Experion Simulation and Pilot Plant Maintenance

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Abstract

The Honeywell Experion Process Knowledge System (PKS) and Pilot Plant are both unique and invaluable teaching tools used in Instrumentation and Control Engineering at Murdoch University. The Pilot Plant is one of the most industry relevant practical components, which can be used to apply and develop theoretical control knowledge. Therefore it is essential to maintain and upgrade the Pilot Plant's operability and performance. The main purpose of this thesis is to extensively analyse the current condition of the Pilot Plant, propose and organise an agenda to fix faulty components, install new components or new coding to ensure safer operations to protect users as well as equipment, and improve its working condition. To successfully achieve these goals, the project holder should have a moderate knowledge about the Pilot Plant server, Experion supervisory control system and the Pilot Plant's C300 controller. This knowledge is usually obtained from working and practicing on the Experion Teaching System, which is the first aim to start the project.

As the Experion Training system was available for 3 months the work done to this system was limited. To improve some of the tutorial exercises and the documentation prepared by previous students, a simulated Experion system using a C300 controller and a Human-Machine Interface (HMI) page for the controlled system was developed and properly documented. The simulated system can use Object Linking and Embedding for Process Control (OPC) to link to a LabVIEW program. This is a fundamental step providing another linkage between Experion and a MATLAB program through OPC in the future.

The Pilot Plant Experion system has been extensively investigated in both hardware and software. By gaining an in-depth understanding of the system it was possible to identify the current problems regarding the plant and devise practical solutions for them. Numerous issues were resolved both physically and in the code. To prevent new issues from occurring, multiple interlocks have been designed, implemented and tested. Additionally the system's code has also undergone restructuring, mainly in the form of removing redundant code. New sensors and actuators have also been installed and integrated into the system.

Through the comprehensive research and development that was undertaken over the course of this thesis, it has become apparent that there is a vast range of projects and opportunities that can build upon this knowledge base and continue to improve the Murdoch University Pilot Plant and ultimately the Instrumentation and Control Engineering degree.

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Glossary

Acronym	Unabbreviated
AI	Analog Input
AC	Alternating Current
AO	Analog Output
BM	Ball Mill
BMT	Ball Mill Tank
CAD	Computer-aided Design
CEE	Control Execution Environment
CM	Control Module
CSTR	Continuously Stirred Tank Reactor
CUF	Cyclone Underflow
CUFT	Cyclone Underflow Tank
DC	Direct Current
DI	Digital Input
DO	Digital Output
FB	Function Block
FCV	Flow Control Valve
HMI	Human – Machine Interface
I/O	Input/Output
ICE	Instrumentation and Control Engineering
ICSE	Industrial Computer Systems Engineering
IOM	Input/Output Module
LT	Lamella Tank
MEDE	Microsoft Excel Data Exchange
MV	Manipulated Variable
MV	Manipulated Variable
NaN	Not a Number
NLT	Nonlinear Tank
NT	Needle Tank
OLE	Object Linking and Embedding
OPC	OLE for Process Control
PID	Proportional Integral Derivative
PKS	Process Knowledge System
PLC	Programmable Logic Controller
PV	Process Variable
SCADA	Supervisory Control And Data Acquisition
SCM	Sequential Control Module
SFC	Smart Field Communicator
SIM-C300	Simulated Honeywell C300 Controller
SP	Set Point
ST	Storage Tank
SV	Solenoid Valve
UF	Under Flow
VSD	Variable Speed Drive

1.0 Introduction

This section provides the overview of the Pilot Plant (PP) and the Experion Teaching System, the project scope and objectives and finally the thesis layout.

1.1 Overview of the Pilot Plant and Experion System

The Pilot Plant was built on the Rockingham Campus of Murdoch University in 1998 by Control & Thermal Engineering. The main purpose of this facility was to enhance teaching of process control and to give practical experience in an industrial plant setting to engineering students. The plant design represents a scaled down version of the Bayer process, which is one of the most economic processes of refining bauxite to extract alumina and can be seen in Figure 1 [1]. The plant can be divided into three stages: Digestion, Clarification and Precipitation to mimic the Bayer process, which can be seen in Figure 2 [2]. The Storage Tanks (ST), Ball Mill (BM), Ball Mill Tank (BMT), Cyclone Underflow (CUF) and Cyclone Underflow Tank (CUFT) make up the Digestion stage [2]. The Clarification stage is simulated by the Cyclone Overflow, the Lamella Tank (LT) and the Needle tank (NT) [2]. Lastly the Precipitation stage is simulated by three Continuously Stirred Tank Reactors (CSTR) in series [2]. Detailed components of the Pilot Plant will be presented in the Background Section.

Figure 1: Murdoch University Pilot Plant

The plant was initially built on Rockingham Campus. It was moved to South Street Campus in 2008 and then relocated in the new Engineering Building in 2011 [1]. During the first relocation a lot of documents regarding the plant were lost. In the second relocation the Pilot Plant's control system was upgraded to Experion Process Knowledge System [3] with a C300 controller [4] by Honeywell. Detail of the upgrade will be shown in the Background Section. To make up the lost documents and to keep track of the changes made to the Pilot Plant including maintenance and upgrade works, since 2009 a library of documents has been built and followed up by undergraduate and master students.

To understand the work to be done for the plant in this project, a simplified flow chart of the Pilot Plant is shown in Figure 2. This flowchart only focuses on the areas and the components to be changed later.

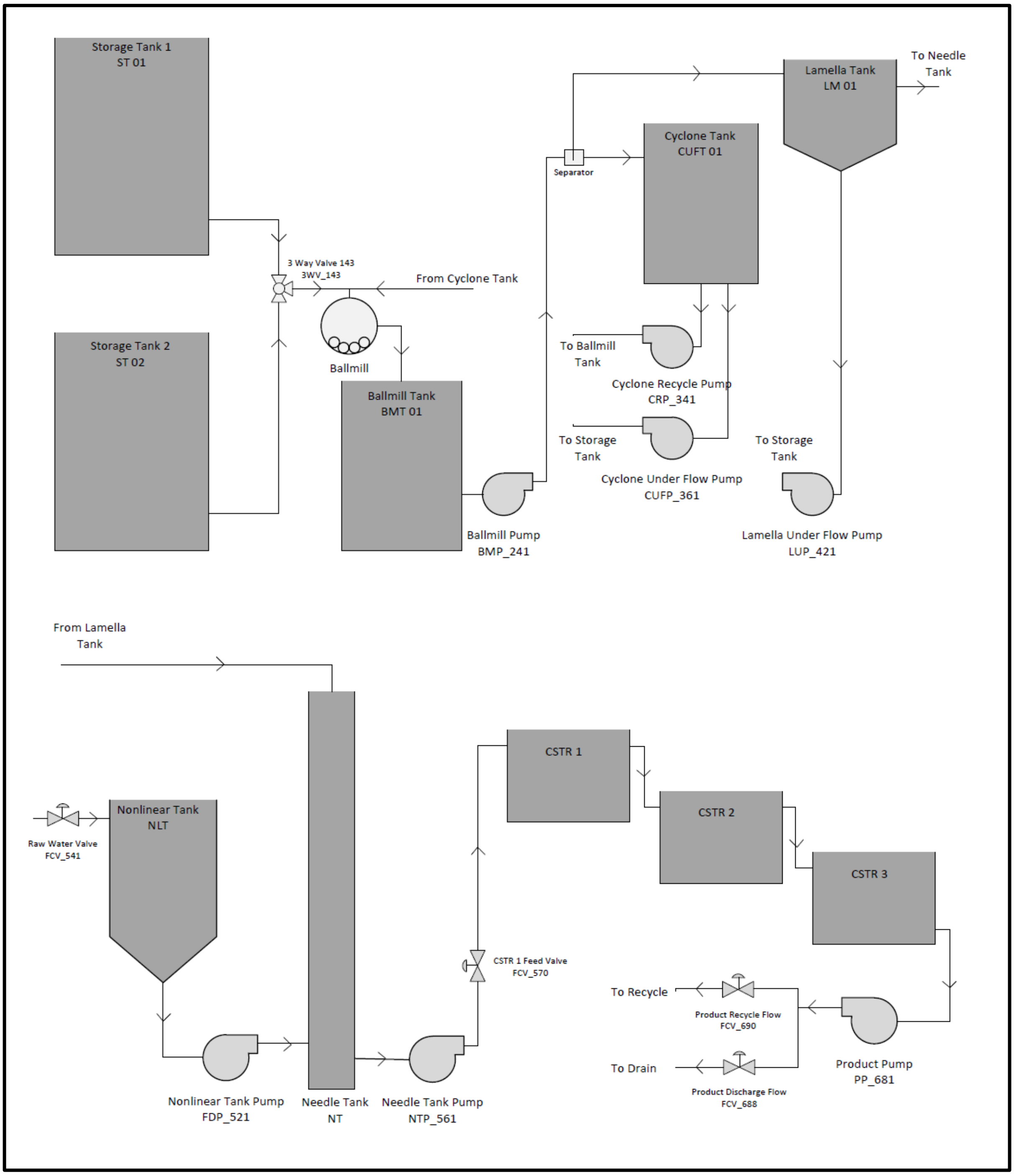

Figure 2: Pilot Plant Flow Diagram

1.2 Overview of the Experion Teaching System

When the Pilot Plant's monitoring system was upgraded to the Experion PKS, a second Experion system with simulation environment capabilities was also purchased and installed on a separate server. This second system is accessible to students to learn and gain experience by understanding the complex Experion system, building Supervisory Control and Data Acquisition (SCADA) points and developing control schemes before being able to implement any modification to the Pilot Plant Experion system.

Previous work has been done to this system including development of simulations and HMI pages to explore the functionality of the Experion PKS. A number of tutorials showing how to use the complex system were prepared [5][6][7]. Over the years the documentation has grown in usefulness but it is still uncompleted as new functionality is explored and tutorials need to be updated to reflect the latest programs.

1.3 Project Scope

This project will focus on two separate systems with different objectives for each. Initially the project will be concerned with obtaining an essential knowledge base and then applying that knowledge to exploring and documenting the functionality of the Experion Teaching System. The work on the Experion Teaching System follows on directly from past thesis students; this will be further detailed in the Background section.

The other portion of this project will continue with the ongoing maintenance, upgrading, and improvement of the Pilot Plant system. This will follow on from previous thesis students; this will be further detailed in the Background section.

This project's staggering size and complexity required an extensive degree of research and preparation. Currently there is no Murdoch University staff member or student that is familiar with the basic operation or navigation of the Experion PKS software; this also extends to the configuration and adaption of the different programs. The limited support for using the software presented an immense challenge and required a substantial degree of research to overcome it.

1.4 Project Objectives

The main project objectives that were set to be completed are described in the following sections.

1.4.1 Experion Teaching System Simulation

The final goal in the Experion Teaching system is to implement a simulated system and to communicate with Experion using OPC. Once the simulated system is implemented a control strategy in the C300 is to be developed using Control Module (CM) and Sequential Control Module (SCM) and then displayed using a custom made HMI. The aim is to understand and gain more experience from practicing on the teaching Experion system before working on the real system.

1.4.2 Identifying and Fixing Existing Issues in the Pilot Plant

A key part of this project is to investigate all of the current problems in the Pilot Plant and devise realisable solutions to get the plant into its optimum working condition and prolong its usable life.

1.4.3 Implementing Interlocks

To prevent future damage being caused to the equipment in the Pilot Plant, the previously installed interlocks will be investigated and tested. If needed, new interlocks are to be designed and implemented to improve the overall safety and working condition of the plant.

1.4.4 Code Restructuring

In the C300 code there is an abundance of redundant code that has either become obsolete after an update in the code, or it was never fully implemented to begin with. This causes people new to learning the system to be overwhelmed with messy and redundant code. By removing this code there will be an improvement in efficiency and it will greatly reduce the visual complexity of the code.

1.4.5 Hardware Installation

Hardware such as two float switches for the Lamella tank and solenoid valves (SV) for the raw water and instrument air lines are to be installed and integrated into the current system. This involves updating wiring diagrams, block diagrams, the systems code and the HMI.

1.5 Thesis Structure

This thesis is broken down is to several sections which detail the works undertaken over the course of this project. The thesis structure is as followed:

2.0 Background: Provides a review of the previous work completed on the Experion Teaching System and the Pilot Plant system. Along with a description of the software and hardware used in the project.

3.0 Work Completed on the Experion Teaching System: Reports on the work that have been completed on the Experion Teaching System.

4.0 Work Completed on the Pilot Plant System: Reports on the work that have been completed on the Pilot Plant System.

5.0 Issues Encountered: Discusses the issues that were encountered and how they have impacted the overall progress of the project.

6.0 Future Work: Discusses future opportunities and work required for this project.

7.0 Conclusion: Reiterates the successful work implemented over the course of the project.

2.0 Background

To understand the work to be done in this project some relevant history and background information are shown in the following sections.

2.1 Previous Work Completed on Experion Teaching System

Starting in 2011 the previous work that has been completed on the Experion Teaching system includes:

E.Hug Hou Lum 2011 [5]:

- A guide to Implementing a Simulated-C300;
- A step-by-step instructions to program simulated Honeywell C300 controllers;
- Guide to Installing the Microsoft Excel Data Exchange Add-In;
- A solution guide to fix the Error 7045.

K.Gumireddy 2013 [7]:

- PID Block/PID-PL Parameter Description;
- Simulation of a First Order System using CMs in Control Builder;
- Simulation of a Non-Linear system using CMs in Control Builder;
- Controlled Simulation of a Non-Linear system using PID;
- Cascade Control System Setup in Experion;
- Feed Forward Control System Setup in Experion;
- Clearing Active locks formed on the Control Modules.

N. Binte Mohamad Nain 2013 [6]:

- A number of HMI Web Display Builder tutorials;
- A tutorial on using Station.

2.2 Previous Work Completed on the Pilot Plant System

The Pilot Plant System originally consisted of a SCADA topology using an Allen Bradley PLC5 to control the hardware and a Honeywell SCAN3000 server as the supervisory computing system [1]. After many years of use the control system no longer represented the industry standard at that time and in 2008 Honeywell was contacted to upgrade the system. Honeywell recommended that the previous SCAN 3000 server be replaced with their Experion Process knowledge System and the PLC5 replaced with C300 controller hardware [1]. This proposal also included the installation of Foundation Fieldbus instrumentation, wireless instrumentation and ModBus communications, which adequately reflected the technology being used at the time in industrial processes [1].This included, but was not limited to, migrating the previous PLC5 code into the C300 controllers and developing a user HMI. Experion Process knowledge System software - release 311.2 was installed during the upgrade but recently in January 2015 to updated to the Experion PKS - release R430.1. The Danfoss VLT5000 Variable Speed Drives used to vary the speeds of the plants pumps were also replaced with Danfoss FC102 drives [8] as they did not support Modbus communication.

The work previously done on the Experion Pilot Plant System by thesis students includes:

A.Punch 2009 [1]:

- Developed Danfoss FC102 electrical schematics;
- Configured Danfoss FC102 drives;

- Developed HMI for the Pilot Plant System;
- Defined Quickbuilder channel to create the SCADA network that established the connection from the Experion system to the variable speed drives;
- Monitored the temperature in the C300 cabinet;
- Oversaw the implementation of the Experion system in the Pilot Plant.

E.Hopkinson 2010 [2]:

- Developed Pilot Plant P&IDs;
- Rewired Cabinet;
- Developed Circuit Diagrams;
- Developed Piping and Instrumentation Diagrams for the entire plant;
- Reconfigured VSDs, Lantronix Bridge converter and Drive Control through Quick Builder;
- Configured Pilot Plant Alarms;
- Configured PPServer1 for read/write MSEDE functionality;
- Implemented Microsoft Excel Data Exchanger MEDE Excel control on Pilot Plant along with all necessary documentation.

S.Mackay 2011 [9]:

- Installed Warning Light & Warning Buzzer;
- Implemented PID control loops on tank levels and temperatures;
- Implemented a Maintenance Program in Sequential Control Module (SCM);
- Developed Demonstration Program SCM;
- Updated HMI.

J.Dring 2012 [10]:

- Combined and Improved Demonstration and Maintenance Program;
- Added DI for Demonstration and Maintenance Program;
- Recalibrated a Flow Meter.

2.3 Miscellaneous Software

Throughout the course of this thesis a number of additional programs that are unrelated to the Experion PKS were needed for completing several essential tasks.

2.3.1 MATLAB

MATLAB is the high-level text language and interactive environment used for numeric computation and data analysis [11]. MATLAB is a staple of learning for ICSE and ICE students as it can be used to simulate process systems and analysis process data.

2.3.2 LabVIEW

LabVIEW software uses a graphical language and is ideal for acquiring and analysing measurement data or simulating and controlling systems [12]. This is another program instrumental to the ICSE and ICE students learning.

2.3.3 TurboCAD

TurboCAD is a Computer-aided design (CAD) software that is used for design and drafting [13]. It needed in this project to view and update the existing Pilot Plant wiring diagrams.

2.4 Experion PKS Software

The Honeywell Experion PKS is a high performance software platform that is utilised by engineers throughout industry. This package which was revolutionary for its time can be used for configuring and integrating of both Distributed Control System (DCS) and SCADA network topologies [5]. The package contains the tools for server configuration, user display creation, data logging, security configuration, alarm configuration and control strategy development in a single integrated environment [2].

The Experion PKS is essentially a large integrated software suite that consists of several development tools and user environments [5]. The core of the Experion PKS consists of the development programs: Configuration Studio, Control Builder, Enterprise Model Builder, HMI Web Display Builder, Quick Builder, Station and the System Displays [5].

The Experion system has an underlying structure that is separated into three key components. They include the physical system (e.g. Murdoch University's Pilot Plant Facility), an Experion accessible server, and finally one or more workstations with Experion client applications. A simplified model of the Experion operation is as followed. The operator's controls are sent from the client workstation through an Experion server to the appropriate instrument(s). The Experion server acts as a middleman between the physical system and the Experion client machine(s).

The C300 controller used in the Pilot Plant are programmed using software in the Honeywell Experion PKS package. The controllers are mainly programmed in Control Builder which is a subprogram of Configuration Studio while the HMI is programmed in HMIWeb Display Builder. This is the same for both the Pilot Plant and the Experion Teaching System.

2.4.1 Configuration Studio

Configuration Studio, as the name suggests, is the top level program used to configure the Experion system. In the Configuration Studio environment it is possible to create and configure your Experion servers and OPC servers. It also contains many subprograms that are used to configure different aspects of Experion's hierarchy like Enterprise Model Builder, which is used to configure assets and Control Builder that is used to program the controller. Murdoch has two Experion servers that have been created and are being used: as the Pilot Plant server (Ppserver1) and the Experion Teaching System (Experion2). Because of the importance of these systems only people with appropriate knowledge and security clearance can logon to the servers and modify system settings.

2.4.2 Control Builder

Control Builder is the subprogram where controllers are programed and configured. It can be used for several different types of controllers but only C300 controllers are used at Murdoch. The main three sections are concerned with are the library window, the project assignment window and the project monitoring window which can be seen highlighted in Figure 3. [9]

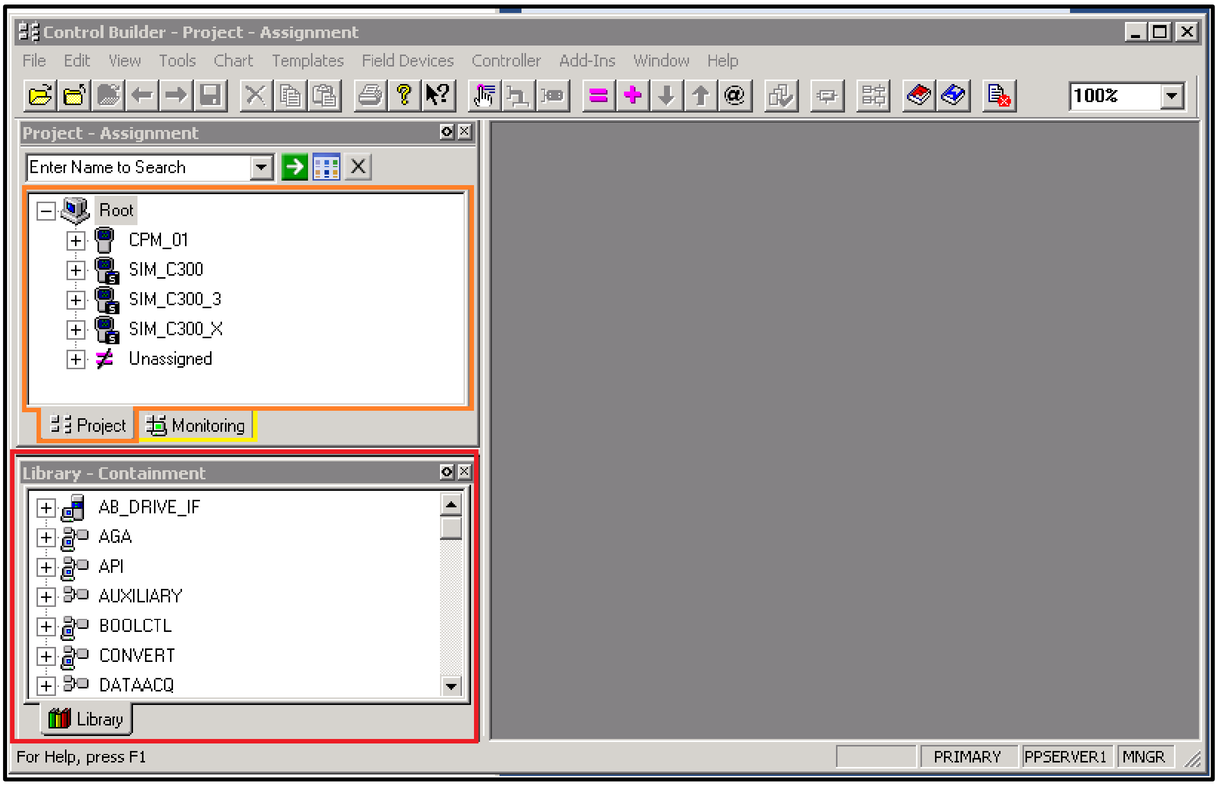

Figure 3: Control Builder

The library window contains a library of standard function blocks (FB) and I/O modules that can be used for programing CMs. Some of the standard function block libraries that are commonly used include logic, arithmetic, timing and alarms.

The Project Assignment window contains a list of all FBs being used and groups them into the CMs that they are used in. From this window it is possible to create, delete and open CMs for manipulation and programming. The code in the Project Assignment window can be edited but it will not affect the Pilot Plant until it has been loaded onto the C300 controller. In the Pilot Plant System there is one physical controller that is the C300, which is named CPM_1. There are three other loaded controllers that are simulated C300 controllers and are used for testing code before implementing it into the CPM_1. These extra CPMs can be deleted or changed at any time as they are not part of the Pilot Plant system and they are just running on the same server. [9]

The Project Monitoring window shows the currently loaded FBs and CMs. It can be used for online monitoring of blocks and changing numeric values or flags. It is a useful tool for debugging and investigating programs that have been loaded onto the C300. [9]

It is possible to program the C300 controllers with either the graphical programing language using FBs in CMs or using the text based state machine language in sequential control modules (SCM).

2.4.2.1 Control Module

The majority of the programing done in the C300 is in the graphical CM style [4]. By using a number of different logic, numeric operators and other controller blocks, such as PID blocks, the plant I/O can be configured. The type of control functions programmed using CM include but are not exclusive to interlocks, flags for monitoring, PIDs, limits, 3 way valve positions and pump and control valve references. An example of the CM program can be seen in Figure 4, this is a portion of the on/off control for the Lamella Tank pump.

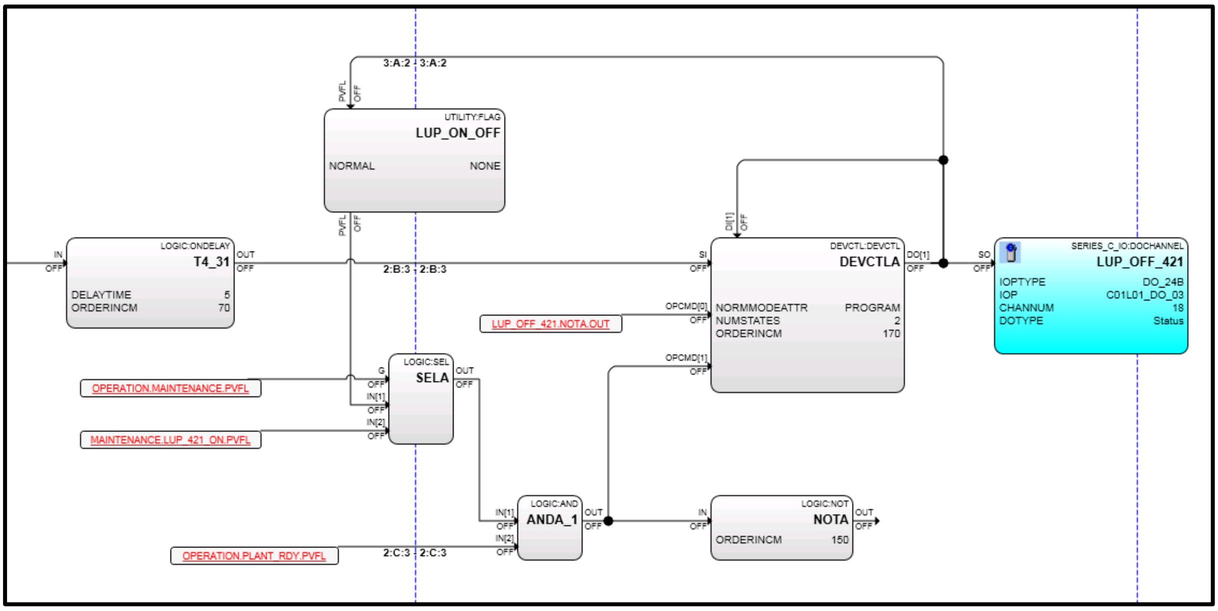

Figure 4: A CM Example

2.4.2.2 Sequential Control Module

The only SCM used in the C300 is for the maintenance /demonstration program. The SCM operates as a text-based state machine. There are certain conditions that invoke the SCM and activate its states of operation which can only be exited when its transition state perquisites are met. In its states of operation parameters will be manipulated and set before transitioning to a new state. An example of the SCM program can be seen in Figure 5, this is the start of the 3rd section of the maintenance program that handles the operation around the Non Linear Tank (NLT).

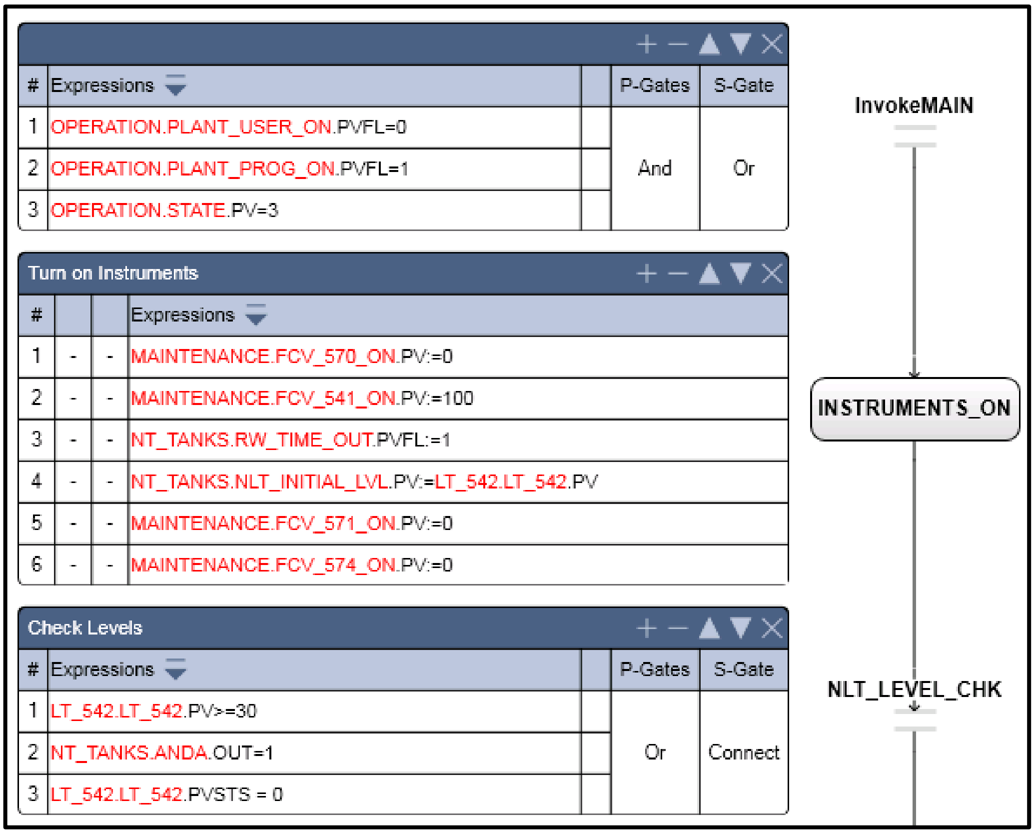

Figure 5: SCM Example

While no SCM programming was done in this project it was important to understand the code so that all new changes would not affect the maintenance /demonstration program.

2.4.3 HMI Web Display Builder

The Experion PKS contains two different HMI Display Builder programs and they both produce a similar HMI end result. However only HMI Web Display Builder was investigated and used during this project since the current setup of the Pilot plant System was developed with it. The HMI created communicates directly with the server and allows the operator to take control of the Pilot Plant. This program is based on the programming language Hyper-Text Mark-up Language (HTML) [10]. In the program it is possible to use shapes, buttons, indicators, numerical displays and numerical controls to create a customised control panel. The Pilot Plant HMI was made as a graphical representation of the Pilot Plant with a separate page to represent the overview, Storage Tanks, Ball Mill, Cyclone, Needle Tank, CSTR bank and Dye tank. There are also pages used for monitoring and changing behind-the-scene settings such as control loop tuning parameters, automatic defined settings, drive operating conditions and program settings.

2.4.4 Station

Station is the Experion program that enables the user to display the HMI created in HMI Web Display Builder for use. The current operator HMI can be used to change manual settings of valves, pumps, agitators and the as PID control parameters. Station also includes the ability to display the trends of all inputs and outputs over a set time, it can also be used for extracting data to Excel. Another important feature of Station is that it contains a log of all alarms and system status on the Experion system.

2.4.5 Knowledge Builder

Knowledge Builder is a documentation system regarding the Experion system. At present it can only be accessed on the old pilot plant server (ppserver1-old). It was built using HTML language and it resembles the common software environment help documentation [10]. This documentation was heavily relied upon while trying to decipher the current C300 code.

2.5 Hardware

The Pilot Plant is equipped with the hardware as described by Table 1:

Table 1: Pilot Plant I/O Modules [10]

Input/Output Module	Quantity	I/O Quantity	Available
Digital Input (DI)	2	64	11
Digital Output (DO)	2	64	24
Hart Analogue Input (AI)	2	32	5
Hart Analogue Output (AO)	1	16	6

2.6 Equipment

The most notable equipment that the Pilot Plant is equipped with is as shown in Table 2:

Table 2: Pilot Plant Instruments [10]

Instrument	Type	Quantity
Flow Transmitter	Magnetic	11
Level Transmitter	Differential	7
Level Indicator	Float Switch	2
Density Transmitter	Differential	4
Temperature Transmitter	Resistive Thermal Detective	4
Pump	Positive Displacement	8
Ball Mill	3-phase Motor	1
Flow Control Valves	Pneumatic	8
Solenoid Valves	24 Volt Direct Current	10
Pump/Motor Controller	Variable Speed Drives	9

3.0 Works Completed on the Experion Teaching System

The Experion PKS is a complex system and there is a high level of required knowledge needed before making any changes to the Pilot Plant Experion system. To demonstrate and gain a more in-depth knowledge using the Experion PKS it was decided to implement the necessary skills on a simulated system. Several ways to create the simulated system were explored such as using Microsoft Excel Data Exchanger (MEDE), OPC and internally in Experion using control blocks as a simple simulated process. To ensure novelty OPC was chosen to be used in creating the simulated system. Since communicating with Experion using OPC has given past students problems, a methodical in-depth method of exploring OPC has been used to eliminate possible causes of error.

3.1 Documentation

When the Experion systems were installed the university was supplied with several large ring binder files containing guides, tutorials and information about all facets of the Experion PKS. While these files contain all the information needed to become proficient in using Experion they are far too extensive and unintuitive to be learnt in the span of any one unit or even thesis. Over the course of the Experion Teaching System's life time students have scoured the files and Knowledge Builder to refine the information into concise easy-to-apply tutorials. This was done in an attempt to stream line the essential learning process for future students. While these tutorials are incredibly important for getting a quick start when learning the important Experion features, there is no one combined centralised location for them which has caused issues. Over the years numerous thesis and ENG454 students have attempted to learn Experion and make their own tutorials. In doing this, they have created a maze of information with tutorial hidden in different thesis submissions and unit handover documents spanning several years. This has caused the following problems:

- There is no clear tutorial order;
- There are multiple copies of the exact same manuals all with different file names;
- Multiple manuals are written to describe the same objectives;
- It might appear that some manuals do not exist and once the correct method had been learnt independently, the manual would then be found in a previously unknown or forgotten folder;
- Some tutorials contain contradicting information;
- Some tutorials contain old versions of programs.

To combat this problem a new documentation system has been implemented that consolidates all found documents and manuals into one well organised place. This new system has tutorials arranged into topics with the topics and tutorials numbered in order in which tutorials should be completed. All duplicates have been removed and some tutorials have been updated with new information and explanations to guild the reader. This file system also includes the following documents to guild the user:

- An overview of the Experion PKS system to give the user some background knowledge;
- An Index of all current tutorials;
- An overview document describing the importance of each section and the order in which to complete them.

It is recommended that future students update this set of documentation with any new tutorial.

3.2 OPC

OPC enables OPC compatible server programs to exchange data with any OPC compatible client application by using a common protocol [6]. OPC is utilized in server/client pairs [14]. Originally OPC was designed as a link between industrial computer networks and closed-source PLCs. OPC server software is used to convert the PLC's hardware communication protocol into an OPC protocol [14]. At Murdoch University the National Instruments (NI) server program NI OPC Servers is currently used for this purpose. OPC client software could be any program with OPC capabilities and needs to be connected to proprietary hardware. An example of this could be, controlling a Siemens PLC with a LabVIEW HMI. The OPC client uses the OPC server to send and receive data from the hardware as illustrated in Figure 6 [14]. The OPC server could also be connected to a simulated process or system instead of a PLC.

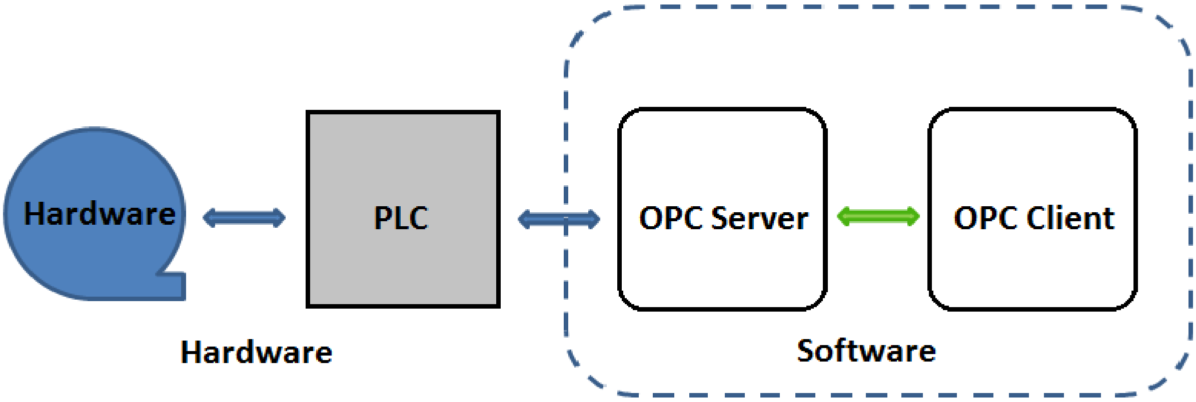

Figure 6: OPC Data Flow Chart (Adapted from [14])

OPC is useful in industry due to it being an open standard; this creates a reduced cost for manufacturers and gives users a larger selection to suit their needs. A hardware manufacturer can produce a single OPC server for use with their devices and it will allow them to be used with any available OPC client [14]. Conversely software vendors can include OPC capabilities into products that will allow them to be used with all reputable hardware devices with ease [14].

While the most basic form of OPC connection is a single server to client connection on the same computer it can get much more complex. Some other possible OPC set ups are as follows:

- Connecting a single OPC client to multiple OPC servers simultaneously;
- Having several OPC clients all connecting to a single OPC server;
- Connecting an OPC client to an OPC server over a network [14];
- Two or more OPC servers can be connected to share data.

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There are three important divisions in the server that need to be understood before implementing OPC:

- **Server** – The **Server** is the top level and contains all of the **Group** objects;
- **Group** – A **Group** contains and organizes the OPC **Items. Groups** can be made to group **Items** for security and access purposes;

- **Item** – The **Item** is the lowest level in the server. **Items** contain the data that the user wants to read from and write to and they each have a unique identifier held within the group. The identifier has multiple purposes such as a reference for the individual data source, its value, quality, and timestamp information.

An OPC program will not access the items directly, it will instead access them through the group. Each group contains a specific update rate; this will dictate the rate at which the server will make data exchanges available to the OPC client. The group will also include a deadband percentage for each group which will cause the server to ignore values that have changed less than the deadband. [15]

OPC servers can also provide alarm and event handling for clients. The server can generate an alarm when abnormal conditions set by the user occur. These conditions could be associated with the state of the server, a group or an item. It can also log events such as system errors, system configuration changes, and operator actions. [15]

3.3 Experion Teaching System Simulation

To understand OPC and the issues associated with its implementation, OPC was used to communicate between a number of different third party OPC compliant programs and devices. The importance of learning the problems that can occur when implementing OPC was important to identify whether the problem of connecting Experion with OPC was an isolated Experion or OPC problem. The final goal of this section of the project was to implement a simulated system using LabVIEW and communicating with it from Experion using OPC. Once the simulated system was implemented a number of controllers in a simulated C300 using CM and SCM were to be developed and then displayed using a custom HMI. The simulated system was to be made to focus and demonstrate what was learnt about the Experion system before moving onto the Pilot Plant system while achieving something meaningful.

A Siemens SIMATIC S7-300 PLC [16] was first connected to a National Instruments (NI) server (NI OPC Servers) and communicated to an NI client program (OPC Quick Client) using OPC. Reading and writing functions were explored along with addressing memory bits and bytes. A LabVIEW program was then written using data socket protocol [17] to read and write to the PLC.

The simulated system was then created in LabVIEW since it is an easy to use program that is used throughout the instrumentation and control engineering (ICE) degree. The system consisted of simple first order system developed in a LabVIEW project using a formula node and shift registers. By making the input and output variables of the system global variables and configuring them to the National Instruments Variable Engine1 server, it was possible to use a client LabVIEW program with data socket to read and write to the system.

To test the use of MATLAB with OPC a MATLAB program was written to connect to the “National Instruments Variable Engine1” server. Matlab was used as well since it is an easy to use program that is used throughout the ICE degree. The writing of the MATLAB code was relatively straight forward but there were many errors that occurred when trying to connect. The first problem was solved by installing some OPC foundation files for MATLAB but a connection still could not be made.

Working with the Department of Engineering and Energy's IT technician and thesis supervisor the problem was identified and then fixed. The problem was caused by the user not being given implicit permissions to access NI OPC DCOM services. MATLAB was then successfully been used as an OPC client to communicate with a simulated first order system in LabVIEW. Once communication had been established reading, writing, logging and extracting certain information was explored. MATLAB was originally intended to be finally used with the Pilot Plant System to implement higher level controllers.

Manuals for using OPC with different programs have been written for each successful application for future students. These new manuals have been added to the revised documentation system. Example programs have also been included with the manuals. The new tutorials include:

- OPC Basics
- NI OPC Server for PLC
- NI OPC Server Using LabVIEW
- LabVIEW OPC Client
- MATLAB OPC Client
- Quick Client

Due to unforeseen circumstances, once it was time to use Experion with OPC, the Experion Teaching system was unusable. Over the semester break Experion was updated from the Experion PKS - release 311 to the Experion PKS - release R430.1. This caused numerous problems with the Experion Teaching systems Control Builder rendering it inoperable and while many weeks were spent trying to identify and fix the problems it was ultimately fruitless. Due to this the communication of Experion using OPC and the implementation of advanced controllers in the Pilot Plant using MATLAB were incomplete and needs to be put into future work.

4.0 Works Completed on the Pilot Plant System

4.1 Investigating Pilot Plant Problems

One of the most important parts of this project was to investigate all the current problems in the Pilot Plant and devising solutions to get the plant into its optimum working condition, and to prolong its usable life. The Pilot Plant is used by students all year round with new students involved every year. With such a high turnover of users, there is a higher chance of misuse and problems developing. This misuse can cause many physical problems. There is also no expert at using the Experion PKS at Murdoch University so every new student that edits the code has the highest level of knowledge about the system at Murdoch at that time. This lack of people well versed in the Experion PKS could cause some coding errors to go unchecked. A list of all known problems that were found has been documented along with the implemented and/or recommended solutions if they have not been solved, these documents can be found in Appendix A.

4.1.1 Three Way Valves

While investigating several alarms that were occurring around the plant's 3 way valves it was discovered that they would not change position. When a position change was selected in the station program, the position would not change and an alarm would then be triggered instead. After investigation of the code by watching the codes activation in the monitoring tab of control builder it was seen that no interlocks were occurring and everything was activating correctly up until the point of sending the DO signal to change the position. The command to change the position was being sent out to the device but no position change was being detected, which triggered the warning. This indicated that the problem must be a physical one and upon visual inspection of the 3 way valves it was observed that the control air supplied to the valves had been cut and taped up. This is a problem since the recycle streams are all are fixed to pump into Storage Tank 1. Upon further reading into past documentation it was found that the line was cut due to a leaking 3 way valve but the particular valve was not specified.

After reattaching the air supply the air leak was immediately apparent in the Needle Tank underflow 3 way valve. The 3 way valves were tested again and it was found that the Lamella Tank's under flow 3 way valve and the Cyclone under flow 3 way valve would still not change position. The Needle Tank underflow 3 way valve would change position now that the air was reconnected but air would leak out in both positions. Each valve was tested individually by forcing redirected air into the valve chambers and by attaching each valve into the one confirmed working pneumatic relay (Needle Tank underflow 3 way valve relay). This was done to try and identify the cause of the problem with each valve which was:

- Needle Tank underflow: Air relay switch works but the valve leaks air between cylinders;
- Cyclone underflow: It appears that the pneumatic relay switch does not work and the valve is stuck and will not change position;
- Lamella underflow: The air relay switch seems to work but the valve is sticky and will not change position without outside assistance;
- Feed stream: Both relay and valve seem to be fully functional.

After removing the relays from the system it was discovered that the Lamella Tank underflow and Needle Tank underflow valves used AC pneumatic relays and were rusted on the inside while the

Feed stream and Cyclone under flow valves had DC pneumatic relays. The plant originally used all AC pneumatic relays but over the years two had been replaced by DC relays. It was decided that all the pneumatic relays would be replaced with four new AC pneumatic relays. AC was chosen so that all of the wiring would be consistent and the same as what was originally implemented in the plant. The relays have been ordered but will not arrive by the end of this project so their installation and testing needs to be put into future work.

4.1.2 Ball Mill Level Sensor

During the ENG346 class of 2014 it was reported that when the Ball Mill tank level transmitter reached 100% it was nowhere near the top of the tank at just approximately 60%. When investigated, it was seen that the 100% point marked on the tank did correspond with a 100% reading from the level sensor but the 0% mark on the tank corresponded with 45.75% on the sensor reading as can be seen in Figure 7.

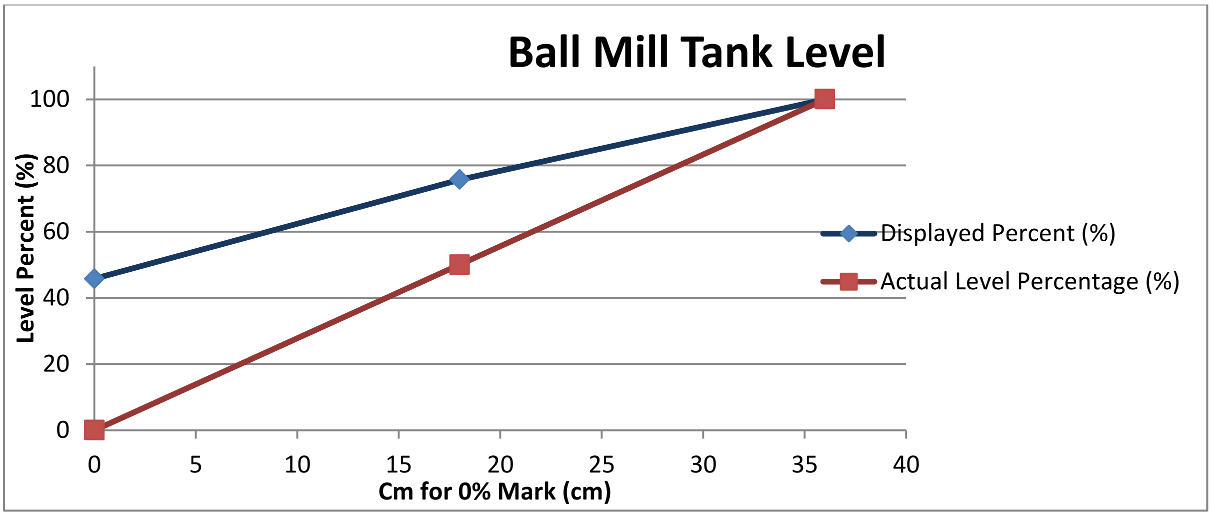

Figure 7: Ball Mill Tank Level

To fix this problem it was made sure that the valves of the Honeywell differential pressure transmitter level sensor were in the correct position. It was confirmed that the valve connecting to air (atmospheric pressure) and the valve connected to the inside of the tank (pressure in tank) were to be fully open and the valve in-between these two was to be fully closed. Tests were then conducted but nothing had changed. The next step was to recalibrate the instrument. The Honeywell Smart Field Communicator (SFC) was obtained, which included manuals for calibrating pressure transmitters, mass flow meters, temperature transmitters and magnetic flow meters. While the manuals instructed what settings needed to be selected in the calibration device, there was no indication of how to connect it to the level sensor. After sourcing a Honeywell pressure transmitter online manual it was found how to connect up the calibrator correctly for an online calibration. An online calibration was conducted as the level transmitted could not be disconnected from the running system as seen in Figure 8.

Figure 8: Ball Mill Level Calibration

Upon setting the 0% signal value while the tank was filled to its correct 0% point 46cm from the top of the tank and setting the 100% signal value at the correct 100% point 10cm from the top of the tank the level was then retested as seen is Figure 9.

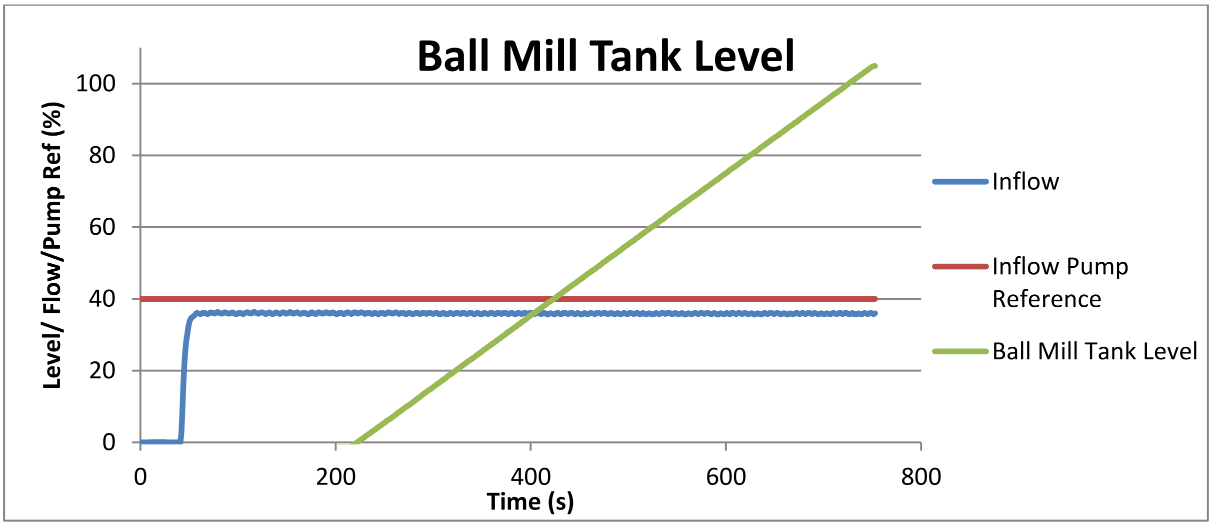

Figure 9: Ball Mill Level Test

This recalibration was found to have fixed the problem but it is unknown why the problem had originally occurred and why the tested problem was different to the reported problem. The level was tested again towards the end of this project to confirm that nothing had unexpectedly changed like before. The Honeywell pressure transmitter manual has been included in the documentation in case the problem reoccurs.

4.1.3 Cyclone Underflow Pump

It was reported that the Cyclone Underflow pump was no longer working. After making sure all the correct hand valves were open and that power was being supplied to the pump, tests were run as can be seen in Figure 10. Code activation was observed and seemed to be working correctly with the no flow interlock activated when the pump would fail to start. The pump was set to 50% and the pump was instructed to run several times with no success as the less than 5% flow interlock would activate. After a few more attempts to run the pump a small flow was observed but the interlock turned the pump off. The pump reference was then increased to 100% and several more attempts to run the pump were made. Eventually a substantial flow occurred and continued to increase slightly but reached a maximum of 28.4 units, which is poor compared to other pumps. This indicates that there was a physical problem with the pump.

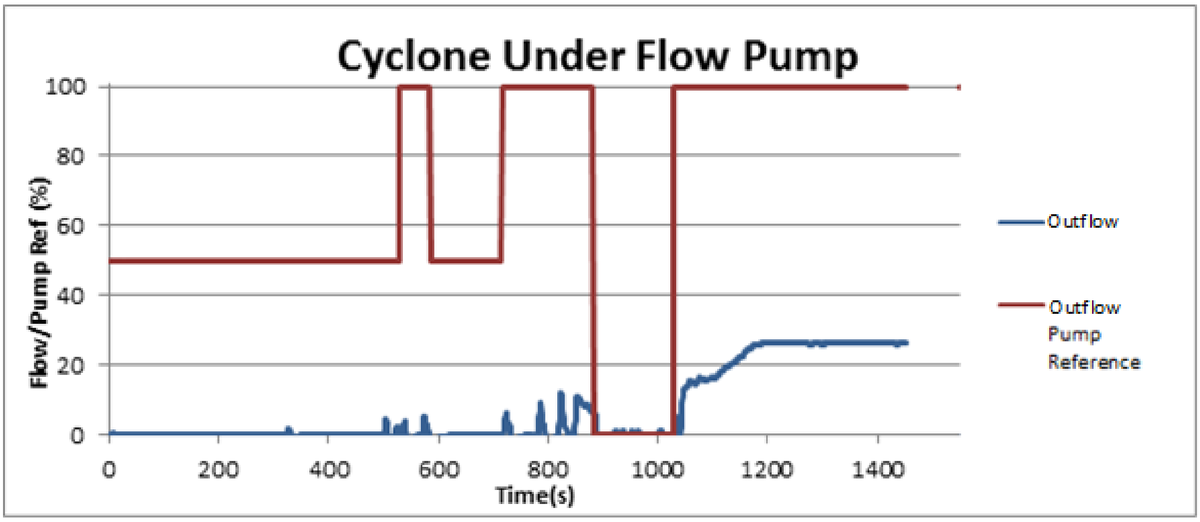

Figure 10: Start Up Test

Upon an inspection of the pump it was seen that the pump shaft was fairly rusted which was thought to explain why the pump would not initially start and a leak from the pump was also evident. After the pump initially ran it was then run again to test the pump at different percentages as shown in Figure 11. The pump started without issue and reached the same maximum flow as in the past test but it could run at a percentage between 25% and 50%.

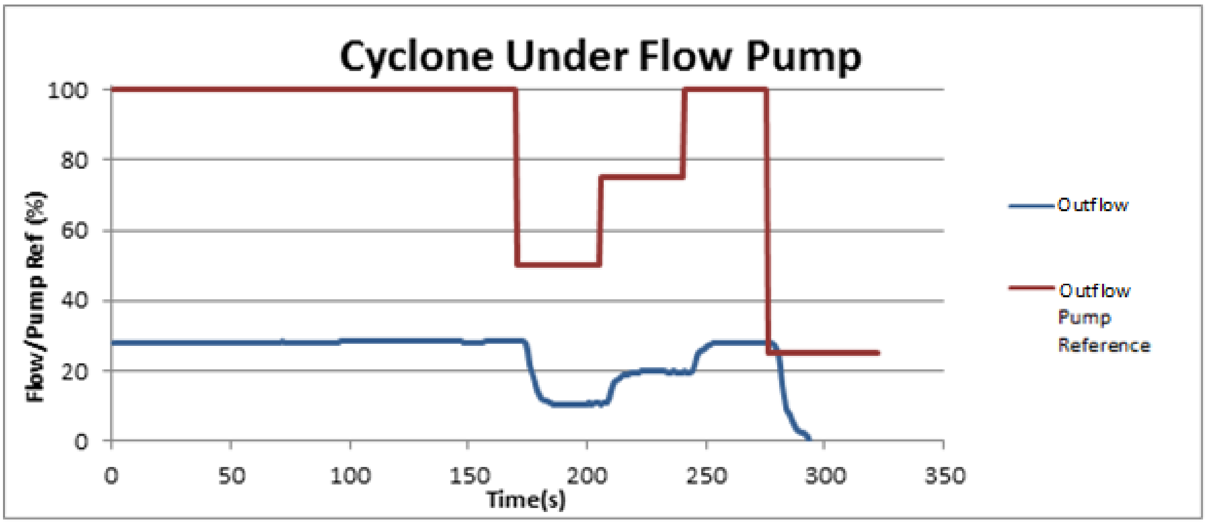

Figure 11: Pump Reference Test

The cause of the problem was thought to be rust on the shaft caused by a leak, so it was recommended that the pump to be taken apart and cleaned.

It was found that the problem was not caused by rust, but by the pump being run while there was no flow. This peristaltic pump has a screw that twists inside a rubber section and this pumps the water, when the pump is run dry then the rubber will burn and stick on the screw which causes it to stop working. The rubber on the screw has been cleaned off.

The leak that was found is also an intentional design feature as it lubricates the rotating seal [18]. When not in use a manual valve above the pump should be shut to stop the water pressure from the tank forcing water through the seal and causing rusting.

While the initial problem was identified as the screw in the pump being stuck in the rubber cap, the underperformance of the pump is still unconfirmed. The problem is thought to be caused by a blockage in the pipe caused by the non-functional 3 way valve down steam. Tests were run with the pump pumping directly into the drain instead of through the 3 way valve into the storage tanks. The pump was compared to the Cyclone Recycle pump and they both seemed to operate with similar rotation speeds and observed flows. Currently it seems as if the pump itself is fully functional but there is a blockage in the pipe, this cannot be fully confirmed until the new pneumatic relays are installed for the 3 way valves.

4.1.4 Lamella Tank Under Flow Pump

When the Lamella Tank Underflow pump was first tested, no water would get pumped out into the Storage Tanks. The Lamella Tank Underflow pump has had low flow issues before due to the small downstream pipe size causing the pump reference having to be kept below 20% to avoid causing damage. When tested recently there was no flow at all which indicated a blockage which can damage the pump. During testing a plastic pipe was attached after draining the manual valve and directed into the drain. It is unclear whether the blockage is caused by the faulty 3 way valves or something else. This cannot be tested until the fixed 3 way valves are reinstalled so this will be part of future work. A pipe has been installed from the draining valve into the drain so that the blockage is avoided. This is a temporary fix. If the problem still persists once the fully functional 3 way valves are installed, it is recommended to increase the size of the pipe going into the storage tanks.

4.1.5 Raw Water Valve

Towards the end of the testing period the Raw Water valve stopped working. The problem was found fairly quickly as the valve would work again after a hardware adjustment (hitting) the electric to pneumatic converter [19]. Every so often it would stop working again and it would need more hardware adjustments, since this is an essential part of the plant it has been recommended that the electric to pneumatic converter be replaced as soon as possible.

4.1.6 Non Linear Tank Pump

A small issue was observed with the Non Linear Tank pump, as when the pump was not active there was still flow between the Non Linear Tank (NLT) and the Needle Tank (NT). In Figure 12 a test was run to fully identify the problem. As the raw water valve was opened and the NLT began to fill up a flow was recorded in-between the NLT and NT even with the NLT pump being off. Once the NLT was almost full the raw water valve was closed and the two tanks reached a steady state. This level in both tanks was measured to be 108cm from the base of the Pilot Plant, which indicates that they have the same pressure head when at the same height relative to the each other. If this is a major issue a solenoid valve could be installed between the two tanks with a program that opened the valve when the pump is activated and closes it when the pump is not running. This would stop the flow between tanks while inactive.

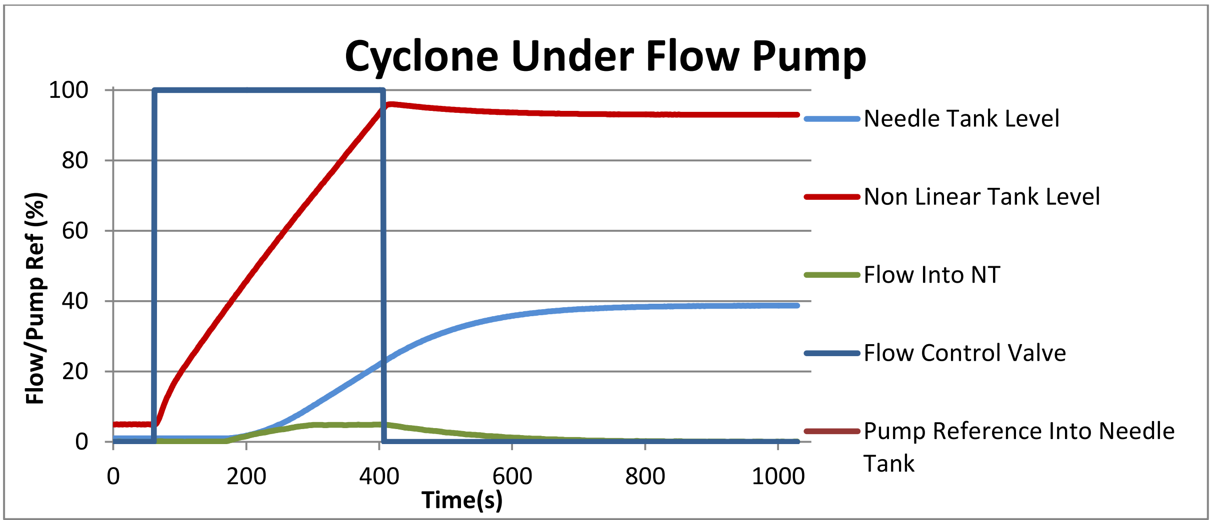

Figure 12: Non Linear Tank Pump Test

4.1.7 Needle Tank Pump

The Needle Tank Pump was investigated due to its observed poor flow rate. A test was run that compared the flow against the pump percentage, as can be seen on Figure 13. It can be observed that 0%- 50% pump reference there is a flow increase from 0%-30% while from 50%-100% only yields a flow increase from 30%-36% which is an obvious problem. The maximum flow of 36% is also concerning since a year before the final maximum recorded flow was 43% and the previous maximum recorded that semester was 50% which is indicating a steady decrease of performance [20].

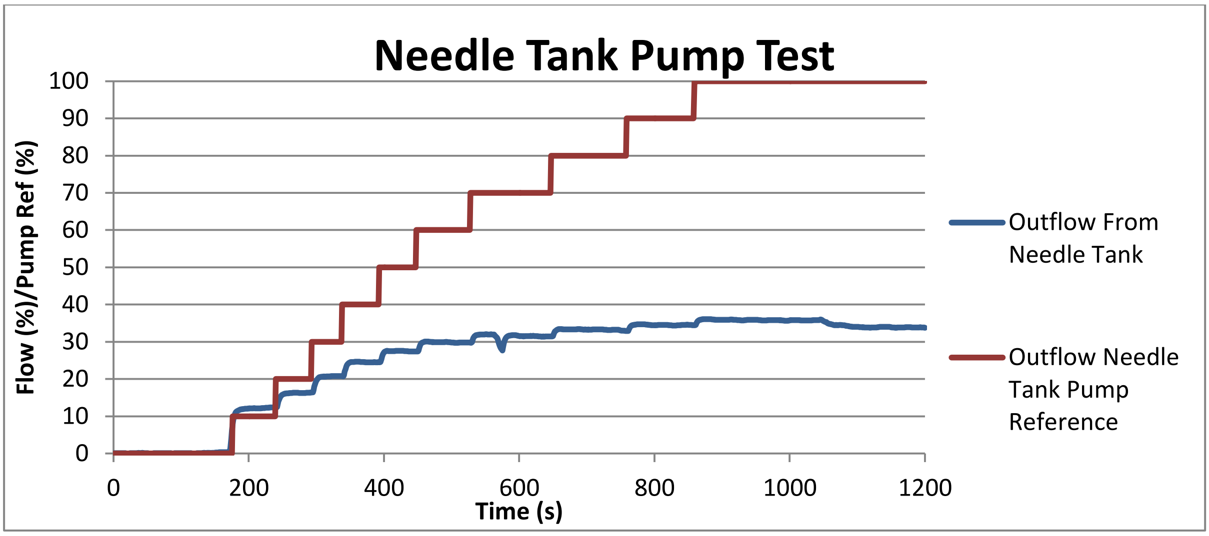

Figure 13: Needle Tank Pump Test 1

The NT pump can be compared to the NLT pump by achieving an equal reading on both the NT flow meter and NLT flow meter. This will keep the level in the NT constant indicating that the flow meters are calibrated the same. The 100% pump reference of the NT pump produces a flow equal to the NLT pump at 53% as can be seen in Figure 14. It can also be observed that the NLT pump far out performs the NT pump as when the pump is increased to 100% the flow almost doubles to 73%.

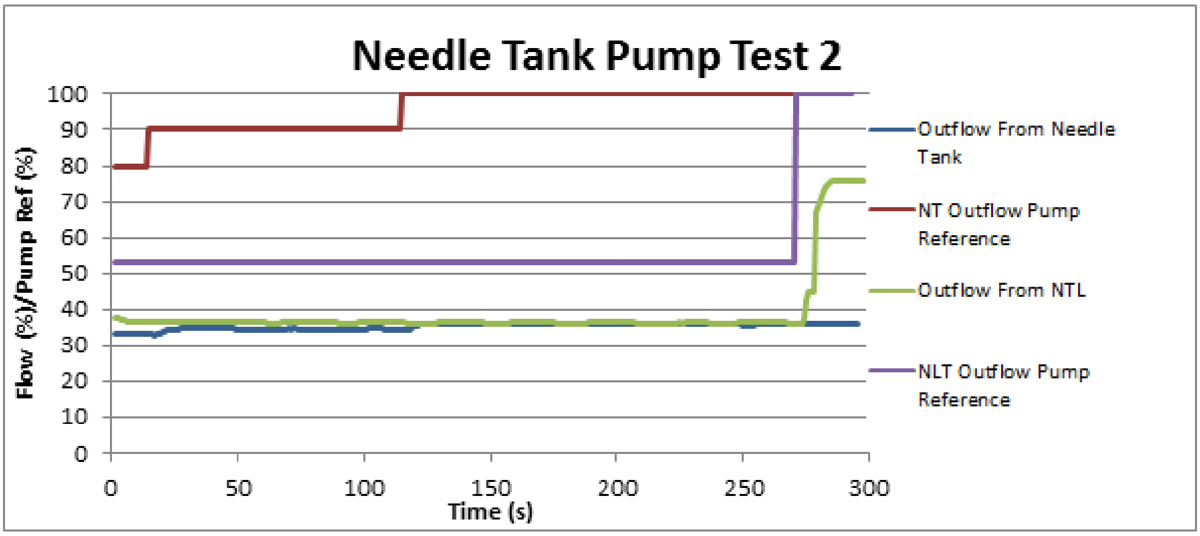

Figure 14: Needle Tank Pump Test 2

While investigating the underperformance of many of the FCVs in the system it was found that the FCV directly downstream from the NT pump could not open to 100%. The FCV was removed to test if this was the cause of the pump's under performance. In Figure 15 it can be see that the pump's performance is greatly improved reaching a flow of 57%.

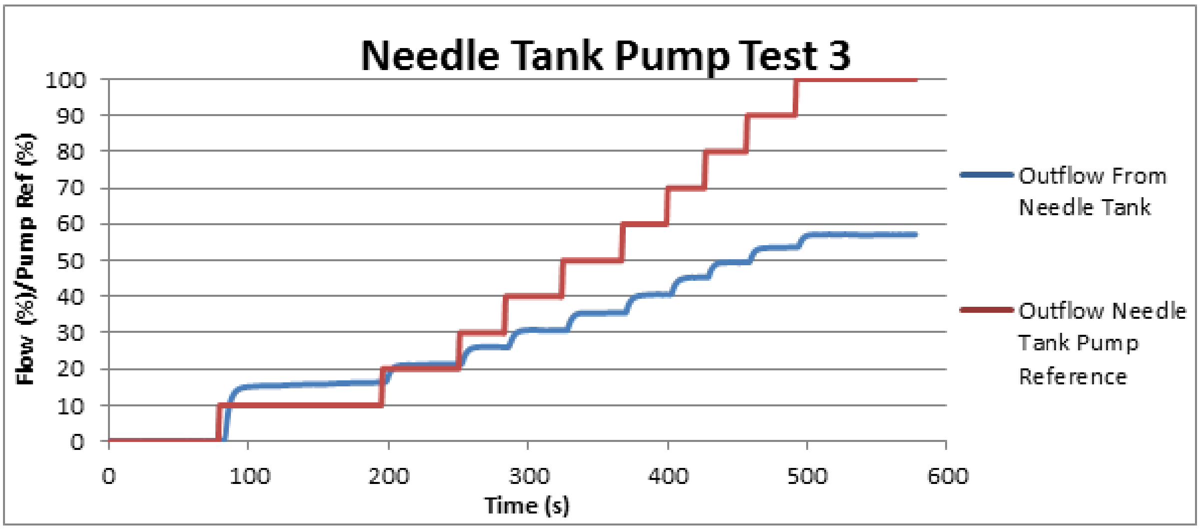

Figure 15: Needle Tank Pump Test 3

A quick comparison was done to compare the pump performances before and after the FCV was removed as can be seen in Figure 16.

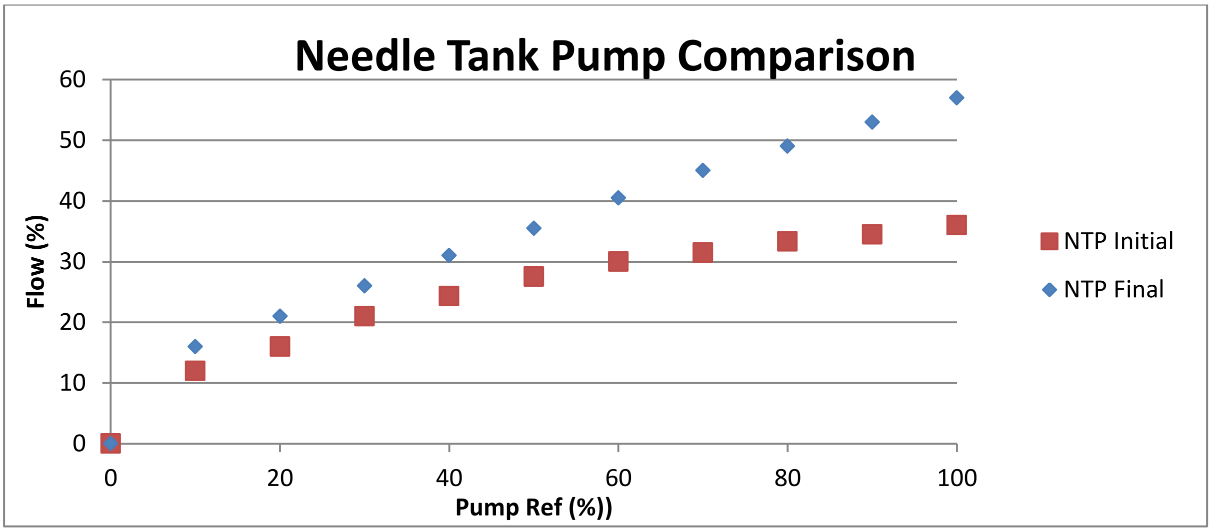

Figure 16: Pump Comparison Before and After

It is recommended that the FCV not be reinstalled as it greatly reduces the ability of the pump to control the NT's level, which it is primarily used for. A manual valve should be installed if the NT's under flow stream ever needs to be used. The FCV should only be installed in the case that a cascade controller needs to be implemented and the FCV is fully functional. While better interlocks have been introduced to stop all misuse of his pump it is still recommended that periodic tests are done to monitor performance especially in the case of another FCV being installed.

4.1.8 Steam Valves

The performance of each steam control valve was noticed to be considerably different. While doing a visual inspection of the valves it could be seen that each valve had a different range of motion. By opening the steam's outlet valve and collecting the condensate the performance difference could be quantified. From Figure 17 it can be seen that steam valve 1 has the least range of control and valve

2 has the greatest. It was also observed that steam valve 2 had a leak which would cause the temperature in CSTR 2 to increase even when closed.

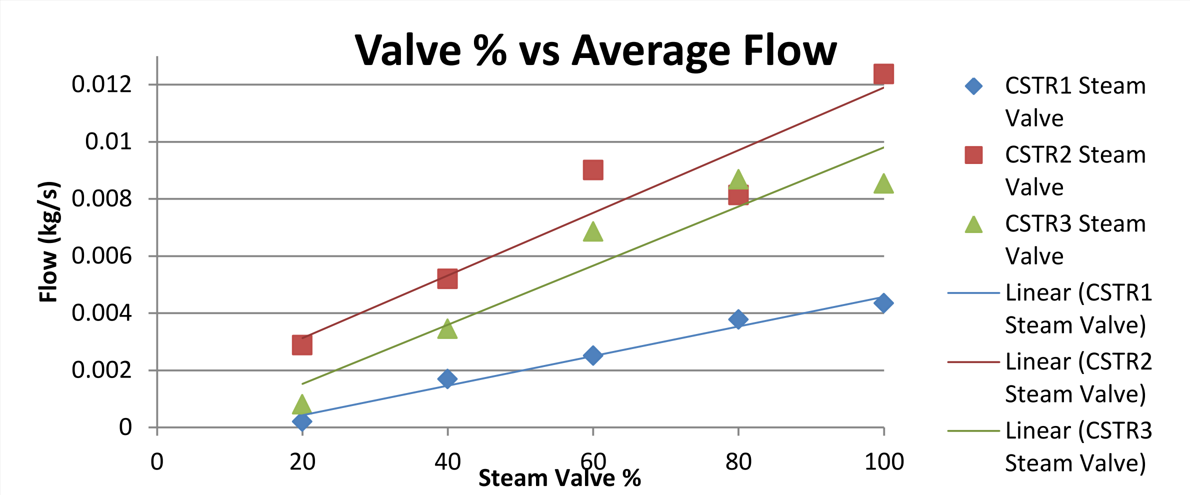

Figure 17: Steam Valve tests

Steam valve 2 also leaks, so when the steam is turned on at the manual valve before the three steam valves the temperature in CSTR2 will increase. It is unclear whether there is a leak in the CSTR3s steam valve or the tank's temperature increases because it is getting a hotter inflow from the CSTR2, which is being heated by the leak in CSTR2s valve.

Since the initial tests the CSTR1 steam valve has become inoperable while all valves no longer fully close causing the average temperature to rise to 58^{o}C with a flow of 73.8 g/s coming from the Needle Tank.

In Figure 18 it can also be seen that when the manual steam valve is opened with all of the steam control valves are at 0% with a flow from the Needle Tank of 55.3 g/s the temperature of the CSTRs begins to increase. This Indicates that on occasion the steam valves will not fully close. The final temperature of the CSTR3 tank settles around 56 ^{o}C. This problem with the leaking steam control valves is a major issue as it prevents proper temperature control.

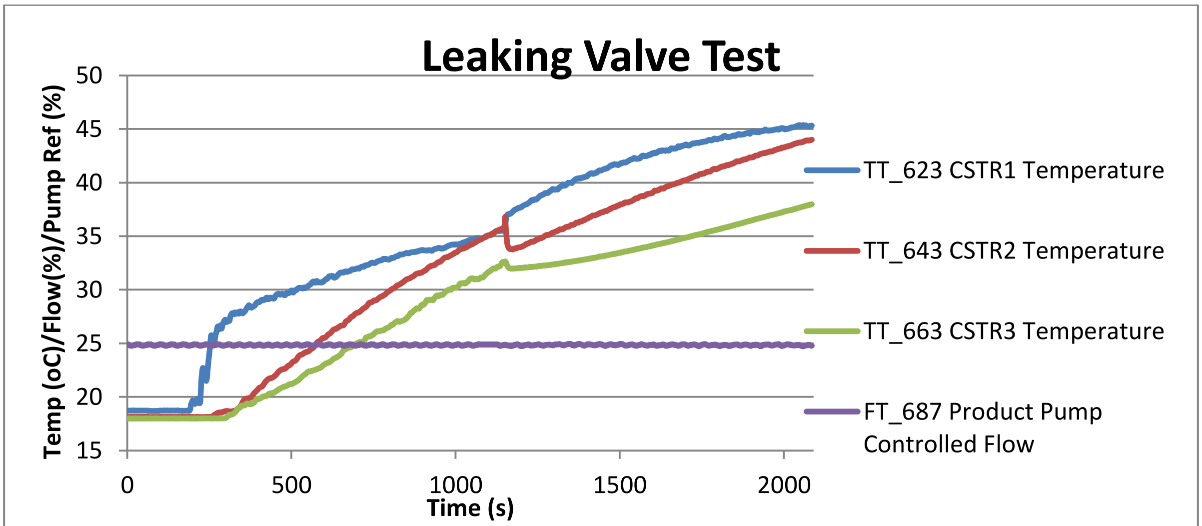

Figure 18: Leaking Steam Valve Test

It is unsure whether the issue with the steam valves is caused by the electric to pneumatic converter or the control valves themselves, it is recommended that both be replaced due to the age of the equipment and the importance of temperature control in the system. This will have to be included in the Future Work section as the approval for the electric to pneumatic converter and the control valve replacements will not be met by the end of this thesis.

4.1.9 Product Pump

The previous Product Pump was replaced in March 2014 [20] due to it overheating, caused by friction on the shaft. The current required to start the pump would trip the VSDs in-built interlocks. The replacement Product Pump also had its own set of problems. When the pump reference is at 0% power there is still a flow of 31.5 g/s indicating a leak. The new pump is a gear pump and when the temperature of the water is too high (greater than 70^{o}C) the cogs will expand and lock together. This causes a current overload where the VSD shuts the pump off and needs to be manually reset to operate again. There is also an issue with the pump being oversized for the pipes being used; the recommendation given to students is that this pump should not be operated over 50%. New interlocks and limits have been introduced to stop students running the pump at a speed greater than 50% and to also close the steam valves if any of the tanks read a temperature greater than 70^{o}C. This should prevent the pump from shutting off unexpectedly and prevent any damage being done to the pump.

During the semester, before the interlocks and limits had been put in place, a VSD in-built interlock was tripped, this was most likely caused by pumping water over 70 ^{o}C. While the pump was out of commission a “Rebuild selected objects and contents checkpoint from monitoring tab” was conducted on the C300 for the first time since the migration of Experion to its latest version. This was done so that new code could be loaded. Once the VSD was reset, the pump was no longer receiving commands or operating at any pump reference causing the students to overflow the CSTR3 while running the plant. It was found that the pump reference could be changed but it would switch continuously between two values so fast that only one was typically observed. When the reference was alternating between the two numbers faster than could be displayed, it was possible to change both but only when that number was being displayed. This was done by continuously entering the same number and hoping that both numbers would change.

To identify the problem, the PP_REF_681 block code was extensively researched by following every connection, finding all sources and learning the full functionality of all blocks. There was no apparent problem with the code’s logic and it was checked against the other working pump reference CM’s but the problem persisted. The code was then tested extensively by isolating or removing portions of code and testing them individually using the monitoring tab to observe the different effects. This was especially difficult as the reference number would alternate so fast it could not always be observed. While observing changes in the programs operation, the problem was identified as the ORDERINCM number in the feedback loop’s numeric block, which caused two numbers to try and overwrite the reference number at once. This can be seen in Figure 19. The ORDERINCM value refers to the order in which the FB will activate in each of the CM’s cycles.

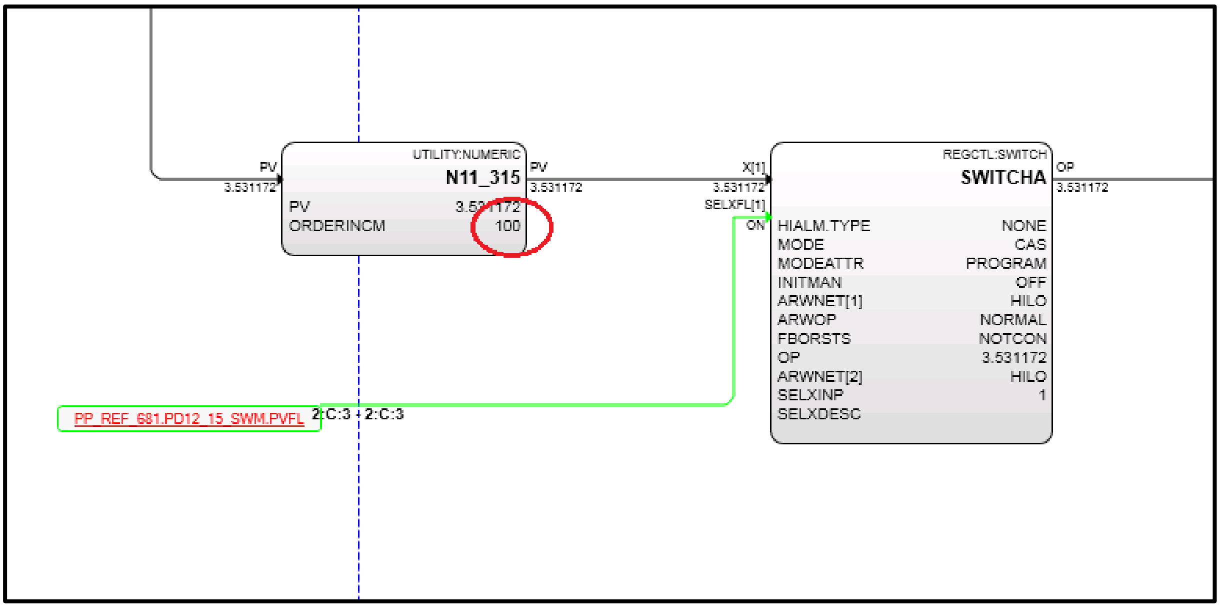

Figure 19: Numeric Order in CM

The order number was changed to be greater than the auto manual mode of PID logic's order number but less than PID blocks order number. This fixed the problem, allowing the students to continue using the plant as they had before.

Once again, before the semester was over, the pump was run with a temperature exceeding 70°C with the tank finally reaching 100°C. After this incident the pump was found to shut off at much lower temperatures, while the plant was being run by an ENG 420 student the following data from Figure 20 was obtained. It can be seen that at approximately 53°C the Product Pump is matching the input flow from the Needle Tank at approximately 42.9 g/s . As the temperature of the tank rises above 55 °C the pump needs to exert more power to match the same input flow and when 58.5 °C is reached the pump's power cuts out.

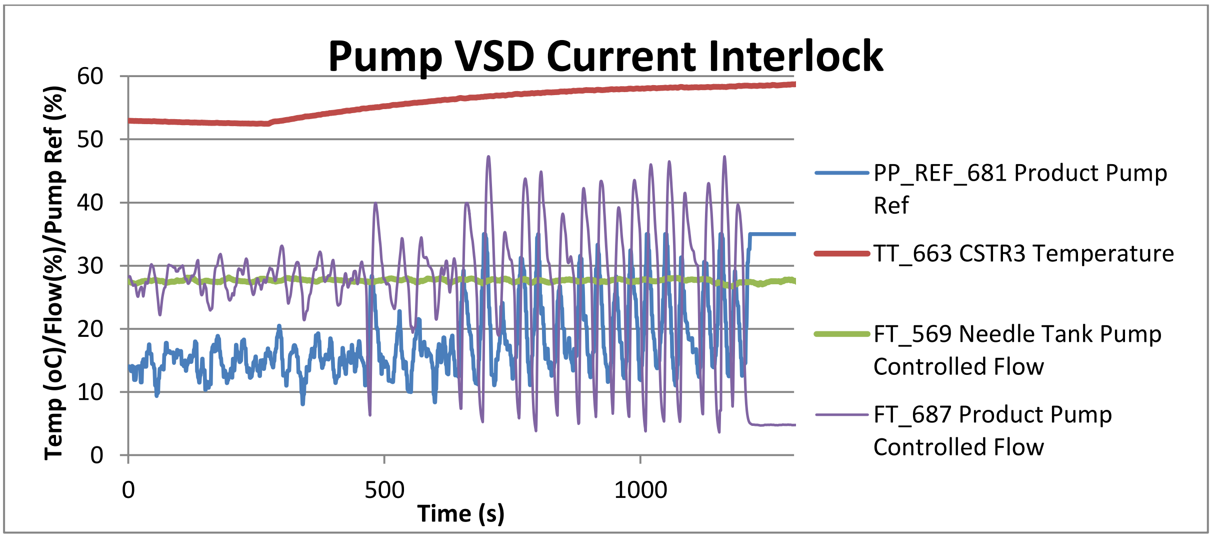

Figure 20: Pump VSD Current Interlock Test

In Figure 21 it can be seen that when the Product Pump is being run to match the maximum Needle Tank pumps flow of 53.2 g/s the flow starts to drop when the temperature reaches 65 °C and shuts off at 77 °C.

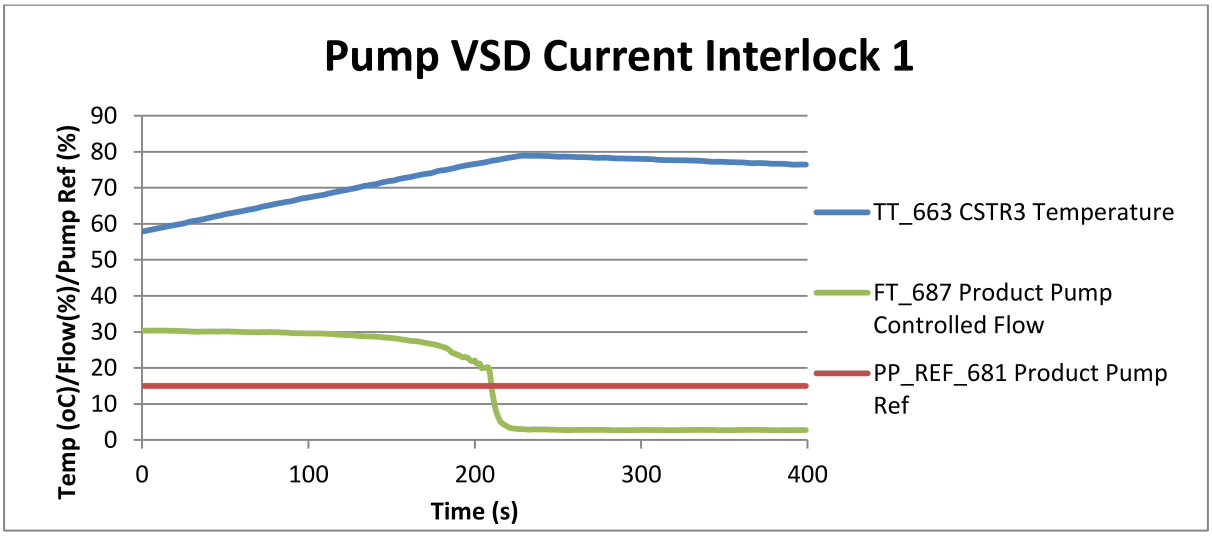

Figure 21: Pump VSD Current Interlock 1

The pump only turns back on when cooled to 75 °C and operates normally at 63 °C, as can be seen in Figure 22. This is an issue as with the steam valve leaks the lowest temperature of the tanks will be 56 °C. It can be seen in Figure 19 that it is possible for the pump to shut at 58.5 °C when not being run to match the maximum inflow, this leaves very little range for control.

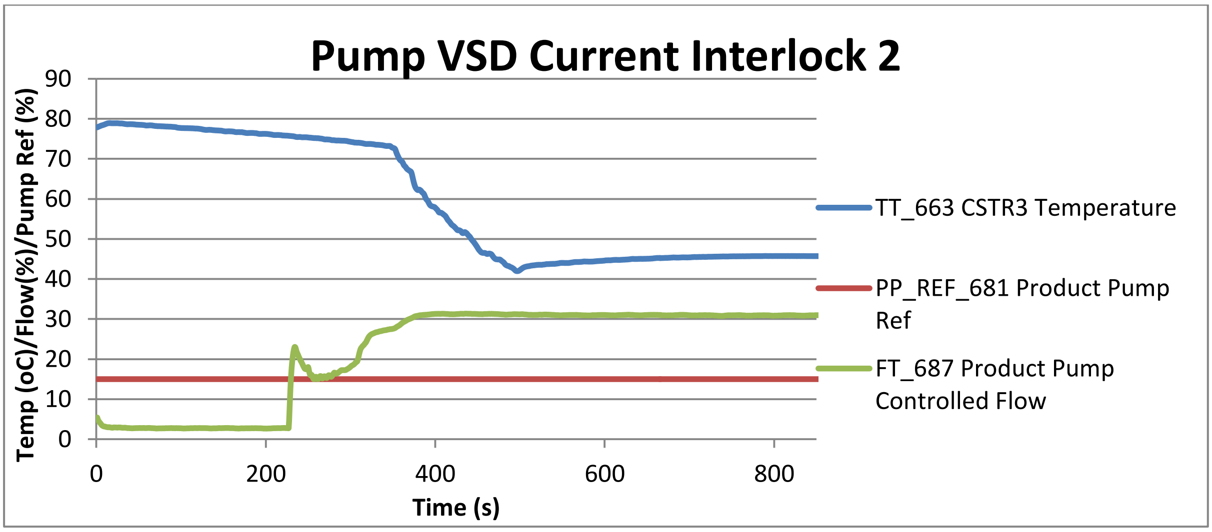

Figure 22: Pump VSD Current Interlock 2

The school's electrician was consulted and it was advised that there were no available VSD controllable pumps that can be used for hot water on the market, so replacing the pump is not an option. The solution to the pump shutting off at high temperatures can be partly corrected with the steam control valves being replaced, as it would allow for a lower minimum CSTR bank temperature and the new temperature interlocks being implemented on the steam valves.

4.1.10 Recycle Stream Solenoid Valves

The CSTR recycle stream control valve and all three solenoid valves were working. Occasionally the recycle stream would read a flow (2% to 10%) even when the flow control valve was at 0%. This could be due to the flow meter being positioned after the pump but before the control valve. This was considered a minor issue with no need for fixing.

4.2 Interlocks

The Pilot Plant has a number of interlocks programmed onto the C300 controllers to prevent the misuse of the equipment. The last known list of interlocks was compiled in 2010 by E.Hopkinson [2].

An interlock is a constraint that will prevent an unwanted state from occurring. They can be applied to any electrical or mechanical device or system and they are commonly used to prevent harming people or damaging equipment. Typically when a certain condition is met it was trigger the interlock to shut down certain devices.

A full list of the interlocks can be found in Appendix B, with all missing or inadequate interlocks highlighted in red. An updated list of interlocks and guide to changing them has been included in the updated documentation.

4.2.1 Investigating Interlocks in the Pilot Plant

While analysing over 150 CMs in the C300, it was found that all current interlocks have been implemented in the CMs containing DO and are linked to the respective DEVCTL (Device Control) Blocks SI (Safety Override Interlock) input.

When checking the interlocks that were in the system against the interlock list, it was found that the majority of the interlocks listed were not present. Most of the low tank level pumps interlocks and all of the agitator interlocks were missing.

4.2.1.1 Overflow Interlocks

A common problem in the Pilot Plant is that students who are inattentive or have designed poor plant control will overflow the tanks. While this is not a major problem at first there have been many instances of tanks overflowing for hours which can cover floor of the Pilot Plant and cause unnecessary slipping hazards. To remedy this, a high tank level interlock was also introduced for each tank by turning off the immediate upstream pump or raw water valve to prevent tank overflow. A 5 minute delay has been added so that students will still be able to tune controllers and learn from the overflowing experience while not completely flooding the Pilot Plant.

4.2.1.2 Control Valve Interlocks

To implement interlocks on the control valves they will need to be added into their respective reference AO CMs to change the reference value to 0% when the interlock occurs. This is in contrast to the existing method of interlocks used on the DOs. This method was used for the NLT overflow interlock as the inflow for the NLT is the raw water valve and the CSTR steam valves.

Since some pumps can be damaged by being run while the downstream control valve is less than 100% a new interlock preventing the FCV from being closed past 50% has been created. This will still allow for cascade control.

4.2.1.2 Temperature Interlocks

The new Product Pump that was installed last year will automatically shut off if it pumps water greater than approximately 70°C. This generates a fault message in its corresponding VSD and needs to be reset manually before it can be used again. To prevent this, temperature interlocks will be introduced into the three steam valves to prevent this from occurring. The temperature interlocks will close the steam valves once the temperature in CSTR3 is greater than or equal to 70°C.

4.2.2 Interlock Implementation

After a table of the intended interlocks was made, they were systematically implemented and tested. The tests were conducted by causing each interlock condition while viewing the CM in the monitoring tab to confirm correct operation. Figure 23 shows the Feed Pump interlocks before work was completed. The circled areas are where low level interlocks were originally missing.

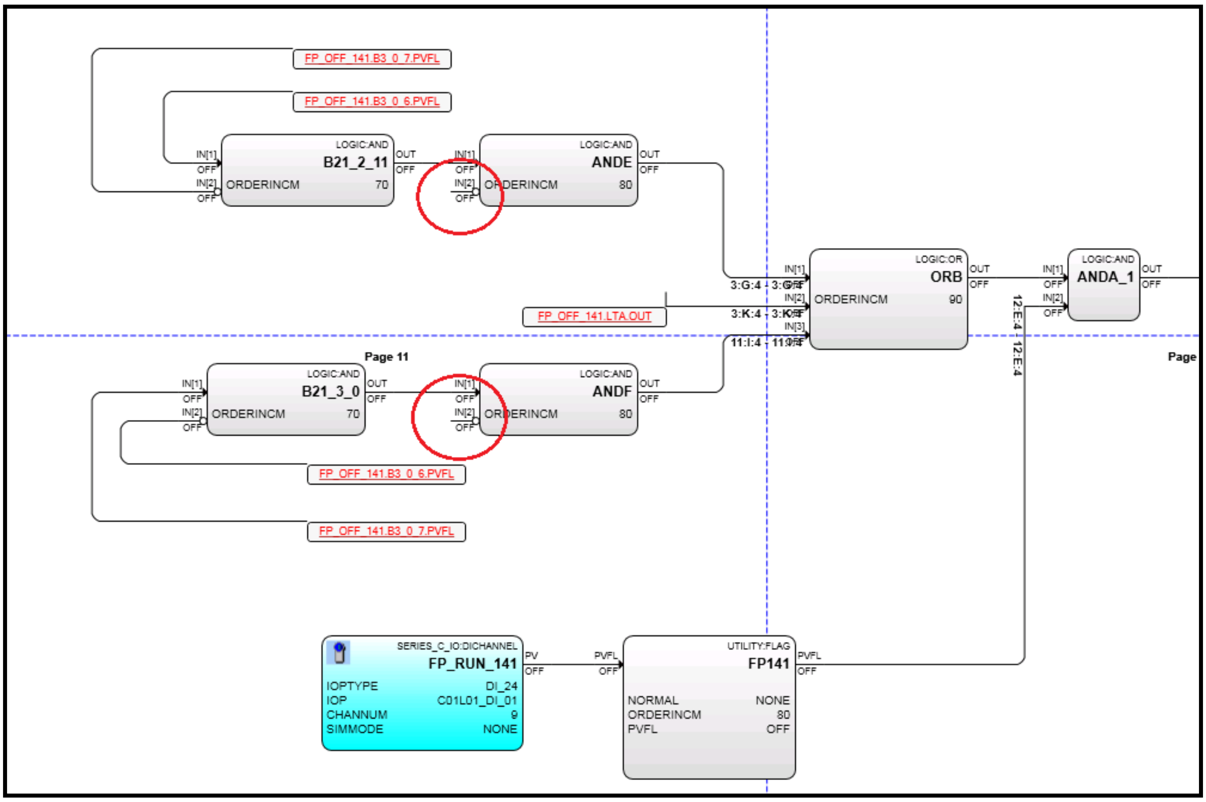

Figure 23: Feed Pump Missing Interlocks

Figure 24 shows the updated interlocks for the Feed Pump.

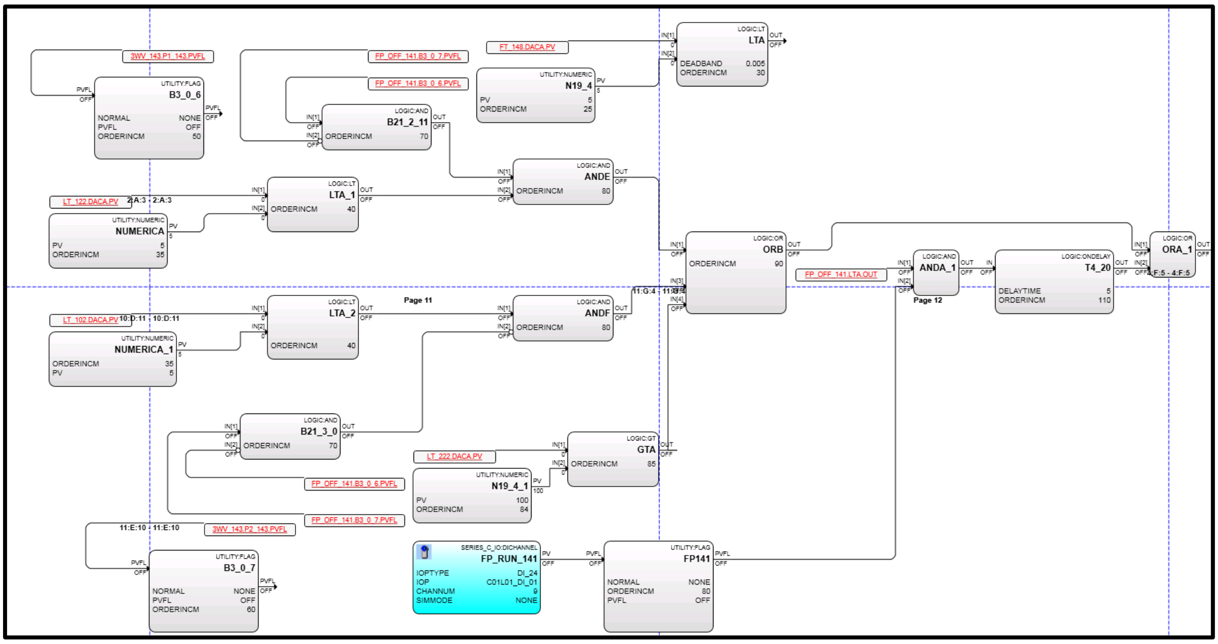

Figure 24: Final Feed Pump Interlocks

4.2.3 Interlock Testing and Results

4.2.3.1 Interlock Delay Redesign

When implementing the BMT low level interlock with a 5 second delay, a problem was detected while running tests. As shown in Figure 25, when there is a pump reference of 50% and the low level interlock is triggered at a level of 5% the level reaches 1.31% because of the 5 second delay. This is dangerously close to running the pump dry with a 50% pump reference so it is highly likely to run the pump dry at a pump reference of 100%. It was also discovered that, due to this delay, the pump could be run dry for 5 seconds if the tank is initially empty, which is a flaw in the interlock design.

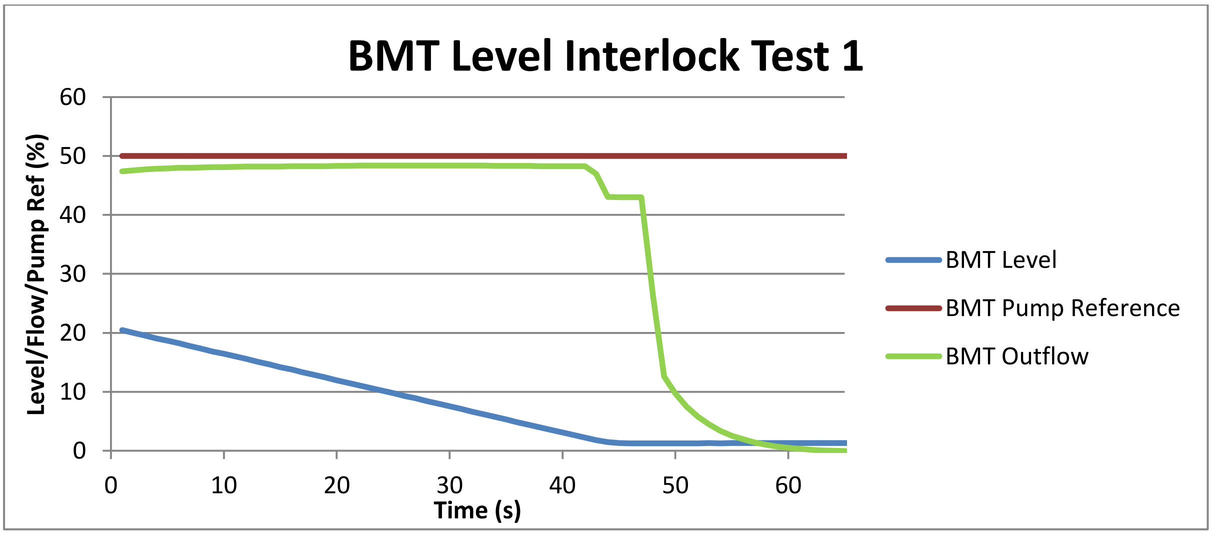

Figure 25: BMT Level Interlock Test 1

To correct this obvious issue all interlocks were redesigned, so that their time delays were removed, with the exception of the interlocks on flow and the steam control valves since the time delays were still necessary; this can be seen in Appendix B. It can be seen from Figure 26 that, with the time delay removed, the level will reach an acceptable final value of 3.63% with a pump reference of 50%.

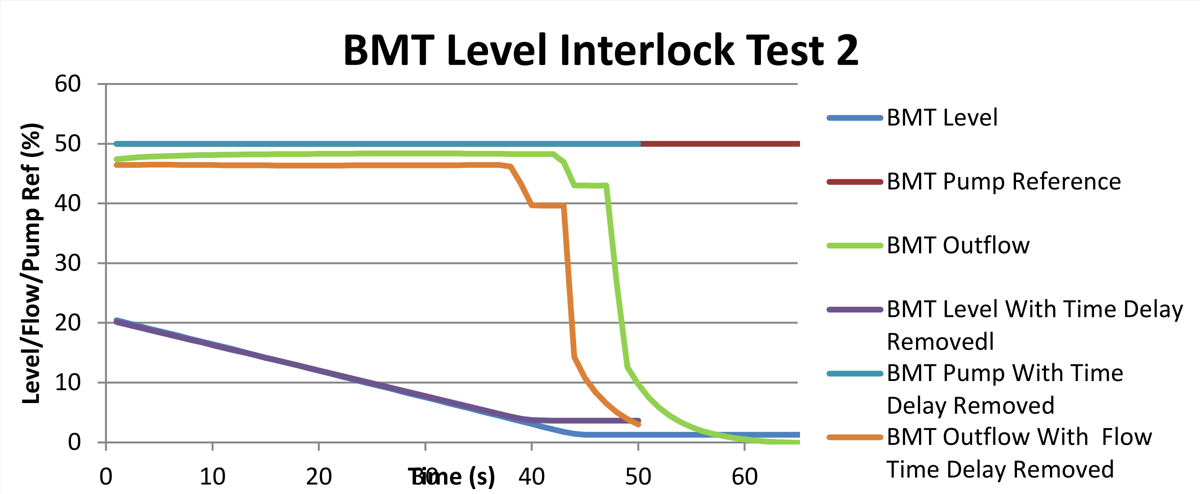

Figure 26: BMT Level Interlock Test 2

It can also be seen in Figure 27 that even with a pump reference of 100% the level will reach 1.30% without the time delay, which is acceptable.

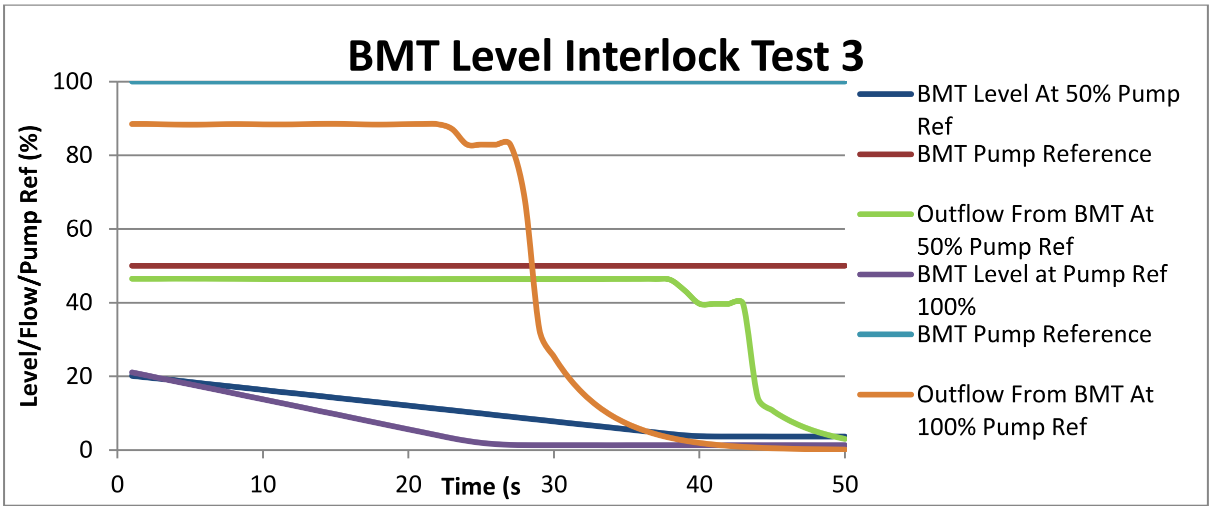

Figure 27: BMT Level Interlock Test 3

With the time delay removed, the pump can no longer be started with a level less than 5%, which is the correct way it should operate to avoid damage.

4.2.3.2 Wiring Errors

While testing the Product Pump interlocks, it was found that the flow less than 5% interlock was not activating due to the Product Pump DI block not activating. This DI block should activate when the pump is turned on. The block settings were investigated and found to be correct, so the physical wiring was inspected. The DI seemed to be wired correctly but would not receive an inverse logic true when the pump was turned on like the other pumps. The wires were traced back to the Product Pump VSD which was generating the correct DO inverse logic true. Since it seemed to be wired correctly, but the true signal was not being received at the C300 DI, the wiring was tested and a loose connection was found that fixed the issue.

While testing the steam flow control valves, it was found that the agitator interlocks were not working because Agitator 661 was activating the Agitator 641 DI FB and vice versa. Rather than just switching the code, the wiring was investigated and the 661-RUN-B and 661-FLT-B was found to be incorrectly switched with 641-RUN-B and 641-FLT-B. The DIs were rewired correctly and tested which fixed the issue.

4.2.4 Not A Number

Another problem was the occurrence of Not a Number (NaN) which displayed on a sensor whenever the limits of sensor have been exceeded i.e. approximately less than -1.5 and greater than 102.5. If a NaN occurs then some interlock and all controllers would stop working correctly as they cannot process this value. Some logic has been put in place to prevent this from causing any unexpected problems.

By searching through the Knowledge Builder documentation and the Control Builder Library an ideal FB CHECKBAD was found that was essential in fixing this issue. The CHECKBAD block has a real number input which tests for a NaN. If a NaN is detected it will output a true and a real number will cause it to output a false. A simple loop back into a NUMERIC block was sufficient in holding the previous loops value. These logic loops were implemented in the 23 AI sensor CMs for flow, level and temperature, an example of the CM before implementation can be seen in Figure 28.

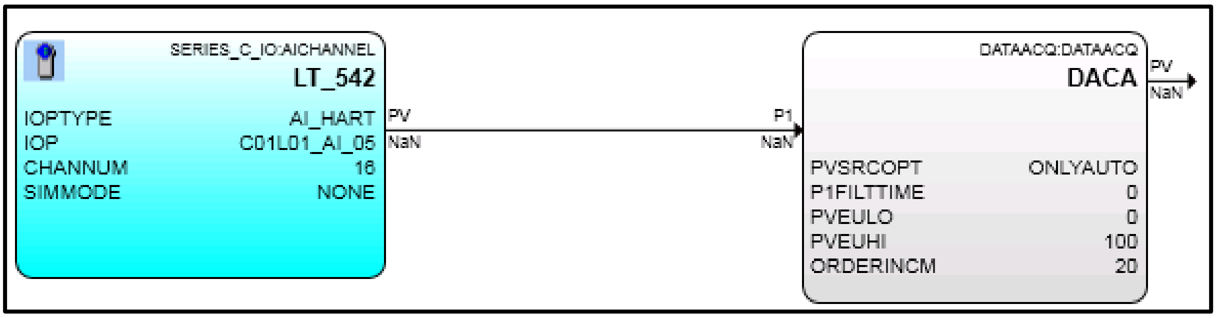

Figure 28: AI Sensor CM

A SELREAL block is used to select between the currently read value from the sensor and the previous value. If the CHECKBAD block is reading a real value it will output a false and the current value will be written into the sensor's data block to be used thoughout the code. But if a NaN is read, then a true will be output causing the SELREAL block to continuosly read and output the last real value. This can be seen in Figure 29.

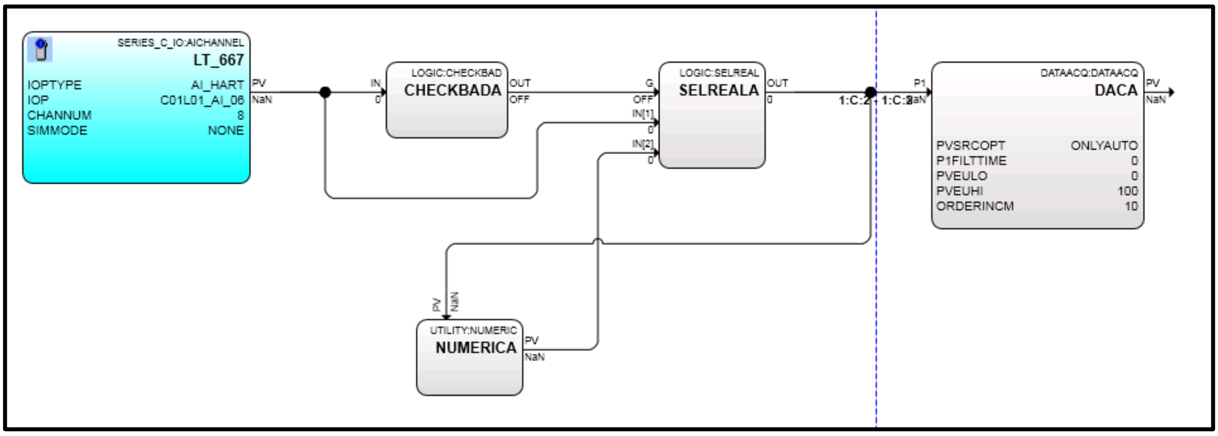

Figure 29: AI Sensor CM NaN Solved

By using this logic it is possible for the sensors to output the last real number that they read before reading a NaN. By taking the last value it will be possible to tell if a tank is reading an overflow value or an empty value. This takes into account the problem a NaN result could create in the interlocks and controllers.

4.2 Limits

At the start of each semester students are instructed not to run the Lamella UF Pump greater than 30% and the Product Pump greater than 50%, however these limits are exceeded time and time again, causing damage to the pumps and reducing their effectiveness. This precaution is due to the downstream from the pumps being too small so when too much water is forced through them the pressure build up will damage the pumps. To prevent this, logical greater than and less than IF statements were to be introduced into the pump's reference CMs that output to the VSDs. A LIMIT FB was found that did the same job as the IF statement logic so that was used instead. The LIMIT block works as follows: If the pump reference is greater than the upper limit then the pump reference will equal the upper limit. If the pump reference is less than the lower limit then the pump reference will be equal to the lower limit. While if neither of the last two conditions are true then the pump reference will equal the set pump reference. The LIMIT block needed to be inserted before the pump reference block so that the feedback loop would not be affected as can be seen in Figure 30. This limit on the pump speeds will prevent the inevitable misuse of exceeding acceptable limits.

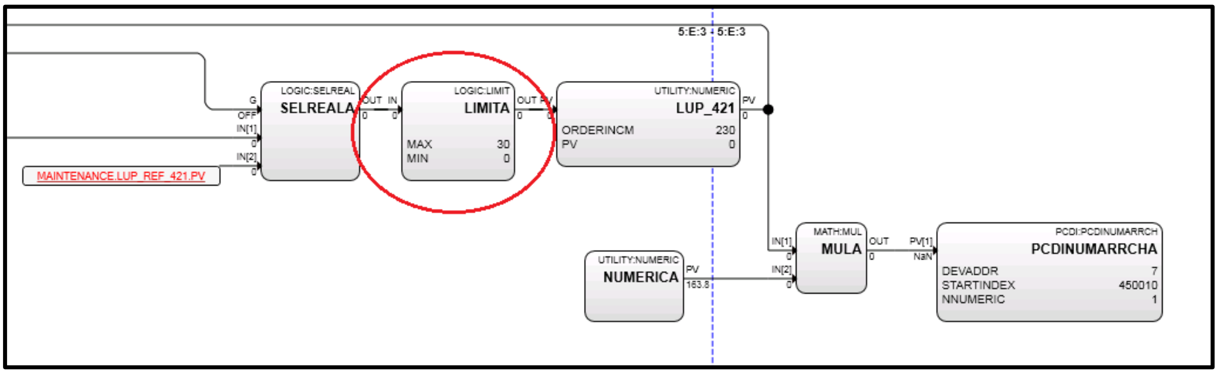

Figure 30: Limit Block Implementation

4.4 Code Restructuring

In the C300 code there is an abundance of redundant code that has either become obsolete after an update in the code or was never fully implemented to begin with. While referring to J.Dring's thesis [10], obsolete code was identified, removed and tested in each individual CM. The most obvious problems in the code were related to the WARN_LIGHT CM and unused Flag FBs.

4.4.1 WARN_LGHT

In every CM that deals with the DO of pump control there is a large unused code as can be seen as in Figure 31. This code is linked to and activated by a CM named WARN_LGHT.

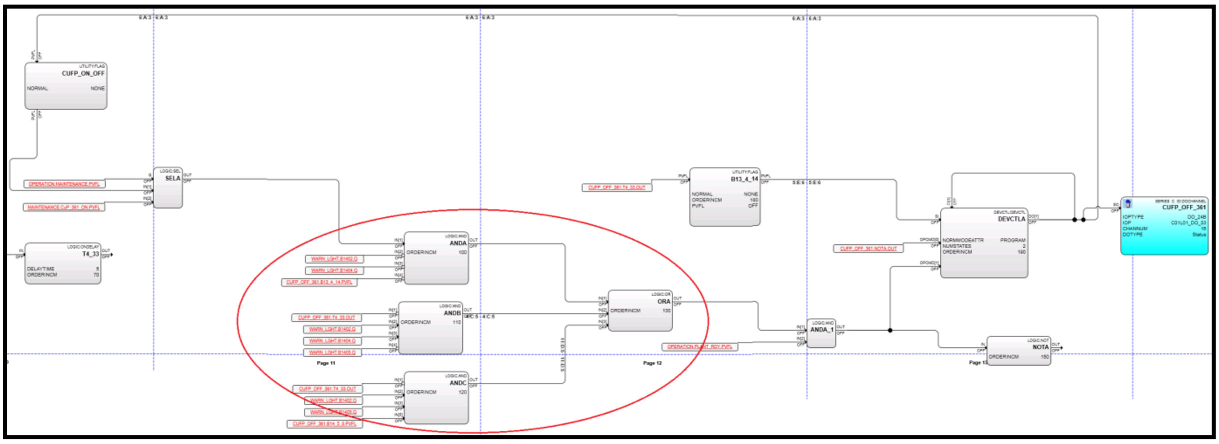

Figure 31: Redundant Warn_light Code

In the WARN_LGHT CM there are two portions of code, the first section of code is quite useful and will run the plants warning light for a short time when the plant is activated by either a user in station or by pressing the maintenance/ demonstration button. The second portion of code has the intention of turning off the Pilot Plant after a certain amount of time after activation by either “Manual/Maintenance” DI18 or “AutoRun” DI19 input. After investigation into the function of the second portion of code it was found to be redundant. The only way this CMs code is set to activate is if the DI 18 is true and a set timer has counted down, or if DI 18 and DI 19 are both true. These events will never occur since there is nothing wired into the physical DIs. By removing each section of code that relies upon the WARN_LGHT CM each DO CM can be reduced in size and tidied. An example the DO code after the redundant code has been removed can be seen in Figure 32.

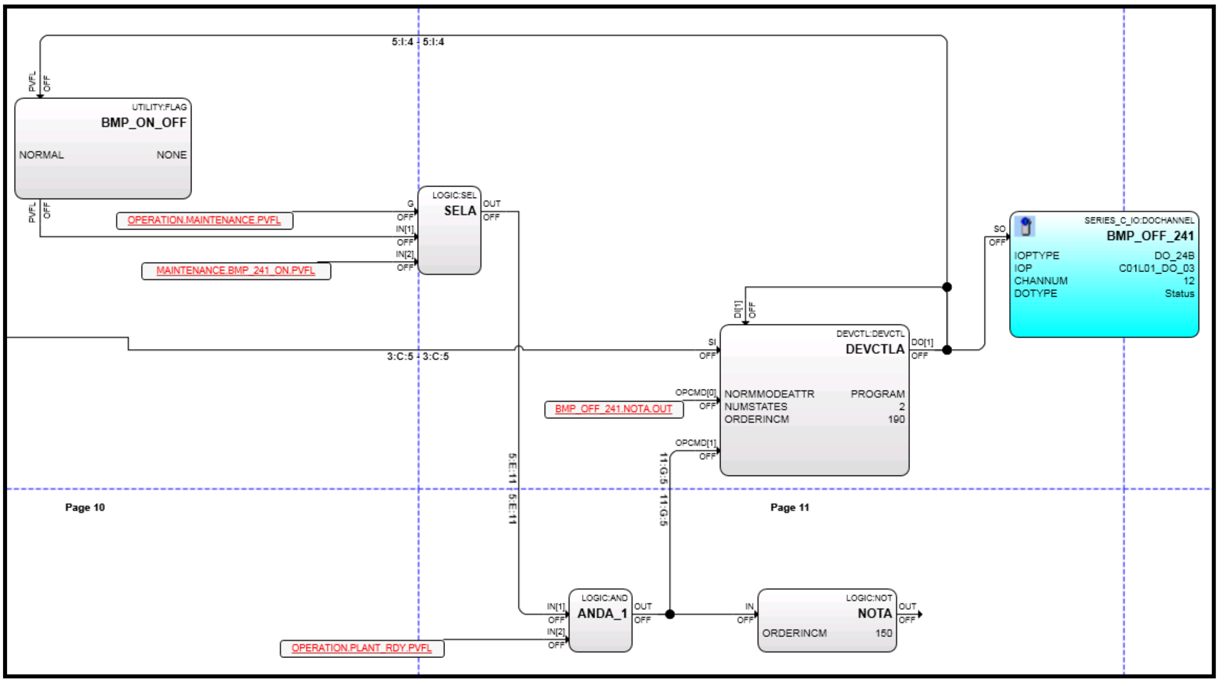

Figure 32: Warn_light Code Removed

Each section was tested after the code was removed, in order to be certain that it would still function as expected. 40 FBs were removed in total from the following CMs:

- FP_OFF_141
- CRP_OFF_341
- CUFP_OFF_361
- FDP_OFF_521
- NUP_OFF_561
- PP_OFF_681

By removing this code there was no effect on the plant operation and it greatly reduced the visual complexity of the code.

4.4.2 Flags

The obsolete FBs include flags that were created during the PLC 5 to Honeywell C300 migration [10]. Originally the flag blocks were needed for monitoring the PLC 5's code, however they are irrelevant in the Experion system [10]. These unneeded flags were removed whenever encountered during the editing of the system. While a large number of the flags were removed, it is possible that many have been missed; if other sections of code are worked on in the future they should be assessed for flags.

4.5 Installing High and Low limit Sensors into the Lamella Tank

There was a need to add level sensors to the Lamella Tank since there was no way to determine the levels in these tanks. This caused unexpected disturbances in the Needle Tank and also an inability to add interlocks on the Lamella Tank pump.

Two float switches were commissioned to be installed as a high and low level sensor with the switches positioned to be normally open. Once they had been fixed to the tank they were wired into spare terminals of the second C300 DI board 23 and 24. The C300 IO list and wring diagram were then updated.

Along with physically wiring the sensors, the HMI and C300 software also needed to be updated. In the C300 program a new CM was created and configured to house the DI blocks. It was named LT_422 to keep the same format with other level sensor blocks. The contents of the CM can be seen in Figure 33.

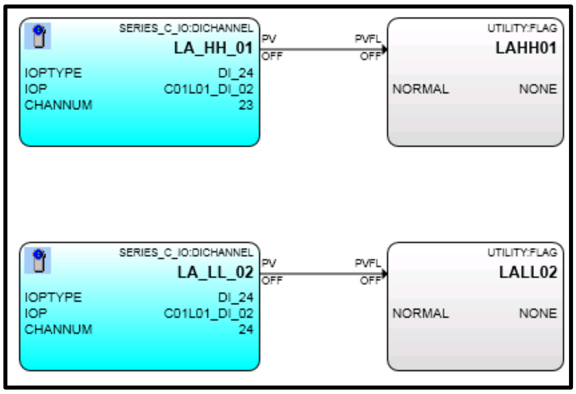

Figure 33: New Level DI CM

I/O tests were then run to confirm wiring and signals being received. Once confirmed, the low level sensor was used in creating a simple interlock for the Lamella Tank pump. By using the DI in series with a NOT block, the pump's interlock would activate when the water level drops below the low sensor. This can be seen in Figure 34.

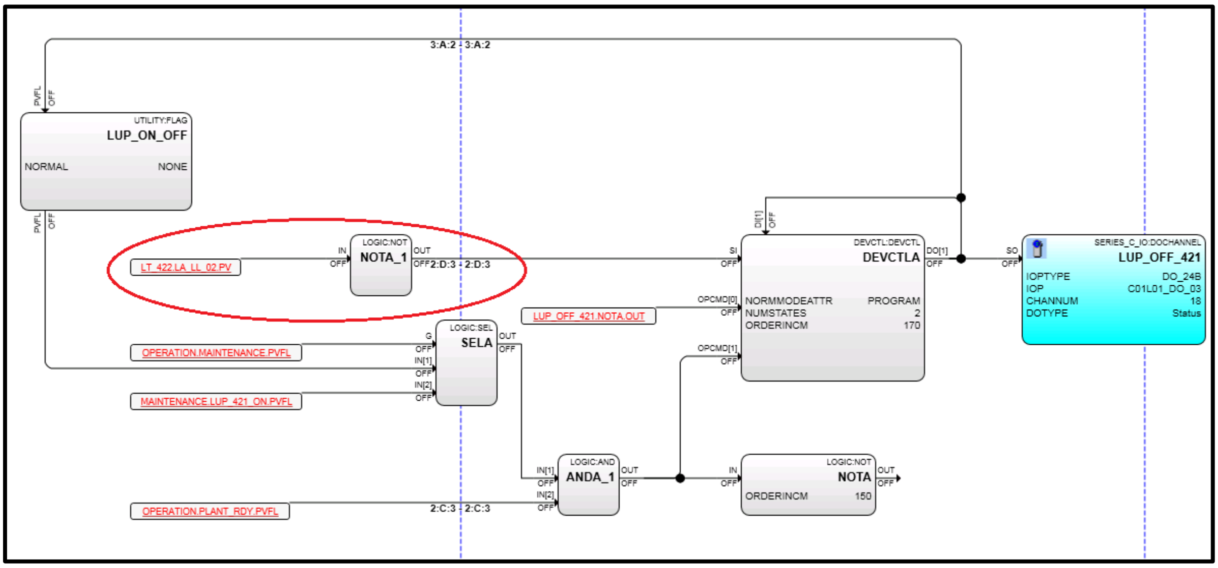

Figure 34: Lamella Tank Pump Interlock

The HMI was also updated for users to indicate when the level sensors were being tripped. In one of the HMI displays the Lamella Tank was extended in size and two indicators were added. The two level indicators created were designed after the Buzzer, Light and Program indicators to keep a uniform look. The indicators were configured to have opposite displays due to the nature of the switches and limits. When the low sensor receives a true, it will be black indicating the water is greater or equal to the mark and when it receives a false it is below the limit and will be red. When the high sensor receives a false, the indicator light will be black showing the water is below the high limit and when it receives a true, it will display red showing it is equal or above the high limit. The modified display can be seen in Figure 35.

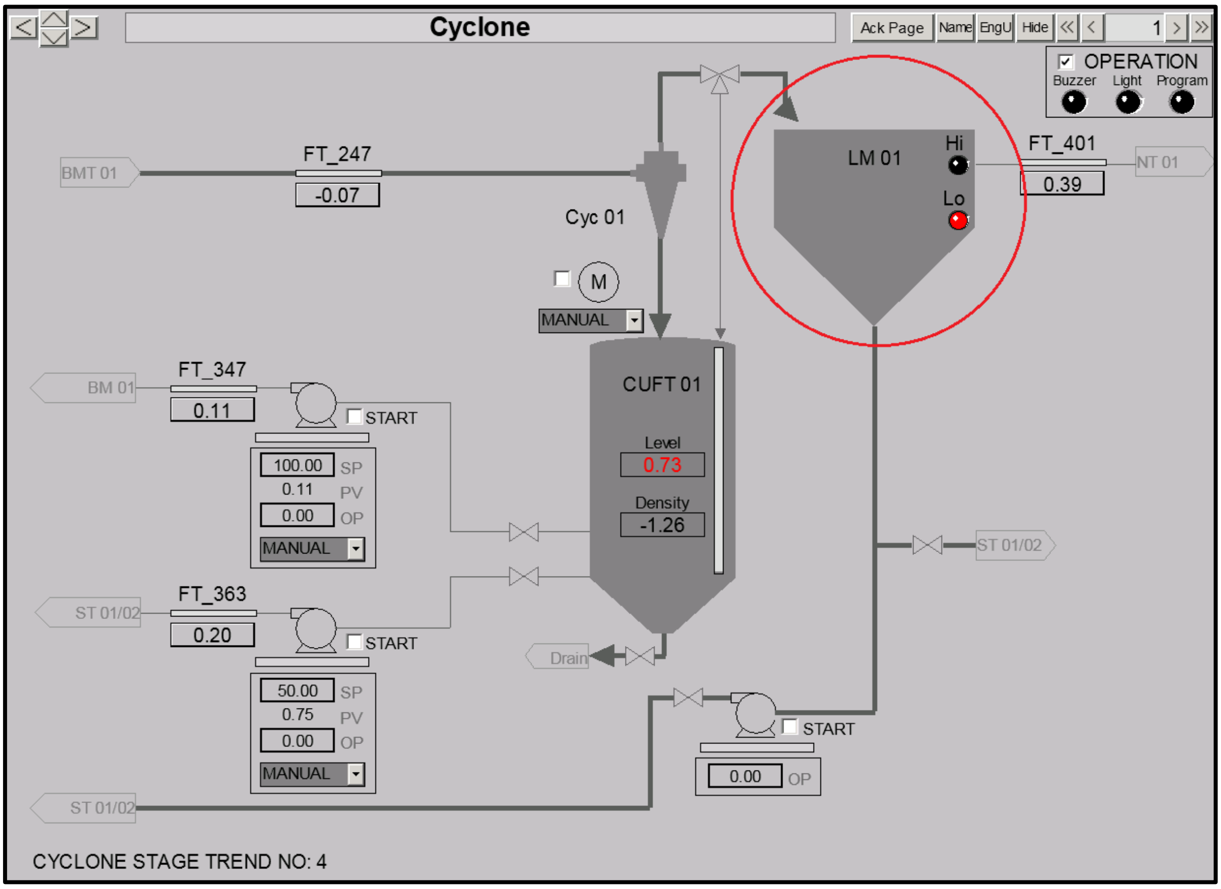

Figure 35: Cyclone HMI

When the high level sensor is activated it also indicates that there will be a flow going from the Lamella Tank into the Needle Tank. Because of this, a high level indicator light was also added to the Needle Tank HMI to alert students of where the disturbance is coming from. This can be seen in Figure 36.

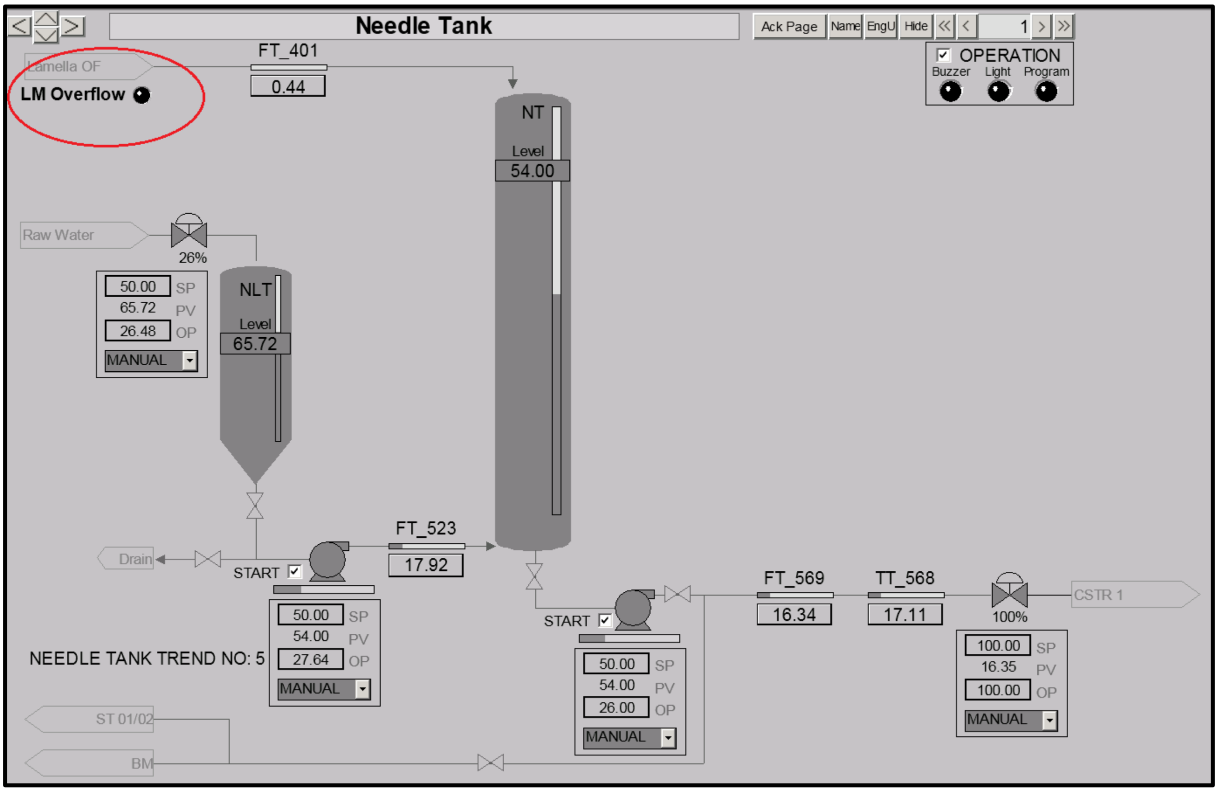

Figure 36: Needle Tank HMI

4.6 Installing Solenoid Valves on Raw Water and Air Supply

Solenoid valves were installed on the raw water and instrument air lines after their respective manual valves. This was done so that the manual valves could be left permanently open so that the maintenance/demonstration program can be run at any time. These are shown in Figure 37.

Figure 37: SV Raw Water and Control Air

AC solenoid valves were used so relays as shown in Figure 38 were needed to convert the C300 DO 24V DC signal into 24V AC.

Figure 38: SV Relays

The relays were wired to the designated DO ports and the IO list was updated. The DOs were then integrated into the code and tested with both the normal running of the plant and with the maintenance/demonstration program. The SVs will open whenever a user or the maintenance/demonstration program activates the plant, as can be seen in raw water SV CM in Figure 39.

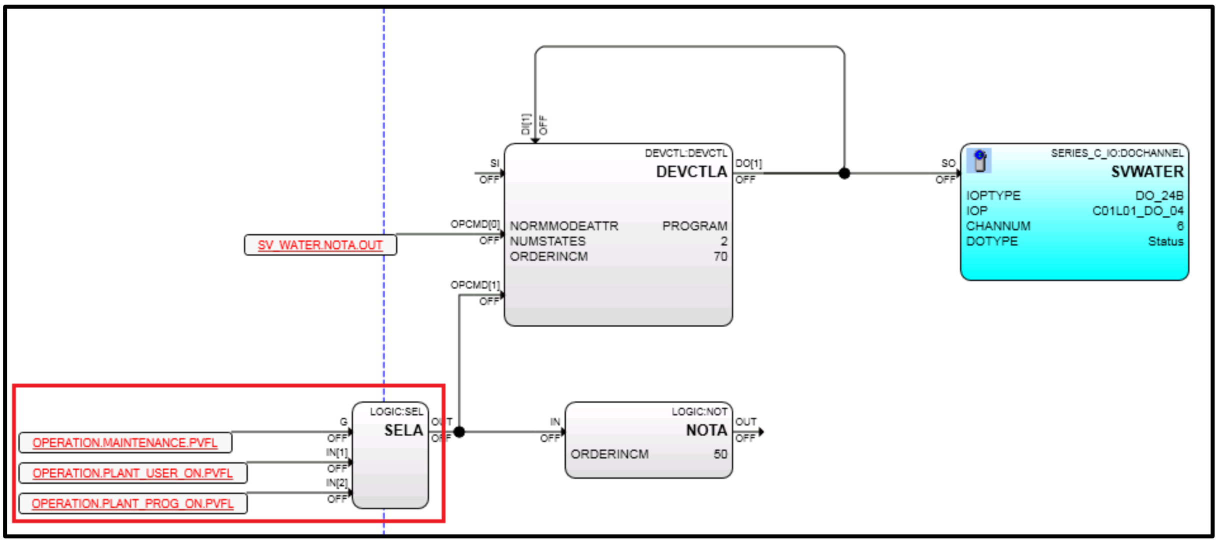

Figure 39: SV Water CM

4.7 Additional HMI Improvements

In addition to the HMI update of the Lamella Tank limit switch indicators a number of other HMI improvements have been made. One problem noted was that in the individual HMI pages the whole plant could not be monitored, which would causing the students to constantly switch between the overview and individual pages. While inside a specific HMI page, it was possible for tanks to over and under flow without the user's knowledge. To fix this problem a display panel was developed to be included in every HMI page. The display included all relevant PVs of level and temperature. The final display, as seen on the overview page in Figure 40. This will help students to monitor the entire plant while working on or manipulating specific areas in Station. Alarms were also set in the CSTR temperatures AI CMs so that the numerical displays would change to red when temperatures are above 65°C. A high alarm will now be triggered at 65°C and a high high alarm at 70°C which is the interlock temperature for the Steam Flow Control Valves.

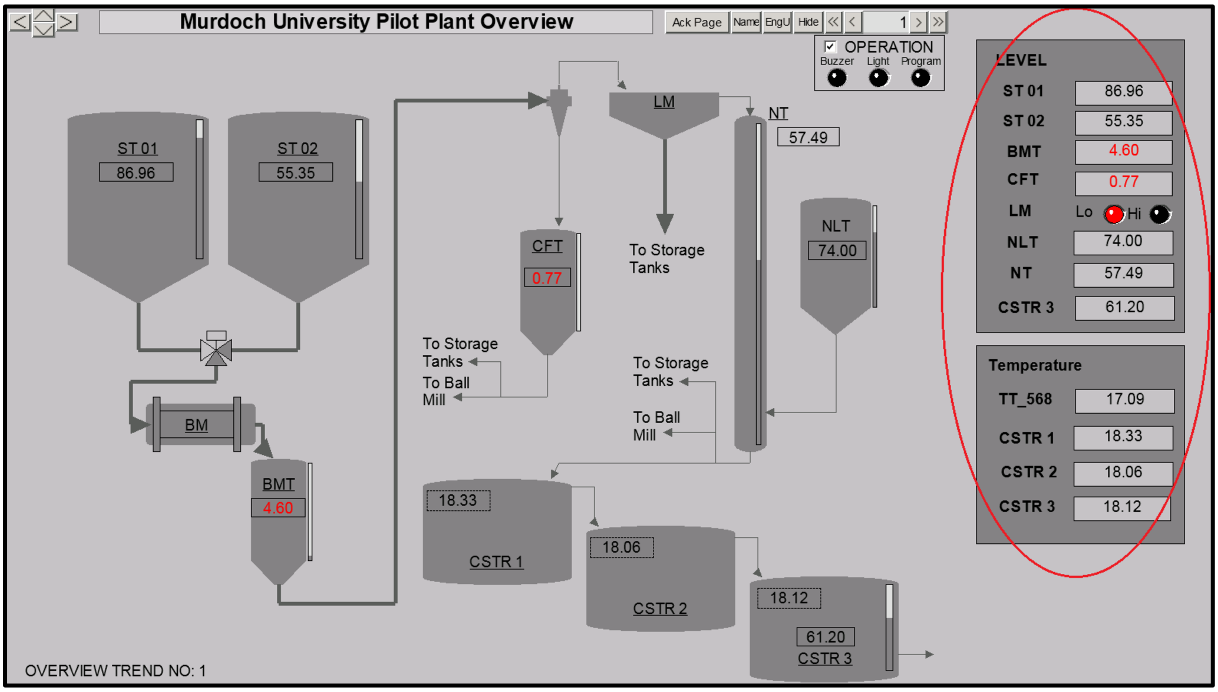

Figure 40: Level & Temperature Display

Another improvement was to display the inflow rate and temperature to the CSTRs in the CSTR page and not just the Needle Tank page so that all the relevant information would be in one page. This can be seen in Figure 41.

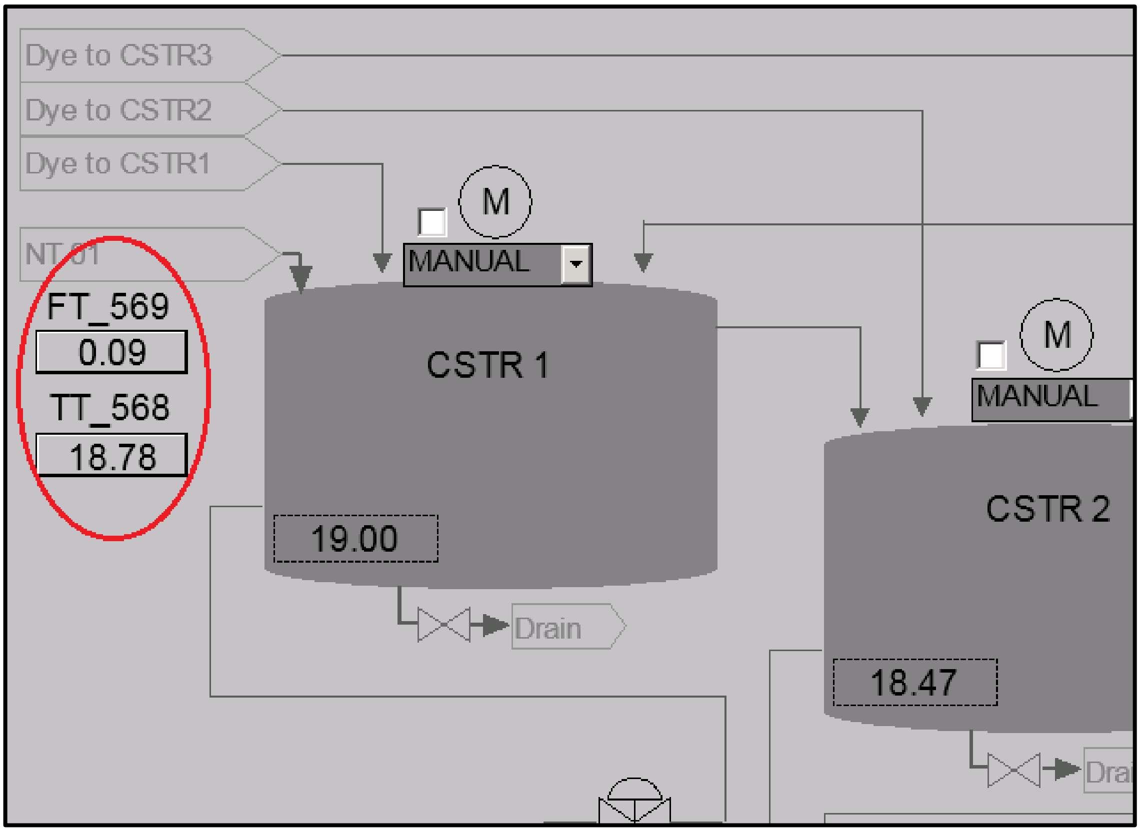

Figure 41: CSTR in Flow Rate and Temperature

5.0 Issues Encountered

Several issues occurred during the course of this project which ranged from delaying progress to completely halting it. Only the major issues encountered will be mentioned here.

5.1 Experion Teaching System

While exploring OPC connection with MATLAB, there were several issues that impeded progress. Many weeks were spent analysing the error messages and trying to isolate the root causes of MATLAB's inability to connect to OPC servers. The two main issues found were the lack of Implicit DCOM access was given to users on each computer, no account for MATLAB and there being missing OPC foundation files.

Due to unforeseen circumstances once it was time to use Experion with OPC, the Experion Teaching system was unusable. Over the semester break Experion was updated from the Experion PKS - release 311 to the Experion PKS - release R430.1. This caused numerous problems with the Experion Teaching systems Control Builder, rendering it inoperable and many weeks were spent trying to identify and fix the problems but it was ultimately fruitless. Due to this the communication to Experion using OPC and the implementation of advanced controllers in the Pilot Plant using MATLAB were incomplete and needs to be put into future work.

5.2 Experion Pilot Plant

Due to the Experion system's migration to its newest version, the Pilot Plant systems code could not initially be backed up. With the Pilot Plant being so important in the Instrumentation and Control engineering degree at Murdoch, no changes could be made to the system without a confirmed working backup that the system could be reverted back to if any problems occurred. It took many weeks to finally create a backup and begin implementing code changes.

Code and hardware implementations were also delayed due to a class needing to use the Pilot Plant all semester. This caused the majority of the implementation to be delayed until the final few weeks of semester.

6.0 Future Work

With several unforseen issues being encountered over the course of this project there was a number of tasks that have been assigned as future work.

For the Experion Teaching System the future work is as follows:

- The successful implementation of OPC Communication with Experion PKS needs to be completed.
- Once OPC has been implemented with Experion, there will be an opportunity to control simulated systems using 3rd party programs.

For the Pilot Plant the future work is as follows:

- 3rd party programs to be used as new interfaces for controlling the Pilot Plant and implementing higher level controllers.
- While investigating the Pilot Plant and devising solutions for the major problems it was discovered that the majority of the problems were related to 3 ways valves and FCVs. These problems most likely occurred due to these valves not being designed for long periods of inaction. A program should be written to prevent these issues from reoccurring. So an SMC that opens and closes all SVs and FCVs and switches the 3 way valve's positions periodically needs to be designed and implemented. This could be done every 24 hours or even several times during the night when the plant is not in use.

7.0 Conclusion

Over the course of this project a great deal of research into the Honeywell Process Knowledge System and C300 controller has been carried out. This knowledge provided the foundation for this report in relation to fully understanding how the Pilot Plant operates and how to edit the pre-existing code to implement the essential changes and additions.

The first major task was to implement a simulated system in Experion using LabVIEW and OPC communication. Due to unforeseen circumstances this could not be completed during the course of the thesis. Even though uncompleted, in the process of implementing the simulated system, the necessary skills were acquired allowing work to be started on the Pilot Plant.

Following this was the investigation of all of the current problems in the Pilot Plant and solutions were devised to get the plant into its optimum working condition. This was ongoing throughout the thesis as new solutions were devised after developing a better understanding of the system. Many coding problems were fixed and recommendations were made for certain hardware to be replaced or fixed. Interlocks were then designed and implemented to prevent and reduce new problems form occurring in the pilot plant. Interlocks were thoroughly tested to verify their efficiency and functionality. The code was also restructured by removing an abundance of redundant code that has either become obsolete after an update in the code or it was never fully implemented to begin with. Once removed, there was an improvement in efficiency and a reduction the visual complexity of the code. Hardware additions to the Pilot Plant were also completed. The two float switches for the Lamella tank and solenoid valves for the raw water and instrument air lines were installed and integrated into the current system. This involved updating the relevant wiring diagrams, block diagrams, the systems code and the HMI.

With a better understanding of the Pilot Plant and Experion Teaching system it is apparent that there is still a substantial range of improvements and innovations that can improve the Murdoch University Pilot Plant and ultimately the Instrumentation and Control Engineering major.

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Appendix A) Additional Documentation

This appendix contains a list and description of all of the supporting documentation of this thesis. If it is required the documentation can be obtained from Associate Professor Graeme R Cole at Murdoch University.

OPC Tutorials: This file contains the manuals for using OPC with different programs that have been developed. These new manuals have been added to the revised documentation system. Example programs have also been included with the manuals. The new tutorials include:

- OPC Basics
- NI OPC Server for PLC
- NI OPC Server Using LabVIEW
- LabVIEW OPC Client
- MATLAB OPC Client
- Quick Client

Updated Interlock List: This document contains list of the currently implemented interlocks.

How to Change Interlocks Tutorial: This document details how to change any of the currently implemented interlocks if the need arises.

Updated I/O Drawings: This document contains the updated lists of I/O in the Pilot Plant System.

Updated Block Library: This document contains the updated CM block library.

Updated Wiring Diagrams: This folder contains the updated relevant updated wiring diagrams for the Pilot Plant System.

Control Builder Access Lock Tutorial: A detailed tutorial on how to clear the common issue of access locks in Control Builder.

Pilot Plant Implemented Improvements: This document is contains a list of all the improvements and changes that were implemented in the Pilot Plant over the course of this thesis.

Pilot Plant Recommendations: This document is contains a recommendation list of all equipment that needs to be replaced or repaired.

Pilot Plant Improvement Upgrade CM Export: This file contains an export of all the current updated CMs files.

HMIWeb Display Screen Modifications: This file contains all of the updated HMIWeb files.

Experion Teaching System Documentation: This file contains the revised documentation system for the Experion teaching system which includes following new documents to help guild new users:

- An overview of the Experion PKS system to give the user some background knowledge.
- An Index of all current tutorials.
- An overview document describing the importance of each section and which manuals are essential in completing.

Pilot Plant System Documentation: This file contains the revised documentation system for the Experion teaching system with all updated documents.

Appendix B) Missing Interlocks

The Pilot Plant currently has interlocks on pumps, agitators, control valves and the Ball Mill. The interlocks that were missing or need to be changed are highlighted in red.

The pump interlocks are shown in Table 3:

Table 3: Pump Missing Interlocks

Pump	Interlock Description	Delay
FP-141	IF FLOW OUT (FT_148) < 5% THEN OFF	5 seconds
	TANK 1 SELECTED & LEVEL (LT_102) < 5 THEN OFF	No Delay
	TANK 2 SELECTED & LEVEL (LT_122) < 5 THEN OFF	No Delay
	BM LEVEL (LT_222) > 100% THEN OFF	5 Minute
BMP-241	IF FLOW OUT (FT_247) < 5% THEN OFF	5 seconds
	BMT LEVEL (LT_222) < 5% THEN OFF	No Delay
	CUFT LEVEL (LT_322) >100%	5 Minute
CRP-341	IF FLOW OUT (FT-347) < 5% THEN OFF	5 seconds
	CUFT LEVEL (LT_322) < 5% THEN OFF	No Delay
	TANK 1 SELECTED & LEVEL(LT_102) >100 THEN OFF	5 Minute
	TANK 2 SELECTED & LEVEL(LT_122) >100 THEN OFF	5 Minute
CUP-361	IF FLOW OUT (FT-363) < 5% THEN OFF	5 seconds
	CUFT LEVEL (LT_322) < 5% THEN OFF	No Delay
	BMT LEVEL (LT_222) >100% THEN OFF	5 Minute
LUP-421	IF LOW LIMIT SWITCH FALSE THEN OFF	No Delay
	IF LUP_REF_421 >30 THEN LUP_REF_421 =30	No Delay
FDP-521	IF FLOW OUT (FT-523) < 5% THEN OFF	5 seconds
	NLT LEVEL (LT_542) < 5 THEN OFF	No Delay
	IF NT LEVEL (LT_501) >100 THEN OFF	5 Minute
NTP-561	IF LEVEL IN NEEDLE TANK IS (LT_501) < 5 THEN OFF	No Delay
	IF BOTH FT-573 & FT-569 < 5% THEN OFF	5 seconds
	IF CSTR3 LEVEL (LT-667) >100 THEN OFF	5 Minute
DP-611	IF FLOW OUT (FT-613) <5% THEN OFF	5 seconds
	IF SV_614, SV _615 OR SV616 ALL CLOSED THEN OFF	No Delay
PP-681	IF BOTH FT-689 & FT-687 < 5% THEN OFF	5 seconds
	IF LEVEL IN CSTR 3 (LT-667) < 5 THEN OFF	No Delay
	IF FCV_688 + FCV_690 <100 THEN OFF	No Delay
	IF LEVEL IN CSTR 3 (LT-667) > 100 & FCV_690=0 THEN OFF	5 Minute
	IF PP_REF_681 >50 THEN PP_REF_681 =50	No Delay

The Flow Control Valve interlocks are in Table 4:

Table 4: Flow Control Valve Missing Interlocks

Flow Control Valve	Interlock Description	Delay
FCV-541	IF NLT LEVEL (LT_542) >100 THEN OFF	No Delay
FCV_570	- NO INTERLOCKS -	
FCV_571	- NO INTERLOCKS -	
FCV_574	- NO INTERLOCKS -	
FCV-622	IF TT_663 >75 THEN 0%	No Delay
	IF AG_621 OFF THEN 0%	No Delay
FCV-642	IF TT_663 >75 THEN 0%	No Delay
	IF AG_641 OFF THEN 0%	No Delay
FCV-662	IF TT_663 >75 THEN 0%	No Delay
	IF AG_661 OFF THEN 0%	No Delay
FCV_688	- NO INTERLOCKS -	
FCV_690	- NO INTERLOCKS -	

The agitator interlocks are shown in Table 5:

Table 5: Agitator Missing Interlocks

Agitator	Interlock Description	Delay
AG-101	OFF when LT-102 < 5 %	No Delay
AG-121	OFF when LT-122 < 5 %	No Delay
AG-221	OFF when LT-222 < 5 %	No Delay
	OFF when LT-222 > 95%	No Delay
AG-321	OFF when LT-323 < 5 %	No Delay
AG-621	- NO INTERLOCKS -	
AG-641	- NO INTERLOCKS -	