Hyperbaric
Pressure Control System

Bachelor Thesis

Group 20

May 2015

Hyperbaric - Pressure Control System

Introduction:
This thesis is written by five cybernetics students for the Qualification Department at FMC Kongsberg Subsea AS as a bachelor assignment done at Buskerud and Vestfold University College, Faculty of Technology and Maritime Sciences. All students holds certification in either Automation or Electro.

FMC Kongsberg Subsea AS delivers a wide range of Subsea Products. These products needs to be qualified for the harsh environment found at the seabed. The Qualification Department scope at FMC is to verify that the new developed products can withstand these environments for the design life-time for these products. Typical stress factors for Subsea Products are pressure, vibration and temperature.
Pressurizing of hyperbaric chambers with a product inside is done for qualifying a product for the water pressure. The operation of these hyperbaric chambers have until now been done manually. It is desirable to make this process fully automated. The automation includes filling, draining and linear pressurization & de pressurization of the chamber.

Abstract:
The requirement specification for the project where changed from delivery of a fully working product to contain only the design of this system due to long lead times on some of the high-pressure hydraulic parts. Three of the students where already working for FMC before project start, where two of them had experience with hydraulic Subsea Systems. Our project model where changed during the project. We started out with a Waterfall model and ended up with an Evolutionary model.

Conclusion:

The change of the requirement specification for the project and the product, happened to save a lot of money. After several offers from a small local supplier of hydraulic high-pressure parts, we got in direct contact with Proserv AS, which could provide a much better price offering and technical guidance about the parts needed. The offering price where reduced by 47,2% from first price offer to the final offer.

The practical experience with high-pressure hydraulics testing that some of the students was in possession of, have done the product design easy maintainable and practical easy to use because of their experience with hyperbaric testing.

Our solution offer an almost infinitely variable rate of pressure increase, and a good range for the pressure decreasing rate.
The derivative pressure control principle used to control the actuators to achieve a linear increase/decrease, have been verified to perform very well by a simulation made with MatLab.

The Waterfall Project Modell that the project started out with, where not suited for this project because of all the uncertainties associated with a development project like this. The Evolutionary model where found to be the most useable since every iteration within will result in deliverable material for the customer.

FMC Technology, Group 20
Hyperbaric - Pressure Control System 2014-2015

Cybernetics student project. Assignment for FMC Technologies. We are a group of five students, which are on part time workers, part time students over four years. Our student group have certificate of apprenticeship as Automation-mechanics and Electricians.

Brian Berg

<u>Main responsibility areas:</u>
Project Leader
Documentation
Electro Schematic & Implementation

Education:
Certificate of apprenticeship within Automation Mechanics.

Job description:
Electro engineer at FMC Kongsberg Metering AS.

Relevant experience:
Worked most with mechanics construction and electrical construction. Have good experience with AutoCAD tools, and electrical engineering.

Anders Skjørten

<u>Main responsibility areas:</u>
Programing of HMI and Electro Design

Education:
Certified Electrician.

Job description:
Lefdal Installasjon AS, Bærum, from 2005.

Relevant experience:
Fire alarm systems, general electrical installations, various automation systems and building power distribution centrals.

Jonas Nicolaysen

<u>Main responsibility areas:</u>
Programming of the controller

Education:
Certified Electrician.

Job description:
Jensen Elektriske AS, Holmen.
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ABB Power Systems AS, Oslo.

Thor Ove Skarseth

<u>Main responsibility areas:</u>
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Certificate of apprenticeship within Automation Mechanics.

Job description:
Workshop technician at FMC Kongsberg Subsea AS.

Relevant experience:
Work experience within testing of Hydraulic Subsea Systems and Hyperbaric Testing.

Jonas Carlstedt

<u>Main responsibility areas:</u>
Test
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Education: Certificate in automation.

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Work experience within testing of Hydraulic Subsea Systems and Hyperbaric Testing.

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Hyperbaric - Pressure Control System

Vision Document

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Revisions

Date	Description	Version	Made By	Approved By
08.12.2014	Idea description	-	JN,JC,TOS,BB,AS	BB, TOS
13.03.2015	Change of plan	A	BB	
01.04.2015	Delivery to FMC	B	BB	AS, JN
09.05.2015	Formatting layout	C	TOS	BB,JC

Table 1 - Revisions

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1.0 Vision Document

1.1 Introduction

Hyperbaric-Pressure Control System (HPCS) is a bachelor project for five cybernetics students at HBV. The project goal is to design a fully automatic Pressure Control System for a hyperbaric chamber that until now has been operated by a manually controlled pressure pump.

The hyperbaric chamber is used by FMCTI with purpose of qualifying new-developed products designed and constructed by FMCTI or other external companies and suppliers too FMCTI. The hyperbaric-pressure chamber is used to simulate the hyperbaric pressure found at the bottom of the seabed, where the qualified products will be operated. Since almost all products developed by FMCTI are placed on the seabed, it is necessary in the qualification process to verify that the construction can handle the sea-pressure, and that the equipment is not leaking any fluid through the sealing in the components.

The HPCS-group will with this project design a fully automatic pressure control system that will replace all manually operated equipment.

1.2 System Description

The customer voice is to have a system that can control and adjust pressure in the tank automatically according to pre-configured parameters.

The operator must be able to adjust parameters like rise-time, pressurized holding-time, lowering-time, unpressurized holding-time, test pressure and number of pressure cycles at the HMI touchscreen interface. Customer also must be able to set the pressure cycling parameters for each individual cycle if needed. Customer also wants to log the amount number of pressure cycles, which will be used to determine service intervals on hyperbaric chamber due to the dynamic stress caused by the cycling pressure. The performance of the system is measured on how well the system regulates the increase & decrease of pressure linearly.

Linearity of pressure increasing & decreasing is important due to internal compensation in test objects. If increasing/decreasing of pressure happens too fast the objects may collapse or implode and leakage through the sealing may occur.

1.3 Main design component

HPCS will mainly consist of:

- Regulation System
- Pressure Pump
- HMI touchscreen for setting system parameters and show system data.
- Hyperbaric chamber
- Frame for equipment installation
- Enclosure
- Hydraulic interface to hyperbaric chamber

1.4 Technical features

The main program should contain three different sequences; filling, test cycling, drain. The filling sequence must ensure that air gets ventilated while the chamber is being filled up with fluid. This is important due to pressure linearity problems that air causes in combination with fluid.

The system should have a quick connection between the hyperbaric chamber and HPCS since the chamber may be used for other test purposes. It is also important that the system is designed robust enough to be used in workshop environments.

1.5 Safety features

The system should have some kind of enclosure to protect the surrounding environment against hydraulic leakage, as this can cause major damage to people and materials. All hydraulic systems need to be equipped with an overpressure relief valve to prevent incidents due to the risk of overpressure.

Hyperbaric - Pressure Control System

Project Plan Document

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Revisions

Date	Description	Version	Made By	Approved By
25.04.2015	Combination of TECH-006 PLN and Project Plan Document	-	BB	
09.05.2015	Layout formatting	A	AS, BB	
10.05.2015	Final formatting changes	B	BB	JC, JN

Table 1 - Revisions

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Table list

Figure list

Equation list

Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
BOM	Bill of material
P&ID	Piping and instrument diagram

Table 2 - Abbreviations

1.0 Project Plan

1.1 Introduction

This document will explain how the HPCS group project plan works, and how to use Microsoft Project to navigate through the project. Throughout the project, there will be different changes to the project plan. Changes are covered in another document.
This document will contain the main changes, and main applications. Details about project model are discussed in project model document, but this document will go briefly thru the history and effect of the project plan.

1.2 Microsoft Project 2013

Microsoft Project is a software for managing a project [1]. It has many complex functions and applications. HPCS group is using the Gantt diagram and the time sheet function for weekly reporting activities, analyzing if HPCS project is on track, task sheet for analyzing tasks without Gantt diagram and due date system. By frequently adjustment of the project plan, HPCS group will be as close to real time estimated as possible.

HPCS group have two plans. The first one is to estimate hours and report hours on, and send weekly report to internal supervisor. The second plan is for iteration planning. By separation of those plans, HPCS gains freedom of easily adjusting the main plan, without losing actual hours reported.

By using Microsoft Project, HPCS group have used many hours for learning the software. In return, HPCS project have an accurate plan and report system for the follow-up documentation.

1.2.1 Microsoft Project navigation

This section will go briefly thru how to navigate thru Microsoft Project, and how to use the basic functions. Figure 1, show in sequence the tabs that will be addressed. Figure 3 is the second part of the Microsoft Project layout.
This part of document will go briefly thru the tabs and functions.

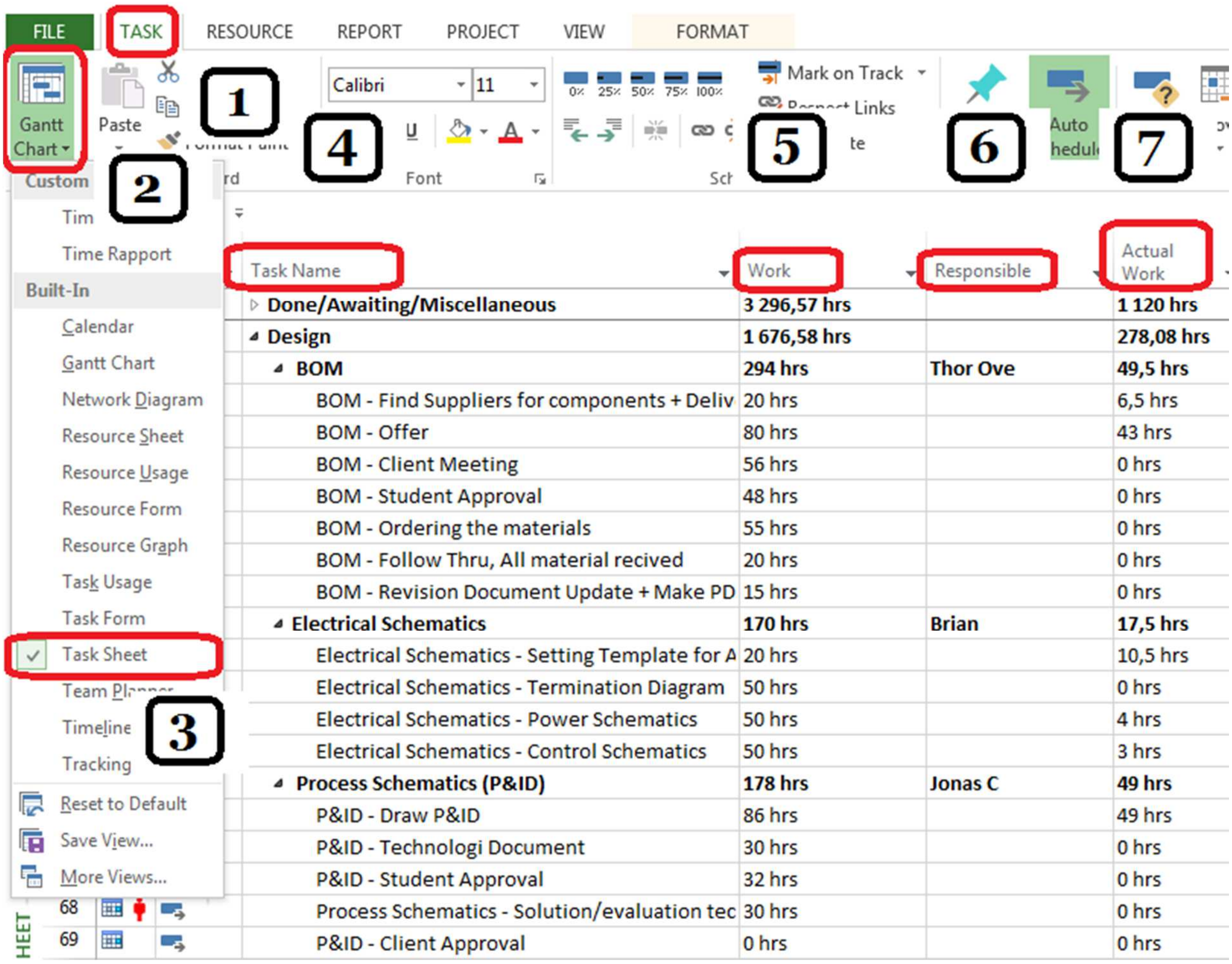


Figure 1 - Navigation thru Microsoft Project part one

1. Task
   - By going to Task, there will be opened more Gantt chart options

2. Gant chart
   - Gantt chart will show all of the tasks to the left, as well as all desired columns. On the right, there is Gantt diagram drawn as blocks.
     Gantt diagram show where the project is currently, compared to time elapsed. Dependence, start / finish dates and percentage completed are some of the features. Figure 2 show the time elapsed compared to iteration milestones.

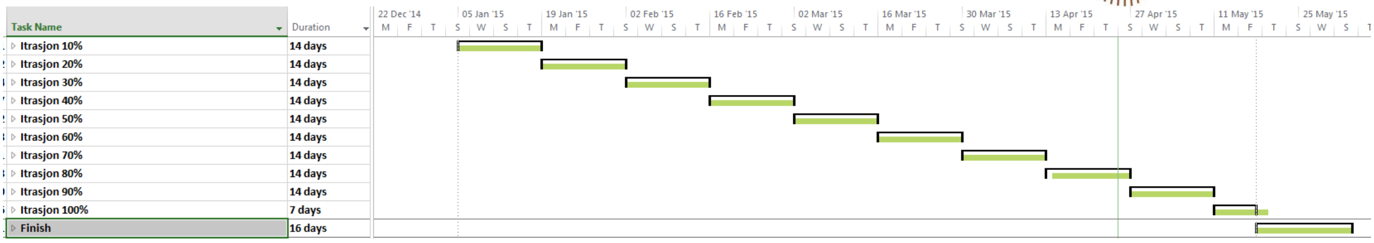


Figure 2 - Iteration layout of Gantt diagram, rev H

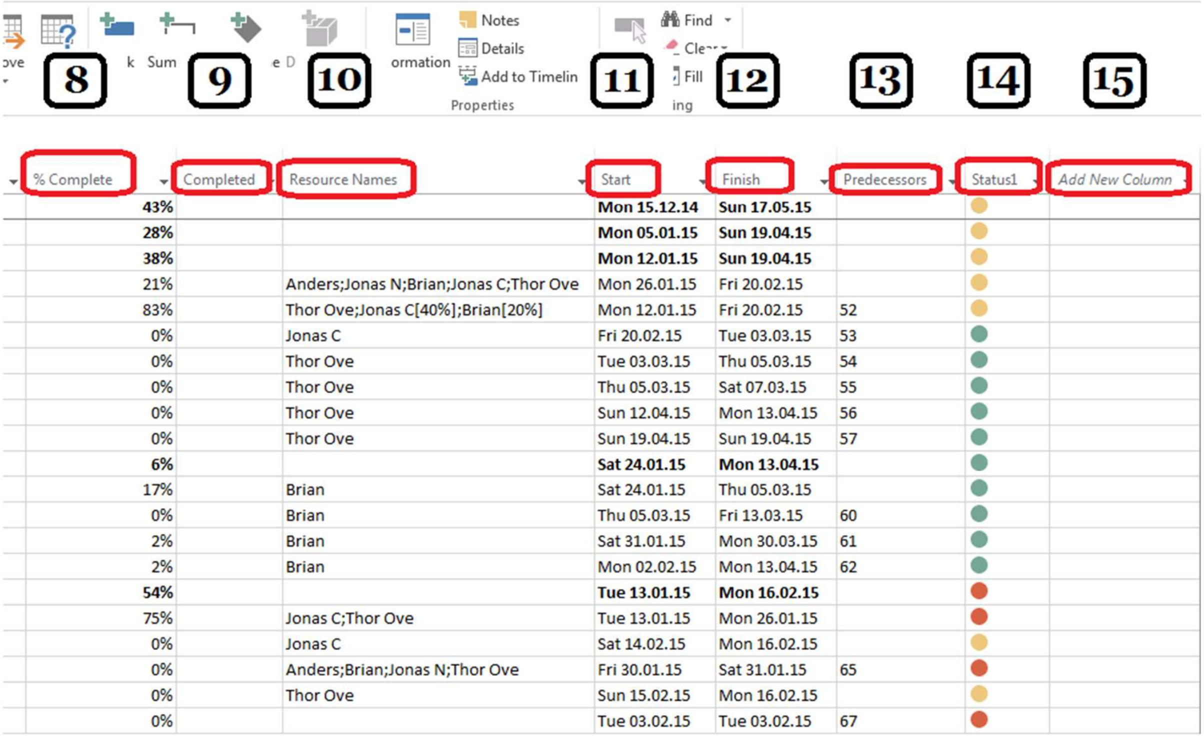
3. Task sheet
   - By pressing the small arrow by Gantt chart, more options will be displayed.
     For entering task list without Gantt diagram, use Task Sheet.

4. Task Name
   - Name of the sub and main tasks are listed below.

5. Work
   - Work [2] is a Microsoft Project Function that is measures as Work = Duration times Units. While duration is the time estimated, and units is how many resources are assigned, and how many percentage of work will be done per resource. Resources in this project are defined as student members.

6. Responsible
   - Responsible tab is custom created as text type with a look-up table function internally.

7. Actual work
   - Actual work is automatic assigned when the student group is registering hours on the project tasks. See section 2.3.1 Microsoft Project Resource Usage for more information.



% Complete	Completed	Resource Names	Start	Finish	Predecessors	Status1	Add New Column
43%			**Mon 15.12.14**	**Sun 17.05.15**			
28%			**Mon 05.01.15**	**Sun 19.04.15**			
38%			**Mon 12.01.15**	**Sun 19.04.15**			
21%		Anders;Jonas N;Brian;Jonas C;Thor Ove	Mon 26.01.15	Fri 20.02.15			
83%		Thor Ove;Jonas C[40%];Brian[20%]	Mon 12.01.15	Fri 20.02.15	52		
0%		Jonas C	Fri 20.02.15	Tue 03.03.15	53		
0%		Thor Ove	Tue 03.03.15	Thu 05.03.15	54		
0%		Thor Ove	Thu 05.03.15	Sat 07.03.15	55		
0%		Thor Ove	Sun 12.04.15	Mon 13.04.15	56		
0%		Thor Ove	Sun 19.04.15	Sun 19.04.15	57		
6%			**Sat 24.01.15**	**Mon 13.04.15**			
17%		Brian	Sat 24.01.15	Thu 05.03.15			
0%		Brian	Thu 05.03.15	Fri 13.03.15	60		
2%		Brian	Sat 31.01.15	Mon 30.03.15	61		
2%		Brian	Mon 02.02.15	Mon 13.04.15	62		
54%			**Tue 13.01.15**	**Mon 16.02.15**			
75%		Jonas C;Thor Ove	Tue 13.01.15	Mon 26.01.15			
0%		Jonas C	Sat 14.02.15	Mon 16.02.15			
0%		Anders;Brian;Jonas N;Thor Ove	Fri 30.01.15	Sat 31.01.15	65		
0%		Thor Ove	Sun 15.02.15	Mon 16.02.15			
0%			Tue 03.02.15	Tue 03.02.15	67		

Figure 3 - Navigation thru Microsoft Project part two

8. % Complete
   - % Complete indicates only how many hours are used compared to estimated work. This way it is always indication of how many hours there are left in hour buffer. Evaluating the plan to be adjusted by percentage completed makes planning more accurate.

9. Completed
   - Completed tab is a Flag function [Flag1], with a graphical indication. This means; task is completed for now, but there might be some changes later. When there will be done more work again, the flag will be removed. See Figure 4.

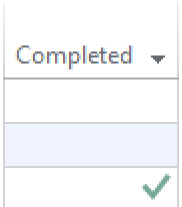


Figure 4 - Completed status flag

10. Resource Name
   - Point 6, mentioned Responsible tab. Resources have the same names as student names. By adding resource names, the amount of work will be increased. Figure 3, also show: “Thor Ove;Jonas C[40%];Brian[20%]”. This indicated that Thor Ove will work with this task 100%, Jonas C will work with this 40% and Brian will work with this task 20%.

11. Start
    - Start indicates start date of the task.
      This is estimated start date, but HPCS group can start before assigned date if possible. The only condition is that the task is started at correct iteration.
      HPCS group had great difficulty about the hour reporting system since actual hours where deleted by changing start / finish date.
      HPCS group solved this problem by having two plans, one for time reporting and second for general planning.

12. Finish
    - Finish indicates when a task shall be finished.

13. Predecessors
    - Predecessors are the same as dependencies, which means one task cannot start before the predeceasing tasks assigned to it are completed.

14. Status1
    - Status1 is a custom bar, with number type field. It calculates the difference between todays date and due date.
      In equation 1, the first IF sentence indicates for completed status. Purple flag is graphically shown as completed status. Code generated will have value 4. [Flag1] is the complete status bar deciding this if sentence.

      Second if sentence show if there are more or equal than 15 days of difference between todays date and due date. This will activate status value to 3.
      The indication for that will be a green circle. [Flag1] is the custom graphical flag as mention in point nine.

      Third IF sentence states if there are more or equal to zero days between due date and today date, status will be two, with indicates as yellow circle. This indicates still as planned, but soon overdue. This gives value output of 2.

      Fourth IF sentence states if there are less than zero days between due date and today. This will make status equal to one, which indicated as red circle. This indicated overdue. Value outcome is one.

```
IIf([Flag1]=Yes;4;IIf((DateDiff("d";NOW();[Date1]))>=15=Yes;3;IIf((DateDiff("d";NOW();[Date1]))>=0;2;IIf((DateDiff("d";NOW();[Date1]))<0;1))))
```

Equation 1 - Status 1 formula

15. Add New Column
    - Add New Column is a Microsoft Project function of adding new bars. There can be created custom bars if needed, or used Microsoft Projects standard bars.

1.2.1.1 Microsoft Project Resource Usage

Resource Usage is a handy tool for reporting hours per student and activity. HPCS group is using this as a tool for weekly reporting to internal supervisor. This tool will update how many available hours that is left in the time buffer. Another good application is that student is not able to write hours, without the task being in the plan. That forces HPCS group to update plan at least weekly.

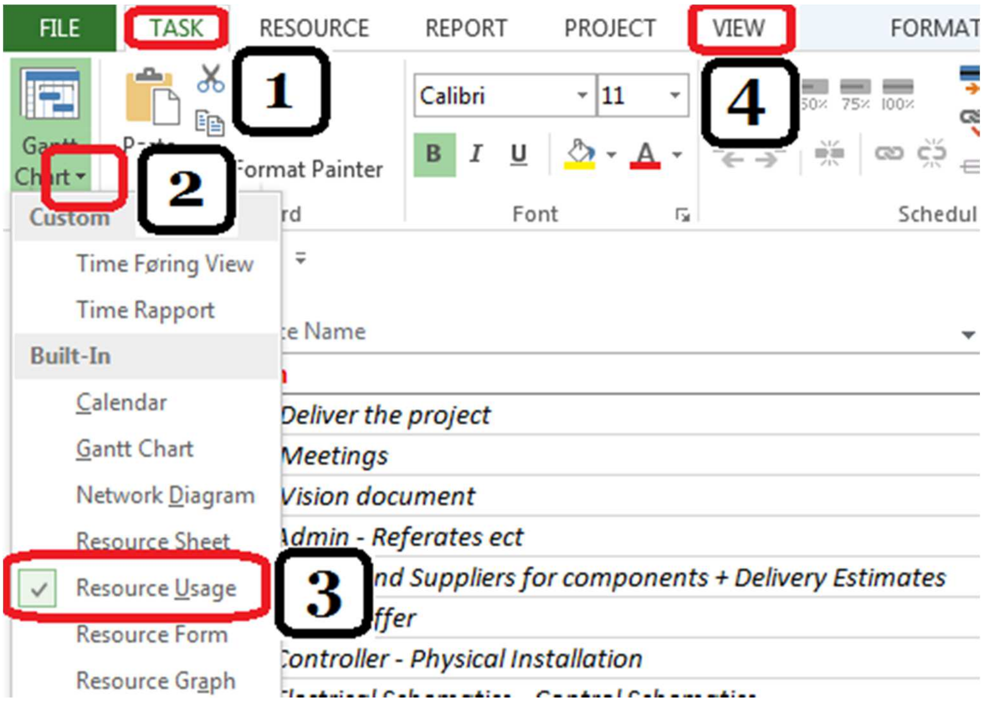


Figure 5 - Resource Usage

To open Resource Usage sheet, follow point 1 to 3 as shown in Figure 5. After clicking on point 4, a new ribbon will be opened. See Figure 6.
View ribbon panel have different view options. HPCS group is mostly using zoom and filter functions. Zoom function is used for adjusting time sheet duration, while filter helps to sort the information. See Figure 8, for time sheet.
There is one filter for each student, so students can write their hours without making mistake of reporting for somebody else.

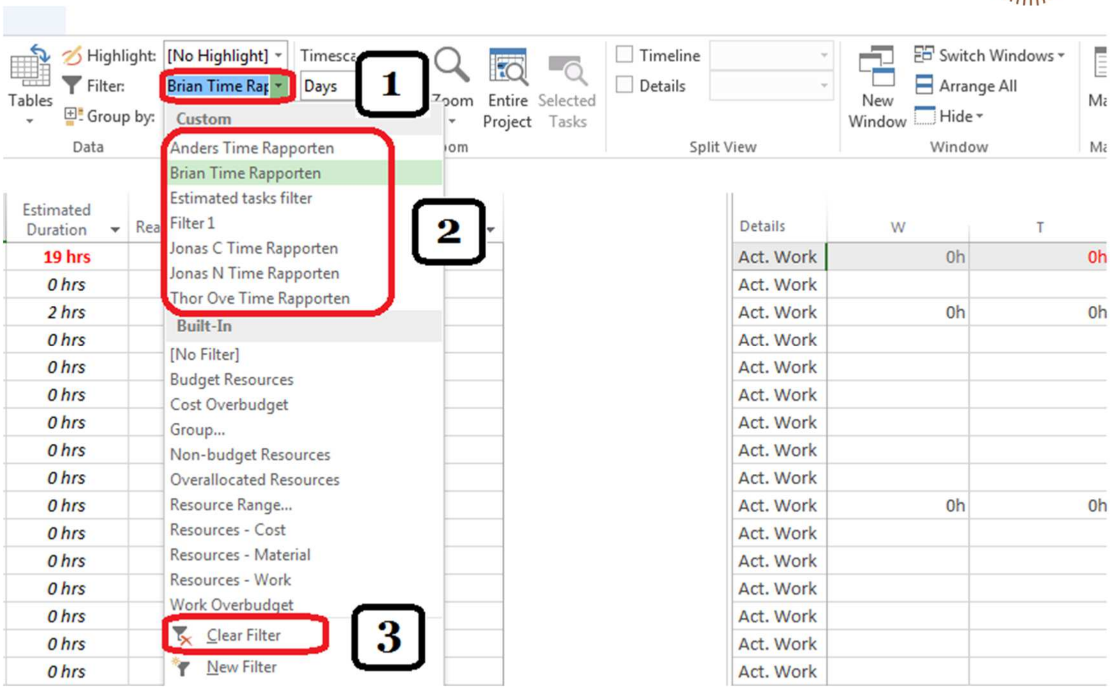


Figure 6 - Resource Usage - View Tab

Point 3 shows how to clear filters, if necessary.

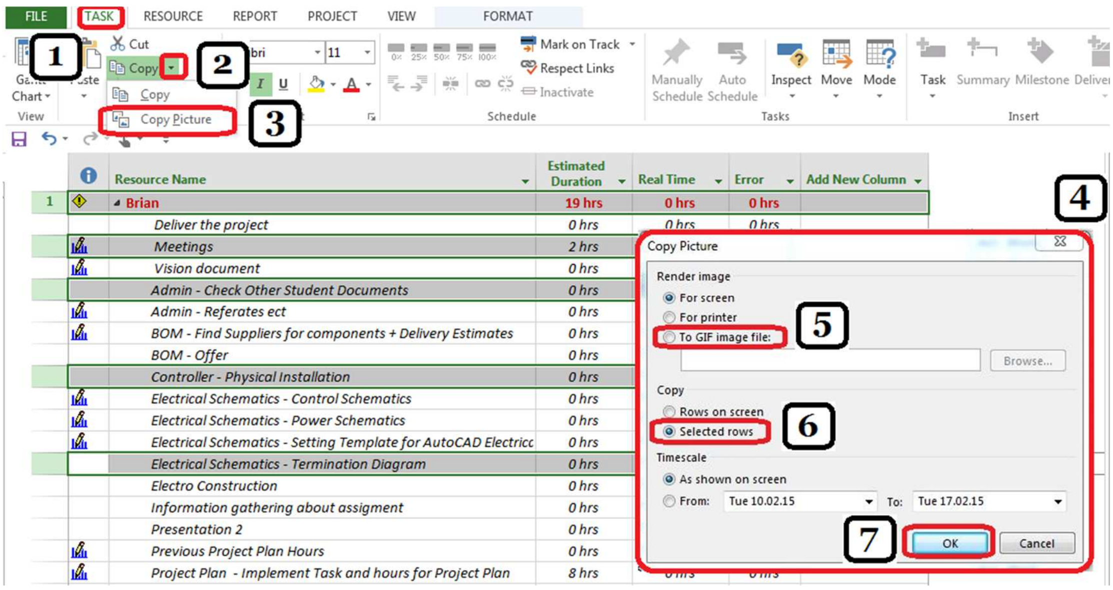
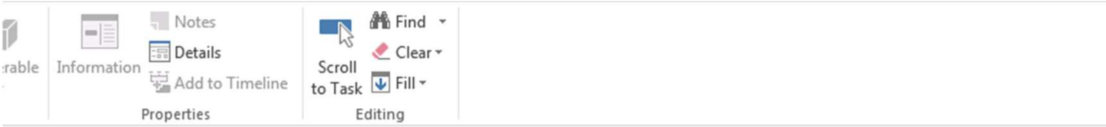


Figure 7 - Copy marked tasks as GIF file

Follow the steps shown in Figure 7, for creating GIF from desired tasks. By holding in Ctrl button, while clicking on the left side of the task, will gather all task desired for reporting. GIF files are used in report for our internal supervisor, Jørn Breivoll.

Figure 8 show actual work compared to time. When HPCS group write hours at one date, project plan will increase amount of hours on actual work for that task. As mentioned before, the zoom function here can increase or decrease duration of the date table shown in figure 8.



							16 Feb '15
Details	T	W	T	F	S	S	M
Act. Work	0h	0h	0h	6h	4h	8,5h	2,5h
Act. Work							
Act. Work	0h	0h	0h	1h			
Act. Work							
Act. Work							
Act. Work						1,5h	0,5h
Act. Work							
Act. Work							
Act. Work							
Act. Work							
Act. Work	0h	0h	0h	0h			0h
Act. Work							
Act. Work							
Act. Work							
Act. Work							
Act. Work							
Act. Work							
Act. Work	0h	0h	0h	5h	2h		

Figure 8 - Time Sheet

2.0 Project Model

2.1 Evolutionary Project Model

Evolutionary project model sets focus on starting the project with just essential and/or most critical applications and tasks first. Requirements for the Evolutionary model are to deliver some value in every iteration steps.
HPCS group have decided to divide those steps in time. Each iteration will be 10% of total time. This gives the advantage of focusing on the essential functions and gives enough time to make each iteration realistic to achieve.

By repeating some of the phases of the project, we will develop a greater product. Evolutionary model is based on always improving the last version of the product by running internal phase cycles. Referring to 3.2 Internal Phase Cycles to see an example of the internal phase cycles.

Project requirements are ranged with priority level. The level of priority can be decided by difficulty/time consuming degree. We can focus on the essential and time-consuming functions of the project [3] [4].

2.2 Iterations

Iterations are milestones of the project. Thru each milestone, there should be a lot of improvement in this amount of time.
A project plan is created for logging time from January 2015 to end of May 2015. With this knowledge, 10% of time buffer is a two weeks period. This calculation is until 17 of May.
HPCS will have 10 iterations in the project. Project will not be finished by then, but the documentation should be send to print by then.

Iterations	1	2	3	4	5	6	7	8	9	10
Start dates 2015	05.01	19.01	02.02	16.02	02.03	16.03	30.03	13.04	27.04	11.05

Table 3 - Iteration staring dates

The report of those iterations can be found in iteration report document, REP-ITR-001.

2.3 Project model effect on plan and history

In the first presentation, HPCS group received a comment that Waterfall method was not suitable for this kind of project. Feedback received was; Evolutionary and Iterative model was more suitable.

At the second presentation, HPCS group received a comment about evolutionary model was good, but HPCS group needed better documentation for it.
HPCS group miss-understood iteration process, but internal supervisor approved project plan revision H. See Figure 2 for more detail.

This led to a change in the project plan. With the Waterfall method, the tasks where ordered in phases. HPCS students had to complete tasks in those phases, before entering next phase of the project.
The tasks are not dependent on each other, except tasks that are set with predecessors. Start date and predecessors are the factors, which decide when one task will start instead.

Revision C was the first Evolutionary project plans, but the project plan was too detailed. HPCS group had one or several tasks per one phase. The amount of tasks made it difficult to make a good plan. See Figure 9.
The problem with this amount of detail was not only the difficulty of the plan, but to register time spent on activities was not accurate, since many of the tasks took less than one hour.
This way HPCS group is using Evolutionary model as a helping tool and not a hindrance.

Project plan is in continuous change, but for today, HPCS group have individual tasks that are divided in different phases.

BOM
Prestudy
BOM - Prestudy - Find Suppliers for components + Delivery Estimates
Requirements
Design
BOM - Design - Document Layout BOM document
BOM - Design - Client Meeting
BOM - Design - Student Approcal
Construction
BOM - Construction - Ordering the materials
Test
BOM - Release - Follow Thru, All material recived
Release
BOM - Release - Student Approval
BOM - Release - PDF Creation
BOM - Release - Revision Document Update

Figure 9 - Early stage of Evolutionary Project Plan

2.4 General project model overview:

Figure 10, shows the basic overview over our Evolutionary project model.

The concept of the model is to choose the basic need of the system and try to improve using Kaizen technique [5]. Kaizen is Japanese for "good change" which is continual change for the better.

For all iterations there will be internally new document revisions. The new revisions are created based on the existing revisions.

In the Evolutionary project model, we will go thru the internal phase cycle as many times as necessary before next iteration. The purpose of this is to have efficient revision rounds. See Figure 10 for more information.

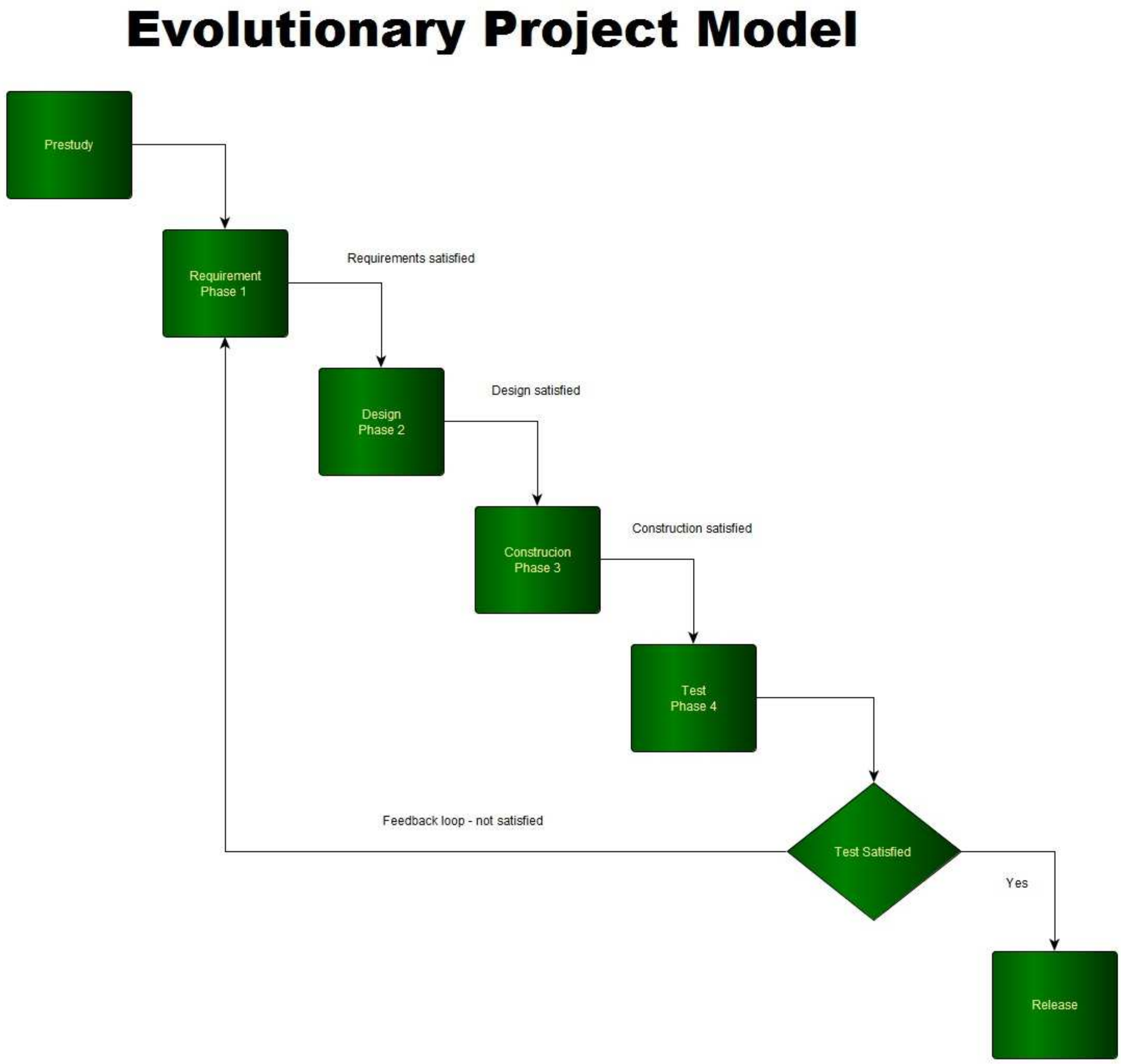


Figure 10 - Evolutionary Project Model

3.0 Phases

There are six phases and one feedback loop in this project model.

1. Prestudy
2. Requirements
3. Design
4. Construction
5. Test
   → Test check.
6. Released

Figure 10, shows the feedback loop and the sequence.

3.1 Phase Groups

In HPCS Evolutionary Project Model will be divided in two groups, main and sub phases. The main group is the main task, and show the general overview over the project. Sub groups are dedicated for smaller tasks, like for example documents or smaller part of a bigger component.

3.1.1 Prestudy:

The Prestudy phase is about gathering information for our assignment. Estimate the probability of completing the assignment and if the assignment is adequate for correct study direction. As well if there is enough work for all student members.
Prestudy phase can also be about gathering information after the project has started to integrate and apply new information to the system. The innovation process is in the Prestudy Phase.

3.1.2 Requirement:

Requirement phase is one of the most important phases. This phase is all about what the project shall contain and the requirements of the project. System project shall contain a requirement specification document. Requirement specification contains a clear description of the project function or non-functional properties. Separating this phase and used in to smaller roles will create clarity in all subtasks.

3.1.3 Design:

Design phase is all about how the task will look like and how it will behave. This phase is more solution orientated. In physical assembly, it is important to use some time to sketch, check and recheck in several revisions, before going to the construction phase.

3.1.4 Construction:

Construction phase is all about building or creating. Documents, software or physical construction can be considered as construction.

3.1.5 Test:
Test phase will go thru all of the work done so far. Going thru in detail between all of the documents, and going thru requirement and test specification, as well go thru FAT procedure.

3.1.6 Release:
Release will be done only when a task have been thru all the steps of the cycle in Figure 10. This means that we may have several revisions before we officially release the document. For every improvement, we will go thru phase cycles, The documents will be released when it is the group decides that it is good enough. We can always improve our released documents and start the sequence again.

3.2 Internal Phase Cycles
Each task in every iteration of the project is ran thru different phase cycles. This phases are described thru 3.2 to 3.7. See example 1.

Example 1
According to the second iteration, one student member should create project plan document. Iteration is called End of Prestudy but all of the phases are included in each iteration. For the prestudy phase the student should find out what information and resources that are needed. Requirement phase can be the input from the previous iteration, requirement specification and so on. Design phase is the idea description or layout of the document. Construction can be to implement the idea to a document. The test is run thru internal student test with student member's approval. Release accrues when non critical work is approved by students or/and critical work is approved by HBV or FMC and student members.

4.0 SWAT Analyze of Evolutionary Project Model

Figure 11 - SWOT analysis [6]

4.1 Strengths:

The main strength with this project model is that we are able to build the essential functions and applications. This will develop the quality of HPCS product since the group set focus on important factors. Other strength is the opportunity of building one revision on top of another. This will develop to a better layout of the product and better technical quality. Critical functions and applications will be included early in the project. This will increase the results of the project, since larger risks often comes with larger results.

4.2 Opportunities:

With evolutionary project model there is an opportunity of implementing a task or phases in smaller steps. This will make sure that the smaller steps are correct before we proceed with the larger steps of some tasks.

4.3 Weaknesses:

Weakness of this project model is the difficulty of estimating duration of each sub phase of the tasks. This will fluctuate from task to task, and from number of times we have been in the phase loop.

4.4 Threats:

Threats of the project model is the same as the strengths. The large risks may be planned at the early stage. If the HPCS group is not able to return some result of

the high risk in correct time, the project may waste many hours for something that will not be used.
Threats are connected to weaknesses as well, which is the difficulty of the estimation. By critically miss estimating the hours, the project may not be completed.

References

[1] "Microsoft Project Software," [Online]. Available: http://en.wikipedia.org/wiki/Microsoft_Project. [Accessed 15 02 2015].

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Note:
Reference [3], [4] and [7] is general basics for this document and project model.

Hyperbaric - Pressure Control System

Iteration Reports

Group:
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Jonas Nicolaysen
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ID: REP - ITR- 001 <A>

Revisions

Date	Description	Version	Made By	Approved By
04.05.2015	Report construction	-	BB	JC, TOS
09.05.2015	Report construction. Adding all previous reports	A	BB	JN, JC

Table 1 – Revisions

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Abbreviation List

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
GA	General arrangement
HBV	Høgskolen I Buskerud/Vestfold
TDI	Technical Data Information
DIP switch	Dual in-line package switch
BOM	Bill of Material
FAT	Factory Acceptance Test
PCB	Printed Circuit Board

Table 2 – Abbreviations

Student List and Initials

Student Name	Initials
Anders Skjørten	AS
Brian Berg	BB
Jonas Carlstedt	JC
Jonas Nicolaysen	JN
Thor Ove Skarseth	TOS

Table 3 - Student Initials

Introduction to Iteration Reports

This documents contains all iteration reports from the project between January 2015 and May 2015.

The following reports are documents based on achievements, status and progress for this project to internal and external supervisors.

Each of the reports include the report purpose, objectives reached, adherence to plan, problems and lessons learned, suggested changes, risk assignment for next iteration, future directions, schedule and best practice.

1.0 First Iteration Report Prestudy

1.1. Report Purpose

This is the first report marking the 10% time elapsed from the total time between January and May. The 10% time elapsed mark is between January 05 2015 and January 18 2015. This mark is named Prestudy.

This report will include status of the completed iteration, and will give input to the next iteration starting at January 19 2015.

1.2. Objectives Reached

Objectives	Status	Input Next Iteration
Implement presentation 1 comments. Change project model from Waterfall to Evolutionary model or Iteration model	Started, need more research	Implement better layout, more details and better overview
Idea description for P&ID	Implemented	Create P&ID drawing
Search for BOM suppliers. Start with order list. Create first hydraulic layout	Started. The first layout is finished of hydraulic components	Update BOM corresponding to new P&ID details
Update Requirement Specification implementing comments from presentation 1	OK	No additional adjustments
Update Test Specification implementing comments from presentation 1	OK	No additional adjustments
Get knowledge about PLC language standards: IEC61131-3 function block diagram ladder diagram structured text	OK	Need to use IEC61131-3, Function block diagram ladder diagram, but structured text was not needed
HMI software	Still trouble with software program	Need to update the software to the latest version

Table 4 – First Iteration Report - Objectives Status for Iteration

1.3. Adherence to Plan

Project plan was created just before the new year of 2015. The plan is not updated according to the whole project, but the short term is well planned. See table 5 for more detail.

Task Name	Doer	Due Date	Delivery Date	Status
Project Plan	BB	08.01.15	10.01.15	Created first revision of the project model document
Requirement specifications	JC	11.01.15	10.01.15	OK, updated
Test Specifications	AS	14.01.15	13.01.15	OK, updated
BOM	TOS	17.01.15	18.01.15	First layout completed. One day late. Waiting for offer from Proserv AS
HPCS Mechanical Construction Frames	TOS	18.01.15	-	Not finished, more work to be done
HMI - Programming	AS	18.01.15	18.01.15	Research of program software is started. Need newer version of program to do more
Controller - Learn structured text	JN	17.01.15	17.01.15	After research on structured text, there is no need to use this in HPCS project. Will not be included anymore
Process Schematics (P&ID)	JC	17.01.15	17.01.15	Started with the idea description.
Project Plan - Time Report	BB	18.01.15	-	Need more time
Revision Document	TOS	18.01.15	-	Not updated

Table 5 – First Iteration Report - Adherence to Plan

1.4. Problems and Lessons Learned

HPCS group had trouble with time reporting system. From September 2014 to December 2014, HPCS group used Microsoft Excel as time reporting system. Group decided to create time reporting system inside the Microsoft Project software, since there was a lot of trouble with Excel time formulas. Other reason was to calculate and update the Gantt diagram according to time used on tasks. Group started to implement time report system to Microsoft Project, but shortly found out that the software is very advanced.
Input for next iteration in 1.2 Objectives Reached mentioned about software upgrade. The HMI software was not adequate version for starting the program. This software program generated communication problems between HMI and PLC.

1.5. Suggested Changes

Presentation 1 given HPCS group feedback about changing project model from Waterfall model to Evolutionary or Iterative model. Changing the project model will have a negative effect on time buffer on the project. This hours are meant for construction phase later on in the project. In return, HPCS group will have more motivating, better project model and project plan to follow.

1.6. Risk Assessment for Next Iteration

Risk	Reduction of the risk
The frames HPCS group may have created not correct size compared to the future component update	Update the components with knowledge of the frame size, and create engineering job after that. Other risk reduction is to reconstruct the frames to another size
Communication between PLC and HMI still not working after software update	Get guidance from the PLC and HMI companies. Get as much knowledge to implement the network communication. Alternatively, if there is no other way, create communication circuit
Wrong BOM components	Have a good dialog with the suppliers, and not to rush thru the order process. Make sure all components are correct, and all components are listed before ordering anything

Table 6 – First Iteration Report - Risk Assessment

1.7. Future Directions

Focus is set on good project plan and model, implement the time report system, create and receive components offers.

1.8. Schedule

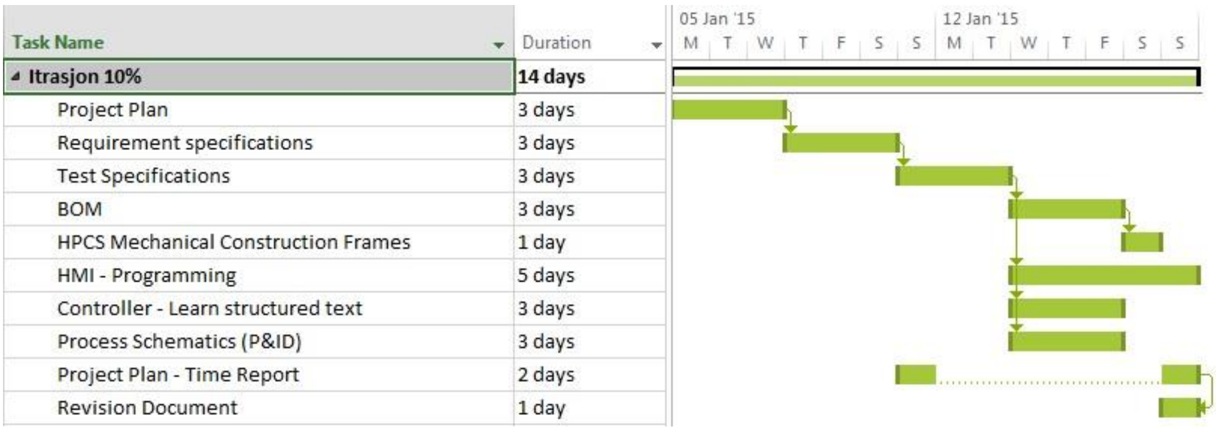


Figure 1 – First Iteration Report - Iteration Prestudy Project Gantt

1.9. Best Practice

Best practice for now is to update the software before implementing risk reduction suggestions, and create better overview plan for the project.

2.0 Second Iteration Report End of Prestudy

2.1. Report Purpose

This is the second report marking the 20% time elapsed from the total time between January and May. The 20% time elapsed mark is between 19 January 2015 and 01 February 2015. This mark is named End of Prestudy.

This report will include status of the completed iteration, and will give input to the next iteration starting at February 02 2015.

2.2. Objectives Reached

Objectives	Status	Input Next Iteration
Finish first revision of P&ID	OK	When suppliers gives offers, BOM will change. Adjust P&ID accordingly to the adjustments.
Update Webpage. Have more professional layout and correct language.	No work done	Update to an newer layout of the web page
BOM Update compared to P&ID	OK, updated BOM in accordance with small components	Update electrical BOM.
First revision of power schematics	OK, need more details about the power at FMC site	Update power schematics according to the next control schematics
Fix communication between PLC and HMI	After installing new software, communication between PLC and HMI worked	No additional adjustments
Create first revision of variable list	First revision OK.	Complete more functions in the PLC program. Need more PLC info before completing this process
Complete the HPCS frames	OK	No additional adjustments
Create time report system	OK, send to Jørn from week one to four	No additional adjustments
Derivation Function research	OK	Will need more info

Table 7 – Second Iteration Report - Objectives Status for Iteration

2.3. Adherence to Plan

All of the tasks are going according to the project plan. Web page was not prioritized as planned.
See table 8 for more detail.

Task Name	Doer	Due Date	Delivery Date	Status
Revision Document	TOS	01.01.15	-	Not updated
Project Plan - Time Report	BB	01.01.15	01.01.15	Send to Jørn
Project Plan	BB	22.01.15	20.01.2015	OK, new plan, new model document and time report delivered
Web Page	JN	23.01.15	-	No work done
BOM	TOS	25.01.15	24.01.15	OK, updated according to new parts. Waiting for offer from Proserv AS
Process Schematics (P&ID)	JC	25.01.15	25.01.15	OK, updated according to the new description
Controller - Network Connection	AS, JN	25.01.15	21.01.15	Communication OK
Controller - PLC Derivation Function	JN	26.01.15	26.01.15	Research OK
Electrical Schematics - Power Schematics	BB	28.01.15	25.01.15	First revision OK, will need to update the drawing
Controller - Variable List	JN	28.01.15	28.01.15	First revision OK, need more update
Controller - Program layout	JN	30.01.15	30.01.15	Created more functions in the program

Table 8 – Second Iteration Report - Adherence to Plan

2.4. Problems and Lessons Learned

One of the students in HPCS group work with AutoCAD Electrical and Mechanical thru out the project. Problem was to set up the basics of the program, template and symbol library. This was solved by consulting IT and setting up the basics for all of the HPCS drawings.

Group had problem with combining hours used on project and on another school subject. The amount of work was not the same as estimated work.

2.5. Suggested Changes

No suggested changes recommended.

2.6. Risk Assessment for Next Iteration

Risk	Reduction of the risk
No risk found	

Table 9 – Second Iteration Report - Risk Assessment

2.7. Future Directions

Dialog with FMC to find a solution to the time elapsing problem is the focus for the group.

2.8. Schedule

Task Name	Duration	Due Date	Responsible
Itrasjon 20%	**14 days**	**NA**	
Project Plan	3 days	NA	
Web Page	1 day	NA	Jonas N
BOM	3 days	NA	Thor Ove
Process Schematics (P&ID)	3 days	NA	
Electrical Schematics - Power Schematics	3 days	Sun 22.03.15	Brian
Controller - Network Connetion	2 days	Fri 06.02.15	Anders
Controller - PLC Derivation Function	2 days	Mon 13.04.15	Jonas N
Controller - Variable List	2 days	Mon 20.04.15	Jonas N
Controller - Program layout	2 days	Tue 28.04.15	Jonas N
Revision Document	1 day	Sun 10.05.15	Thor Ove
Project Plan - Time Report	2 days	Sun 17.05.15	Brian

Figure 2 – Second Iteration Report - Iteration End of Prestudy

2.9. Best Practice

For now the best what HPCS group can do is to continue working with documents and updating administration work while the group is waiting for the suppliers offers.

3.0 Third Iteration Report Requirement Phase

3.1. Report Purpose

This is the third report marking the 30% time elapsed from the total time between January and May. The 30% time elapsed mark is between February 02 2015 and February 15 2015. This mark is named Requirement Phase.

This report will include status of the completed iteration, and will give input to the next iteration starting at February 16 2015.

3.2. Objectives Reached

Objectives	Status	Input Next Iteration
Update and simplify the project plan	OK	Update project plan according to the project status
Gain some knowledge about simulation of the project	OK	Need to get more knowledge about Simulink and implementation of motor datasheet figures
Create better layout of HMI and programming of the HMI to be finished at 70%	OK	Update HMI program after PLC program is worked more on
Update existing documentation	OK	BOM, electro drawings and other started documents

Table 10 – Third Iteration Report - Objectives Status for Iteration

3.3. Adherence to Plan

The amount of hours are less than estimated, but work done is quite adequate. See table 11 for more detail.

Task Name	Doer	Due Date	Delivery Date	Status
Project Plan	BB	05.02.15	03.02.15	Plan updated
Project Plan - Technology Document	BB	06.02.15	05.02.15	Project Plan Technology document updated to new revision
Interface between components list	TOS	09.02.15	11.02.15	First revision is delivered
Electrical Schematics - Control Schematics	BB	09.02.15	15.02.15	First revision of control schematics is delivered
BOM	TOS	12.02.15	12.02.15	Updated BOM compared to input from suppliers. Waiting for offer from Proserv AS

Controller - Program layout	JN	12.02.15	18.02.15	Continued on program layout. Struggle with some functions
Simulation Physical	JC	13.02.15	-	Need more time. Algorithm problems
Simulation Electrical Control	AS, BB	14.02.15	-	Need more time. Struggle with describing the project
HMI - Tech Doc for HMI	AS	14.02.15	17.02.15	OK, new layout implemented
Revision Document	TOS	15.02.15	15.02.15	OK, updated
Project Plan - Time Report	BB	15.02.15	15.02.15	Ok, send to Jørn
Controller - Network Connection	AS, JN	08.04.15	08.04.15	Update program, connection OK

Table 11 – Third Iteration Report - Adherence to Plan

3.4. Problems and Lessons Learned

HPCS group suspect that the bachelor project is more time consuming than expected. This is regarding to component delivery time. All administration work took much longer time than expected at begin of the project.

Group have problem with the use of the project model. The group will have focus on this aspect of the project in near future.

Simulating the HPCS module is very difficult. This type of task is a high risk task that may lead to no effect, or may lead to great results. HPCS students found one internet page explaining Simulink and regulation system quite well. This lead to better overview over functions and capabilities of Simulink. One of the functions is called interpolation, with is to generate "3D" model of system responses. This function is very difficult and time consuming.

3.5. Suggested Changes

It was discussed with internal supervisor about changing the requirement specifications.

According to requirement specification revision <A>, HPCS group should build the HPCS module. This leaves a risk of not completing the assignment if HPCS group continue the building process.
The amount of hours left of the project, and the amount of time elapsing each time suppliers offers, will make the project more difficult to physically build the HPCS module.

Suggestion is to not create the physical version of HPCS, but to document, simulate it, and build a simple prototype to show that program is working.

3.6. Risk Assessment for Next Iteration

Risk	Reduction of the risk
HPCS group will run out of time to fulfill all of the requirement specifications, or create a half done product because of supplier's long delivery time for component offers	Establish more contact with the suppliers, and ask them to prioritize those offers. Or set an appointment with FMC to discuss changing the requirement specification in near future time as mentioned in 3.5 Suggested Changes
Difficulty of the process simulation is high and may lead to no or little result	Get guidance from Simulink experts from FMC or HBV

Table 12 – Third Iteration Report - Risk Assessment

3.7. Future Directions

FMC will be invited inn for a meeting discussing the status, requirement specification and other information.

3.8. Schedule

Task Name	Duration
Itrasjon 30%	14 days
Project Plan	3 days
Project Plan - Technology Document	1 day
Controller - Network Connetion	2 days
Interface between components list	3 days
Electrical Schematics - Control Schematics	3 days
BOM	3 days
Controller - Program layout	3 days
Simuleringer Physical	4 days
Simuleringer Electrical Control	1 day
HMI - Tech Doc for HMI	5 days
Revision Document	1 day
Project Plan - Time Report	2 days

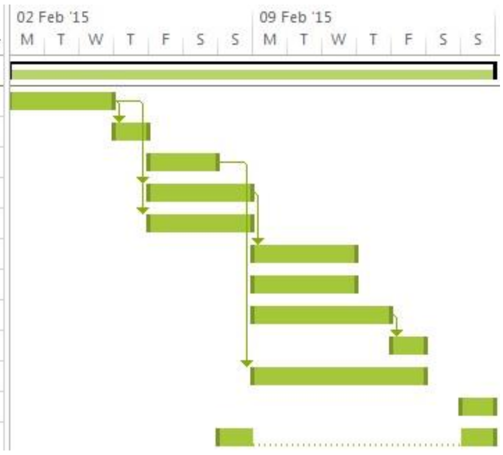


Figure 3 - Third Iteration Report - Iteration Requirement Phase Project Gantt

3.9. Best Practice

Most effectively is to start simulation research right away to be prepared for meeting with FMC.

4.0 Fourth Iteration Report
First Design Phase

4.1. Report Purpose

This is the fourth report marking the 40% time elapsed from the total time between January and May. The 40% time elapsed mark is between February 16 2015 and March 01 2015. This mark is named First Design Phase.

This report will include status of the completed iteration, and will give input to the next iteration starting at March 02 2015.

4.2. Objectives Reached

Objectives	**Status**	**Input Next Iteration**
Finish HMI interface, start visualization design	HMI interface is finished, and first revision of visualization of HMI have begun	Create more graphical interface in HMI
Update variable list compared to new PLC program version	Updated	No additional adjustments
Create sort function for PLC	Created, but need more work to function well	Include all PLC functions
Research and documentation of DA	First revision of the DA technology document is finished	No additional adjustments
Create simulation design layout	Not finished	Need more information about intersection of the model

Table 13 – Fourth Iteration Report - Objectives Status for Iteration

4.3. Adherence to Plan

Many of the documents are finished with the first revision. All of those documents need to be updated in the future since the project is evolving in evolutionary steps. Program layout is taking longer time than expected compared to estimated finish percentage of the program.
See table 14 for more detail.

Task Name	Doer	Due Date	Delivery Date	Status
Project Plan	BB	19.02.15	17.01.15	OK, project plan is updated
Controller - Variable List	JN	21.02.15	25.02.15	Need more update, for now OK
HMI - Programming	AS	25.02.15	25.02.15	OK, according to objectives
Controller - Program layout	JN	23.03.15	23.03.15	Sort function not working well, will update in next iteration
Controller- Tech Doc Analog Block (DA)	AS	25.02.15	28.02.15	Technology document late, but created the first revision
HMI - Tech Doc for HMI	AS	28.02.15	28.02.15	Technology document updated compared to the new HMI program
Controller - Technology Document	JN	28.02.15	28.02.15	Technology document updated compared to the new PLC program
Electrical Schematics - GA Cabinet	BB	22.02.15	17.02.15	Created first revision of control cabinet GA. Layout is not detailed enough, will update next revision
System Description - Tech Doc	TOS	22.02.15	21.02.15	System description delivered on time. Just including the hydraulic components
Simulation Physical	JC	22.02.15	-	Not able to create simulating program
Simulation Electrical Control	AS, BB	24.02.15	-	Not able to create simulating program
BOM	TOS	24.02.15	25.02.15	Updated BOM compared to suppliers response. Received the first offer from Proserv
Project Plan - Time Report	BB	23.02.15	23.02.15	OK, send to Jørn
Revision Document	TOS	01.03.15	-	Not updated

Table 14 – Fourth Iteration Report - Adherence to Plan

4.4. Problems and Lessons Learned

Program layout for controller will take much longer time than expected. There are many variables and scenarios that need to be taken in account. There is little help to get about the subject.

In simulation there was some ODE algorithm problems in Simulink.

There was many errors in the offer from Proserv AS. Wrong components, wrong amount of the components and some components missing in the offer.

4.5. Suggested Changes

Focus more time on finishing the PLC program to implement the technology document for the PLC.

Request a new and updated offer from Proserv.

4.6. Risk Assessment for Next Iteration

Risk	Reduction of the risk
Risk the same at mention in 3.6 Risk Assessment for Next Iteration. Simulation is still a high risk, since a lot of information is not available thru the internet or library	Since there is still many months left of the project, it is better to simulate this now at the earlier stage, than try to simulate this at late stage. Project risk is still quite low
PLC program will not be finished in time	Have more focus on delivering the project program in right time
After receiving new offer, more error can occur and more time will elapse of the project before receiving the new offer	Follow up the supplier more frequently

Table 15 – Fourth Iteration Report - Risk Assessment

4.7. Future Directions

The design phase is well on the way. Continue creating and updating document according to the project plan.

4.8. Schedule

Task Name	Duration
Itrasjon 40%	**14 days**
Project Plan	3 days
Controller - Variable List	2 days
HMI - Programming	2 days
Controller - Program layout	2 days
Controller- Tech Doc Analog Block (DA)	2 days
HMI - Tech Doc for HMI	3 days
Controller - Technology Document	3 days
Electrical Schematics - GA Cabinet	3 days
System Description - Tech Doc	3 days
Simuleringer Physical	3 days
Simuleringer Electrical Control	2 days
BOM	2 days
Project Plan - Time Report	2 days
Revision Document	1 day

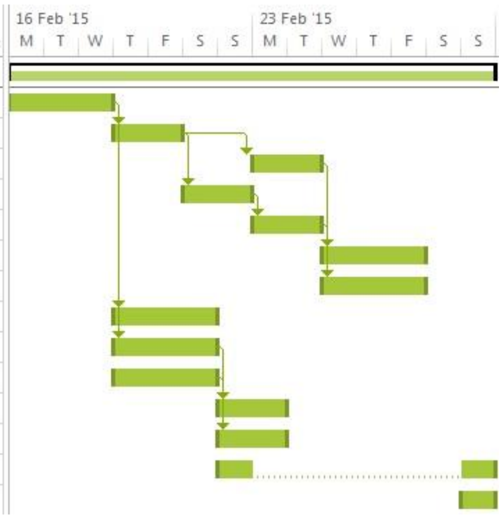


Figure 4 – Fourth Iteration Report - Iteration First Design Phase Project Gantt

4.9. Best Practice

Focus on delivering the program layout, learn as much as possible about simulation and continuing the process of updating and creating technology documents.

5.0 Fifth Iteration Report Second Design Phase

5.1. Report Purpose

This is the fifth report marking the 50% time elapsed from the total time between January and May. The 50% time elapsed mark is between March 02 2015 and March 15 2015. This mark is named Second Design Phase.

This report will include status of the completed iteration, and will give input to the next iteration starting at March 16 2015.

5.2. Objectives Reached

Objectives	Status	Input Next Iteration
Export report from HMI to SD card	OK, managed to export data	Export report from HMI thru the Ethernet and extract report on laptop
Add alarms on HMI as requirement specification applies	OK, alarms are included in the HMI program	No additional adjustments
Create HMI script for start and stop function of process, filling and drain	OK, script is created	Adjustments of the program when PLC and HMI update will come
Create the first version of test rig	OK, started with some home depot equipment. Test rig is just an actuator for the water pump	Design the PCB
Simulate decrease function. Check with FMC to buy MathWork licenses	Awaiting meeting with MathWorks for licenses offer	Licenses are very expensive. Drop this simulation function depending on MathWork meeting
Finish first revision of Physical Simulation	OK	Update with the discontinuity function and signal bus system

Table 16 – Fifth Iteration Report - Objectives Status for Iteration

5.3. Adherence to Plan

The project plan had too many tasks, but all of those task are not that time consuming.
See table 17 for more detail.

Task Name	Doer	Due Date	Delivery Date	Status
Project Plan	BB	03.03.15	03.03.15	OK, updated plan
Controller - PLC Derivation Function	AS	05.03.15	03.03.15	Not work on. Just research
Controller - Program layout	JN	07.04.15	-	No result. Changed focus on PLC technology document
Controller - Variable List	JN	09.03.15	09.03.15	OK, variable list is updated
Controller - Technology Document	JN	10.03.15	10.03.15	OK, technology document updated
Test Rig Construction	AS	12.03.15	12.03.15	Started to create first design layout of test rig
HMI - Programming	AS	08.03.15	10.03.15	OK, updated according to the iteration objectives
HMI - Tech Doc for HMI	AS	11.03.15	16.03.15	OK, updated according to the new HMI program interface
HMI - Tech Doc Programming Log	AS	12.03.15	12.03.15	Program log is updated
Electrical Schematics - Control Schematics	BB	07.03.15	06.03.15	Control schematics is updated compared to new components and additional information from PLC
Increase / Decrease Function	JC	04.03.15	-	Not able to simulate increase / decrease function because software available is not adequate
Simulation Physical	JC	13.03.15	-	First revision for simulation is complete
System Description - Tech Doc	TOS	15.03.15	13.03.15	Updated compared to new BOM components
Revision Document	TOS	15.03.15	15.03.15	Updated
Project Plan - Time Report	BB	15.03.15	15.03.15	Send to Jørn

Table 17 – Fifth Iteration Report - Adherence to Plan

5.4. Problems and Lessons Learned

Derivate function is difficult to implement in PLC. Discrete derivate needs to have sampling time. This is not available for now.

Learned that Simulink's ODE algorithm get internal algebraic loop error while using an ideal derivative operator in the closed control feedback path.

5.5. Suggested Changes

Get licenses for SimHydraulic and upgrade project plan for better overview.

5.6. Risk Assessment for Next Iteration

Risk	Reduction of the risk
Many tasks in one iteration	Make sure to have a detailed working plan for each student for all of the tasks this iteration
Not able to simulate the decrease function	Not include in the plan forward, or get guidance from experts

Table 18 – Fifth Iteration Report - Risk Assessment

5.7. Future Directions

Complete all started revisions for the documents, get guidance for simulation progress and focus on the delivery times.

5.8. Schedule

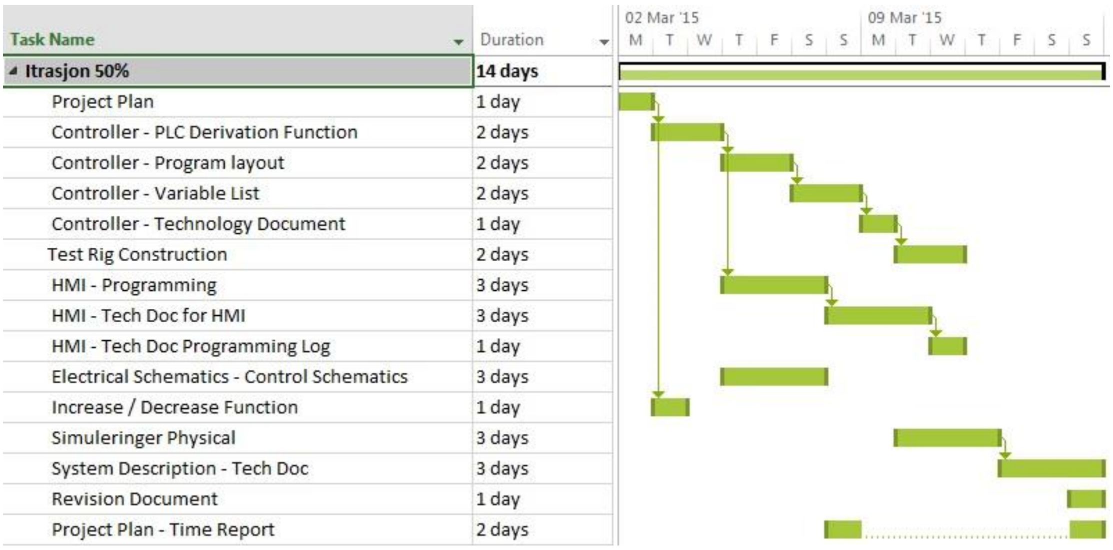


Figure 5 – Fifth Iteration Report - Iteration Second Design Phase Project Gantt

5.9. Best Practice

Follow up the working plan to great detail this iteration for completing all of the tasks.

6.0 Sixth Iteration Report First Construction Phase

6.1. Report Purpose

This is the sixth report marking the 60% time elapsed from the total time between January and May. The 60% time elapsed mark is between 16 March 2015 and 29 March 2015. This mark is named First Construction Phase.

This report will include status of the completed iteration, and will give input to the next iteration starting at March 30 2015.

6.2. Objectives Reached

Objectives	Status	Input Next Iteration
Create 3D System GA drawing. This should be an simple sketch of the total system	OK, first revision is finished	Need to find adequate measurements and add a 3D figure to have a reference of sizes
Update Vision document, Requirement Specification and Test Specification, implementing FMC comments	OK, all comments are implemented and released	No additional adjustments
Update the electro and hydraulic component	OK, this is implemented	When GA Cabinet is updated, update the electro component and when System GA is updated, update hydraulic components

Table 19 – Sixth Iteration Report - Objectives Status for Iteration

6.3. Adherence to Plan

Project Plan is tight scheduled in this iteration. See table 20 for more detail.

Task Name	Doer	Due Date	Delivery Date	Status
Test Rig Construction	AS	16.03.15	15.03.15	Designing the PBC card. Starting to print
Project Plan	BB	18.03.15	18.03.15	OK, plan updated. Layout is changed and tasks are rearranged
Vision document	BB	19.03.15	17.03.15	Updated visions document compared to the new requirement specification
Process Schematics (P&ID)	JC	19.03.15	23.03.15	Updated compared to the revision, document author and pneumatic lines
Requirement specifications	BB	19.03.15	17.03.15	Implemented the comments from FMC and HPCS group meeting
HMI - Tech Doc Programming Log	AS	19.03.15	19.03.15	Updated
GA over system	BB	20.03.15	20.03.15	Created the first version of the GA system. Need to update the dimensions of the frames
Test Specifications	AS	20.03.15	20.03.15	Implemented the comments from FMC and HPCS group meeting
HMI - Function Test	AS	20.03.15	18.03.15	Was able to get 4-20mA from HMI to DA
Increase / Decrease Function	JC	21.03.15	-	No result reported
Controller - Program layout	JN	22.03.15	-	No result reported
HMI - Programming	AS	22.03.15	20.03.15	Updated HMI program according to the new DA information
Controller- Tech Doc Analog Block (DA)	AS	23.03.15	21.03.15	OK, no additional adjustments
System Description - Tech Doc	BB, TOS	24.03.15	23.03.15	Updated the layout

Controller - Technology Document	JN	24.03.15	28.03.15	Late, but updated to newer revision
Simulation Electrical Control	JC	26.03.15	-	No result to report
System Description - Tech Doc - Hydraulic	TOS	27.03.15	25.04.15	Implemented comments from other student members
System Description - Tech Doc - Electro	BB	27.03.15	25.04.15	Implemented comments from other student members
Plant Model	JC	27.03.15	-	No result to report
Electrical Schematics - GA Cabinet	BB	29.03.15	28.03.15	Create first version of system GA. Need to add smaller components. BOM will be updated according to this
Revision Document	TOS	29.03.15	29.03.15	Updated
Project Plan - Time Report	BB	29.03.15	29.03.15	Send to Jørn

Table 20 – Sixth Iteration Report - Adherence to Plan

6.4. Problems and Lessons Learned

AutoCAD Mechanical have a 3D simulation module. It is much more easy to use than anticipated. Problem in the drawing was the uncertainty of the dimensions of the components and the main components. The complexity of the valves was so great, that the HPCS group drawings are simplified version.

6.5. Suggested Changes

As mentioned in the Input Next Iteration, HPCS group must update the dimensions of the drawing. Set up one reference point for those who will see the drawing to have an idea of dimension relations.

6.6. Risk Assessment for Next Iteration

Risk	Reduction of the risk
Dimensions are wrong compared to reality. Component will not fit at	Make sure to see all of the datasheets, and include the dimensions of all the main components

Table 21 – Sixth Iteration Report - Risk Assessment

6.7. Future Directions

Finish all of the document with the 80% marked as finished. This is not easily measured, but this will be approximated.

6.8. Schedule

Task Name	Duration
Itrasjon 60%	14 days
Project Plan	2 days
Vision document	1 day
GA over system	1 day
Test Rig Construction	1 day
Process Schematics (P&ID)	1 day
Requirement specifications	1 day
Test Specifications	1 day
Increase / Decrease Function	2 days
System Description - Tech Doc	5 days
Controller - Technology Document	3 days
Controller - Program layout	1 day
Controller- Tech Doc Analog Block (DA)	1 day
System Description - Tech Doc - Hydraulic	3 days
System Description - Tech Doc - Electro	3 days
Electrical Schematics - GA Cabinet	2 days
HMI - Tech Doc Programming Log	3 days
HMI - Function Test	1 day
HMI - Programming	2 days
Simuleringer Electrical Control	1 day
Plant Model	1 day
Revision Document	1 day
Project Plan - Time Report	2 days

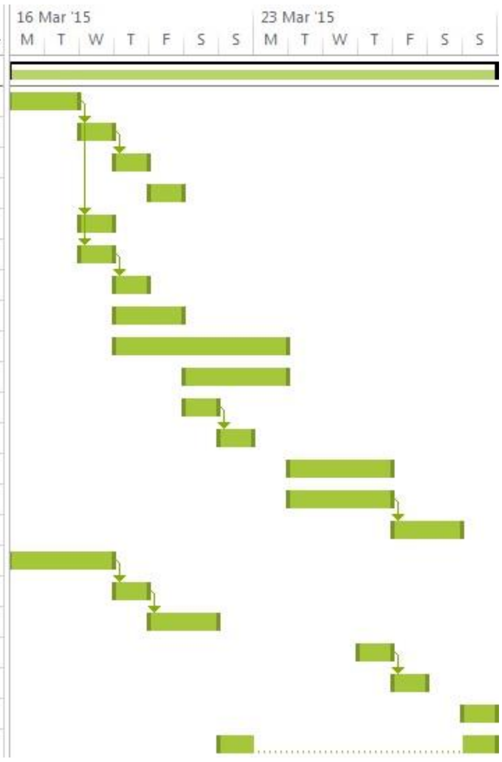


Figure 6 – Sixth Iteration Report - Iteration First Construction Phase Project Gantt

6.9. Best Practice

As mentioned in 5.9 Best Practice, continue to follow project plan in great detail to finish all of the documents in time.

7.0 Seventh Iteration Report Second Construction Phase

7.1. Report Purpose

This is the seventh report marking the 70% time elapsed from the total time between January and May. The 70% time elapsed mark is between 30 March 2015 and 12 April 2015. This mark is named Second Construction Phase.

This report will include status of the completed iteration, and will give input to the next iteration starting at April 13 2015.

7.2. Objectives Reached

Objectives	Status	Input Next Iteration
Finish 80% of the PLC program	Not accomplished 80% of the program	Simplify the program, and continue working on the

Table 22 – Seventh Iteration Report - Objectives Status for Iteration

7.3. Adherence to Plan

HPCS group is according to the updated plan. PLC programming is not at the level is should be, but group estimate it for be finished within the finishing project date. See table 23 for more detail.

Task Name	Doer	Due Date	Delivery Date	Status
Project Plan	BB	01.04.15	01.04.15	OK, plan updated
Vision document	BB	02.04.15	01.04.15	OK, updated layout
Test Rig Construction	AS	02.04.15	04.04.15	Need more work done
HMI - Tech Doc Programming Log	AS	04.04.15	04.04.15	OK, updated
Controller - Technology Document	JN	05.04.15	08.04.15	Updated technology document compared to the new PLC software
Electrical Schematics - PLC & HMI Schematics	BB	07.04.15	04.04.15	OK, need to update terminal strip tags and amount
System Description - Tech Doc - Electro	BB	03.04.15	05.04.15	Updated document according to the updated electro schematics
Controller - Program layout	JN	04.04.15	03.04.15	Function block for filling and draining done
Controller - Derivate Function Tech Doc	JN	10.04.15	-	No result to report

Simulation Physical	JC	11.04.15	-	No result to report
Plant Model	JC	12.04.15	-	No result to report
Pump Model	JC	07.04.15	-	No result to report
System Evaluation - Tech Doc	TOS	12.04.15	11.04.15	Updated according to
Revision Document	TOS	12.04.15	-	Not updated
Presentation 2	TOS	12.04.15	12.04.15	All members are presentation ready. Will use two next days of the next iteration for general presentation and actual presentation
Project Plan - Time Report	BB	12.04.15	12.04.15	Send to Jørn

Table 23 – Seventh Iteration Report - Adherence to Plan

7.4. Problems and Lessons Learned

No problems or lessons learned this iteration.

7.5. Suggested Changes

No suggested changes recommended.

7.6. Risk Assessment for Next Iteration

Risk	Reduction of the risk
Not enough time for presentation practice	Leave at least between two or three days free to presentation practice before the second presentation

Table 24 – Seventh Iteration Report - Risk Assessment

7.7. Future Directions

HPCS group will keep the second presentation at 14 of April 2015, and continue working with the technology documents. Focus on delivering the PLC program.

7.8. Schedule

Task Name	Duration
Itrasjon 70%	**14 days**
Project Plan	2 days
Vision document	1 day
Test Rig Construction	1 day
HMI - Tech Doc Programming Log	1 day
Controller - Technology Document	3 days
Electrical Schematics - PLC & HMI Schematics	1 day
System Description - Tech Doc - Electro	2 days
Controller - Program layout	2 days
Controller - Derivate Function Tech Doc	1 day
Simuleringer Physical	3 days
Plant Model	1 day
Pump Model	1 day
System Evaluation - Tech Doc	2 days
Revision Document	1 day
Presentation 2	2 days
Project Plan - Time Report	2 days

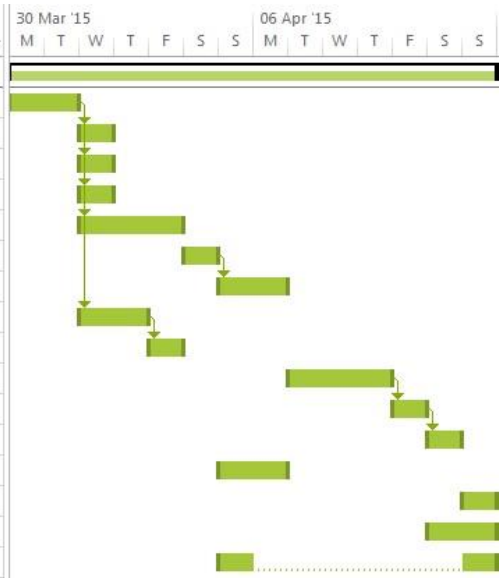


Figure 7 – Seventh Iteration Report - Iteration Second Constriction Phase Project Gantt

7.9. Best Practice

Starting to focus on documentation the simulation in greater degree, as well as continuing the PLC programing and documentation of it.

8.0 Eighth Iteration Report Document Completion and Construction

8.1. Report Purpose

This is the eighth report marking the 80% time elapsed from the total time between January and May. The 80% time elapsed mark is between April 14 2015 and April 26 2015.
This mark is named Document Completion and Construction.

This report will include status of the completed iteration, and will give input to the next iteration starting at April 27 2015.

8.2. Objectives Reached

Objectives	Status	Input Next Iteration
Finish the most of the documentation:		
Simulation document update	First revision done	Continue in next iteration to finish. Comment all figures
FAT procedure, update revision	First revision done	Continue in next iteration to finish. Change layout and add more FAT procedure information
Update Project plan and create iteration report. Project plan to be updated according to real activities and iteration process.	Updated according to iteration process	Create Iteration Report. Start with 80% and check with Karoline and FMC if OK. Send Karoline the Project plan document and Gantt chart for check.
GA system overview, update revision	First revision	Continue to finish. Update some valves, change dimensions of the frames
Web page, update layout	Updated and new layout	Update project status. Add Iteration Report to web page
HMI, update software and technology document	Updated to next revision	Continue in next iteration to finish. Technology document to be finished when the HMI program is finished
PLC, update software and technology document	Updated to next revision	Continue in next iteration to finish. Technology document to be finished when the PLC program is finished.
Test rig document	Created new revision	Complete documentation, when test rig is finished
Revisions document	Updated	No needed actions reported.
BOM	Updated BOM	Continue in next iteration to finish. No needed actions reported.

Discrete document	First revision	Continue in next iteration to finish. Add technical data and have better layout of the document
Create test rig	OK, first revision	Complete test rig. Implement function test of HMI and PLC

Table 25 – Eighth Iteration Report - Objectives Status for Iteration

8.3. Adherence to Plan

Until now most of the documents are at correct revision as planned. Some of the documents are postponed, and some of the documents where overdue compared to Project Plan. See table 26 for more detail.

Task Name	Doer	Due Date	Delivery Date	Status
Presentation 2	All	14.04.15	14.04.15	OK
Project Plan	BB	19.04.15	17.04.15	Updated
FAT Procedure	TOS	21.04.15	20.04.15	Updated
Test Rig Construction	AS, JN	23.04.15	24.04.15	1 day late, updated
Micrometer valve Model	JC	23.04.15	23.04.15	OK
Web Page	BB	24.04.15	24.04.15	OK
PID Simulation	JC	24.04.15	-	Included in Increase / Decrease tech doc
Controller - Technology Document	JN	24.04.15	-	Need more time
Controller - Tech Doc Iteration Document	JN	25.04.15	-	Need more time
Test Rig Tech Doc	AS, JN	25.04.15	-	Need more time
Increase/Decrease Function Tech Doc	JC	25.04.15	27.04.15	2 days late
Controller - Derivate Function Tech Doc	JN	26.04.15	-	Need more time
Controller - Program layout	JN	26.04.15	-	Need more time
Discrete Document	AS	26.04.15	-	Need more time
Spare List	TOS	26.04.15	-	Included in BOM
TDI (Technical Data Information)	TOS	26.04.15	-	Postponed
Revision Document	AS	26.04.15	16.04.15	OK
Project Plan - Time Report	BB	26.04.15	26.04.15	OK
Bulk Modulus Tech Doc – 001	JC	26.04.15	23.04.15	OK

Table 26 – Eighth Iteration Report - Adherence to Plan

8.4. Problems and Lessons Learned

This iteration was including the construction of a prototype. The prototype is made from home equipment just for testing the functions. What HPCS group have struggled with was pressure transmitter calibration.
After reading carefully the data sheet HPCS group figured out that the setup of the pressure transmitter was not correct for calibration. There was one DIP switch that had to change the setup to be able to calibrate zero and span value of the PT [1]. Another thing that datasheet helped with was to calculate the right amount of resistance in series to be able to get 4-20mA, it also needed a resistor in series, which needed to be calculated for the setup.

HPCS group is using Google Web Designer for page layout. Button function did not work and animations could not be created. This was fixed by changing layout from HTLM to HTLM with Pages. Second problem was the compatibility problem with Internet Explorer and intranet for FMC. Removed some functions and now compatibility problem are less problematic.
FMC is using older version of Internet Explorer as well as intranet is blocking the webpage. This was consulted with FMC IT, but there was no help to get. Solution is to ether download Chrome as internet browser at FMC technologies laptops, or see the web page at home internet.

8.5. Suggested Changes

Postpone some of the document to the next iteration. Those documents are not critical for the testing iteration.

With contact of the IT from FMC, change the web page for the FMC supervisor to follow up the group without having to log through the home internet or all included in the project; install Chrome browser.

8.6. Risk Assessment for Next Iteration

Risk	Reduction of the risk
Documents not finished:	
Not able to finish all the documents in time	Finish one document at a time. More effective way of putting. Putting more hours to finishing the undone documents
Work not tested:	
Document must be finished before test can be applied. Test must take place with significate time margin before delivery date. This can cause large hour loss in double testing of correlated documents or work. This applies also to test rig and test rig technology document	For time efficiency, do not test documents or work if they have correlation with other unfinished documents or work. Start tests on work that are 100% done

Table 27 – Eighth Iteration Report - Risk Assessment

8.7. Future Directions

The next half of the iteration there is all about finishing all the documents that are not done. Test of the documents and GA for the system is the primal focus. HPCS group created a better layout of the document and need to be implemented in all documents, since not all document used the same layout. Result of this will make all layout of the documents unified. Those hours are written as a task in time report named Quality Assurance.

8.8. Schedule

Task Name	Duration
Itrasjon 80%	14 days
Presentation 2	1 day
Project Plan	5 days
FAT Procedure	1 day
Test Rig Construction	2 days
Controller - Technology Document	3 days
Controller - Tech Doc Iteration Document	1 day
Controller - Derivate Function Tech Doc	1 day
Web Page	1 day
Test Rig Tech Doc	2 days
Controller - Program layout	2 days
Micrometer valve Model	1 day
PID Simulation	1 day
Increase/Decrease Function Tech Doc	1 day
Discrete Document	1 day
Spare List	1 day
TDI (Technical Data Information)	1 day
Revision Document	1 day
Project Plan - Time Report	2 days
Bulk Modulus Tech Doc - 001	1 day

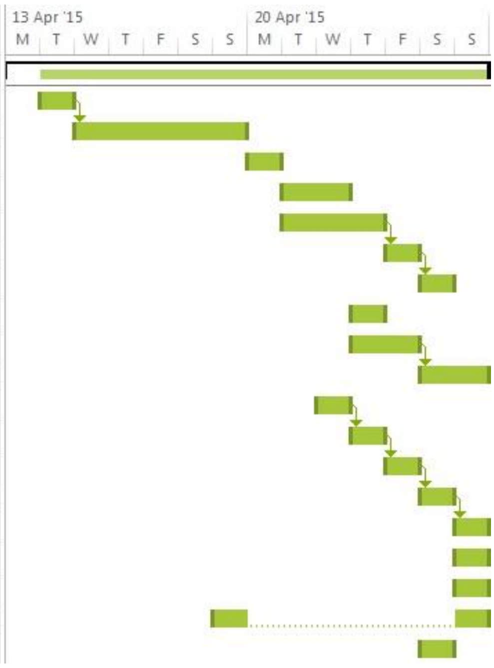


Figure 8 – Eighth Iteration Report - Iteration Document Completion and Construction Project Gantt

8.9. Best Practice

The best practice for this project now is to do as much work as possible for testing the documents and work as mention in seventh iteration.
This will give the advantage for the group of having many days free from the technical aspect and focusing on the finishing aspect of the project.

HPCS group expect the finishing of the project to take many work hours, so HPCS group is putting energy for testing aspect, and making the layout correct and unified.

9.0 Ninth Iteration Report
Test Phase

9.1. Report Purpose
This is the ninth report marking the 90% time elapsed from the total time between January and May. The 90% time elapsed mark is between April 27 2015 and May 10 2015.
This mark is named Test Phase.
This report will include status of the completed iteration, and will give input to the next iteration starting at May 11 2015.

9.2. Objectives Reached

Objectives	Status	Input Next Iteration
Complete all documents, and create the finishing bachelor information	All documents are finished. Started with finishing bachelor information	Create project summary, conclusion and so on
Test all documents	All documents are tested and approved	No additional adjustments
Set up table of constant for the project	Not implemented	Will be done in early stage of next iteration
Complete all iteration reports	OK	No additional adjustments

Table 28 – Ninth Iteration Report - Objectives Status for Iteration

9.3. Adherence to Plan
According to the plan, HPCS group should have printed and done all of the documentation. Documentations are done, and tested, but bachelor project layout need more time. See table 29 for more detail.

Task Name	Doer	Due Date	Delivery Date	Status
Project Plan	BB	09.05.15	09.05.15	OK, all iteration documents are complete.
User Manual	JC	04.05.15	09.05.15	Late, but released
Controller - System test	JN	10.05.15	-	Not tested the planned function test. Will do this finished in next iteration
Revision Document	TOS	10.05.15	10.05.15	Updated
Quality control of documents	BB	09.05.15	10.05.15	OK, done. One day late compared to the plan
Project Plan - Time Report	BB	10.05.15	-	Will deliver in next iteration as soon as possible

Table 29 – Ninth Iteration Report - Adherence to Plan

9.4. Problems and Lessons Learned

HPCS group was very detailed with the test process of the documents. The documents are carefully checked. This took much longer time than estimated in the first place. This lead to some of the tasks to be transferred to next iteration. Next iteration will not be reported.

9.5. Suggested Changes

Setting layout of the print in the next iteration, as well as formatting the bachelor project index.

9.6. Risk Assessment for Next Iteration

Risk	Reduction of the risk
Due date for all documents test and implementation is Sunday 09.05. 2015. If the due date is not held, bachelor project may have problems with due date for binding of the files.	Work long hours, with group together and structured.

Table 30 – Ninth Iteration Report - Risk Assessment

9.7. Future Directions

Deliverer all documents in the start of the next iteration. Start to

9.8. Schedule

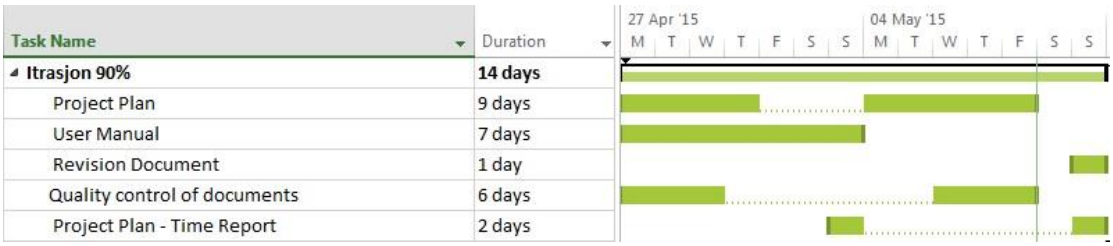


Figure 9 – Ninth Iteration Report - Iteration Document Completion and Construction Project Gantt

9.9. Best Practice

Deliver all of the documents for printing at start at next iteration. This give the group an advantage of many days of slack to fix and correct some of the work done, prepare well for the final presentation and create a good project poster coming in the next iteration.

Conclusion of the Iteration Reports

Project plan in some iterations had overwhelming amount of tasks. Important note is that there are five students, so the working load is correct.

Overall the project plan was by the due dates assigned, with some exceptions.

HPCS group see now that HPCS Mechanical Construction Frames and P&ID should not be included this early in the prestudy phase. This is still in the report to document what actually happened.

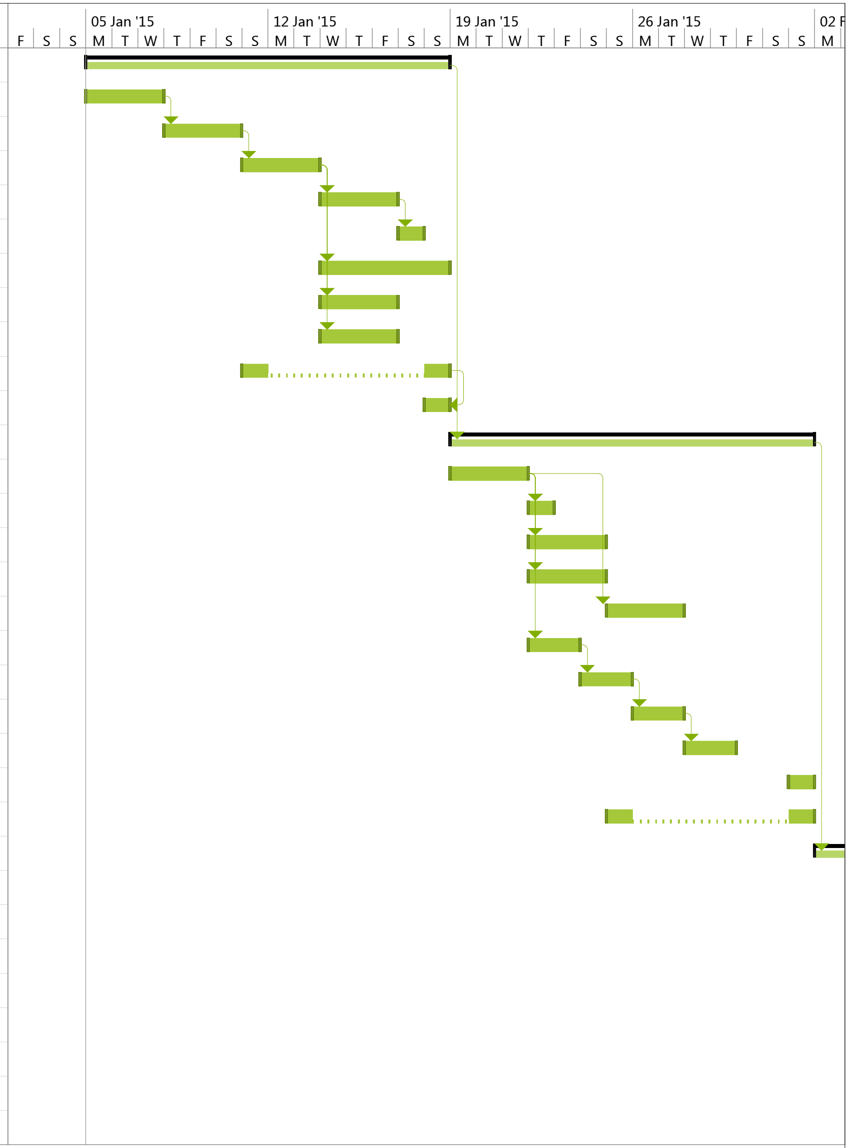
References

[1] Wikipedia, "DIP Switch," [Online]. Available: http://en.wikipedia.org/wiki/DIP_switch. [Accessed 01 05 2015].

[2] G. Dogan, "How to Write an Iteration Report?," [Online]. Available: https://dogangokhan.wordpress.com/2009/03/14/how-to-write-an-iteration-report/. [Accessed 01 05 2015].

Note: This document layout is based on reference [2].

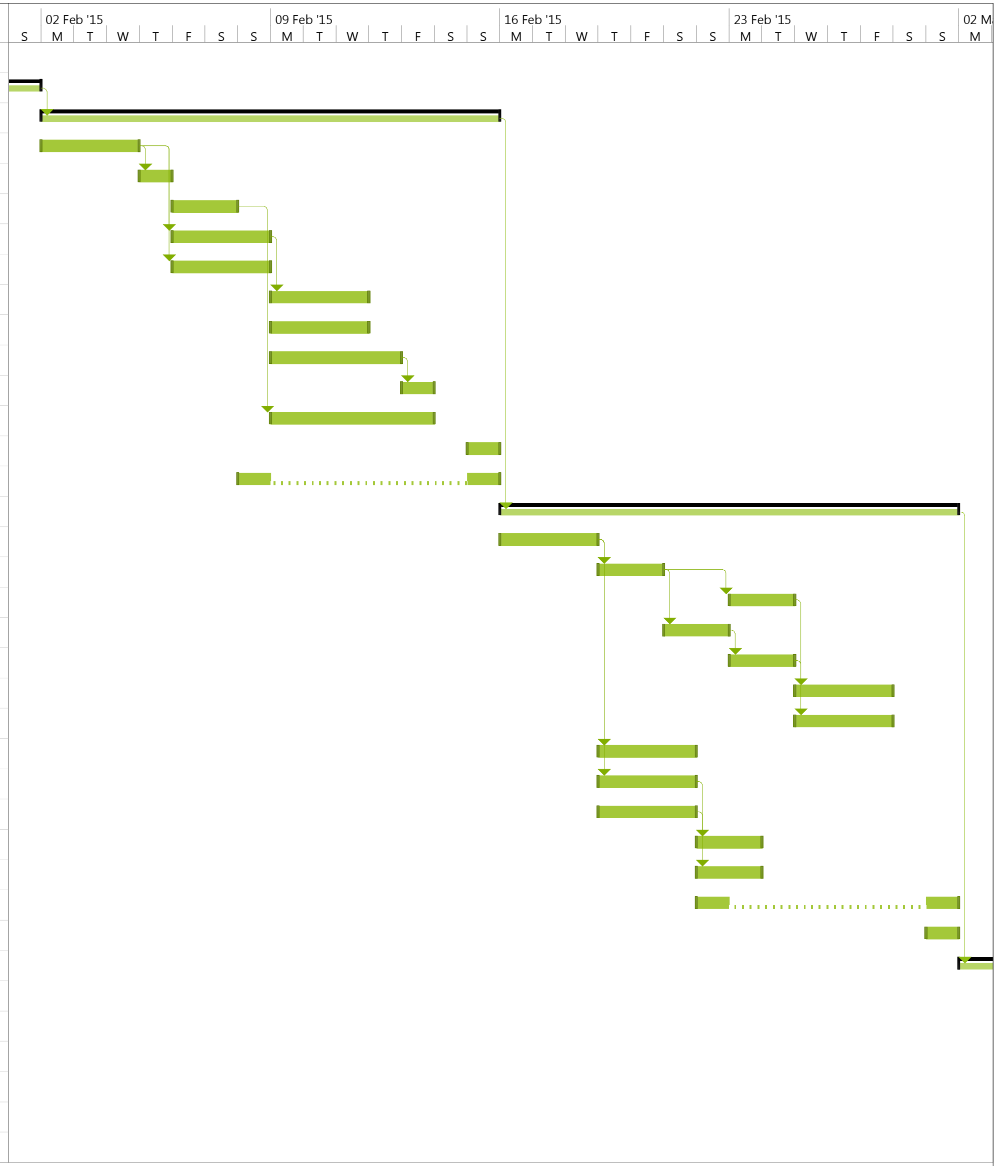
ID	Task Name	Duration	Due Date	Responsible	Predecessors	Status1
1	**Itrasjon 10%**	**14 days**	**NA**			
2	Project Plan	3 days	Thu 08.01.15	Brian		
3	Requirement specifications	3 days	Sun 11.01.15	Jonas C	2	
4	Test Specifications	3 days	Wed 14.01.15	Anders	3	
5	BOM	3 days	Sat 17.01.15	Thor Ove	4	
6	HPCS Mechanical Construction Frames	1 day	Sun 18.01.15	Thor Ove	5	
7	HMI - Programming	5 days	Sun 18.01.15	Anders	4	
8	Controller - Learn structured text	3 days	Sat 17.01.15	Jonas N	4	
9	Process Schematics (P&ID)	3 days	Sat 17.01.15	Jonas C	4	
10	Project Plan - Time Report	2 days	Sun 18.01.15	Brian		
11	Revision Document	1 day	Sun 18.01.15	Thor Ove	10FF	
12	**Itrasjon 20%**	**14 days**	**NA**		**1**	
13	Project Plan	3 days	Thu 22.01.15	Brian		
14	Web Page	1 day	Fri 23.01.15	Jonas N	13	
15	BOM	3 days	Sun 25.01.15	Thor Ove	13	
16	Process Schematics (P&ID)	3 days	Sun 25.01.15	Jonas C	13	
17	Electrical Schematics - Power Schematics	3 days	Wed 28.01.15	Brian	13	
18	Controller - Network Connetion	2 days	Sun 25.01.15	Anders	13	
19	Controller - PLC Derivation Function	2 days	Mon 26.01.15	Jonas N	18	
20	Controller - Variable List	2 days	Wed 28.01.15	Jonas N	19	
21	Controller - Program layout	2 days	Fri 30.01.15	Jonas N	20	
22	Revision Document	1 day	Thu 01.01.15	Thor Ove		
23	Project Plan - Time Report	2 days	Thu 01.01.15	Brian		
24	**Itrasjon 30%**	**14 days**	**NA**		**12**	
37	**Itrasjon 40%**	**14 days**	**NA**		**24**	
52	**Itrasjon 50%**	**14 days**	**NA**		**37**	
68	**Itrasjon 60%**	**14 days**	**NA**		**52**	
91	**Itrasjon 70%**	**14 days**	**NA**		**68**	
108	**Itrasjon 80%**	**14 days**	**NA**		**91**	
128	**Itrasjon 90%**	**14 days**	**NA**		**108**	
134	**Itrasjon 100%**	**7 days**	**NA**		**128**	
139	**Finish**	**16 days**	**NA**		**134**	



Project: Evo Project Plan (2)
Date: Sun 10.05.15

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

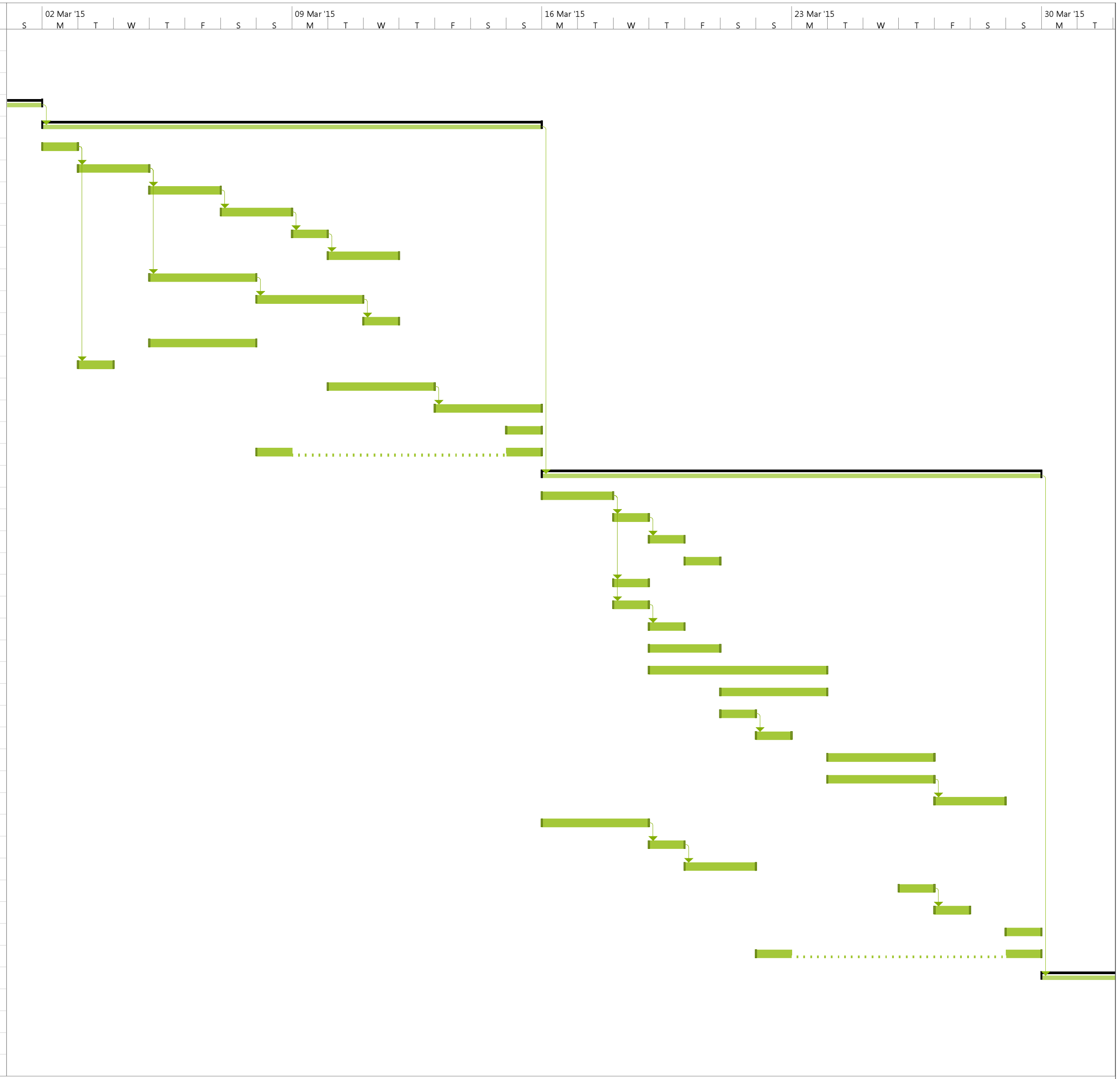
ID	Task Name	Duration	Due Date	Responsible	Predecessors	Status1
1	**Itrasjon 10%**	**14 days**	**NA**			
12	**Itrasjon 20%**	**14 days**	**NA**		**1**	
24	**Itrasjon 30%**	**14 days**	**NA**		**12**	
25	Project Plan	3 days	Thu 05.02.15			
26	Project Plan - Technology Document	1 day	Fri 06.02.15	Brian	25	
27	Controller - Network Connetion	2 days	Wed 08.04.15	Anders		
28	Interface between components list	3 days	Mon 09.02.15	Thor Ove	25	
29	Electrical Schematics - Control Schematics	3 days	Mon 09.02.15	Brian	25	
30	BOM	3 days	Thu 12.02.15	Thor Ove	28	
31	Controller - Program layout	3 days	Thu 12.02.15	Jonas N		
32	Simuleringer Physical	4 days	Fri 13.02.15	Jonas C		
33	Simuleringer Electrical Control	1 day	Sat 14.02.15	Jonas C	32	
34	HMI - Tech Doc for HMI	5 days	Sat 14.02.15	Anders	27	
35	Revision Document	1 day	Sun 15.02.15	Thor Ove		
36	Project Plan - Time Report	2 days	Sun 15.02.15	Brian		
37	**Itrasjon 40%**	**14 days**	**NA**		**24**	
38	Project Plan	3 days	Thu 19.02.15	Brian		
39	Controller - Variable List	2 days	Sat 21.02.15	Jonas N	38	
40	HMI - Programming	2 days	Wed 25.02.15	Anders	39	
41	Controller - Program layout	2 days	Mon 23.03.15	Jonas N	39	
42	Controller- Tech Doc Analog Block (DA)	2 days	Wed 25.02.15	Anders	41	
43	HMI - Tech Doc for HMI	3 days	Sat 28.02.15	Anders	40	
44	Controller - Technology Document	3 days	Sat 28.02.15	Jonas N	42	
45	Electrical Schematics - GA Cabinet	3 days	Sun 22.02.15	Brian	38	
46	System Description - Tech Doc	3 days	Sun 22.02.15	Thor Ove	38	
47	Simuleringer Physical	3 days	Sun 22.02.15	Jonas C		
48	Simuleringer Electrical Control	2 days	Tue 24.02.15	Jonas C	47	
49	BOM	2 days	Tue 24.02.15	Thor Ove	46	
50	Project Plan - Time Report	2 days	Mon 23.02.15	Brian		
51	Revision Document	1 day	Sun 01.03.15	Thor Ove		
52	**Itrasjon 50%**	**14 days**	**NA**		**37**	
68	**Itrasjon 60%**	**14 days**	**NA**		**52**	
91	**Itrasjon 70%**	**14 days**	**NA**		**68**	
108	**Itrasjon 80%**	**14 days**	**NA**		**91**	
128	**Itrasjon 90%**	**14 days**	**NA**		**108**	
134	**Itrasjon 100%**	**7 days**	**NA**		**128**	
139	**Finish**	**16 days**	**NA**		**134**	



Project: Evo Project Plan (2)
Date: Sun 10.05.15

Task		Project Summary		Manual Task		Start-only		Deadline	
Split		Inactive Task		Duration-only		Finish-only		Progress	
Milestone		Inactive Milestone		Manual Summary Rollup		External Tasks		Manual Progress	
Summary		Inactive Summary		Manual Summary		External Milestone			

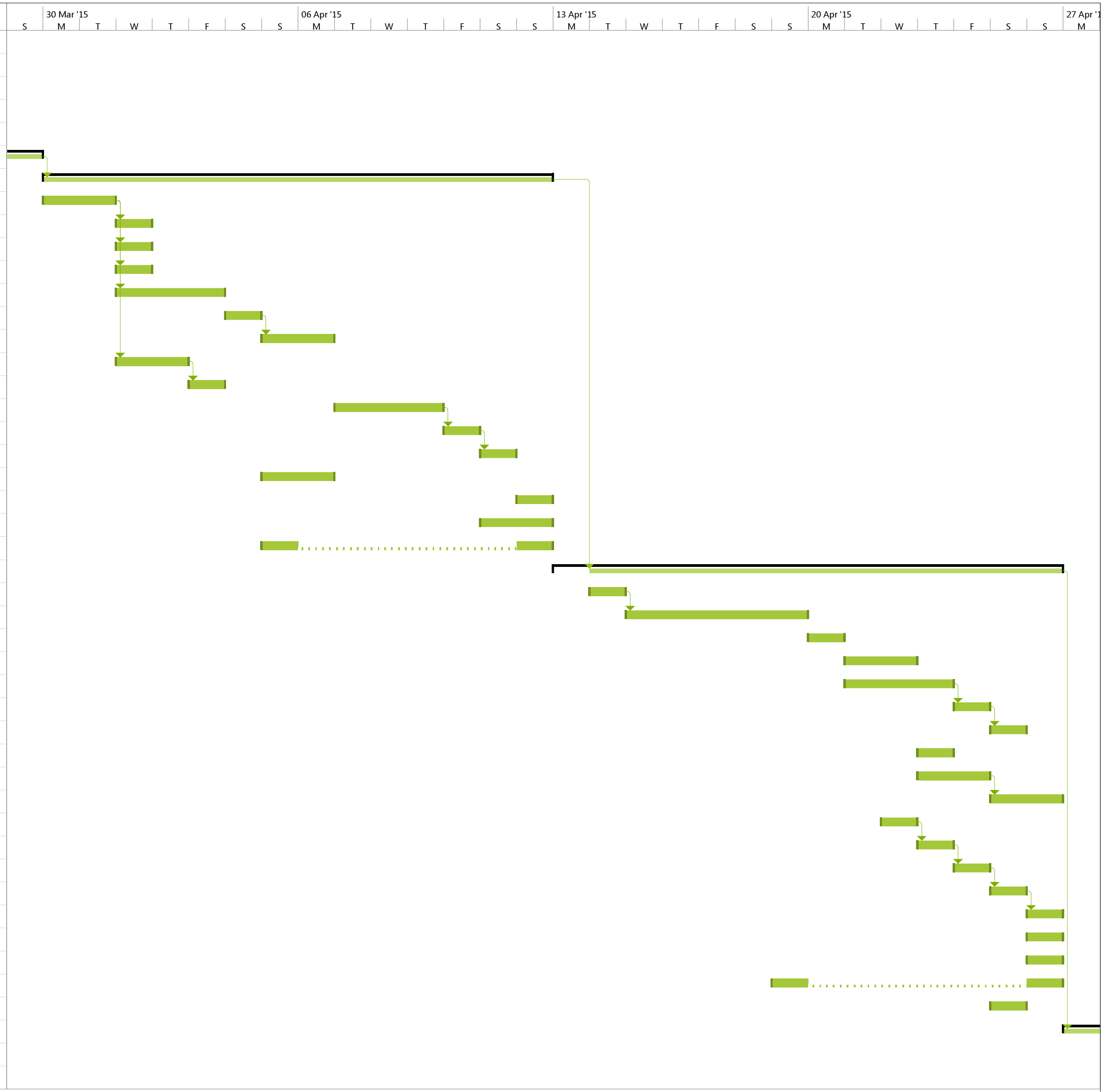
ID	Task Name	Duration	Due Date	Responsible	Predecessors	Status1
1	**Itrasjon 10%**	**14 days**	**NA**			
12	**Itrasjon 20%**	**14 days**	**NA**		**1**	
24	**Itrasjon 30%**	**14 days**	**NA**		**12**	
37	**Itrasjon 40%**	**14 days**	**NA**		**24**	
52	**Itrasjon 50%**	**14 days**	**NA**		**37**	
53	Project Plan	1 day	Tue 03.03.15	Brian		
54	Controller - PLC Derivation Function	2 days	Thu 05.03.15	Jonas N	53	
55	Controller - Program layout	2 days	Tue 07.04.15	Jonas N	54	
56	Controller - Variable List	2 days	Mon 09.03.15	Jonas N	55	
57	Controller - Technology Document	1 day	Tue 10.03.15	Jonas N	56	
58	Test Rig Construction	2 days	Thu 12.03.15	Anders	57	
59	HMI - Programming	3 days	Sun 08.03.15	Anders	54	
60	HMI - Tech Doc for HMI	3 days	Wed 11.03.15	Anders	59	
61	HMI - Tech Doc Programming Log	1 day	Thu 12.03.15	Anders	60	
62	Electrical Schematics - Control Schematics	3 days	Sat 07.03.15	Brian		
63	Increase / Decrease Function	1 day	Wed 04.03.15	Jonas C	53	
64	Simuleringer Physical	3 days	Fri 13.03.15	Jonas C		
65	System Description - Tech Doc	3 days	Sun 15.03.15	Thor Ove	64	
66	Revision Document	1 day	Sun 15.03.15	Thor Ove		
67	Project Plan - Time Report	2 days	Sun 15.03.15	Brian		
68	**Itrasjon 60%**	**14 days**	**NA**		**52**	
69	Project Plan	2 days	Wed 18.03.15	Brian		
70	Vision document	1 day	Thu 19.03.15	Brian	69	
71	GA over system	1 day	Fri 20.03.15	Brian	70	
72	Test Rig Construction	1 day	Mon 16.03.15	Anders		
73	Process Schematics (P&ID)	1 day	Thu 19.03.15	Jonas C	69	
74	Requirement specifications	1 day	Thu 19.03.15	Jonas C	69	
75	Test Specifications	1 day	Fri 20.03.15	Anders	74	
76	Increase / Decrease Function	2 days	Sat 21.03.15	Jonas C		
77	System Description - Tech Doc	5 days	Tue 24.03.15	Thor Ove		
78	Controller - Technology Document	3 days	Tue 24.03.15	Jonas N		
79	Controller - Program layout	1 day	Sun 22.03.15	Jonas N		
80	Controller- Tech Doc Analog Block (DA)	1 day	Mon 23.03.15	Anders	79	
81	System Description - Tech Doc - Hydraulic	3 days	Fri 27.03.15	Thor Ove		
82	System Description - Tech Doc - Electro	3 days	Fri 27.03.15	Brian		
83	Electrical Schematics - GA Cabinet	2 days	Sun 29.03.15	Brian	82	
84	HMI - Tech Doc Programming Log	3 days	Thu 19.03.15	Anders		
85	HMI - Function Test	1 day	Fri 20.03.15	Anders	84	
86	HMI - Programming	2 days	Sun 22.03.15	Anders	85	
87	Simuleringer Electrical Control	1 day	Thu 26.03.15	Jonas C		
88	Plant Model	1 day	Fri 27.03.15	Jonas C	87	
89	Revision Document	1 day	Sun 29.03.15	Thor Ove		
90	Project Plan - Time Report	2 days	Sun 29.03.15	Brian		
91	**Itrasjon 70%**	**14 days**	**NA**		**68**	
108	**Itrasjon 80%**	**14 days**	**NA**		**91**	
128	**Itrasjon 90%**	**14 days**	**NA**		**108**	
134	**Itrasjon 100%**	**7 days**	**NA**		**128**	
139	**Finish**	**16 days**	**NA**		**134**	



Project: Evo Project Plan (2)
Date: Sun 10.05.15

Task · Split · Milestone · Summary · Project Summary · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · External Tasks · External Milestone · Deadline · Progress · Manual Progress

ID	Task Name	Duration	Due Date	Responsible	Predecessors	Status1
1	**Itrasjon 10%**	**14 days**	**NA**			
12	**Itrasjon 20%**	**14 days**	**NA**		**1**	
24	**Itrasjon 30%**	**14 days**	**NA**		**12**	
37	**Itrasjon 40%**	**14 days**	**NA**		**24**	
52	**Itrasjon 50%**	**14 days**	**NA**		**37**	
68	**Itrasjon 60%**	**14 days**	**NA**		**52**	
91	**Itrasjon 70%**	**14 days**	**NA**		**68**	
92	Project Plan	2 days	Wed 01.04.15	Brian		
93	Vision document	1 day	Thu 02.04.15	Brian	92	
94	Test Rig Construction	1 day	Thu 02.04.15	Anders	92	
95	HMI - Tech Doc Programming Log	1 day	Sat 04.04.15	Anders	92	
96	Controller - Technology Document	3 days	Sun 05.04.15	Jonas N	92	
97	Electrical Schematics - PLC & HMI Schematics	1 day	Tue 07.04.15	Brian		
98	System Description - Tech Doc - Electro	2 days	Fri 03.04.15	Brian	97	
99	Controller - Program layout	2 days	Sat 04.04.15	Jonas N	92	
100	Controller - Derivate Function Tech Doc	1 day	Fri 10.04.15	Jonas N	99	
101	Simuleringer Physical	3 days	Sat 11.04.15	Jonas C		
102	Plant Model	1 day	Sun 12.04.15	Jonas C	101	
103	Pump Model	1 day	Tue 07.04.15	Jonas C	102	
104	System Evaluation - Tech Doc	2 days	Sun 12.04.15	Thor Ove		
105	Revision Document	1 day	Sun 12.04.15	Thor Ove		
106	Presentation 2	2 days	Sun 12.04.15	Thor Ove		
107	Project Plan - Time Report	2 days	Sun 12.04.15	Brian		
108	**Itrasjon 80%**	**14 days**	**NA**		**91**	
109	Presentation 2	1 day	Tue 14.04.15	Thor Ove		
110	Project Plan	5 days	Sun 19.04.15	Brian	109	
111	FAT Procedure	1 day	Tue 21.04.15	Thor Ove		
112	Test Rig Construction	2 days	Thu 23.04.15	Anders		
113	Controller - Technology Document	3 days	Fri 24.04.15	Jonas N		
114	Controller - Tech Doc Iteration Document	1 day	Sat 25.04.15	Jonas N	113	
115	Controller - Derivate Function Tech Doc	1 day	Sun 26.04.15	Jonas N	114	
116	Web Page	1 day	Fri 24.04.15	Jonas N		
117	Test Rig Tech Doc	2 days	Sat 25.04.15	Anders		
118	Controller - Program layout	2 days	Sun 26.04.15	Jonas N	117	
119	Micrometer valve Model	1 day	Thu 23.04.15	Jonas C		
120	PID Simulation	1 day	Fri 24.04.15	Jonas C	119	
121	Increase/Decrease Function Tech Doc	1 day	Sat 25.04.15	Jonas C	120	
122	Discrete Document	1 day	Sun 26.04.15		121	
123	Spare List	1 day	Sun 26.04.15		122	
124	TDI (Technical Data Information)	1 day	Sun 26.04.15			
125	Revision Document	1 day	Sun 26.04.15	Thor Ove		
126	Project Plan - Time Report	2 days	Sun 26.04.15	Brian		
127	Bulk Modulus Tech Doc - 001	1 day	Sun 26.04.15			
128	**Itrasjon 90%**	**14 days**	**NA**		**108**	
134	**Itrasjon 100%**	**7 days**	**NA**		**128**	
139	**Finish**	**16 days**	**NA**		**134**	



Project: Evo Project Plan (2)
Date: Sun 10.05.15

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

ID	ID	Task Name	Duration	Due Date	Responsible	Predecessors	Status1	Completed
1	**1**	**Itrasjon 10%**	**14 days**	**NA**				
12	**12**	**Itrasjon 20%**	**14 days**	**NA**		**1**		
24	**24**	**Itrasjon 30%**	**14 days**	**NA**		**12**		
37	**37**	**Itrasjon 40%**	**14 days**	**NA**		**24**		
52	**52**	**Itrasjon 50%**	**14 days**	**NA**		**37**		
68	**68**	**Itrasjon 60%**	**14 days**	**NA**		**52**		
91	**91**	**Itrasjon 70%**	**14 days**	**NA**		**68**		
108	**108**	**Itrasjon 80%**	**14 days**	**NA**		**91**		
128	**128**	**Itrasjon 90%**	**14 days**	**NA**		**108**		
129	129	Project Plan	9 days	Sat 09.05.15	Brian			✓
130	130	User Manual	7 days	Mon 04.05.15	Jonas C			✓
131	131	Revision Document	1 day	Sun 10.05.15	Thor Ove			✓
132	132	Quality control of documents	6 days	Sat 09.05.15	Brian			✓
133	133	Project Plan - Time Report	2 days	Sun 10.05.15	Brian			✓
134	**134**	**Itrasjon 100%**	**7 days**	**NA**		**128**		
135	135	Create three versions of project	3 days	Sun 17.05.15	Jonas C			
136	136	Controller - System test	7 days	Sun 10.05.15	Jonas N			
137	137	Project Plan - Time Report	2 days	Sun 17.05.15	Brian			
138	138	Project Poster	1 day	Fri 15.05.15				
139	139	Print and Layout	1 day	Mon 11.05.15				
140	**140**	**Finish**	**14,5 days**	**NA**		**134**		
141	141	Final presentation	5 days	Thu 28.05.15	Anders			
142	142	Final Delivery	10 days	Sun 17.05.15				

Project: Evo Project Plan (2) Date: Sun 10.05.15	Task	Summary	Inactive Milestone	Duration-only	Start-only	External Milestone	Manual Progress
	Split	Project Summary	Inactive Summary	Manual Summary Rollup	Finish-only	Deadline	
	Milestone	Inactive Task	Manual Task	Manual Summary	External Tasks	Progress	

Hyperbaric - Pressure Control System

Requirement Specification

Group:
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Jonas Nicolaysen
Jonas Carlstedt
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Brian Berg

Document author: Thor Ove Skarseth and Jonas Carlstedt

ID: REQ-001 <D>

1.0 Revisions

Table 1 - Revisions

Date	Description	Version	Made By	Approved By
08.12.2014	Requirement Specification	-	JC, TOS	AS, BB
10.01.2015	Feedback from presentation one	A	JC, TOS	AS, BB, JN
15.03.2015	Change of Plan, added User Manual to R16-E	B	BB, TOS, JN, AS, JC	FMC
02.04.2015	R8-E formatting change, remove R3-I and R15-I	C	BB, TOS, JN, AS	TOS, JN, AS,BB
09.05.2015	Formatting layout	D	JC	TOS, JN, AS, BB

1.1 Table of contents

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1.2 Table list

1.3 Abbreviation list

Table 2 - Abbreviations

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
GA	General arrangement
HBV	Høgskolen I Buskerud/Vestfold
TDI	Technical Data Information

2.0 Requirement Specification

2.1 Introduction

This document contains all requirements for HPCS, and establish the basis for test specification which again establish the basis for the FAT to ensure that all requirements have been met.

This document covers functional & non-functional requirements.
Each requirement is given an individual priority of importance, ranging from three to one, where one is the most significant grade. For the customer to be satisfied with the project, at least all requirements with priority grade one has to be accomplished. FMCTI is represented by Joakim Lerstang while HPCS is represented by the student group.

2.2 Specification priority grade

1. Most important requirements for design of HPCS.
2. Important requirements, but not critical for design of HPSC.
3. Less important requirements that are desirable, but does not affect safety and the main function of HPCS.

2.3 Requirements

Table 3 – Functional requirements

2.3.1 Functional requirements				
ID	**Priority**	**Require**	**Explanation**	**Correlation**
R1-E	1	FMCTI	The system design shall contain a touch-screen based HMI.	
R3-E	1	FMCTI	The system design shall have adjustable derivative parameters for increasing/decreasing of pressure in the tank.	R2-I
R4-E	1	FMCTI	Operator shall be able to set pressure program parameters to the system design.	
R8-E	3	FMCTI	The system shall be designed to isolate the pressure inside the tank at holding time.	
R9-E	1	FMCTI	The system design shall keep trace on how many pressure cycles performed by the HPCS.	
R10-E	1	FMCTI	The system design shall contain equipment to prevent overpressure.	
R11-E	1	FMCTI	The system design shall contain a manually bleed valve to bleed down pressure inside system in case of system failure.	
R12-E	1	FMCTI	The system design shall contain an emergency shutdown switch.	
R13-E	2	FMCTI	The system design shall have hydraulic quick coupler for hose on the output line.	
R14-E	1	FMCTI	The system design shall maintain as close as possible linearity while increasing & decreasing pressure.	
R15-E	1	FMCTI	The system design shall perform pressure cycles automatically when pressure program parameters are given to the system and the operator has declared system to start through the HMI.	R13-I
R21-E	1	FMCTI	The system design shall be movable without use of crane.	

ID	Priority	Require	Explanation	Correlation
R2-I	1	HPCS	The system design shall have adjustable derivative parameters for increasing/decreasing of pressure in the tank. Tolerance: ≤±40bar/min.	R3-E
R4-I	1	HPCS	System design shall have a method of preventing vacuum and pressure in reservoir when fluid is being used or returned.	
R5-I	2	HPCS	The reservoir tank design shall have drain valve for draining of test fluid.	
R6-I	1	HPCS	The system design shall have hydraulic filtration to prevent damage to components due to particle contamination in the hydraulic fluid.	
R10-I	1	HPCS	The system design shall contain a manual isolation needle valve on hydraulic output line of HPCS.	
R11-I	1	HPCS	The hydraulic system design shall be covered some way to prevent damage to human being or external equipment caused by hydraulic leakage. Hose(s) between HPCS and reservoir tank and hose(s) between pressure tank is not required to be covered.	
R1-I	2	HPCS	System design shall contain a reservoir level alarm signal to prevent damage to the pressure pump.	

Table 4 – Non-functional requirements

2.3.2 Non-functional requirements				
ID	**Priority**	**Require**	**Explanation**	**Correlation**
R16-I	1	HBV	Project shall produce a project poster for HBV.	
R17-I	1	HBV	Project shall produce & deliver three copies of the documentation according to project guidelines given by HBV.	
R18-I	1	HBV	The project shall create their own web-site on web-domain supplied by HBV.	
R16-E	1	FMCTI	Project shall produce & deliver these technical documents to customer on final delivery of project: • GA • Hydraulic schematics • Electrical schematics • TDI • Component list • Spare part list • User Manual	
R17-E	1	FMCTI	The systems hydraulic parts are to be dimensioned in correctly pressure class according to its application.	

Hyperbaric - Pressure Control System

Test Specification

Group:
Thor Ove Skarseth
Jonas Nicolaysen
Jonas Carlstedt
Anders Skjørten
Brian Berg

Document author: Anders Skjørten

ID: TSPC-001 <D>

Revisions

Date	Description	Version	Made By	Approved By
19.11.2014	Idea Description	-	AS, BB	TOS, JN
10.01.2015	Changes to Table 1 Removed: T5-E, T6-E, T7-E, T7-I, T8-I, T9-I, T12-I, T14-I, T2-E, T18-E Changed: T3-E, T4-E, T10-E, T13-E, T21-E, T10-I, T11-I, T14-I, T15-I, T1-I, T12-I, T16-I, T17-I, T18-I, T16-E, T17-E Removed referance	A	AS	TOS,BB,JC,JN
24.03.2015	Removed T3-I and T15-I	B	AS	JN
09.05.2015	Text editing	C	AS	TOS, AS
10.05.2015	Approval	D	BB	All Group Members

Table 1 - Revisions

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Table list

Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
GA	General arrangement

Table 2 - Abbreviations

1.0 Test Specification

1.1 Introduction

This document describes how the requirements from FMCTI and the HPCS group will be tested. It also describes the significance of the test. All the tests are designed to meet the requirements given in the requirement specification. The meaning of the document is to ensure quality in the final product.

1.2 Functional requirement test

Test ID	Requirement ID	Priority	Test type	Method	Approved
T1-E	R1-E	1	Documentation	Inspection	When the system design includes a HMI.
T3-E	R3-E	1	Software	Inspection	When derivative parameters are adjustable from HMI.
T4-E	R4-E	1	Software / design	Inspection	When the pressure program parameters can be set in the system.
T8-E	R8-E	1	Software / design	Inspection	When a solution for isolating pressure at holding time exists in the system design.
T9-E	R9-E	1	Software / design	Inspection	When the amount of cycles is logged in HMI.
T10-E	R10-E	1	Documentation / design	Inspection	When the system is documented to prevent overpressure.
T11-E	R11-E	1	Documentation / design	Inspection	When manual bleed valve is included in the design.
T12-E	R12-E	1	Documentation / design	Inspection	When emergency shutdown is included in the design.

Test ID	Requirement ID	Priority	Test type	Method	Approved
T13-E	R13-E	2	Documentation / design	Inspection	When the system is designed with quick couplers.
T14-E	R14-E	1	Software	Inspection	When the PLC is programed and documented to have a function for linearity.
T15 –E	R15-E	1	Software	Inspection	When the PLC is programmed to run all sequences automatically after operator starts the program from the HMI.
T21-E	R21-E	1	Documentation	Inspection	When the system is designed and documented to be movable.
T2-I	R2-I	1	Software	Inspection	When the HMI and PLC is programed to take adjustable derivative parameters (±40bar/min).
T4-I	R4-I	1	Documentation	Inspection	When the system design contains a solution for vacuum.
T5-I	R5-I	2	Documentation	Inspection	When the system design contains a solution for reservoir draining.
T6-I	R6-I	1	Documentation	Inspection	When the system design contains a solution for hydraulic filtration.
T10-I	R10-I	1	Documentation	Inspection	When the system design includes a manual isolation needle valve.
T11-I	R11-I	1	Documentation	Inspection	When the system design includes a solution for safety barrier.

Test ID	Requirement ID	Priority	Test type	Method	Approved
T1-I	R1-I	2	Documentation	Inspection	When system design contains a solution for reservoir level alarm.

Table 3 - Functional requirement tests

1.3 Non-functional requirement tests

Test ID	Requirement ID	Priority	Test type	Method	Approved
T16-I	R16-I	1	Documentation	Inspection	When a Physical Poster is produced.
T17-I	R17-I	1	Documentation	Inspection	When there are produced & delivered three correct versions of the project documentation.
T18-I	R18-I	1	Construction	Inspection	When the webpage exists.
T16-E	R16-E	1	Documentation	Manual overview	When the document required by FMCTI is delivered.
T17-E	R17-E	1	Construction	Inspection	When pressure classification for parts is documented.

Table 4 - Non-functional requirement tests

1.4 Functional requirement tests

1.4.1 Test ID: T1-E

Requirement R1-E: The system design shall contain a touch-screen based HMI.

How:
Inspector will check that the system design includes a HMI.

1.4.2 Test ID: T3-E

Requirement R3-E: The system design shall have adjustable derivative parameters for increasing/decreasing of pressure in the tank.

How: Inspector will check that the derivative parameters is adjustable on the HMI.

1.4.3 Test ID: T4-E

Requirement R4-E: Operator shall be able to set pressure program parameters to the system design.

How:
Inspector will check that the pressure parameters can be set in the HMI

1.4.4 Test ID: T8-E

Requirement R8-E: The system design shall isolate the pressure inside the tank at holding time.

How:
Inspector will check that the system design contains a solution for isolating pressure at holding time.

APPROVED

1.4.5 Test ID: T9-E

Requirement R9-E: The system design shall keep trace on how many pressure cycles performed by the HPCS.

How:
Inspector will check that the HMI logging of cycles is functional.

APPROVED

1.4.6 Test ID: T10-E

Requirement R10-E: The system design shall contain equipment to prevent overpressure.

How:
Inspector will check the system design documents contain solutions for overpressure.

APPROVED

1.4.7 Test ID: T11-E

Requirement R11-E: The system design shall contain a manually bleed valve to bleed down pressure inside system in case of system failure.

How:
Inspector will check that system design documents contain solutions for manual bleed valve.

APPROVED

1.4.8 Test ID: T12-E

Requirement R12-E: The system design shall contain an emergency shutdown switch.

How:
Inspector will check that the system design documents contains a solution for emergency shutdown switch.

APPROVED

1.4.9 Test ID: T13-E

Requirement R13-E: The system design shall have hydraulic quick coupler for hose on the output line.

How:
Inspector will check that the system design documents include quick couplers.

1.4.10 Test ID: T14-E

Requirement: R14-E: The system design shall maintain as close as possible linearity while increasing & decreasing pressure.

How:
Inspector will check that the PLC documents and program contains functions for linearity.

1.4.11 Test ID: T15-E

Requirement R15-E: The system design shall perform pressure cycles automatically when pressure program parameters are given to the system and the system operator has declared to start through the HMI.

How:
Inspector will check that the PLC documents and program contains functions running all sequences of the system automatically after parameters are set in the HMI.

1.4.12 Test ID: T21-E

Requirement R21-E: The system design shall be movable without use of crane.

How:
Inspector will check that the system design is documented to be movable.

1.4.13 Test ID: T2-I

Requirement R2-I: The system design shall have adjustable derivative parameters for increasing/decreasing of pressure in the tank.
Tolerance: ≤±40bar/min.

How:
Inspector will check that the HMI and PLC is programmed for adjustable derivative parameters.

1.4.14 Test ID: T4-I

Requirement R4-I: System design shall have a method of preventing vacuum and pressure in reservoir when fluid is being used or returned.

How:
Inspector will check that the system design document includes solutions to prevent vacuum in reservoir.

APPROVED

1.4.15 Test ID: T5-I

Requirement R5-I: The reservoir tank design shall have drain valve for draining of test fluid.

How:
Inspector will check that the system design documents include a solution for reservoir draining.

1.4.16 Test ID: T6-I

APPROVED

Requirement R6-I: The system design shall have hydraulic filtration to prevent damage to components due to particle contamination in the hydraulic fluid.

How:
Inspector will check that the system design documents include a solution for hydraulic filtering.

1.4.17 Test ID: T10-I

APPROVED

Requirement R10-I: The system design shall contain a manual isolation needle valve on hydraulic output line of HPCS.

How:
Inspector will check that the system design documents include a manual needle valve.

1.4.18 Test ID: T11-I

APPROVED

Requirement R11-I: The hydraulic system design shall be covered some way to prevent damage to human being or external equipment caused by hydraulic leakage. Hose(s) between HPCS and reservoir tank and hose(s) between pressure tank is not required to be covered.

How:
Inspector will check that the system design documents include a solution for safety barrier.

1.4.19 Test ID: T1-I

Requirement R1-I: System design shall contain a reservoir level alarm signal to prevent damage to the pressure pump.

How:

Inspector will check that the system design documents includes a solution for reservoir level alarm.

1.5 Non-functional requirement tests.

1.5.1 Test ID: T16-I

Requirement R16-I: Project shall produce a project poster for HBV.

How:
Check if there is a poster made.

APPROVED

1.5.2 Test ID: T17-I

Requirement R17-I: Project shall produce & deliver three copies of the documentation according to project guidelines given by HBV.

How:
Have three copies of the project physically printed out, and deliver them to the correct person. The copies must be produced according to HBV guidelines.

APPROVED

1.5.3 Test ID: T18-I

Requirement R18-I: The project shall create their own web-site on web-domain supplied by HBV.

How:
Go to the project web site. Check if the site is online.

APPROVED

1.5.4 Test ID: T16-E

Requirement R16-E Project shall produce & deliver these technical documents to customer on final delivery of project:
GA, Hydraulic schematics, Electrical schematics, TDI, Component list and Spare part list.

APPROVED

How:
Check that all the specified documents are made and approved.

1.5.5 Test ID: T17-E

Requirement R17-E: The systems hydraulic parts are to be dimensioned in correctly pressure class according to its application.

How:
Check that the hydraulic parts is documented to have sufficient pressure classification.

APPROVED

Referanser

[1] J. Carlstedt and T. O. Skarseth, "Requirement specification," HPCS, 2015.
[2] «Approved Stample,» [Internett]. Available: http://cmiplanners.com/wp-content/uploads/2014/08/approved.jpeg. [Funnet 10 05 2015].

Hyperbaric - Pressure Control System

Factory Acceptance Test

Group:
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Jonas Nicolaysen
Jonas Carlstedt
Anders Skjørten
Brian Berg

Document author: Thor Ove Skarseth

ID: FAT-001 <A>

Revisions

Date	Description	Version	Made By	Approved By
18.04.2015	FAT	-	TOS	
08.05.2015	Layout formatting, added references	A	AS,TOS	JN, BB, JC

Table 1 - Revisions

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Table list

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Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
GA	General arrangement
HBV	Høgskolen I Buskerud/Vestfold
TDI	Technical Data Information
FAT	Factory Acceptance Test
PPE	Personal Protective Equipment

Table 2 - Abbreviations

Safety precautions

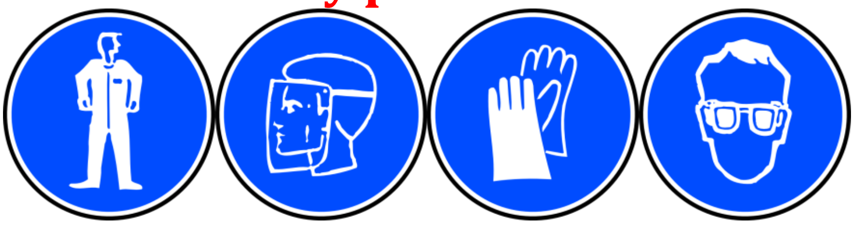

Figure 1 – Safety signs [1]

To ensure safe work conditions always use proper PPE!
Always treat electrical system as active until other is stated!
Always treat hydraulic systems as pressurized until other is stated!

1.0 Test setup

This chapter states the prerequisites and the test setup to be able to perform FAT.

1.1 Air Supply

Step	Description	Criteria	Date/Result
1.	Connect air supply hose to HPCS.	OK/NOT OK	
2.	Verify pressure on inlet pressure regulator.	≥7bar	

Table 3 - Air Supply

1.2 Pressure Tank Connection

Step	Description	Criteria	Date/Result
3.	Connect hoses from the pressure tank to HPCS by quick couplers.	OK/NOT OK	
4.	Ensure that all manual isolation valves are in open position (V-012 and V-015).	OK/NOT OK	

Table 4 - Pressure Tank Connection

1.3 Electrical Supply

Step	Description	Criteria	Date/Result
5.	Plug HPCS power socket to suited power socket in the workshop.	OK/NOT OK	
6.	Turn on main switch, and ensure that emergency switch not is activated.	OK/NOT OK	
7.	Verify that HMI power up and initial screen is showed.	OK/NOT OK	

Table 5 - Electrical Supply

1.4 Fluid Reservoir

Step	Description	Criteria	Date/Result
8.	Connect reservoir line hose to HPCS by quick coupler.	OK/NOT OK	
9.	Verify that reservoir is filled with fluid in the visual level inspection hose (LI-001).	OK/NOT OK	
10.	Verify in HMI at visual screen that reservoir level corresponds to visual level inspection in step 9. (See figure 2).	OK/NOT OK	

Table 6 - Fluid Reservoir

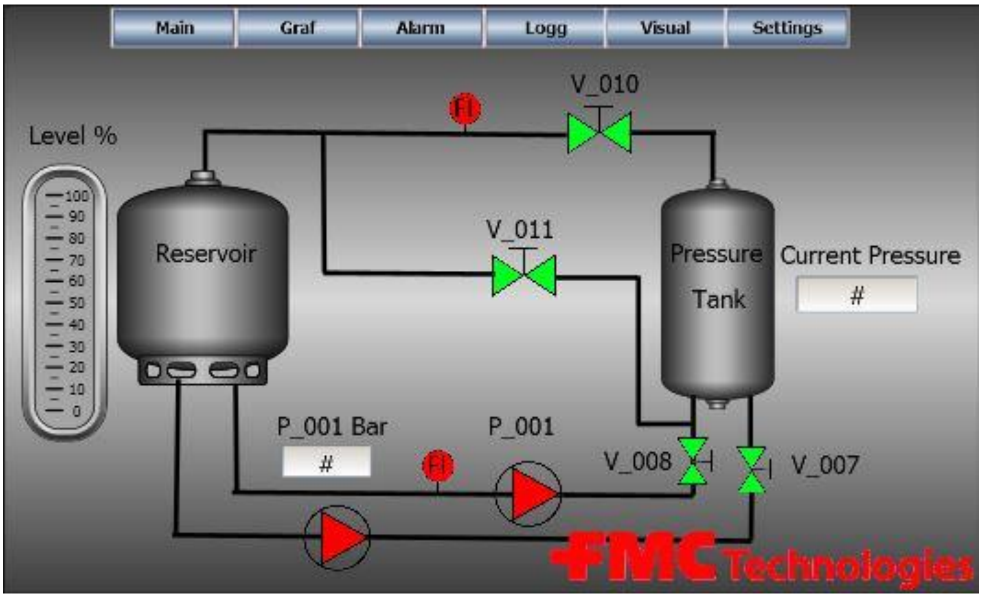

Figure 2 – HMI Visual Screen

1.5 Configuration Parameters

Configuration parameters are used in HPCS to design a pressure curve as wanted for a test. This chapter creates a pressure curve that will be compared against a pressure curve logged with external and calibrated equipment.

Step	Description		Criteria	Date/Result
11.	Go to main screen at HMI		OK/NOT OK	
12.	Configure parameters according to step 13(see figure 3.).		OK/NOT OK	
13.	**Setup parameters**		OK/NOT OK	
	Pressure bottom	50 Bar		
	Pressure top	400 Bar		
	Derivative up	40 Bar/Min		
	Derivative down	40 Bar/Min		
	Holding time bottom	15 Min		
	Holding time top	15 Min		
	Total cycles in test	2 Cycle		
14.	Go to settings screen at HMI.		OK/NOT OK	
15.	Configure parameters and note down "Cycle count" according to step 16(see figure 4.).		OK/NOT OK	
16.	**Setup parameters**		Cycle count:	
	Height	100 cm		
	Diameter	50cm		
	Max cycles	Cycle count + 4 cycles		
17.	Verify that volume parameter is calculated correctly. $Volume = \pi * \left(\frac{Diameter}{2}\right)^2 * Height$ Equation 1 – Volume Calculation of Reservoir Tank		OK/NOT OK	

Table 7 - Configuration Parameters

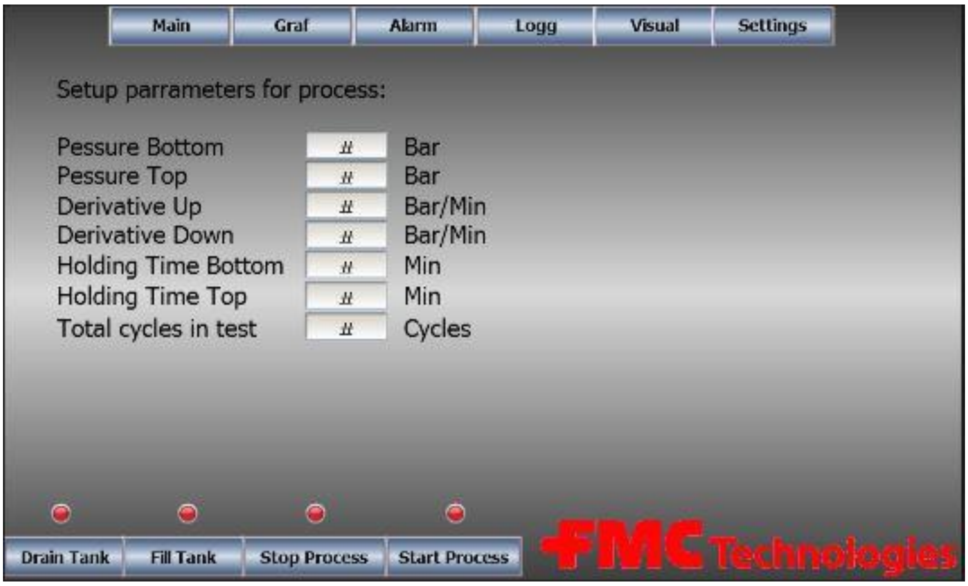

Figure 3 – HMI Main Screen

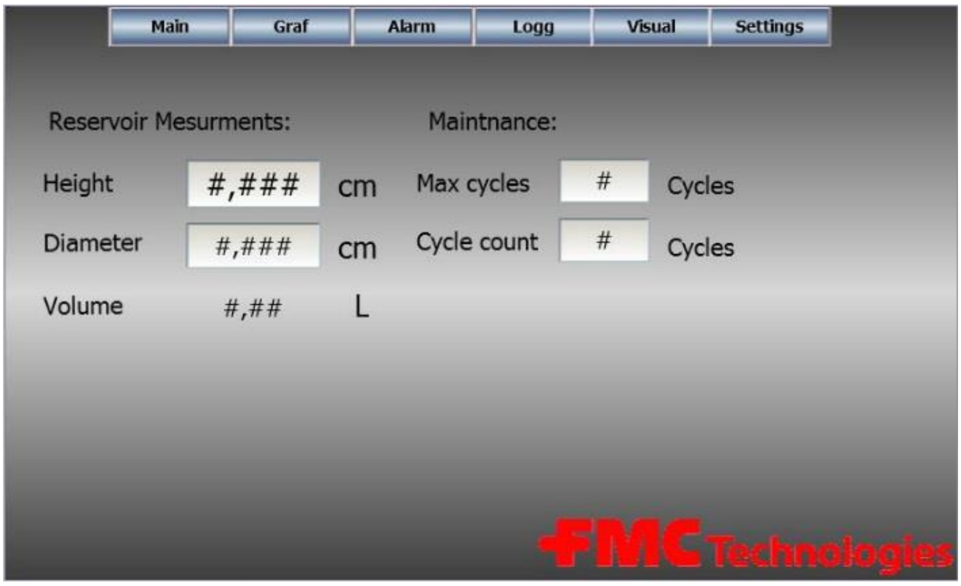

Figure 4 – HMI Setting Screen

2.0 Hydraulic Test

NOTE: During FAT an alarm that states that "Maintenance work to be done" will appear in HMI screen, this alarm is a part of the test and result must be filled in chapter 4.3.

2.1 Filling Sequence

Step	Description	Criteria	Date/Result
18.	From main screen at HMI press button "Fill tank".	OK/NOT OK	
19.	Verify at visual screen that P-001 changes status to green and starts running.	OK/NOT OK	
20.	Verify that water returns to reservoir when tank is filled, and that FI-001 change to green status at visual screen.	OK/NOT OK	

Table 8 - Filling Sequence

2.2 Pressurizing Sequence

Step	Description	Criteria	Date/Result
21.	At main screen push button "Start process".	OK/NOT OK	
22.	Verify at visual screen that P-002 changes status to green and starts running.	OK/NOT OK	
23.	Log pressure curve with external logging equipment and compare with configured parameters in chapter 1.5.	OK/NOT OK	
24.	Verify that pump stop when reaching "Pressure top" configured in chapter 1.5.	OK/NOT OK	
25.	Verify at visual screen that P-001 now change to red status.	OK/NOT OK	
26.	Stop external logging and compare result with configured parameters. Attach a copy of pressure curve to Appendix A	OK/NOT OK	

Table 9 - Pressurizing Sequence

2.3 Holding Time

Step	Description	Criteria	Date/Result
27.	Start a stopwatch to verify holding time.	OK/NOT OK	
28.	While holding time, manually reduce the pressure to P-001 with the pressure regulator at supply line to the pump.	OK/NOT OK	
29.	Verify that pressure starts to decrease after "Holding time top" is performed and that the time on the stopwatch corresponds to configured value for "Holding time top".	OK/NOT OK	

Table 10 - Holding Time

2.4 De-Pressurize Sequence

Step	Description	Criteria	Date/Result
30.	Verify at visual screen that V-011 changes status from red to green and that the pressure starts to fall.	OK/NOT OK	
31.	Log pressure curve with external logging equipment and compare with configured parameters in chapter 1.5.	OK/NOT OK	
32.	Verify that V-011 goes back to red status when "Pressure bottom" configured in chapter 1.5 is reached.	OK/NOT OK	
33.	Stop external logging and compare result with configured parameters. Attach a copy of pressure curve to Appendix A	OK/NOT OK	

Table 11 - De-Pressurize Sequence

2.5 Cycle Test

NOTE: If "Total cycles in test" parameter is more than one the test shall continue after de-pressurize sequence is completed.

Step	Description	Criteria	Date/Result
34.	Start a stopwatch, verify that the test continues to run and go to chapter 2.6.	OK/NOT OK	
35.	Verify that the test stops after the cycles configured in "Total cycles in test" is performed.	2 cycles	
36.	Go to chapter 2.7 to continue the test.	OK/NOT OK	

Table 12 - Cycle Test

2.6 Holding Time Bottom

Step	Description	Criteria	Date/Result
37.	Verify that "Holding time bottom" parameter configured in setup parameters screen at HMI corresponds to the time at the stopwatch.	OK/NOT OK	
38.	Verify that P-002 start to run and build up pressure after "Holding time bottom" is performed.	OK/NOT OK	
39.	Go back to step 35 in chapter 2.5	OK/NOT OK	

Table 13 - Holding Time Bottom

2.7 Check of Pressure Prior to Drain

Step	Description	Criteria	Date/Result
40.	Verify the pressure on PT-001 (Current pressure) in visual screen.	50bar	

Table 14 - Check of Pressure Prior to Drain

2.8 Drain Sequence

NOTE: Since "Pressure bottom" can be configured as any value from 0-500bar we have to verify that the drain function de-pressurizes the system before water is pumped out.

Step	Description	Criteria	Date/Result
41.	From main screen at HMI press button "Drain tank".	OK/NOT OK	
42.	Verify that the pressure start to go slowly down to 0 bar.	OK/NOT OK	
43.	Verify that P-001 do not start until PT-001(Current pressure) in visual screen indicates 1bar±1.	OK/NOT OK	
44.	Verify at visual screen that P-001 changes status to green and starts running.	OK/NOT OK	
45.	Verify that water returns to reservoir tank and that FI-002 change to green status at visual screen when the pressure tank is empty.	OK/NOT OK	

Table 15 - Drain Sequence

2.9 Leakage test

Step	Description	Criteria	Date/Result
46.	Add loop from output to return connection at HPCS.	OK/NOT OK	
47.	Install a valve at hydraulic line between P-002 and V-007.	OK/NOT OK	
48.	Pressurize the system to 500bar	OK/NOT OK	
49.	Open the valve installed in step 47 to ventilate the pressure so that leakage can be detected.	OK/NOT OK	
50.	Write down the pressure when the test starts in step 51.	OK/NOT OK	
51.	In a 30min period verify no leakage to return and no leakage through the valve installed after HP pump in step 47. After 30min write down end pressure.	Start pressure: End pressure:	
52.	Calculations: $1 - \frac{End\ pressure}{Start\ pressure} * 100 = Pressure\ drop(\%)$ Equation 2 – Pressure drop calculation for leakage test	≤5%	
53.	Close and remove the valve installed in step 47.	OK/NOT OK	
54.	Remove loop installed in step 46.	OK/NOT OK	

2.10 Safety function (emergency stop)

The purpose for this test is to verify that the function of emergency stop for both electric and pneumatic works as intended.

Step	Description	Criteria	Date/Result
55.	Verify that no pressure is applied to the system.	OK/NOT OK	
56.	Go to main screen at HMI and push "Fill tank".	OK/NOT OK	
57.	Verify that P-001 start to fill up the pressure tank with water.	OK/NOT OK	
58.	Press emergency stop button and verify that P-001 stops and HMI indicates that emergency stop alarm is activated.	OK/NOT OK	
59.	Release emergency stop button and verify that no components do any action.	OK/NOT OK	
60.	When reset button is activated, the alarm at HMI shall stop.	OK/NOT OK	
61.	PLC and HMI must be reset by turning off and on again the main switch.	OK/NOT OK	
62.	Verify that PLC and HMI power up and is back in normal state.	OK/NOT OK	
63.	Go to main screen at HMI and push "Fill tank".	OK/NOT OK	
64.	Wait until filling sequence is finished.	OK/NOT OK	
65.	Push "Start process" button at main screen on HMI.	OK/NOT OK	
66.	Verify that P-002 start to pressurize the tank.	OK/NOT OK	
67.	When PT-001(Current pressure) in visual screen reach 100bar press emergency stop.	OK/NOT OK	
68.	Verify that P-002 stop, V-007 → V-010 close (pressurized air in the system shall be released) and HMI indicates that emergency stop alarm is activated.	OK/NOT OK	
69.	Release emergency stop button and verify that no components do any action.	OK/NOT OK	
70.	When reset button is activated, the alarm at HMI shall stop.	OK/NOT OK	
71.	Bleed down pressure inside tank manually with V-014.	OK/NOT OK	
72.	PLC and HMI must be reset by turning off and on again the main switch.	OK/NOT OK	
73.	Verify that PLC and HMI power up and is back in normal state.	OK/NOT OK	

3.0 Program test

3.1 Configure parameters (changed function)

This test is to check that the parameters configured in setting screen controls the function of the cycle programs and the pressures applied to the tank.

Step	Description	Criteria	Date/Result
74.	Change Setup parameters at main screen in HMI according to step 75.	OK/NOT OK	
75.	**Setup parameters** Pressure bottom: 100 Bar Pressure top: 200 Bar Derivative up: 20 Bar/Min Derivative down: 20 Bar/Min Holding time bottom: 5 Min Holding time top: 5 Min Total cycles in test: 3 Cycle		
76.	Press "Fill tank" at main screen on HMI.	OK/NOT OK	
77.	Start logging the pressure curve with external logging equipment to compare with configured parameters in step 75	OK/NOT OK	
78.	Press "Start process" button at HMI to begin pressure test.	OK/NOT OK	
79.	After all 3 cycles is performed, press "Drain tank".	OK/NOT OK	
80.	Stop external logging and compare result with configured parameters. Attach a copy of pressure curve to Appendix A.	OK/NOT OK	

3.2 Maintenance alarm

Step	Description	Criteria	Date/Result
81.	When alarm that states "Maintenance work to be done", go to settings screen at HMI.	OK/NOT OK	
82.	Write down value for "Cycle count".	Cycle count:	
83.	Check that "Cycle count" noted in chapter 1.5 step 16 is 4 counts less than value noted in this step	OK/NOT OK	
84.	Reset alarm at HMI.	OK/NOT OK	

4.0 Appendix A

References

[1] «Free vector,» [Internett]. Available: http://all-free-download.com/free-vector/mandatory.html. [Accessed 2015 05 09].

Hyperbaric - Pressure Control System

Technical Data Information

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Revisions

Date	Description	Version	Made By	Approved By
08.05.2015	TDI	-	TOS	BB, AS

Table 1 - Revisions

Table of Contents

Table list

Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
GA	General arrangement
HBV	Høgskolen I Buskerud/Vestfold
TDI	Technical Data Information

Table 2 - Abbreviations

1.0 Dimensions & weight

Hight	1000
Width	1200
Dept	1600
Weight	TBA

Table 3 – Dimensions & weight

2.0 Electrical specification

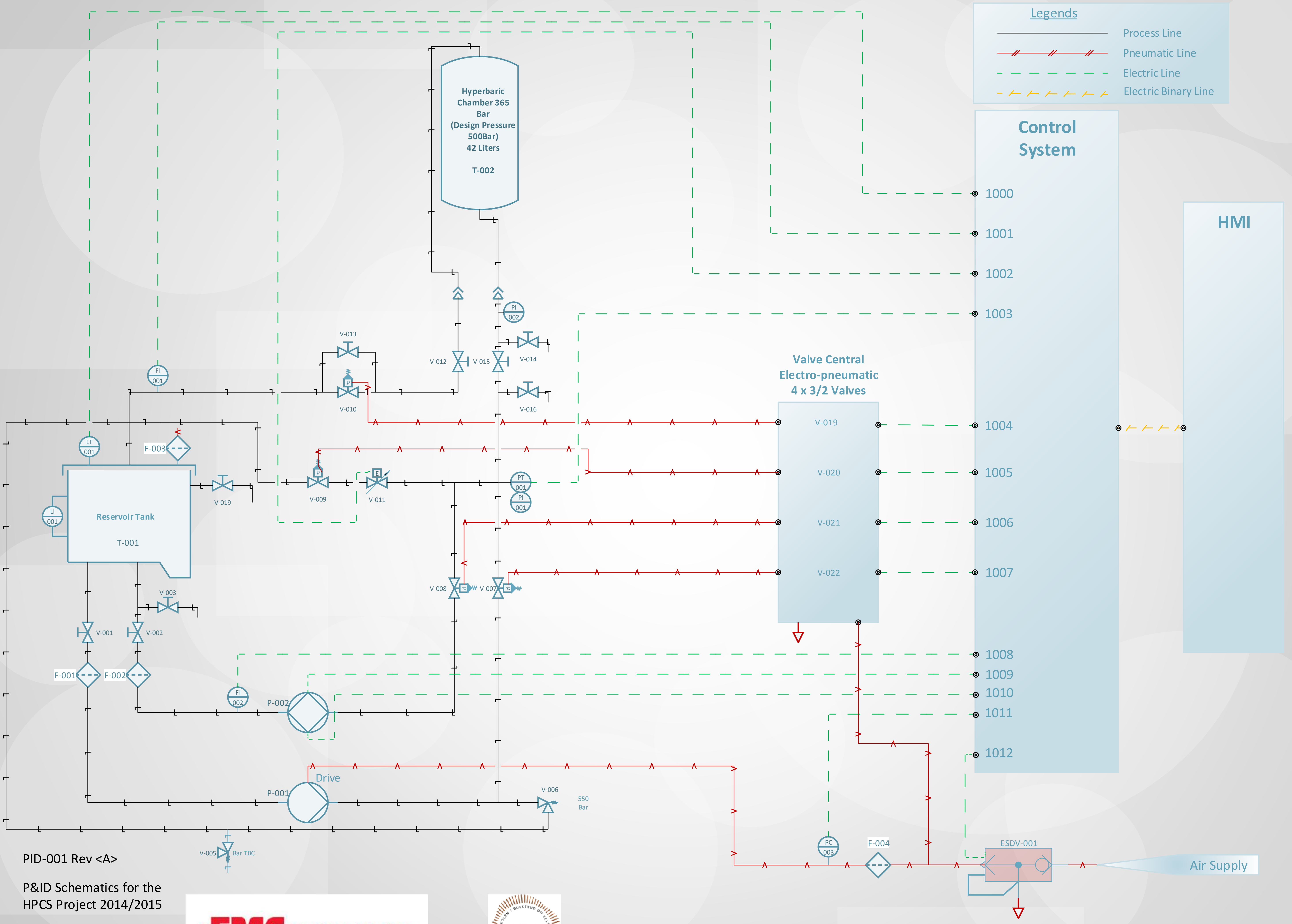
Voltages	
Supply voltage	3phase 400VAC
Control system voltage	24VDC
I/O	
AI	2 (4-20mA)
AO	1 (4-20mA)
DI	14
DO	10 (2 Digital output used for DA block.)

Table 4 – Electrical specification

3.0 Hydraulic specification

Maximum Pressure	365bar
Design pressure	500bar
Test pressure	438bar
Pressure line relief valve	384bar
Return line relief valve	8bar
Derivative increase/decrease	±40bar

Table 5 – Hydraulic specification



PID-001 Rev <A>

P&ID Schematics for the HPCS Project 2014/2015

A Bachelor assignment in Cybernetics by

Document author: Jonas Carlstedt

Hyperbaric - Pressure Control System

Interface List

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Revisions

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30.01.2015	Interface list	-	TOS	JN, AS, BB
07.05.2015	Changed Table 3, document template and references	A	TOS	AS,JN

Table 1 – Revisions

Table of Contents

Table list

Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
GA	General arrangement

Table 2 - Abbreviations

1.0 Interface list

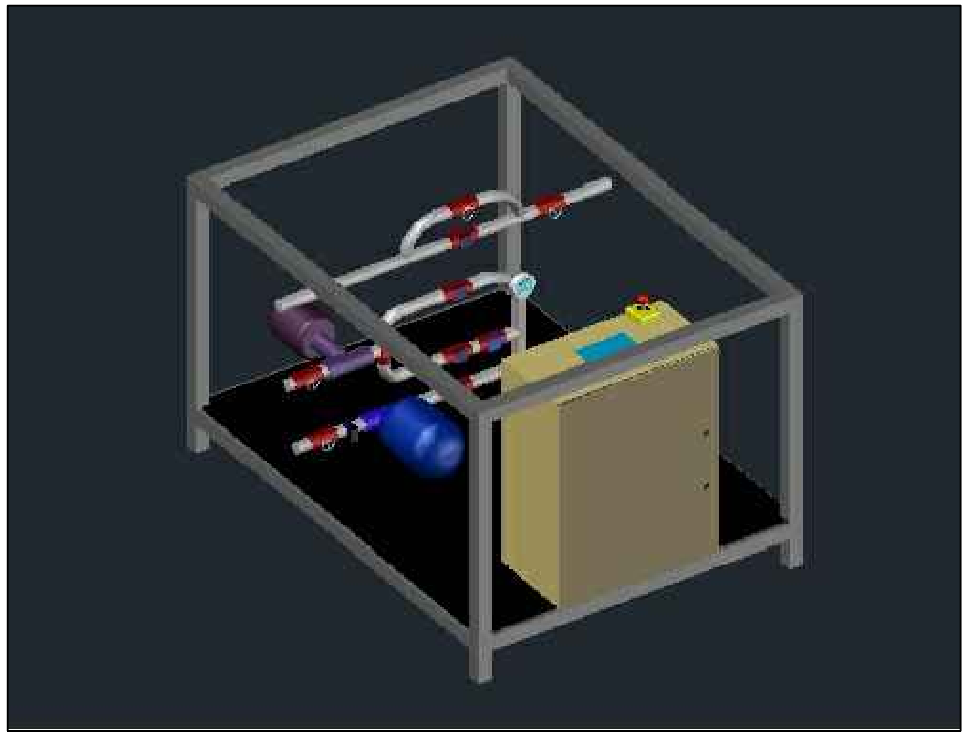
Interface list between components			
From	**Connection**	**To**	**Connection**
T-001(SUPPLY 1)	G1"	V-001	G1"
T-001(SUPPLY 2)	G1"	V-002	G1"
		V-003	G1"
V-001	G1"	F-001	G¾"
V-002	G1"	F-002	G¾"
F-001	G1"	P-001	NPT ½"
F-002	G1"	P-002	G 1 ¼"
		FI-002	G ¾"
P-001	NPT ½"	V-006	BuTech 3/8"
		V-007	BuTech 3/8"
P-002	G 1 ¼"	V-008	BuTech 3/8"
V-007	BuTech 3/8"	PT-001	BuTech 3/8"
		PI-001	BuTech 1/4"
		V-015	BuTech 3/8"
		V-016	BuTech 3/8"
		V-009	BuTech 3/8"
V-008	BuTech 3/8"	V-009	BuTech 3/8"
		V-015	BuTech 3/8"
V-009	BuTech 3/8"	V-011	BuTech 3/8"
V-011	BuTech 3/8"	T-001(RETURN)	G ¾"
V-015	BuTech 3/8"	V-014	BuTech 3/8"
		PI-002	BuTech 3/8"
		HC-001	BuTech 3/8"
HC-001	BuTech 3/8"	T-002(BOTTOM)	BuTech 3/8"
T-001(RETURN)	G ¾"	V-006	BuTech 3/8"
		V-011	BuTech 3/8"
		V-010	BuTech 3/8"
		V-013	BuTech 3/8"
		FI-001	G ¾"
T-001(FILLING)	G ¾"	V-019	G ¾"
T-001(VENTILATION)	G ¾"	F-003	G ¾"
T-001(LEVEL)	M20x1mm	LT-001	M20x1mm
V-010	BuTech 3/8"	V-013	BuTech 3/8"
		V-012	BuTech 3/8"
V-012	BuTech 3/8"	HC-002	BuTech 3/8"
HC-002	BuTech 3/8"	T-002(TOP)	BuTech 3/8"

Table 3 – Interface list

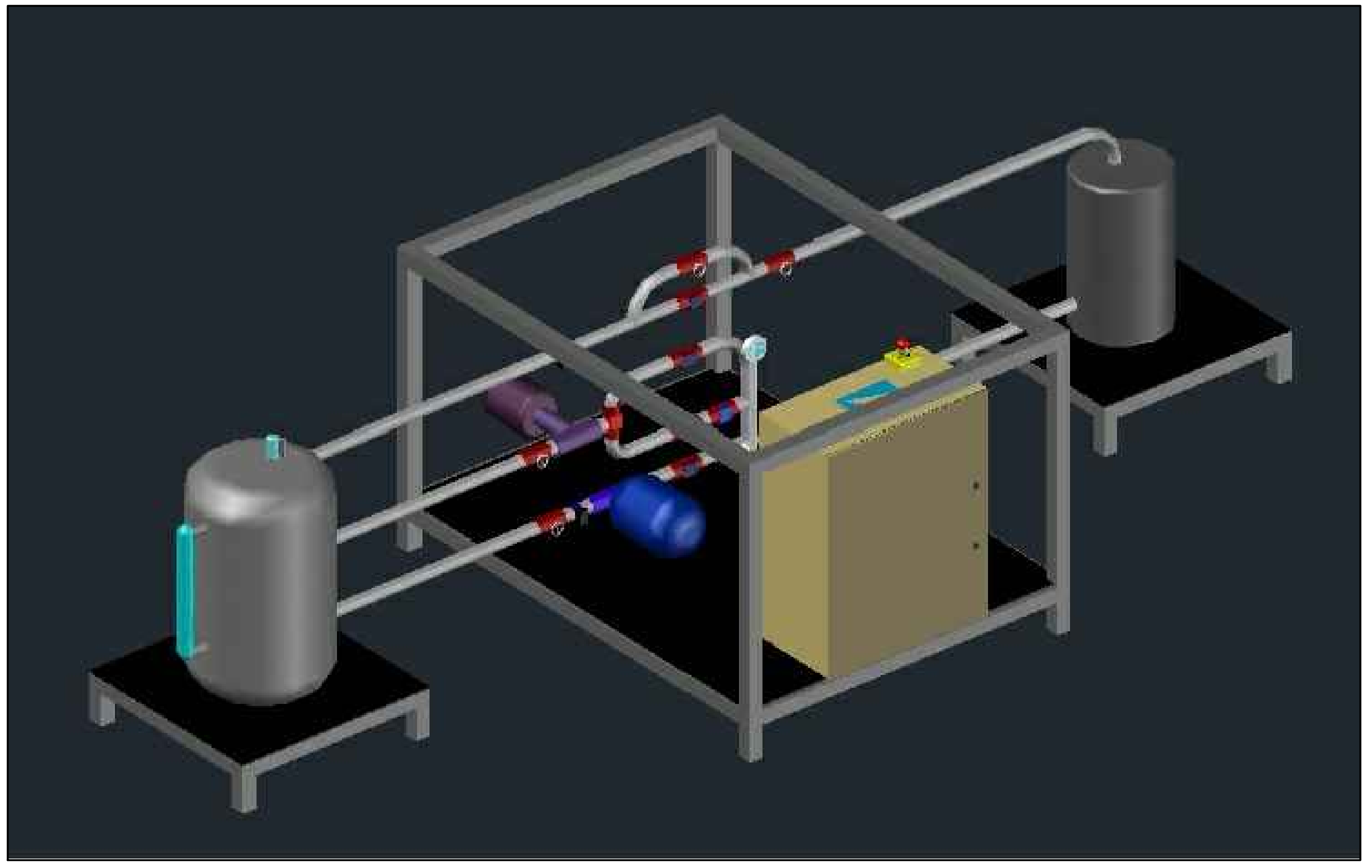
References

[1] J. Carlstedt, «PID-001 <A>,» HBV, Kongsberg, 2015.
[2] T. O. Skarseth, «BOM-001 <D>,» HBV, Kongsberg, 2015.

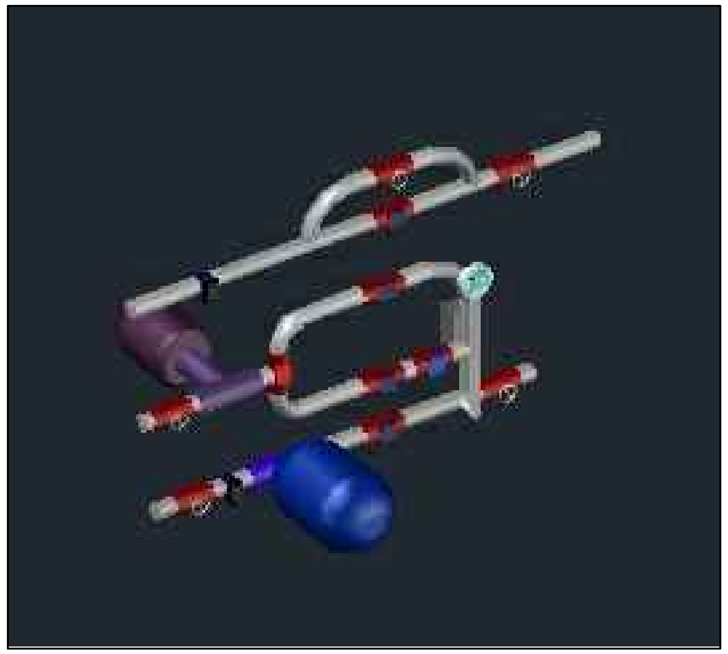
HPCS FRAME



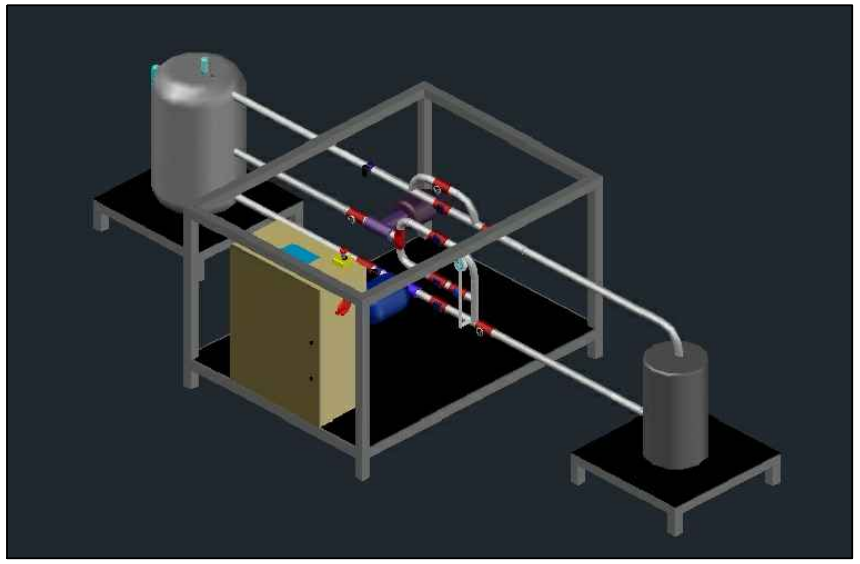
FULL PICTURE VIEW 1



HPCS HYDRAULIC PIPING



FULL PICTURE VIEW 2



FMC Technologies — HBV

REV.	DATE	REASON FOR ISSUE	PREPARED	CHECKED	APPROVED
C	10.05.15	AS BUILD 2D	BRIAN B	THOR O S	JONAS C
B	10.05.15	AS BUILD	BRIAN B	THOR O S	JONAS C
A	09.05.15	DIMENTION UPDATE	BRIAN B	THOR O S	JONAS C
-	24.04.15	PREPERATION	BRIAN B	JONAS N	ANDERS S

DESIGNER	LAST SAVED (DATE)	NO. OF.	REV.
BRIAN BERG	10.05.15	△	C

SCALE 2:1

SIZE

FMC Technologies

SYSTEM GA

EASY OVERVIEW OVER SYSTEM

HPCS BACHELOR PROJECT

DRAWING NO. SYS-001

SHEET 1 OF 1

Hyperbaric - Pressure Control System

Technology Document - SMQAM

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Revisions

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09.12.2014	System Modell description & Qualification of Autoclaves Micro metering valve.	-	JC	BB, TOS
09.04.2015	Added Abbreviations table and formatting text	A	BB, JN, AS, TOS, JC	BB, JN, AS, TOS
09.05.2015	Text formatting	B	AS, JC	AS, BB

Table 1- Revisions

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Table list

Figure list

Equation list

Abbreviations

Abbreviation	Explanation
FMCTI	FMC Technologies
HBV	Høgskolen i Buskerud/Vestfold
BOM	Bill Of Material
HPCS	Hyperbaric – Pressure Control System
K	Bulk modulus factor
SG	Specific gravity
SMQAM	System Modell description & Qualification of Autoclaves Micro metering valve.

Table 2 - Abbreviations

1.0 Brief Introduction

This document contains calculation and explanation of the physics behind the linear decrease function for HPCS.

The rate of pressure decrease for the system is probably one of the main performance characteristics for the system. The linear increase of pressure inside the tank is explained in ACT-001 and therefor is not included in this document.

2.0 Bulk modulus of liquid water

The bulk modulus of liquid water is an important parameter to this process because it will be the biggest factor contributing in the dynamics associated to this system. In practice, it will most probably be used glycol mixed into the water to avoid corrosion to system components. For simplicity, the effects this implies on the bulk modulus property and other physical properties to the fluid, the glycol effect is neglected [1].

The bulk modulus (denoted K in this document) of a substance measures the substance's resistance to uniform compression [1]. Another parameter that will contribute to increased compressibility, is the amount of trapped air in the water. When water pressure increase, the gas volume decrease and this leads to a compressed liquid volume. The bulk modulus for water found outside after a raining day has a higher content of gas than liquid stored in a tank for longer time. For simplicity we assume the water in this calculation to have zero trapped air, which is the worst case scenario for pressure regulation.

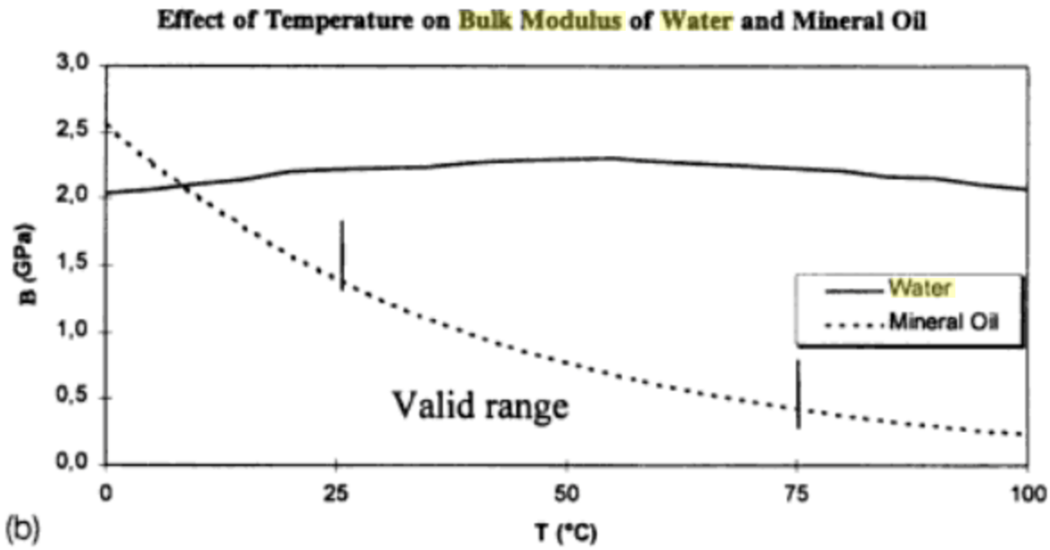

Figure 1 - Effects on temperature on Bulk Modulus of Water and Mineral Oil.

Figure 1 [4] is showing small changes in bulk modulus with respect to temperature for water compared to mineral oil. This implies that we can neglect the adiabatic effects, and it seems convenience to assume the process to be isothermal for simplicity.

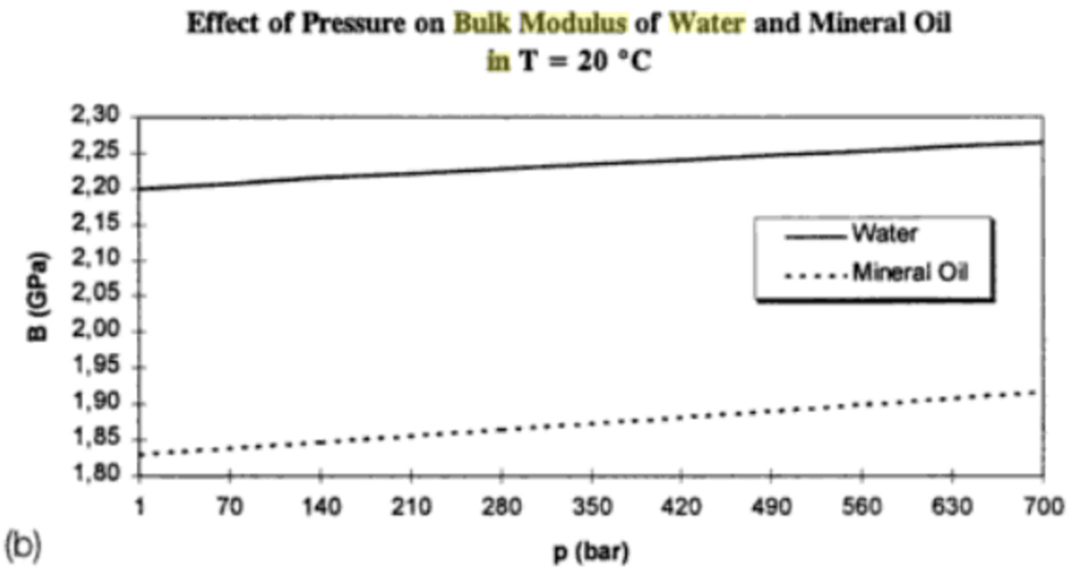

Figure 2 - Effects of pressure on bulk modulus of water and mineral oil in T = 20 Celsius degree.

Figure 2 [4] shows the effects of pressure on bulk modulus of water with respect to pressure. As we can see the effects are minimal, and by assuming a static bulk modulus value neglects the fact that the pressure affects the bulk modulus constant K.

We are assuming the pressure in the tank to be 400 bars at maximum pressure before the decent starts. This is a little bit more than what the tank is certified for (365 bars).

$$K = -V\frac{\mathrm{d}P}{\mathrm{d}V} \quad [1]$$

Equation 1 – Bulk modulus constant   Where K > 0

K	=> Bulk modulus constant for water	= 2.2×10^9	[Pa]
V	=> Initial volume of the container	= 0.042	[m^3]
dV	=> Differential Volume	= ?	[m^3]
dP	=> Differential Pressure	= 40×10^6	[Pa]

Calculation gives us:

$dV = -7.64 \times 10^{-4}$ [m^3] = -0.764 liters

Since the tank is assumed to not change volume, the 0.764 liters has to be added to the tank to increase pressure from 0 bar to 400 bars. This also implies that we have 0.764 liters of fluid to regulate with if we want to decrease the pressure from 400 bars to 0 bar. This gives the tank an accumulating effect that makes it possible to control. Pressure is a linear function of flow in/out of the tank after assumption made in this document so far.

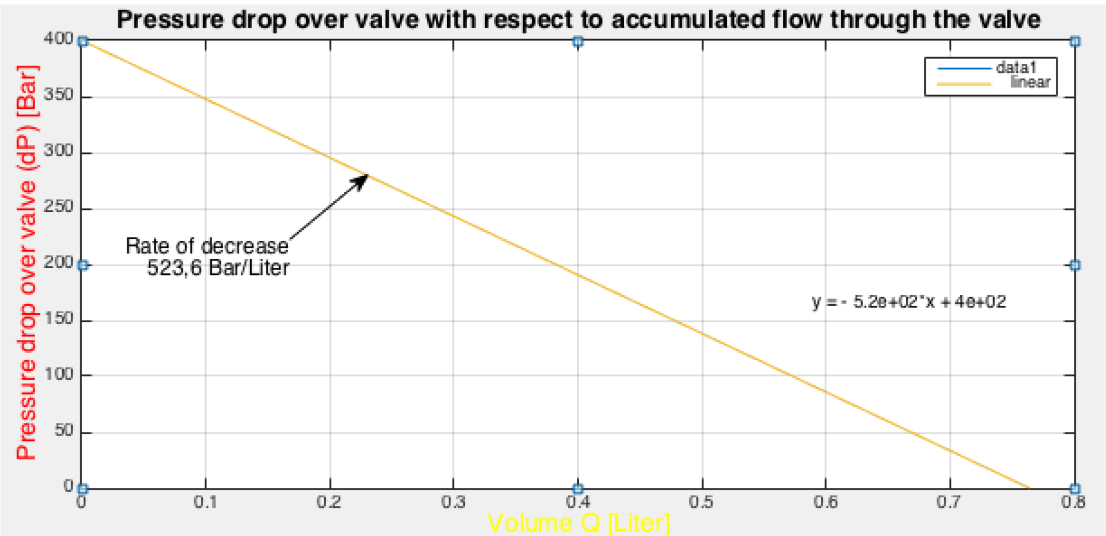

Figure 3 - Pressure drop over valve with respect to accumulated volume flow through valve.

3.0 Valve coefficient required of a valve according to internal requirements

So far in this document, we have tried to describe the system with a bulk modulus model. The HPCS group have concluded that the pressure in this model is a linear function of accumulated flow out of the tank. The next question is: What is required of a valve to regulate the pressure according to our internal requirement R2-I, which states that the pressure decrease function should be equal or less than 40bar/min.

Autoclave has designed a micro metering valve suitable for this application. The valve offers a very small cv coefficient and a precise control compared to ordinary hydraulic needle valves. The range for cv coefficient is indicated in figure 4 [3], and is from about 0 to 0.004 with 6 revolutions, which is much more precise that ordinary hydraulic needle valves.

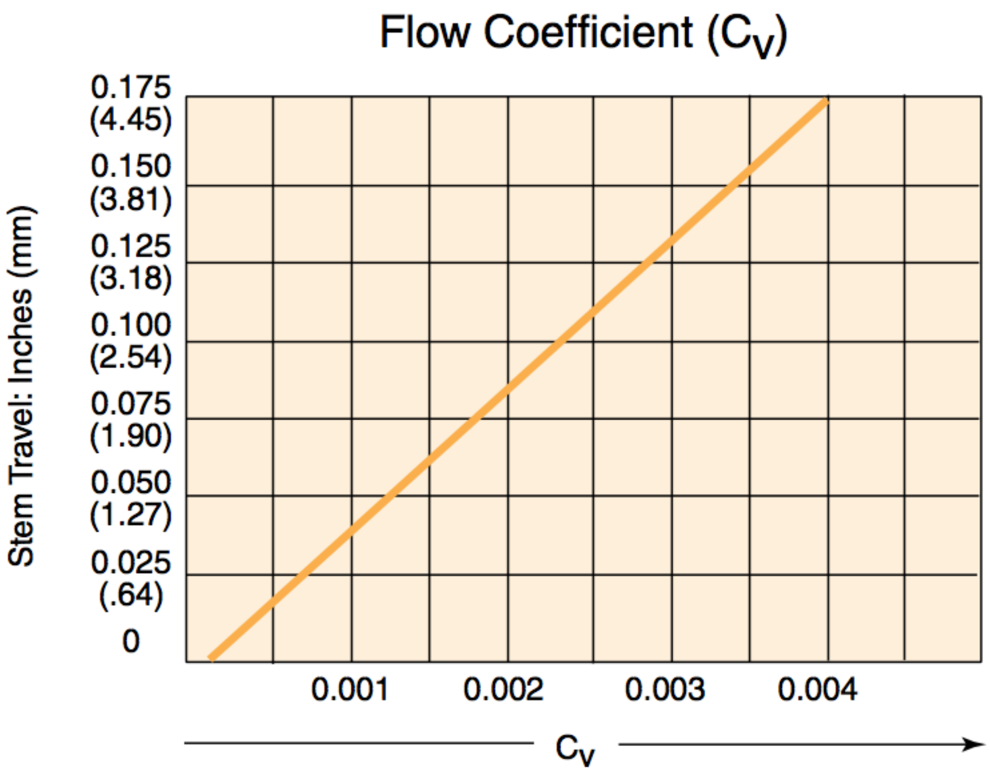

Figure 4 - Valve Coefficient for Autoclaves micro metering valve.

It is important to notice that the micro metering valve is not to be operated below 0 mm stem travel. This will make permanent damage to the seat inside the valve. Therefore, the micro metering valve is not suitable for isolating the system because it will not seal properly without enough force acting from the needle to the seat of the valve. [3]

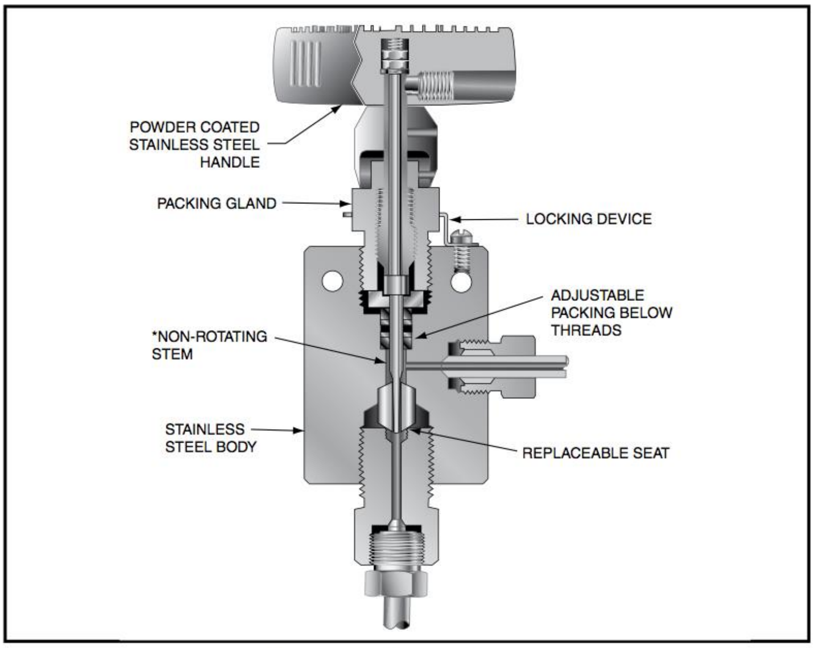

Figure 5 - Autoclaves micro metering valve equipped with a handle for manual operation [3].

Figure 6 - Autoclaves micro metering valve with electrical operation [3].

The actuator placed on top of the micro metering valve contains a microprocessor-controlled motor. The microprocessor controlled motor guarantees optimum voltage, current and torque control when starting, running or stopping valve rotation. The microprocessor also assures accurate stem location and repeatability. The actuator can be ordered in pressure class up to 4137 bars (60 000 Psi) [3].

With this valve in mind and the internal requirement R2-I , which states that our system have to handle decrease of pressure equal or less than 40bar/minute in mind, we can calculate if the valve seems suitable or not.

In Figure 7 below, an equation for flow though a valve is given. We can use this equation to see what kind of cv value is required to maintain linearity while decreasing the pressure. This will be a function of the differential pressure occurring over the valve. Since it is no restriction on the hydraulic line from the valve back to the reservoir tank, the differential pressure over the valve equals the pressure found in the pressure tank.

The specific gravity of the fluid denoted SG, are 1 for water. We will assume the fluid to be purely water for this model.

0.764 liter is the volume needed to depressurize the system from 400 bars down to 0 bar. Since the pressure model with respect to flow is linear, our system needs to handle a flow rate less than or equal to:

$$\frac{0.764\ Liter}{400\ Bar} \times \frac{40\ Bar}{Min} = \frac{0.0764\ Liter}{Min} \rightarrow \frac{0.0202\ U.S\ Gallons}{Min}$$

Equation 2 – Calculation L/m

$$C_v = F\sqrt{\frac{SG}{\Delta P}}$$

Equation 3 - Flow through a valve [3]

Cv	=> Coefficient for valve	= Y – Axe	[Unitless]
F	=> Flow over valve	= 0.0202	[U.S. Gallons/Min]
SG	=> Specific gravity	= 1	[Unitless]
dP	=> Differential Pressure	= X – Axe	[Psi]

Noticed that the pressure in the flow equation use Psi as input pressure. This is handled in Matlab so that the X-Axe showed in figure 8 is scaled in bar.

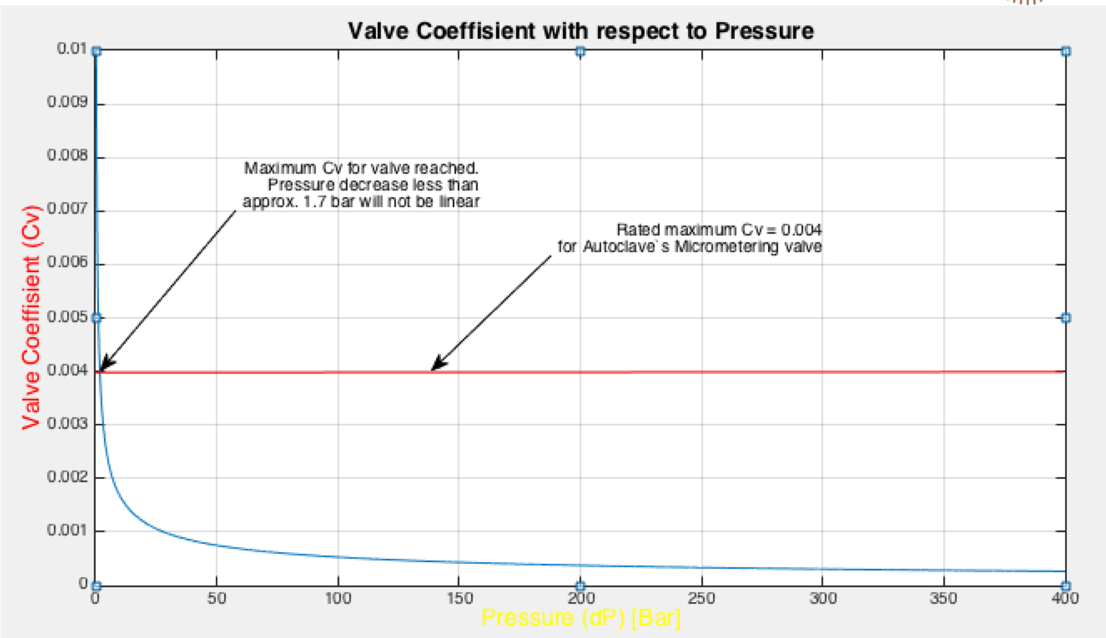

Figure 7 - Cv required of Valve to maintain linear operation while decreasing 40 bar/minute.

Operation of the micro metering valve will almost operate one revolution from the smallest cv possible for this valve at the beginning of the decent. At approximately 1.7 bar, the valve will not be able to let enough flow drain through to keep a linear decent of pressure because it will be fully open. To accomplish linearity all way down requires several valves, which is a great cost for the project, and would not be needed according to the customer.

References

[1] G. E. Totten, Handbook of Hydraulic Fluid Technology, New York: Mercel Dekker, Inc, 2000.

[2] Wikipedia, "Wikipedia," [Online]. Available: http://en.wikipedia.org/wiki/Bulk_modulus. [Accessed 30 September 2014].

[3] Wikipedia, "Wikipedia," [Online]. Available: http://en.wikipedia.org/wiki/Flow_coefficient. [Accessed 30 September 2014].

[4] Autoclave, "Micrometering Valve," [Online]. Available: http://www.autoclave.com/products/valve_actuators/electric_flow_control/index.html. [Accessed 30 September 2014].

Hyperbaric - Pressure Control System

Arduino

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Revisions

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08.11.2014	Reviewed Solutions	-	AS	TOS, BB
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Table 1 - Revisions

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Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
HBV	Høgskolen I Buskerud/Vestfold

Table 2 - Abbreviation

1.0 Arduino

1.1 Introduction

This document contains information about the Arduino Uno circuit board and the Atmega328p micro controller chip that the Arduino utilizes. The document's meaning is to give a detailed description on what the Arduino is and how it can be used as a controller in the HPCS project.

1.2 The circuit

The Arduino is a circuit board that runs an Atmega microcontroller. It contains integrated circuits for crystal clocks and other components to drive the microcontroller. There are many different types of Arduino but the main difference is which type of micro controller it contains. Arduino Uno is the most usual one and it runs on the Atmega328p. The Atmega328p is a 32pin IC-socket chip where 14 of them are digital input/output and six are analog outputs. Six of the digital pins is PWM capable and the chip has 32KB of flash memory where 0.5KB is used for the boot-loader. The recommended voltage for the Arduino Uno is 6-20V and its operating voltage is 5V. Atmega328p has an internal 8MHz clock, but the Arduino Uno circuit contains a 16MHz clock. Maximum output current on the I/O pins are 40mA for 5V and 50mA for 3,3V. Arduino Uno also has an Atmega 16U2, this microcontroller is programmed to operate as an USB to serial converter for computer communication and power. [1]

Figure 1 - Arduino Uno

1.3 Use of microcontroller in HPCS

Although this document was written in an early stage of the project, it was possible to anticipate some of the essential parts of the project. By then we know that the project had to use industry-standardized components for easy replacement. This means that we probable need to deal with actuators that uses a 4-20mA signal for regulation. Sins the Arduino Uno dos not have an analog out port we will have to manipulate the PWM port to make this signal with some kind of external circuit that we will need to build our self.
The next challenge is to get communication working between the Arduino Uno and the HMI (IX-T7A) that FMC would like us to use. HMI IX-T7A is made to communicate with industrial PLC's and there is no "easy fix" for communication with microcontrollers. Therefore, to make it work the engineering group would have to design a C code that is able to communicate with one of the communication ports on the HMI. [2]

1.4 Conclusion

It is certainly possible to use the Arduino Uno in this project, although there are some big challenges in the communication part of the project and circuitry design that the engineer group has to overcome for this to work. It might be wiser to use an industrial PLC as the controller of the HPCS. This will ease the workload for the engineers.

Reference

[1] Arduino, «arduino.cc,» 2014. [Internett]. Available: http://arduino.cc/en/Main/ArduinoBoardUno. [Funnet 8 November 2014].

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Hyperbaric - Pressure Control System

HMI

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30.01.2015	Idea Description	-	AS	TOS, JC
06.03.2015	Added program layout and program function part.	A	AS	
02.04.2015	Formatting text	B	AS, BB, TOS, JN	AS, BB, TOS, JN
01.05.2015	Formatting text	C	AS	
04.05.2015	Added report description	D	AS	JN, BB

Table 1 - Revisions

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HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies

Table 2 - Abbreviations

1.0 HMI

1.1 Introduction
This document contains information about the HMI that is being used in the HPCS project.

1.2 General Information
In the project requirement document, requirement R1-E states that "The system design shall contain a touch-screen based HMI" [1]. This is a requirement from FMCTI. FMCTI have already bought the IX T7A HMI from Beijer Electronics for this purpose and would like it to be used in the HPCS project.

Figure 1 - IX T7A

The HMI is based on a custom made software from Beijer with graphical objects. It has a 7 inch touch screen and an aluminum case to shield the electronic components from electrical noise. The T7A is CE approved and tested for noise according to EN61000-6-4 emission and EN61000-6-2 immunity. The front panel of the T7A has an IP classification of IP 65 while the back panel has an IP classification of IP 20. The system runs on a 400MHz AMR9 processor and it can operate in temperatures from -10 ° C to +60° C. Relative operating humidity is 5% - 85% non-condensed. So it should have no problem operating in an industrial environment. T7A has an Application memory of 80MB. The power supply is marked to be +24V DC, but it can run on voltages from +18-32V DC, however the power supply must conform with the requirements for class 2 power supplies. The internal fuse is 2A. [2]

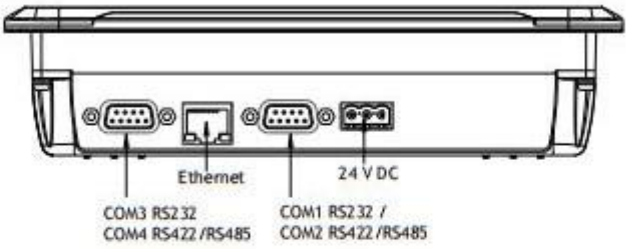

Figure 2 - T7A Bottom [3]

T7A is equipped with one 10 Base-T / 100 Base-T Ethernet port, one USB 2.0 port with maximum output current of 200 mA, two 9-pin D-sub serial ports for RS422/485, one extension module slot for fieldbus and one SD card slot for external storage.

Beijer has their own programing software called IX Developer for programming of their HMI devises. IX Developer is a graphical programming utility and the basic programing is done with "drag and drop" however it is possible to write scripts in C-sharp for more advanced functions. [2]

2.0 Program layout

2.1 Main Screen

In the main screen all the parameters for the process is set. The process is also started from this screen. The function of the start, stop, fill and drain buttons is described in the script section of this document. Current cycle in test is shown over the FMC logo and indicators shows what function is active in process (indicator green for active). Parameters are edited by pushing the white box next to the parameter that needs editing and punch in the value.

Derivative up parameter currently limited value to min 40 and max 500.
Derivative down parameter currently limited value to min 40 and max 500.
Pressure top parameter currently limited value to max 500.

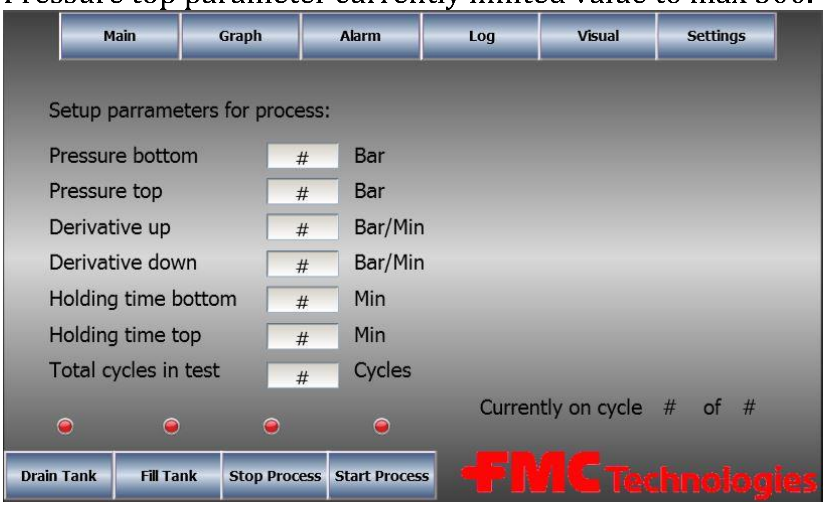

Figure 3 - Main Screen

2.2 Graph Screen

The graph plots pressure over time. The history button stops the graph and shows the graph history. The legend button brings up legend description.

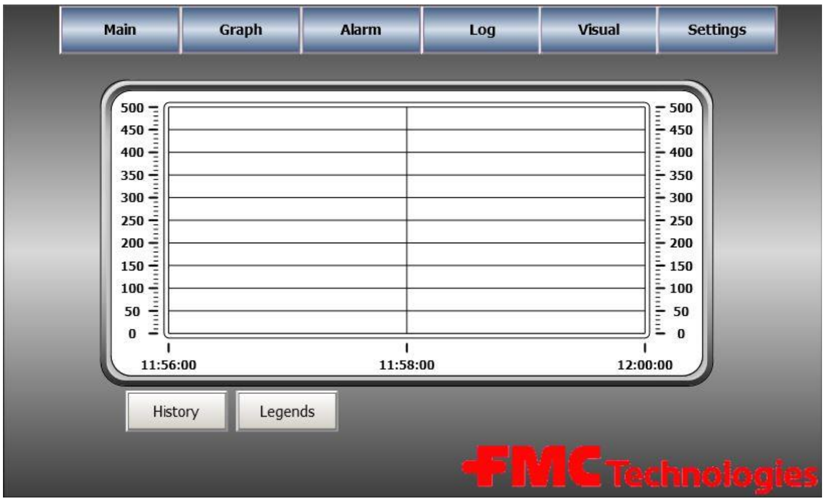

Figure 4 - Graph Screen

2.3 Alarm list

Over pressure alarm and emergency shutdown alarm will be show in the alarm screen. To deactivate alarm ether push "Ack All" or select one and push "Ack Selected". Push "Clear" to clear list (not possible when alarm is active). The "Info" button is not implemented. The "Filter" button brings up some filter parameters and the pause button pauses alarms. Alarms implemented to the log is reservoir low level alarm, emergency pneumatic shutdown and pressure level to high.

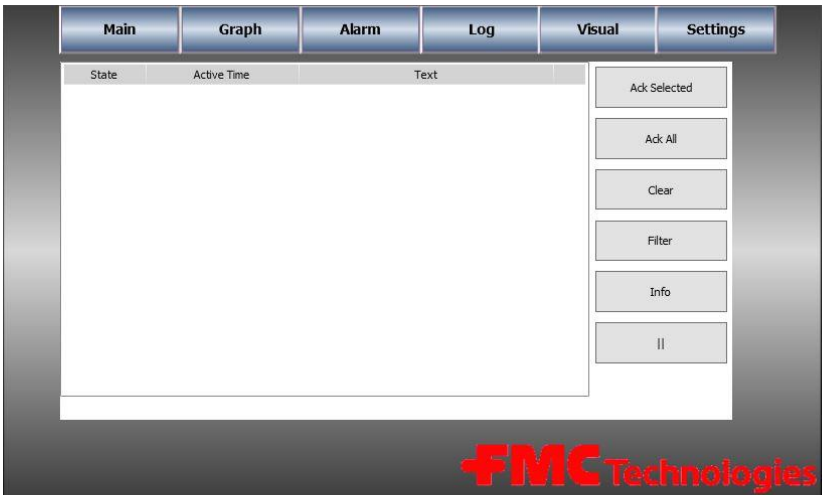

Figure 5 - Alarm Screen

2.4 Log Screen

In this screen it is be possible to export the logged data from the test to the SD card.

- Push "Export data" button to export data logger file.
- Push "Export graph" button to export graph date form the test.
- Push "Export report" button to export defined date form the test.
- Push "Export alarm" button to export defined date form the test.

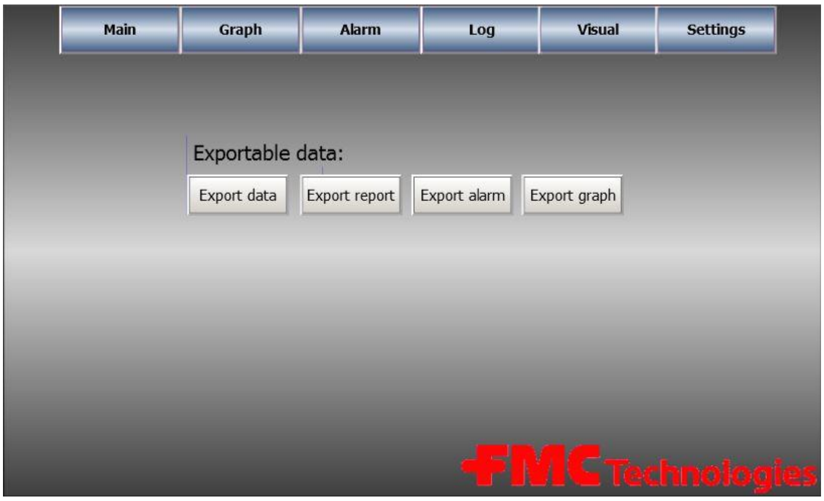

Figure 6 – Log Screen

2.5 Visual Screen

The visual screen gives a live overview of the process. It shows the state of the crucial parameters.

- V_007, V_008, V_009, V_010 and V_011 shows on/off state of the valves.
- P_001 shows the on/off state of the pressure pump as well as the reference pressure in bar sent from the PLC (this is a calculated value)

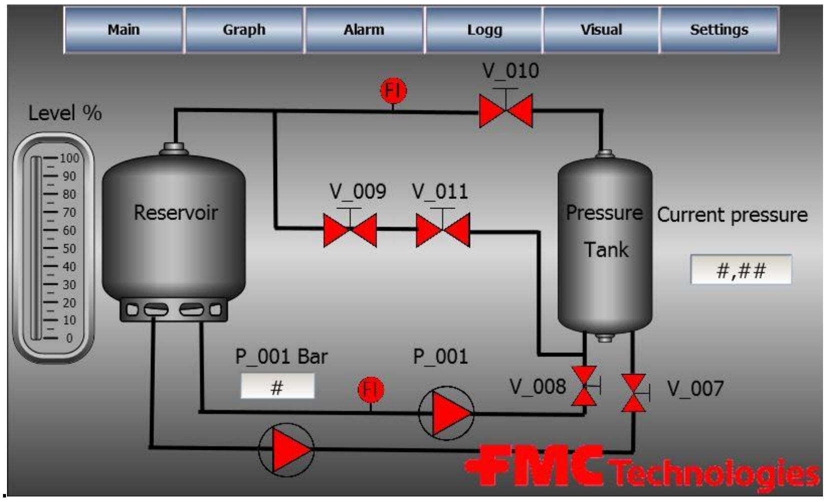

Figure 7 - Visual Screen

2.6 Settings Screen

Because HPCS is an adaptable system that can be used on different pressure thanks and reservoirs the settings screen contains all the settings parameters like reservoir height, width and depth. It is also necessary to tell the program how many cycles the pressure tank is qualified for, so that the program can keep track and alarm the user when the tank needs to be switched out or serviced.

- Parameters are edited by pushing the white box next to the parameter that needs editing.
- Push "Reset Cycles" to reset cycle count

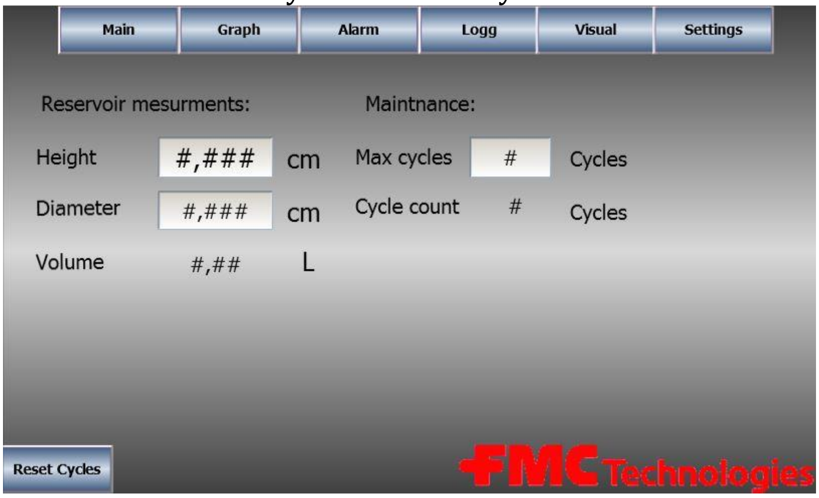

Figure 8 - Settings Screen

3.0 Program Function

3.1 Report

3.1.1 Making the report template

The program contains a pre-configured report template in .xls excel format made by HPCS. This format is an old excel format, the reason an old format is used is because IX developer dos not support any other format. The report template must have a <#config> sheet like in Figure 9. The information inn row 10 tells the program what data logger to get data form. It is crucial that the info is in row 10 and setup as in Figure 9. In this case set up for DataLogger1.

9		
10	Data	SQL(General; SELECT * FROM DataLogger1)
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		

Ark1 | Ark4 | Ark2 | <#config>

Figure 9 – Report config sheet

In sheet 1 the user can select where the content of the data logger should be written. Figure 10 shows how the report is setup in the HPCS project. In cell A2 the last value of Pres_CurrentValue tag is setup. Further in sell A8, B8, C8 and D8 the logged data from Pres_currentValue, Time, PT_001 and PC_003_CurrentValue is setup. This will give corresponding colons in colon A, B, C and D.

	A	B	C	D
1	*Pres_CurrentValue*			
2	<#Tag(Pres_CurrentValue)>			
3				
4				
5				
6				
7	*Pres_CurrentValue*	*Time*	*PT_001*	*PC_001*
8	<#Data.Pres_CurrentValue>	<#Data.Time>	<#Data.PT_001>	<#Data.PC_003_CurrentValue>
9				

Figure 10 – Report setup sheet

Sheet 4 is shown in Figure 11. This shit is the setup sheet for the pivot table and graph. It contains all the 3 graphs from the data in Datalogger 1.

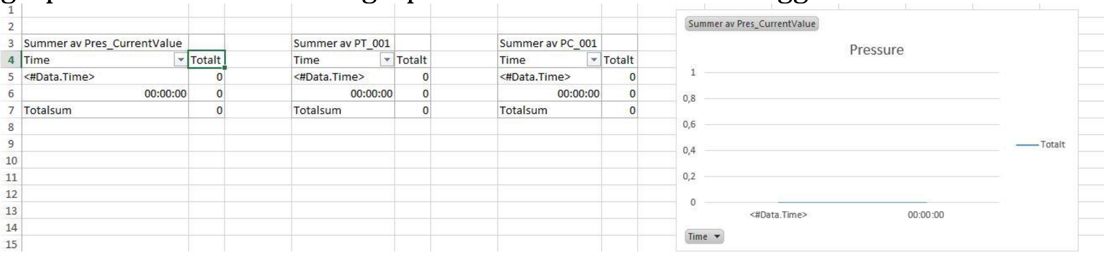

Figure 11 - Sheet 4 pivot table

3.1.2 Result

After the test is done it is possible to export a report from the HMI. This is done from the log screen. When the report is written to the SD card one can remove the SD card and transport them to a computer. The excel file can be located on the SD card in the reports folder. It contains the logged data from variables Pres_CurrentValue, PT_001 and PC_003. The graph in Figure 13 will be plotted automatically in sheet 3 of the excel file. The only thing the user needs to do is to update the pivot table as shown in Figure 12.

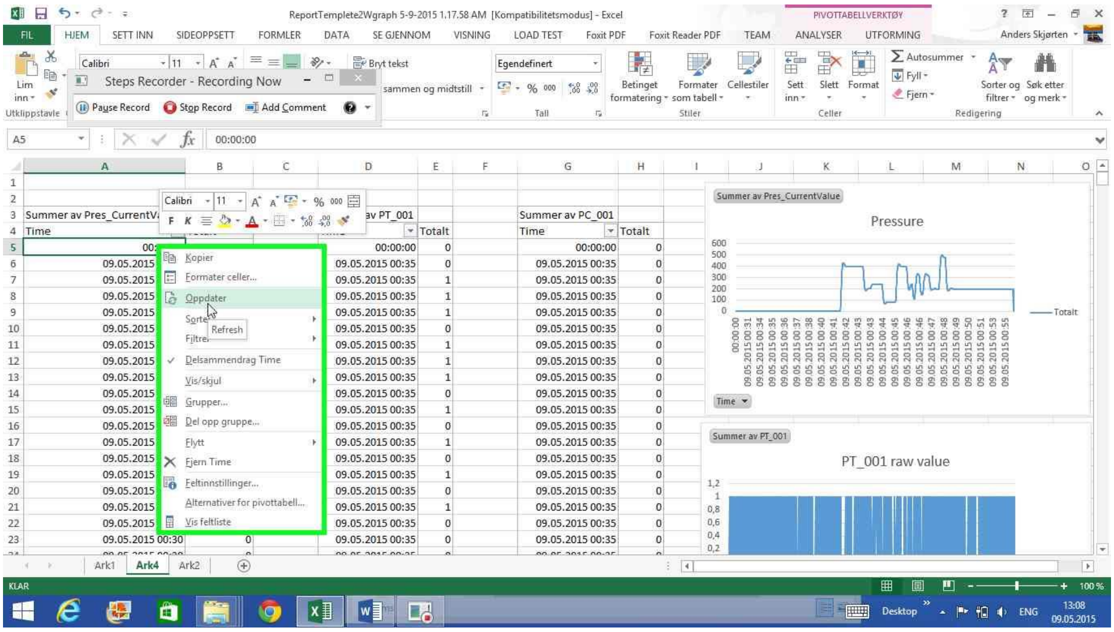

Figure 12 - Update pivot table

The graph in Figure 13 was made from the data report exported from the HMI under a test of PLC and HMI. The data shown was generated from the PLC and simulates pressure. The pivot table and graph function in excel was used to generate the graph.

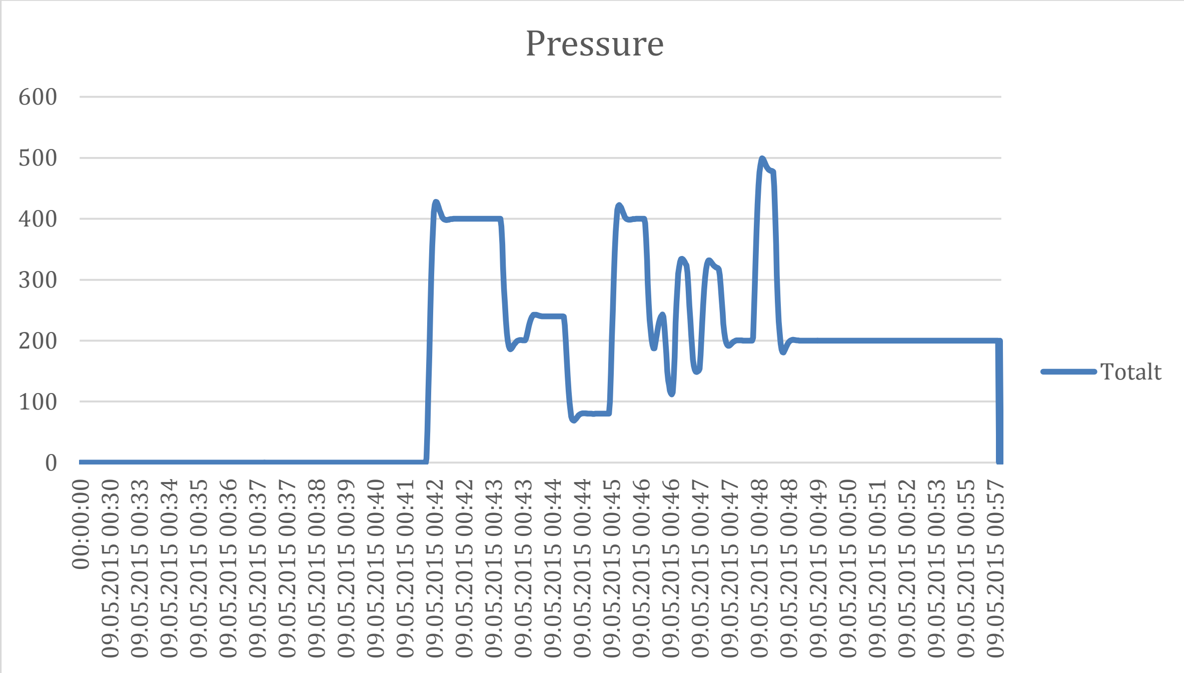

Figure 13 - Graph exported from HMI

3.2 Tag

In IX developer the variables used to import and export data is called tags. Table 3 shows the list of tags used in this project and what the tag is connected to on the controller as well as access properties of the tag and controller.

// Name	DataType	Address_1	AccessRight_1	Description //
ESDV_001	BIT	X1	Read	Emergency pneumatic shutdown valve(3/2 high flow)
FI_001	BIT	X2	Read	Flow indicator
FI_002	BIT	X3	Read	Flow indicator
P_002F	BIT	Y3	Read	HP pump F
P_002T	BIT	Y4	Read	HP pump T
VA_019	BIT	Y6	Read	Control valve 3/2(air)
VA_020	BIT	Y7	Read	Control valve 3/2(air)
VA_021	BIT	Y10	Read	Control valve 3/2(air) for
VA_022	BIT	Y11	Read	Control valve 3/2(air)
LT_001	INT16	D8280	Read	Level transmitter Raw
PT_001	INT16	D8281	Read	Pressure transmitter(0-500bar)RAW
VM_011	INT16	D8282	Read	Micro metering valve
PC_003	INT16	D2	Read	Pressure regulator
Pres_TarTop	INT16	D3	Write	The highest pressure point in the test
Pres_TarBottom	INT16	D4	Write	The lowest pressure point in the test
Cycle_TarTest	INT16	D5	Write	How many cycles PR test
Pres_CurrentDerv	INT16	D7	Write	Pressure speed at the current moment
HoldTime_TarTop	INT16	D8	Write	Holding time at top
Pres_TarDervUp	INT16	D9	Write	Curve speed up
HoldTime_TarBottom	INT16	D10	Write	Holding time at bottom
Pres_TarDervDown	INT16	D11	Write	Curve speed down
Cycle_Total	DEFAULT			Total numbers off cycles.
Start_Pros	BIT	M1	Write	Start the process
Stop_Pros	BIT	M2	Write	Stop the process
Start_Fill	BIT	M3	Write	Start filling sequence
Start_Drain	BIT	M4	Write	Start drain sequence
Reservo_Lev	INT16	D14	Read	reservoir level indicator
PC_003_CurrentValue	INT16	D15	Read	PC_003 converted
Prosess	INT16	D16	Read	Current active part of process
P_002_TarDir	INT16	D17	None	P_002 direction 0 = off 1 = drain 2 = fill
Reservo_Height	DEFAULT			Height of reservoir
Reservo_Volume	DEFAULT			Volume of reservoir
Reservo_Diameter	DEFAULT			Diameter of reservoir
Cycle_CurrentTest	INT16	D12	None	The current cycle in test at the current moment
Cycle_Maint	DEFAULT			Max cycles before maintenance
Cycle_Maint1	INT16	D18	None	Cycles maintenance plc
Pres_CurrentValue	FLOAT	D6	None	The current pressure at the current moment
Reservo_HeightPLC	INT16	D20	None	Height of reservoir variable for PLC
DataloggerBit	BIT			Data logger on/off

Table 3 - Tag list exported from IX Developer

3.3 Script

To prevent that some functions starts when others is active it is necessary to make a script to govern the rules of the process. This script is named Process and it contains the functions StartPros(), StopPros(), FillTank() and DrainTank().

3.3.1 StartPros()

The StartPros() function checks if fill, drain and stop process is active and sets the start bit to 1 if the other bits are 0. Sensors can be checked in the second “if” test.

```
		public static void StartPros(){
			//checking if the other prosseses is inactive.
			if(Globals.Tags.Start_Fill.Value == 0 &&
Globals.Tags.Start_Drain.Value == 0 && Globals.Tags.Stop_Pros.Value == 0){
				//checking if the sensors has the correct value
				if(true){
					Globals.Tags.Start_Pros.Value = 1;
				}
			}
		}
```

3.3.2 StopPros()

This function checks if the stop bit is 1 and if so it resets it to 0. If it is 0 the script continues to check if fill, drain or start function is 1 and if so it resets all these functions to 0 and sets the stop bit to 1. Sensors can be checked in the second “if” test.

```
		public static void StopPros(){
			//checking if the other prosseses is inactive.
			if(Globals.Tags.Stop_Pros.Value == 1){
				Globals.Tags.Stop_Pros.Value = 0;
			}else if(Globals.Tags.Start_Fill.Value == 1 ||
Globals.Tags.Start_Drain.Value == 1 || Globals.Tags.Start_Pros.Value == 1){
				//checking if the sensors has the correct value
				if(true){
					Globals.Tags.Stop_Pros.Value = 1;
					Globals.Tags.Start_Fill.Value = 0;
					Globals.Tags.Start_Drain.Value = 0;
					Globals.Tags.Start_Pros.Value = 0;
				}
			}
		}
```

3.3.3 FillTank()

This function sets drain bit to 0 and checks if drain, start and stop bits is 0, before setting the fill bit to 1. Sensors can be checked in the second "if" test.

```
              public static void FillTank(){
                     //Stopping drain sequence
                     Globals.Tags.Start_Drain.Value = 0;
                     //checking if the other prosseses is inactive.
                     if(Globals.Tags.Start_Drain.Value == 0 &&
Globals.Tags.Start_Pros.Value == 0 && Globals.Tags.Stop_Pros.Value == 0){
                            //checking if the sensors has the correct value
                            if(true){
                                   Globals.Tags.Start_Fill.Value = 1;
                            }
                     }
              }
```

3.3.4 DrainTank()

This function sets fill bit to 0 and checks if fill, start and stop bits is 0, before setting the drain bit to 1. Sensors can be checked in the second "if" test.

```
              public static void DrainTank(){
                     //Stopping fill sequence
                     Globals.Tags.Start_Fill.Value = 0;
                     //checking if the other prosseses is inactive.
                     if(Globals.Tags.Start_Fill.Value == 0 &&
Globals.Tags.Start_Pros.Value == 0 && Globals.Tags.Stop_Pros.Value == 0){
                            //checking if the sensors has the correct value
                            if(true){
                                   Globals.Tags.Start_Drain.Value = 1;
                            }

                     }
              }
```

References

[1] J. Carlstedt and T. O. Skarseth, "Requirement specification," HPCS, 2015.

[2] Beijer Electronics, "beijerelectronics.com," [Online]. Available: http://www.beijerelectronics.com/web/web_en_be_com.nsf/AllDocuments/E6196C4373DFCC1FC125795200394C0A. [Accessed 08 02 2015].

[3] Beijer Electronics, "T7A_outline.pdf," 2015. [Online]. Available: http://ftc.beijer.se/files/C125728B003AF839/DAAC14A334BB5B17C125786900277575/T7A_outline.pdf. [Accessed 08 02 2015].

Hyperbaric - Pressure Control System

PLC

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Revisions

Date	Description	Version	Made By	Approved By
13.02.2015	Idea Description	-	JN	
17.03.15	Formatting, added function and added programming	A	BB	
02.04.15	I/O list description change at X1 and formatting of document.	B	AS, JN	TOS, BB
04.04.15	Removed added programming part temporary	C	TOS, BB	AS, JN
09.05.15	Formatting layout, adding technical info	D	BB, JN	JC, TOS

Table 1 - Revisions

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Table list

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Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
GA	General arrangement
PLC	Programmable logic controller
I/O	Input/output
DA	Digital to analog
Spec	Specification
LL	Ladder logic
FBD	Function block diagram
ST	Structured text
FB	Function block
NC	Not connected

Table 2 - Abbreviations

1.0 PLC

1.1 Introduction

This document contains information about the PLC that is being used in the HPCS project. We decided to use a PLC as controller for our system, instead of designing and making our own or using other controller types. This decision was made by three main factors.

- The time cost:
  It would take a considerable part of the time we have to design, build and test a new controller.
- The HMI:
  Since FMC already had a HMI they wanted us to use, the IX T7a from Beijer. It would make a lot of extra work to get our self-made controller or similar to interact to the HMI in any good way.
- Industrial standard:
  A PLC is the industrial standard choice for processes like HPCS.

The choice of what PLC to use is based on:

- Price
- Number of digital and analog I/O ports needed
- Communication with the HMI

We wanted a PLC that could communicate over Ethernet for reliability, ease of use and speed. The speed factor partly for the transfer of data back and forth to the HMI to give the safest and best user experience.
This is what FMC's supplier Beijer would deliver [1].

Based on this we decided to use Mitsubishi's FX3GE-24M +one FX2N-2DA module.

Figure 1 - FX2N-2DA

Figure 2 - FX3GE module

1.2 The General Information.

A PLC is often used for automation of typically industrial electromechanical processes such as HPCS. Other typical tasks is control of machinery on factory assembly lines, amusement rides and similar. PLC can be designed to be able to handle multiple analogue and digital inputs and output arrangements. They are also tested for immunity against electrical noise and vibration.

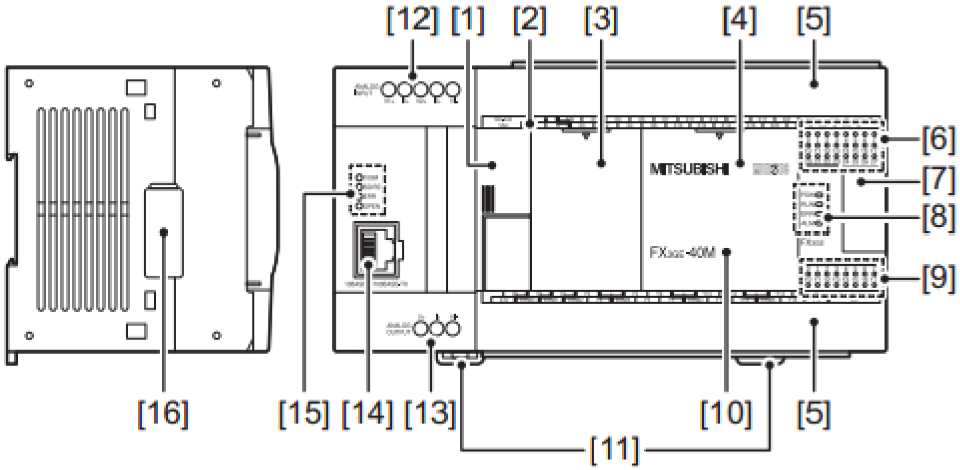


Figure 3 - Part names

Number name:
[1] Peripheral device connector cover
[2] Terminal names
[3] Top cover (S) (40points type only)
[4] Top cover
[5] Terminal block covers
[6] Input display LEDs (red)
[7] Extension device connector cover
[8]Operation status display LEDs
POW Green On while power is on the PLC.
RUN Green On while the PLC is running.
ERR
Red Flashing when a program error occurs.
Red Lit when a CPU error occurs.
ALM Red Lit when the battery voltage drops.
(When the optional battery is used)
[9] Output display LEDs (red)
[10] Model name (abbreviation)
[11] DIN rail mounting hooks
[12] Analog input terminal block
[13] Analog output terminal block
[14] 10BASE-T/100BASE-TX connector (RJ45)
[15] Ethernet status LEDs
[16] Special adapter connector cover

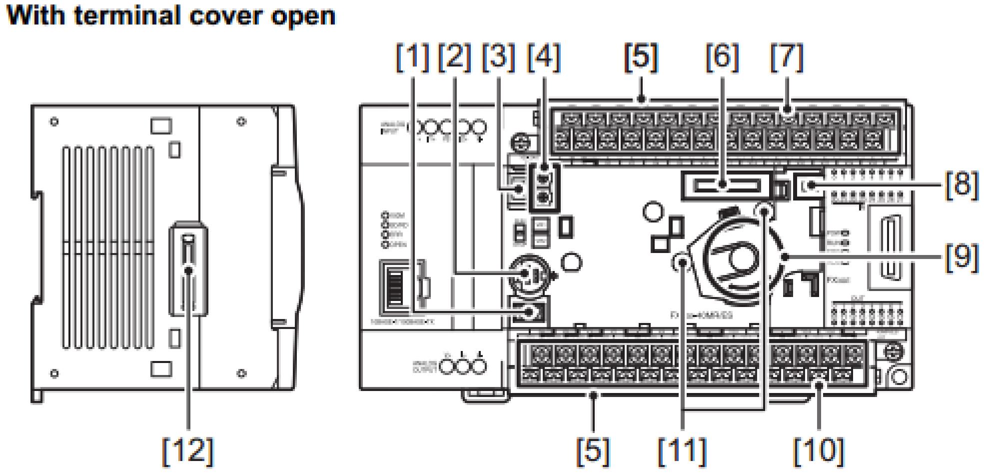


Figure 4 - Part names under cover

[1] Peripheral device connector (USB)
[2] Peripheral device connector (RS-422)
[3] RUN/STOP switch
[4] Variable analog potentiometers
  Upper side : VR1, Lower side : VR2
[5] Terminal cover
[6] Optional equipment connector
[7] Power supply terminal, Input (X) terminals
[8] Battery connector
[9] Battery holder
[10] Power supply terminal, Output (Y) terminals
[11] Optional equipment connecting screw holes
[12] Special adapter connector

1.3 The FX3ge-24m

1.3.1 Programing tool

GX Works2 Ver. 1.91V or later can be used.
It has to be 1.91V or later to use the built-in ethernet port.
GX Works2 license is supplied to HPCS group by FMC.

1.3.2 I/O

Built-in:
Digital inputs: 14
Digital outputs: 10
Analog inputs: 2
Analog outputs: 1
The FX2N-2DA have 2 analog outputs.

1.3.3 The analog ports

The analog ports can be selected to be controlling either voltage or current. We will be using current for our project.
When reading an analog signal the PLC converts the real value to a scaled number.

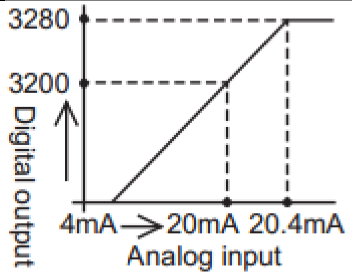
Analog input range	4 to 20mA DC (Input resistance: 250Ω)
Absolute maximum input	-2mA, +30mA
Resolution	5μA(16mA/3200)
Overall accuracy	±0.5% (±80μA) for 16mA full scale (when ambient temperature is 25 ± 5°C) • ±1.0% (±160μA) for 16mA full scale (when ambient temperature is 0 to 55°C)
Input characteristics	

Table 3 - Analog current input specification [1]

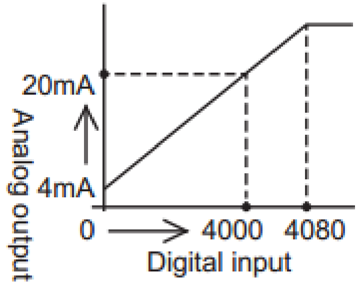
Analog output range	4 to 20mA (External load resistance 400Ω or less for FX2-2DA) (External load resistance 500Ω or less for FX3ge built inn module)
Resolution	4μA(16mA/4000)
Overall accuracy	• ±0.5% (±80μA) for 16mA full scale (when ambient temperature is 25 ± 5°C) • ±1.0% (±160μA) for 16mA full scale (when ambient temperature is 0 to 55°C)
Output characteristics	0 to 4000 are adjusted to 4 to 20mA when the external load resistance is 250Ω 
Consumption current of 24V DC for one FX2n-2DA unit	85mA

Table 4 - Analog current output specification [1] [2]

2.0 Programming

2.1 Programming language

The programming languages that most PLCs follow is after the standard IEC_61131-3 [7].
Programming used in the HPCS is mostly done in a combination of FBD and ST.

2.2 Layout of program

The programming of PLC in the HPCS is made with one main LL/FBD which includes all the 5 phases that a full cycle run have. Which phase is selected to run is controlled by a control variable.

The phases are

1. Wait:
    a. While waiting the system will close all valves and do nothing other than keep checking the pressure.
    b. It will wait for as long as its told by a variable containing the time
2. Fill chamber:
    a. In the start of a run the tank needs to fill. To do this the filling line valve and overflow line valve need to be open.
    b. The filling pump starts the filling procedure.
    c. The filling will stop after the overflow line have registered overflow. This will make sure there is no air in the tank which would end in bad regulation and possible dangerous situation.
3. Increase pressure:
    a. The only valve that will be open is the pressure line valve.
    b. The system shall then measure the derivative of the pressure, this will tell how fast the pressure is changing by the unit bar/min.
    c. The user have entered the reference speed of pressure change PR min.
    d. The reference and current speed is put in to a PID regulator that will control a pressure regulator controlling the pressure pump.
    e. When the final pressure is reached, the system goes back to waiting mode.
4. Decrease pressure:
    a. The only valve open will be the decrease pressure line for the micro metering valve.
    b. The micro metering valve will start in closed position and will open up to bleed of the pressure in according to the reference speed for decreasing.
    c. When final value is reached, the system goes back to waiting mode.
5. Clear chamber:
    a. Equalize the inside and the outside pressure of the pressure tank.
    b. Drain pressure tank.

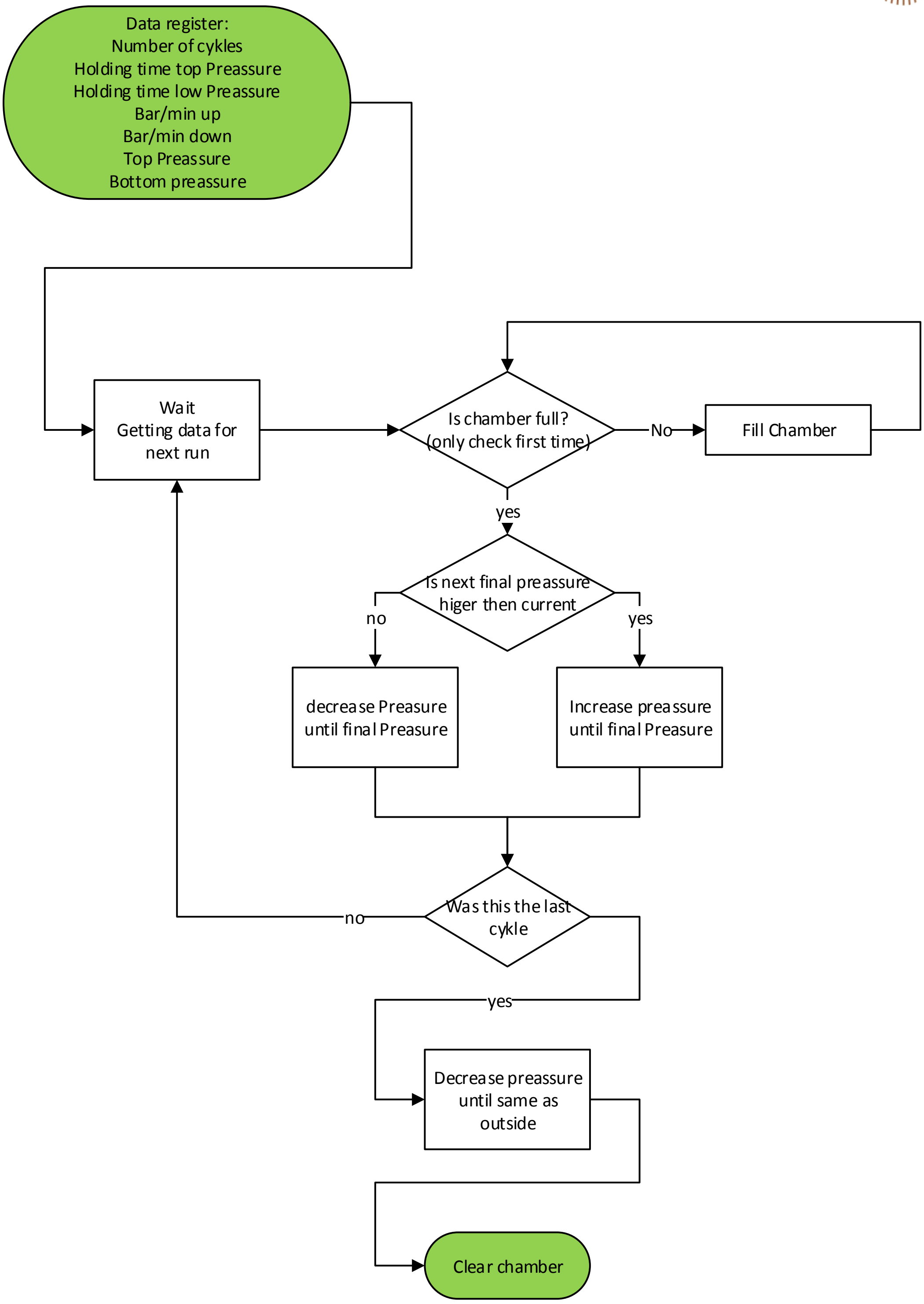


Figure 5 - Program overview

2.3 PLC program

2.3.1 Main

The main was chosen to be made in FBD style, this is because it's easier for most people to see how thing works as it's a graphical language.

In this plc programmer I could not find a build in way to scale signals. So I made a function block for scaling signals.

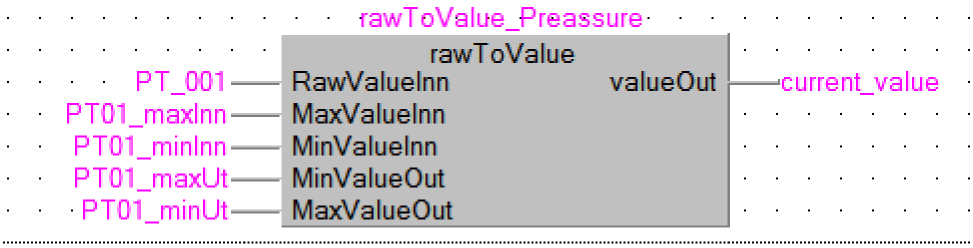


Figure 6 - signal scaling for pressure

In to this function we send the raw value from the transmitter, in this case it's the 0-3200 signal from pressure transmitter "PT_001".
And out one gets the float value "current value"

2.3.2 RawToValue

This is what that function block does to the values put in to it.
This is also done in FBD language

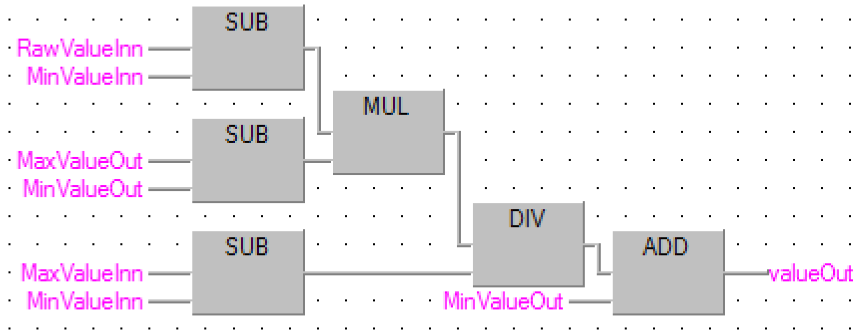


Figure 7 - Raw to value FBD formula

This transfers to the following formula.

$$\frac{(RawValueInn - MinValueInn) * (MaxValueOut - MinValueOut)}{MaxValueInn - MinValueInn} + MinValueOut = Value\ out$$

Equation 1 Signal scaling FBD formula

It scales the transmitter value to the working area in the correct unit.

2.3.3 Sampler

The sampling is done every time the timer block "TON" turns on for a cycle. When this happens the value in sample3 is moved to sample4 the sample2 value is moved to sample3 and so on. At the end it takes the current value and samples. To sample0 it's now made to take five samples but can easily add or remove samples by adding more blocks in the same fashion. Figure 8

The next time the sampler schematics is run it will turn its self of with the normally closed switch connected to the output.

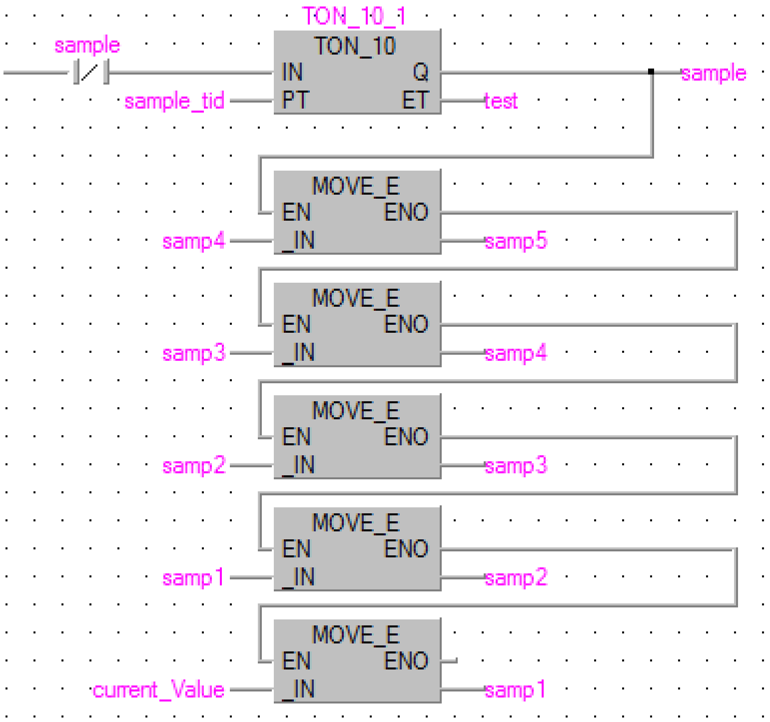


Figure 8 - Sampling system

2.3.4 Second order derivative with low pass filter

This is the derivative function block. It returns the second order derivate with low pass filter, of the sampled values.

This HPCS project need to be regulated on the derivative value of the signal. [2]

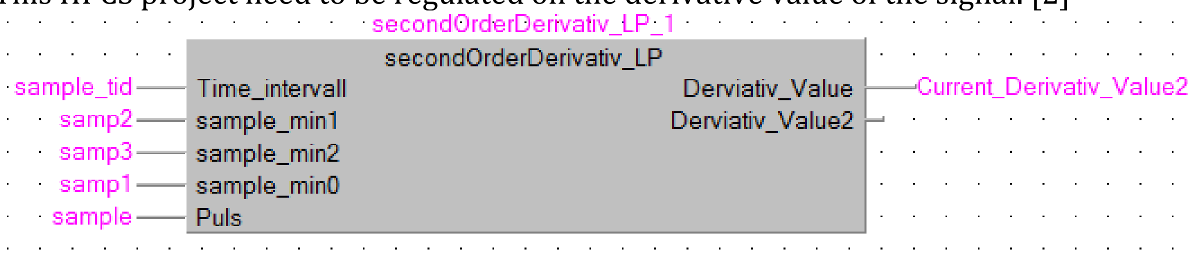


Figure 9 - Second Order Derivative Low Pass block

It need the last three samples, the sampling interval and sampling pulse witch says when the value is ready for the next calculation. This will return the derivative value.

2.3.4.1 Derivativ

The derivative block is based on the discretization formula from tech14 [3] using Tustin's method.

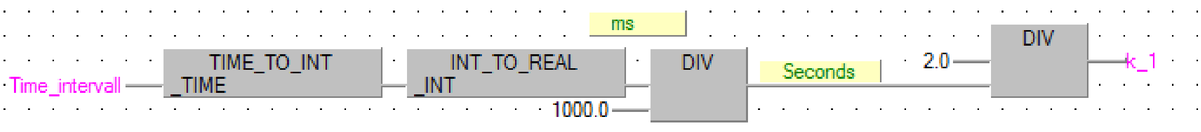


Figure 10 - Convert time to a number representing seconds

Sins Tustin's method need the sampling interval time given in seconds to be flexible of sampling intervals, the program converts 'Time_interval' witch is a value in the form of T#1s250ms as example it converts it first to a number representing ms in this example

1250.0 then we divide it by 1000 to get 1.25 seconds, then convert it to the value k_1 witch the formula uses.

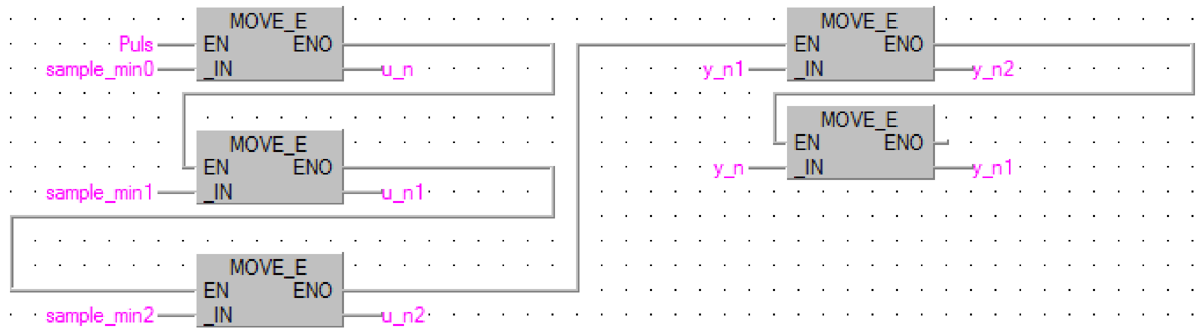


Figure 11 - Moving from input to formula factors and tracking output.

Every time the sampler sends a pulse, the function in Figure 11 takes the input values and send them to the formula value holders. The function also shifts the current output to the output register.

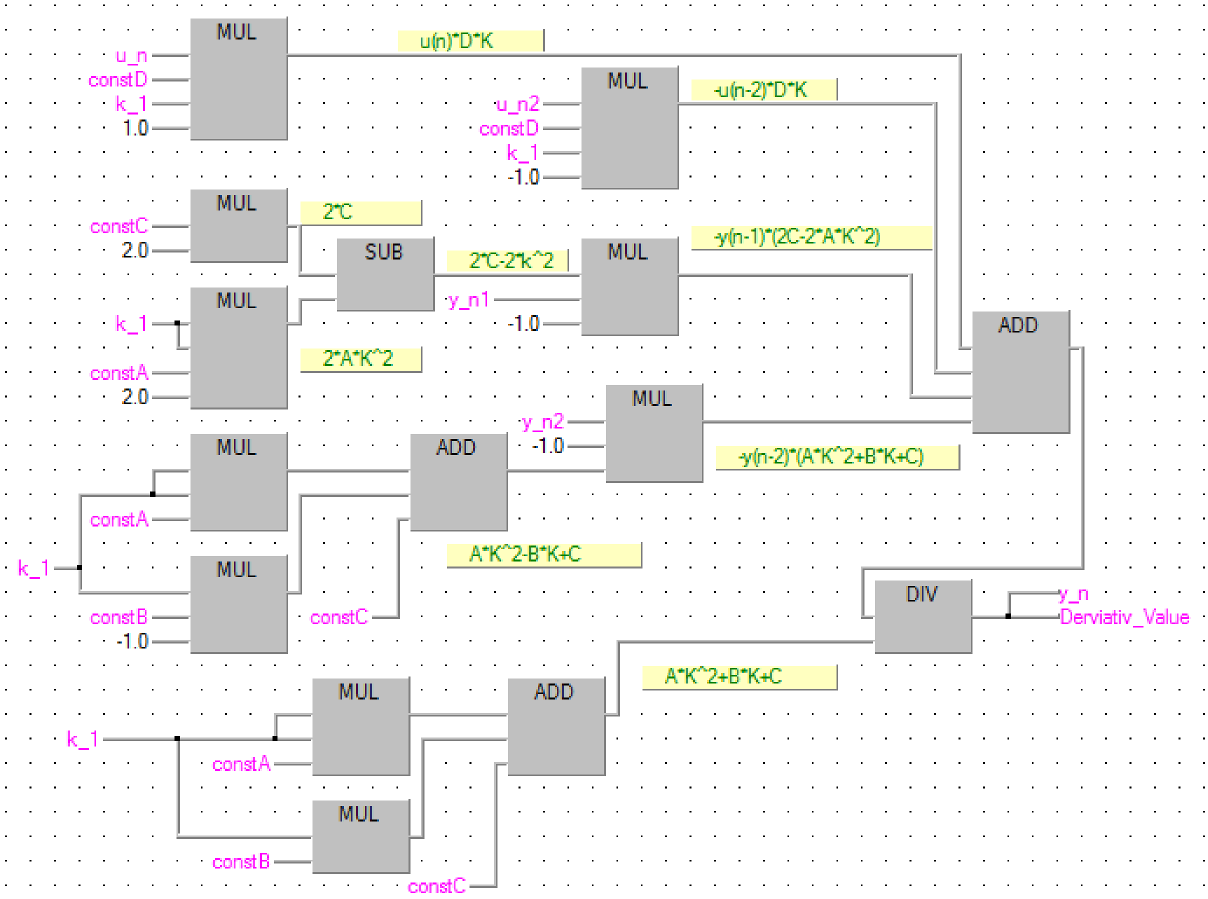


Figure 12 - General 2.order discrete algorithm derivate LP

This is constructed after Tech14 Eq.14. [3]

$$y(n) = \frac{u(n)dK - u(n-2)dK - y(n-1)(2c - 2aK^2) - y(n-2)(aK^2 - bK + c)}{ak^2 + bK + c}$$

Equation 2 General 2.order discrete algorithm derivate LP

The resulting value is stored in the formula variable y_n and is put to the output of the FB.

This function block have some optimization possibility, like writing the samples directly to the formula.

This is tested with giving sampling value a steady inclining value and reading the result in the HMI. In the following is a test example. Adding a 100 to the sampling value four times a second should give a derivate value of 400. This was done simply in the programmer by using sampel0=sampel0+100 instead of sample0=current_value in the sampler sequence.

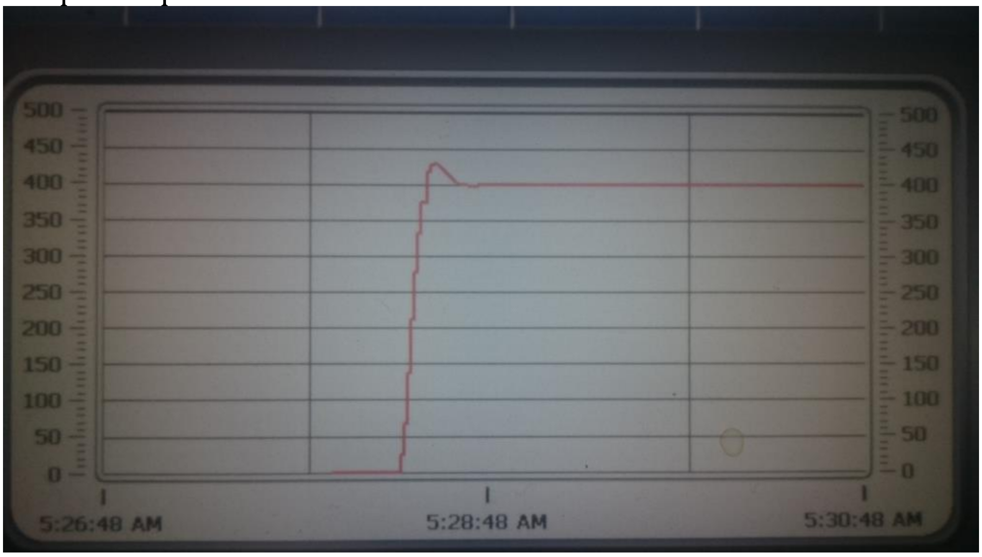


Figure 13 - Picture of HMI screen showing derivate value of test

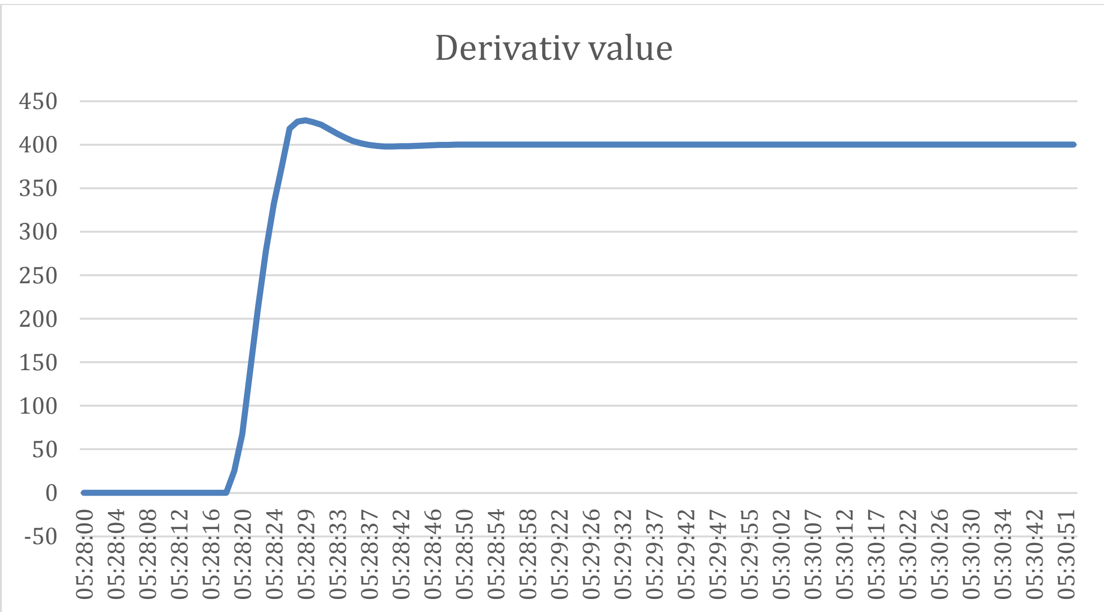


Figure 14 - Diagram from an early HMI rapport function

This shows that the function works. It's calculate and finds the derivative value of the input signal. It also show the overshoot to be about 30of400 =7.5%. This will be acceptable sins this is a hard step response of the derivative value and the settling time is not too long. The graph is very similar to the computer model in the tech14 document [3]

2.3.5 PID pressuring

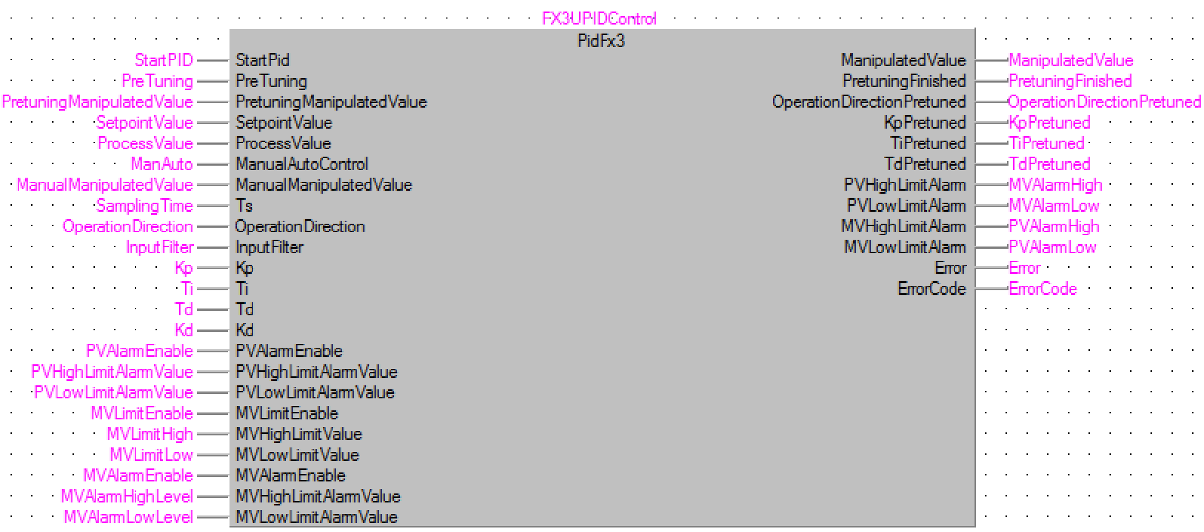


Figure 15 - Example PIDFx Block

The controller will use two sets of PID regulators, one for the pressure increasing and one for the decreasing. This to avoid mixing up the parameters for the two outputs (the air pressure regulator in and the fluid flow valve out.
This function block is not a standard FB in the GxWorks2 program but is downloaded on the Mitsubishielectrics home page.
One of the advantages of this is the auto tuning possibility. It makes the HPCS project more versatile for different output systems and sizes. This can be activated with a button in the HMI. The steps for this would be 1. Prepare the tank by connecting the system 2. Filling it up. 3. Enter the parameter limits for the tank 4. Start the auto tuning.

2.3.6 IO list

Unit	IO	TAG	Comment
PLC			
DI	**X0**	**NC**	
	X1	ESDV001 and K1: 24	Emergency shutdown
	X2	FI001	Pressure tank full
	X3	FI002	Pressure tank not empty
	X4	**NC**	
	X5	**NC**	
	X6	**NC**	
	X7	**NC**	
	X15	**NC**	
DO	**Y0**	**NC**	
	Y1	**NC**	
	Y2	**NC**	
	Y3	P002F	Filling pump
	Y4	P002T	Draining pump
	Y5	**NC**	
	Y6	VA019	Air valve 19
	Y7	VA020	Air valve 20
	Y10	VA021	Air valve 21
	Y11	VA022	Air valve 22
AI	**V1+&I1+**	LT001	Reservoir level transmitter
	V2+&I2+	PT001	Pressure transmitter
AO	**V+**	**NC**	
	I+	VM011	Micro metering valve
DA module			
AO	**Iout1**	PC003	Air regulator for pressure pump
	Iout2	**NC**	
	Vout1	**NC**	
	Vout2	**NC**	

Table 5 - IO list

This is a list telling what's connected to the screw terminal of the plc and module. First colon contain what kind of signal and what module. Second colon tells what terminal. Third tells what is connected and the last colon contains an easier description of the connected device.

References

[1] AS, Beijer Electronics, *Telefon: +47 32 24 30 00,* Drammen, 2014.

[2] J. Carlsted and T. O. Skarseth, "Requirement Specification".

[3] A. Skjørten, "Tech-014 A Discretization," Høgskolen i Buskerud, Kongsberg, 2015.

[4] Mitsubishielectric, "FX3GE hardware manual JY997D49401E," [Online]. Available: http://dl.mitsubishielectric.com/dl/fa/document/manual/plc_fx/jy997d49401/jy997d49401e.pdf.

[5] Fapro, "FX2N-2DA SPECIAL FUNCTION BLOCK JY992D74901E," [Online]. Available: http://www.fapro.com.tw/DB/download/Mitsubishi%20PLC%20Manual/jy992d74901e.pdf.

[6] Mitsubishielectric, "Programming Manual II JY992D88101," [Online]. Available: http://forums.mrplc.com/index.php?app=downloads&showfile=508.

[7] "IEC_61131-3 Standard," [Online]. Available: https://webstore.iec.ch/publication/4552. [Accessed 13 02 2015].

Hyperbaric - Pressure Control System

Digital to Analog Converter

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ID: TECH - 005 <A>

Revisions

Date	Description	Version	Made By	Approved By
15.02.2015	Idea Description	-	AS	TOS, JC
09.05.2015	Formatting text	A	AS, BB	BB, AS

Table 1 - Revisions

Table of Contents

Table list

Figure list

Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
GA	General arrangement

Table 2 - Abbreviations

1.0 FX2N-2DA

1.1 Introduction

This document contains information about the FX2N-2DA digital to analog converter. The document gives brief information on how the module works and how to communicate to it from a Mitsubishi FX series compact PLC. The software used to program the PLC is GX Works 2 from Mitsubishi.

1.2 General Information

Figure 1 - FX2N-2DA

The FX2N-2DA is an expansion module for the Mitsubishi FX series compact PLC. PLC provides the power and there is direct communication between PLC and DA thru serial bus system. This module contains two digital to analog converter ports and it is possible to select two different output standards. Where one of those output standards is a 4-20mA output current witch is widely used in industrial environments to control components that is sensitive to electrical noise. This standard has a resolution of $4\mu A$ so the PLC can control this output linearly with values from 0-4095 witch is 12 bit of data information. However the value 4000 from the controller gives a 20mA output form the DA converter so one should not use values higher than 4000. The other output standard gives an output voltage from 0-10V. This method has a resolution of 2,5mV and the controller controls this output at the same time as the mA output so the control values is the same. The overall accuracy of the FX2N-2DA is given in the datasheet to be $\pm 1\%$ [1].

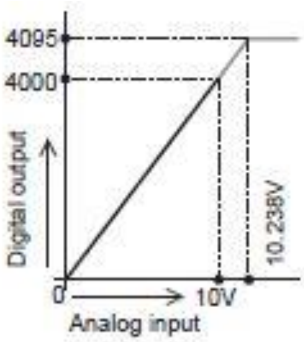

Figure 2 - Output standard one, 0-10V [2]

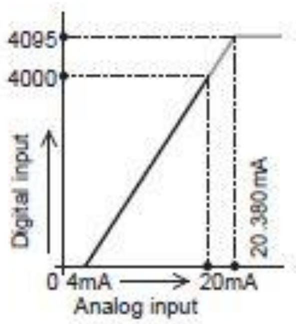

Figure 3 - Output standard two, 4-20mA [2]

1.3 PLC Program

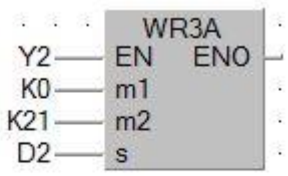

Figure 4 – Function test of FX2N.

WR3A is a function block in GX Works 2 that handles the communication to the FX2N-2DA. It needs 4 input parameters to operate correctly. The first parameter is EN which stands for enable. As long as this input is high the function will run and if it is low the function will hold current values. M1 is the special block or module number and it expects an input from K0-K7 witch specifies what place the module has in the bus line. M2 is referred to as the analog output number so for the FX2N-2DA it can take either K21 or K22 witch refers to output 1 or 2 in the DA converter. Input S is the data to be transferred to the DA and this input expects a value between 0-4000. It also expects to be reading straight from the memory so the input on S is usually set to a memory of type D [2].

Figure 4 shows a working example of the WR3A function block with enable connected to output Y2 of the PLC. It controls module number one to the right of the controller and is writing from memory D2 to output one on the module. This picture is form an initial function test of the DA converter where the FX T7A HMI from Beijer was used to regulate value D2 form 0 to 4000 and toggle Y2 between 0 and 1 on the PLC.

1.4 Connection

Figure 5 describes the two different ways to connect actuators to the FX2N-2DA.

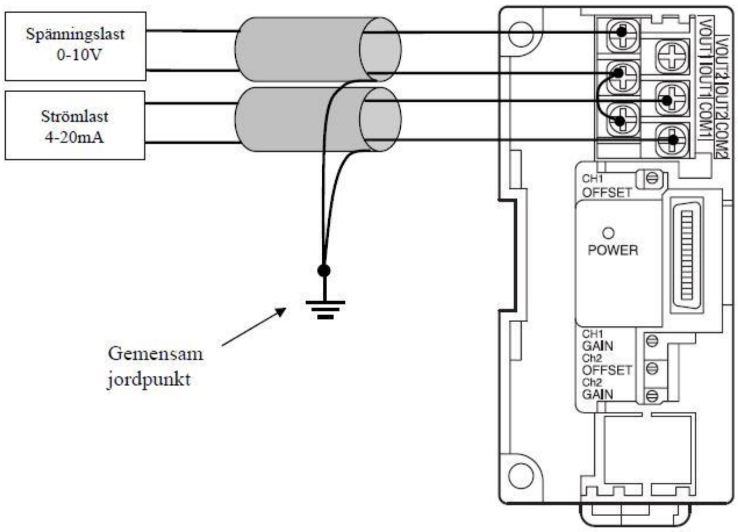

Figure 5 - Connection diagram [3]

References

[1] Mitsubishi, "FX2N-2DA-Mitsubishi-datasheet," 09 11 2009. [Online]. Available: http://datasheet.octopart.com/FX2N-2DA-Mitsubishi-datasheet-10733218.pdf. [Accessed 15 02 2015].

[2] Mitsubishi, "FX Series Programmable Controllers WR3A," [Online]. Available: http://www.fapro.com.tw/DB/download/Mitsubishi%20PLC%20Manual/jy992d74901e.pdf. [Accessed 06 05 2015].

[3] Mitsubishi, "User's manual FX3G," [Online]. Available: http://dl.mitsubishielectric.com/dl/fa/document/manual/plc_fx/jy997d31301/jy997d31301j.pdf. [Accessed 06 05 2015].

Hyperbaric - Pressure Control System

System Description

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Revisions

Date	Description	Version	Made By	Approved By
20.02.2015	Idea Description	-	BB	
28.02.2015	Formatting changes	A	BB, TOS	
02.04.2015	Formatting changes	B	BB, JN, AS	BB, JN, AS
09.04.2015	Formatting	C	BB, TOS	
29.04.2015	Formatting text and layout to standard	D	BB	AS, BB
10.05.2015	Finishing	E	BB	JC, JN

Table 1 - Revisions

Table of Contents

Figure list

Table list

Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
GA	General arrangement
PLC	Programmable logic controller
BOM	Bill of Material
NEK	Norsk Elektroteknisk Komite
TN	Terra Neutral
IEC	The International Electrotechnical Commission
NO	Normally Opened
NC	Normally Closed
I/O	Input / Output
DA	Digital to analog Converter
P&ID	Piping and Instrument Diagram

Table 2 - Abbreviations

1.0 Document Overview

1.1. Introduction

Chapter 1, chapter 2 and chapter 3 of this document will go thru electrical description. Overview over some terms and norms. Electrical BOM will be described in more detail for main components. This part of document is fundamental of all technical drawings and system description.
Chapter 4 and chapter 5 of this document will go thru hydraulic description. Overview over basic functions of the components and describe the main pumps in this system.

2.0 Electrical System

2.1. Electrical System Description

TN-system is installed in FMC workshop. There are three phases, and between two phases there is 400VAC input. Between N leader and one of the phases there is 230VAC. To obtain the same flow rate of energy the system should divide phases equal to power system.
TN stands for Terra Neutral, witch the first letter "T" stands for direct connection from alive point to earth. Second letter "N" stands for direct electrical connection between the exposed conductive parts and installation separate earth electrode [5] [8].

NEK 400 contains norms to electrical low voltage system. All industry installation are recommended to follow those norms. HPCS system will follow thru those norms, and will be designed according to them [6].

HPCS project is based on low voltage systems.
«The International Electro technical Commission (IEC) defines supply system low voltage as voltage in the range 50–1000V AC» [7]. HCPS system will have 400VAC as input with three phases. This will be transferred to 230VAC by using one phase connected to N leader.

NEK 400 [16], section 5.2.3.1 refers to the earth fault of a TN-system.
Fault of TN-system will carry current thru protective conductor. This leads to high fault current by the first earth fault.

For TN-system release time can be affected by slow circuit breakers, long cables and/or small cross-section of the cable. Table 3 - Segment of NEK 400 Table 41A [5] show the time required.

Nominal voltage to earth U_0	Released time
230V	0.4s
400V	0.2s

Table 3 - Segment of NEK 400 Table 41A [5]

System will have 400V connected to the HPCS control cabinet. From the cabinet, power will be distributed to 230V for all main components. Control system equipment will be supplied by 230VAC/24VDC power supply.

HMI and PLC interface will control the system.

2.2. Technical Drawings

2.2.1 Navigation of the drawing references

TECH-007-SYS will have references between documents and drawings. Figure 1 shows the drawing coordinate referencing and note references. When there are some changes between revisions, there will be marked with revision cloud and revision triangle. The final release of the technical drawings will go one revision up, and remove all of the revision markings.

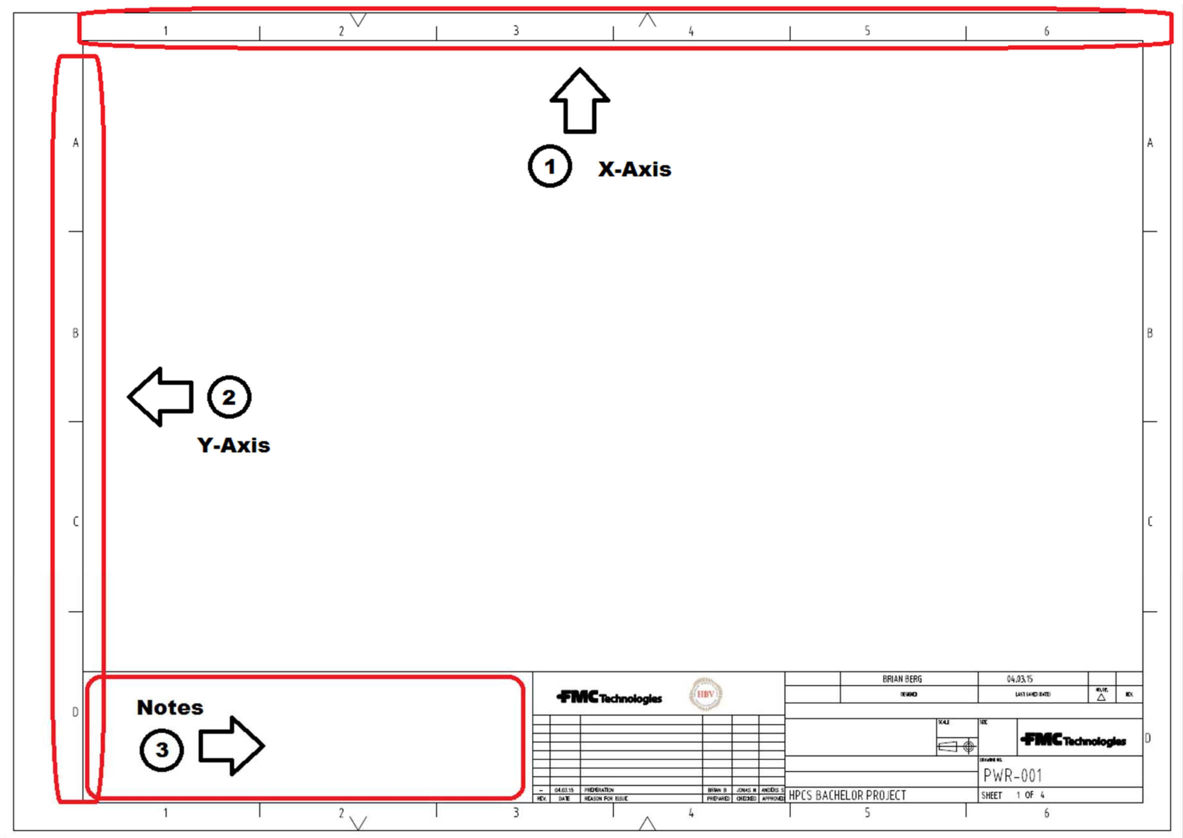

Figure 1 - References of the drawings

Explanation of Figure 1:

1. X-Axis is shown as a first coordinate letter in reference
2. Y-Axis is shown as a second coordinate letter in reference
3. Notes are changing from drawing to drawing. All relevant notes are described at placement 3, and are marked in the drawing.

Example of referring of point 1 in Figure 1 is:
Referring PWR-001 at 3A.

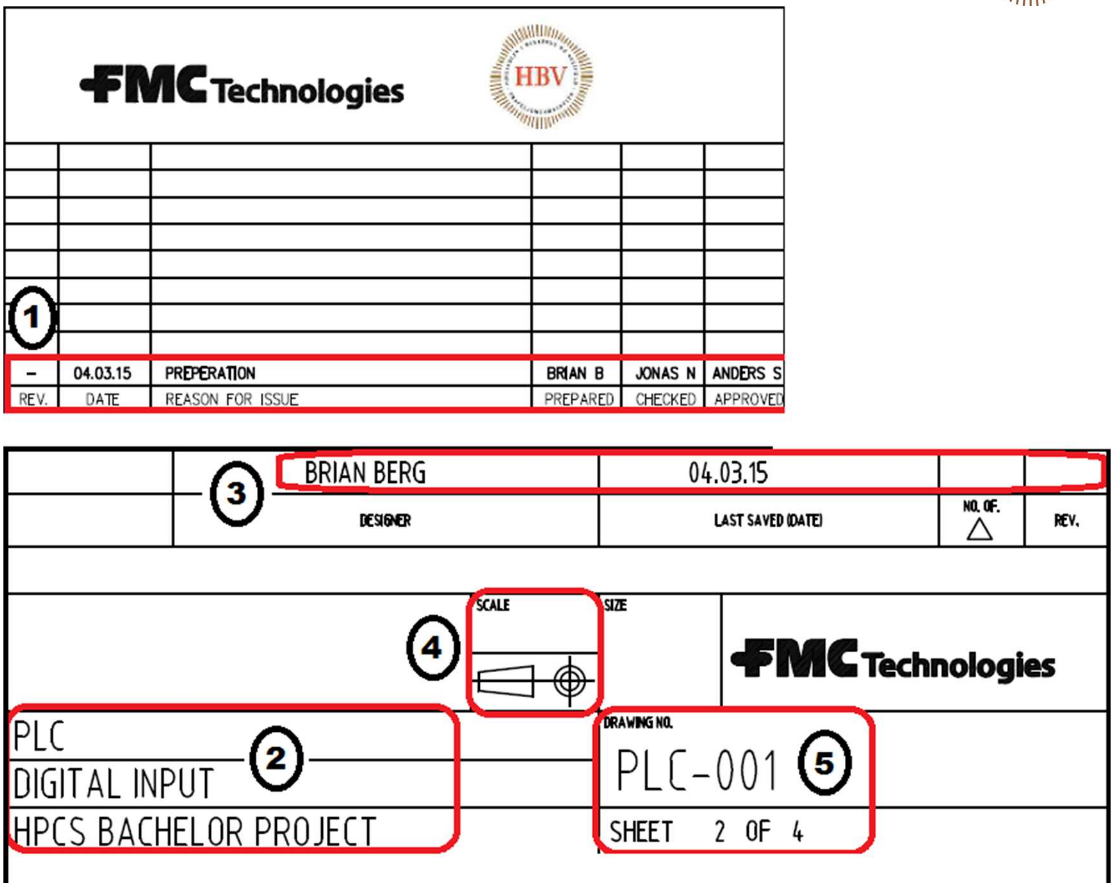

Figure 2 - Title block explanation

Explanation of Figure 2:

Revision title block:

This block contains information about revision, date, reason for issue, prepared, checked and approved.

1. Reason for issue is an overall description of why change has been applied. Prepared column is who have prepared the drawing. Check and approved is as applied, who will check the drawing, and who will release it.

Info title block:

This title block is to give detail information about the drawing. Title name of drawings, date and designer name is displayed.

2. This section is describing the drawing. First title name is about witch category of system is described. Second title name describes what kind of signal or interface of the drawing. This is a sub section in for first title name. Third title name is HPCS Bachelor Project, which will be constant thru the whole project.
3. Designers name, start date of current revision, amount of revision changes, and lastly, current revision is described in this part of Figure 2.

4. Drawings are drawn in accurate dimensions compared to datasheets for the components. Referring to section 2.2.2 GA as an example, HPCS cabinet may want to scale some components for viewing more details. In this section, we see how many times the scaling is applied. The small figure under scale text, is an indication of how to read the technical drawing.
5. Drawing name and sheet is the file name and sheet of the current drawing.

2.2.2 GA

Referring to CAB-001, General Arrangement for the cabinet is a detailed drawing of the physical part of the system. Arrangement of part placement, measurements or detailed physical drawing. Section 4.0 Electrical Component Description will go thru electrical component description, which will be placed inside GA drawings. All of the components are designed and measured compared to the real values. GA drawing should have real type of scaling compared to the cabinet. This provides correct check if the cabinet is adequate size.
Some of the components like HMI have recommended distance between other components, this line is indicated within the GA.
First page of GA is the external view of the cabinet, which gives us an overview over dimensions and of the cabinet, and component placement. CAB-001, sheet 1 has some components with a number tag. Those tags are explained in sheet 2 in more detail.

System GA will be designed according to the P&ID. The detail of the drawing will be limited. Reason for this is the difficulty level of the drawing and the time consumption. This drawing will be used as a principle drawing.

2.2.3 Power Schematics

PWR-001 drawing show how the main power wiring to the system. This is based on section 2.1 Electrical System Description. This is a basic wiring form for control of a motor in both directions. Drawing PWR-001ref 1A, show that Q1 is the main switch. Properties of this is to cut off all the power to the system. F1 at reference 1A is the circuit breaker while F2 at reference 1C is the overcurrent protection for motor. Overcurrent protection can be used to do maintenance on the motor.
Schematic PWR-001, ref 1B and 3B, show us the contactors for the pump. This will be 400VAC over those contactors, and the pump will have star connection [26]. The terminal strip 230V: L and 230V: N is supplying the desired effect to all of the main 230VAC components.

2.2.4 Control Schematics

CTL-001 is a schematics description for how control of the system will be. This is mainly focused on;
Electrical safety components, control of contactor and signals thru PLC.
At reference 2C and 3C, contactors are connected thru the PLC. PLC will control the pump. When emergency stop switch is activated, the control over the pump is not active thru the PLC. Otherwise PLC is controlling the pump.

K2 and K3 are the contactors help switches. They are interlocking for each other by being normally closed. This will enable the pump from being activated in both directions at the same time.

2.2.5 PLC and HMI

PLC-001 document show loop diagram for PLC and HMI communication. Drawings are showing all connections that are used in the system.
This document is based on TECH - 004-PLS drawing. TECH - 004-PLS included the I/O list, with all of the PLC and DA-module terminals are shown.

Drawing shows the connections of the PLC for power, digital and analog input/output. Communication between PLC and HMI is thru Ethernet wire. HMI power connections are shown in PLC-001 drawing.

3.0 Power Consumption

3.1. Power Consumption Description

Power consumption section is about approximation of power usage of the system.

Power consumption approximation calculations are designed for the worst-case scenario. Table 4 is power consumption table with the power values given by datasheets.
Under normal operating conditions the effect will not come near of the total 917W power consumption table indicates.

Components	Power
Power Supply 24VDC, 10A	240W
Drain / Filling Pump	750W
PLC	32W
Fan	15W
HMI	6W
Total:	**923W**

Table 4 - Power Consumption

Important note is to know that the drain / filling pump will only be activated under start and end procedure, while power supply ration of 120W is only accurate at the full load of the power supply.

4.0 Electrical Component Description

4.1. Safety Relay

Safety relay is a good way to isolate outsourced power with inside of the cabinet. Figure 3 shows a safety relay.
«Safety relays are intended to reliably monitor the signals from safety devices at all times and switch off quickly in an emergency» [9].

Figure 3 - Safety Relay

Emergency stop switch or power failure are the only things that will cut off the control power to safety relay. This will lead to relay function cutting power fast for critical components. Figure 4 shows the logic of a safety relay. At the time the system is energized, and emergency stop switch is not activated, all of the NO contacts are closed, and all of the NC contacts are open.

By cutting the power to A1, while A2 is wired to 0V. All of the NO will be opened again, and all of the NC will be closed again. This gives the opportunity of giving PLC a feedback if the safety relay is deactivated and activates other safety procedures. Figure 4 show that safety relay looks the same way as a normal relay. The difference is in closing time. Safety relay is many times faster than a contactor for closing.
Maximum current thru safety relay at 24VDC is 5A, this is adequate for the power consumption of the system.

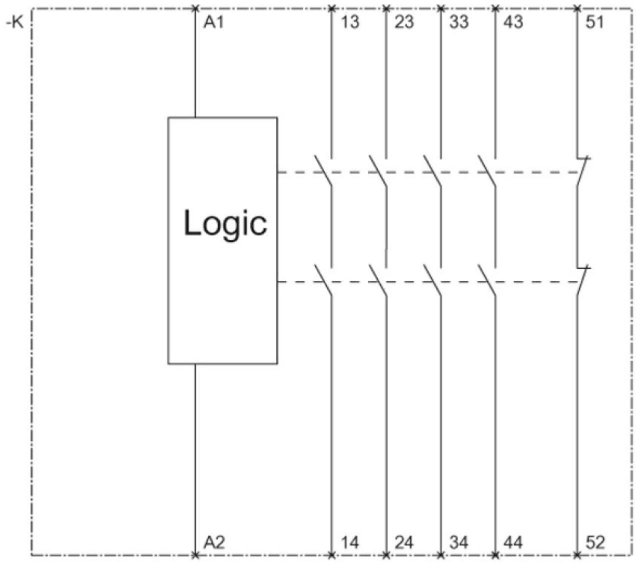

Figure 4 - Safety Relay Logic

4.2. CEE-Power Plug 32 A/400 VAC


Figure 5 - CEE-Power Plug 32 A/400 VAC

There are blue and red plugs for 230VAC and 400VAC. For HPCS system, input is 400VAC. This must be indicated by red plug. The conductors must be correct dimensioned compared to effect the system.

4.3. Emergency Stop Switch

Systems must be equipped with one or several emergency stop switch to avoid threatening situations or limit the impact of the threatening situations.
The emergency stop switch must be easy to access and easy to identify. It shall be impossible to activate emergency stop switch without activating stop function. Release of the emergency stop switch shall not lead the machine to start again, but make it possible to start the machine again [4].


Figure 6 - Emergency Stop

HPCS system is a small system, so it will not need more the one emergency stop switch. Emergency stop is placed on top of the control cabinet. See section 4.1for more detail about the safety relay.

4.4. Contactor for electro pump

Figure 7 - Contactor for electro pump

[10] «A contactor is controlled by a circuit which has a much lower power level than the switched circuit». HPCS group will use two contactors to control reservoir tank pump direction. This will be done by PLC with control voltage. See section.

For more information about control voltage. Voltage applied to the pump will be 400VAC thru contactors.

4.5. Help switch for contactor

Figure 8 - Help switch for contactor

Help switch for contactor is installed on top of the contactor. There will be too many available contactor switches compared to HPCS design, but it will be installed for future use. Voltage used id 24VDC.

4.6. Surface mounted cabinet

Figure 9 - Surface mounted cabinet

Figure 9 show the cabinet. Inside the cabinet there will be assembled electro components. The cabinet must be modified for cable gland, filter fan and other adjustments. See CAB-001 electro schematics for more details.

4.7. Main switch

Figure 10 - Main switch

Main switch is meant for cutting all power to the system. It is possible to install padlock when the switch is set to off. This will provide possibilities for maintenance for the powerless system.

4.8. Filter fan

Figure 11 - Filter fan

Filter fan is needed to reduce the temperature by circulating the air in the cabinet. Dimensions of the filer fan is adequate compared to the depth and width of the control cabinet.

4.9. Circuit breaker 2 A 3-pole type C

Figure 12 - Circuit breaker 1 A 3-pole type C

Figure 12 show the circuit breaker for system input voltage of 400VAC. This will then be connected to the pump.
From specification of drain / filling pump, we see that the pump is specified for 0.75kW [12].
By using 400VAC, and equation 1 we obtain;

$$I = \frac{P}{(U)\sqrt{3}}$$

Equation 1 - *Ohms Law with factor of power, voltage and current*

Equation 1 show Ohms Law with three phase compensation.

$$I = \frac{750W}{(400VAC)\sqrt{3}}$$

$$I = 1.08A$$

Circuit breaker for 1A will be enough for this pump.
It was taken to consideration about having 2A circuit breaker. It was not chosen since 750W is maximum power out of pump. This means that current will be less than 1A, and it will not be active for long period of time.

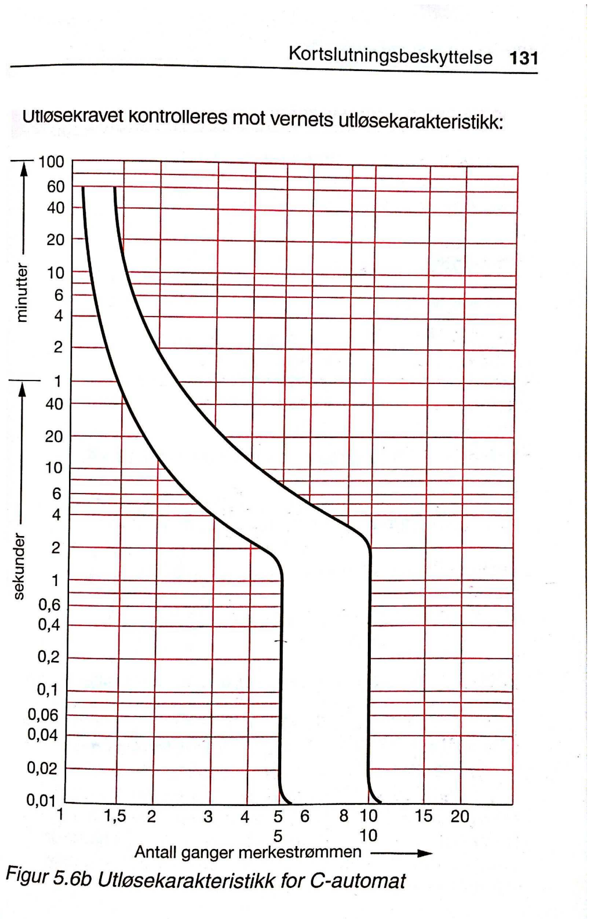

Figure 13 - Characteristic of a C-Automat Circuit Breaker [5]

Figure 13 is in Norwegian. Y-axis show time elapsed, while x-axis show multiplication factor of nominal current. Nominal current is the current circuit breaker is specified for.
From the table we see that if the current is five times nominal current, circuit breaker will instantaneous switch off.
[5] [11].

4.10. Circuit breaker control current 2A

Figure 14 - Circuit breaker control current 2A

Figure 14 show circuit breaker for 230VAC. See section 2.0 for wiring details. 230VAC will be distributed to the control system components.

Error! Reference source not found. show power consumption of the components. Circuit breaker for 240VAC will protect power supply, PLC, Fan and HMI touch screen. This indicated of total 287 W protection. Equation 2 show the circuit breaker calculation.

$$\frac{287W}{230VAC} = 1.2A$$

Equation 2 - Ohms low for circuit breaker calculation

Circuit breaker for 2A is adequate for 230VDC distribution.

4.11. Overcurrent relay

Figure 15 - Overcurrent relay

Referring to section 4.9, we obtained 1.08A if we have 400VAC connected to the motor.
Overcurrent relay can very between 0.9A to 1.25A, with is within 1.08A. This is adequate for this pump.
Voltage can vary from one location to another. After measuring actual voltage at the workshop, we can adjust overcurrent relay to the workshop voltage.
Overcurrent relay can be mounted directly on contactor, or it can be separated by overcurrent support equipment.

Equation 3 show the maximum and minimal voltage the workshop can have.

$$Umax = \frac{P}{(Imin)\sqrt{3}} \qquad Umin = \frac{P}{(Imax)\sqrt{3}}$$

Equation 3 - *Ohms Law with factor of power, min/max voltage and current*

$$Umax = \frac{750W}{(0.9A)\sqrt{3}} \qquad Umin = \frac{750W}{(1.25A)\sqrt{3}}$$

$$Umax = 481V \qquad Umin = 346V$$

4.12. Overcurrent Relay Equipment

Figure 16 - Overcurrent relay

Figure 16, show the support equipment for overcurrent relay.

There are two contactors for drain/filling pump, and overcurrent relay needs to be wired in series with both of the contactors. Overcurrent relay support will save some cost of a second overcurrent relay. Important note is that the connectors for L1, L2 and L3 in support bracket is adequate enough in size for having several cables connected in one connection. If not, this can be solved by adding terminal strips and adding jumpers.

4.13. PLC

PLC is described in TECH - 004-PLS and is HPCS system controller. By using their I/O connections, system program will be programmed for the derivative pressure regulation of the tank, and also for sequential control of components like valve etc.

4.14. HMI

HMI is described in TECH - 003 –HMI.
HMI is a touch-screen display that is directly connected to PLC. From there operator can set and read system parameters.

4.15. Power supply 230VAC/24VDC

Figure 17 - Power Supply 24VDC – 10A [36]

Figure 17 show the 24VDC power supply. 10A is too much compared to what the system needs. Since the price of this power supply was near of the price of the smaller one, it was good choice in case of future upgrades. 24VDC will be distributed thru PLC for control of the system.

5.0 Hydraulic Component Description

5.1. Ball Valves

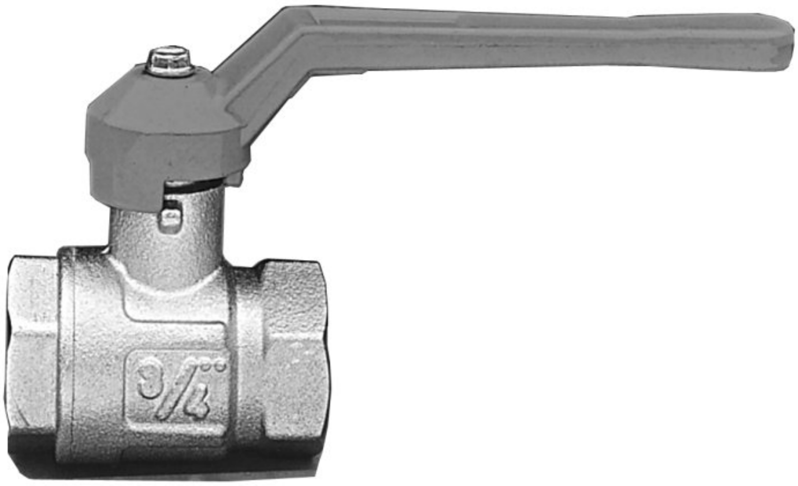

Figure 18 - Ball Valve [13]

Figure 18 shows a ball valve that is used for low pressure applications up to 30bar. In this project they are used as isolation valves for maintenance work.

5.2. Relief Valve (Pressure Line)

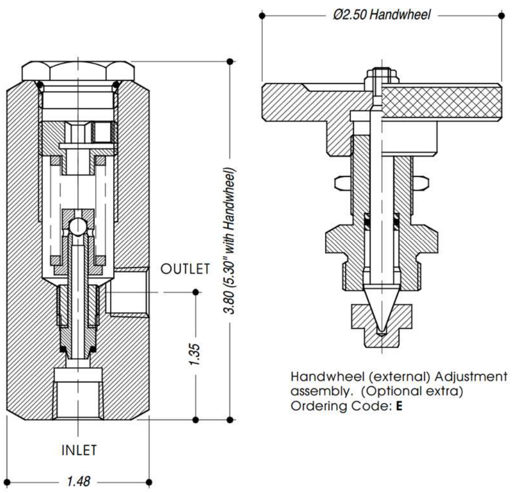

Figure 19 - Relief Valve (Pressure Line) [14]

The relief valve is a seat valve with adjustable spring tension for adjusting the relief pressure. Max working pressure for HPCS is 500bar, and the set pressure for the relief valve is calculated according to Equation 4.

$$Set\ pressure\ = 1.1 * Max\ working\ pressure$$
$$Set\ pressure\ = 1.1 * 500bar = 550bar$$

Equation 4 - *Set Pressure for Relief Valve*

5.3. Needle Valve

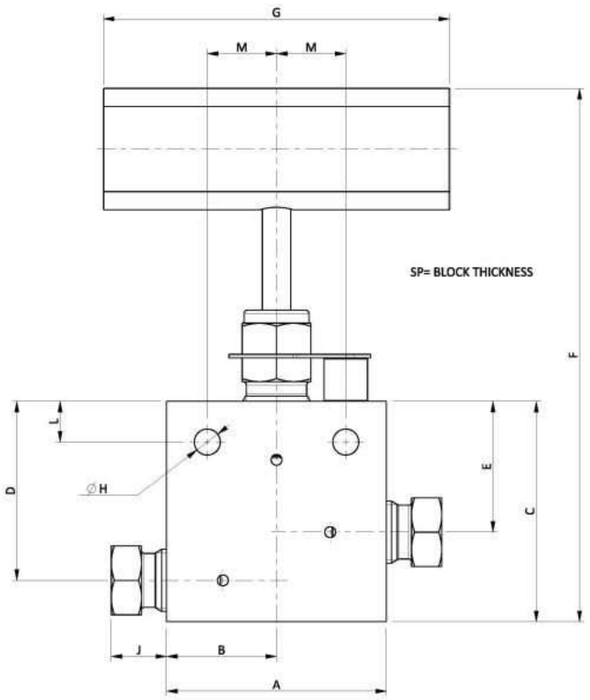

Figure 20 - Needle Valve [15]

The needle valves series used within this project, are used for high pressure applications up to 1380bar, the construction is made to handle high pressure and therefore the flow through these valves are limited.
In HPCS their function is to bleed down the pressure manually in case of system failure and to be able to isolate the lines out of the system when the pressure tank is disconnected from HPCS.

5.4. Emergency Pneumatic Shutdown Valve (3/2 high-flow)

Figure 21 - Emergency Pneumatic Shutdown Valve [24]

The pneumatic emergency valve is fitted to secure that the system goes into a safe state when the emergency switch is activated. When emergency switch is activated this valve will drain the system to return and all hydraulic valves will be closed and the hydraulic pump will stop. This valve together with the safety relay described under electrical components secures that HPCS to fulfill safety control system standard EN ISO 13849-1 for machines [16].

5.5. Control Valve 3/2 (Air)

Figure 22 - SMC pnaumatic valves [18]

The control valves are used for controlling the pneumatic-needle valve that is used to isolate the pressure inside the tank. 3/2 means 3 ports and 2 positions (A = Working port, P = Supply port, R = Return port). In closed position there is connection from port A to R, and in open position there is connection from A to P. An electrical solenoid moves the valve between open and closed position.

5.6. Drain / Filling Pump

Figure 23 – Drain / Filling Pump [19]

This is an impeller pump fitted to a standard asynchronous motor with an adapter block. One of the benefits with an impeller pump is that you can reverse the flow direction, so that we can both fill and drain the tank with the same pump. The pump is on 0.75 kW and secured with overcurrent relay, which is described earlier in this document.

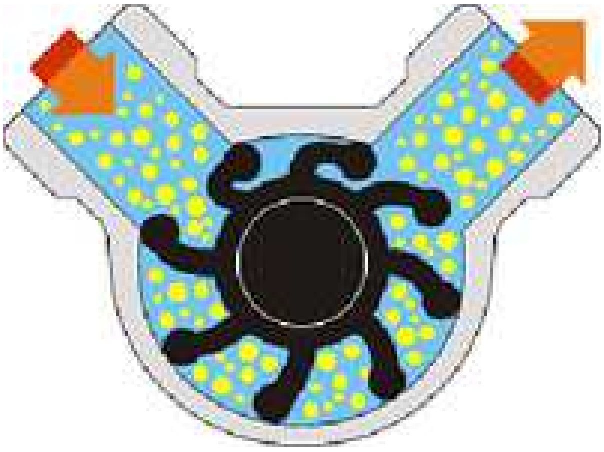

Figure 24 - Drain / Filling Pump [19]

Figure 24 show the principle behind an impeller pump, an impeller made of rubber rotates inside a housing with intake port and outlet port. When the impeller rotates from intake port to outlet port the fluid is locked in by two impellers and forced from input to outlet. When the motor changes direction the rubber impeller will be bent over the opposite way and flow direction will change. This pump is suited to deliver a high-flow with low pressure (max. 4bar) and is not suited to perform the pressurizing sequence for our tank.

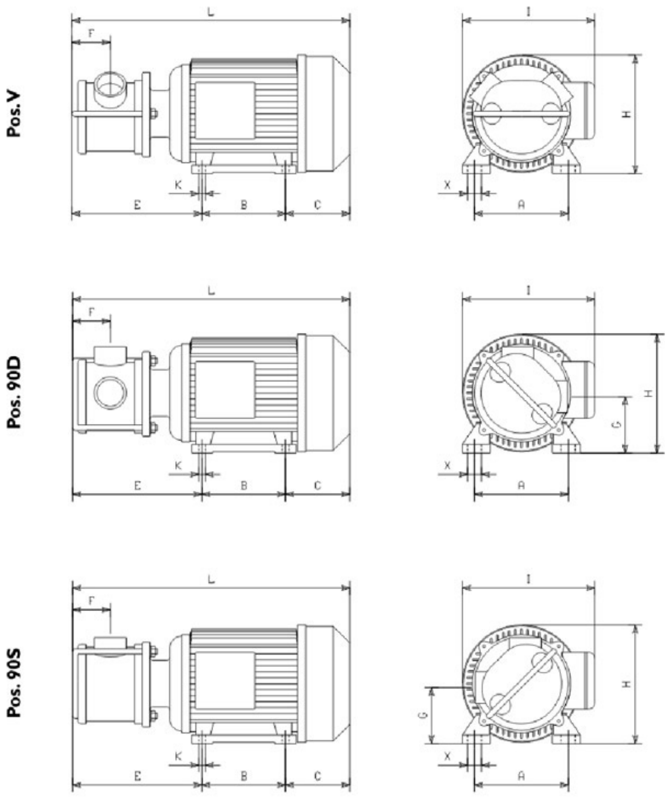

Figure 25 – Drain / Filling Pump [19]

EP Midex ”1/4	Rpm	L	H	I	A	B	C	E	F	G	K	X
	700/1400	338	159	215	125	100	85	153	38	70	8	16

Table 5 - Drain / Filling Pump [19]

5.7. High Pressure Pneumatic Pump

Figure 26 - HP Pump [20]

This is the pump that pressurizing the tank with the test pressure. This pump produces high pressure with a low flow, and is therefore not used as a filling pump for the system. The pump is driven by air, and has an air to hydraulic gear ratio of 1:60. This means that with 1 bar air pressure applied to inlet port of the pump will approximately produce 60bar at the outlet port. Maximum outlet pressure is 600 bar at 10 bar inlet pressure. In document TECH-018 this pump is described further.

5.8. Flow Indicator

Figure 27 - Flow Indicator [22]

The flow indicator is a switch with NO and NC contact sets. The principle used to detect if there is water or air in the tube is with a tuning fork witch have a resonance frequency in air. When water surrounds the tuning fork the frequency changes and the output signal changes. To produce and detect the resonance frequency there is a piezoelectric crystal.

5.9. Level Transducer

Figure 28 - Level Transducer [22]

The ultrasonic level transmitters have a piezo-ceramic transducer that detects and produces sound waves. The transducer sends out a sound wave and when the wave meets some kind of material, a sound wave will reflect and sent back and detected by the transducer. The piezo-ceramic transducer generates a voltage when compressed (receiving), and expands (sending) when a voltage is applied. Based on the time Δt (time from sent to received) and the velocity of sound the distance is calculated and converted to a voltage by a built in controller. The range is from 70mm to 1000mm and with a resolution on 0.13mm.

5.10. Pressure Gauge (0-600bar)

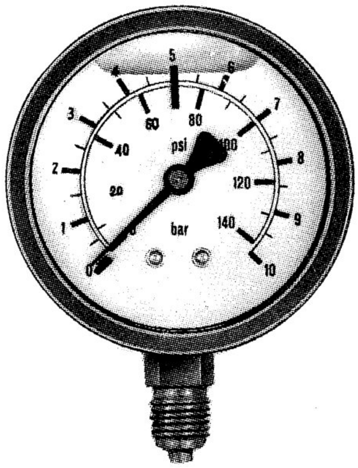

Figure 29 - Pressure Gauge [23]

Pressure gauges are implemented for visual indication on the pressure on different places in the system. They do not have any function in the system other than pressure indication, without looking at parameters in HMI.

5.11. Manual Reduction Pressure Regulator

Figure 30 - Manual Pnaumatic Pressure Regulator [24]

Manual pressure regulators are used to limit the supply pressure to the high pressure pneumatic pump and the air actuated needle valves so that they are not supplied with higher pressure than needed.

5.12. Controlled Pressure Regulator – Pneumatic

Figure 31 - Controlled Pressure Regulator [25]

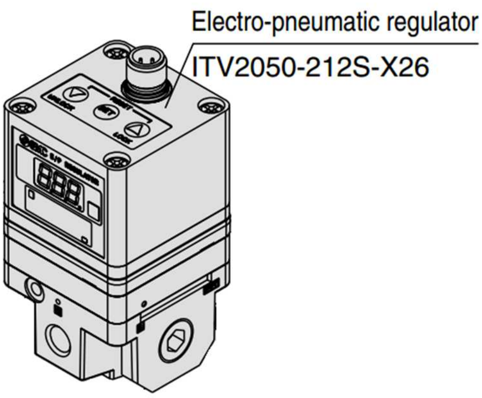

Figure 32 - Controlled Pressure Regulator [25]

This controlled pressure regulator is used to control the inlet pressure for the high pressure pneumatic pump, and is therefore the actuator in the regulation system. Output pressure is limited to 9 bar which means that the pump will not reach maximum pressure that is rated to 10 bar.

Inlet pressure: This is the pressure applied to air inlet on high pressure pneumatic pump.

Gear ratio: This is the relationship between inlet and outlet pressure, inlet pressure is geared up 60 times from inlet to outlet.

Outlet pressure: Due to the gear ratio this becomes the pressure on outlet of the pump.

$$Outlet\ pressure = Inlet\ pressure * Gear\ ratio$$

$$Outlet\ pressure = 9bar * 60 = 540bar$$

Equation 5 - Outlet pressure HP pump

5.13. Intake Filter HP Pump

Figure 33 - Intake Filter HP Pump [25]

Due to specific tolerances for the air cleanness to the HP pump this filter has to be mounted. This filter cleans the air for particles down to 5my witch are according to manufacturer tolerances for the high pressure pump.

5.14. Air Actuated Needle Valves

Figure 34 - Air Actuated Needle Valves [21]

Most manufacturers have different kinds of actuators available for their needle valves. Most common is diaphragm and piston actuators, and HPCS is designed with piston actuators since the size is smaller and cycle life is better than with diaphragm actuators. The actuators is of air to open type, which means that pneumatic pressure has to be applied to open the valve. A spring returns the valve to closed position when the pressure no longer is applied. This feature makes the system failsafe since pressure is isolated and will not increase further in case of system failure.

6.0 Mechanical Safety

6.1. Safety Barrier

Hydraulic components must be covered behind thermoplastic polycarbonate plates to protect against hydraulic leakage. This will ensure personal safety. The plates will be mounded at the frame with extra support stronger.

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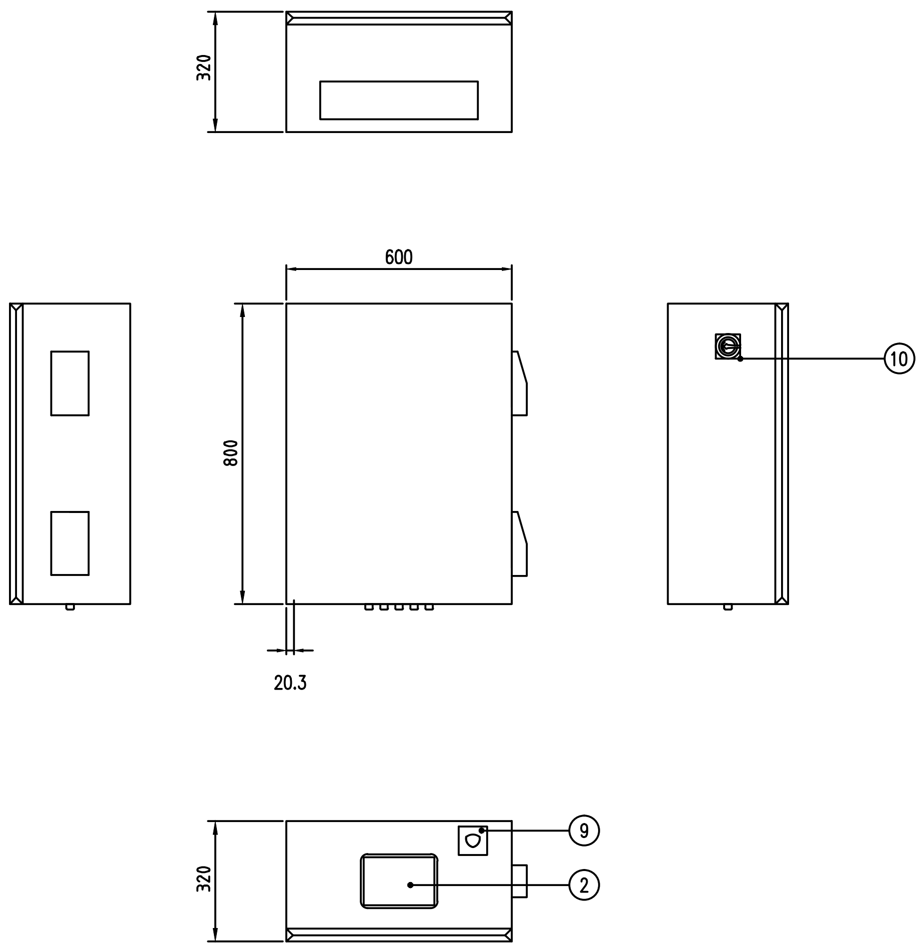
Note: Components datasheet and references can be found in BOM [1].



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REV.	DATE	REASON FOR ISSUE	PREPARED	CHECKED	APPROVED
B	10.05.15	AS BUILD	BRIAN B	THOR O S	JONAS C
A	18.03.15	UPDATE OF REVISON	BRIAN B	ANDERS	JONAS C
-	04.03.15	PREPERATION	BRIAN B	JONAS N	ANDERS S

DESIGNER	LAST SAVED (DATE)	NO. OF.	REV.
BRIAN BERG	09.05.15		B

SCALE 2:1

SIZE

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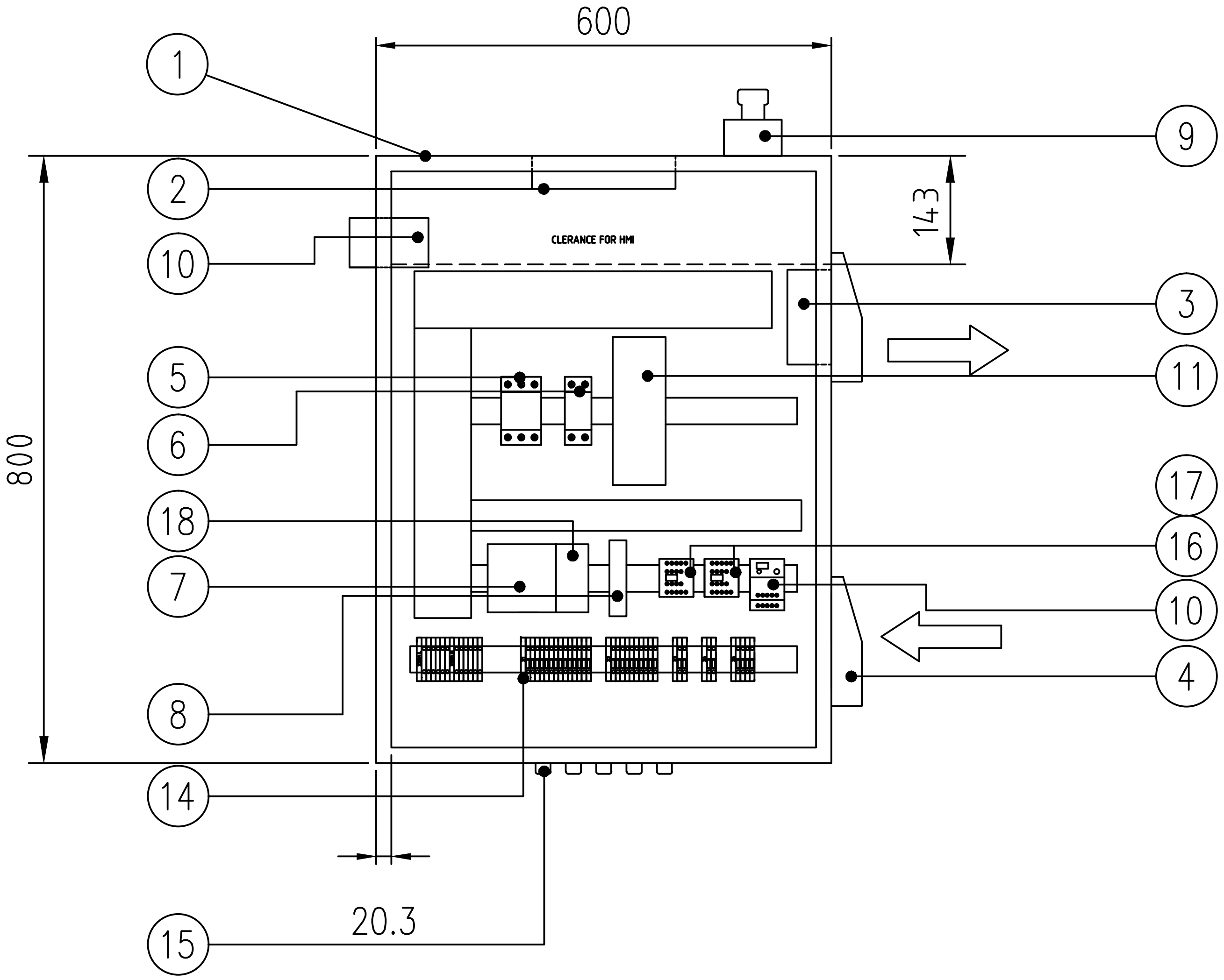
CONTROL CABINET
GENERAL ARRANGMENT
HPCS BACHELOR PROJECT

DRAWING NO. CAB-001

SHEET 1 OF 2



CABINET EQUIPMENT

CROMP.	COMP. NAME	DESCRIPTION	MANUFACTURER / TYPE
1	CAB-001	CABINET	SCHROFF – 12506-032
2	I-001	HMI	BEIJER – IX7A
3	FAN-001	FAN	STEGO – 01801.0-00
4	FAN-002	FAN AIR INLET	STEGO – 11801.0-00
5	F-001	CIRCUIT BREAKER 1A, 3 PHASE	SIEMENS – 5SY4301-7
6	F-002	CIRCUIT BREAKER 2A, 2 PHASE	SIEMENS – 5SY4202-7
7	I-002	PLC	MITSUBISHI – FX3GE-24M
8	K1	SAFETY RELAY	SIEMENS – 3SK1211-1BB00
9	S1	EMERGENCY STOP	BACO – LBX17501
10	Q1	MAIN SWITCH	EATON – P1-25/V/SVB
11	PS1	POWER SUPPLY 24VDC	SIEMENS – SMPS, 6EP1334-1LB00
12	K001	OVERCURRENT RELAY	SIEMENS – 3RU21160KB0
13	K002	OVERCURRENT RELAY SUPPORT	SIEMENS – 3RU1916-3AA01
14	X1...	TERMINAL STRIP BLACK	PHOENIX CONTACT
15	GL-01...	CABLE GLAND M20	–
16	K2, K3	CONTACTORS FOR PUMP	SIEMENS – 3RT1015-1AB01
17	K2, K3	CONTACTORS HELP SWITCHES	SIEMENS – 3RH1911-1FA40
18	–	PLC – DA	–
19	–	–	–
20	–	–	–
21	–	–	–
22	–	–	–

NOTES:

NOTE1: FRAME SCALED TO 0.75 COMPARED TO DRAWING CAB-0001, SHEET 1

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HBV

REV.	DATE	REASON FOR ISSUE	PREPARED	CHECKED	APPROVED
B	09.05.15	AS BUILD	BRIAN B	ANDERS S	JONAS N
A	18.03.15	SCALING OF FRAME, ADDING SOM COMPONENTS	BRIAN B	JONAS N	ANDERS S
-	04.03.15	PREPERATION	BRIAN B		

DESIGNER	LAST SAVED (DATE)	NO. OF.	REV.
BRIAN BERG	10.05.2015	-	B

SCALE 2:1

SIZE

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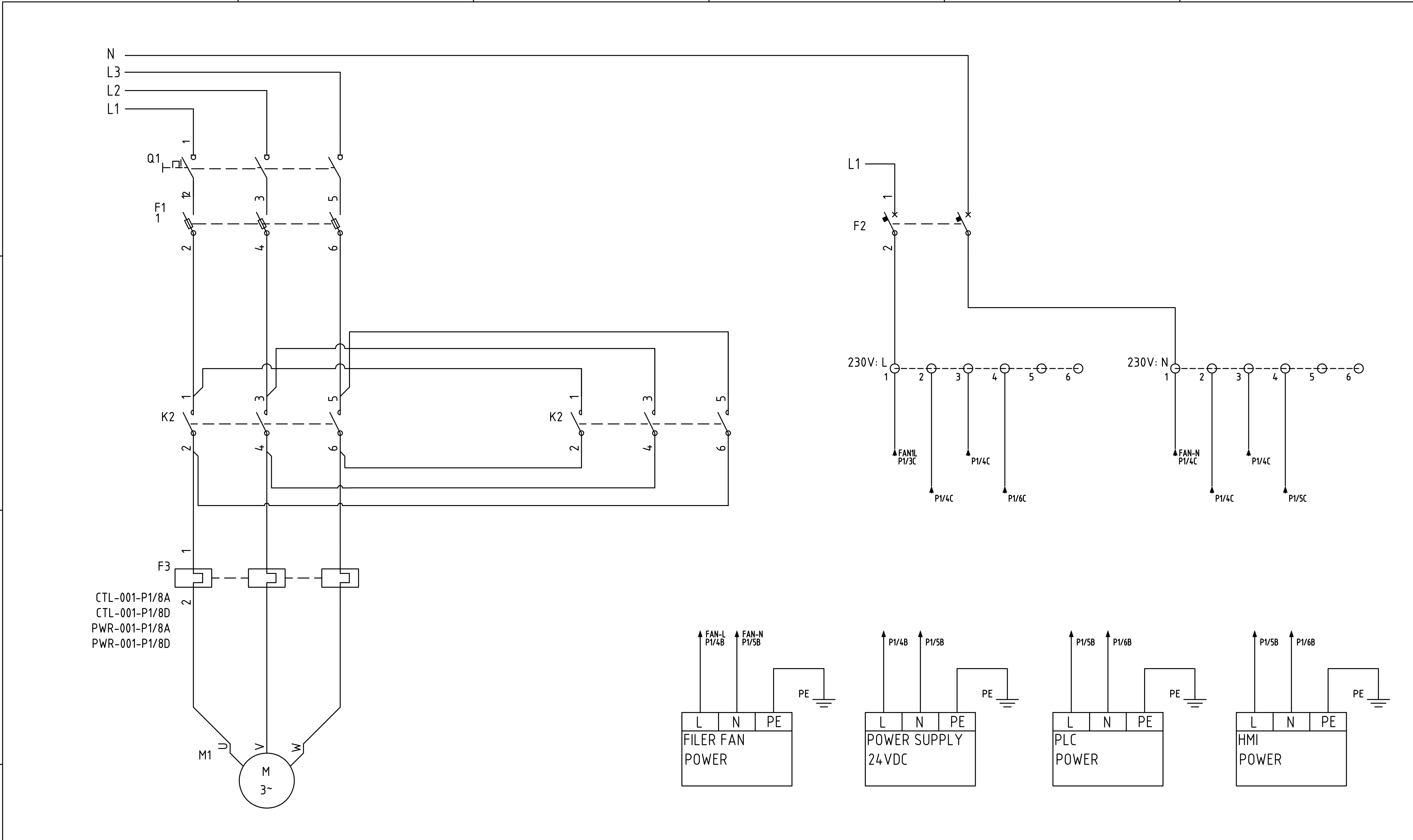
CONTROL CABINET

GENERAL ARRANGMENT, INTERNAL VIEW

HPCS BACHELOR PROJECT

DRAWING NO. CAB-001

SHEET 2 OF 2



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B	05.04.2015	COMMENTS FROM HPCS GROUP	BRIAN B	JONAS N	ANDERS S
A	25.03.15	ADD CONTROL POWER DRAWING	BRIAN B	JONAS N	ANDERS S
–	04.03.15	PREPERATION	BRIAN B	–	–

DESIGNER	LAST SAVED (DATE)	NO. OF.	REV.
BRIAN BERG	09.05.15	-	C

SCALE

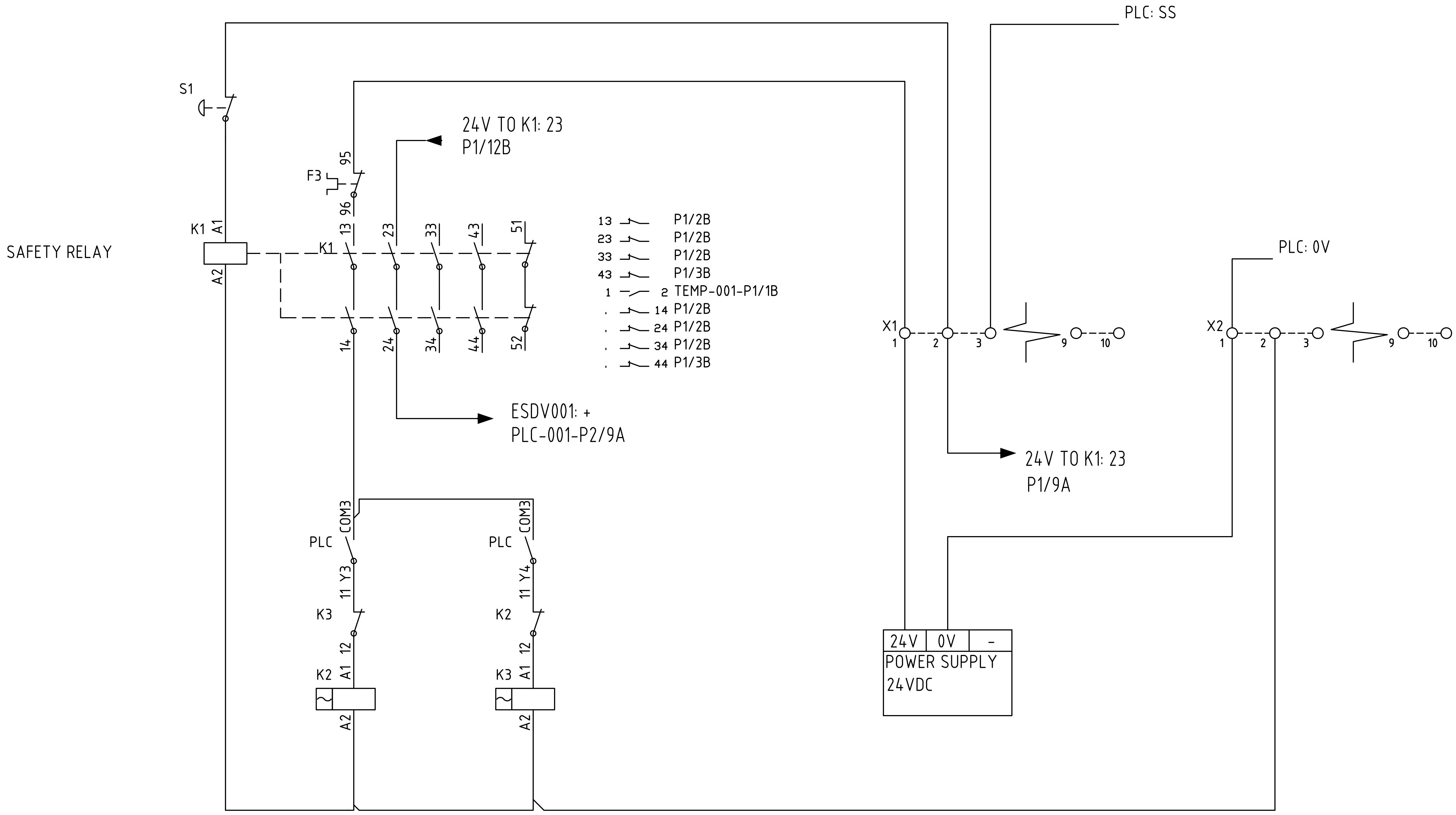
SIZE

FMC Technologies

MAIN AND CONTROL
POWER
HPCS BACHELOR PROJECT

DRAWING NO.
PWR-001

SHEET 1 OF 1



FMC Technologies

HBV

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A	25.03.15	MOVE BIMETAL RELAY	BRIAN B	JONAS N	ANDERS S
–	04.03.15	PREPERATION	BRIAN B	–	–
REV.	DATE	REASON FOR ISSUE	PREPARED	CHECKED	APPROVED

BRIAN BERG	09.05.15	-	C
DESIGNER	LAST SAVED (DATE)	NO. OF.	REV.

SCALE

SIZE

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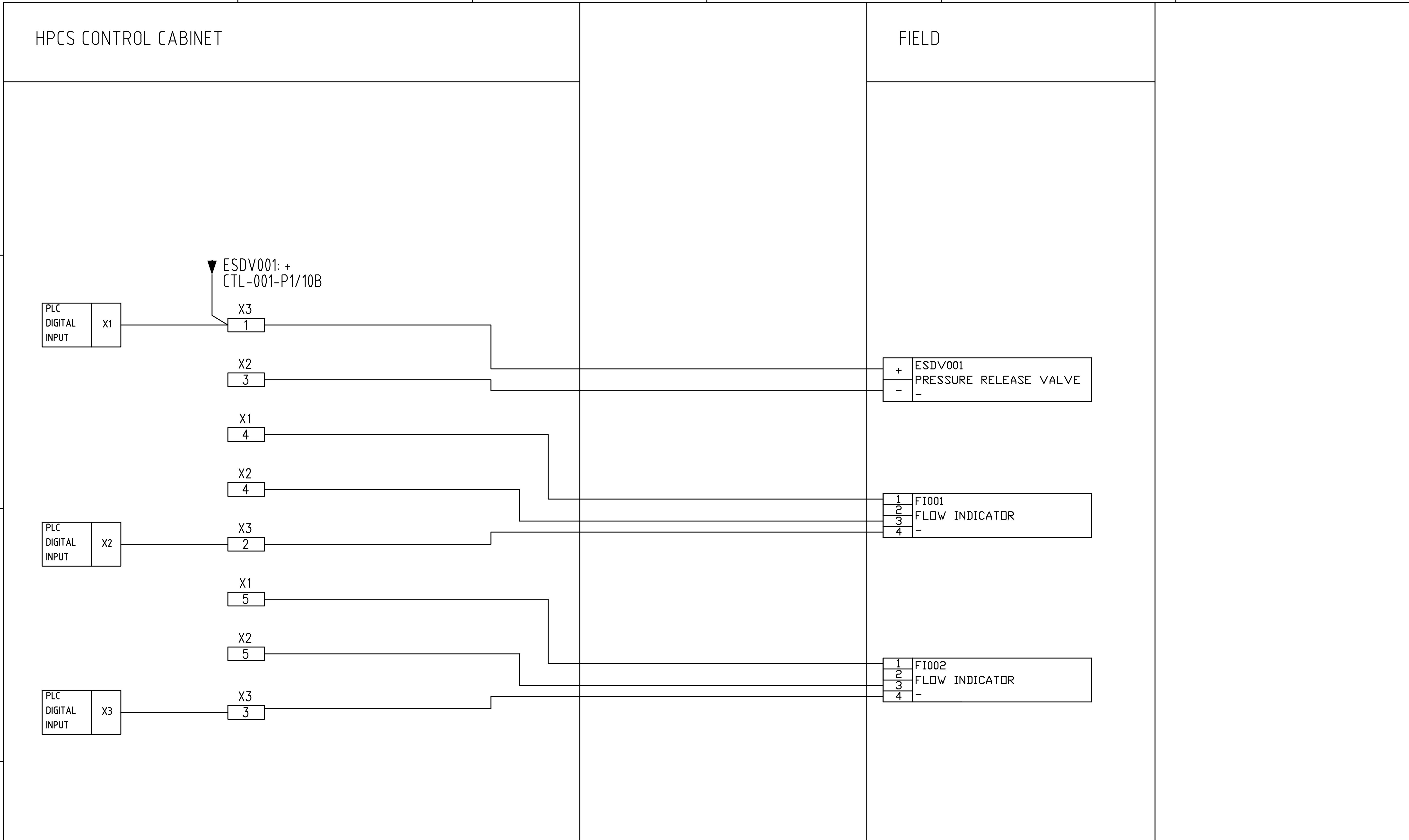
CONTROL AND SAFETY SYSTEM

HPCS BACHELOR PROJECT

DRAWING NO. CTL-001

SHEET 1 OF 1



REV.	DATE	REASON FOR ISSUE	PREPARED	CHECKED	APPROVED
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C	09.05.2015	AS BUILD	BRIAN B	THOR O S	JONAS C
B	05.04.2015	COMMENTS FROM HPCS GROUP	BRIAN B	JONAS N	ANDERS S
A	01.04.2015	ISSUED FOR REVIEW	BRIAN B	JONAS N	ANDERS S
–	04.03.2015	PREPERATION	BRIAN B	–	–

FMC Technologies

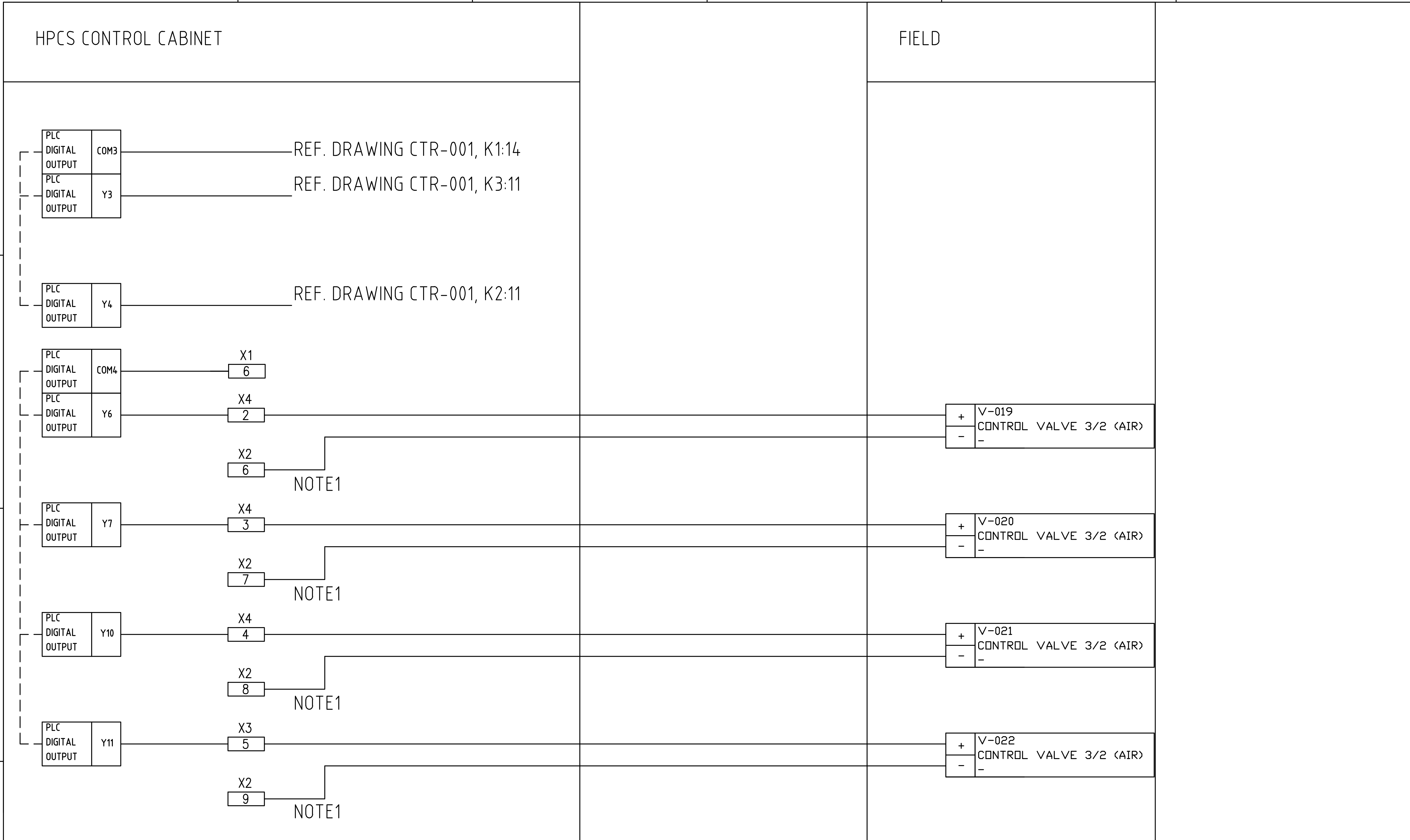
DESIGNER	LAST SAVED (DATE)	NO. OF	REV.
BRIAN BERG	16.05.2015	-	D

SCALE | SIZE

DIGITAL INPUT
PLC
HPCS BACHELOR PROJECT

DRAWING NO. PLC-001

SHEET 1 OF 3



Note :
NOTE 1: All X2 terminal strips are linked together with 0V

------ INTERNAL CONNECTION IN PLC

FMC Technologies

REV.	DATE	REASON FOR ISSUE	PREPARED	CHECKED	APPROVED
D	16.05.2015	AS BUILD FIX	BRIAN B	ANDERS S	JONAS N
C	09.05.2015	AS BUILD	BRIAN B	THOR O S	JONAS C
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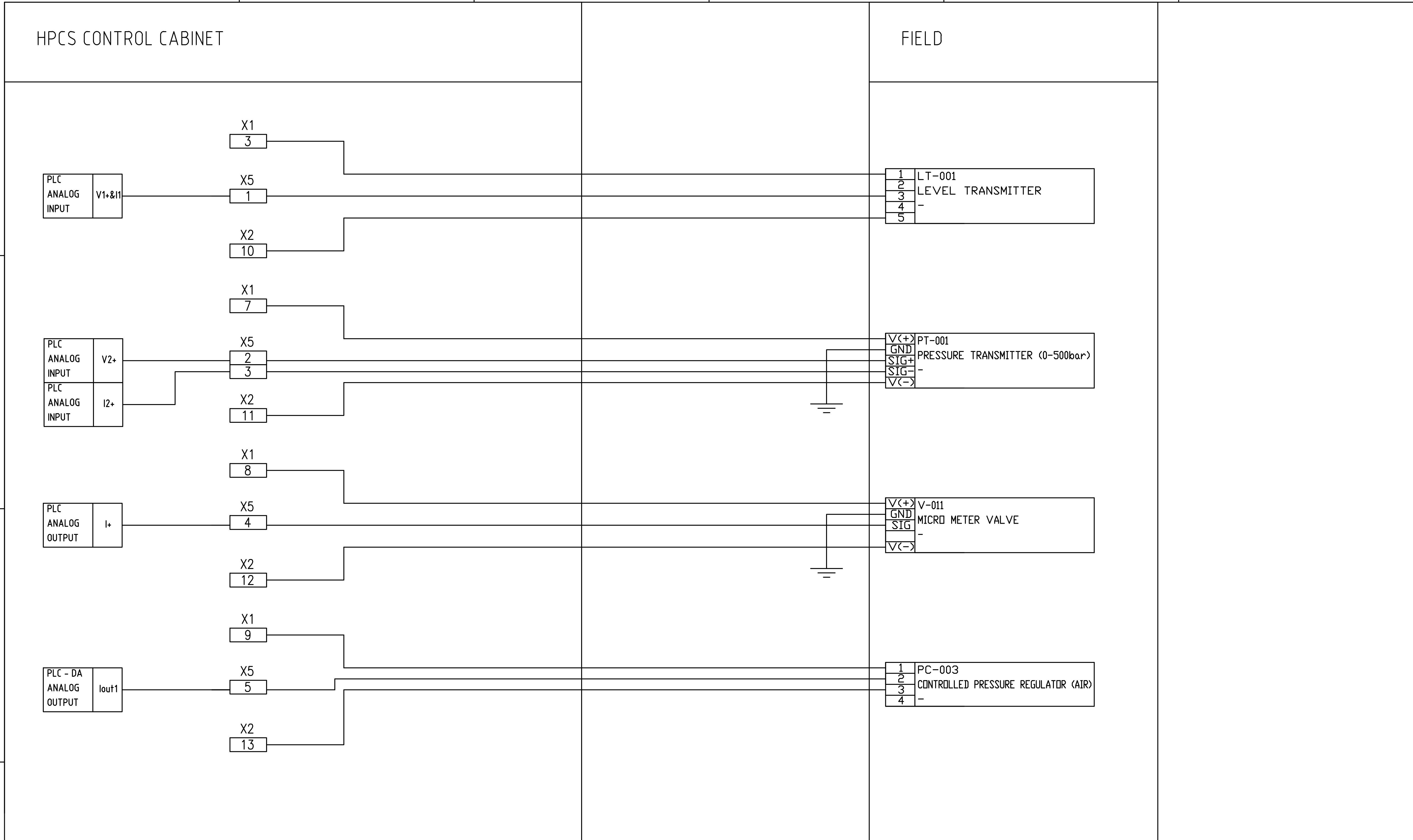
BRIAN BERG	16.05.2015	-	D

SCALE | SIZE

DIGITAL OUTPUT
PLC
HPCS BACHELOR PROJECT

DRAWING NO. PLC-001
SHEET 2 OF 3



FMC Technologies HBV

REV.	DATE	REASON FOR ISSUE	PREPARED	CHECKED	APPROVED
D	16.05.2015	AS BUILD FIX	BRIAN B	ANDERS S	JONAS N
C	09.05.2015	AS BUILD	BRIAN B	THOR O S	JONAS C
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–	04.03.2015	PREPERATION	BRIAN B	–	–

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BRIAN BERG	16.05.2015	-	D

SCALE

SIZE

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ANALOG SIGNALS

PLC

HPCS BACHELOR PROJECT

DRAWING NO. PLC-001

SHEET 3 OF 3

Hyperbaric - Pressure Control System

Ethernet Setup

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ID: TECH – 009 <B>

Revisions

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18.02.2015	Document creation	-	AS	
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09.05.2015	Updated document layout	B	AS, BB	TOS, BB

Table 1 - Revisions

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Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies

Table 2 - Abbreviations

1.0 Ethernet Setup

1.1 Introduction

This document describes how to connect an IX T7A to the Mitsubishi FX PLC over an Ethernet connection.

1.2 Ethernet Connection

The HMI used in the project communicates with the PLC over Ethernet connection. It is possible to inter-connect them through router or directly connect them with a switched RJ45 cable. If the PLC communication is connected over a router it will be possible to add Wi-Fi or Internet connectivity to the project. This means that one can run live monitoring of the process in the office with GX Works 2. The FX3GE PLC from Mitsubishi needs to be configured before Ethernet connection can be established. This is done by following the steps below. This steps is created from the start up document from Beijer [1].

1. GX Works 2 should always be updated to the newest version. This can be done by registering the GX Works 2 product key in "MyMitsubishi" on the Mitsubishi homepage. Before doing this it is necessary to register a user account and a group account for the product. It will then be possible to download and install the newest version of the software. Follow this reference link to do this [2].
2. To configure the PLC, open the PLC parameters and Ethernet tab in GX Works 2. Select the correct channel according the location of the Ethernet module (if FX3GE the channel is CH1). Select the IP address for the PLC as shown in Figure 1. The IP address must correspond to the routers IP address.

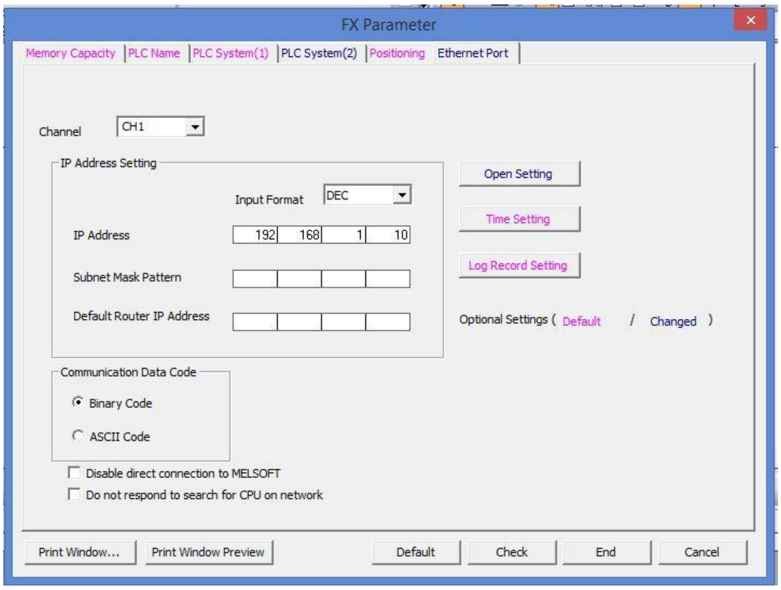

Figure 1 – FX Parameter

3. Click the "open setup" button and fill in the same info bellow. In the "Destination IP Address" tab write the IP Address of the HMI.

	Protocol	Open System	Host Station Port No.	Destination IP Address	Destination Port No.
1	UDP	MC Protocol	1281	192.168. 1. 2	1281
2					
3					
4	TCP	MELSOFT Connection			

Figure 2 – Fx parameters setting

4. Setup of the IX T7A HMI from Beijer Electronics is done in IX Developer. When a new project is created one has to select a controller to talk to. Select MELSEC and FX3U-ENET. Under function menu open tags, go click on controller and enter "settings" menu. For Local UDP port enter 1281.

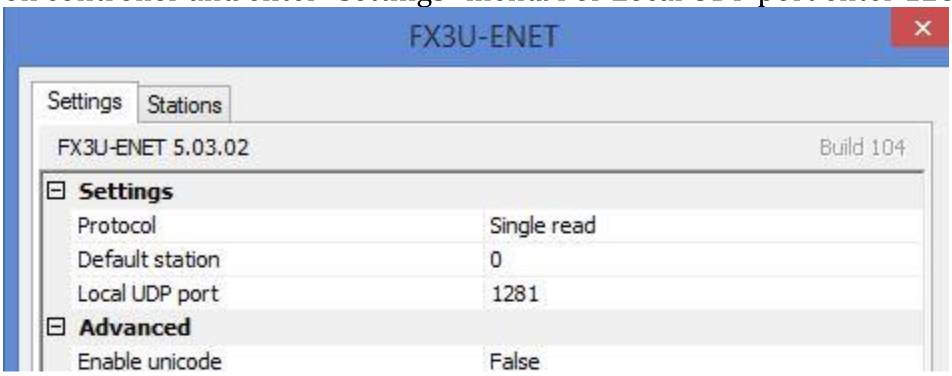

Figure 3 – ENET Settings

5. Under station tab enter the IP Address of the PLC and the port number 1281.

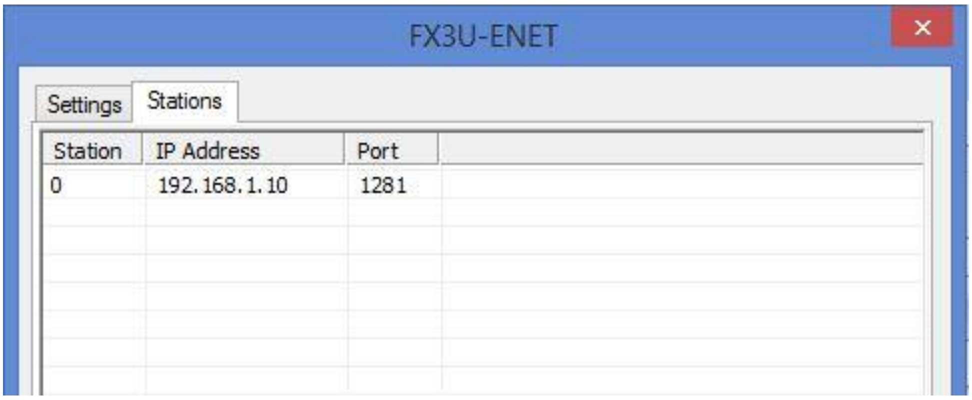

Figure 4 – ENET Settings

6. When all the steps are done and the code is loaded to the PLC and HMI (not covered in this document) restart the PLC. The PLC will not get the new IP address before it is restarted.

References

[1] Beijer, «iX - FX3U-ENET(ADP) and FX3GE,» [Internett]. Available: http://ftc.beijer.se/files/C125728B003AF839/1BC9D6829DA07080C1257C7D00323F91/KI00311A.pdf. [Funnet 12 02 2015].

[2] «Mitsubishi Log In,» [Internett]. Available: https://eu3a.mitsubishielectric.com/fa/en/mymitsubishi/login?url=https%3A%2F%2Feu3a.mitsubishielectric.com%2Ffa%2Fen%2Fmymitsubishi. [Funnet 18 02 2015].

Hyperbaric - Pressure Control System

System evaluation

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Revisions

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20.02.2015	Idea Description	-	TOS	
09.04.2015	Formatting, Spellcheck	A	JN	BB,AS
06.05.2015	Updating layout	B	AS	JC, TOS
10.05.2015	Added chapter 1.7 and references	C	TOS	JC,AS

Table 1 - Revisions

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Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
GA	General arrangement
PLC	Programmable Logic Controller

Table 2 - Abbreviations

1.0. Final system function

1.1. Introduction

The system shall fill the tank with water before pressure is applied. This is a very common way to perform pressure tests of equipment in the subsea industry.
The use of a fluid for pressure testing of equipment is recommended since fluids do not have the ability to be compressed much in contrast to gases. Waters property to not be compressed is utilized to reduce damage in case of leakage or blow out.
To rise the pressure in a tank filled with gas to a given pressure it would be necessary to add the volume of tank x test pressure of gas. For a tank volume of 100L it would need to add 40000L gas to reach 400bar pressure inside the tank [2].
If the tank then had exploded, the 100L gas at 400bar would increase to 40000L at 1bar in a very short amount of time. This would cause huge damage to the surrounding area and in worst case people.
Water is often said to be non-compress able which is not totally correct, but nearly (More about this is discussed in [3]). For a tank of 42L as we have performed calculations for it has to be added 0.764L of water to reach 400bar. That means that 0.764L of water will leave the tank until the pressure inside the tank is 0bar. This is a much better scenario in case of blow out compared to gas testing.

1.2. Filling of the tank

A pump fills up the tank with water while a valve located at the highest point of the tank ventilates the initial air volume that is inside the tank. When all the air is ventilated, a sensor bases on change of resonance frequency in a fork located at the ventilation line detects if there is water or air that is leaving the tank.
When there is clean water without air that leaves the tank the sensor gives a signal to stop the filling pump and close the valve to isolate the system.

1.3. Pressurizing

After filling, the system is ready to be pressurized with water. This is performed by a pneumatic pump. But since we have a requirement that says that the pressure build up have to be controlled within maximum 40bar/min, we need to regulate this some way. Our solution to control this is an electrically controlled pneumatic pressure regulator. The regulator has ±1% linearity fault from 0.05 to 9bar, which will give us good control of the pressure. The pump has a pneumatic to hydraulic ratio on 1:60 which means that maximum output pressure is 540bar with 9bar air supply. But to be able to increase the pressure by a given amount per minute we need some feedback from the system and a regulation system to adjust the performance of the pump. So there is placed a pressure transmitter at the pressure line to the tank that tells us the pressure that is used to calculate how many bar/minute the pressure increases and the regulation system then adjust the performance of the pump according to the desired value. When the final value is accomplished the regulation system stops the pump and isolates the system.

1.4. Holding time

Since the pressure test shall simulate environments where the subsea equipment is located, the customer wants to perform a holding time at a desired pressure. Within this holding time there is interesting to monitor the pressure inside the tank to detect leakages of water into test objects or deformation of test objects, in those cases the pressure will decrease if there is no other leakages or pressure applied to the system. Therefore all output and input lines to the system shall be isolated with valves, and a pressure stabilization time shall be performed before logging of the pressure in the tank over a period starts.

1.5. De-pressurizing

Since the pneumatic pump is used to pressurize the system, it does not have any function to drain out the water to decrease the tank pressure. There is fitted an electrically controlled flow valve for pressure reduction. This valve has a servo motor attached to the valve stem and is able to perform a decreasing of the pressure in opposite way of the pneumatic pump according to requirement R2-I for increasing/decreasing pressure (calculations for this valve is covered in [3]).

1.6. Draining of tank

The same valve as used to ventilate air out when filling with water now let air go into the system when water is pumped out. And the same pump that is used for filling is used to drain the tank, and an equal sensor. The sensor that detect when the tank is empty is located on the opposite side of the pump to detect when clean air returns from the tank, which means the tank is completely drained for water.

1.7. HMI & PLC

To configure how the system shall work there is a touch-screen where the operator can configure parameters for the pressures, holding times and cycles. As well as other system parameters like reservoir dimensions and maintenance parameters. The HMI also have a visual screen to display status of the process and a graph screen where the pressure curve is shown. The pressure graph can be logged and exported to a SD card. The PLC collects the parameters that is configured in HMI and use these to run the process according to these parameters. PLC controls the whole system except the emergency function which is a stand-alone system.

2.0. Other evaluated concepts

2.1. System with accumulator on tank

Early in the project we had a concept with a pre-charged accumulator located at the tank to get a more dynamic system due to larger volume and more compressible volume inside the tank. After some discussion and evaluating, we found out that this is not an ideal concept since a pre-charged accumulator will make the system highly nonlinear. This is because the gas in the accumulator will not be compressed until the pressure in the system is higher than pre-charged accumulator pressure. In other words; the accumulator will not have any function until the system reaches the pre-charged pressure, and it will cause a linear curve from 0bar to pre-charge pressure and then it will be an exponential curve from there.
This is not any good property for this system since we want a straight and linear curve as possible.

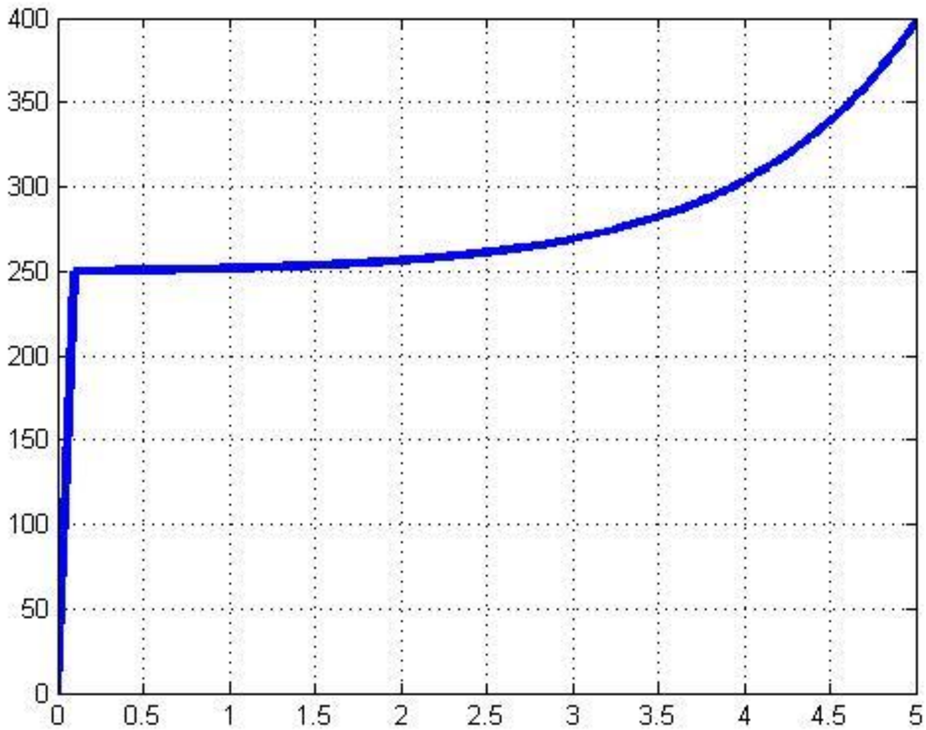

Figure 1 – Pressure graph with accumulator

Figure 1 illustrates the pressure curve in the tank with an accumulator pre-charged with 250bar located at the pressure tank and a constant flow into the tank. To handle the break point on 250bar at y-axis it would have to be a very fast response for the control system to handle the big difference in the pressure curve with respect to the injected fluid.

2.2. System with hydraulic screw/piston pump

A second system that was evaluated was a system with a screw pump controlled by a servo motor to pressurize the system. The screw pushes at one end of the piston and produces a pressure on the opposite side. This is good idea, and would probably work fine. But due to cost, size etc. we choose to not build more on this idea. The principle with this system is to add a force to a piston that will produce the same force to the system (not exactly due to friction loss etc.) on the other side of the piston, and this is a benefit since both pressurizing and depressurizing is performed by the same component. On most of these pumps there are low volumes of fluid that can be supplied by the pump, since they often is used for small laboratory tests or calibrations of pressure transmitter etc.

2.3. System with pre-charged pressure reservoir

A third system that was evaluated was an accumulated pressurized water reservoir before a regulation valve to adjust the pressure inside the tank. This was the first system that we evaluated, and the idea behind the accumulated pressurized water was to simplify the pressure regulation by having a "constant" pressure into the regulation valve. But with the pump we are using in our final system, there are no issues of this kind with pressurizing the tank.

References

[1] J. Carlstedt, "TECH-018 - Simulation of Pressure Increasing Control Loop," HBV, Kongsberg, 2015.

[2] "Wikipedia," [Online]. Available: http://en.wikipedia.org/wiki/Boyle%27s_law. [Accessed 01 04 2015].

[3] J. Carlstedt, "TECH-001 - SMQAM," HBV, Kongsberg, 2015.

[4] A. Skjørten, "TECH-003-D-HMI," HBV, Kongsberg, 2015.

[5] J. Nicolaysen, "TECH-004-D-PLS," HBV, Kongsberg, 2015.

Hyperbaric - Pressure Control System

Discretization

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Revisions

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30.01.2015	Idea description	-	AS	
09.05.2015	Changed formulas	A	AS	BB, TOS

Table 1 - Revisions

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Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
GA	General arrangement
TF	Transfer function

Table 2 - Abbreviations

1.0 Discretization

1.1 Introduction

This document describes the method used to discretize the derivate transfer function obtained from the simulations of HPCS. All Graphs in this document is plotted using Matlab and the calculations is done partly in Matlab and partly by hand. Matlab files and hand calculations can be found under TECH-014 in Technology Document folder on the cd attached to final delivery of HPCS.

1.2 The Transfer Functions

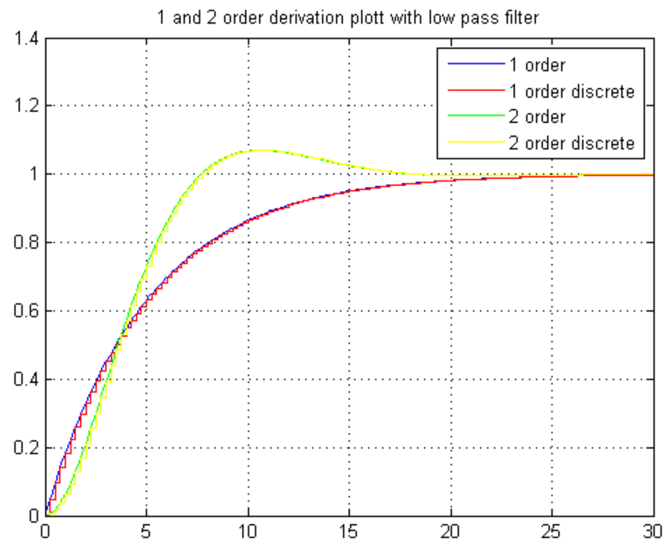
Transfer functions is based on describing functions of a physical system that can be used to predict the system behavior. The transfer function is usually given in the frequency domain or in the matrix form called state space. The frequency domain is the Laplace transform to the describing function of the system while the State Space form consist of derivations of states to the system in the time domain. This document will use the Laplace method in the frequency domain. If a sensor in the system is effected by noise, the data from the sensor will be unpredictable and regulation can become unstable. This is why it is necessary to make mathematical models of the system parts so that the engineer can predict how the system will respond to noise.

Because the system is to be regulated on the derivative of the pressure change in the pressure chamber, it is necessary to calculate the derivative with a transfer function. This can be done with the transfer function operator seen below.

$$\frac{s}{s+1}$$

Equation 1 - Derivate TF function with low pass filter

Figure 1 shows the response of the derivative transfer function for the first and second order low pass filter as well as the their discrete equivalent when it is given a ramp input with the slope of 1. From the Figure 1 it is clear to see that the function settles in an amplitude of 1, which is the derivative of the ramp. And it has a rise time of about 12.5s for the first order function and about 7s for the 2 order function.



$$\frac{2s}{9s+2}$$

Equation 2 – Low pass Derivate TF

$$\frac{3s}{20s^2 + 10s + 3}$$

Equation 3 – 2 order Low pass Derivate TF

Figure 1 – Ramp response of LP derivate function

Although

Figure 1 shows a perfect derivation of the ramp, derivation functions are especially sensitive to noise and there are no noise in the analyses in

Figure 1 Most sensors generates some noise so in Figure 2 the same function is plotted and noise is added to the ramp input.

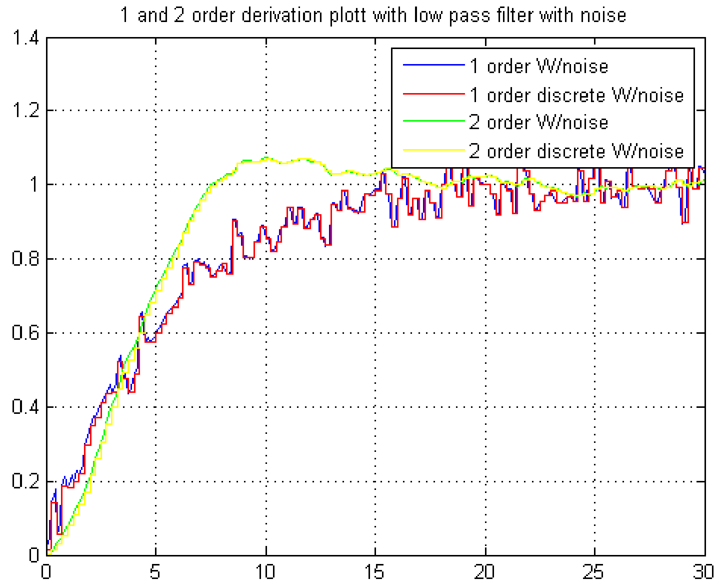


Figure 2 - Ramp response of derivate TF with noise

Figure 3 shows the block diagram of the first order transfer function made in Simulink to generate the response of the blue graph in Figure 2.

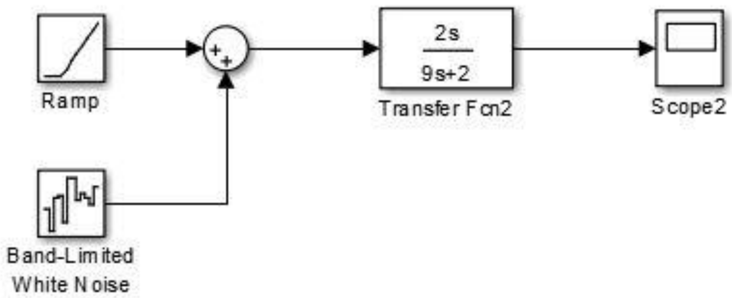


Figure 3 - Block diagram

Analyzing the system with a ramp input and noise one can see that the first order plot in Figure 2 is more affected by the noise then the second order plot is. The second order plot has also a faster response due to the extra poles in the system.

With some trial and error it was found that the 2 order low pass filter handles the filtration much better and faster than the first order low pass filter with a rise time of about 7 seconds.

1.3 Discretization of Transfer Functions

To implement transfer functions of the frequency domain in controllers like PLC the transfer functions must be converted to time domain functions that consists of "unit steps". Before the system can be converted the system must be in a discrete form, because the PLC is a digital controller and it is running with a sampling frequency. This means that the transfer function needs to be transformed to a transfer function of the Z – domain, which is the discrete version of the Laplace domain. The unit Z^{-n} can be seen as a delay in time and therefore a previous sample.

There are many methods to discretize transfer functions but this document will use the Tustin approximation. [1]

1.3.1 Tustin's Approximation

Tustin approximation is a bilinear transformation of the Laplace form. It can be implemented by exchanging all the poles and zeroes (S) in the Laplace form of the transfer function with the Tustin approximation.

$$\frac{2}{T}\frac{Z-1}{z+1}$$

Equation 4 - Tustin approximation

Where T is the sampling time of the PLC.

1.3.2 Discretization of the Low Pass First Order Derivate Transfer Function

From Equation 2 we have the function:

$$\frac{y(s)}{u(s)} = \frac{2s}{9s+2}$$

The discrete equivalent with sampling time 0.25s is shown in Equation 5

$$\frac{y(Z)}{u(z)} = \frac{0.2162-0.2162Z^{-1}}{1-0.9459Z^{-1}}$$

Equation 5 - Discrete equivalent of derivate TF

The algorithm for the controller would then be as in Equation 6.

$$y(n) = 0.2162u(n) - 0.2162u(n-1) + 0.9459y(n-1)$$

Equation 6 - Algorithm for derivate TF function

1.3.3 Discretization of the Low Pass Second Order Derivate Transfer Function

From Equation 3 we have the function:

$$\frac{y(s)}{u(s)} = \frac{3s}{20s^2 + 10s + 3}$$

Equation 7 - Equation 3 in TF form

The discrete function of the system with a sampling time of 0.25s then becomes as in Equation 8.

$$\frac{y(z)}{u(z)} = \frac{0.01761 - 0.01761z^{-2}}{1 - 1.874\, z^{-1} + 0.8826z^{-2}}$$

Equation 8 - Discrete form of Equation 3 at sampling time 0.25s

The corresponding algorithm is shown in

$$y(n) = 0.01761u(n) - 0.01761u(n-2) + 1.874y(n-1) - 0.8826y(n-2)$$

Equation 9 - Algorithm for 2 order derivate TF

The blue graph in Figure 4 shows the output of a PID controller with the second order transfer function in Equation 3 as a negative feedback. Input to the system is the derivate of the ramp shown in Figure 4. The red graph shows the discrete response with Equation 8 in the negative feedback path. The responses are not perfect but with more fine tuning it is possible to get an even better trace of the ramp.

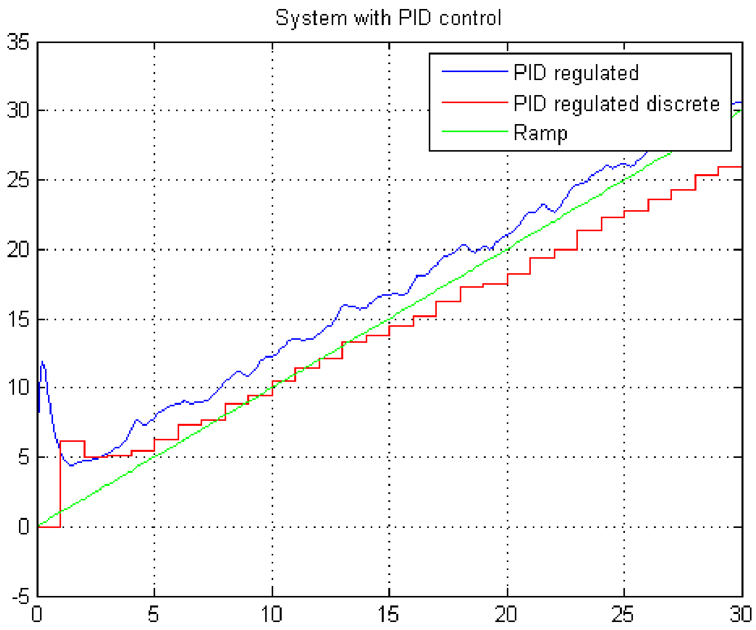


Figure 4 - PID regulation with derivate reference

1.4 Implementation to PLC

A sample frequency is usually required to implement the algorithm on the PLC. This frequency is restricted by the PLC capability to read from the AD ports and also depends on how often it activates the command to read. However the plant will also have an effect on the regulation and because it is unknown how the plant will react it would be a good idea to implement some parameters in the controller so that the low pass filter could be adjusted and fine-tuned on the controller.

1.4.1 Generalized Tustin formula

To be able to fine-tune the system on the PLC controller it is trivial to make a general formula for the discrete step function of the derivate low pass transfer function. Equation 10 to Equation 15 is the result of this generalization of the first and second order TF of a low pass derivate.

Equation 10 and Equation 11 is tunable first order TF that consist of tuning parameters a, b and c. Buy varying these constants the TF can be fine-tuned to give an optimal response. In Equation 11 the K is the sampling constant that consists of $\frac{2}{T}$. Equation 12 is the unit-step algorithm equivalent to Equation 11. The algorithm is a function that consists of previous and current samples and it calculates the output based on these samples.

Equation 13 shows a second order TF. The only difference between Equation 13 and Equation 10 is that the de-nominator in Equation 13 consists of a second order polynomial and it has an additional tuning parameter d. Just like for the first order TF the formula in Equation 14 is the equivalent discrete TF of Equation 13 and Equation 13 results in the unit step algorithm In Equation 15.

1.4.2 First order

$$\frac{cs}{as+b}$$

Equation 10 - General 1 order derivate LP

Where a, b, c is constants

$$\frac{y(z)}{u(z)} = \frac{cK(1-Z^{-1})}{aK(1-Z^{-1})+b(1+Z^{-1})}$$

Equation 11 - General 1 order discrete derivate LP

Where K = 2/T

$$y(n) = \frac{u(n)cK - u(n-1)cK + y(n-1)(-aK-b)}{aK+b}$$

Equation 12 - General 1 order discrete algorithm derivate LP

1.4.3 Second order

$$\frac{ds}{as^2 + bs + c}$$

Equation 13 - General 2 order derivate LP

$$\frac{y(z)}{u(z)} = \frac{dK(1 - Z^{-1})}{aK^2(1 - 2Z^{-1} + Z^{-2}) + bK(1 - Z^{-2}) + c(1 + 2Z^{-1} + Z^{-2})}$$

Equation 14 - General 2 order discrete derivate LP

$$y(n) = \frac{u(n)dK - u(n-2)dK - y(n-1)(2c - 2aK^2) - y(n-2)(aK^2 - bK + c)}{ak^2 + bK + c}$$

Equation 15 - General 2. order discrete algorithm derivate LP

1.5 Conclusion

By implementing Equation 12 or Equation 15 as a filter on the controller for pressure reading it is possible to make the system tunable for a better response. For systems running with sampling time of 0.25s the tuning parameters can be selected as in Equation 5 for first order and Equation 8 for second order.

Finally after the filter design is complete it is time to test it in combination with a PID controller to generate the output to the pressure pump. Figure 5 shows how the system is set up in Simulink. The input consists of three ramps, one positive and two negative that has different start time but the same gain. Ramp 1 starts at 0s, ramp 2 starts at 100s and ramp 3 starts at 200s. These ramps combined with a derivation block generates the input to the system. In Figure 5 there are 2 PID control loops. The top one is in continues time while the other one is the discrete version which will be used in the controller. The gains of the discrete PID controller used in this Simulink simulation is:

Proportional = 33.6863529310747
Integral = 3.39955156838448
Derivate = 0

The method used to discretize the derivate filter is the Tustin's method so a trapezoid method is also used in the PID controller.

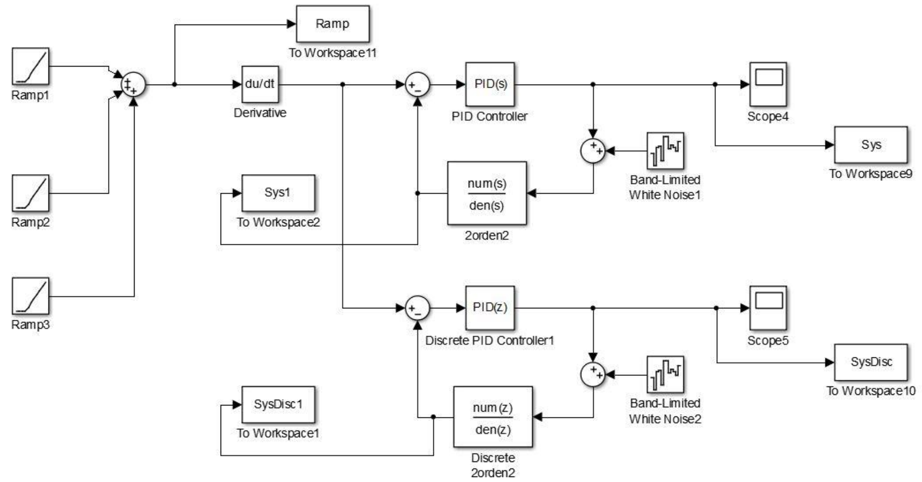


Figure 5 - PID control w/derivative input

Figure 6 shows the output of the continues (in blue) and discrete (in red) 2.order derivate transfer functions plotted over time in seconds. It shows a great response to the changes in derivate input.

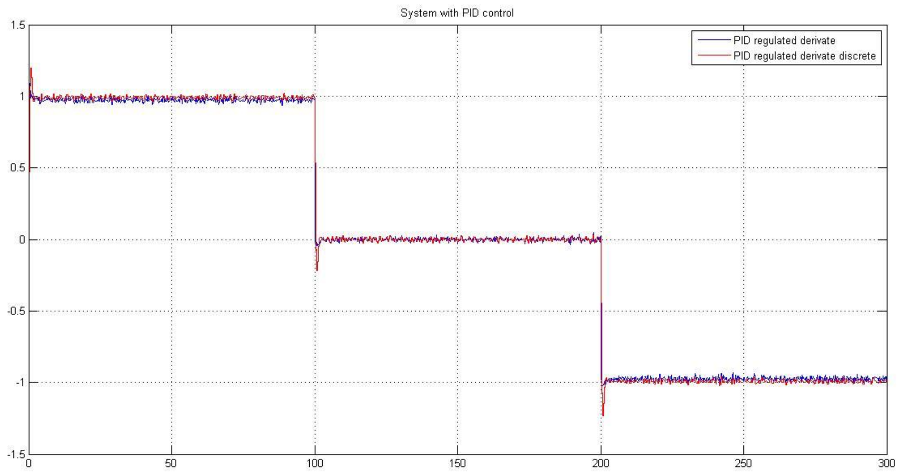


Figure 6 - Derivate of Cycle

The output of the system is shown Figure 7 it simulates a pressure cycle with barley no overshoot or error plotted over time in seconds. There is negative spike when the derivative input value goes from 1 to 0 and from 0 to -1, but this spice does not last very long so it most certainly can be ignored because the pump will not have time to react to it and the system will be isolated at this stage.

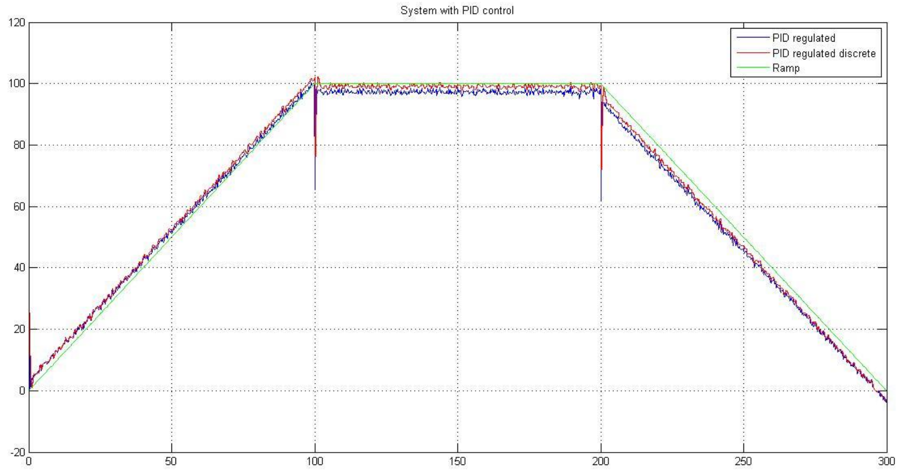


Figure 7 - Pressure Cycle

Based on Figure 6 and Figure 7 one can conclude that Equation 15 with the tuning parameters of Equation 7 should give a good regulation to the sensor reading.

Referanser

[1] G. F. Franklin, J. D. Powell and A. Emami-Naeini, in *Feedback Control of Dynamic Systems Sixth Edition, Chapter 8*, Pearson, 2010.

Hyperbaric - Pressure Control System

Test Rig

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Anders Skjørten
Brian Berg

Document author: Anders Skjørten

ID: TECH-015 <A>

Revisions

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24.04.2015	Creating the document	-	AS, BB	
09.05.2015	Formatting layout	A	AS	BB, TOS,

Table 1 - Revisions

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Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
TF	Transfer function

Table 2 – Abbreviations

1.0 Test Rig

1.1 Introduction

This document describes how the test rig will be designed and implemented to test the controller program. The test rig will be produced by the HPCS group. The purpose of the test rig is to test the PLC and HMI program in a low pressure environment. It is important to note that this test rig is not a miniature of the system but more a prototype without all functionality of HPCS and a test platform for the programming code. The main feature of the design is the 4-20mA interface between the controller and test rig.

1.2 Components

The test rig will consist of a water column, a 12V DC water pump, a driver/interface circuit board for the pump, a power supply and a low pressure transmitter.

1.2.1 Water column

The water column is designed to simulate a pressure chamber. When the column is filled with water it will create a pressure at the bottom that corresponds to the height of the column. For a 10m water column the corresponding pressure would be about 1 bar. The test rig water column is designed to be roughly 2m high so the maximum pressure of the column is about 0.2 bar.

1.2.2 DC pump

The pump used in the test rig is a 12VDC, 2A centrifuge pump. It is documented to have a maximum water flow of 7.5 L per min and a maximum lifting height of 5m. The pump is designed to be lowered in a water reservoir. [1]

Figure 1 - DC pump from Biltema

1.2.3 Driver/interface circuit board

The driver/interface board is a homemade circuit board that is designed to convert 4-20mA to 0-100% PWM of 12V. This circuit board drives the DC pump. More information about the circuit board can be found in TECH – 16.

1.2.4 Power supply

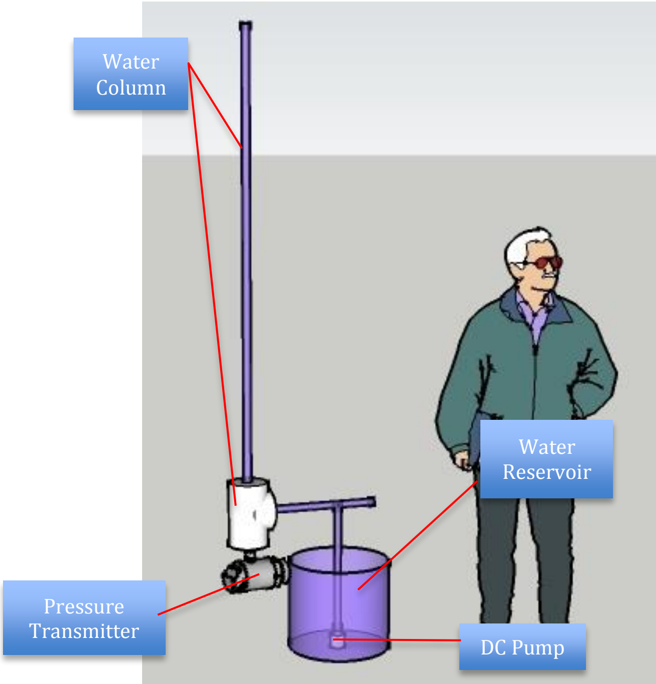
The power supply is a 12V car battery.

1.2.5 Pressure transmitter

The pressure transmitter used is the HART pressure transmitter from ABB witch is a programmable transmitter. The programing method used for the transmitter is called zero/span. This programing method lets the user set the low (zero) and high (span) pressure level. This is done by pushing the programming buttons when the wanted lower an upper pressure is applied to the system. The pressure total span of the transmitter is 0-1.6 bar which corresponds to 4-20mA signal. It also comes pre calibrated so this is not necessary to do. However it will be adjusted so that the maximum output signal of 20mA is given at 0.2 bar. [2]

Figure 2 - Pressure transmitter from ABB [3]

1.3 Design



1.3.1 Description

Figure 3 shows a rough sketch of the test rig. The water column is made of 15mm plastic tubing and a 75mm T section to minimize disturbance from the pump to the pressure transmitter. The pressure transmitter is located at the bottom of the water column to get maximum reading of pressure. The DC pump is lowered in to the water reservoir which can be any kind of container that will hold about 1 liter of water. A man is placed in the figure only for reference reasons.

1.3.2 How it works

The PLC controls the driver/interface circuit board with a 4-20mA signal which is converted to PWM to regulate the flow thru the pump. The water will then begin to fill the column and the pressure transmitter will begin to detect pressure and regulate a 4-20mA signal back to the PLC. The PLC will calculate the derivative error of the pressure increase/decrease and adjust the 4-20mA signal to the driver/interface circuit board accordingly. This will result in an increase or decrease of flow thru the pump and a close to liner increase of pressure. To obtain a nearly constant pressure at holding time the pump given a constant PWM signal and the pressure will stabilize.

Figure 3 - Sketch of pressure test rig

Referanser

[1] "Biltema," [Online]. Available: http://www.biltema.no/no/Fritid/Campingvogn-og-bobil/Vann-og-avlop/Nedsenkbar-pentrypumpe-12-V-2000017743/. [Accessed 06 05 2015].

[2] "Zero – Span Calibration PDF," [Online]. Available: https://www.isa.org/pdfs/calibration-principles-chapter1/. [Accessed 07 05 2015].

[3] ABB, «ABB.com,» [Internett]. Available: http://www.abb.com/. [Funnet 07 05 2015].

Hyperbaric - Pressure Control System

DC Motor Driver

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ID: TECH-016 <B>

Revisions

Date	Description	Version	Made By	Approved By
21.04.2015	Idea description	-	JN	
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Table 1 - Revisions

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Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
FMCTI	FMC Technologies
HBV	Høgskolen I Buskerud/Vestfold
TDI	Technical Data Information
MCU	Microcontroller unit
PWM	Pulse Width Modulation
LED	Light Emitting Diode
PCB	Printed Circuit Board
MOSFET	The Metal–Oxide–Semiconductor Field-Effect Transistor
RPM	Rotation Per Minute
ISP	In-System Programmer
MCU	Micro Controller Unit

Table 2 - Abbreviations

1.0 DC Motor Drive for Test Rig

1.1 Introduction

The PLC 4-20mA output is not designed to run a motor. Therefore, to control the DC motor in the test rig HPCS group designed and created a driver circuit, using a micro controller and some electronic parts. For simplicity, the program Fritzing [1] (v0.9.2) was the program of choice, since the program have all the parts needed and have built inn schematic to PCB layout converting.
Electronic parts assembled on the PBC card was the parts HPCS group had available without ordering from the suppliers.

1.2 Design and Schematic

The design was done section by section.

1.2.1 MCU

Figure 1 - Attiny85

The MCU was chosen to be an Attiny85 [2]. Attiny85 can be programed in the programing language C. HPCS group had this MCU and software to program it available.

1.2.2 Voltage Regulator

To replace a proper voltage regulator like a LM7805 that was not available, a makeshift voltage regulator for the MCU was needed. It needed to supply the circuit between 1,8 - 5,5VDC. This was designed with six diodes with 0,7VDC forward voltage in series creating 4,2V as VCC. The rest of the voltage will rest over R4. To be sure the 0,25W resistor that was available does not overheat, the power dispassion needed to be calculated with Ohms law.

$$R = \frac{U^2}{P} = \frac{(12-4,2)^2}{0,25} = 244\Omega \; minimum$$

Equation 1 - Minimum Resistor Value in Voltage Regulator

The result was to use 330Ω. A capacitor was added to remove ripple and to buffer the supply voltage.

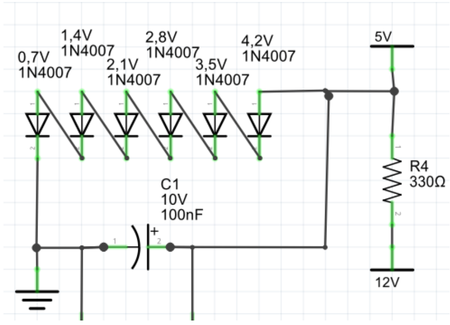

Figure 2 - Voltage Regulator

1.2.3 Signal Converter

The MCU is not capable of reading current, so the signal is sent thru a resistor and the MCU read the voltage across the resistor. The resistor for the 4-20mA needed to be calculated. Adjusting the top signal (20mA) to be represented by VCC voltage level according to Ohms law.

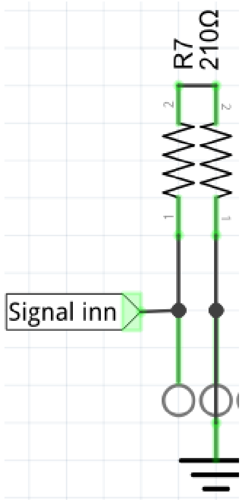

Figure 3 - Ampere to Voltage Converter

$$R = \frac{VCC}{I_{Max}} = \frac{4{,}2V}{20mA} = 210\Omega$$

Equation 2 - Resistor in Signal Converter

The power disposition is:

$$P = R * I^2 = 210\Omega * 0{,}020A^2 = 0{,}084W$$

Equation 3 - Power Disposition in Signal Converter

This is within the 0,25W the resistor can handle.
The normal operation voltage range is:

$$R * I = U$$
$$210\Omega * 4mA = 0{,}84V\ minimum\ \ and\ 210\Omega * 20mA = 4{,}2V\ maximum = VCC$$

Equation 4 - Operational Voltage Level from Signal

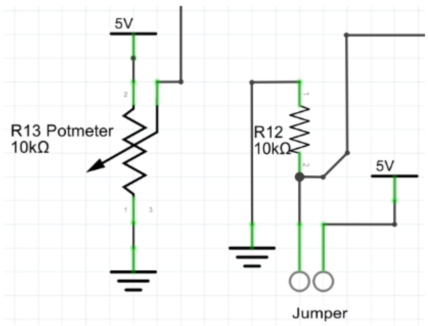

Figure 4 - Potentiometer and Jumper

1.2.4 Signal Override and Base Setting

Since the PLC is not ready at this time, the circuit made it possible to adjust the pump with a potentiometer. Test operator of the test rig can chose what input to use with a jumper.

Later it is possible to reprogram the MCU. The MCU can than make the potentiometer to set the base point of the pressure (lowest RPM setting).

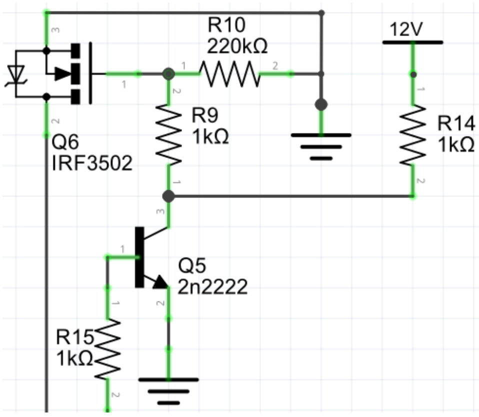

Figure 5 - MOSFET and MOSFET Driver

1.2.5 Driver

When the MCU reads the voltage, it translates this to a PWM signal. This signal drives a NPN transistor that acts like a voltage level shifter from 4,2VDC to 12VDC, witch again drives the MOSFET transistor. Since this is not a logic level MOSFET this setup is needed to make sure the MOSFET is totally saturated when ON, totally unsaturated when OFF and not overheated. To save parts HPCS group only used one transistor and this inverted the signal in.

The result of when the MCU turns the signal on, the transistor turns the signal off, but this is handled in the program to invert the signal in the first place.

1.2.6 Status LED

The circuit is also fitted with to LEDs, one is called heartbeat and will fade inn and out to shown that the MCU is functioning. This is helpful in case of troubleshooting. The other LED will adjust its brightness proportionally to the PWM signal, to have an indicator of the motor speed even without a motor present.

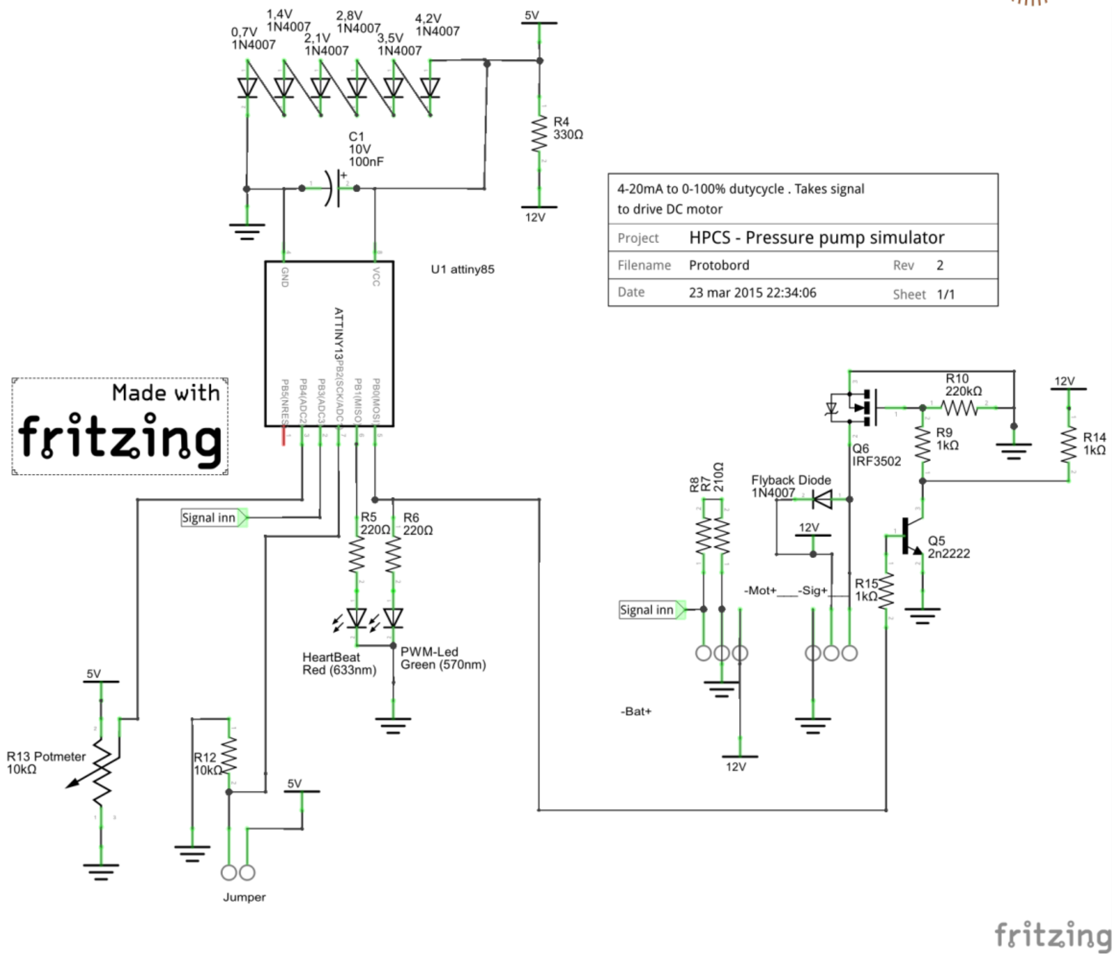

Figure 6 - Circuit Schematic

2.0 Programing

2.0 Programing Tool

To program the Attiny we used an Arduino as ISP following the guide from a website [3].
To write the program one can use the Arduino IDE program. HPCS group used Microsoft Visual studios 2012 with an add-on for the Arduino programming.

2.1 Program Code

```
//Sett pin number
const int AliveLedPin=1;            //Will show that the tiny is alive
const int PWMPin=0;          //sending out the pwm signal
const int AnalogPin=A3;             //Analog input signal
const int PotPin=A2;         //Potmeter input signal
const int jumper=2;          //If high the program will use potmeter value

const int offLvl=51;         //4mA*210ohm=0.84v    255/4.2v*0.84v=51 → 4mA=OFF
const int highLvl=1023;

void setup(){
//Sett pin function
       pinMode(PWMPin,OUTPUT);
       pinMode(AliveLedPin,OUTPUT);
       pinMode(jumper,INPUT);
       }
void loop(){
       //set jumper to choose to potmeter as set point, else use signal
       int value;
       if (!digitalRead(jumper)){value=analogRead(PotPin);}
       else{value=analogRead(AnalogPin);}

       //int value=ReadValue();  //read the signal value
       int PWMvalue=map(value,offLvl,highLvl,255,0); //convert the signal value
to PWM lvl and setting 4mA=off
       PWMvalue=max(PWMvalue,0);
       PWMvalue=min(PWMvalue,255);
       analogWrite(PWMPin,PWMvalue);

       //this will make a led fade up and down to show that the MCU its alive.
       long interval = 20;
       static int brightness = 0;
       static int fadeAmount = 5;
       static long previousMillis = 0;

       unsigned long currentMillis = millis();

       if(currentMillis - previousMillis > interval) {
              previousMillis = currentMillis;
              analogWrite(AliveLedPin, brightness);
              brightness = brightness + fadeAmount;

              // reverse the direction of the fading at the ends of the fade:
              if (brightness == 0 || brightness == 255) {
                     fadeAmount = -fadeAmount ;
}}}
```

3.0 PCB

3.0 Design and Layout

After the circuit was tested with a breadboard setup, the designed one layer PCB card was fitted with permanent components. The board size was chosen to match the one that was available; 100*70mm. A multilayer board requires viases and is more complicated to print, but is easier to route.

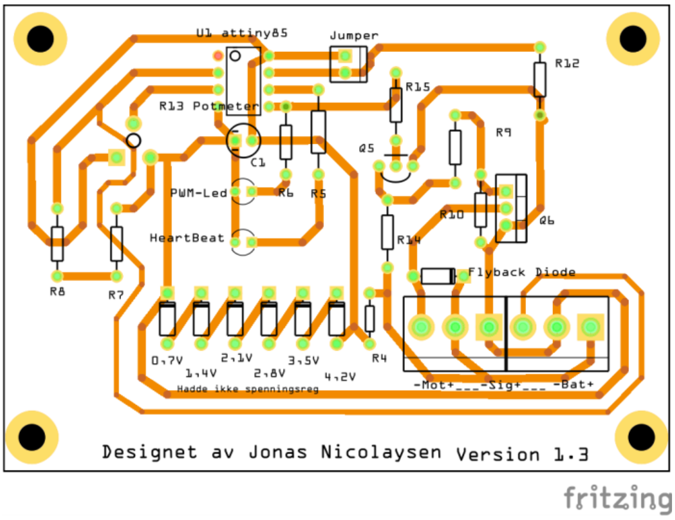

Figure 7 - PCB Design v1 100*70mm

Later this was updated and made smaller with a proper voltage regulator.

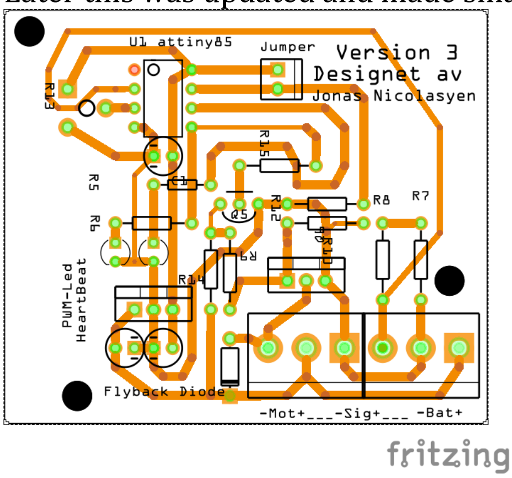

Figure 8 - PCB Design v3 65*55mm

This made the board simpler to solder and cheaper to make if this task needed to be done again.

3.1 Production

A method called toner transfer to get the circuit printed on a cobber plated PCB [4]. This consists of printing the circuit on to a glossy paper, lay paper on to the PCB and use heat and pressure to transfer the ink from the paper to the PCB. The ink traces will protect the cobber beneath it in the next phase.
When the board is marked up with the traces we put the PCB in to a plastic tray and added the acid, Ferric Chloride. After ten minutes and some washing rest of the cobber layer is etched away. Then one also drills the holes for the pins of the components.

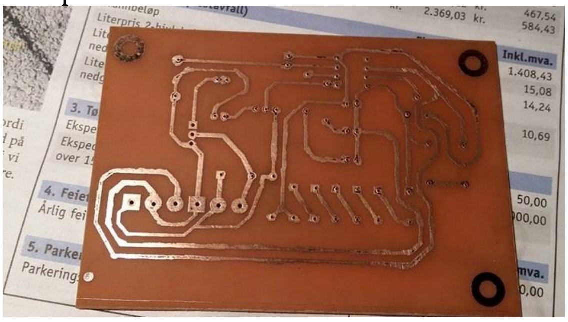

Figure 9 - Etched PCB

The board is then ready for being populated and soldered.

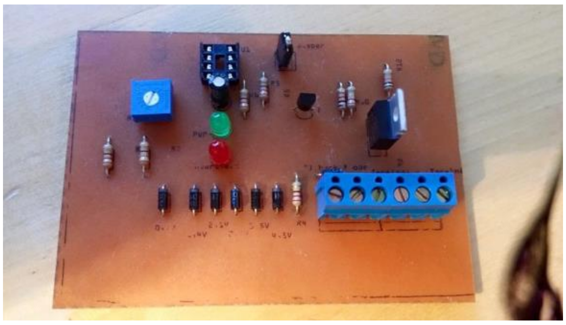

Figure 10 - Populated Board

3.2 BOM v1

Amount	Part Type	Properties
2	Screw terminal - 3 pins	pins 3; package THT; pin spacing 0.2in (5.08mm); hole size 2mm,1mm
7	Rectifier Diode	type Rectifier; package 300 mil [THT]; part number 1N4007
1	Electrolytic Capacitor	voltage 10V; package 100 mil [THT, electrolytic]; capacitance 100nF
1	Red (633nm) LED	color Red (633nm); package 3 mm [THT]; leg yes
1	Screw terminal -	pins 2; package THT; pin spacing 0.1in

Amount	Part Type	Properties
	2 pins	(2.54mm); hole size 1.0mm,0.508mm
1	Green (570nm) LED	color Green (570nm); package 3 mm [THT]; leg yes
1	NPN-Transistor	type NPN (EBC); package TO92 [THT]; part number 2n2222
1	Basic FET N-Channel	type n-channel; package TO220 [THT]; part number IRF3502
1	Trimmer Potentiometer	maximum resistance 10kΩ; type Trimmer Potentiometer; track Linear; package THT; size Trimmer - 6mm
2	220Ω Resistor	resistance 220Ω; package THT; pin spacing 400 mil; bands 5; tolerance ±5%
1	330Ω Resistor	resistance 330Ω; package THT; pin spacing 400 mil; bands 5; tolerance ±5%
1	210Ω Resistor	resistance 210Ω; package THT; pin spacing 400 mil; bands 4; tolerance ±5%
3	1kΩ Resistor	resistance 1kΩ; package THT; pin spacing 400 mil; bands 5; tolerance ±5%
1	220kΩ Resistor	resistance 220kΩ; package THT; pin spacing 400 mil; bands 4; tolerance ±5%
1	10kΩ Resistor	resistance 10kΩ; package THT; pin spacing 400 mil; bands 4; tolerance ±5%
1	ATTINY85	variant dip08; package dip; attiny85

Table 3 – BOM v1

References

[1] "Fritzing.org," [Online]. Available: http://www.fritzing.org. [Accessed 27 04 2015].

[2] Atmel, "www.atmel.com," 08 2013. [Online]. Available: http://www.atmel.com/Images/2586_105.pdf. [Accessed 27 04 2015].

[3] High-Low Tech Group :: MIT Media Lab , "Highlowtech," [Online]. Available: http://highlowtech.org/?p=1695. [Accessed 27 04 2015].

[4] [Online]. Available: http://www.george-smart.co.uk/wiki/Toner_Transfer_PCBs. [Accessed 15 05 2015].

Hyperbaric - Pressure Control System

User Manual

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Brian Berg

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ID: TECH-017 <->

Revisions

Date	Description	Version	Made By	Approved By
09.05.2015	User manual	-	AS	TOS, JC

Table 1 - Revisions

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Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
LP	Low pass
TF	Transfer function

Table 2 - Abbreviations

1.0 User manual

1.1 Introduction

This document describes how to use the HPCS. The “Start Test” and “Screen Description” chapters are based on TECH-003. [1]

1.2 Emergency switch

Emergency functions are implemented in HPCS. If any dangers occur press the emergency button located at the side of the control cabinet.
This will stop the whole process and the system will go into a steady state.
To continue after an emergency shutdown the pressure inside tank has to be bleed down manually by opening V-014 (if the system is pressurized). When the pressure is 0 bar, close V-014 and press reset button on control cabinet door. Now the alarm at HMI stops and the system is ready to drain tank or start a new test.

1.3 Start test

1.3.1 Step 1

Go to settings menu. When starting the HPCS for the first time the software needs information about the dimensions of the reservoir and how many cycles the pressure tank is certified for. Enter the height and diameter in cm, the program will calculate the volume of the reservoir in liters. Next enter maximum cycles that the pressure tank is certified for. The parameters will be saved to the system memory so it is not necessary to repeat this step in future tests, but one should always verify that the values is correct before starting a new test.

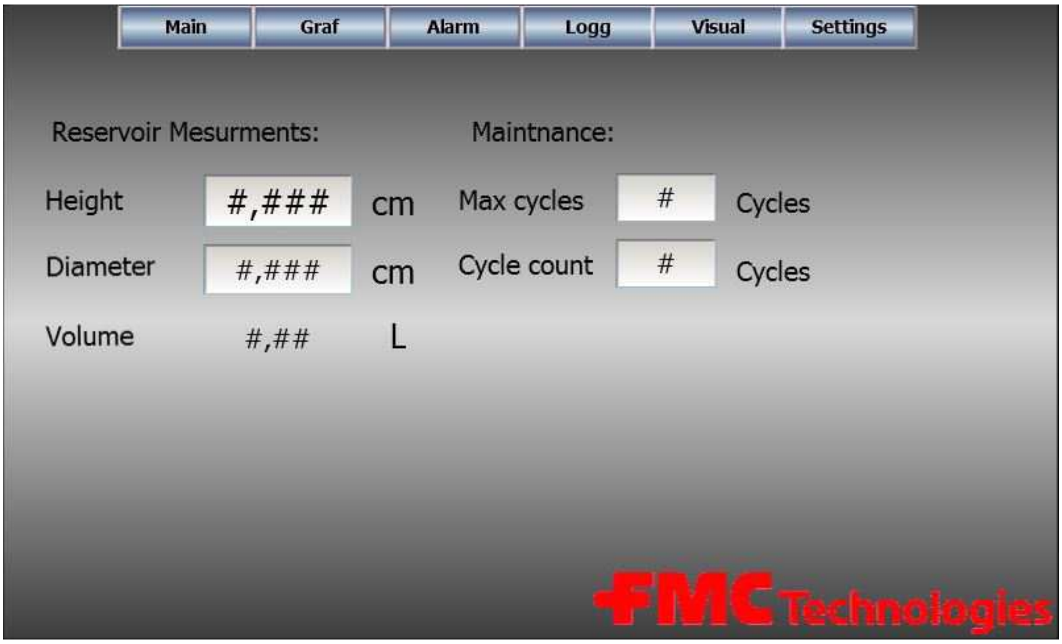

Figure 1 - Settings Screen

1.3.2 Step 2

Go to main menu. This screen contains all the system parameters. Be sure to set all the parameters according to the test specifications:

Pressure bottom – the lower pressure value in the test minimum 0 bar
Pressure top - the highest pressure value in the test maximum 500 bar
Derivative Up – how fast the pressure should increase in bar per minute
Derivative Down - how fast the pressure should decrease in bar per minute
Holding time bottom – How many minutes of holding time at pressure bottom
Holding time top – How many minutes of holding time should be at pressure top
Total cycles in the test – How many cycles is the test going to run for.

- When all parameters is set the test can start. Press “start process” to start the test. The pressure tank will then be filled with liquid and the test will start automatically.
- If for some reason the test needs to be stopped push the stop process button.
- If for some reason the pressure tank needs to be drained push the “stop process” button twice and then the “drain tank” button.
- It is possible to start filling sequence on the pressure tank if a test is not currently active. This is done by pressing “fill tank” button.

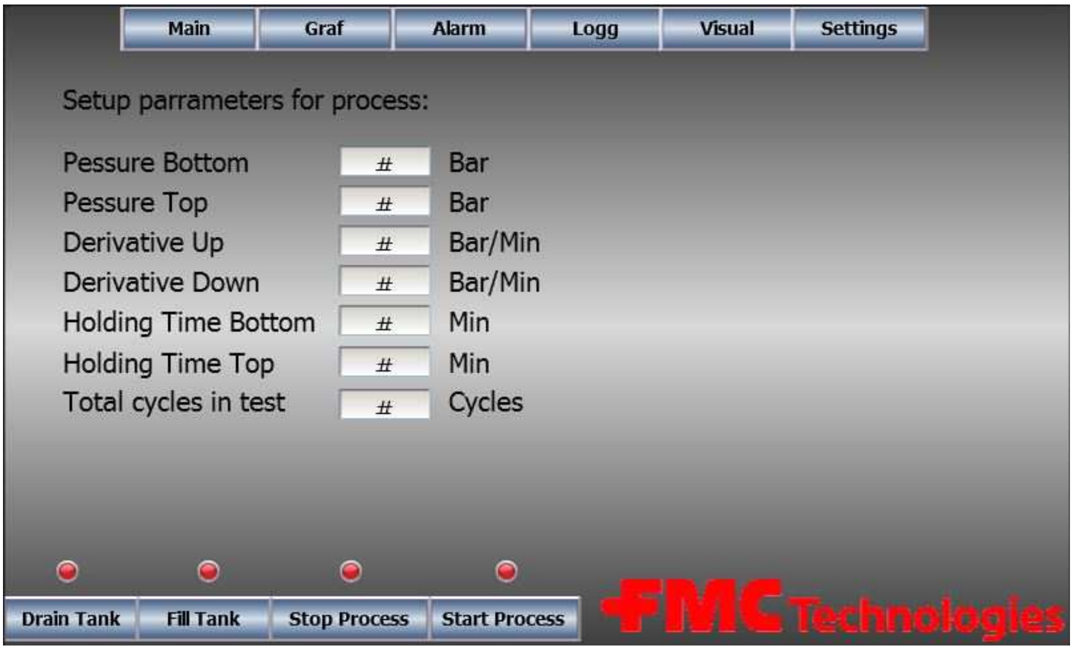

Figure 2 - Main screen

1.4 How to generate a report

After the test is done it is possible to export a report from the HMI. This is done from the log screen. When the report is written to the SD card one can remove the SD card and transport them to a computer. The excel file can be located on the SD card in the reports folder. It contains the logged data from variables Pres_CurrentValue, PT_001 and PC_003. The graph in Figure 4 will be plotted automatically in sheet 3 of the excel file. The only thing the user needs to do is to update the pivot table as shown in Figure 3.

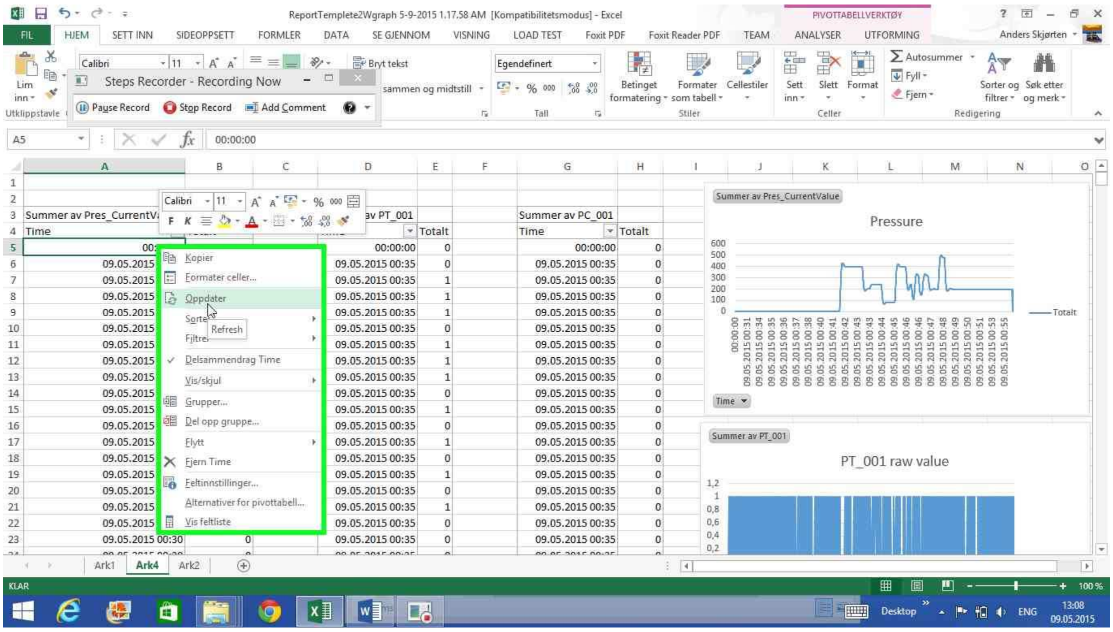

Figure 3 - Update pivot table

The graph in Figure 4 was made from the data report exported from the HMI under a test of PLC and HMI. The data shown was generated from the PLC and simulates pressure. The pivot table and graph function in excel was used to generate the graph.

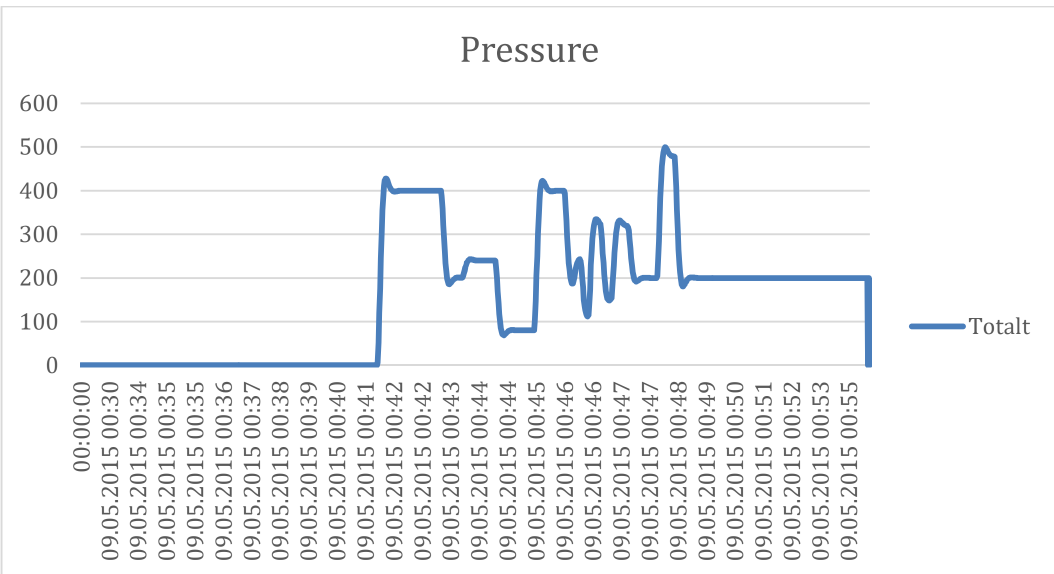

Figure 4 - Graph exported from HMI

1.5 Screen description

1.5.1 Main screen

In the main screen all the parameters for the process is set.

- The current cycle of the test is shown over the FMC logo in the bottom right corner.
- Parameters are edited by pushing the white box next to the parameter that needs editing.
- To start the test push “Start Process” the indicator will turn green.
- To stop the test push “Stop Process” the indicator will turn green. Push it again to reset it. The indicator will then turn red.
- To fill the pressure tank push “Fill Tank” the indicator will turn green.
- To drain the pressure tank push “Drain Tank” the indicator will turn green.
- Note it is not possible to start drain, fill or process if one of them are active (indicator green) without pushing stop button first.

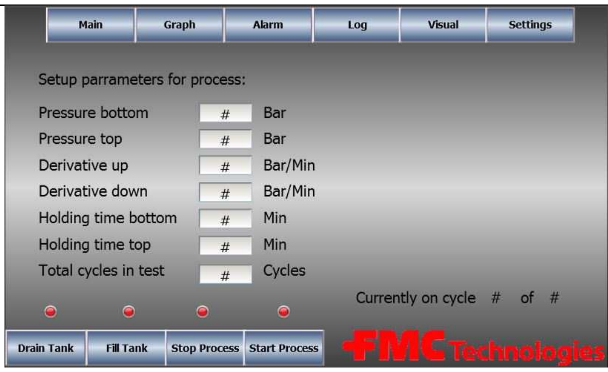

Figure 5 - Main Screen

1.5.2 Graph screen

The graph plots pressure over time.

- To show the history of the graph push the history button.
- To show legend of graph push Legend button.

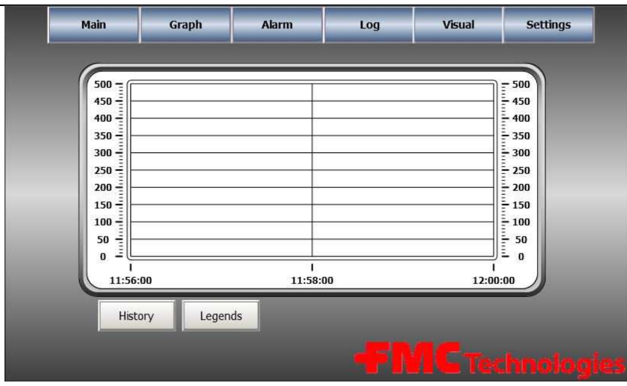

Figure 6 - Graph Screen

1.5.3 Alarm screen

The alarm screen will show the log of the alarms throughout the process.

- Alarms implemented to the log is reservoir low level alarm, emergency pneumatic shutdown and pressure level to high.
- To deactivate alarm ether push “Ack All” or select one and push “Ack Selected”.
- Push “Clear” to clear list (not possible when alarm is active).
- “Info” button not implemented
- “Filter” button brings up some filter parameters.
- Pause button pauses alarms.

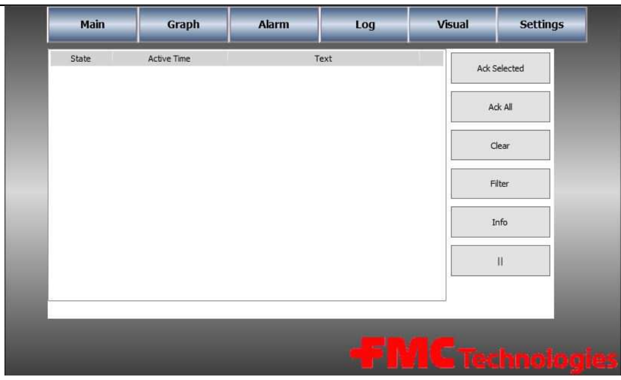

Figure 7 - Alarm Screen

1.5.4 Log screen

In this screen it is be possible to export the logged data from the test to the SD card.

- Push "Export data" button to export data logger file.
- Push "Export graph" button to export graph date form the test.
- Push "Export report" button to export defined date form the test.
- Push "Export alarm" button to export defined date form the test.

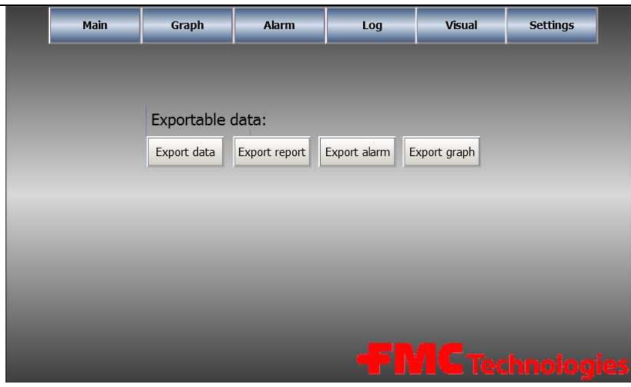

Figure 8 - Log screen

1.5.5 Visual screen

The visual screen gives a live overview of the process. It shows the state of the crucial parameters.

- V_007, V_008, V_009, V_010 and V_011 shows on/off state of the valves.
- P_001 shows the on/off state of the pressure pump as well as the reference pressure in bar sent from the PLC (this is a calculated value).

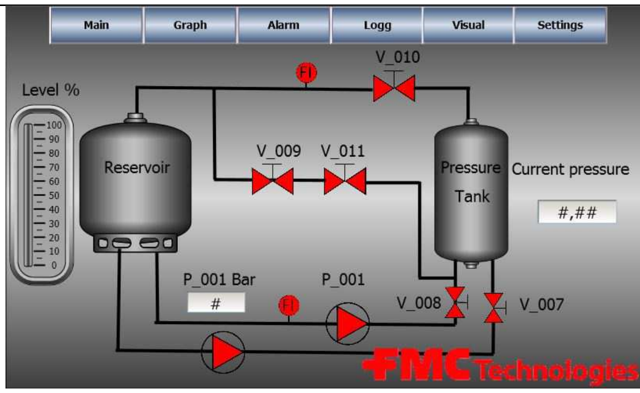

Figure 9 - Visual Screen

1.5.6 Settings screen

Because HPCS is an adaptable system that can be used on different pressure thanks and reservoirs the settings screen contains all the settings parameters like reservoir height, width and depth. It is also necessary to tell the program how many cycles the pressure tank is qualified for, so that the program can keep track and alarm the user when the tank needs to be switched out or serviced.

- Parameters are edited by pushing the white box next to the parameter that needs editing.
- Push "Reset Cycles" to reset cycle count

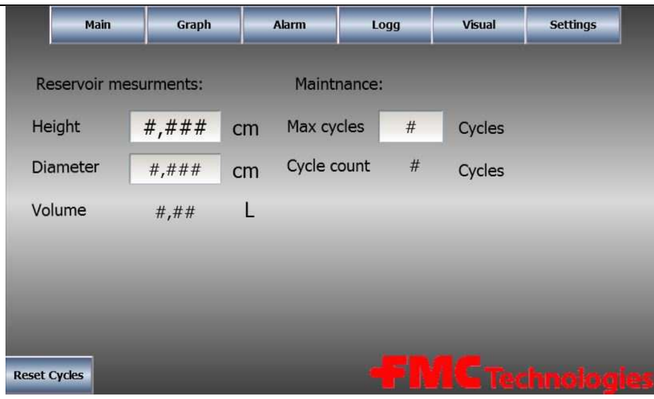

Figure 10 - Settings screen

Table 3 - Screen description

References

[1] A. Skjørten, «Tech-003 <B>, HMI,» HBV, Kongsberg, 2015.

Hyperbaric - Pressure Control System

Technology Document - Simulation of the Pressure Increasing Control Loop

Group:
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Jonas Carlstedt
Anders Skjørten
Brian Berg

Document author: Jonas Carlstedt

ID: TECH-018 <B>

Revisions

Date	Description	Version	Made By	Approved By
16.02.2015	Haskel ASFD-60	-	JC	
27.04.2015	Simulation of Increasing pressure control loop	A	JC	
09.05.2015	Technology Document - Simulation of the Pressure Increasing Control Loop. (Document name changed from ACT-001 to TECH-018)	B	JC	BB, TOS, AS

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Abbreviation list

Abbreviation	Explanation
HMI	Human machine interface
FMCTI	FMC Technologies
HBV	Høgskolen I Buskerud/Vestfold
P&ID	Piping and instrumentation diagram

1.0 Introduction

Our system design uses a pneumatic actuated hydraulic pump to build pressure inside of the pressure tank. This document is intended to describe the basic of how the pneumatic actuated hydraulic pump work, and to establish a dynamic model prior to simulation using the Simulink toolbox in MatLab.

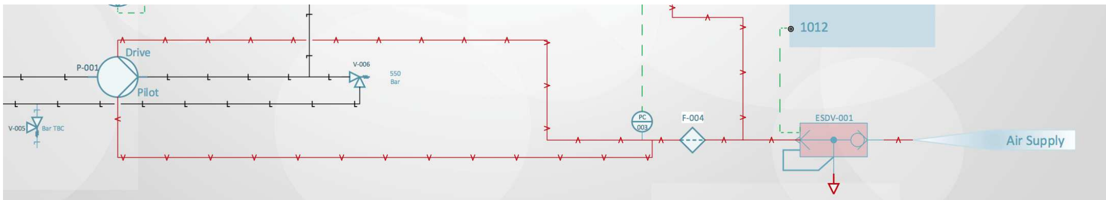

Figure 1 - Cropped image of the P&ID schematics showing the high-pressure pump in the system.

The idea is to control the pneumatic pressure at the input of the pneumatic-hydraulic pump to drive the hydraulic output flowrate from the pump to desired flowrate at all time to maintain the configured pressure build-up. With our design we intend to regulate this input pressure with an electro-pneumatic pressure regulator which will have an analogous electrical signal from the control system to adjust the pneumatic output pressure supplied to the pump.

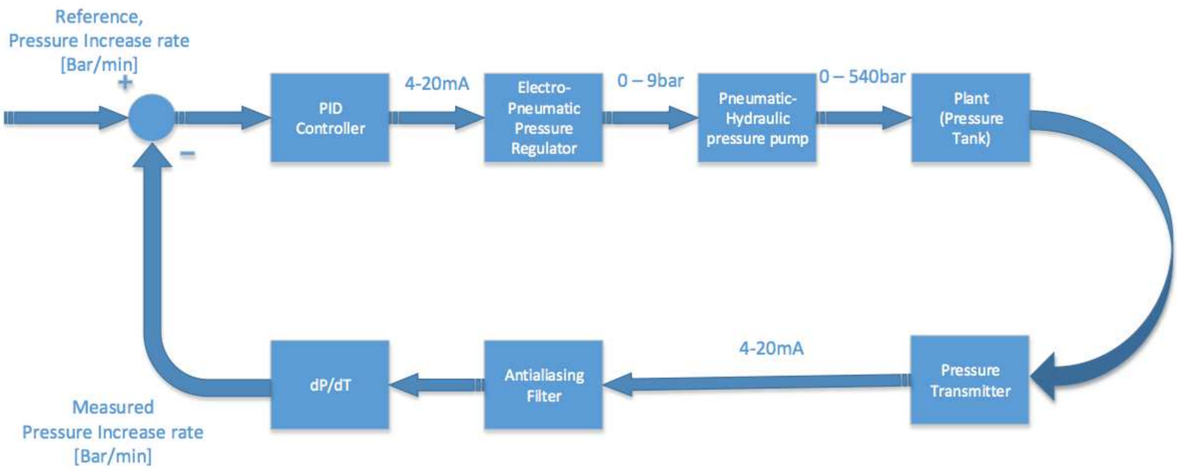

Figure 2 - Feedback loop represented with block schematics.

Drawing above shows the negative closed loop control system that is designed to regulate on the positive derivative of the pressure in the tank with respect to a reference derivative pressure parameter configured on the HMI system.

2.0 Basic Principle for Reciprocating Piston Pumps

These pumps use a pneumatic pressure source to drive a piston with relative big surface area to push a piston with relative small surface area. The relationship between the pneumatic surface area and the hydraulic surface area is the steady state relationship between the pneumatic input pressure with respect to the hydraulic output pressure [3].

If you have a Pneumatic-hydraulic pump with nominal ratio 60:1, the hydraulic steady state output pressure will be 60 bar with 1 bar pneumatic input pressure induced on the pneumatic input of the pump [3].

Using this kind of pump have several features that is not found in a piston pump [3].

- Safe Pneumatic Operation – No heat, flame or spark risk
- Infinitely variable cycling speed
- Stall feature at pre-determined pressure to hold that pressure without consuming power.
- Problem-free stop start applications
- Easily automated

2.1. Single acting pumps

2.1.1 Compression stroke for single acting pumps

When the pneumatic input pressure of the pump increase, a pneumatic flowrate enters the pneumatic chamber forcing the pneumatic piston to push the hydraulic piston. This cause the hydraulic piston to deliver a hydraulic flow rate on the output. The hydraulic output and pneumatic input of the pump is fitted with check valves that allows only one flow direction for the hydraulic fluid which is respectively out of the pump and out to the system plant. This prevents liquid on the downstream side of the pump to flow back into the pump when the pistons are returning to start a new compression stage. The exhaust valve on the pneumatic piston chamber is closed, and the pneumatic inlet valve is open at this stroke to build pneumatic pressure to move the pistons.

Pneumatic inlet valve:	Open
Pneumatic exhaust valve:	Closed
Hydraulic inlet valve:	Closed
Hydraulic outlet valve:	Open

2.1.2 Suction stroke for single acting pumps

When both pistons are in the end position after the compression stroke, it will have to return to the starting position before it can deliver any more fluid to the system. This is causing a discontinuity in the flow delivered from the pump for a short duration of time. This discontinuity represent a non-linearity in the dynamic model of the system.

The suction stroke is done by letting the pressure accumulated on the pneumatic input out, and then pressurize the other side of the pneumatic piston to drive the piston back to the starting position. This can also be done with a spring mounted on the other side of the pneumatic piston, or in combination with pressurized air. The hydraulic piston will do the same movement since they are mechanically connected. Since the hydraulic pressure on the hydraulic output cannot go back to the hydraulic piston chamber, it sucks hydraulic fluid from the reservoir tank through a check valve that only allows fluid to enter the hydraulic piston chamber during suction stage. This check valves will then be closed when the pressure in the hydraulic piston chamber is higher than the pressure in the reservoir tank during the compression stroke. At this stage, the check valves will have these states:

Pneumatic inlet valve:	Closed
Pneumatic exhaust valve:	Open
Hydraulic inlet valve:	Open
Hydraulic outlet valve:	Closed

2.2. Double acting pumps

Double acting pumps consists of two hydraulic pump heads, unlike single acting pumps which only consist of one single hydraulic pump head. Double acting pumps is performing the suction & compression stroke at the same time, so when one of the two pump heads finish a compression stroke, it will start the suction stroke while the other pump head will start a compression stroke. This will eliminate the problem with the flowrate falls to zero that will occur in a single acting pump while it is doing a suction stroke. This kind of pumps are driven with the same pneumatic principles, but is always driven back and forth with pneumatic force unlike the singe acting which can be returned with spring force alone or in combination with pneumatic force. A small decrease of the flowrate out of a pump will most likely also occur with this system since the pneumatic piston will have to change direction which means that the mass of the pneumatic piston will have to decelerate before it comes to a stop, before the piston starts accelerate in the opposite direction. The duration of the reduced flow delivered by the pump will be very dependent of how fast the pump is driven. When the pump runs fast, the flow-reduction time will be very short, while running the pump slowly will increase the flow-reduction time.

2.3. Single, Dual & Triple Air-head

To increase the force of the pneumatic pump head, it is common to use several pneumatic pistons areas to get a higher ratio between the hydraulic surface area and the pneumatic surface area. With a dual air-head system, we will have twice as much pneumatic surface area which will result in twice the force given to the hydraulic pump head. The result is a pump that can deliver twice as much pressure on its output. With a tipple air-head system, the pneumatic surface area and the output pressure will be tripled [3].

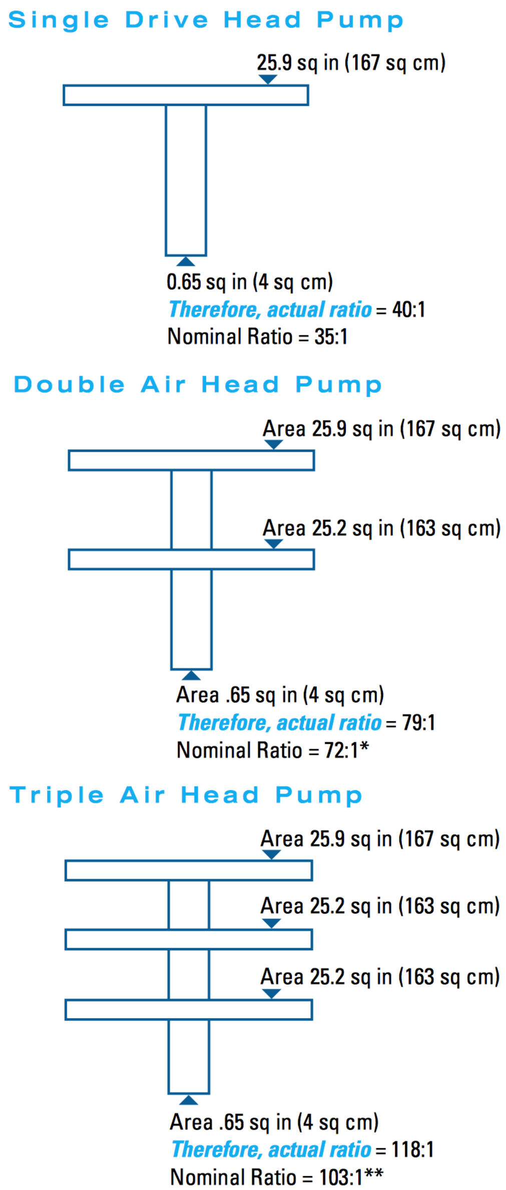

Figure 3 - Shows how multiple air-head increases a pumps nominal pressure ratio [3].

3.0 Haskel ASFD-60 (Actuator)

The specific pump suitable for our application is found after several dialogs with Proserv AS. Proserv is an international company with headquarters in Aberdeen, UK. They have offices in Stavanger as well, and have been supplying FMC Kongsberg Subsea with Hydraulic tubing, valves and pumps and complete HPU`s (Hydraulic Pressure Units).

The chosen pump is developed and produced by a company named Haskel, located in Burbank, California. The name of the pump is ASFD-60.

The pump is a single air-head, double-acting pump. The nominal ratio for the pump is 1:60, so with a pneumatic input pressure of 7 bar, the steady state hydraulic output pressure will be 420 bar. The volume of the hydraulic chamber is 22ml so the pump will deliver 22ml per stroke. Since the pump is double acting, one cycle will consist of two compression stroke, so one pump cycle will result in 44ml of fluid delivered on the hydraulic pump output.

If a higher output pressure is needed, a double or tipple air-head drive could be used to drive the output pressure even higher.

Figure 4 - Chosen pump for our application, Haskel ASFD-60 [3]

4.0 3D flow model of the Haskel ASFD-60 Hydraulic Pump

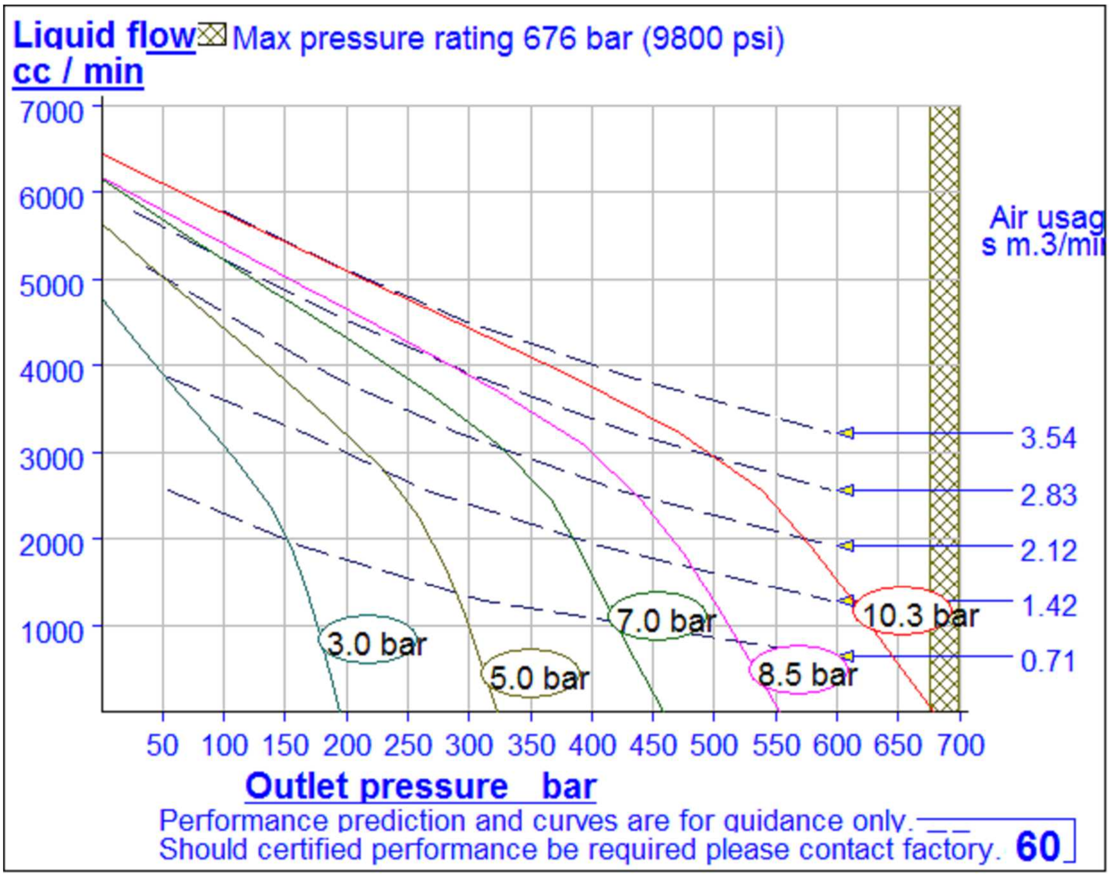

Figure 5 - Performance characteristic for Haskel ASFD-60 [3]

The characteristics for the ASFD-60 pump is showed in the figure 5. Since we don't have the complete documentation for the pump (internal mechanical drawing etc.), it is hard to simulate the pump with each component inside. Instead, we have chosen to create a model based on the characteristic curves in figure 5 supplied by Proserv AS in combination with interpolation and extrapolation techniques since we need to know what happens at every point between the 5 curves showed in figure 5. In the simulation we can use 2-dimensional lookup table which determine the output flow from the pneumatic input pressure and the hydraulic output pressure.

As we can see from figure 5, the flowrate becomes zero when the output pressure reach 180 bar with 3 bar pneumatic pressure. This is because the force acting on the pistons from both the pneumatic and the hydraulic side are in balance, and the piston motion become static. The output pressure is now 60 times higher than the input pressure.

	0 bar	100 bar	190 bar	320 bar	460 bar	550 bar	675 bar
3.0 bar	4800 ml	3100 ml	0 ml	0 ml	0 ml	0 ml	0 ml
5.0 bar	5600 ml	4500 ml	3200 ml	0 ml	0 ml	0 ml	0 ml
7.0 bar	6200 ml	5300 ml	4400 ml	3200 ml	0 ml	0 ml	0 ml
8.5 bar	6300 ml	5500 ml	4700 ml	3700 ml	2100 ml	0 ml	0 ml
10.3 bar	6500 ml	5800 ml	5200 ml	4300 ml	3300 ml	2400 ml	0 ml

Figure 6 - The information from figure 5 can be read out to this table.

The first zero in each row in the matrix in figure 6 indicates the steady state of the pump so that the column header information is chosen wisely to make sure the matrix is caring this important information.

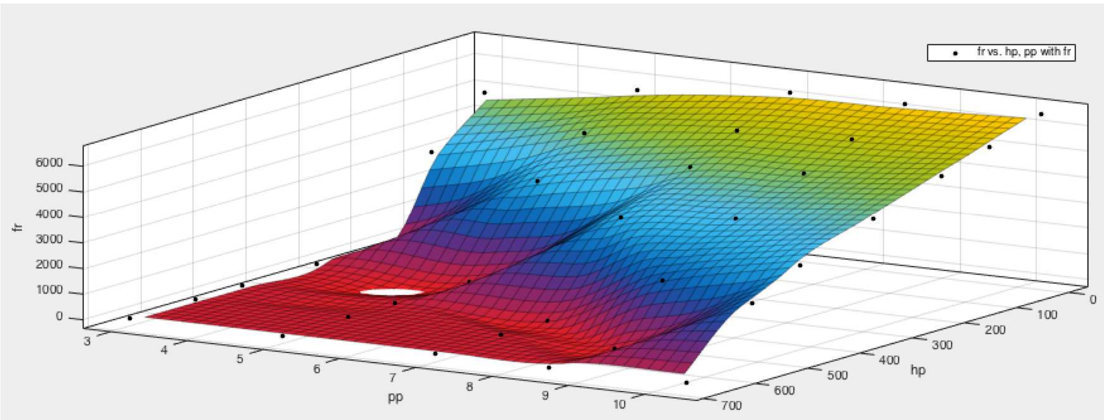

Figure 7 - Interpolation and extrapolation of information given in figure 6

After interpolating using cubic splines, the information given in figure 6 is represented with a continuous 3D model that can be used as a 2D-lookup table in the simulation to determine the flowrate from the pump at every given time with these input parameters:

- Pneumatic Input Pressure: 3 – 10.3 bar.
- Hydraulic Output Pressure: 0 – 700 bar.

But this is not enough if we want to know what happens with the flowrate at input pressure under 3 bar. We will need to make some assumptions.

1. With no applied pressure, the flow rate is zero.
2. The steady state output pressure is 60 times the input pressure.

	0 bar	100 bar	190 bar	320 bar	460 bar	550 bar	675 bar
0 bar	0 ml	0 ml	0 ml	0 ml	0 ml	0 ml	0 ml
1.5 bar	2000 ml	0 ml	0 ml	0 ml	0 ml	0 ml	0 ml
3.0 bar	4800 ml	3100 ml	0 ml	0 ml	0 ml	0 ml	0 ml
5.0 bar	5600 ml	4500 ml	3200 ml	0 ml	0 ml	0 ml	0 ml
7.0 bar	6200 ml	5300 ml	4400 ml	3200 ml	0 ml	0 ml	0 ml
8.5 bar	6300 ml	5500 ml	4700 ml	3700 ml	2100 ml	0 ml	0 ml
10.3 bar	6500 ml	5800 ml	5200 ml	4300 ml	3300 ml	2400 ml	0 ml

Figure 8 - New matrix with two new column made with assumptions.

The assumption made let us add two new rows to the model matrix (Marked with yellow).

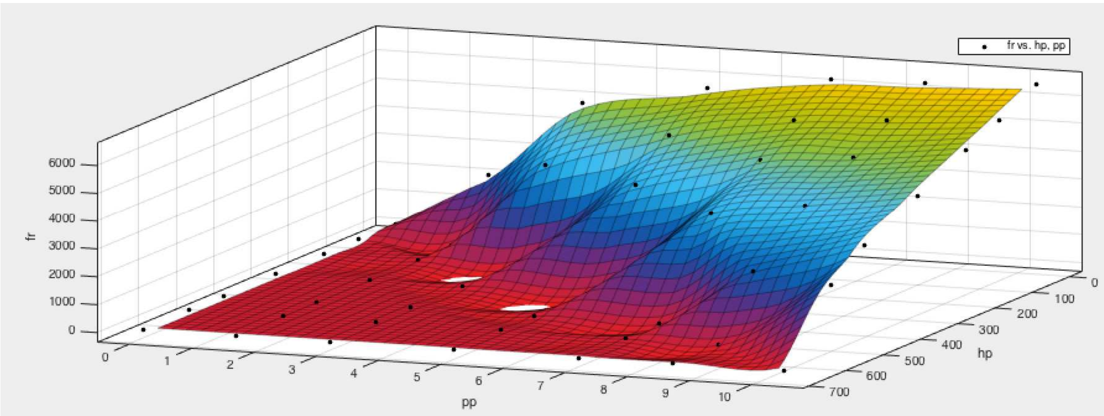

Figure 9 - Complete 3D model for the Haskel ASFD-60 pump.

Now we have a model that gives us the flowrate out of the hydraulic pump with these input parameters:

- Pneumatic Input Pressure: 0 – 10.3 bar.
- Hydraulic Output Pressure: 0 – 700 bar.

5.0 Simulation

To verify that the principle for the derivative control are working for both control loops in this project, we have created a Simulink model that simulates the pressure increase control loop. The control principle is the same for the increasing pressure control loop as for the decreasing pressure control loop, so it should be sufficient enough to only simulate one of the loops. In the simulation, the reference we want the system to track is set to 40 bar/min. The simulation also verify that the dimensioning of the actuator (Haskel ASFD-60). The actuator for the decreasing pressure control loop is verified in TECH-001.

The simulation are grouped into five main sub-systems:

- Compensator
  - Saturated PID Compensator with Anti-windup function
- Pre-Actuator
- Actuator
  - Flow discontinuity
  - Pneumatic Flowrate Estimator
- Plant
- Derivative Operator & Anti-aliasing filter

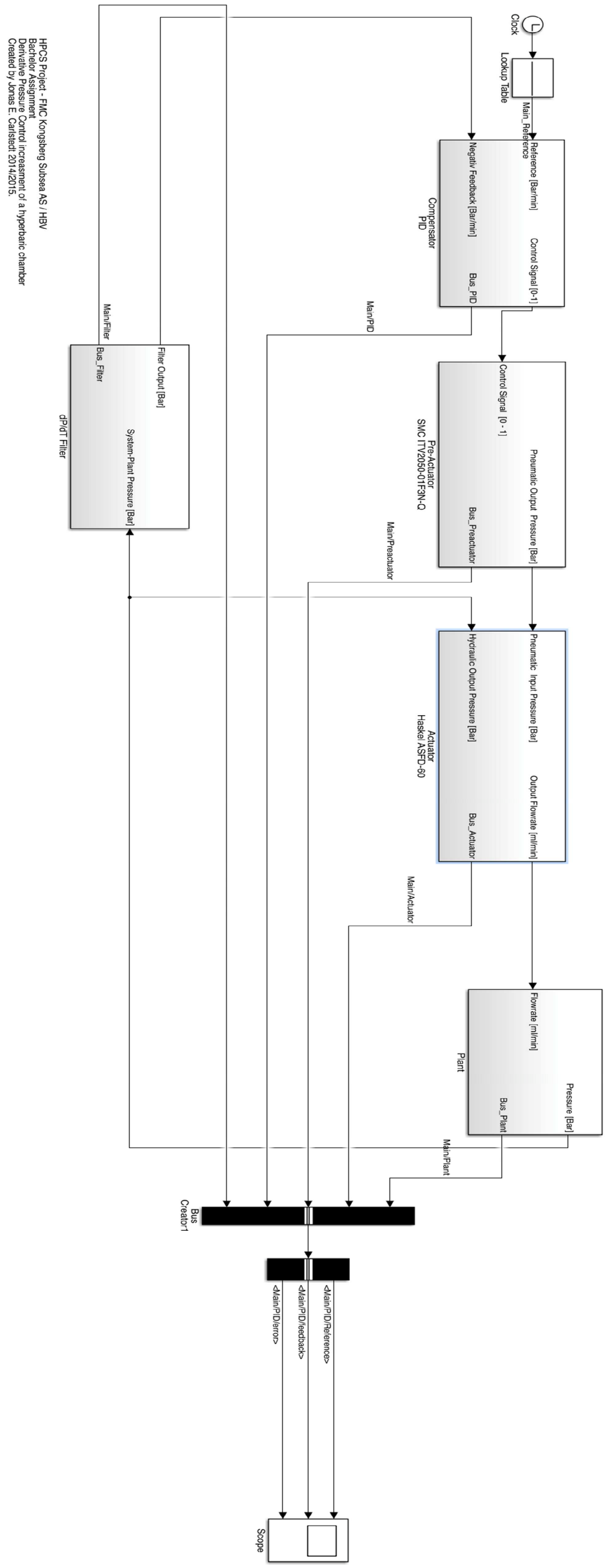

Figure 10 - Shows the outline of the pressure increase control loop simulation

The signal-flow between each sub-system showed in figure 10 are identical to the signal-flow represented with block schematics in figure 2 with one exception; the actuator (Haskel ASFD-60) is dependent of the pressure in the plant. A signal that represent the plant pressure is taken back to the actuator.

The reference signal to the control-loop that we want the system to follow, is created with a lookup-table with the simulation time as the input parameter. Depending on the simulation time and the data contained in the lookup-table, the output of the lookup-table is the tracking reference for this control-loop.

The appropriate algorithm chosen for this simulation is the ODE 23t, which is a variable time-step solver included in Simulink. This algorithm is suitable for differential-algebraic equations (DEA). The maximum time-step is configured to be 1 second, while the minimum time-step is set to auto. With the minimum time-step set to auto, Simulink evaluates how fast the signals are changing to determine each time step in the simulation for increased accuracy.

5.1. Bus Topology

Each sub-system have their own signal bus which is then multiplexed together in a way that makes it easy to choose which signal we want to see in the scope after the simulation is carried out.

- Main/Plant
    - Main/Plant/Flowrate
    - Main/Plant/Acc.Flow
    - Main/Plant/HydraulicPressure

- Main/Actuator
    - Main/Actuator/PneumaticFlowEstimator
        - Main/Actuator/PneumaticFlowEstimator/Acc.Flow
        - Main/Actuator/PneumaticFlowEstimator/Flowrate
    - Main/Actuator/PneumaticPressure
    - Main/Actuator/HydraulicPressure
    - Main/Actuator/Flowrate
    - Main/Actuator/Flowrate&Discontinuty
    - Main/Actuator/Discontinuty
        - Main/Actuator/Discontinuty/CorrectionGain
        - Main/Actuator/Discontinuty/IntegratorStateNormalized
        - Main/Actuator/Discontinuty/IntegratorState

- Main/Pre-Actuator
    - Main/Pre-Actuator/ControlSignal
    - Main/Pre-Actuator/PneumaticPressure

- Main/PID
    - Main/PID/Error
    - Main/PID/Compensation
    - Main/PID/Feedback
    - Main/PID/Reference

- Main/Filter
    - Main/Filter/Input
    - Main/Filter/Output

5.2. Compensator

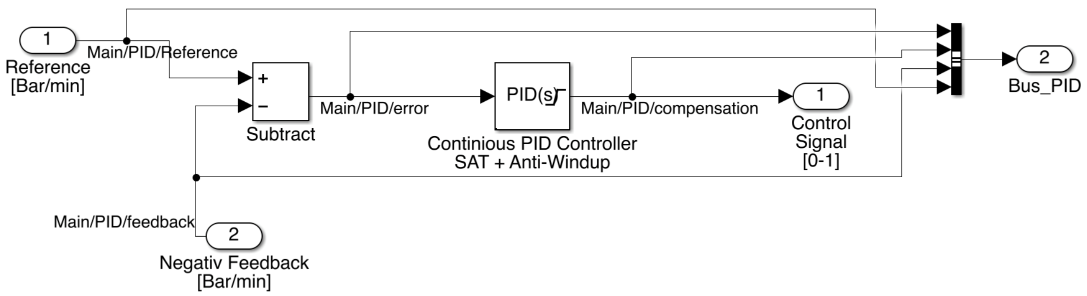

Figure 11 - Shows the Compensator subsystem

The compensator system is based on a saturated continuous parallel PID controller which is equipped with an anti-wind-up function.

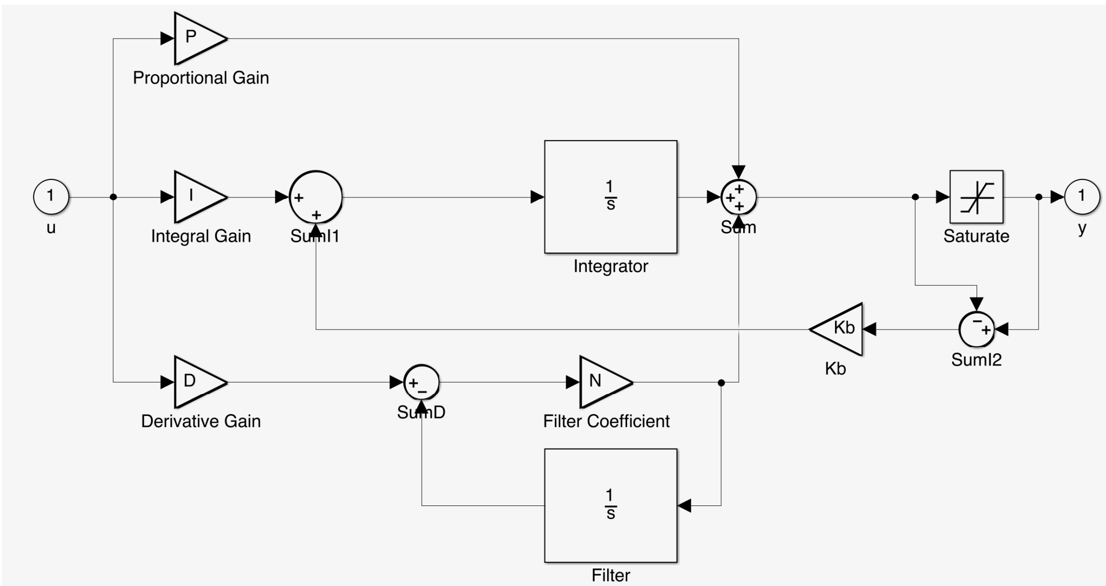

Figure 12 - Shows the Continuous PID controller

5.2.1 Anti-Wind-Up

The anti-wind-up function is implemented using back-calculation. The difference between the input and the output on the saturation block on the output stage of the controller is fed back before the integral part of the controller through gain block Kb.

The reason why we use an anti-wind-up function is that the controller is not "aware" of the limitations associated with the actuation of the system, so when we saturates the output of the controller to 0 – 1, the integrator accumulates, and gives an actuation that is not possible to perform for the actuator. Another scenario that comes to mind is that a sudden change in the reference signal will result in a very high actuation as well. Both scenarios can be interpretended as non-linearity's which will accumulate the integrator state.

5.2.2 Filtered Derivative

$$Ideal\ Derivative\ Operator = DS$$

Equation 1 - Ideal Derivative Operator

$$Ideal\ Compensator\ Formula = P + I\frac{1}{S} + DS$$

Equation 2 - Ideal Compensator Formula

The derivative part of the controller is implemented using an integrator and a filter gain coefficient. This is because the ideal derivative action have very high gain for high frequencies (measurement noise or white noise etc.). We want the derivative operator to be slower and act more like a low pass filter. This is done with the approximation given in equation 3.

$$Filtered\ Derivative\ Operator\ = D\frac{N}{1 + N\frac{1}{S}}$$

Equation 3 - Filtered Derivative Operator

Which yields,

$$Compensator\ Formula = P + I\frac{1}{S} + D\frac{N}{1 + N\frac{1}{S}}$$

Equation 4 - Compensator Formula

The pole location of the filter is placed by changing filter coefficient N.
This implementation gives the high-frequencies a constant gain, while acting like a derivative operator on the low-frequencies.

$$Compensator\ Formula = P + I\frac{1}{S} + D\frac{N}{1 + N\frac{1}{S}}$$

P	=	0.00021098846312487
I	=	0.000168332169898204
D	=	5.70633775688233e-05
N	=	18.6910115958332

The values above are determined using the PID-tuner tool box in Simulink. The corresponding values gives us the step response plotted in figure 13.

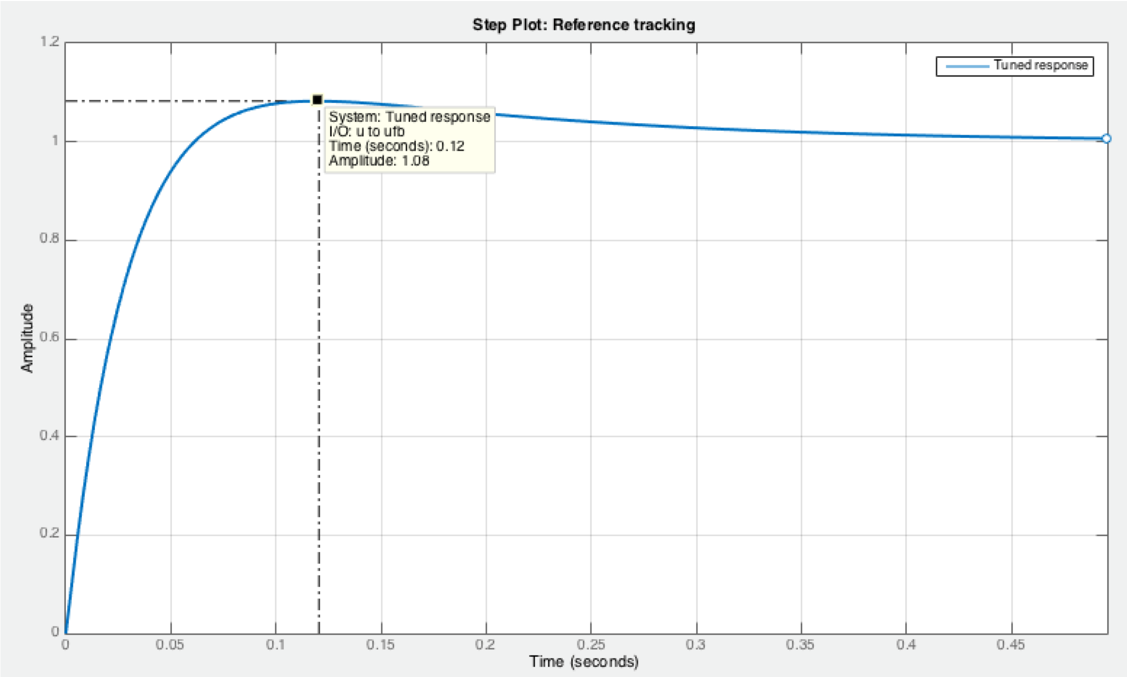

Figure 13 - Response from the compensator with the tuned parameters

The step response plotted in figure 13 above have a rise-time approximately 0.1 seconds. The plot shows also that the compensation is causing a slight overshoot without any steady state error.

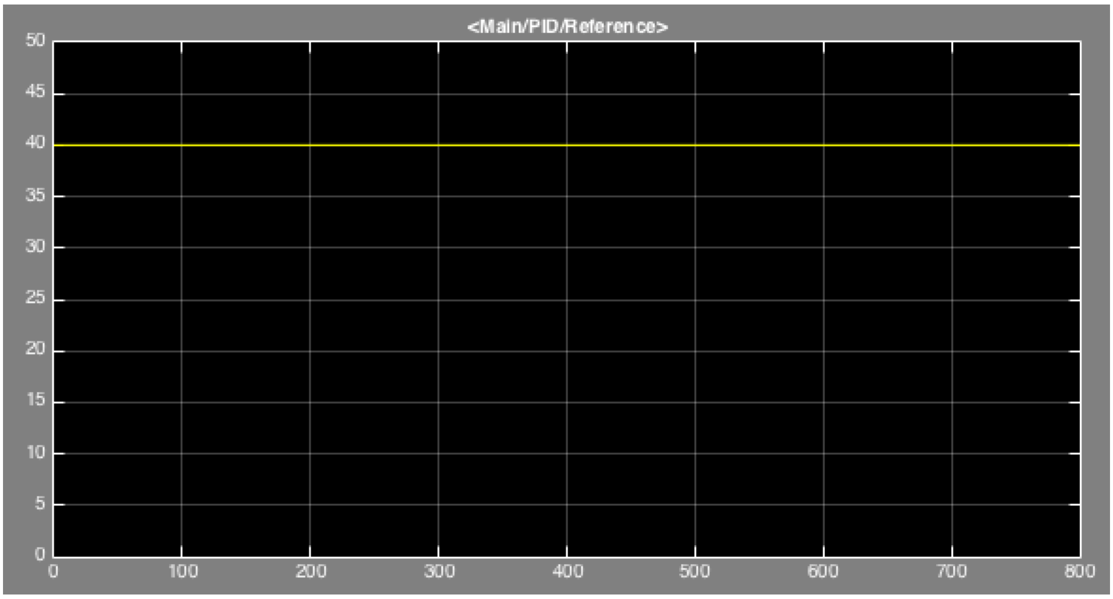

Figure 1 - Shows that the reference signal is 40 bar/min throughout the simulation

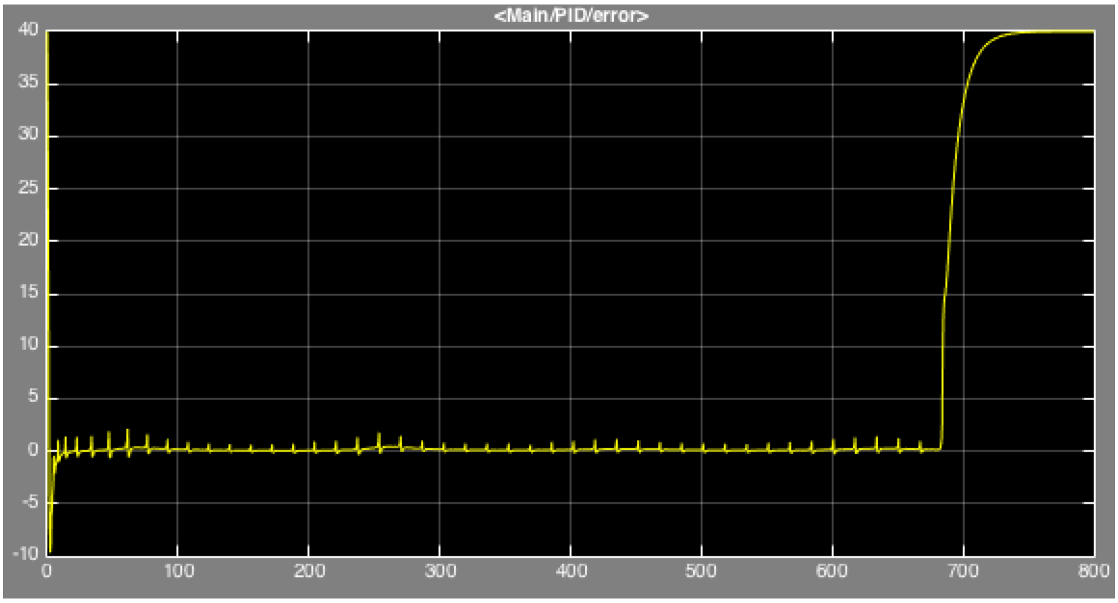

Figure 14 - Shows the error signal after the reference and the feedback signal is compared

The simulation shows that the error signal to the compensator is kept around zero. Right before 700 seconds, the error signal increases. This is because the actuator is saturated, and can`t keep up with the 40 bar/min pressure increase after the pressure in the hyperbaric chamber reaches 450 bar.

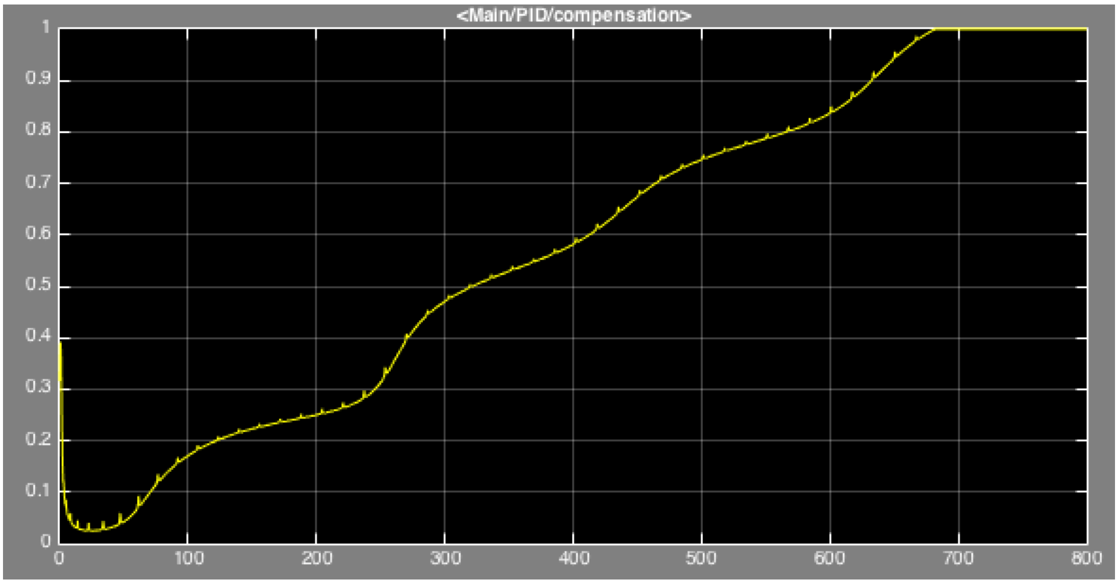

Figure 16 - Shows the compensations signal with respect to the time in seconds

Figure 16 is showing the control compensation signal needed to maintain linearity while increasing 40 bar/min.

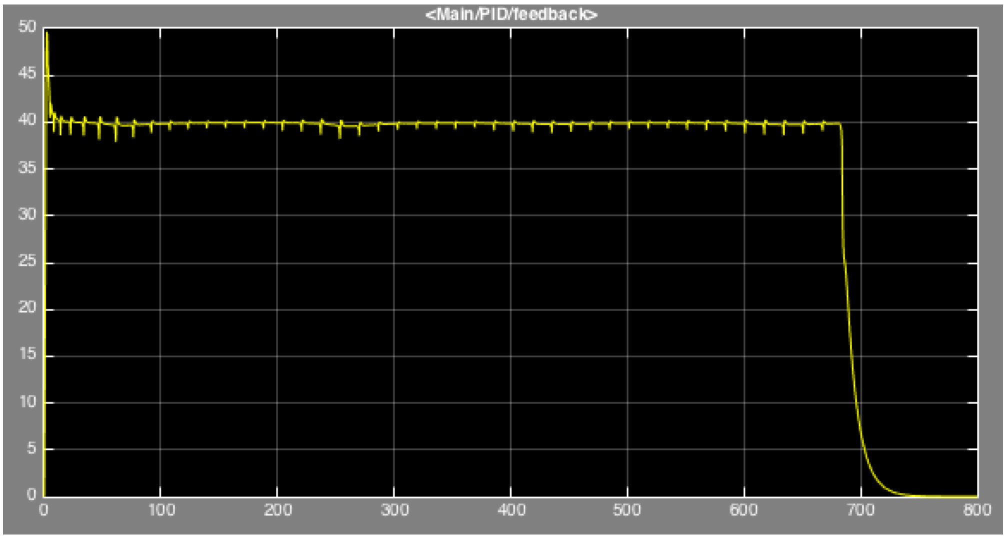

Figure 15 - Shows the feedback signal from the filter to the compensator.

From figure 17, we can see that the system is tracking the reference well. The feedback signal tells us that the pressure is increasing 40 bar/min with some minor deviations.

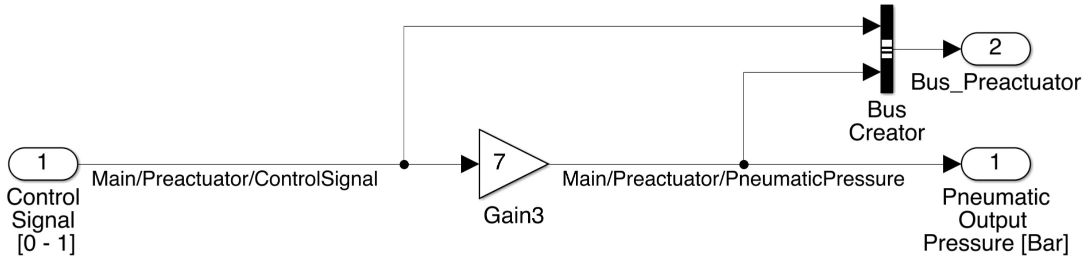

Figure 16 - Shows how the pre-Actuator is made in Simulink.

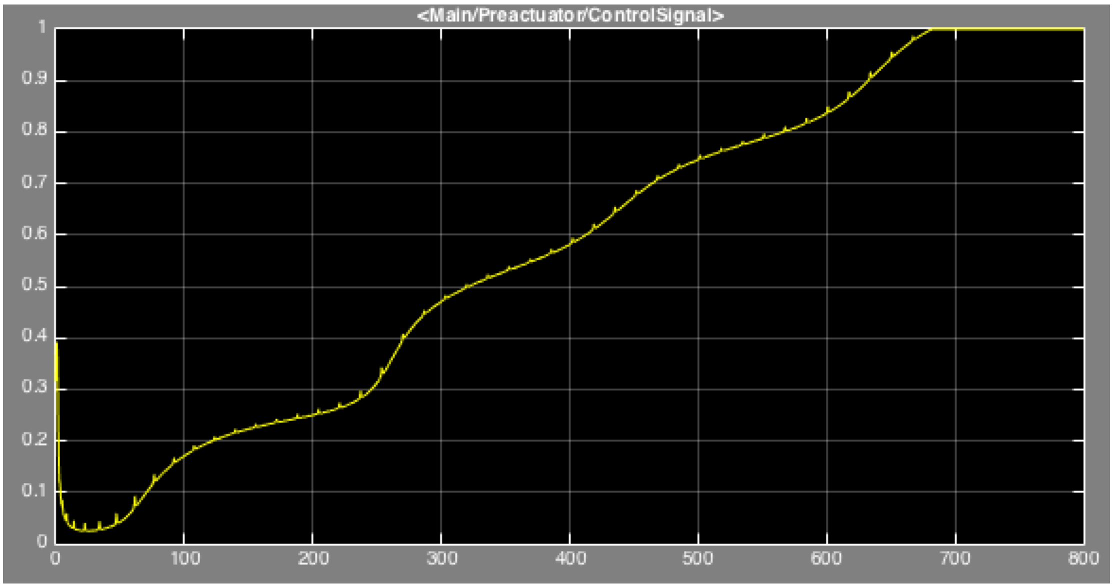

Figure 17 - Shows the electrical input signal to the pre-actuator

The Pre-Actuator is modeled as an ideal component. When the normalized control-signal enters the pre-actuator, it get multiplied with a gain factor of 7. This is because the pneumatic supply pressure that is available in most workshops often is limited to 7 bar. In figure 19, we can see the input signal to the pre-actuator.

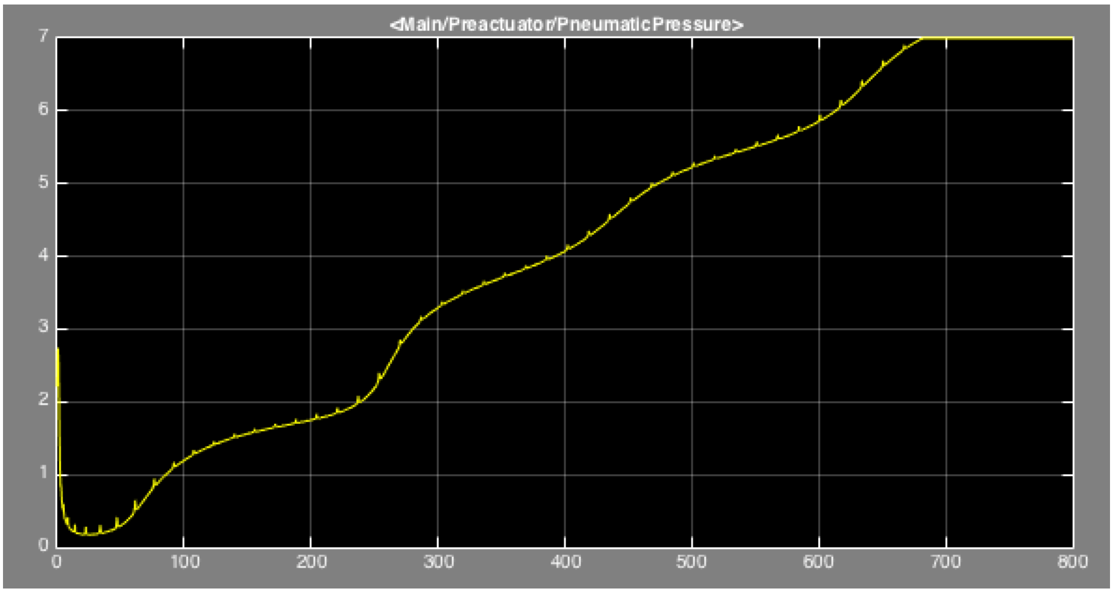

Figure 18 - Shows the actuation form the pre-actuator.

Since the pre-actuator is modeled as an ideal component, the curve in figure 20 and figure 19 is a proportional copy of each other. Figure 20 is showing the pneumatic output pressure of the pre-actuator.

5.4. Actuator

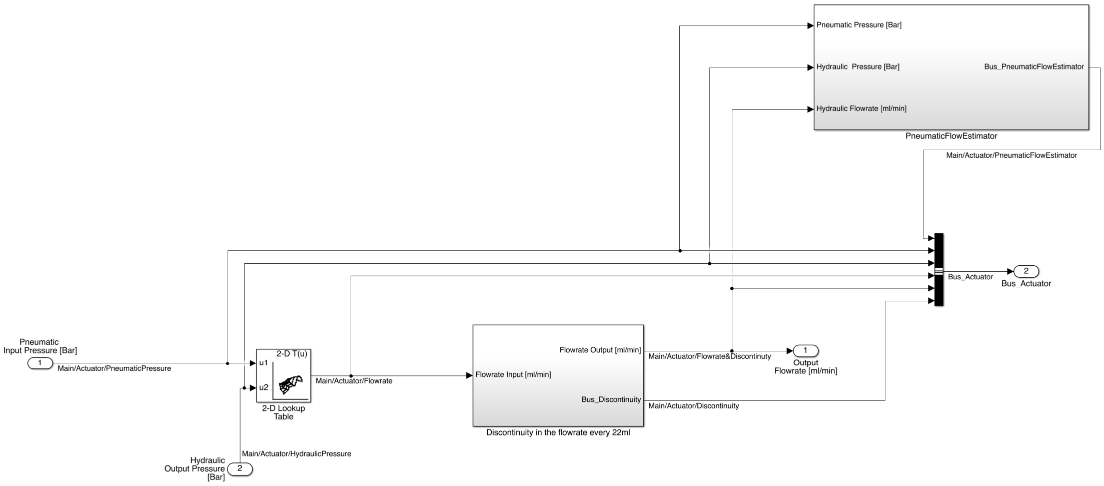

Figure 19 - Shows how the actuator is made in Simulink.

The pneumatic pressure measured in bars is the input for this system. The output is a flowrate measured in ml/min. The pneumatic pressure that enters the input gate of the actuator, and the hydraulic pressure on the output of the actuator determines the flowrate out of the 2D-lookup table. The data in this lookup table is the same as described in the 3D flow model of the Haskel ASFD-60 Hydraulic Pump previously in this document. This flowrate is then corrected with a discontinuity in the flow rate by the discontinuity subsystem. The actuator system is also equipped with a pneumatic flowrate estimator which indicates the air usage of the actuator.

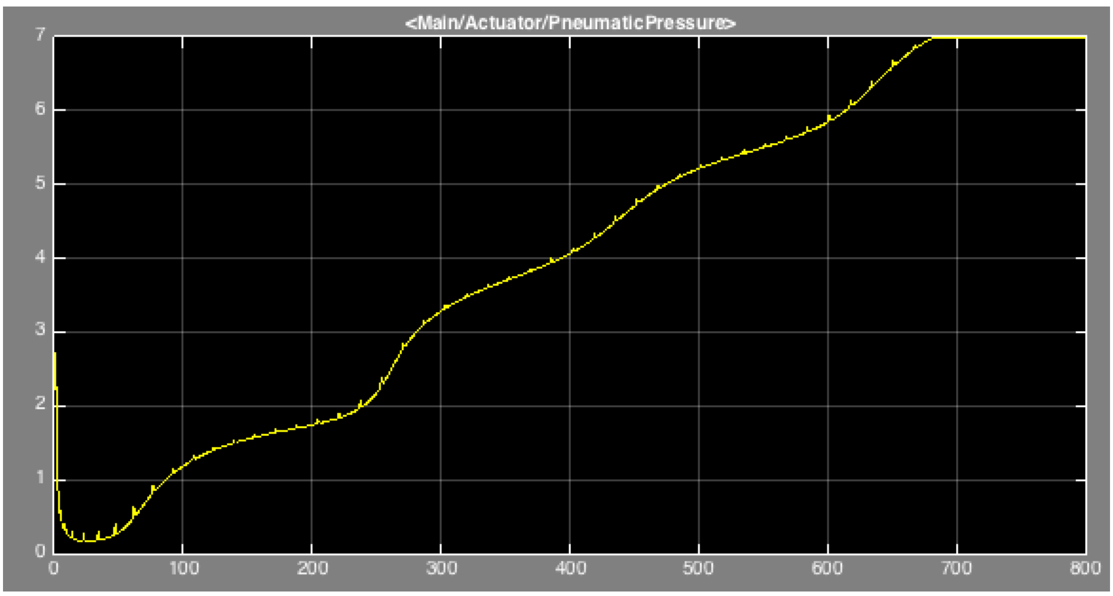

Figure 20 - Shows the pneumatic input pressure to the actuator.

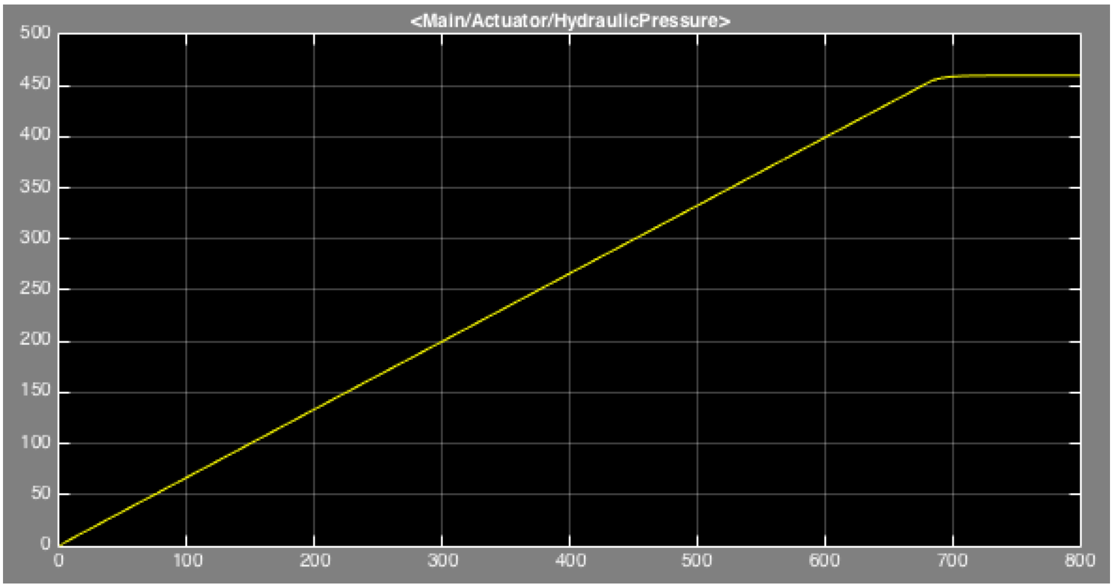

Figure 21 - Shows the hydraulic output pressure from that the actuator is causing on the hyperbaric chamber.

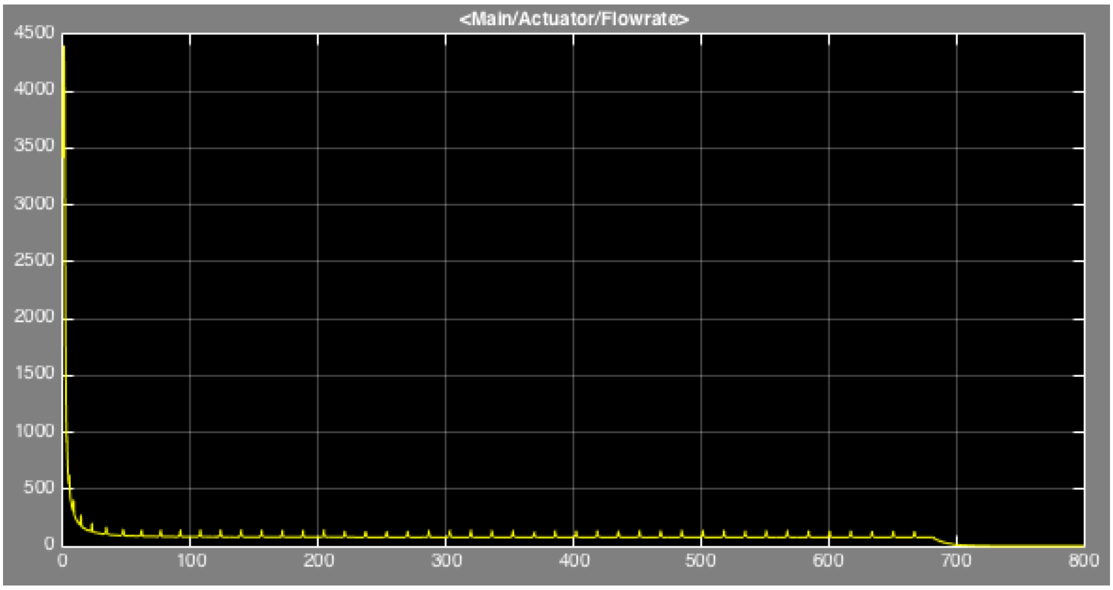

Figure 22 - Shows the supplied flow from the actuator.

5.4.1 Flow Discontinuity

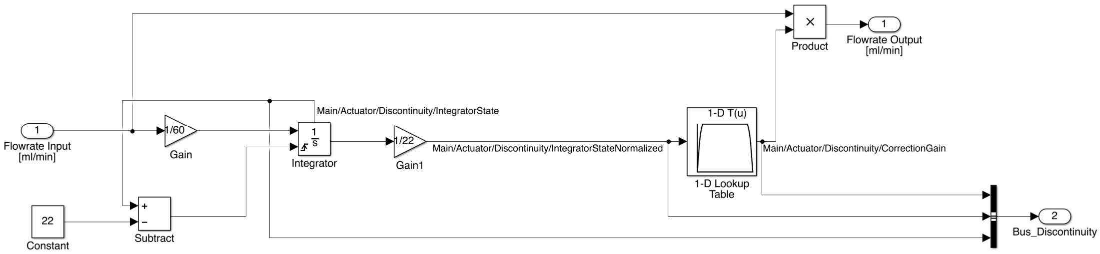

Figure 23 - Shows the discontinuity system inside the actuator system.

The flow rate from the 2D-lookup table is accumulated with respect to time, where the unit is seconds. The input signal is in the unit ml/min, so it is necessary to divide this signal by 60 to get appropriate input to the integrator (ml/s). This is because the time unit in the simulation is in seconds. The integrator will then be reset when it accumulates 22ml, which equals one compression stroke for the actuator. The signal from the integrator is then normalized by dividing by 22, resulting in a signal that oscillate with same time period as the piston moves inside the actuator. This signal is the input for a lookup table with data given in table 2, and plotted in figure 26. The output of the lookup table is then multiplied with the input flowrate, which corrects the flowrate with a reduction of flow supplied in the start and the end of each compression stroke. It is important to note that this correction is completely arbitrary and is not based on any documentation supplied by the manufacture. The assumption of the correction is selected from earlier experience with actuators like this, and by dialog with Proserv AS.

	Acc. Volume pr. stroke normalized	Correction Factor
1.	0	0.5
2.	0.02	0.7
3.	0.04	0.8
4.	0.06	0.9
6.	0.08	0.95
7.	0.1	1
8.	0.9	1
9.	0.92	0.95
10.	0.94	0.9
11.	0.96	0.8
12.	0.98	0.7
13.	1	0.5

Table 2 - Shows the data in the lookup table in the discontinuity system

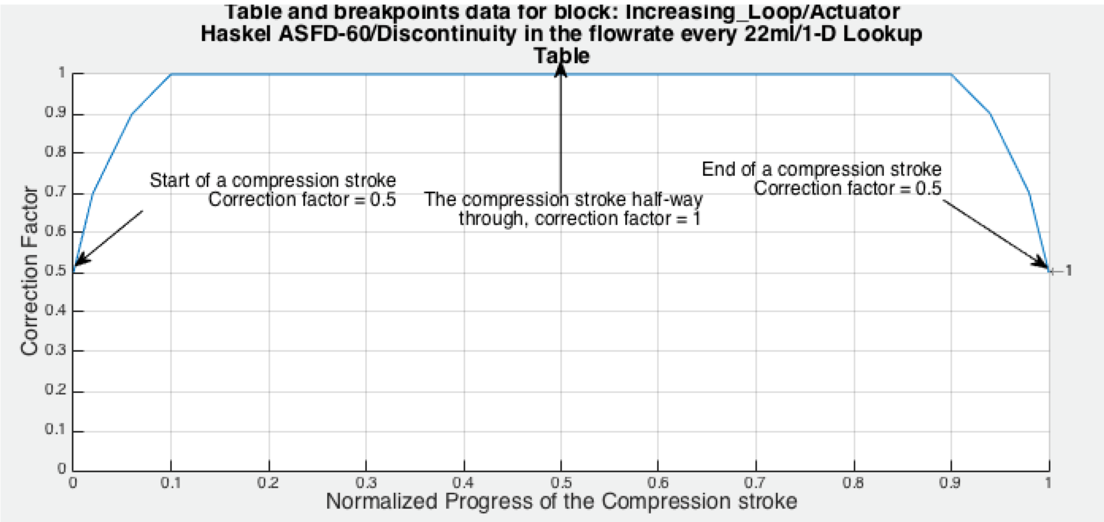

Figure 24 - Plots the data in the lookup table in the discontinuity system.

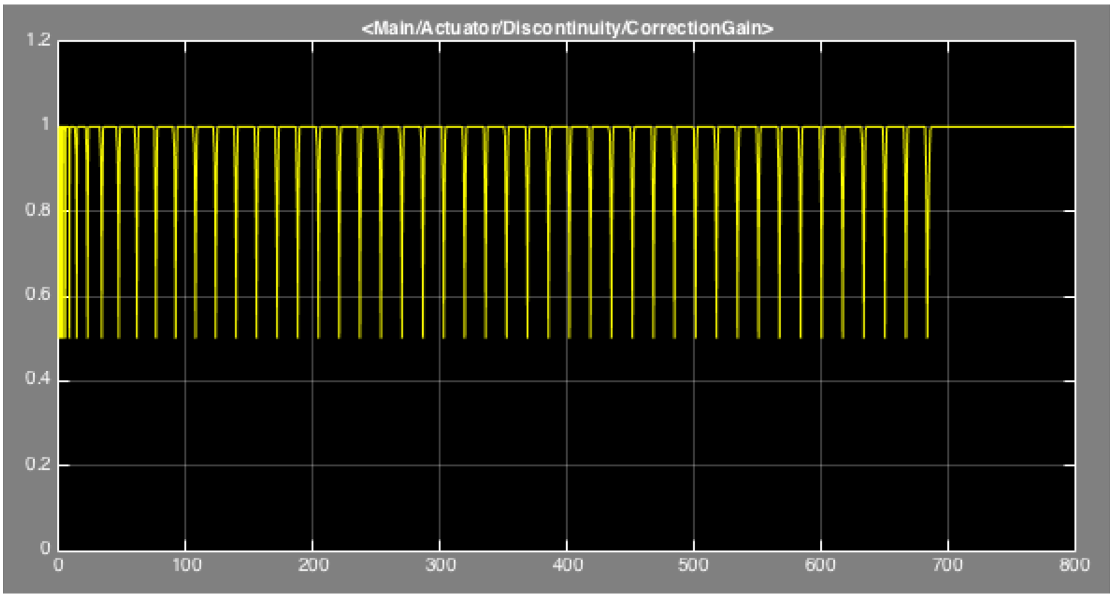

Figure 25 - Shows the correction gain that simulates the discontinuity that occurs every 22ml supplied from the actuator.

Figure 27 shows the correction gain that changes the flow given by the lookup table. One period of the signal corresponds to one compression stroke.

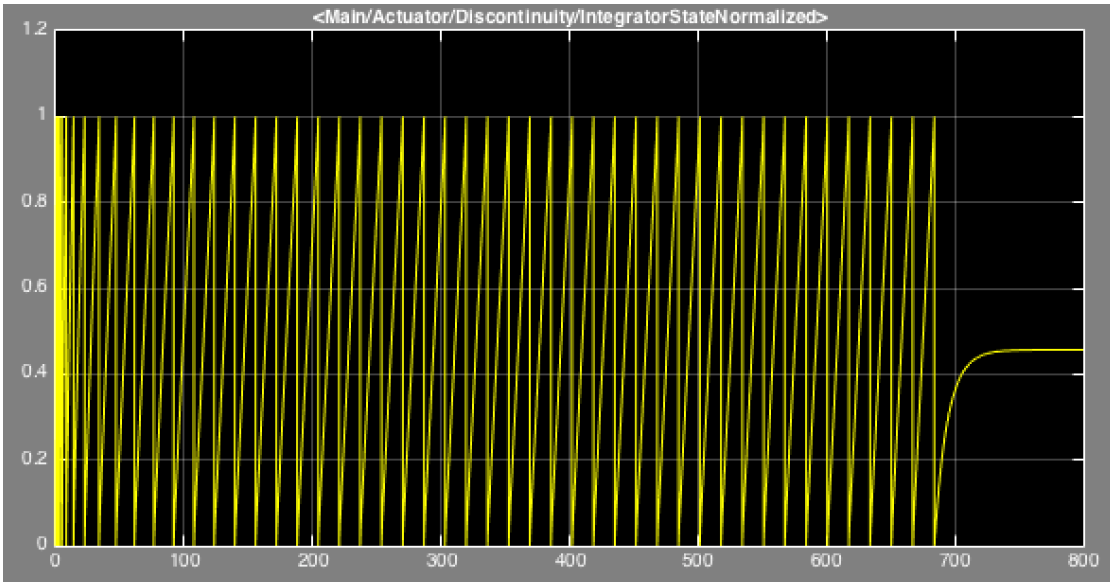

Figure 26 - Shows the integrator state in the discontinuity function.

Figure 28 shows that the last compression stroke stops at approximately 45 %. At this point, the maximum pneumatic pressure is reached (7 bar), and the hydraulic piston and the pneumatic piston reach an equilibrium.

5.4.2 Pneumatic Flowrate Estimator

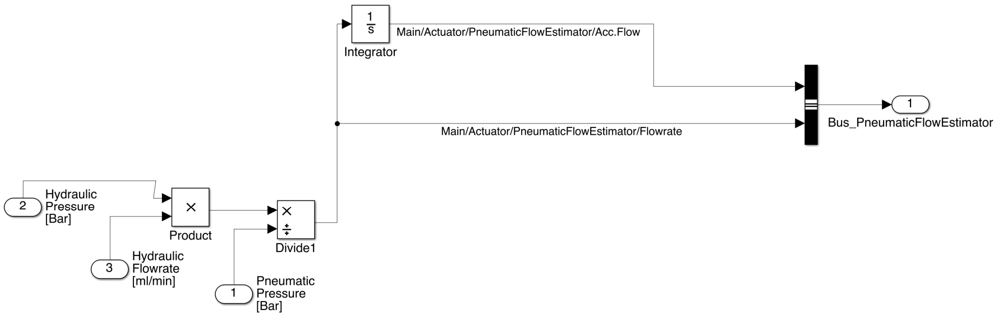

Figure 27 - Shows how the flowrate estimator system is made in Simulink.

The estimator is based on Boyle`s gas law which states that:

$$P_1V_1 = P_2V_2$$

Equation 5 - Boyle`s Gas Law

Which yields how the pressure of a gas tends to decrease as the volume of a gas increases.

$$V_1 = V_2\frac{P_2}{P_1}$$

V_1 = Pneumatic Flowrate
V_2 = Hydraulic Flowrate
P_1 = Pneumatic Pressure
P_2 = Hydraulic Pressure

Since V_2 is the hydraulic flowrate instead of a volume, V_1 will be the pneumatic flowrate. This is a modification from the Boyles law, and is only an estimate of how much air the actuator consumes. This is the ideal amount of air it takes to deliver the hydraulic flow from the actuator, so the actually air flowrate is probably higher due to air consumed by the internal valves inside the actuator. The internal valves are used to switch between the compression stroke and the suction stroke. The output of the estimator is not used directly in the simulation, but is a nice indicator for dimensioning of the pre-actuator. To make the simulation more realistic, the signal caring the pneumatic flowrate used by the actuator could be fed back to the pre-actuator to give the pre-actuator a realistic characteristic instead of an ideal characteristic used in our simulation.

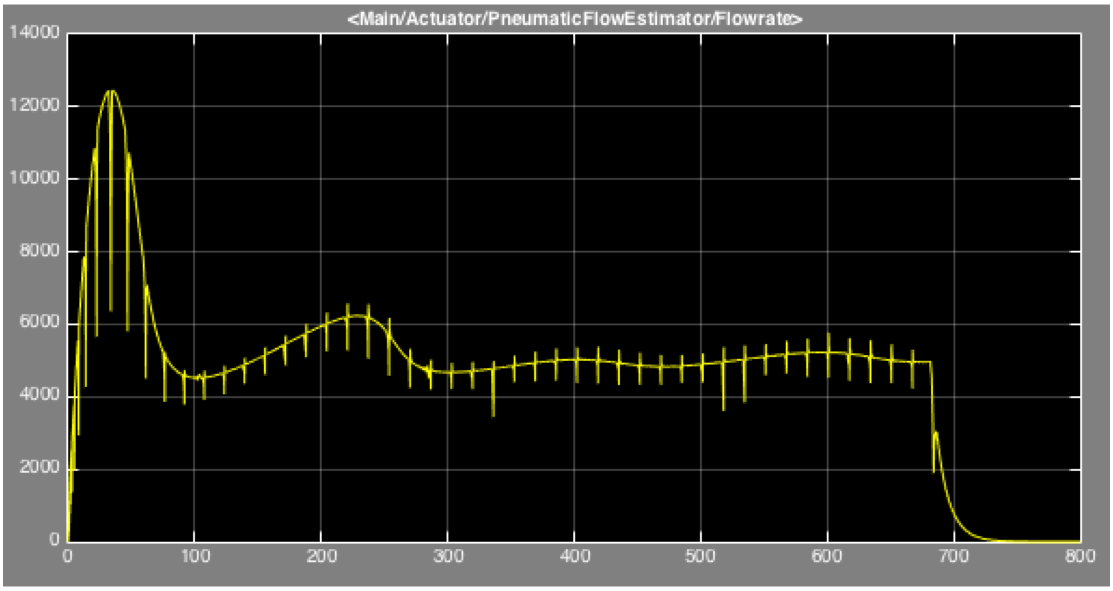

Figure 28 - Shows the estimated pneumatic flowrate.

5.5. Plant

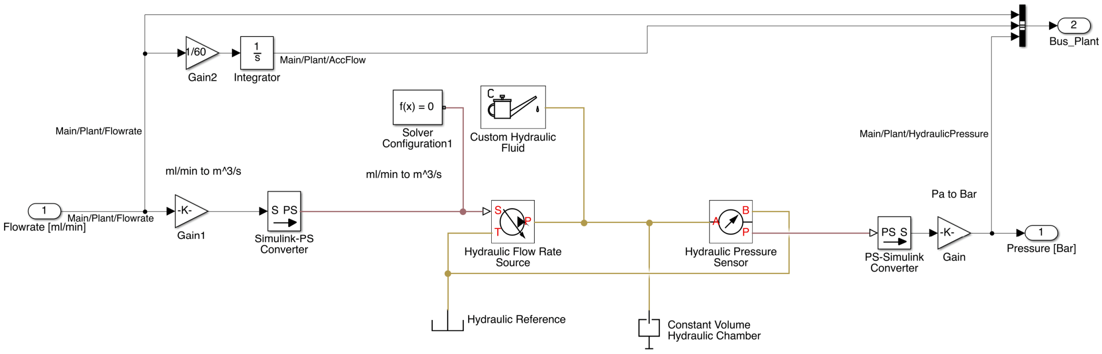

Figure 29 - Shows how the plant is built in Simulink.

The plant is made from objects in Simscape, which is a physical domain component library for Simulink. The difference between a Simulink and a Simscape signal is that a Simulink signal is dimensionless, while a Simscape signal could be like in this case, pressure, measured in Pascal. MathWorks, which is the developer of Matlab, Simulink & Simscape, have created a own programming language for Simscape which is object oriented, and looks very much like Matlab code. This let us create objects like the figure 31 is showing.

The interface between a Simulink signal and a Simscape signal is made with converting blocks. In our plant, the Simulink input signal showed in figure 19, is a dimensionless signal that carries the hydraulic flowrate in unit ml/min. It is scaled to the unit m^3/s which is supported by simscape, and then converted into a hydraulic domain signal. This signal enters an ideal hydraulic flowrate source, which then supplies a flow to a constant volume chamber. The result of this is a pressure increase in the constant volume chamber which is measured with a hydraulic pressure sensor. The signal from this sensor have Pascal as the unit, and is converted back to a Simulink signal. This signal is then scaled back to bar before reaching the output of the plant. The constant volume hydraulic chamber is set to have an initial volume of 42 liters. Simscape are not using the global ODE algorithm to solve the simulation linked with the Simscape objects like for the rest of the simulation. A block named "Solver configuration" is used to set up the Simscape solver with correct parameters.

The simulated fluid is water, with standard parameters (given below) configured with "Custom hydraulic fluid" block.

- Fluid density: 999kg/m^3
- Kinematic viscosity: 1.004e-6 m^2/s
- Bulk modulus: 2.2e9 Pascal
- Relative amount of trapped air: 0.005

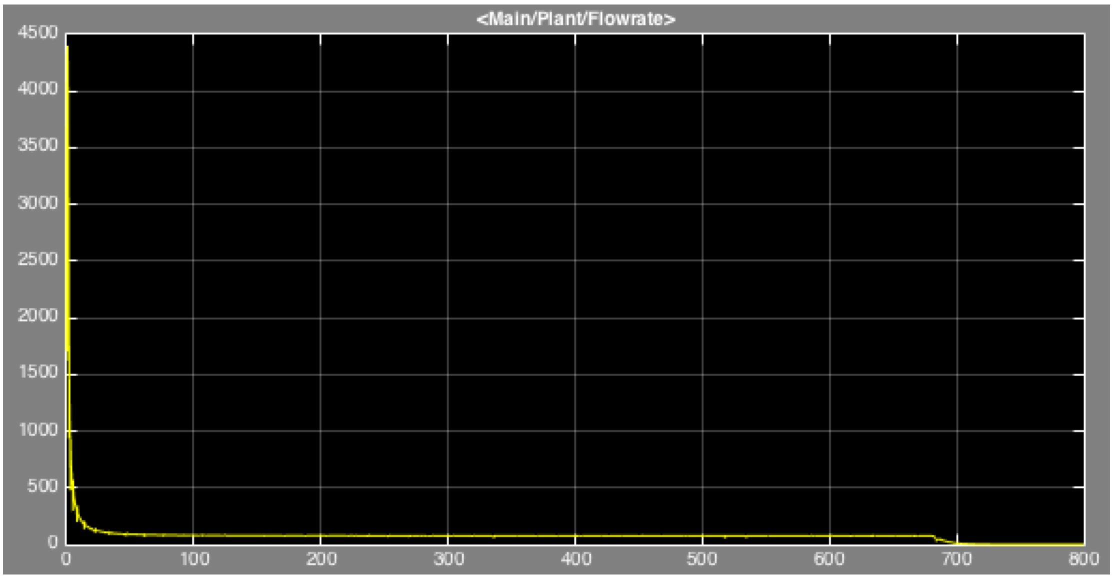

Figure 30 - Shows the hydraulic flowrate that enter the hyperbaric chamber.

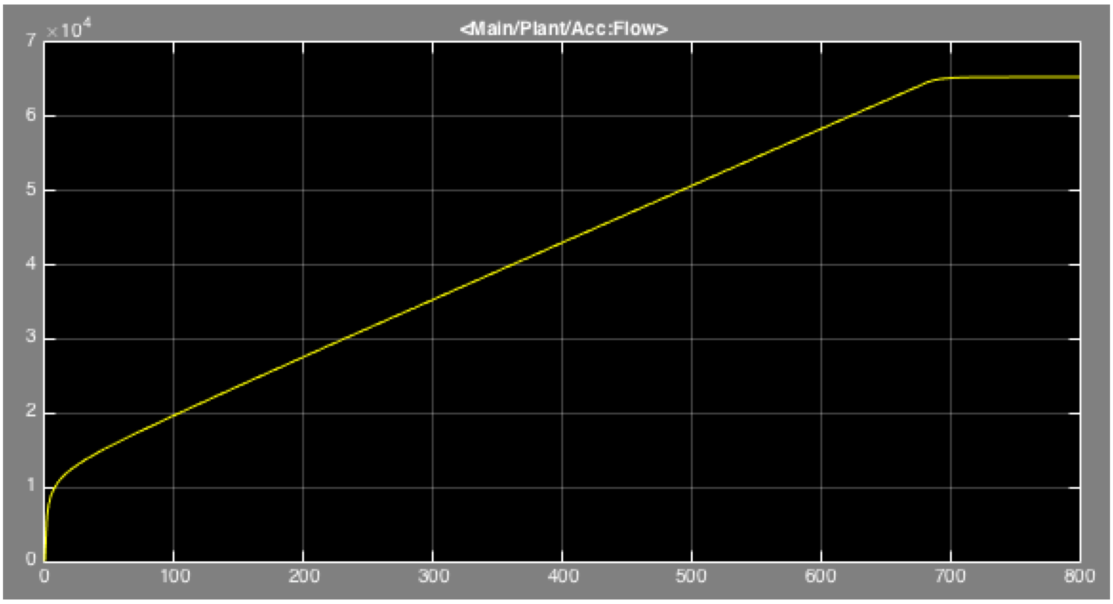

Figure 31 - Shows the accumulated hydraulic volume that enter the hyperbaric chamber.

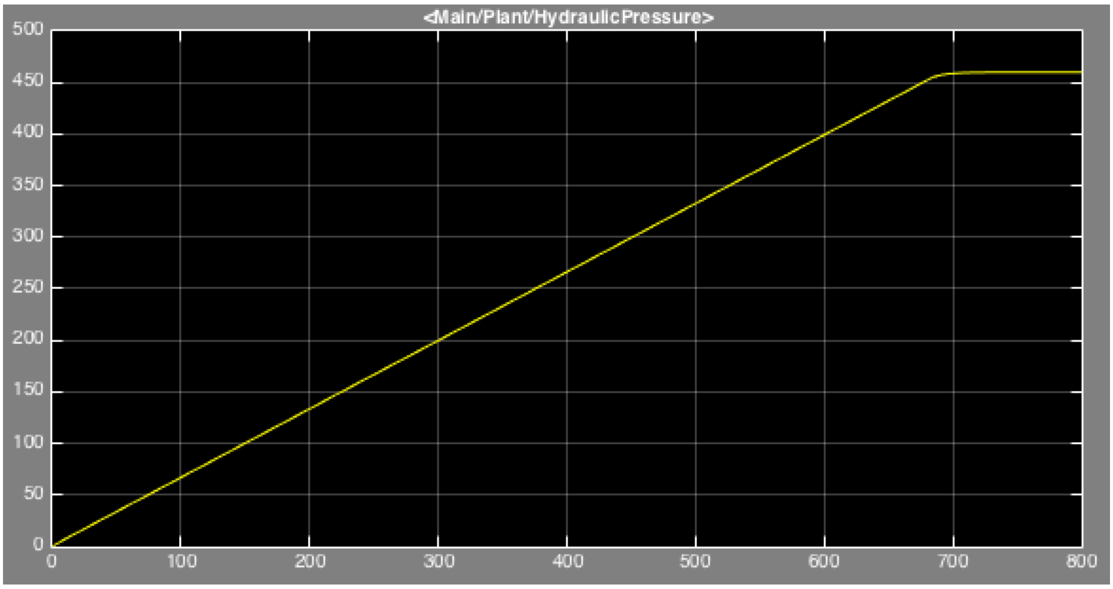

Figure 32 - Shows how the pressure increase in hyperbaric chamber.

5.6. Derivative Operator / Filter

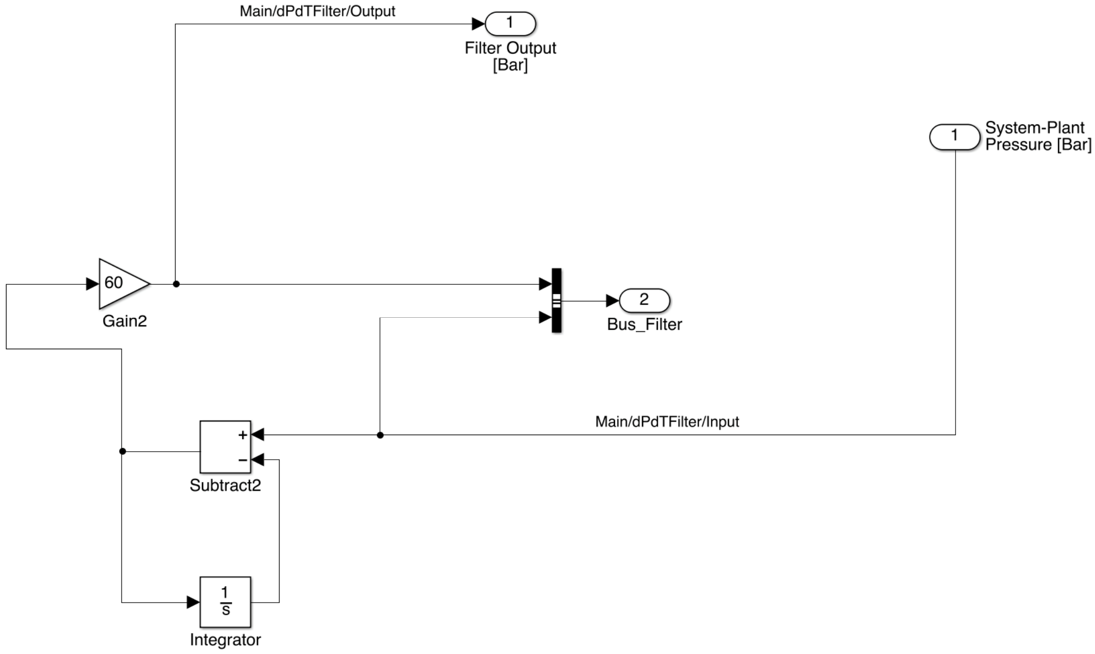

Figure 33 - Show how the Derivative Operator and the filter is built in Simulink.

We are using a filtered derivative operator to implement the derivative operator and the filter. This is the same technique used for implementing the filtered derivative part of the PID controller described earlier in this document.

5.6.1 Demonstration of Derivative Filtering

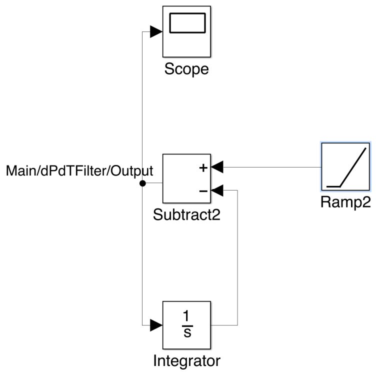

Figure 34 - Demonstrates Derivative filtering.

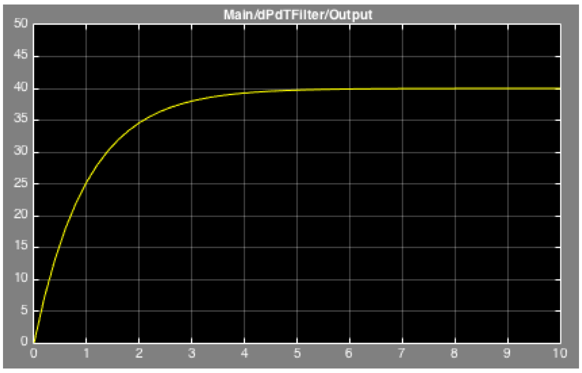

Figure 35 - Plots the output signal from figure 21.

In figure 38 we have given the filter a ramp input with a slope of 40. The response are plotted in figure 39, and we can see that the system have a rise time of approximately 3 seconds without any overshoot or steady state error.

5.6.2 Demonstration of filtered derivative with white noise

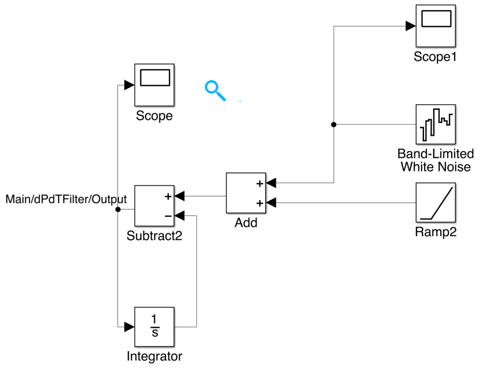

Figure 36 - Demonstrates filter derivative with white noise superimposed.

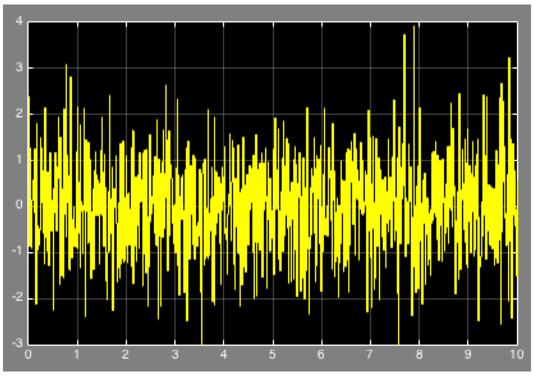

Figure 37 - Plots the white noise introduced in figure 40.

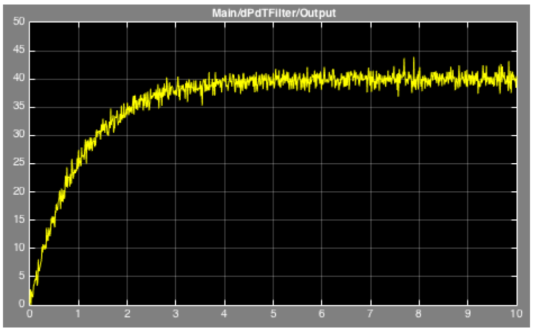

Figure 38 - Plots the output signal from the filtered derivative with superimposed white noise.

In figure 40 we have superimposed a bandlimited white noise signal to the ramp signal. The white noise is plotted in figure 41, and figure 42 shows the output of this system. We can see that the white noise does not affect the information the signal is carrying. The filter acts like a derivative operator on the low frequency components while giving the high frequencies a constant gain. The rise time, overshoot and steady state error is still the same as in the demonstration of the derivative filter where the white noise was not introduced yet.

5.6.3 Demonstrates of an ideal derivative filter

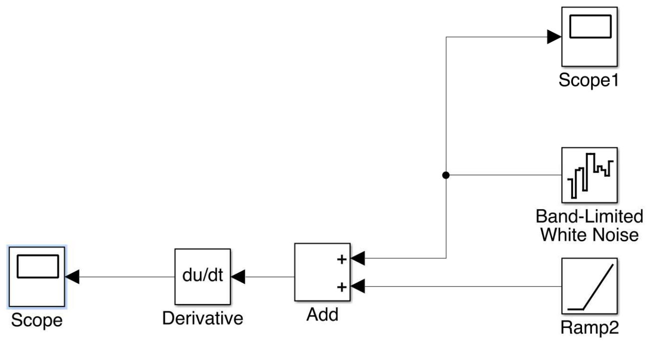

Figure 39 - Demonstrates an ideal derivative filter.

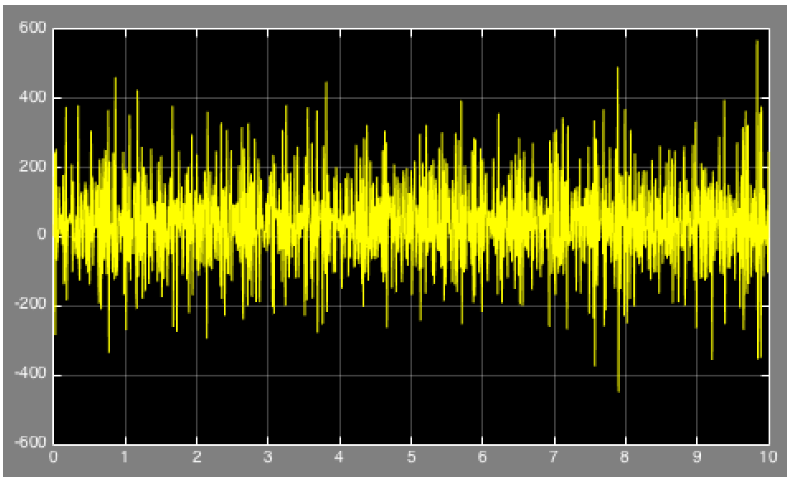

Figure 40 - Plots the ideal derivative filter.

This demonstrates why we cannot use an ideal derivative filter. A derivative operator is extremely sensitive to noise, and the output of the system is totally demolished down by the noise as we can see by signal plotted in figure 44.

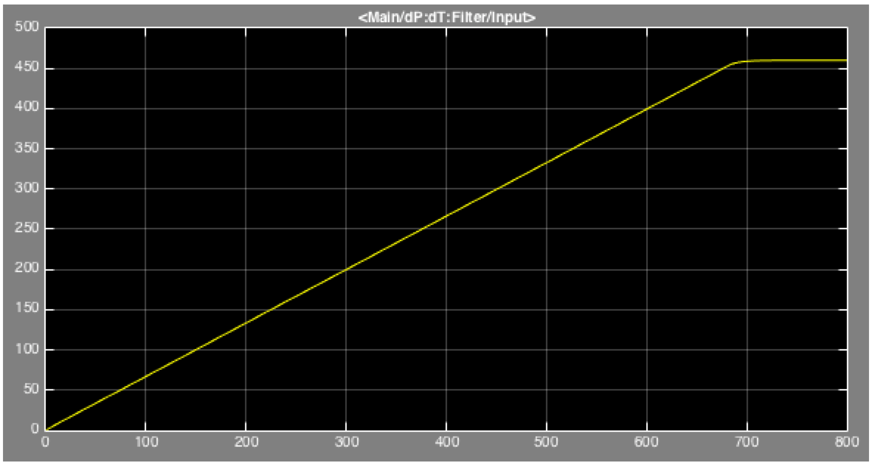

Figure 41 - Shows the pressure from the hyperbaric chamber, which is the input for the derivative filter.

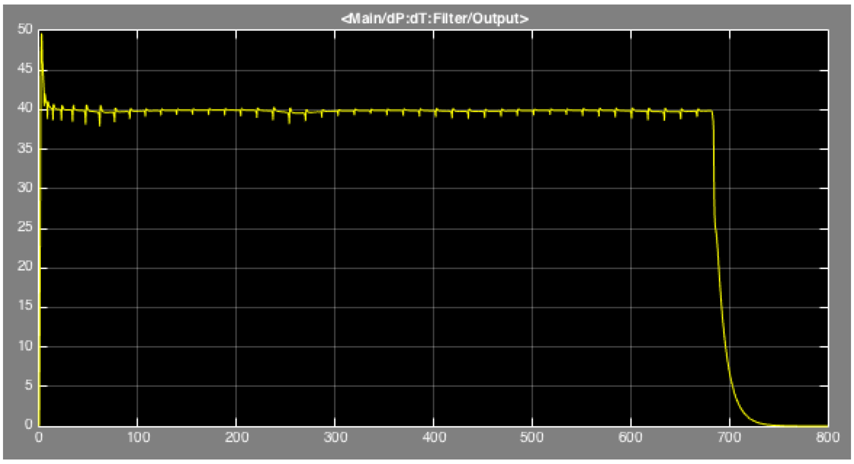

Figure 42 - Shows the output of the derivative filter that is used for feedback for the compensator.

References

[1] G. F. Franklin, Feedback Control of Dynamic Systems, Sixth Edition ed., New Jersey: Pearson, 2010.

[2] L. Ferrer-Arnau, "Operators to calculate the derivative of digital signals," 18 7 2013. [Online]. Available: http://upcommons.upc.edu/e-prints/bitstream/2117/22001/1/imeko_Ferrer.pdf. [Accessed 1 10 2014].

[3] Haskel International LLC, "Haskel," 01 03 2012. [Online]. Available: http://liquidpumpcatalog.haskel.com/pdf/LP-9.pdf. [Accessed 01 01 2015].

[4]

[5] D. Honeywell, "PID Control," 2000. [Online]. Available: http://www.cds.caltech.edu/~murray/courses/cds101/fa04/caltech/am04_ch8-3nov04.pdf.

[6] Unknown, "Boyle's law," 30 March 2015. [Online]. Available: http://en.wikipedia.org/wiki/Boyle's_law.

[7] Mathworks, Director, *PID Control Made Easy - Simulink Webinar.* [Film]. 2015.

[8] Prof. Bill Messner, "Aircraft Pitch: PID Controller Design," 1 January 2012. [Online]. Available: http://ctms.engin.umich.edu/CTMS/index.php?example=AircraftPitch&section=ControlPID. [Accessed 1 January 2015].

Hyperbaric - Pressure Control System

Bill of Material

Group:
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Brian Berg

Document author: Thor Ove Skarseth

ID: BOM-001 <D>

Revisions

Date	Description	Version	Made By	Approved By
17.01.2015	Bill of material	-	TOS, BB	
09.03.2015	Add more components, and update tags and prices	A	TOS, BB	
21.03.2015	Turn BOM documents in horizontal view, added some delivery times and updated suppliers	B	TOS, BB	
02.04.2015	Added more supplier part numbers	C	TOS, BB	BB, JN, AS
09.05.15	Update of prices, spell correction.	D	TOS, JN	BB,JC

Table 1 - Revisions

Table of Contents

Table list

Abbreviation list

Abbreviation	Explanation
FMCTI	FMC Technologies
HBV	Høgskolen i Buskerud/Vestfold
BOM	Bill Of Material
HP	High Pressure

Table 2 - Abbreviations

1.0 BOM

1.1. Hydraulic BOM

Pos. ID:	Description	Supplier	Price	Delivery time	Part number
V-001	Ball valve 1"	Tess	165	N/A	93742-16
V-002	Ball valve 1"	Tess	165	N/A	93742-16
V-003	Ball valve 1"	Tess	165	N/A	93742-16
V-005	Relief valve(Return line)	N/A	N/A	N/A	N/A
V-006	Relief valve(Pressure line)	Bis valve's	4500	14 weeks	RL-37
V-007	Pneumatic-Needle valve(Air to open)	Autoclave	6940	14 weeks	20SM6071-O1S
V-008	Pneumatic-Needle valve(Air to open)	Autoclave	6940	14 weeks	20SM6071-O1S
V-009	Pneumatic-Needle valve(Air to open)	Autoclave	6940	14 weeks	20SM6071-O1S
V-010	Pneumatic-Needle valve(Air to open)	Autoclave	6940	14 weeks	20SM6071-O1S
V-011	Micro metering valve	Autoclave	28985	14 weeks	60VRMM6812-C4
V-012	Needle valve	Tess	951	N/A	962000-06
V-013	Needle valve	Tess	951	N/A	962000-06
V-014	Needle valve	Tess	951	N/A	962000-06
V-015	Needle valve	Tess	951	N/A	962000-06
V-016	Needle valve	Tess	951	N/A	962000-06
V-017	Ball valve ¾"	Tess	115	N/A	93742-12
ESDV-001	Emergency pneumatic shutdown valve(3/2 high flow)	Elfa	2078	2 weeks	10-634-17
V-019	Control valve 3/2(air)	Elfa	340	1-2weeks	54-229-32
V-020	Control valve 3/2(air)	Elfa	340	1-2weeks	54-229-32
V-021	Control valve 3/2(air)	Elfa	340	1-2weeks	54-229-32
V-022	Control valve 3/2(air)	Elfa	340	1-2weeks	54-229-32
P-002	HP pump	Haskel	33065	14 weeks	ASFD-&60

P-003	Drain/filling pump	Froster as	7984	1-2weeks	EP MIDEX 1 ¼”
FI-001	Flow indicator	Hypteck	2920	4-5 weeks	NWS-r20-200-0070
FI-002	Flow indicator	Hypteck	2920	4-5 weeks	NWS-r20-200-0070
LT-001	Level transmitter	Elfa	3276	1-2weeks	37-607-66
LI-001	Level Indicator	Tess	100	N/A	N/A
PI-001	Pressure gauge(0-600bar)	Tess	465	N/A	96838-600
PI-002	Pressure gauge(0-600bar)	Tess	465	N/A	96838-600
PT-001	Pressure transmitter(0-500bar)	N/A	N/A	N/A	N/A
PC-001	Manual pressure regulator(air)	Tess	340	N/A	06-90034-02
PC-002	Manual pressure regulator(air)	Tess	1520	N/A	06-90034-12
PC-003	Controlled pressure regulator(air)	Elfa	5021	1week	54-236-47
F-001	Intake filter (HP pump)	Tess	1016	2weeks	CH123129 and CRFTAC91274
F-002	Intake filter(Filling pump)	Tess	1016	2weeks	CH123129 and CRFTAC91274
F-003	Ventilation filter	Tess	1400	2-3 weeks	HC0239SEE5
F-004	Intake filter HP pump (5my)	Tess	975	N/A	06-90045-12
T-001	Reservoir tank	OSO Hotwater as	N/A	N/A	N/A
T-002	Hyperbaric chamber	N/A	N/A	N/A	N/A
SUM ex. Taxes			132531		

Table 3 – Hydraulic BOM

1.2. Electrical BOM

Pos. ID:	Description	Supplier	Price	Delivery time	Part number
PS1	240V to 24VDC, 10A	Phoenix Contact	1034	N/A	69-888-17
K1	Safety Relay, 3SK1211-1BB00	Siemens	2078kr	N/A	10-828-94
X1…	Terminal Strip. Black 0.14…4 mm^2, UT 4-MT (Knife Strips)	Phoenix Contact	27.20kr	N/A	48-292-59

X1…	Terminal Strip for earth yellow/green 0.5...10 mm^2, PT 10-PE	Phoenix Contact	45.10kr	N/A	10-497-10
N/A	CEE-Power Plug 32 A/400 VAC	Bals	407kr	N/A	43-358-98
S1	Emergency Stop inside a house, LBX17501	Baco	402kr	N/A	36-050-87
N/A	Cable Connector Glans			N/A	Nipler
K2	Contactor for electro pump	Siemens	344kr	N/A	36-228-14
K2	Help switch for contactor	Siemens	153kr	N/A	36-228-32
K3	Contactor for electro pump	Siemens	344kr	N/A	36-228-14
K3	Help switch for contactor	Siemens	153kr	N/A	36-228-32
CAB-001	Surface mounted cabinet, 12506-032 800mm x 600mm x 320mm	Schroff	2362kr	N/A	10-779-78
N/A	Shrinking tube	HellermannTyton	4.15kr	N/A	55-085-61
Q1	Main switch	Eaton	369kr	N/A	35-118-93
FAN-001	Filter fan 157 x 170 mm 15 W	Stego	715kr	N/A	54-218-91
FAN-002	Filer fan air inlet 157 x 170 mm, 11801.0-00	Stego	183kr	N/A	54-218-97
F1	Circuit breaker 1 A 3-pole type C Pump circuit breaker	Siemens	1065kr	N/A	36-078-16
F2	Circuit breaker control current 2A	Siemens	664kr	N/A	36-078-08
F3	Overcurrent relay, 0.9A – 1.25A	Siemens	474kr	N/A	36-230-68
F3	Overcurrent relay equipment	Siemens	109kr	N/A	36-229-51
I-001	HMI (Beijer IX7A)	Beijer	N/A	N/A	N/A
I-002	PLC (FX3GE-24 MR)	Beijer	4122,5	N/A	FX3GE-24 MR
I-003	PLC add-on (2DA)	Beijer	2082,50	N/A	2DA
SUM ex. Taxes			16998,45		

Table 4 – Electrical BOM

2.0 Cost Calculations

Total budget	
Hydraulic parts	132531kr
Electrical parts	16998,45kr
Total sum ex. taxes	149529,45kr

Table 5 – Cost Calculations

3.0 Spare Part List

Pos. ID:	Description	Supplier	Part number
F-001	Intake filter (HP pump)	Tess	CH123129 and CRFTAC91274
F-002	Intake filter(Filling pump)	Tess	CH123129 and CRFTAC91274
F-003	Ventilation filter	Tess	HC0239SEE5
F-004	Intake filter HP pump (5my)	Tess	06-90045-12

Table 6 – Spare Part List

References

[1] J. Carlstedt, «PID-001 <A>,» HBV, Kongsberg, 2015.

[2] B. Berg, «PWR-001,» HBV, Kongsberg, 2015.

[3] B. Berg, «PLC-001,» HBV, Kongsberg, 2015.

[4] B. Berg, «CTR-001,» HBV, Kongsberg, 2015.

Hyperbaric - Pressure Control System

Revision overview document

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Anders Skjørten
Brian Berg

Document author: Anders Skjørten

ID: REV-001 <D>

Revisions

Date	Description	Version	Made By	Approved By
09.12.2014	Revision overview document	-	AS	JC,BB,TOS
03.02.2015	Updating revision markings	A	BB	
15.02.2015	Added documents	B	AS	BB, JN
09.04.2015	Updating revision markings Added documents	C	JN, BB	
18.05.2015	AS BUILD	D	BB	TOS, JC

Table 1 - Revisions

Table of Contents

Table list

Abbreviation list

Abbreviation	Explanation
HPCS	Hyperbaric Pressure-Control System
HMI	Human machine interface
FMCTI	FMC Technologies
GA	General arrangement

Table 2 - Abbreviations

Revision Explanation

Revision version sequence	- , A, B, C…
Changes	Explain reason for the revision
Date	Date the revision is made
Made / Approved By	Participant Working / Approved
Participants	AS = Anders Skjørten BB = Brian Berg JC = Jonas Carlstedt JN = Jonas Nicolaysen TOS = Thor Ove Skarseth

Table 3 – Revision Explanation

1.1 Introduction

This document contains an overview of all revisions to all the documents related to HPCS.

1.2 Revisions

Code	Document	Date	Revision	Changes
VIS-001	Vision document	08.12.2014	-	
		13.03.2015	A	Change of plan
		01.04.2015	B	Delivery to FMC
		09.05.2015	C	Formatting layout
Code	**Document**	**Date**	**Revision**	**Changes**
REQ-001	Requirement specifications	08.12.2014	-	
		10.01.2015	A	Removal and rewriting of requirements
		15.03.2015	B	Change of Plan, added User Manual to R16-E
		02.04.2015	C	R8-E formatting change, remove R3-I and R15-I
		09.05.2015	D	Formatting layout
Code	**Document**	**Date**	**Revision**	**Changes**
TSPC-001	Test specifications	12.11.2014	-	
		30.01.2015	A	Changes to Table 1 <u>Removed:</u> T5-E, T6-E, T7-E, T7-I, T8-I, T9-I, T12-I, T14-I, T2-E, T18-E <u>Changed:</u> T3-E, T4-E, T10-E, T13-E, T21-E, T10-I, T11-I, T14-I, T15-I, T1-I, T12-I, T16-I, T17-I, T18-I, T16-E, T17-E Removed reference

		24.03.2015	B	Removed T3-I and T15-I
		09.05.2015	C	Text editing
		10.05.2015	D	Approval
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-001	System Modell description & qualification of autoclaves micro metering valve	09.12.2014	-	
		09.04.2015	A	Added Abbreviations table and formatting text
		09.05.2015	B	Text formatting
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-002	Arduino	08.11.2014	-	
		27.04.2015	A	Formatting text
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-003	HMI	30.01.2015	-	
		06.03.2015	A	Added program layout and program function part.
		02.04.2015	B	Formatting text
		01.05.2015	C	Formatting text
		04.05.2015	D	Added report description
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-004	PLS	13.02.2015	-	
		17.04.2015	A	Formatting, added function and added programming
		02.04.2015	B	I/O list description change at X1 and formatting of document.
		02.04.2015	C	Removed added programming part temporary
		09.05.2015	D	Formatting layout, adding technical info
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-005	DA	15.02.2015	-	
		09.05.2015	A	Formatting text

Code	Document	Date	Revision	Changes
TECH-006	Project Plan	15.02.2015	-	
		02.03.2015	A	Formatting text
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-007	System Description	20.02.2015	-	
		28.02.2015	A	Formatting changes
		02.04.2015	B	Formatting changes
		09.04.2015	C	Formatting
		29.04.2015	D	Formatting text and layout to standard
		10.05.2015	E	Finishing
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-008	Simulation of the Controller	15.02.2015	-	
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-009	Ethernet Setup	18.02.2015	-	
		02.04.2015	A	Formatting text
		09.05.2015	B	Updated document layout
Code	**Document**	**Date**	**Revision**	**Changes**
PWR-001	Power Schematic	04.03.2015	-	
		23.03.2015	A	Added 230VAC components
		05.04.2015	B	Updated terminal strip and jumper connections
		09.05.2015	C	Remove revision clouds
Code	**Document**	**Date**	**Revision**	**Changes**
CTL-001	Control Schematic	04.03.2015	A	
		25.03.2015	B	Fixed some errors, added 24VDC supply and added overcurrent relay
		05.04.1205	C	Add drawing links and add jumpers
		09.05.2015	D	Remove revision clouds

Code	Document	Date	Revision	Changes
PLC-001	PLC and HMI Schematics All 3 sheets	04.03.2015	-	
		01.04.2015	A	Signal update
		05.04.2015	B	Terminal strips update
		09.05.2015	C	Remove revision clouds
		16.05.2015	D	As Build Fix
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-012	System evaluation	20.02.2015	-	
		09.04.2015	A	Formatting, Spellcheck
		06.05.2015	B	Updating layout
		10.05.2015	C	Added chapter 1.7 and references
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-013	Product Catalog	21.03.2015	-	
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-018 (ACT-001)	Simulation of the Pressure Increasing Control Loop.	16.02.2015	-	
		27.04.2015	A	Simulation of Increasing pressure control loop.
		09.05.2015	B	Technology Document - Simulation of the Pressure Increasing Control Loop. (Document name changed from ACT-001 to TECH-018)
Code	**Document**	**Date**	**Revision**	**Changes**
BOM-001	Bill of materials	17.01.2015	-	
		09.03.2015	A	Add more components, and update tags and prices
		21.03.2015	B	Turn BOM documents in horizontal view, added some delivery times

				and updated suppliers
		02.04.2015	C	Added more supplier part numbers
		09.05.2015	D	Update of prices, spell correction.
Code	**Document**	**Date**	**Revision**	**Changes**
ILST-001	Interface List	30.01.2015	-	
		07.05.2015	A	Changed Table 3, document template and references
Code	**Document**	**Date**	**Revision**	**Changes**
P-001	P&ID	05.02.2015	-	Idea
		08.05.2015	A	Redesigned
Code	**Document**	**Date**	**Revision**	**Changes**
VLST-001	Variable List	30.01.2015	-	
		10.05.2015	A	Layout editing
Code	**Document**	**Date**	**Revision**	**Changes**
PLN-001	Project Plan Document	25.04.2015	-	Combination of TECH-006 PLN and Project Plan Document
		09.05.2015	A	Layout formatting
		10.05.2015	B	Final formatting changes
Code	**Document**	**Date**	**Revision**	**Changes**
PLN-001	Project Plan MP (Not valid anymore)	01.11.2014	-	
		03.11.2014	A	Project plan
		25.12.2014	B	Change project model (Evolutionary Model, feedback from presentation one)
		18.01.2015	C	Adjustment of the model
Code	**Document**	**Date**	**Revision**	**Changes**
PROL-001	Programing log	27.01.2015	-	
Code	**Document**	**Date**	**Revision**	**Changes**
REV-001	Revision overview document	09.12.2014	-	

		-	A	Updating revision markings
		15.02.2015	B	Added documents
		09.04.2015	C	Updating revision markings Added documents
Code	**Document**	**Date**	**Revision**	**Changes**
REP - ITR- 008	Iteration Reports	01.05.2015	-	
		09.05.2015	A	Report construction. Adding all previous reports
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-014	Discretization	30.01.2015	-	
		09.05.2015	A	Changed formulas
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-015	Test Rig	24.04.2015	-	
		09.05.2015	A	Creating the document and Formatting layout
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-017	User manual	09.05.2015	-	
Code	**Document**	**Date**	**Revision**	**Changes**
TECH-016	DC motor driver	24.04.2015	-	
		09.05.2015	A	Formatting layout
		15.05.2015	B	Form correction, adding some references
Code	**Document**	**Date**	**Revision**	**Changes**
TDI	Technical Data Information	08.05.2015	-	
Code	**Document**	**Date**	**Revision**	**Changes**
Project Plan	Project Plan	04.11.2014	-	See Iterative Document For

				Project Plan in CD
		16.11.2014	A	Same as rev <->
		09.12.2014	B	Same as rev <->
		03.01.2015	C	Same as rev <->
		11.01.2015	D	Same as rev <->
		13.01.2015	E	Same as rev <->
		31.01.2015	F	Same as rev <->
		09.02.2015	G	Same as rev <->
		17.02.2015	H	Same as rev <->
		13.03.2015	I	Same as rev <->
		28.03.2015	J	Same as rev <->
		18.04.2015	K	See rev <K> comments in CD
Code	**Document**	**Date**	**Revision**	**Changes**
REP-ITR-001	Iteration Reports	04.05.2015	-	Report construction
		09.05.2015	A	Report construction. Adding all previous reports
Code	**Document**	**Date**	**Revision**	**Changes**
FAT-001	FAT	18.04.2015	-	
		08.05.2015	A	Layout formatting, added references
Code	**Document**	**Date**	**Revision**	**Changes**
SYS-001	System GA	24.04.2015	-	
		09.05.2015	A	Dimension Update
		10.05.2015	B	As Build
		10.05.2015	C	As Build 2D
Code	**Document**	**Date**	**Revision**	**Changes**
CAB-001	Control Cabinet GA Sheet 1	04.03.2015	-	
		18.03.2015	A	Update of revision
		10.05.2015	B	As Build
CAB-001	Control Cabinet GA Sheet 2	04.04.2015	-	
		18.03.2015	A	Scaling of frame, adding some components
		09.05.2015	B	As Build

Table 4 - Revisions

Self-assessment

1.1 Brian Berg

My main role in this project has been project leader, responsibility for the documents, electro design and electro description.
In the beginning of the bachelor project, there was many uncertainties about how to do a project plan and follow thru the project. This consumed many working hours for understanding and implementing. The project plan at one time of the project was so complex that there was no help to get. This we have solved by accepting the total change of the plan and creating an easier one. At the end of the project, project plan was so good, that the iteration process was very easy to follow thru.
Thru out the project there was many contradictions in information HPCS group have received. This resulted in confusion of all HPCS members at the beginning. The more time elapsed, the more knowledge all members gained. All of the HPCS group members have become more independent and confident in they work. HPCS group have thru out the project work together quite well.
I think this project have been an large learning curve both in technical part, but as well as becoming structural and good planner. The last part of the project was quality control. In that phase, one powerful lesson is to have the same layout for all documents from the start. This was very time consuming to fix in a later stage.

1.2 Jonas Nicolaysen

My main participation in the project has been with the controller for the system. Challenges connected with this have not been few. Learning new programing languages choose out equipment that I have little experience in. other task I have participated in have been the group tasks like choosing the model for the group to work with and planning the path for the project.
If we had started again I would do a lot of things different. I probably would choose another PLC for the controller. And made the layout template for the documents much earlier in the project, since it have eaten a lot of hours making the documents uniform after they are finished.
All in all I think that the project have gone from a rocky start to a group that works more with each other and communicates more, this have helped the group spirit a lot, and putted more pressure in doing the tasks.

1.3 Anders Skjørten

My main role in this project has been documentation and programming of the control system. My main responsibility in the control system is the HMI program. This task have been a challenge for me because I have never programmed a HMI before and never worked with a Mitsubishi PLC so I had to learn different programming software's and the C sharp programming language. Because this software are new to us, we had some problems with communication between the HMI and PLC that ended up delaying the programming process. However the problem was solved within a few weeks with only a few hours expense.
Overall, I feel that the project has been a good learning experience with hindrances in form of communication and misunderstandings but also good cooperation within the group to reach a common goal.

1.4 Jonas Carlstedt

My main role in this project has been to lead the System Design because I have experience with Hyperbaric Testing and will probably be the one to use this system sometime in the future. I have also been responsible to verify the control principle performed by simulation made in MatLab.
In the beginning of the bachelor project, I had several ideas of how the System Design should be. By combining some of the ideas, and rejecting others, we were able to come up with what I think is a very good professional solution to the problem. We were focusing on not get stucked with any idea to early in the process, which had pro and cons. The Pro where that we probably ended up with a much better solution compared to our first solutions. The con was that we burned a lot of time needed to decide the parts for the product, which again lead to lack of time to order all parts in time for the assembly & test phase of the project. Parts needed to build this system is associated with long price-offering & delivery times.
I have used a lot of resources on logistical task like meetings with suppliers in the process of getting price offers for the parts needed. Since we found out that the documentation and the project process where more important for the assignment than I first thought of, the reduction of the assignment where a correct thing to do to save the HPCS group for time used on logistical and assembly that would be needed to produce the idea that we ended up with designing.
The HPCS group had a steep learning curve, and we made a lot mistakes in the early stage that we corrected and learned a lot from. Especially the time a project can save with having good process from the project start was a good experience to have for my further carrier.
The group have been set up by people that are practical oriented, and I think we have learned a lot about team work and using the resources found in the group on a effectively way of developing a new product. The team work have been very good, and members have been good to follow up task that are planned out in each iteration.

1.5 Thor Ove Skarseth

My main role has been hydraulic design and layout as well as economics and material. After working 7 years with maintenance work on electrical and hydraulic subsea components I have been using the old manually operated system a lot, and had a good insight in how the system that we designed should work. With this experience there was important to think new and not focus on the old system function too much. I have been working a lot with the hydraulic components, and to find components that suits the function in the system is not always easy. The cost for hydraulic components for this use is expensive. After getting offers from multiple suppliers, the calculated cost was reduced drastically.

The project plan was not so helpful for us at the beginning of the project, since none of the group members had any experience with it. The project planning worked better and better trough the project and I wish that we had this experience as we have now at the beginning of the project. At the end of the project the plan was a really helpful tool.

All group members have worked together as a team and cooperated well.

In many other bachelor groups there is a mix of students from different classes, with different specializations. This group consists of only cybernetic students, and has been a disadvantage sometimes since some of the work would suit other study specializations well. This problem is solved well by that the group members have gained experience in tasks that might not is a part of the cybernetic specialization.