 16 - 1

Program blocks

Analog_HMI [DB5]

Analog_HMI Properties			
General			
Name	Analog_HMI	**Number**	5
Type	DB	**Language**	DB
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Start value	Retain
▼ Static			
Abs_Pos	DInt	0	True
Max_pres	Int	207	True
Dev_Pres	Int	2	True
Interval_step	Int	2000	True
Width_step	Int	1000	True
steps_open2close	DInt	200	True
Calc_pos_%open	DInt	50	True
Pos_Sens_%open	DInt	50	True
PT_supply_bar	DInt	0	True
PT_open_bar	DInt	0	True
PT_close_bar	DInt	0	True
Set_pos_%open	Int	0	True
Step_down	Int	0	True
Step_up	Int	0	True
Step_cycles	Int	0	True
Dev_pos	DInt	5	True
Set_pos	DInt	50	True



Network 13: Step_up

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 6

Program blocks

Binary_HMI [DB4]

Binary_HMI Properties			
General			
Name	Binary_HMI	**Number**	4
Type	DB	**Language**	DB
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Start value	Retain
▼ Static			
DCV1_con	Bool	false	True
DCV2_con	Bool	false	True
Pause_con	Bool	false	True
Abort_con	Bool	false	True
Step_up_con	Bool	false	True
Step_down_con	Bool	false	True
Step_cycle_con	Bool	false	True
Pos_S_con	Bool	false	True
Step_S_con	Bool	false	True
Pres_S_con	Bool	false	True
Abs_pos_con	Bool	false	True
Alarm	Bool	false	True
Pos_Sens_Dis	Bool	false	True
Step_S_can	Bool	false	True
Pres_S_can	Bool	false	True
Pos_S_can	Bool	false	True
DCV1_Lock	Bool	false	True
DCV2_Lock	Bool	false	True
Step_up_Lock	Bool	false	True
Step_down_Lock	Bool	false	True
Abs_pos_Lock	Bool	false	True
Step_cycle_Lock	Bool	false	True
Step_S_Lock	Bool	false	True
Pres_S_Lock	Bool	false	True
Pos_S_Lock	Bool	false	True
Pause_lock	Bool	false	True
Pos_S_Q	Bool	false	True
Pres_S_Q	Bool	false	True
Step_S_Q	Bool	false	True
Cycle_Q	Bool	false	True

Program blocks

HMI_settings [DB8]

HMI_settings Properties			
General			
Name	HMI_settings	**Number**	8
Type	DB	**Language**	DB
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Start value	Retain
▼ Static			
Interval_step_S	Int	2000	True
Width_step_S	Int	1000	True
open2close_S	DInt	200	True
Max_pres_S	Int	207	True
Max_pres_dev_S	Int	2	True
Set_pos_S	DInt	0	True
Dev_pos_S	DInt	2	True
Pos_sens_dis_S	Bool	false	True

Program blocks

Internal [DB6]

Internal Properties			
General			
Name	Internal	**Number**	6
Type	DB	**Language**	DB
Information			
Title		**Author**	
Comment		**Family**	
Version	0.1	**User-defined ID**	

Name	Data type	Start value	Retain
▼ Static			
M1	Bool	false	True
Timer M1	Bool	false	True
Timer M2	Bool	false	True
Timer M3	Bool	false	True
Timer M4	Bool	false	True
M2	Bool	false	True
M3	Bool	false	True
M5	Bool	false	True
M6	Bool	false	True
DInt M1	DInt	0	True
Timer M5	Bool	false	True
Timer M6	Bool	false	True
M4	Bool	false	True
M7	Bool	false	True
M8	Bool	false	True
M9	Bool	false	True
DInt M2	DInt	0	True
Alarm_M1	Bool	false	True
Alarm_M2	Bool	false	True
Alarm_M3	Bool	false	True
Alarm_M4	Bool	false	True
Alarm_M5	Bool	false	True
Alarm_M6	Bool	false	True
Alarm_M7	Bool	false	True
Alarm_M8	Bool	false	True
Alarm_M9	Bool	false	True
Alarm_M10	Bool	false	True
Hold_M1	Bool	false	True
Hold_M2	Bool	false	True
Hold_M3	Bool	false	True
Hold_M4	Bool	false	True

Program blocks / System blocks / Program resources

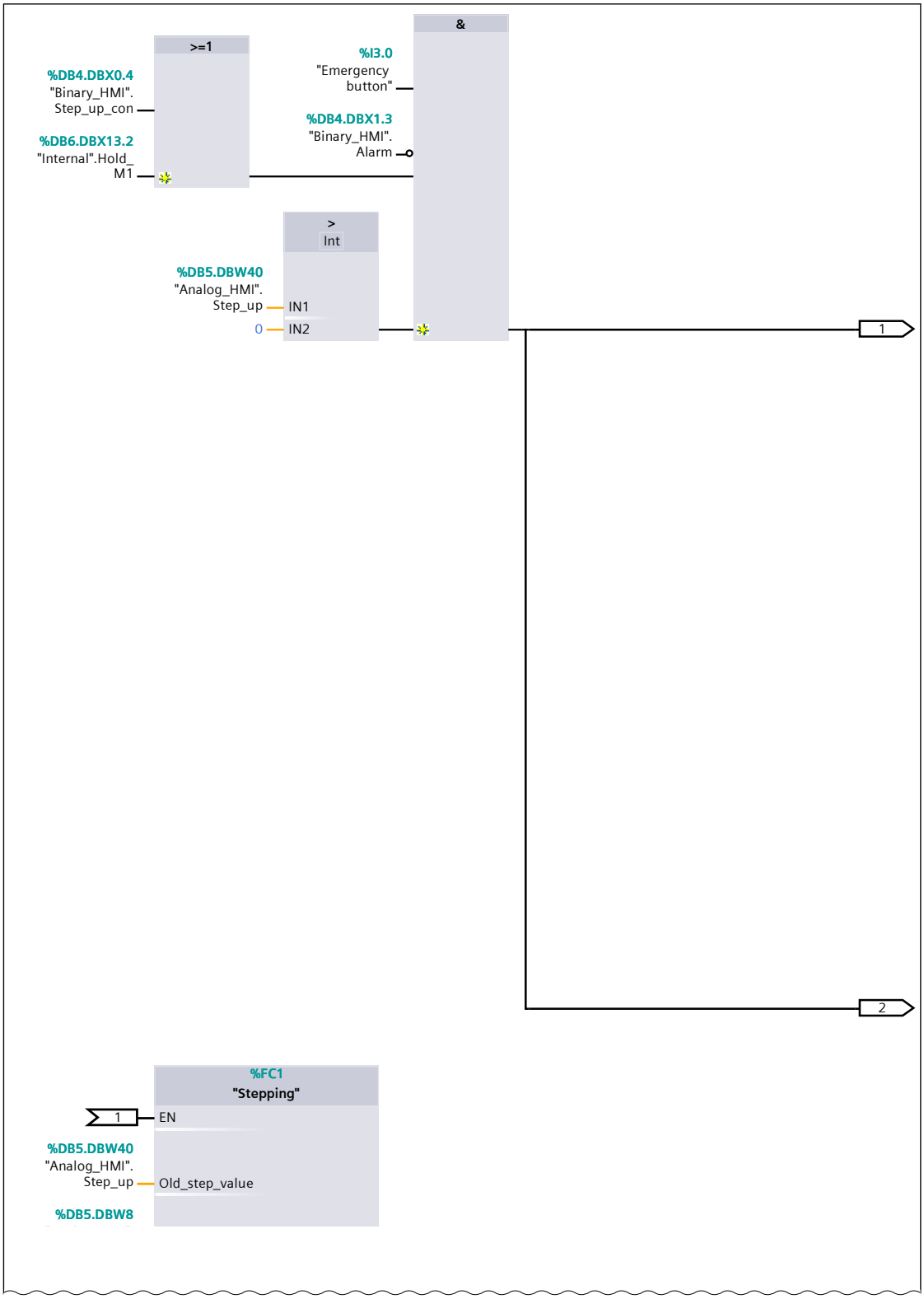
CONT_C [FB41]

CONT_C Properties			
General			
Name	CONT_C	**Number**	41
Type	FB	**Language**	SCL
Information			
Title	continuous PID controller	**Author**	SIMATIC
Comment		**Family**	ICONT
Version	1.5	**User-defined ID**	CONT_C

Name	Data type	Offset	Default value	Retain
▼ Input				
COM_RST	Bool	0.0	FALSE	Set in IDB
MAN_ON	Bool	0.1	TRUE	Set in IDB
PVPER_ON	Bool	0.2	FALSE	Set in IDB
P_SEL	Bool	0.3	TRUE	Set in IDB
I_SEL	Bool	0.4	TRUE	Set in IDB
INT_HOLD	Bool	0.5	FALSE	Set in IDB
I_ITL_ON	Bool	0.6	FALSE	Set in IDB
D_SEL	Bool	0.7	FALSE	Set in IDB
CYCLE	Time	2.0	T#1S	Set in IDB
SP_INT	Real	6.0	0.0	Set in IDB
PV_IN	Real	10.0	0.0	Set in IDB
PV_PER	Word	14.0	W#16#0	Set in IDB
MAN	Real	16.0	0.0	Set in IDB
GAIN	Real	20.0	2.0	Set in IDB
TI	Time	24.0	T#20S	Set in IDB
TD	Time	28.0	T#10S	Set in IDB
TM_LAG	Time	32.0	T#2S	Set in IDB
DEADB_W	Real	36.0	0.0	Set in IDB
LMN_HLM	Real	40.0	100.0	Set in IDB
LMN_LLM	Real	44.0	0.0	Set in IDB
PV_FAC	Real	48.0	1.0	Set in IDB
PV_OFF	Real	52.0	0.0	Set in IDB
LMN_FAC	Real	56.0	1.0	Set in IDB
LMN_OFF	Real	60.0	0.0	Set in IDB
I_ITLVAL	Real	64.0	0.0	Set in IDB
DISV	Real	68.0	0.0	Set in IDB
▼ Output				
LMN	Real	72.0	0.0	Set in IDB
LMN_PER	Word	76.0	W#16#0	Set in IDB
QLMN_HLM	Bool	78.0	FALSE	Set in IDB
QLMN_LLM	Bool	78.1	FALSE	Set in IDB
LMN_P	Real	80.0	0.0	Set in IDB

Name	Data type	Offset	Default value	Retain
LMN_I	Real	84.0	0.0	Set in IDB
LMN_D	Real	88.0	0.0	Set in IDB
PV	Real	92.0	0.0	Set in IDB
ER	Real	96.0	0.0	Set in IDB
InOut				
▼ Static				
sInvAlt	Real	100.0	0.0	Set in IDB
sIanteilAlt	Real	104.0	0.0	Set in IDB
sRestInt	Real	108.0	0.0	Set in IDB
sRestDif	Real	112.0	0.0	Set in IDB
sRueck	Real	116.0	0.0	Set in IDB
sLmn	Real	120.0	0.0	Set in IDB
sbArwHLmOn	Bool	124.0	FALSE	Set in IDB
sbArwLLmOn	Bool	124.1	FALSE	Set in IDB
sbILimOn	Bool	124.2	TRUE	Set in IDB
▼ Temp				
Hvar	Real	0.0		
rCycle	Real	4.0		
Diff	Real	8.0		
Istwert	Real	12.0		
ErKp	Real	16.0		
rTi	Real	20.0		
rTd	Real	24.0		
rTmLag	Real	28.0		
Panteil	Real	32.0		
Ianteil	Real	36.0		
Danteil	Real	40.0		
Verstaerk	Real	44.0		
RueckDiff	Real	48.0		
RueckAlt	Real	52.0		
dLmn	Real	56.0		
gf	Real	60.0		
rVal	Real	64.0		

Network 13: Step_up (1.1 / 2.1)



2.1 (page 1 - 8)

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
Operator	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 7

Default tag table_1 [10]

PLC tags

PLC tags				
	Name	Data type	Address	Retain
	Tag_1	Bool	%M0.7	
	Tag_2	Bool	%M0.4	
	Tag_3	Bool	%M0.3	
	Tag_4	Int	%IW352	
	Tag_9	DWord	%MD3	
	Tag_10	Real	%MD4	
	Tag_11	DInt	%MD5	
	Tag_12	Real	%MD6	
	Tag_13	Int	%IW354	
	Tag_5	Counter	%C1	

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 1

PLC_Input [6]

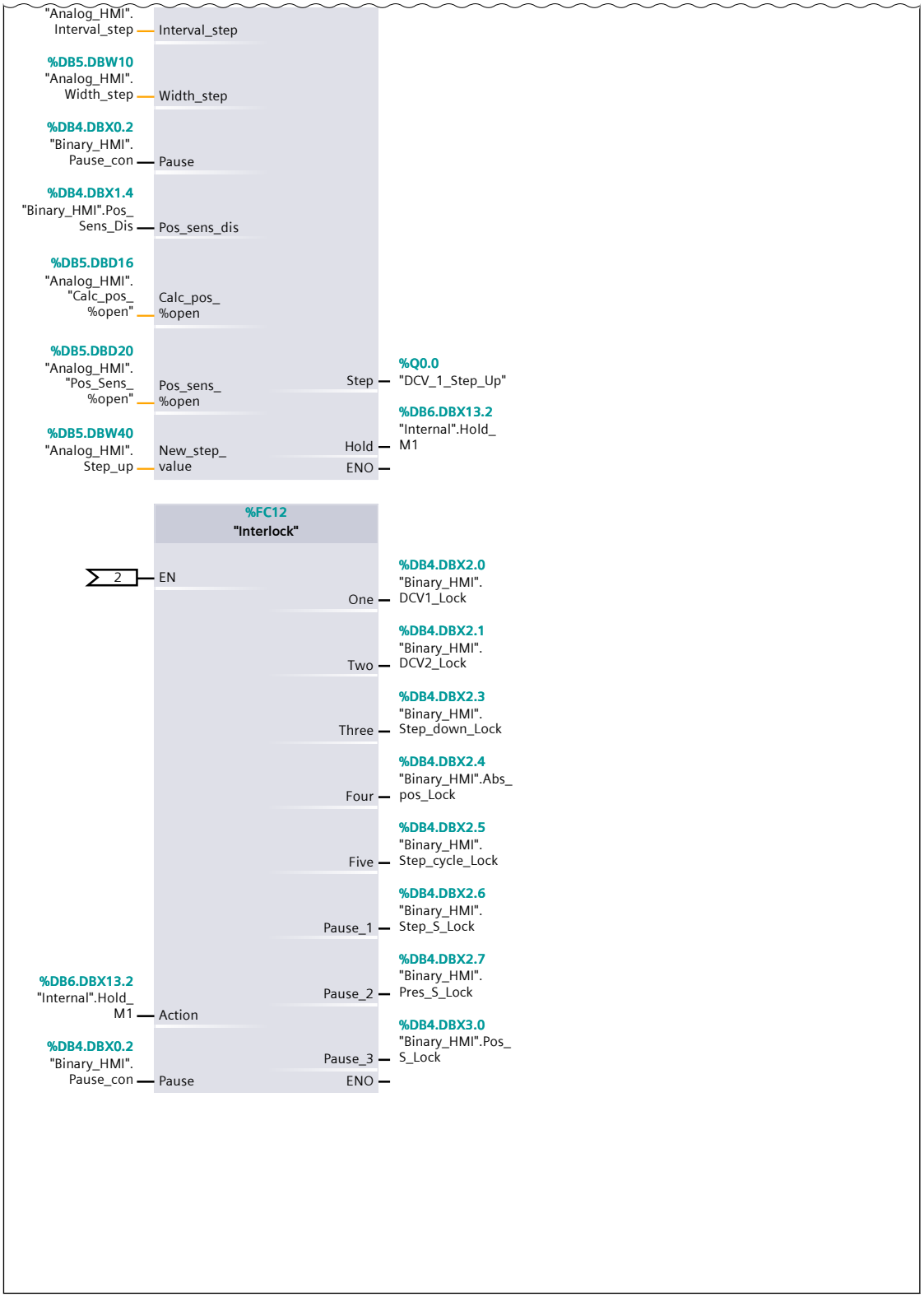
PLC tags

PLC tags				
	Name	Data type	Address	Retain
	Emergency button	Bool	%I3.0	
	PT_Supply	Int	%IW752	
	PT_Step_Up	Int	%IW754	
	PT_Step_Down	Int	%IW756	
	Pos_sensor	Int	%IW758	
	Test tag input	Int	%IW760	

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 1

Network 13: Step_up (2.1 / 2.1)

1.1 (page 1 - 7)



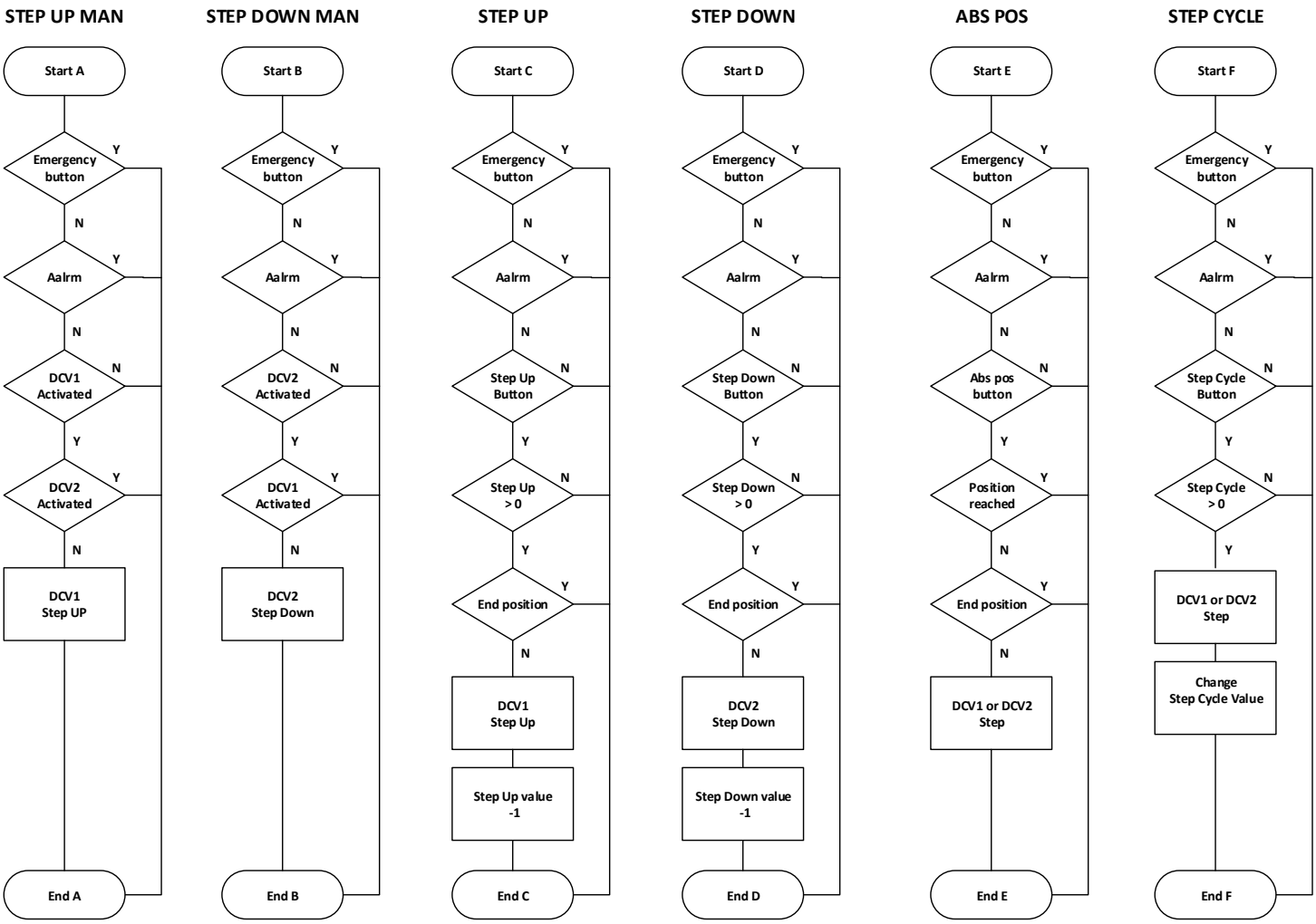
Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 8

PLC_Output [2]

PLC tags

PLC tags				
	Name	Data type	Address	Retain
	DCV_1_Step_Up	Bool	%Q0.0	
	DCV_2_Step_Down	Bool	%Q0.1	

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 1


STEP UP MAN
Start A
Emergency button
Y
N
Aalrm
Y
N
DCV1 Activated
N
Y
DCV2 Activated
Y
N
DCV1 Step UP
End A
STEP DOWN MAN
Start B
Emergency button
Y
N
Aalrm
Y
N
DCV2 Activated
N
Y
DCV1 Activated
Y
N
DCV2 Step Down
End B
STEP UP
Start C
Emergency button
Y
N
Aalrm
Y
N
Step Up Button
N
Y
Step Up > 0
N
Y
End position
Y
N
DCV1 Step Up
Step Up value -1
End C
STEP DOWN
Start D
Emergency button
Y
N
Aalrm
Y
N
Step Down Button
N
Y
Step Down > 0
N
Y
End position
Y
N
DCV2 Step Down
Step Down value -1
End D
ABS POS
Start E
Emergency button
Y
N
Aalrm
Y
N
Abs pos button
N
Y
Position reached
Y
N
End position
Y
N
DCV1 or DCV2 Step
End E
STEP CYCLE
Start F
Emergency button
Y
N
Aalrm
Y
N
Step Cycle Button
N
Y
Step Cycle > 0
N
Y
DCV1 or DCV2 Step
Change Step Cycle Value
End F

1 2 3 4

A B C D E F

Network 14: Step_down

Owner	Project name PLC_CVWT_rev23_complete		Date 5/16/2014
	Project Path E:\Users\Bjorn\Dropbox\Masteroppgave\Code_Complete\PLC_CVWT_rev23_complete		
Operator	Location		
Designed By	Description 1st		
Checked By	Description 2nd	Language nb-NO	
Approved By	1st View	Version	Sheet 1 - 9

Appendix D

Minutes of Meeting

Minutes of Meeting (MOM)

Project:	Production Choke Valve - GE Oil&Gas
Student:	Bjørn André Lia
Date:	30.01.2014
Time:	10.00-11.00
Attendees:	Bjørn André Lia Ziya Heydarov Trond Flaa Edmary Altamiranda

Actions item review	Item details
Work on CVWT design/specification	On schedule
Present draft of CVWT specification for Ziya Hedarov	On schedule

Agenda item	Item details
Questions regarding the project	Need to have: PC-controling DCV valves. Pressure rated up to 5,000psi Nice to have: Portable rack whit wheels, pressure rated up to 10,000psi. Testing conditions: dry, atmospheric pressure, temperature between 5-30C storage -10-65C How the tool should operate: Adjustable parameters such as length of steps in time, number of steps, and number of cycles. Another meeting will be necessary to specify all details. Platforms as starting point: N/A Tool restrictions: None given regarding size and weight, as small as possible and preferable, portable or on wheels. Hydraulic: HPU in workshop can be used, connections to choke valve is done by a custom made tool. Other connections are standard. Use GE`s DCV if possible. Look in ePIMS for manifold. Electrical: Interface toward 110V and 220V Software: Logging of data needed. Parameters are valve dependent and must therefore be able to update. Will be discussed in details in a separate meeting at a later time.

Other	Engineering Workstation with simple topology is preferred.

New action items	Responsible	Due Date
Work with design specification.	BAL	12/02-2014
Engineering Design Review	BAL	12/02-2014

Minutes of Meeting (MOM)

Project:	Production Choke Valve - GE Oil&Gas
Student:	Bjørn André Lia
Date:	20.01.2014
Time:	13.00-14.30
Attendees:	Bjørn André Lia, Stig Andre Torkelsen (Supervisor GE Oil&Gas) Jens Jensen Trond Flaa Morten Kjeld Ebbesen-Telephone (Supervisor UIA)

Actions item review	Item details
N/A	

Agenda item	Item details
Questions regarding the project.	N/A
Gantt chart	N/A
Other	Discussion regarding the workload and whether this task was suitable for a Master Thesis or not. As a result a dynamic model of the CVWT shall be created in SimulationX and the control system shall be tested on this model through a HIL setup.

New action items	Responsible	Due Date
Start working on CVWT design/specification. Get answers on questions from Meeting Agenda from 20.01.2014.	BAL	ASAP
Present draft of CVWT specifications for Ziya Hedarov.	BAL	ASAP

Meeting Agenda

Project:	Production Choke Valve - GE Oil&Gas
Student:	Bjørn André Lia
Date:	20.01.2014
Time:	13.00-14.30
Attendees:	Bjørn André Lia, Stig Andre Torkelsen (Supervisor GE Oil&Gas) Jens Jensen

Actions from last meeting	Responsible	Due Date
NA		

Agenda item	Presenter	Time [min]

Questions regarding the project
• Expected outcome (Nice to have/Need to have)
  ○ Engineering
  ○ Workshop
• Who is the end user?
• Testing conditions?
• How should the tool operate? Equal to the subsea control unit?
• Is there any platform that can be used as a starting point? (Software, hardware)
• Tool restrictions:
  ○ Size?
  ○ Weight?
  ○ Portable?
  ○ Cost?
  ○ Quality (Working hours)?
  ○ Materials?
  ○ Flexibility?
  ○ Accuracy?
  ○ Reliability?
  ○ Design?
• Hydraulic:
  ○ Connections/pressure/flow, is it valve dependent?
• Electrical
  ○ Connections/number of sensors, is it valve dependent?
	BAL	40

• Software
  ○ How advanced should it be?
  ○ How automated?
  ○ Manual override?
  ○ User interface?
  ○ Storing information?
  ○ Use of stored information?
• Suggestions to analysis/optimization part of project?		

Presentation and discussion of Gantt chart	BAL	10
Other	ALL	10

Attached documents: Project text, Gantt chart.

Minutes of Meeting (MOM)

Project:	Production Choke Valve - GE Oil&Gas
Student:	Bjørn André Lia
Date:	30.01.2014
Time:	10.00-11.00
Attendees:	Bjørn André Lia Ziya Heydarov Trond Flaa Edmary Altamiranda

Actions item review	Item details
Work on CVWT design/specification	On schedule
Present draft of CVWT specification for Ziya Hedarov	On schedule

Agenda item	Item details
Questions regarding the project	Need to have: PC-controling DCV valves. Pressure rated up to 5,000psi Nice to have: Portable rack whit wheels, pressure rated up to 10,000psi. Testing conditions: dry, atmospheric pressure, temperature between 5-30C storage -10-65C How the tool should operate: Adjustable parameters such as length of steps in time, number of steps, and number of cycles. Another meeting will be necessary to specify all details. Platforms as starting point: N/A Tool restrictions: None given regarding size and weight, as small as possible and preferable, portable or on wheels. Hydraulic: HPU in workshop can be used, connections to choke valve is done by a custom made tool. Other connections are standard. Use GE`s DCV if possible. Look in ePIMS for manifold. Electrical: Interface toward 110V and 220V Software: Logging of data needed. Parameters are valve dependent and must therefore be able to update. Will be discussed in details in a separate meeting at a later time.

Other	Engineering Workstation with simple topology is preferred.

New action items	Responsible	Due Date
Work with design specification.	BAL	12/02-2014
Engineering Design Review	BAL	12/02-2014

Meeting Agenda

Project:	Production Choke Valve - GE Oil&Gas
Student:	Bjørn André Lia
Date:	30.01.2014
Time:	10.00-11.00
Attendees:	Bjørn André Lia, Ziya Heydarov

Actions from last meeting	Responsible	Due Date
Work on CVWT design/specification	BAL	NA
Present draft of CVWT specifications for Ziya Hedarov.	BAL	ASAP

Agenda item	Presenter	Time [min]
Questions regarding the project	BAL	20
Present draft of CVWT specification	BAL	20
Other	BAL	20

Minutes of Meeting (MOM)

Project:	Production Choke Valve - GE Oil&Gas
Student:	Bjørn André Lia
Date:	30.01.2014
Time:	10.00-11.00
Attendees:	Bjørn André Lia Stig Andre Torkelsen (Supervisor GE Oil&Gas) Ziya Heydarov Anders Maeland

Actions item review	Item details
N/A	
N/A	

Agenda item	Item details
Presentation of CVWT design	**Hydraulic:** -All fittings and output connectors shall be 3/8" MP. Not JIC. -By pass valve for DCV shall be installed, due to flushing. -Consider whether a pressure damper is needed. -Block and bleed valves shall be mounted in from of gauges, pressure transducers etc. -Check valve shall have 0.5-1 bar cracking pressure. -Sampling point for hydraulic fluid shall be added -Return from PRV shall be drawn to the return line -Needle valve shall be mounted on the pressure inlet. -Consider whether a combined gauge and pressure transmitter would be a better solution. **Mechanical:** -Forklift pockets shall be installed. -Dust protection shall be installed for the laptop -Drip tray due to HSE regulations shall be added. **Electrical:** -Test connectors shall be used, due to cost. **Miscellaneous** -Misuse of the word "Manually" in context with DCV operation. -Parts chosen must be available for a long time period.
Comments to the CVWT specification?	A more general description of the hydraulic parts such as fittings etc shall be used.

New action items	Responsible	Due Date
Update the hydraulic drawing and CVWT specification in accordance with the bulletins mentioned above	BAL	21/02-2014

Meeting Agenda

Project:	Production Choke Valve - GE Oil&Gas
Student:	Bjørn André Lia
Date:	17.01.2014
Time:	13.00-14.00
Attendees:	Bjørn André Lia, Stig Andre Torkelsen (Supervisor GE Oil&Gas) Jens Jensen Ziya Heydarov Anders Maeland Trond Flaa

Actions from last meeting	Responsible	Due Date
NA		

Agenda item	Presenter	Time [min]
Presentation of CVWT design • Engineering Workstation – PC/HMI • Hydraulic • Mechanical	BAL	15
Questions and discussion of presented solution	BAL	20
Comments to the CVWT specification?	BAL	20
Other	BAL	5

New Actions	Responsible	Due Date

Attached documents: PowerPoint Presentation, CVWT Specification, Appendix B (Hydraulic Schematic, Electric Schematic and Conceptual drawings of trolley).