Major Project - Final Report

by James Davies

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UWTSD/Coleg SirGar



BSc Electrical and Electronic Engineering

PSDE 6019 – Major Project

Final Report

Kiln Plant H2 Blower Pressure Switch Replacement and Functional Safety Assessment

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Abstract

The following project was focused on process safety, and demonstrated the application of functional safety in an industrial setting. This included calculations to determine the safety integrity level required, as well as certain design elements.

The Safety critical element at the core of this project was a High-High pressure trip for the H2 blowers in the site's kiln plant. The existing pressure switch was set to be replaced by a pressure transmitter coupled with a Moore Industries Safety Trip Amplifier for increased reliability.

Another key focus of this project was process monitoring. In order to achieve this, a Siemens PLC was implemented. A Siemens HMI was also implemented to provide local information.

The SIL rating was calculated for the project, and any reasoning behind the choices made were shown. The design was determined by this SIL rating, as shown by the hardware fault tolerance and safe failure fraction.

A prototype was built in order to perform functional tests. The results of these tests determined whether the system will work properly when implemented on site.

An abstract of this nature should state the company in which the project was carried out, give a brief overview of the problem and should end with a clear statement of whether the project was successful or not. This abstract leaves the reader wondering. No budget mentioned.

Acknowledgements

I'd like to acknowledge the CIE team at Vale for their support during design and prototype build of this project, as well as Darren Paddison, Neil Hopkins and Shaun Collins from Vale. I'd also like to acknowledge Robert Davies, Bill McIntyre and Robert Jenkins from Coleg Sir Gâr for their support during the entire project.

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1. Introduction

The Vale Clydach refinery is a world-leading producer of nickel products for various industries. The carbonyl extraction process discovered by Ludwig Mond and Carl Langer in 1899 is the main process used on site. This process involves extracting pure nickel from nickel oxide. This oxide is obtained from ore, and is concentrated by various processes in order to maximize yield.

Once the pure nickel has been obtained, it is fed into kilns and reacts with hydrogen gas in order to reduce the nickel oxides, leaving impure nickel. This can then react with CO (Carbon Monoxide) in order to form the volatile gas, nickel tetra-carbonyl, $Ni(CO)_4$. Upon application of further heat, this molecule readily decomposes back into pure nickel and carbon monoxide gas. (Lancashire, 2000)

Hydrogen gas used in the nickel extraction process is highly flammable. Any amount leaking into the atmosphere can present a significant hazard to any persons in the vicinity. The H2 blowers on-site are a potential area for a major leak in the event of an overpressure scenario. There are currently high and high-high pressure switches on each blower as a safety instrumented system (SIS), but they are unreliable and provide spurious trips. In the event of pressure switch failure, there will be a potential for a H2 leak; and a spurious trip will lead to down time, which inhibits the capability of nickel production.

To resolve these issues, a decision has been made to replace the high-high pressure switch with a pressure transmitter. This transmitter will be connected to a logic solver, which will be programmed with the correct set point. A monitoring system will also be implemented, using web servers to create a remote station.

The aim of this project will be to design the new system following all relevant protocols stated in the IEC61508 functional safety standards. The following objectives will be met:

- Research the existing system in order to learn its operation so that an effective solution can be implemented.
- Calculate the Safety Integrity Level (SIL) rating for this system. Use this rating to determine the design of the circuit and the required components.
- Show three possible solutions that can solve this problem, and choose the most appropriate one. Full justification should be shown for choice.
- Examine another three solutions for the monitoring system and justify the option chosen here.

This section provides useful background information while setting out the aims and objectives of the project

- Develop a specification for solving the problem, and produce deliverables that can be reviewed to check if project was successful.
- Build and test the prototype. Review the data and determine whether the specification has been met.

2. Background Research and Literature Review

2.1 Research

2.1.1 Existing System

Hydrogen Blowers

The first stage of the carbonyl extraction process is to reduce the nickel oxide in the FMW in order to separate the nickel. This reaction involves H2, and blowers are used to move the gas around the system. As stated, blower overpressure trips are necessary to control the circuit and avoid a catastrophic failure, which could cause a fatality.

The system currently has two pressure switches for each blower; these are arranged to provide a high and high-high level trip. Throughout their lifetime in the plant, their reliability has been questionable; therefore, the high-high switch will be replaced with the Foxboro IDG20B pressure transmitter that will feed an analogue signal into a logic solver. This logic solver will then provide the necessary trip signal.

The following formula is used to calculate the mA output for a given pressure (SensorONE ltd, n.d.):

Linear mA out = 4 + (16 x ((Rdg – Low Rdg) / (High Rdg – Low Rdg)))

The lowest and highest readings for the IGP10 are set to 0 and 10 psi respectively. By using these values, along with the desired pressure of 5.5psi, the output current will be 12.8mA. This will be set in the STA as a percentage of the total span.

The transmitters will be in an explosive zone according to the ATEX (Explosive Atmospheres) section of the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR). It is vital that they are rated for this area. Careful analysis of the datasheet confirms this with the following extract “The transmitters are designed to meet Agency flameproof and zone requirements.” (Foxboro Inc., 2013)

There are four H2 blowers in the kiln plant, with two on each kiln line; one of these is shown in Figure 1. Photos can only be taken at a distance as only equipment rated for explosive zones can be used in close proximity.do you mean photographed?
In this photograph, the blower itself is clearly visible in the centre. It is the blue coloured object, and is the component that pressurises the gas. To the right of the blower is a large purple vessel. This is the inlet knock-out (KO) pot, and it is there to remove any moisture contained within the incoming gas through condensation. From the KO pot, there are two pipes. One of these is fed through the blower, and the other is a bypass line. In this bypass, there is a Fisher hand operated valve.



Figure 1: H2 Blower

Figure 2 shows the IA display. The purple line represents the flow of the hydrogen gas, which is continually cycled throughout the system. The reduction kiln is shown at the bottom of the display, and the blowers, XK102A and XK102B; are shown in the middle. This display is used by the engineers and technicians in order to inspect each element of the process, and alarms are displayed if there are any issues.

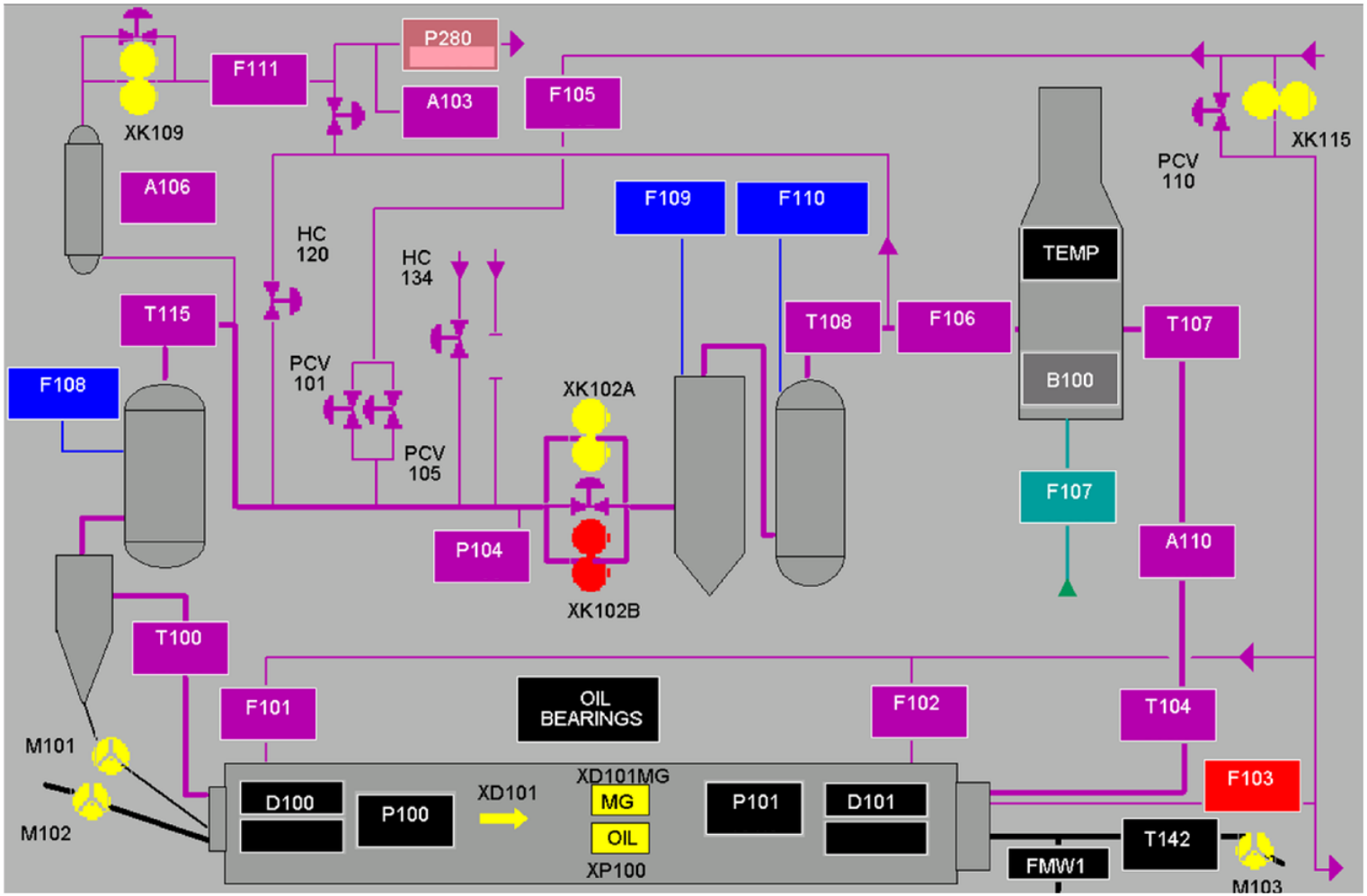


Figure 2: IA display

The Piping and Instrumentation Diagram (P&ID), shown in Figure 3; is a graphical representation of the system. It contains information such as the pipe identification numbers and dimensions, the medium within a pipe, instrument name and identification, as well as the names and identification numbers for pumps, blowers etc.

Both blowers are shown, with the ID tags of K202A and K202B. These blowers are fed hydrogen gas from the inlet KO pot, V221. The inlet pipe, C1; feeds gas in into the vessel, and takes in gas from the bypass valve. The outlet, C2; feeds gas into the H2 blowers. C3 is an inlet that accepts a return gas feed from the activation kiln outlet. Finally, C4 is an outlet for the condensate contained within the vessel. The water is removed using a water pump, V233; and sent to a drain, where it will travel to the on-site wastewater treatment facility. Once the water is treated, it is returned the river Tawe.

The outlet KO pot, V222; is shown on the outlet side of the blowers. This vessel is used to ensure that any remaining moisture is removed before the gas is used in the process.

The inlet pipe, C1; is where H2 gas is fed in. C2 is the outlet pipe for the H2 gas, which is sent to the secondary gas scrubber before being heated and used in the reduction kiln. As with the inlet KO pot, there is a condensate drain at the bottom of the vessel.

A bypass line connects the outlet of the blowers back to the inlet of the KO pot. This is hand cranked, and can be opened to relieve pressure on the blowers. The identification number of the valve is '14"-G(H)-511-140.'

Good background information

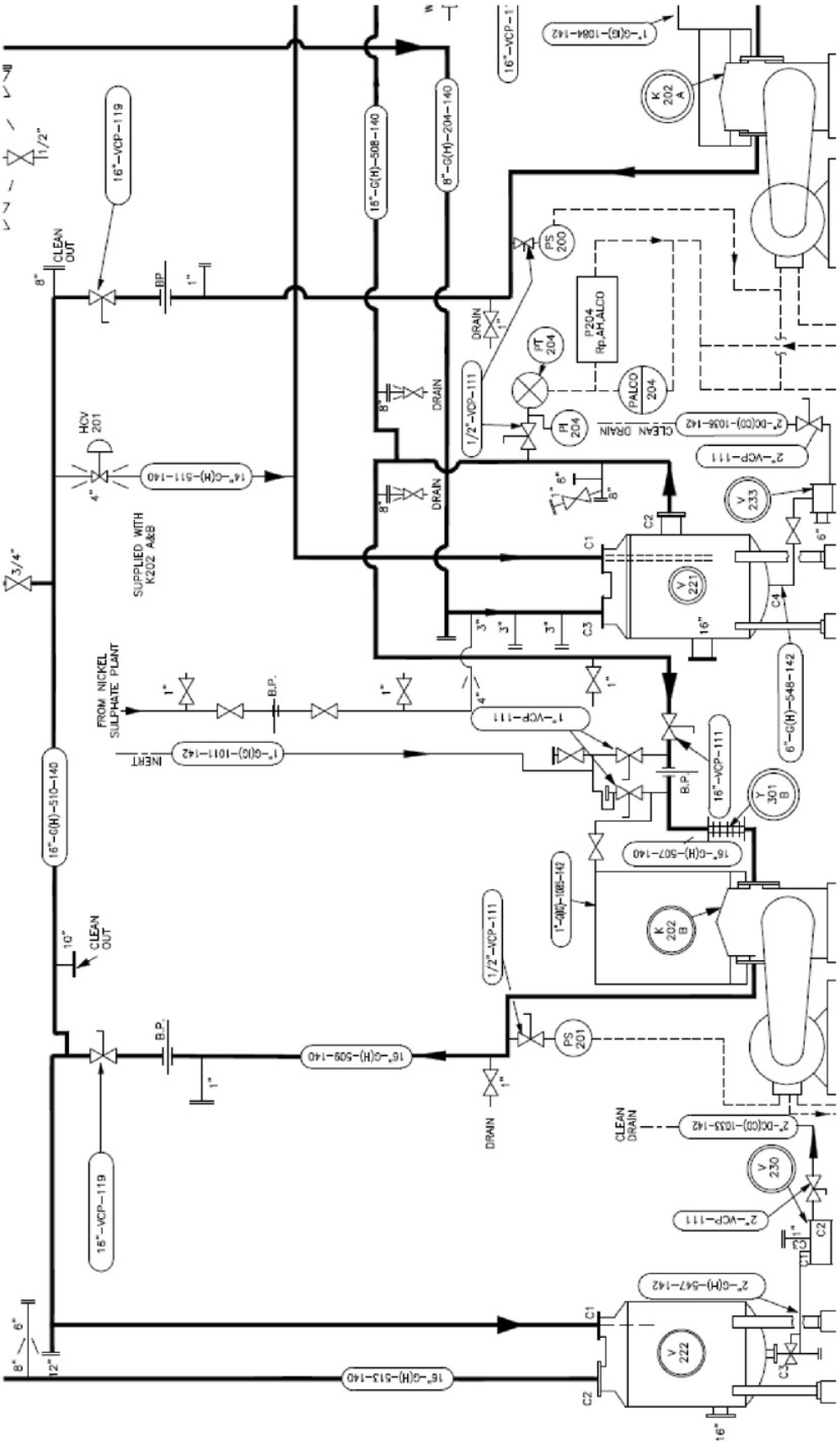


Figure 3: PID diagram

Was there a source that you could have cited your source for this drawing? 15

The existing pressure switches are wired directly into safety relays located in a local wiring panel. The transmitter replacing these switches will output a 4-20mA signal that will be proportional to the pressure.

The current pressure switch used is the HNL series 700, as show in Figure 4. These provide a simple relay output which switches when the specified pressure is reached. They are EX rated, which means they are suitable for use in explosive atmospheres.

this would have been a good place to explain Ex rating in more detail with citations



Figure 4: HNL Series700 pressure switch (MJ Wilson Group Ltd., n.d.)

2.1.2 Communication between Web Server and Web Browser

Web servers and web browsers form a client-server system, which means that the server hosts the content, which can then be displayed in the client. Data can be requested at any point from the server, and be displayed by multiple browsers simultaneously.

The communication between web servers and web browsers take place over a TCP/IP connection; these stand for Transmission Control Protocol and Internet Protocol respectively. A protocol is a set of rules agreed on between two computers to allow data to be communicated effectively. TCP is used to divide messages into individual packages, which are then reassembled upon reaching their target destination. IP is used to assign an address to these packages so that they reach the correct client. (Mitchell, 2018)

There are four layers to TCP/IP communication, with each layer having its own protocol. These layers are as follows:

- The datalink layer, used to provide protocols that operate on a link. This is the component of the network used to connect hosts or nodes. These protocols include Ethernet.
- The networking layer is used to connect networks so that data packets can be transported across network boundaries. Protocols *more to say ?*
- The transport layer, which is used to handle hosts communication. This layer is responsible for the reliability, control and multiplexing of a system. Protocols on this layer include TCP and UDP.
- Finally, the application layer is used to standardize the exchange of data for applications. Protocols here include HTTP.

In order for a web browser to communicate with the server, a Hyper Text Transfer Protocol (HTTP) is generally used on top of TCP/IP. A Domain Name System (DNS) is also required to work with Uniform Resource Locators (URLs); these URLs are the addresses of the website. What a DNS allows is communication between different web browsers and different brands of web server without the need for different logic combinations for each permutation. (Mitchell, 2018)

This would be how a typical browsing session occurs:

- An URL is specified in the browser by the user.
- A TCP connection gets initiated by the browser to the web server, using the IP address that the DNS publishes. Another part of this process is a DNS lookup by the browser in order to convert the URL into an IP address.
- Once the server has acknowledged the connection, the browser will send HTTP requests for the content.
- Once a reply has been made by the server, the browser will display the content in its appropriate format.

2.1.3 Cyber Security

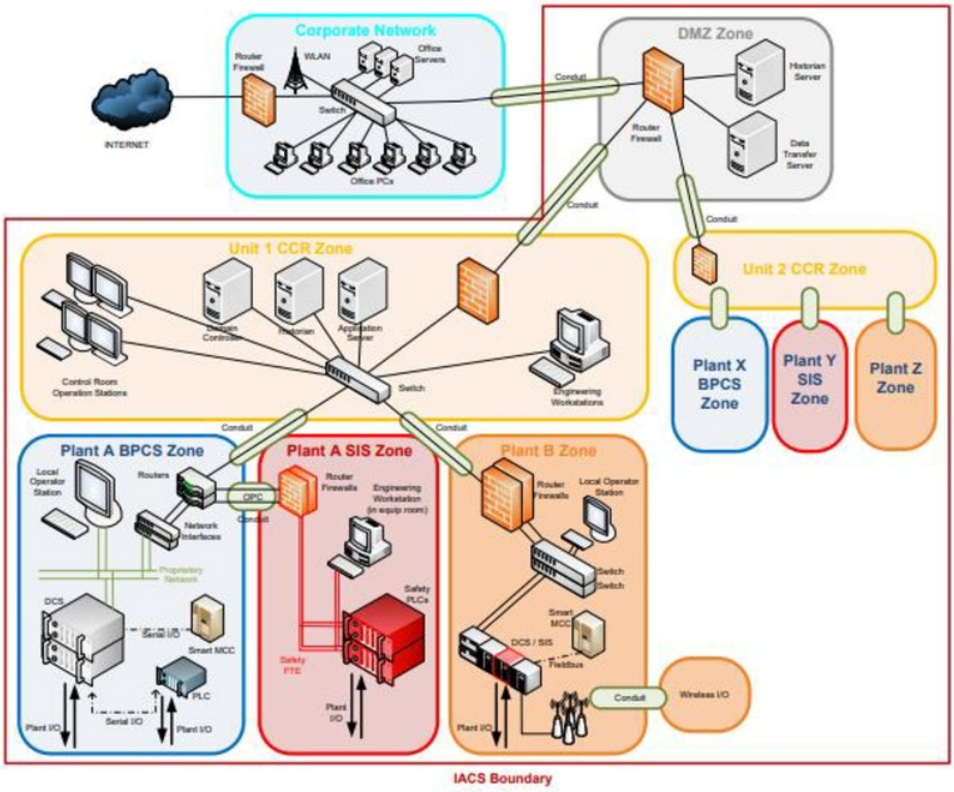
It is critical that cyber security is thoroughly implemented in this day and age. With an alarming number of viruses targeted at companies, and the various tools hackers have at their disposal, systems can easily be compromised. This can result in a loss of production, or even more malicious consequences such as safety critical systems being cut-off. Threats can come from internet sources, as well as the corporate network and through maintenance activities.

Figure 5 demonstrates a typical network that would be found on a large site. It shows the internet being fed to the corporate network, where a basic firewall will be set up to protect company information from unauthorised access. Everything after the corporate network falls under the Intelligent Automation and Control System (IACS) boundary.

The first point of contact will be the De-militarised Zone (DMZ). This is there to provide an additional layer of protection between the corporate and process networks, and has a firewall on the incoming side. The DMZ also provides a means to include historian services from the IACS plants to the corporate network, as well as a means of transferring data without needing removable media. Data transfer is handled under strict controls to prevent the process network from being compromised.

After the DMZ, the process network begins. This includes any workstations that relate to the IACS, as well as the process server. An additional firewall is placed on the incoming side of this server to provide further protection. This network is accessed by the Basic Process Control System (BPCS), as well as any safety instrumented systems. (Health and Safety Executive, 2017)

The official guidelines for safety state that web communication can't be used for any control purposes, which means that web pages will only be able to monitor information.


Corporate Network
Router Firewall
WLAN
Office Servers
Switch
Office PCs
INTERNET
DMZ Zone
Conduit
Historian Server
Router Firewall
Data Transfer Server
Conduit
Conduit
Unit 1 CCR Zone
Unit 2 CCR Zone
Control Room Operation Stations
Switch
Engineering Workstations
Plant X BPCS Zone
Plant Y SIS Zone
Plant Z Zone
Conduit
Conduit
Plant A BPCS Zone
Plant A SIS Zone
Plant B Zone
Local Operator Station
Routers
OPC
Conduit
Network Interfaces
Router Firewalls
Engineering Workstation (in equip room)
Router Firewalls
Local Operator Station
Switch
Switch
DCS
Serial I/O
Smart MCC
Safety PLCs
Smart MCC
DCS / SIS
Fieldbus
Safety FTE
PLC
Serial I/O
Plant I/O
Plant I/O
Plant I/O
Conduit
Wireless I/O
IACS Boundary

2.1.4 Hyper Text Mark-up Language (HTML) programming

HTML is a language designed to allow programmers create website. It relies on a series of tags that dictate how the content inside should appear on a web browser. Tags are put into angle brackets, and they typically surround the desired content as follows (Shannon, 2012):

Bold Text

Note the closing bracket has a forward slash. This is to indicate that only the content inside has the desired properties. It is possible to place images and hyperlinks into a web page using specific tags, and this can lead to the creation of more complex websites. A list of the most common HTML tags is shown in Figure 50. (Herdon, 2013)

HTML is a language mostly aimed at website layout. It is also possible to use scripting languages in conjunction in order to perform other functions. Languages such as JavaScript and PHP allow scripts to update content either on the client side or the server side.

Tag	Description
<html> ... </html>	Declares the Web page to be written in HTML
<head> ... </head>	Delimits the page's head
<title> ... </title>	Defines the title (not displayed on the page)
<body> ... </body>	Delimits the page's body
<h *n*> ... </h*n*>	Delimits a level *n* heading
...	Set ... in boldface
...	Set ... in italics
...	Center ... on the page horizontally
...	Brackets an unordered (bulleted) list
...	Brackets a numbered list
	Starts a list item (there is no)
 	Forces a line break here
<p>	Starts a paragraph
<hr>	Inserts a Horizontal rule
<img src="...">	Displays an image here
 ... 	Defines a hyperlink

Figure 6: Common HTML tags (Herdon, 2013)

2.2 Solutions

2.2.1 Fail-Safe System

You could have combined the two systems into one block diagram with three solutions.

The following three design solutions have been considered to a trip signal when the pressure reaches a certain level:

2.2.1.1 Moore Industries Safety Trip Alarm (STA)

Spelling

The STA is designed to perform as a logic solver, and will produce alarm outputs based on the how it is programmed; it is certified to SIL 2 and SIL 3. It is user programmable, and can be set using SIL certified software or via the front panel.

The STA will accept 4-20mA signals which are currently provided by Crowcon Xgard gas detectors. However, for the purposes of this prototype, a 4-20mA generator can be used in its place and the user can manually set the input. A 4-20mA output is also provided so that the input signal may be relayed to an IA system for trending and data logging. (Moore Industries Inc., 2017)

The cost of each unit is approximately £783 as of 2017, and four units will be required leading to an approximate cost of £3000. (Radwell International, n.d.)

The STA will be connected directly to a Pilz safety relay, which will remain closed when active. These relays are SIL certified, and are used to provide a trip for the system. Figure 7 demonstrates how these devices will interconnect:

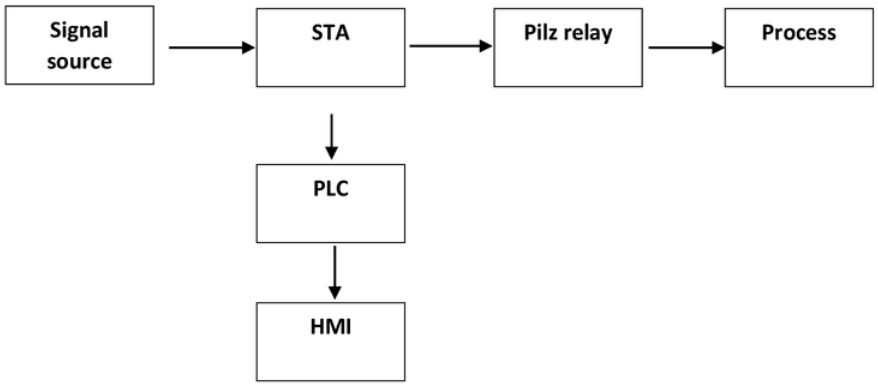


Figure 7: Moore Industries STA block diagram

2.2.1.2 Siemens Fail-safe CPU

The Siemens fail-safe CPU is a product designed for functional safety applications. These controllers satisfy the functional safety standards up to SIL3. There are a number of products under this category, which all have different specifications based on requirement. (Siemens Inc., n.d.)

There are CPUs available that offer IO as well as analogue inputs, and these could be used to both monitor and trip the blower circuit. The s7-1200 1214 fc CPU offers 24 standard IO, as well as expandability using standard and fail-safe modules. (Siemens Inc. , n.d.)

The cost of these units is approximately £532 (Parmley Graham Ltd., n.d.). A representation of how this solution would fit into the system is shown in Figure 8.

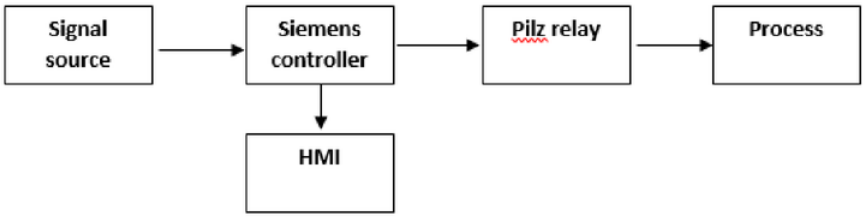


Figure 8: Siemens fail-safe CPU block diagram

2.2.1.3 Crowcon Gasmaster

The Crowcon Gasmaster is a gas detector control panel designed to be used in conjunction with Crowcon gas detectors. The sensor will accept 4-20mA inputs and display these values on a built-in LCD. The unit has an RS485 Modbus module installed for communication purposes, and an optional port is available for PC communications.

There are two alarm outputs available on this device, a low alarm and a high alarm; which can be fed into another system. The device itself is rated to SIL 2, which means it will have a certain level of reliability. (Crowcon Inc., n.d.)

Figure 9 represents how the Gasmaster would fit into a system:

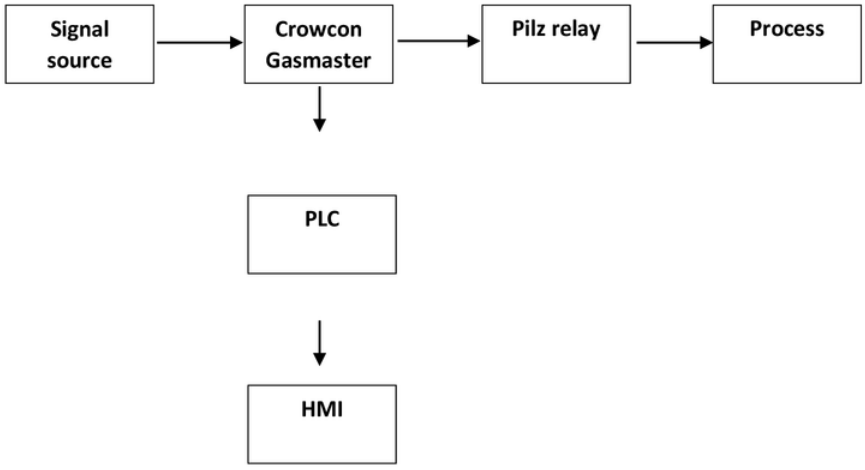


Figure 9: Crowcon Gasmaster Block Diagram

The approximate cost of the Gasmaster is around £1742 (PSE Priggen, n.d.)

2.2.1.4 Chosen solution

Table 1: Summary of solutions

Criteria	Moore Industries STA	Siemens 1214fc Fail-Safe CPU	Crowcon Gasmaster
Operating Voltage	24V	24V	24V
Dimensions	102x56x142mm	100x110x75mm	288x278x110mm
SIL capability	SIL 2	SIL 3	SIL 2
IP rating	NA	NA	IP65
Function	General	General	Specific
Cost per unit	£1000 approx.	£500 approx.	£2000 approx.
Inputs	Analogue	Analogue/Digital	Analogue
Outputs	Analogue/relay	Digital	Relay

You could have used a rating system to score the solutions to allow a choice to be made.

The three solutions are summarised in Table 1 for ease of comparison. To begin, each solution will run on 24V. This is beneficial as there is no need to be concerned about dangerous voltages, which makes the risk assessment considerably easier.

The STA and the Siemens are considerably smaller than the Gasmaster, which is important, as they will take up far less panel space. It would be necessary to mount the Gasmaster outside of the panel, which adds to the amount of work required. The STA and Siemens can be easily mounted within the panel to DIN rail.

In terms of SIL capability, each system is capable of at least SIL 2. The Siemens is capable of SIL3, but this level of integrity will rarely be required, and is generally avoided unless necessary. In terms of cost, the Siemens is the cheapest of the three solutions, with the Gasmaster being the most expensive.

Each unit has analogue inputs that are capable of reading the signal. The Siemens unit only accepts a 0-10V signal meaning it will require a 250Ω resistor in series to convert the loop current, whereas the other two solutions will accept 4-20mA. The STA has an analogue output to daisy chain the signal, as well as relay outputs. The Siemens unit has digital outputs, and the Gasmaster only has relay outputs.

The chosen solution was the Moore STA. The reason for this is primarily that it is widely used on site. This means that it will be available as a stocked item in stores, resulting in reduced down time. It will also be easier to maintain, as the instrument technicians will be accustomed to the unit. The availability of an analogue output allows the input signal to be chained into a separate controller so that the pressure can be monitored externally.

Another benefit of the STA is the ability to set the device from the front panel. The buttons on the front provide full access to the settings, meaning there is no need to use a computer for the setup. This is not only a time saving feature, but also provides ease of use when maintaining the device.

2.2.2 Data Monitor Solutions

2.2.2.1 National Instruments cRIO

National Instruments are a company which develop a range of high quality instruments for data gathering and automation, including a range of embedded controllers such as the RIO, whose available processing targets include: a real time processor for communication and signal processing, or a user programmable FPGA for high speed applications. (National Instruments, n.d.). There are digital and analogue cards available for the cRIO platform which means it can accept a 4-20mA signal and provide the logic for the alarms.

The software used to control and provide a graphical interface for the user is LabView, meaning the current IA system would be redundant. This software is programmed by using functional blocks, and process variables can be displayed to the user. Figure 10 shows layout of this system:

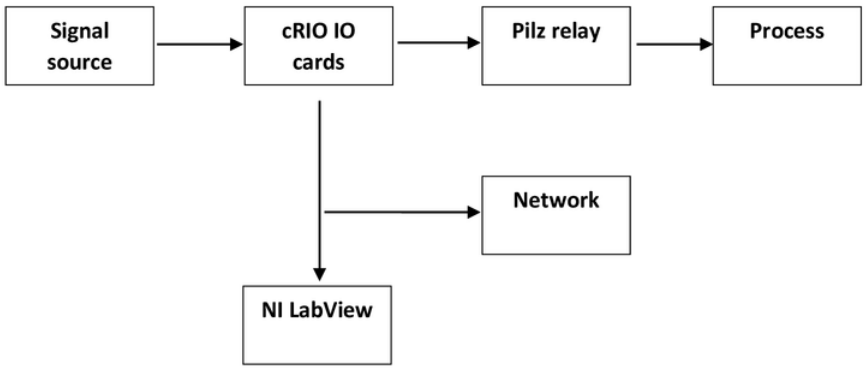


Figure 10: NI cRIO Block Diagram

The following is a price breakdown for this solution:

- NI cRIO 9030 - £2,210
- NI 9375 (x2) - £970
- NI 9219 - £1,020
- Ni LabView software - £2,980
- Total - £7,180

These prices were obtained from the National Instruments website (National Instruments, n.d.)

2.2.2.2 Siemens S7-1200 PLC

Siemens develop a range of products for industrial control applications. Their Simantec PLC range is common, and can deliver a comprehensive range of services. There are several ranges available from Siemens, and the S7-1200 will be discussed here.

The specific CPU discussed is the 1214c. This unit boasts 24 standard IO, an Ethernet interface, and a single analogue input. It can be expanded using modules that allow features such as increased IO, increased network ports and increased analogue inputs. The analogue input accepts a 0-10V signal. (Siemens Inc., n.d.)

The approximate cost per unit of this PLC is £350 (Parmley Graham Ltd., n.d.)

In order to display the analogue value, a HMI would be required. The cost of the Siemens KTP700 HMI is £633 excluding VAT (RS components Ltd, n.d.). An Ethernet switch will also be necessary to provide additional ports. The cost of the Siemens XB005 switch is £82 excluding VAT (RS Components Ltd. , n.d.). This brings the total cost of this solution to £1,278 including VAT.

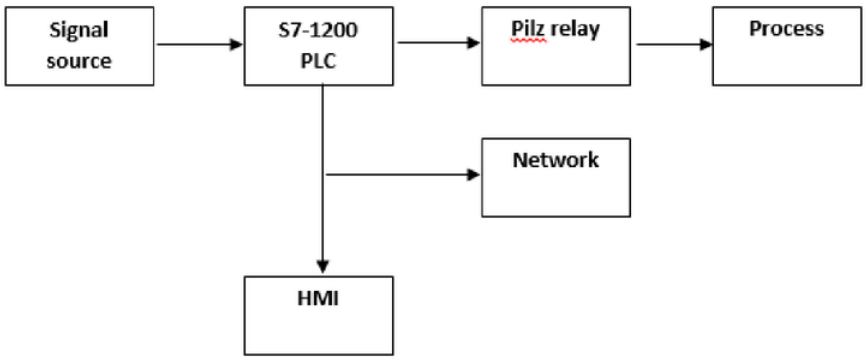


Figure 11: Siemens S&-1200 PLC block diagram

2.2.2.3 Industrial Shields M-DUINO

The industrial shields M-DUINO is a relatively new competitor in the market. They make PLC controller built on the Arduino programming environment. What this offers is great flexibility at a reasonable price, as well as the ability to customize the open source software.

The M-DUINO features several communication types, including Ethernet, USB, I2C, RS-232, RS-485 and Modbus; all of which provide different options for communication.

The larger M-DUINO has 20 digital inputs and 16 analogue inputs. This will be the requirements to monitor the entire system. (Industrial Shields Inc., n.d.)

A simple TFT display can be used as the HMI, but it requires far more involvement to program, and does not provide a durable solution. The cost of the M-DUINO is approximately £278.

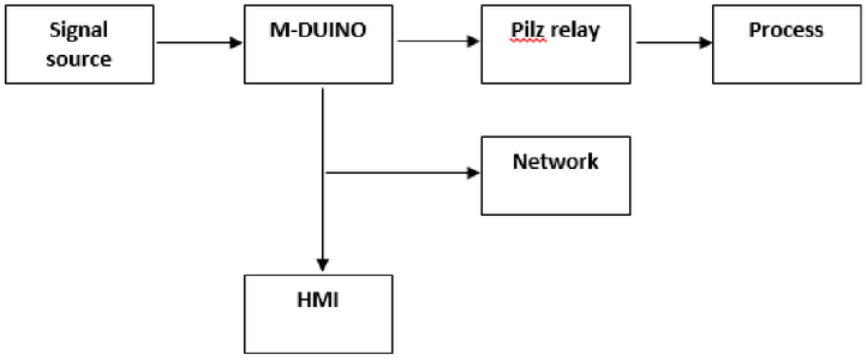


Figure 12: M-DUINO block diagram

2.2.2.4 Chosen Solution

Table 2: Data monitor solutions comparison

Criteria	National Instruments cRIO	Siemens S7-1200 PLC	Industrial Shields M-DUINO
Operating Voltage	24V	24V	24V
Dimensions	219.5× 88.1×109.2 mm	100x110x75mm	100x75x115mm
Ethernet	Y	Y	Y
Cost per unit	£7000 Approx.	£1278 Approx	£300 Approx
Inputs	Expandable	14 digital/ 1 analogue	20 digital/ 16 analogue
Outputs	Expandable	10 digital	22 Digital

As with the previous comparison, a summary of each solution has been shown in Table 2: Data monitor solutions comparison. Each solution operates at 24V, meaning there is minimal risk of electrocution when working on these units. The size of each solution means that there will be no issue with installation, and they can be attached to standard DIN rail. The fact that each solution has an Ethernet port means that they can be easily connected to a network to transfer data.

In terms of cost, the NI cRIO is too expensive. When added to the cost of the four STAs and the pressure transmitters, it would exceed the budget. This cost only includes hardware, and does not account for the costs of training engineers to use the LabView software. The M-DUINO is the cheapest of the three solutions, but this is for the controller alone. There is a HMI available by industrial shield based on a raspberry pi, which retails for £318.36 excluding VAT (RS Components Ltd., n.d.)

The budget has not yet been stated.

The Siemens solution is more expensive than the M-DUINO, but that also brings a network of support from professionals in the field, as well as from Siemens themselves. Industrial Shields is a relatively new company, and that support network may not yet be established; however, it is based on the Arduino platform, and support from hobbyists is plentiful.

In terms of IO, each solution has an adequate amount as standard. Both the cRIO and Siemens PLC can be expanded, while the M-DUINO cannot. This could be an issue if there were ever any need for the system to be enlarged, and the monitor to require more IO.

The chosen solution was the Siemens PLC. The cost of the NI cRIO is unjustifiable, and is more suited to a laboratory environment than an industrial process. Whilst the M-DUINO is inexpensive, it is also built on a platform whose primary language is C. This can make implementation of certain features cumbersome, and maintenance even more difficult. Ladder

logic has been a staple of industry for a long time, which means that engineers and technicians are likely to be able to better understand them.

Furthermore, the in-built web server simplifies the use of web pages and scripting languages, and will allow data to be easily transferred across the internet. The M-DUINO will require custom programs at a low level language, which will be difficult to implement.

A good choice made. However, there appears to be a contradiction in that the Siemens PLC was rejected from system 1 on the grounds that it was not a standard item yet it was the preferred option for the monitoring part.

3. Specification and Test Planning

3.1 Project Requirements

The scope of this project will be to investigate the functional safety requirements of this modification and manage the change of each valve, to include modifying the design and allocating resources. The following requirements are the project deliverables in a black box format:

1. Pressure to be continuously monitored
2. Trip to occur at 5.5 psi
3. Must conform to the following regulations:
    a. DSEAR
    b. IEC 61511 and 61508 functional safety regulations
    c. Low voltage directive
4. Design must conform to SIL rating, to encompass the following:
    a. Hardware Fault Tolerance
    b. Safe Failure Fraction
5. Must not exceed budget of £15,000
6. Accuracy of 1% to be achieved across the full range
7. Trip signal supplied by volt-free contact at 24VDC

These have been provided by the kiln plant supervisor, and will be used to assess whether the project has been completed as intended.
In addition to the previous requirements, the following items will now be added:

1. Provide local and remote monitoring
2. User interface to display blower outlet pressure and trip alarms
3. Basic blower control to be implemented
4. System to communicate via Local Area Network (LAN)
5. Web server must be implemented to allow information to be displayed remotely
6. HMI must be used for local display

3.2 Technical Specification

The following technical specification will provide more in depth details about the project:

1. All equipment installed must work at 24VDC
2. Foxboro IGP10 pressure transmitter to be used
3. Pressure transmitter must be calibrated to provide 12.80mA output at 5.5psi
4. Pressure transmitter to provide analogue signal to the STA, which in turn will provide a trip signal to the existing Pilz relays
5. Correct wire colouring and numbering scheme to be followed
6. STA output relays to be configured as a redundant pair
7. All equipment used must have a CE rating to show conformity to European regulations
8. Conform to cyber security guidelines to prevent system from being compromised
9. Ensure all drawings are properly updated in the system
10. 12 digital inputs required
    a. High alarm for each blower
    b. High-high alarm for each blower
    c. Status of each blower
11. 4 analogue inputs required to show blower pressure
12. Network connection required

3.3 Environmental Specification

The following will be a list of all environmental requirements for the project:

1. Ensure that all waste is properly recycled
2. Ensure that any effluent is directed to the proper processing facilities
3. Ensure any spills are properly managed

A good, detailed section

3.4 Safety Specification

The following list details the safety requirements of the project:

1. Ensure that all work procedures conform to the Health and Safety at Work Act 1974
2. Ensure correct PPE is provided to the technicians installing the project
3. Ensure the correct isolation procedures are followed in order to prevent electrocution and gas leaks when implementing the new transmitters
4. Ensure risk assessment is carried out for the work being undertaken

SIL rating could have been mentioned here.

All of the requirements will become part of the project testing once the chosen solution has been implemented. A testing table will be made in order to check against the test criteria, and to write any relevant comments.

4. Safety, sustainability, environment, professionalism, maintenance and reliability

4.1 Safety

4.1.1 SIL Rating Calculation

In order to find the SIL rating, a Layers of Protection Analysis (LOPA) was conducted. LOPA is the newest tool for determining SIL. In terms of rigour and sophistication, it lies between the qualitative (Hazard operability, what if analysis etc.) and quantitative (fault trees and event trees) methodologies. It is mainly suited towards companies striving to meet specific risk targets (ABS Group, n.d.).

The process starts by first identifying the Safety Instrumented Function (SIF) and providing an identifying tag. The trip that will be looked at in this instance will be for Hydrogen Blower A/B outlet pressure (high).

The next task is to determine the hazard that is being protected against, as well as the consequences. In the case of blower overpressure, the likely outcome would be a release of H2 and a subsequent explosion. The consequence of this would be severe injury or death to anyone occupying the area.

With this information in place, a tolerable risk (TR) factor can be stated; the standard figure for the Clydach refinery is 1e-5 in the event of a fatality. The TR is the acceptable figure for this system and in this case represents one occurrence every 100,000 years. (Dearden, 2016)

With that decided, the required Risk Reduction Factor (RRF) could be calculated. The next task will be to identify the initiating events in the system, as well as any inherent protection layers there may be.

Two initiating events could be identified for this scenario. The first would be a downstream valve closure as a result of basic process control system (BPCS) error, and the second would be operator error when switching blowers, resulting in the same scenario.

Conditional modifiers will also influence the outcome of an event. Whilst the modifiers are a layer of protection, they cannot be influenced in any way and act more like a last line of defence i.e. a failure has occurred, but no event has happened due to the conditional modifiers. The conditional modifiers in this system are ignition probability of the gas, the occupancy, and the individual profile time on site.

Typically, there will be independent protection layers (IPLs) for a given SIF. These are factors inherently built into the system, and will provide some degree of protection against risk. In this case, the BPCS is the only IPL, but no more than a factor of 0.1 can be claimed.

It is worth noting that even though certain defences may be present, they are illusory i.e. they occur too late to prevent a consequence. An example of an illusory defence in this scenario is the H2 detection system, which sounds an alarm when a leak is detected. This would only take action if an overpressure event had already led to a burst, and does nothing to prevent the pressure build up.

The aforementioned factors can be put into Table 3 along with their values:

Initiating event:		Valve failure	Operator error
	Frequency:	0.02	0.02
Independant Protection Layers	BPCS	1	1
Conditional Modifiers	Ignition Probability	0.1	0.1
	Occupancy	1	1
	individual presence on site	0.2	0.2
Intermediate Event Frequency		0.0004	0.0004
Total Event Frequency (without SIF)		0.0008	
Tolerable Risk		1.00E-05	
Required Risk Reduction Factor		80	

Table 3: LOPA Summary

The explanation of these values is as follows. The frequency of each event is decided because the blowers are switched over from A to B every six months. The operator will likely leave the valve closed in error every one out of a hundred operations, which results in a frequency of 0.02 events per year, or one every 50 years. The same can be said of BPCS failure in the event of start-up, which could lead to upstream valves being kept closed.

The ignition probability was decided to have a value of 0.1, or one event every ten years based on it being a zone 2 area, whilst individual presence on site was 0.2 because an individual would be on site $1/5^{th}$ of the time on average. No claim can be made against occupancy because the occupant carries out the action near the blowers, putting them at risk

100% of the time; therefore, it is left at one. A claim also cannot be made against the BPCS as it is already an initiating event, and claiming would be what is known as 'double-dipping' in this situation.

With all of these values, an intermediate event frequency is calculated by multiplying the figures in each column. The sum of these intermediate values is then found to give the total event frequency that will occur with no SIF in place. In order to find the RRF, the total event frequency is divided by the TR.

SIL Safety Integrity Level (per IEC 61508)	Safety Availability	PFD Probability of Failure on Demand 1 – Availability	RRF Risk Reduction Factor 1 / PFD
4	> 99.99%	< 0.0001 ($1E^{-4}$)	> 10,000
3	99.9 – 99.99%	0.001 – 0.0001 ($1E^{-3}$ to $1E^{-4}$)	1,000 – 10,000
2	99 – 99.9%	0.01 – 0.001 ($1E^{-2}$ to $1E^{-3}$)	100 – 1,000
1	90 – 99%	0.1 – 0.01 ($1E^{-1}$ to $1E^{-2}$)	10 - 100
0	Basic Process Control		

Figure 13: SIL requirements

Figure 13 shows the RRF ranges required for each SIL rating, which is visible in the right-most column. The calculated RRF was 80, which results in a SIL 1 rating.

Safe Failure Fraction (SFF)

Safe failure fraction is a measure of how many units were tested to fail safe on demand. This figure is expressed as a percentage. The reason for this testing is that, whilst rare, it is entirely possible for safety critical equipment to fail in a manner where it does not react to demand i.e. fail dangerously.

Companies conduct tests to identify the percentage of units that will fail dangerously, and provide a certificate detailing the SFF of a particular device.

In order to find the SFF, the equation shown in Figure 14 is used.

$$SFF = \frac{\lambda_{SD} + \lambda_{SU} + \lambda_{DD}}{\lambda_{SD} + \lambda_{SU} + \lambda_{DD} + \lambda_{DU}}$$

Figure 14: SFF equation (exida inc., 2010)

Where λ_{SD} are the detected safe failures, λ_{SU} are the undetected safe failures, λ_{DD} are the detected dangerous failures and λ_{DU} are the undetected dangerous failures.

The company responsible for this testing is exida, whom are world leaders in product safety certification. A certificate for the Moore STA, found through the exida website, has been included in the appendix. Figure 15 shows the table from this certificate. The model of STA used in this project is the STA/HLPRG/3PRG/U [DIN] Relay Output, which has a SFF of 91.40%.

Element	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF
STA/TPRG/3PRG/24DC/-AO [DIN] Relay Output	0	669.8	174.2	89.5	90.40%
STA/TPRG/3PRG/24DC [DIN] Relay Output	0	663.7	167.1	85.6	90.70%
STA/TPRG/3PRG/UAC/-AO [DIN] Relay Output	0	758.6	174.5	89.6	91.20%
STA/TPRG/3PRG/UAC [DIN] Relay Output	0	752.5	167.4	85.8	91.50%
STA/TPRG/3PRG/U/-AO [DIN] Relay Output	0	708.4	214.2	92.3	90.90%
STA/TPRG/3PRG/U [DIN] Relay Output	0	703.1	207.2	90.4	91.00%
STA/HLPRG/3PRG/24DC/-AO [DIN] Relay Output	0	679.8	175.8	84.9	91.00%
STA/HLPRG/3PRG/24DC [DIN] Relay Output	0	673.7	168.7	81	91.20%
STA/HLPRG/3PRG/UAC/-AO [DIN] Relay Output	0	776.1	176.1	85.2	91.80%
STA/HLPRG/3PRG/UAC [DIN] Relay Output	0	770	169	81.2	92.00%
STA/HLPRG/3PRG/U/-AO [DIN] Relay Output	0	719.3	215.1	88.2	91.40%
STA/HLPRG/3PRG/U [DIN] Relay Output	0	714	208.1	86.2	91.40%

Figure 15: SFF values for various Moore trip amplifiers

Hardware Fault Tolerance (HFT)

The functional safety standards impose architectural constraints, as there is a need to compensate for uncertainties and assumption in design. Hardware fault tolerance describes the architecture required to ensure there is system availability upon demand. The different configurations e.g. 1 out of 1 (1oo1), are selected based on the safe failure fraction of the devices, and the required SIL rating. (Generowicz, 2015)

Figure 17 shows the SIL compatibility for a give HFT and SFF. The table shown is type B, as the STA is a logic solver. In the previous section, the SFF was found to be 91.40%, which means that a HFT of 0 would be SIL 2 compatible.

Type B subsystems – e.g. Logic Solver, Smart Tx			
Safe failure fraction	Hardware fault tolerance		
	0	1	2
< 60 %	Not allowed	SIL1	SIL2
60 % - 90 %	SIL1	SIL2	SIL3
90 % - 99 %	SIL2	SIL3	SIL4
≥ 99 %	SIL3	SIL4	SIL4

Figure 16: Type B HFT table (Honeywell Inc., n.d.)

Figure 17 shows the corresponding architecture of each HFT. In this case, with a HFT of 0, a 1oo1 (one out of one) architecture is acceptable. This is beneficial to the project as it simplifies the design and reduces cost.

Architecture	Hardware Fault Tolerance
1oo1	0
1oo1D	0
1oo2	1
2oo2	0
2oo3	1
2oo2D	0
1oo2D	1
1oo3	2

Figure 17: Table of architecture for the desired HFT (exida, n.d.)

4.1.2 DSEAR

DSEAR regulations are put in place to protect workplace personnel, as well as the public, from risks arising due to dangerous substances. These risks can include combustion, explosion and metal corrosion. Many substances come under the regulations e.g. solvents, flammable gases, dust, pressurized gases and substances which can corrode metal. (Health and Safety Executive, n.d.)
The following list details the employer requirements (ExVeritas, n.d.):

- Identify the dangerous substances used onsite.
- Implement control measures either to remove the risks, or to reduce the risk if elimination is not possible.
- Implement control measures to reduce the consequence of an incident involving dangerous substances.
- Prepare emergency plans and procedures in the event an incident involving dangerous substances.
- Inform employees of the dangers, and provide training to handle and control risks from these substances.
- Provide classification for areas in the workplace where explosive atmospheres may occur and ensure there are no sources of ignition within these zones.

One of the main prevention methods under DSEAR is zoning. Zones allow engineers to select the most appropriate equipment and methods to prevent ignition. Manufacturers will rate their equipment based on these zones.
There are two main categories for zoning: one for gases, vapours or mists; and another for dusts. There is no dust involved in this project; therefore, the focus will be on the former category. There are four distinct zones, detailed here (Newcastle University, 2017):

- Safe-zone – This zone has no potential for explosive atmospheres, which means that equipment can be used indiscriminately.
- Zone 0 – An area where an explosive atmosphere is continuously present, or is present for long periods.
- Zone 1 – An area where an explosive atmosphere is likely to occur.

- Zone 2 – An area where an explosive atmosphere is unlikely to occur, and will occur in short periods only.

Figure 18 shows the classification of equipment that can be used within the zoned areas. As well as the suffix used to describe the type of protection offered. The required information is generally printed on the nameplate of the unit.

Zone 0	Zone 1	Zone 2
Category 1	Category 2	Category 3
'ia' intrinsically safe EN 50020, 2002	'd' - Flameproof enclosure EN 50018 2000	Electrical Type 'n' - EN 50021 1999 Non electrical EN 13463-1, 2001
Ex s - Special protection if specifically certified for Zone 0	'p' - Pressurised EN 50016 2002	
	'q' - Powder filling EN 50017, 1998	
	'o' - Oil immersion EN 50015, 1998	
	'e' - Increased safety EN 50019, 2000	
	'ib' - Intrinsic safety EN 50020, 2002	
	'm' - Encapsulation EN 50028, 1987	
	's' - Special protection	

Figure 18: Zone classifications (Health and Safety Executive, n.d.)

Figure 19 shows a graphical representation of the zones. This example demonstrates a typical scenario in the forecourt of a petrol station. It can clearly be seen that the inside of the storage tanks are zone 0, as these will typically be full of explosive vapours. The areas where fuel is pumped fall under zone 1 as they will frequently become an explosive zone, but not on a permanent basis. The remaining area will be classified as zone 2 as the potential for an explosive atmosphere will only be occur during the occasional spill, and will be short lived as the vapours disperse.

It is worth noting that every explosive substance will have an explosive range, and will not pose a risk outside of the lower and upper limits.

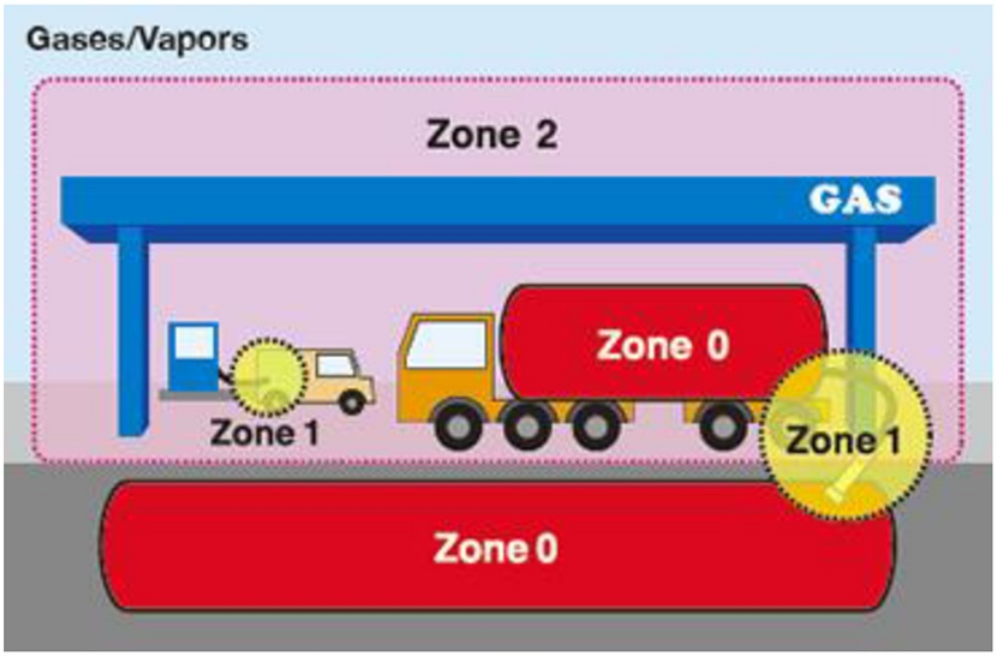


Figure 19: graphical representation of zones under DSEAR classification (Patlite inc., n.d.)

4.1.3 Site Safety

Across the site, there are general safety procedures aimed at reducing the frequency and severity of incidents. The primary method for this is to perform a risk assessment prior to any work activities taking place. The main technique to keep employees safe is to perform risk assessments on each job that takes place.

Risk is defined as the likelihood of an event occurring multiplied by the consequence. A traffic light ranking system will generally be employed to categorise the risk i.e. green corresponds to low, amber to medium and red to high. When performing a risk assessment, the aim is to address any hazards and lower their rating. (IOSH Services Ltd., n.d.)

A risk matrix is generally used to easily categorise hazards. Likelihood will be pace on the horizontal axis and severity will be placed on the vertical axis. An ascending numerical value is assigned to each axis, and the product of these values provides the risk level. Figure 20 shows the risk matrix used for Vale risk assessments.

Likelihood / Impact Severity		Rare 2	Unlikely 3	Occasional 5	Likely 9	Frequent 13		Risk Levels	
Catastrophic (E)	32	64	96	160	288	416			>=140
Critical (D)	16	32	48	80	144	208			
Severe (C)	8	16	24	40	72	104			70 - 140
Moderate (B)	4	8	12	20	36	52			25 – 70
Minor (A)	2	4	6	10	18	26			<25

Figure 20: Vale risk matrix

In order to mitigate risk, it is necessary to introduce control measures. These measures are ranked on a hierarchy of control, with the top being the most effective at risk mitigation and bottom being the least.

The control hierarchy is as follows (Health and Safety Executive, 2011):

1. Elimination – Remove the hazard from the job entirely by changing the scope of the work, or by using safer substances.
2. Substitution – Change the hazard into one with less consequence e.g. use a mobile platform instead of a step ladder.
3. Engineering controls – Introduce equipment that will reduce the severity of the hazard, such as guarding on hot or moving parts.
4. Administrative controls – this includes work order, permits to work and signage.
5. Personal Protective Equipment – PPE should be considered only if no other option is effective in reducing the risk.

A risk assessment had been carried out for this project, and is included in the appendix.

4.2 Sustainability

There are several company policies in place to improve companywide sustainability standards, and some of these affect this project. First, suppliers must be able to package their products using sustainable materials. This means using recyclable packaging, and avoiding single use plastics; manufacturers must also show that they use sustainable methods. The STAs had arrived in the company stores in bubble wrap, which itself is recyclable.

As for the pressure transmitters, Foxboro has included a policy document within the box. Figure 21 shows the packaging used for the Foxboro transmitters, which has been included in the appendix. The cardboard and plastics used can be recycled, which means that there is no breach of the company sustainability policy.



Figure 21: Foxboro pressure transmitter packaging

4.3 Environment

In terms of environmental responsibility, the company adheres to the standards set out in ISO14001. These standards specify the requirements for an effective environmental management system (EMS), and allow the company to reduce their impact.

There are several aspects of this project where good environmental practice is necessary. The first concerns proper waste management. Vale aim to recycle as much waste as possible, and there are recycling bins found throughout the majority of the site. Secondly, it is important to avoid contamination to the natural surroundings. The waste management system prevents this, as well as

Figure 22 shows a waste disposal station. The bins, from left to right, are for the following waste:

How does this relate to your project?

- Batteries – Used batteries are disposed in this bin. This is not only for their materials to be recycled, but also to provide safe disposal.
- Waste electrical equipment (WEE) – This bin is for the disposal of WEE waste in order for them to be properly recycled.
- Waste paint canisters – this is for the proper disposal of paint canisters for them to be recycled.
- Waste process consumables – this is for the safe disposal of oil covered process consumable e.g. belts, gaskets etc.
- Waste clean-up materials – this is for the safe disposal of oil covered clean-up materials and PPE such as latex gloves.
- Oil covered overalls – this is for the safe disposal of oil covered disposable overalls.



Figure 22: Waste disposal system

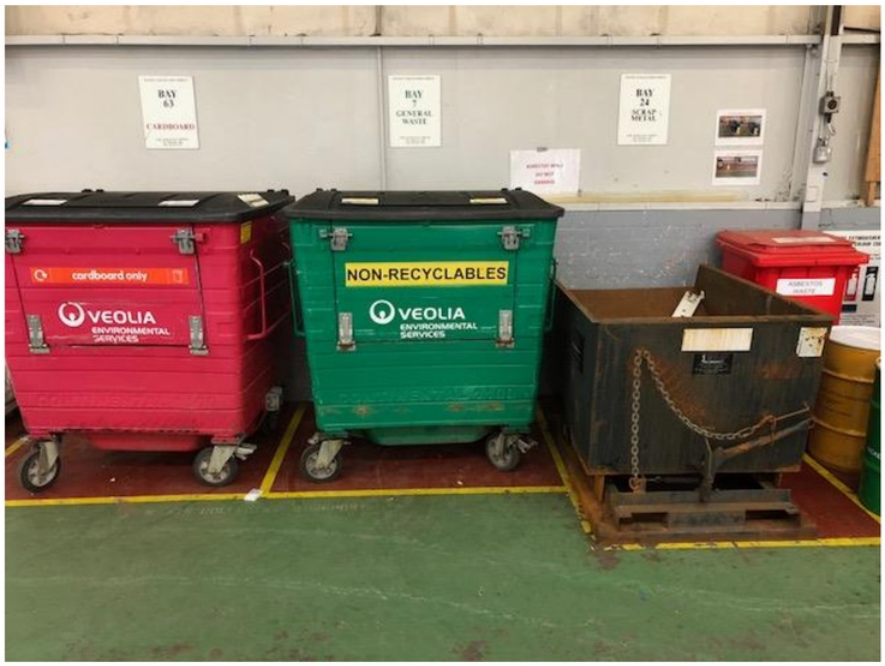


Figure 23: Waste disposal system continued

Figure 23 continues the waste disposal system. From left to right the bins are as follows:

- Cardboard Waste – this includes cardboard boxes of any size, as well as flat pieces of cardboard.
- Non-recyclable waste – this is a bin dedicated to materials that cannot be recycled. The aim is to use as little non-recyclable material as possible.
- Scrap metal – this bin contains scrap metal, which will go on to be recycled.

The focus of this section should have been on the environmental impact of your project rather than company procedures only.

Another commitment to the environment is to prevent any foul waste e.g. oil, grease from gaining access to natural waterways. This is managed onsite through several methods. There are foul drains onsite that do not connect to external drainage network, and any oil will enter this system. There are also spill kits located across the refinery in the event a major spill needs to be contained as shown in Figure 24. If oil were to enter the surrounding river, then an emergency environmental procedure would take action.



Figure 24: Spill control station

This has no bearing on your project.

4.4 Professionalism

You could have included the MoFC document in the appendix.

In order to maintain professional conduct at all times, a series of site procedures were adhered to. To begin, a Manufacture of Facilities Change (MoFC) document had to be created. This document details the change to be made on plant, and is signed by the plant supervisor to give approval for the project to go ahead. The second part to the MoFC, SFO2, details the specific requirements of the project, and is signed off by a team of individuals involved with the project.

Several meetings had been required throughout the course of the project, and these were all pre-booked using the company's outlook system. Not only does this ensure that all parties are well aware of the meeting taking place, but it also ensures that there are no schedule clashes. It also provides a fixed time-slot where the project can be properly discussed.

Any required components were booked through the company system. Not only did this ensure that there was a record of the purchase, but also ensured that the budget was adhered to. Certain consumables e.g. screws, crimps etc. could be freely booked from the stores, but equipment such as the pressure transmitters and the STAs had to be approved before purchase.

4.5 Maintenance

was

In order to keep the equipment well maintained, a maintenance plan will be required. Part of this process is to create asset numbers in the company system so that maintenance and calibration requirements can be tracked.

In the case that equipment needs replacement, it is important to consider lead times. It is preferable to keep equipment as stores stock, and ensure they are always available. The lead times on the pressure transmitters are approximately six weeks, and in the case that new components are required, the process would be down until these components arrived.

The transmitters will be calibrated once a year in order to ensure they are accurate.

4.6 Reliability

Reliability is critical for safety implemented systems. Failure of the components to work on demand could lead to an incident occurring, which could cause serious harm or death to personnel. In order to avoid this, the components used are compliant with ISO9001 standards. These are standards of quality, and demonstrate how a manufacturer has achieved good manufacturing practices.

To further increase reliability, certain devices can be configured to provide higher integrity. The relays of the STA can be chained so that any trips or faults will trip the final element. This configuration, however; is vulnerable to spurious trips. The high integrity wiring configuration for the STA is shown in Figure 25.

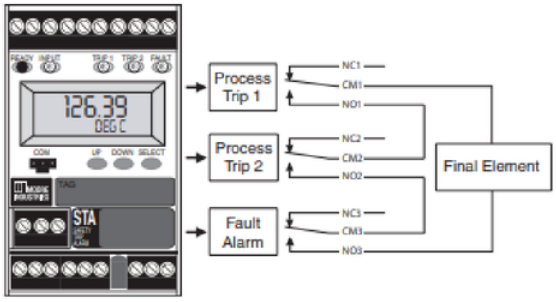


Figure 25: STA high integrity configuration

5. Project Design

5.1 PLC and HMI Program

The PLC and HMI program was made using the Siemens Totally Integrated Portal (TIA) portal. The language used was ladder, and the blocks are discussed below. Each block is placed into the main loop, where they are called during each loop iteration. Figure 26 shows the pressure monitor block as it appears in the main block.

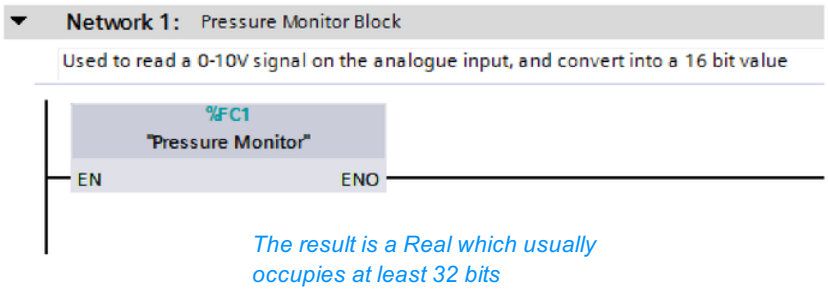


Figure 26: Pressure monitor block

The content of this block is shown in Figure 27**Error! Reference source not found.**. The first step on network 1 is to convert the value at AI0 from an unsigned integer to a real value. %IW64 refers to the address of the analogue input in memory. The output of this conversion block is a real value with the name "input channel 0." The next step was to condition the input signal. This was done by first subtracting the zero offset from the reading. In this case there was no offset meaning nothing had to be subtracted. The next step was to multiply by the specified pressure range, in this case 0-10 psi. Once that was complete the final step was to divide by the maximum ADC value, which was found by pumping up to the maximum specified pressure.

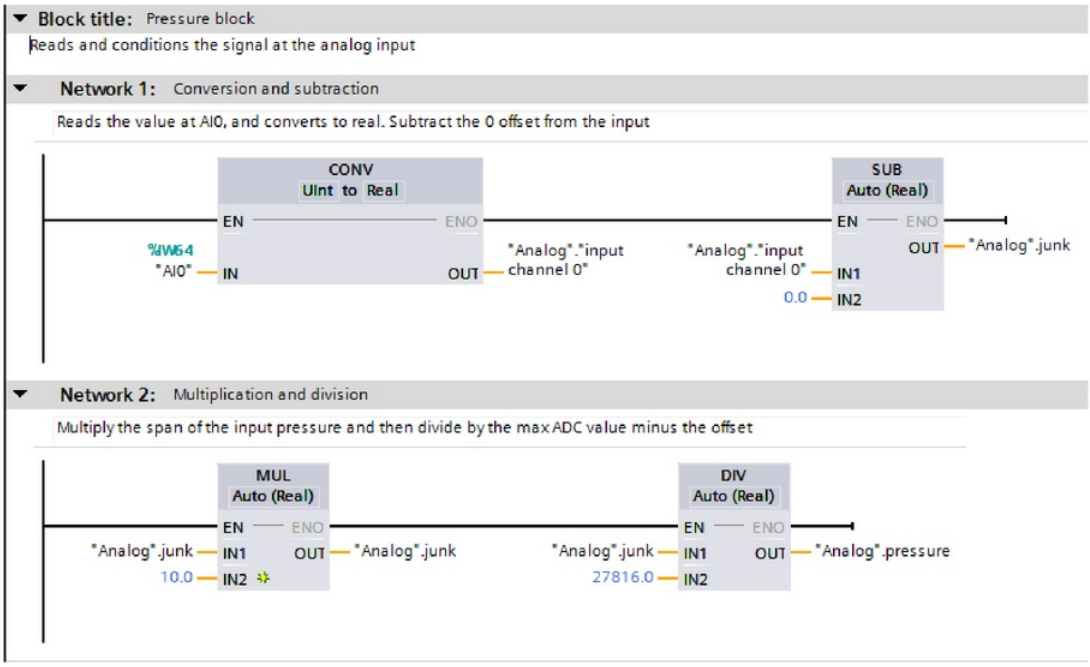


Figure 27: Pressure block

Figure 28 shows the block used to create the web server. The web server is used to display information on web pages, and allows for remote monitoring of the pressure and status. The "CTRL_DB" input informs the compiler of the memory location where the first web data block should be placed. In this case, the location is 333.

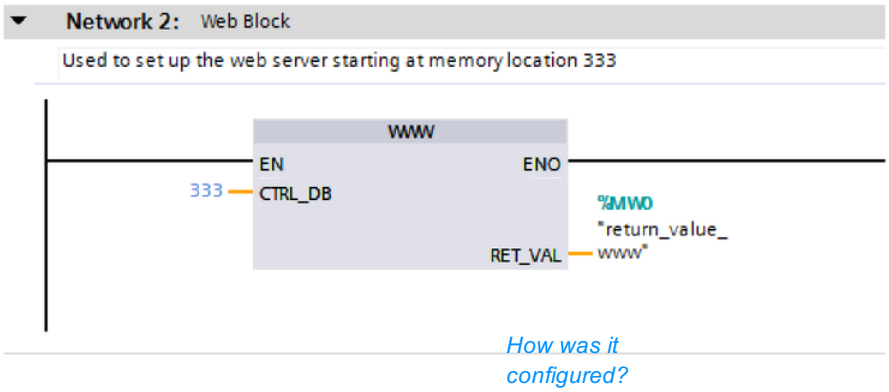
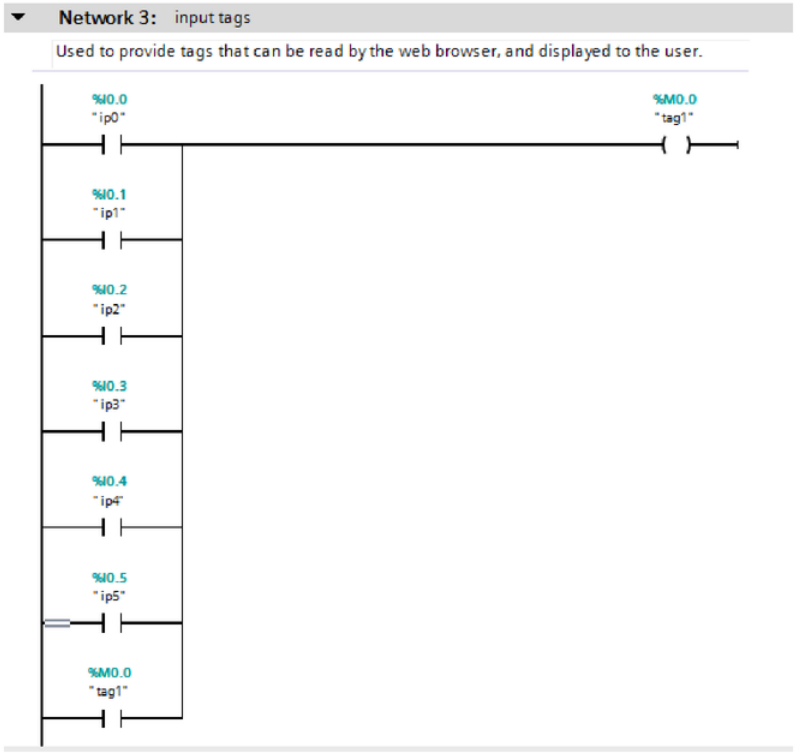


Figure 28: Web block

Finally, the input tags are shown in Figure 29. These tags hold the status of the inputs, which can then be polled by the web browser.



In order to poll the pressure in the web browser, it was necessary to move the "Analog".pressure variable to a tag. This is shown in Figure 30.

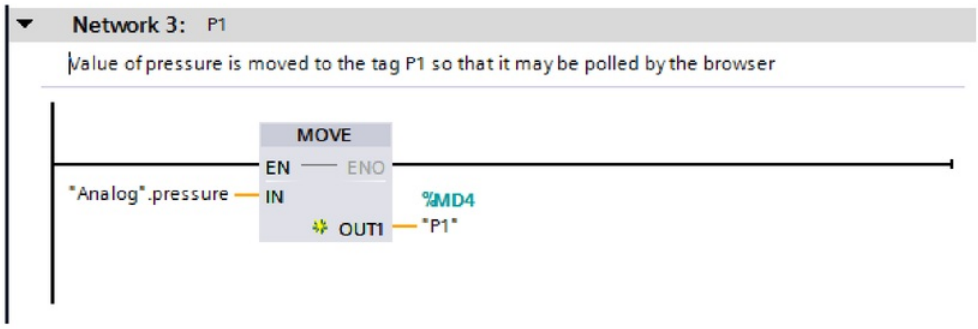


Figure 30: Pressure moved to P1 tag

The variables created were all stored in data blocks. Figure 31 shows the analogue data block, where all the variables created in the pressure block are stored.

		Name	Data type	Start value	Comment
1		Static			
2		input channel 0	Real	0.0	Analog input real value
3		junk	Real	0.0	Analog value during conditioning
4		pressure	Real	0.0	Actual pressure

Figure 31: Analogue data block

Helpful information

Figure 32 shows the tag table used. The tags allow data from memory locations to be used throughout the program, or to be accessed on a network.

PLC tags

	Name	table	Data type	Address	Comment
1	AI0	ault tag table	Word	%IW64	Analog input
2	return_value_www	ault tag table	Word	%MW0	
3	ip0	ault tag table	Bool	%I0.0	Digital input 0
4	tag1	ault tag table	Bool	%M0.0	Retaining contact
5	ip1	ault tag table	Bool	%I0.1	Digital input 1
6	ip2	ault tag table	Bool	%I0.2	Digital input 2
7	ip3	ault tag table	Bool	%I0.3	Digital input 3
8	P1	ault tag table	Real	%MD4	Pressure
9	ip4	ault tag table	Bool	%I0.4	Digital input 4
10	ip5	ault tag table	Bool	%I0.5	Digital input 5

Figure 32: Default tag table

The HMI screen was used to display information on the process. It features a numeric display, a gauge and a graph. The screen was also programmed using the TIA portal, as it allowed elements to be easily dropped into place where they were required. Once the elements were in place, the ""Analog".pressure" value was chosen in the settings to provide a reading. The root screen of the HMI is shown in Figure 33.

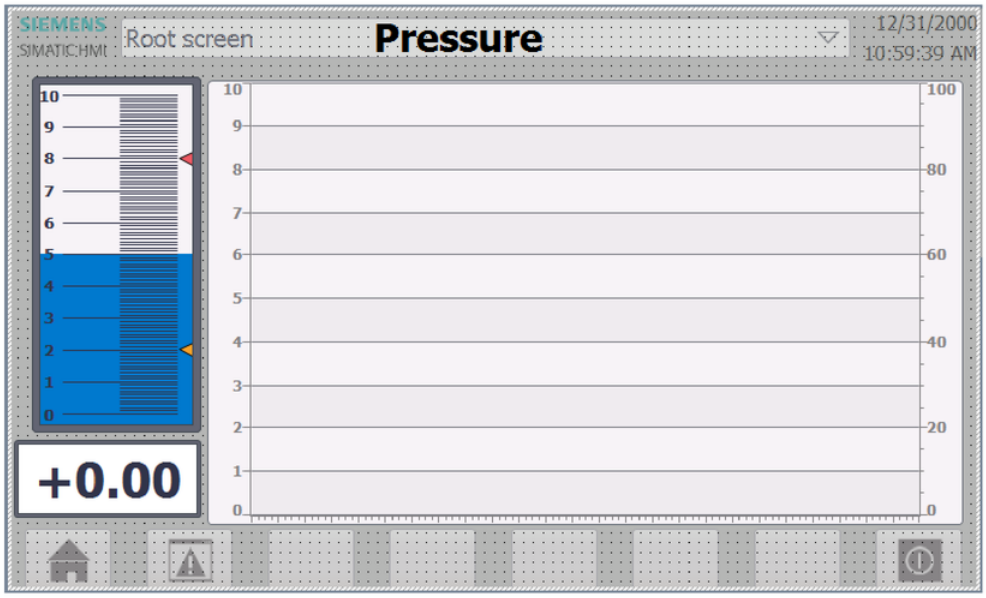


Figure 33: HMI root screen

5.2 Web Pages

In order to create a remote display, a web page was programmed. This would be able to show the pressure as well as monitor the inputs from the tags. All web pages were put into a single folder, and were then called through links in the browser. Figure 34 shows the code for the index page. This page simply creates the frames, and provides the sources of the web content that will be displayed.

```
1  <!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
2  "http://www.w3.org/TR/html4/loose.dtd">
3  <html>
4  <head>
5  <meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
6  <title><h2>Control status</h2><HEAD>
7
8  <TITLE>web_based control</TITLE> <!--Declare page title-->
9
10 <frameset rows="15%, *" frameborder = "No"> <!-- decalre row frame as being 15% of the page-->
11
12 <frame name="title" src="title.htm" scrolling="no"> <!--Declare name of the frame, as well as the source of the content-->
13
14 <frameset cols="20%, 80%" frameborder = "No"> <!-- Declare column frame as being a 20/80% split of the page-->
15
16 <frame name="menu" src="menu_page.htm" scrolling="auto"> <!-- Declare first frame as menu as well as the source-->
17
18 <frame name="result" src="Status_Page.htm" scrolling="auto"> <!-- Declare second frame as the result, as well as the source-->
19 </HTML>
20 </head>
21 <body>
22 </body>
23 </html>
```

Figure 34: Index page code

Lines one through five simply define the document type, so that the browser knows how to display it. Line 6 declares the header of the page, which will be displayed on the browser tab. Line 8 declares the document title, and lines 10 to 18 handle the creation of frames. Frames are a feature in html that allows different files to be loaded into different sections of the page. In this case, it allows a navigation menu to be implemented and the content to be displayed separately.

This is the main web page where all other content will be loaded to, and it is shown in Figure 35.

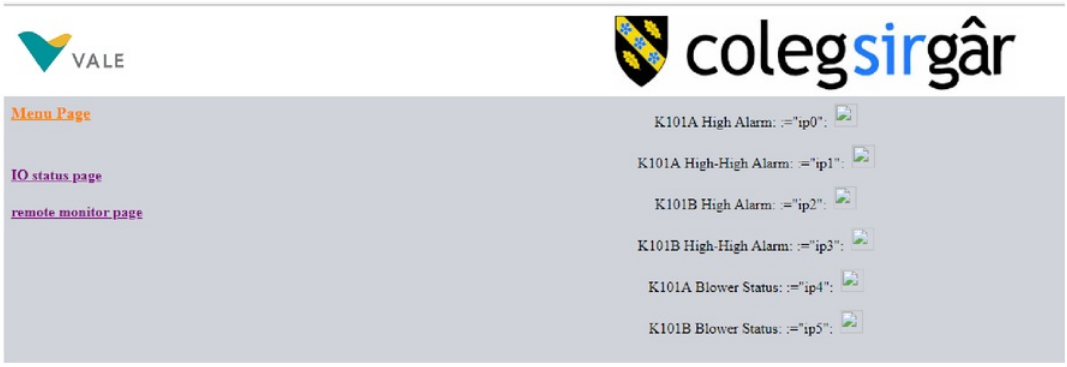


Figure 35: Index page

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
"http://www.w3.org/TR/html4/loose.dtd">
<html>
<head>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
<title>Untitled Document</title> <!-- Declare document title-->
</head>

<body> <!-- Main body of the web page-->
<table width="1098" border="0"> <!--Create a table of width 1098 pixels, do not include border-->
  <tr>
    <!--Display image from the source with width of 124 pixels and height of 60 pixels-->
    <td width="536"><img src="Vale logo.png" width="124" height="60"></td>
    <!--Display image from the source with width of 437 pixels and height of 81 pixels-->
    <td width="546"><div align="right"><img src="colegsirgar_logo.gif" width="437" height="81"></div></td>
  </tr>
</table>


</body>
</html>

```

Figure 36: Title page code

Figure 36 shows the code for the title page. This is a simple piece of code that displays the respective logos of Vale and Coleg Sir Gâr. These images are loaded on to the top frame defined in the index code, and their size is specified within this program. HTML also sets the alignment of the second image to the right. Figure 37 shows the title web page open in a browser.



Figure 37: Web page title

```
1  <!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN">
2  <html>
3  <head>
4  <title>menu-page</title>
5
6  <meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1"></head>
7
8  <body bgcolor="#D0D3DA"> <!--Set background colour to grey-->
9
10 <p><font color="#FF8000" size="4"><strong><u>Menu Page </u></strong></font></p> <!--Set font colour, size and underline-->
11
12
13 <div><a href="Status_Page.htm" target="result"><font color= 'purple'> <!-- Link to the Status page-->
14   <h4 onmouseover=style.color='rgb(0,0,102)'onmouseout=style.color='purple'>IO status page</h4></a> <!--Configure link text-->
15   <a href="Monitor_page.htm" target="result"><font color= 'purple'>  <!--Link to Monitor page-->
16   <h4 onmouseover=style.color='rgb(0,0,102)'onmouseout=style.color='purple'>remote monitor page</h4> </a> <!-- Configure link text-->
17
18 </div>
19
20 </body>
21 </html>
```

Figure 38: Menu page code

The code for the menu page is shown in Figure 38. As mentioned previously, this page acts as a navigation menu for the site. Two links are defined using the "a href" tag in lines 13 and 15, and the sources of the HTML files are given. The target of these links is the "result" frame that was defined in the index. Lines 14 and 16 define the names and formats of the links, as it is clearer to the user if intuitive names are given. Figure 39 shows the menu page open in the browser.



Figure 39: Menu page

```
1  <!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN">
2  <html>
3  <head>
4  <meta http-equiv="refresh" content="2"> <!-- Refresh the page at 2 second intervals-->
5  <title>Untitled Document</title> <!-- Declare document title -->
6  <meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
7  </head>
8
9  <body bgcolor="#D0D3DA"> <!-- Declare background colour-->
10
11 <!--the following code is used to read the PLC tags loaded to the web server -->
12
13 <!-- AWP_In_Variable Name='"op0"'  -->
14 <!-- AWP_In_Variable Name='"op1"'  -->
15 <!-- AWP_In_Variable Name='"op2"'  -->
16 <!-- AWP_In_Variable Name='"ip0"'  -->
17 <!-- AWP_In_Variable Name='"ip1"'  -->
18 <!-- AWP_In_Variable Name='"ip2"'  -->
19 <!-- AWP_In_Variable Name='"ip3"'  -->
20 <!-- AWP_In_Variable Name='"ip4"'  -->
21 <!-- AWP_In_Variable Name='"ip5"'  -->
22 <!-- AWP_In_Variable Name='"ip6"'  -->
23 <!-- AWP_In_Variable Name='"ip7"'  -->
24
```

Figure 40: IO status page code

The code for the IO status page is shown in

incomplete sentence

Figure 40. This page was made to show whether the signal at the inputs of the PLC were high or low. To do this, Hypertext Preprocessor (PHP) was used. PHP is a scripting language that runs on the server, and is incorporated into the html file. The client side, the web browser in this case, will poll this information on every page refresh. Line 4 demonstrates the code that will automatically refresh the page every two seconds. Lines 13 to 23 show the code

responsible for declaring the tags in the browser. This will not appear on the web browser, but will run on the server.

Figure 41 shows the end of the IO status page code. This is the section of code that displays the correct image depending on the status of the inputs. The two images in the folder are names "Status00" and "Status01." In order to select these images, the second number is defined by the input status. Siemens PLCs have a specific method of using tags on the web server. *":= "…":"* is used with the desired tag put where the ellipses are.

```
<!-- the following code choses the appropriate lamp image based on the status of the input-->

<p align="center">K101A High Alarm: :="ip0":  <img src="Status0:="ip0":.png" """""""""""""width="25" height="25"" >
<p align="center">K101A High-High Alarm: :="ip1":  <img src="Status0:="ip1":.png" """""""""""""width="25" height="25"" >
<p align="center">K101B High Alarm: :="ip2":  <img src="Status0:="ip2":.png" """""""""""""width="25" height="25"" >
<p align="center">K101B High-High Alarm: :="ip3":  <img src="Status0:="ip3":.png" """""""""""""width="25" height="25"" >
<p align="center">K101A Blower Status: :="ip4":  <img src="Status0:="ip4":.png" """""""""""""width="25" height="25"" >
<p align="center">K101B Blower Status: :="ip5":  <img src="Status0:="ip5":.png" """""""""""""width="25" height="25"" >
</body>
</html>

```

Figure 41: IO status page code continued

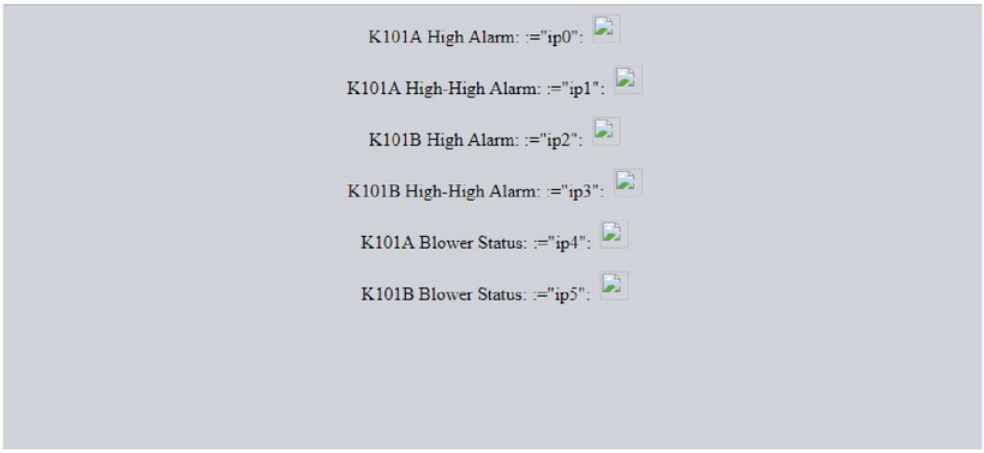


Figure 42: Status page

Figure 42 demonstrates the status page. The reason for the images not showing is due to the file being loaded directly into the browser. For the page to display properly it must be loaded from the web server in the PLC.

Finally, the monitor page code is shown in Figure 43. As with the status page, this code utilizes PHP to retrieve the pressure values from the PLC. The page is automatically refreshed every 0.2 seconds in order to update the pressure quickly. "P1" is the tag that is polled for its value on this page.

```
1  <!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN">
2  <html>
3  <head>
4  <meta http-equiv="refresh" content="0.2"> <!-- Refresh page every 0.2 seconds -->
5  <title>Untitled Document</title>
6  <meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
7  </head>
8
9  <body bgcolor="#D0D3DA"> <!-- Set background colour -->
10 <font size="+4"></font>
11 <!-- AWP_In_Variable Name='"P1"' --> <!--Load in tag "P1"-->
12
13 <!--Display current value of "P1"-->
14 <font size="+3" face="Arial, Helvetica, sans-serif">Blower Outlet Pressure: :="P1": psi </font>
15
16 </body>
17 </html>
```

Figure 43: Monitor page code

The monitor page is shown in Figure 44. When the PLC is connected, the page displays a numerical value in place of the PHP script.

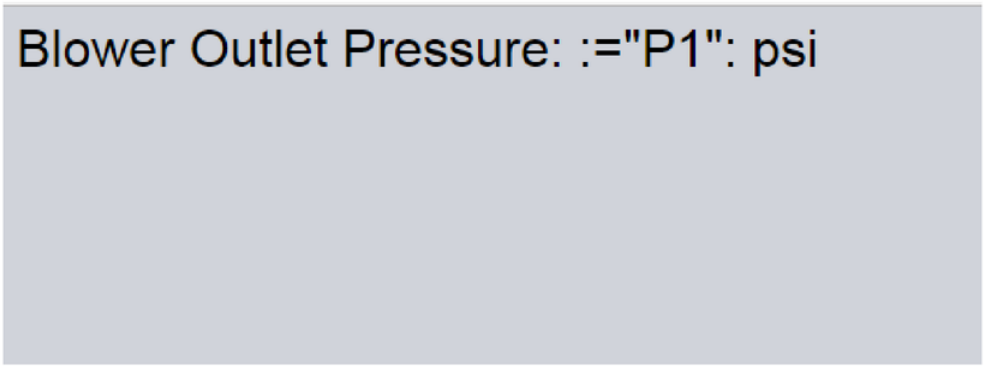


Figure 44: Monitor page

6. Project Implementation

Due to being unable to implement the project onsite until a scheduled plant shutdown, a prototype system was created in order to perform functional tests. These tests were to prove that the project was successful. The first step taken to implement the prototype was to create a drawing. This allowed wire numbers to be assigned, and eased the process.

You could have included the drawing in the report.

Once a drawing had been made, the next step was to fit the required components to a surface. The STA was fitted to DIN rail along with the various terminal blocks used, whilst the transmitter was fitted to its own bracket. The bracket was securely fastened to the wall to prevent the transmitter from coming loose and sustaining damage.

In order to keep the cables neat, trunking was fitted to the surface. This would provide a convenient channel to run the cabling, and a means to cover them up. Figure 45 shows the components fitted before the wiring had been done.



Figure 45: Components and trunking fitted to surface

Once the instruments and terminal blocks had been fitted, the next step was to wire the circuit up. The cables chosen for this circuit were 1.5mm^2 brown tri-rated for 24V, 1.5mm^2 blue tri-rated for 0V, 1mm SY cable for the main power source and shielded cable for the current loop. The ale wiring colour have been included in the appendix.

Figure 46 shows the finished prototype. With the wiring complete, the system could e powered up. A bench top power supply unit (PSU) was used to give 24V to the system. the next step was to configure the transmitter and the STA to provide the desired ranges and trip values.

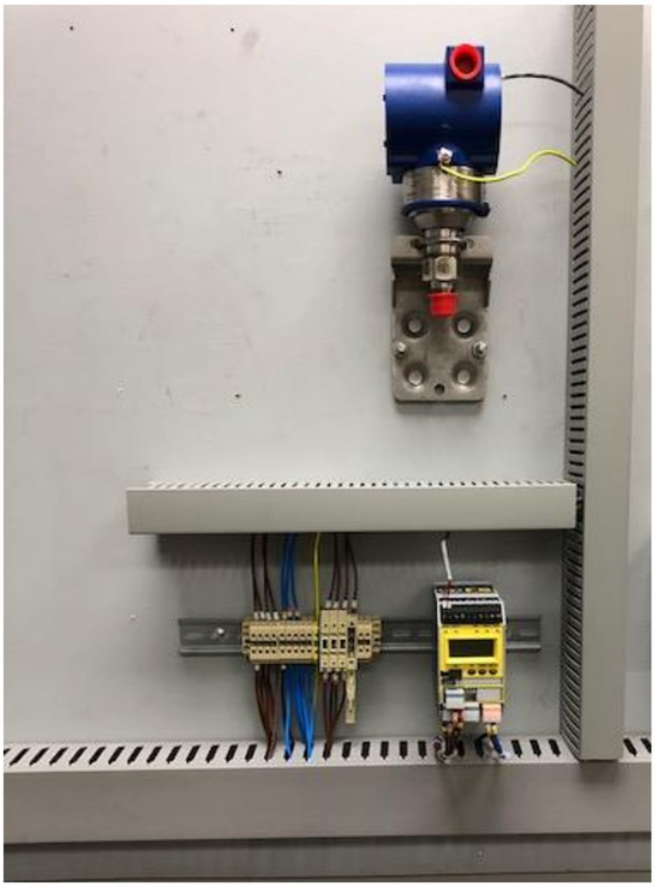


Figure 46: Finished prototype

It was possible to set both devices up through their on-board controls. The STA was configured in this manner, however; the transmitter was set up through the use of the Pactware configuration program.

The STA allows for many configuration options through the inbuilt menu, but only a select few options needed reconfiguring. Figure 47 shows the password entry flow diagram to access the settings. When the "Sel" button is pressed, a password prompt appears. The correct password must be chosen to have access to the STA settings. (Moore Industries Inc., 2017)

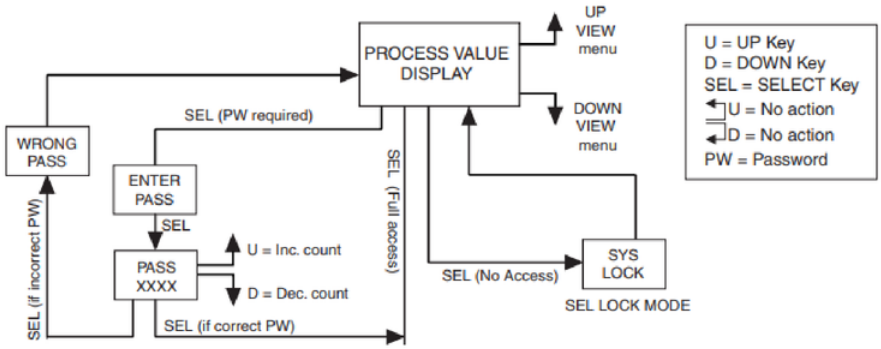


Figure 47: Password entry for STA settings (Moore Industries Inc., 2017)

The flow diagram for the settings is shown in Figure 48. There are more settings available, but the main requirements were the alarm and analogue output configuration sub menus.

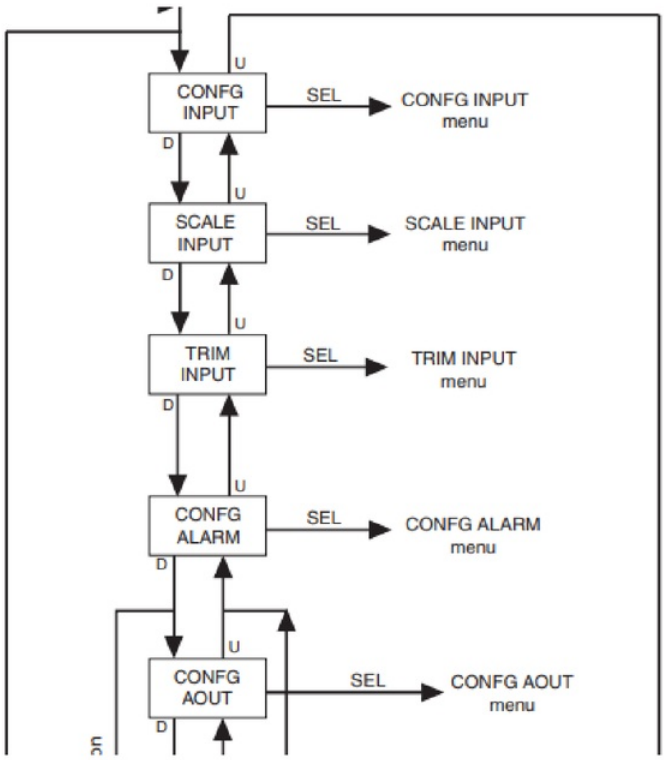


Figure 48: STA settings (Moore Industries Inc., 2017)

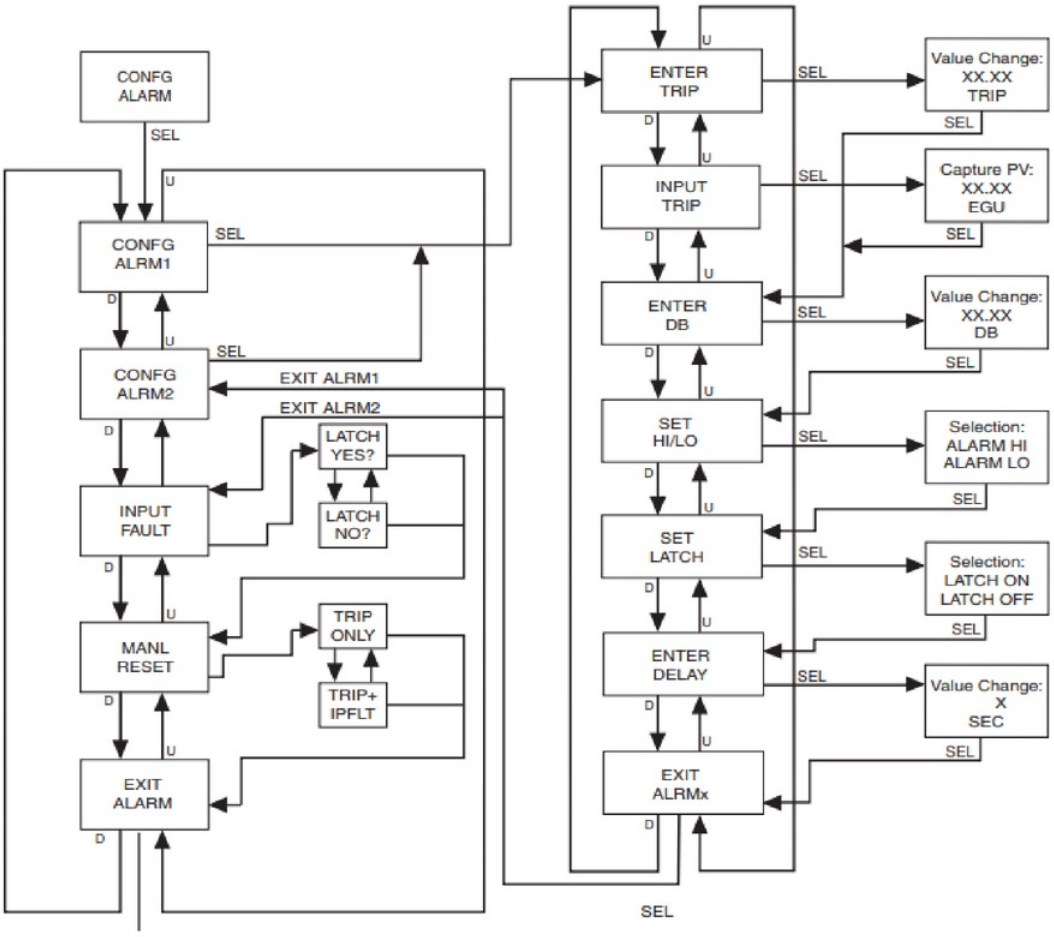


Figure 49: Alarm configuration flow chart (Moore Industries Inc., 2017)

The configuration flow chart for the alarms is shown in Figure 49. The trip value was changed to 12.8mA as calculated earlier. Alarm 2 was unnecessary for the test, but was changed to 20mA so as not to interfere with the testing.

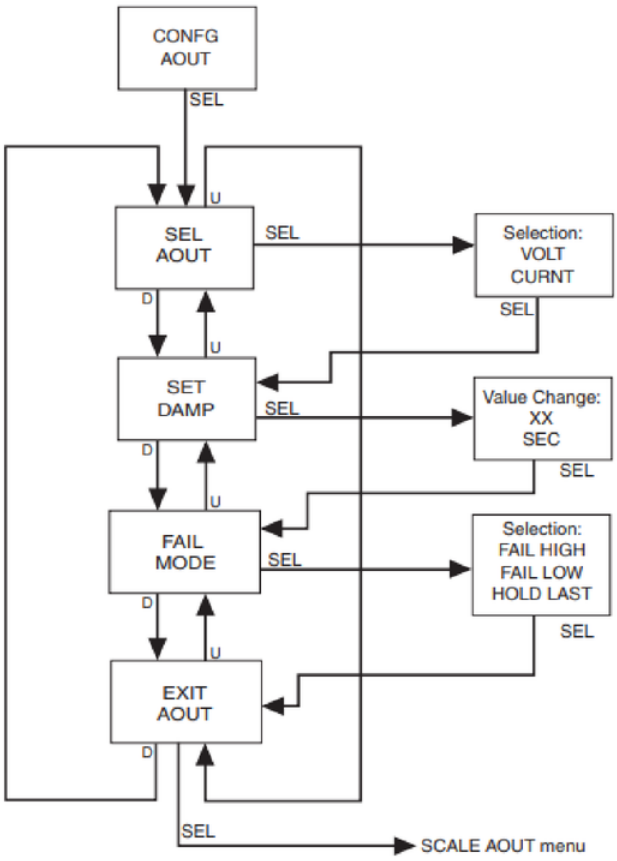


Figure 50: Analogue output configuration (Moore Industries Inc., 2017)

Finally, the analogue output configuration is shown in Figure 50. The only option that needed to be changed here was the type of output signal. In this case, it needed to be a voltage signal. Typically, the signal would be current out on site as it is less susceptible to signal degradation. A resistor will then be used to convert the current to volts. Here, however, voltage will be fine as it is only a short run of cable.

Figure 51 shows the wiring required for a loop powered 2-wire transmitter. This configuration is required for the chosen pressure transmitter. This image also shows where the power supply is connected.

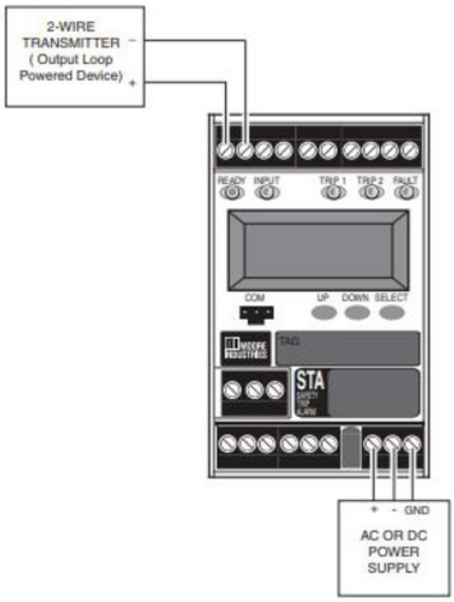


Figure 51: STA wiring (Moore Industries Inc., 2017)

The terminal designations for the STA are shown in Figure 52. This shows which terminals are used for the trip and fault relays, as well as the terminal designations for the analogue output signal. The voltage signal is required because as mentioned, the Siemens PLC will only accept 0-10V.

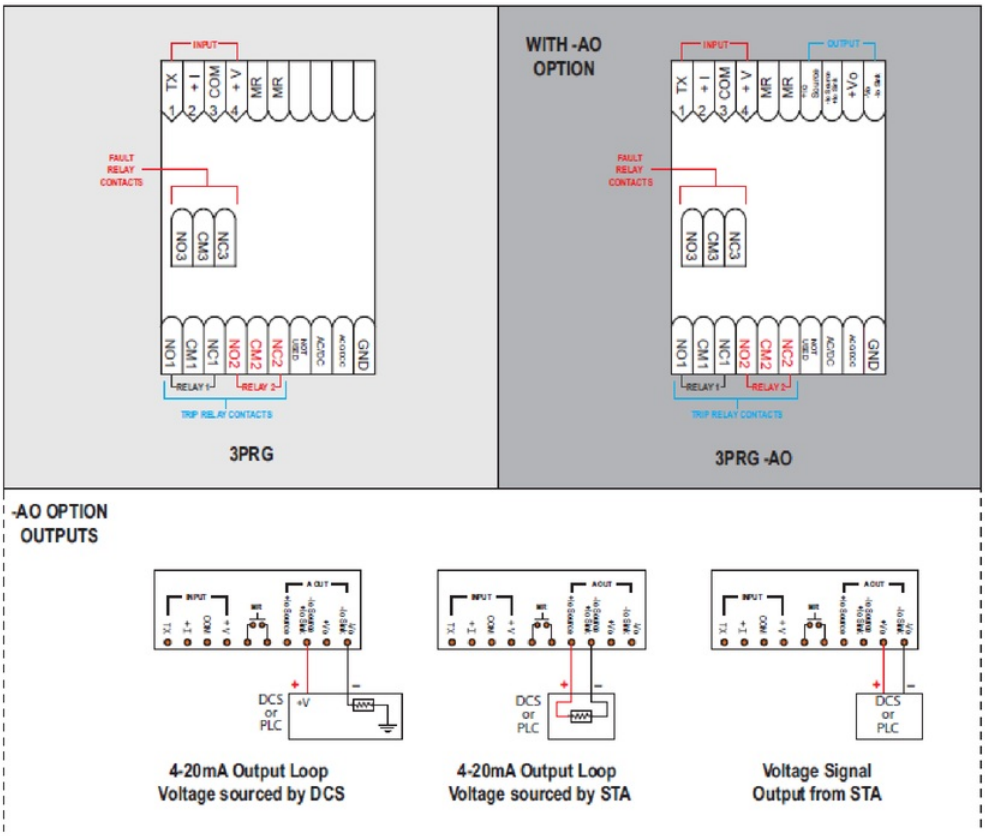


Figure 52: STA terminal designations (Moore Industries Inc., 2017)

Which drawing applies to your project?

In order to set up the transmitter, it was wired up to the laptop as shown in Figure 53.

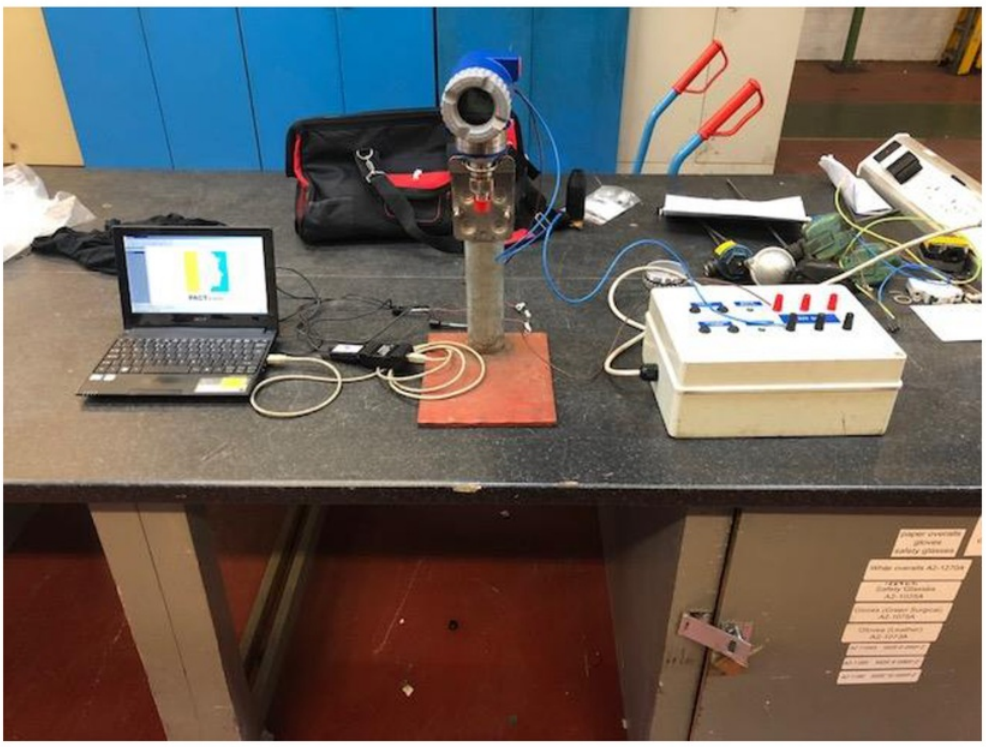


Figure 53: Pressure transmitter configuration setup

The Pactware software shown on the laptop was used to set the range to 0-10psi, as well as set the tag name. It was also confirmed whether the transmitter was set to fail high.

It would have been good to see a screenshot of the Packware software running.

Figure 54 shows the HMI display working.

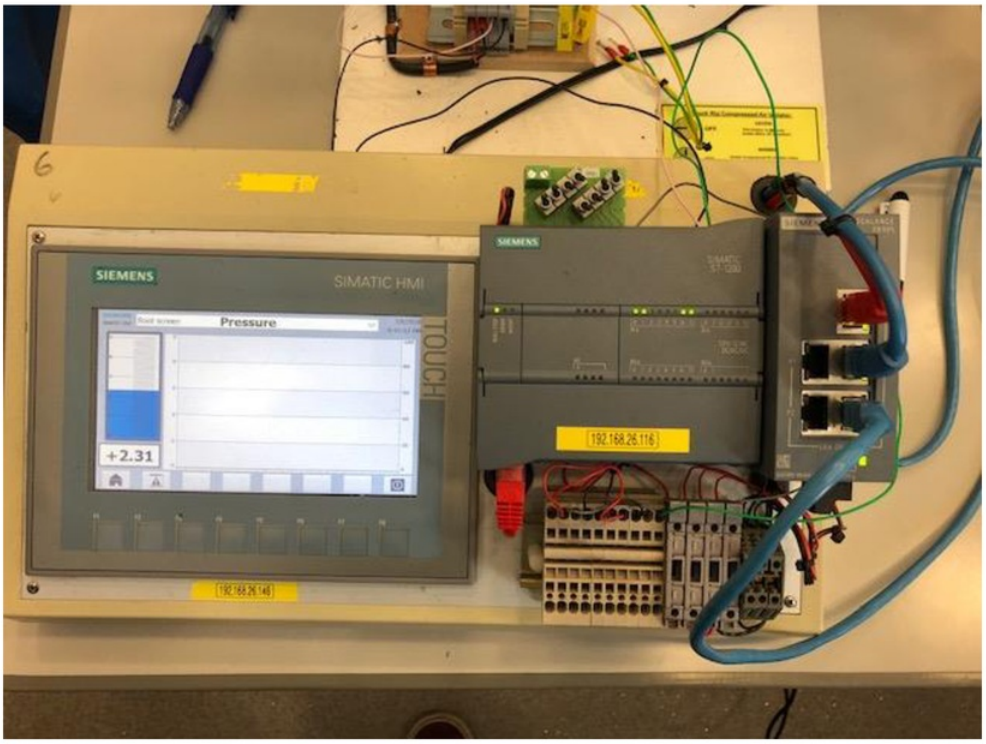


Figure 54: HMI display

7. Project Testing/ Project Evaluation

7.1 Functional Tests

In order to test the project was operating correctly, it was necessary to perform several functional tests on the prototype. The first check was a calibration check on the pressure transmitter. It was essential to confirm that the correct value was being outputted as having the wrong pressure could lead to a trip occurring too early or too late.

The setup for this test is shown in Figure 55. A Druck calibration pump was used to pressurise the system for testing, and a calibrated pressure meter was used to verify the pressure. Please note that the testing does not involve any of the equipment attached to the right side of the panel.

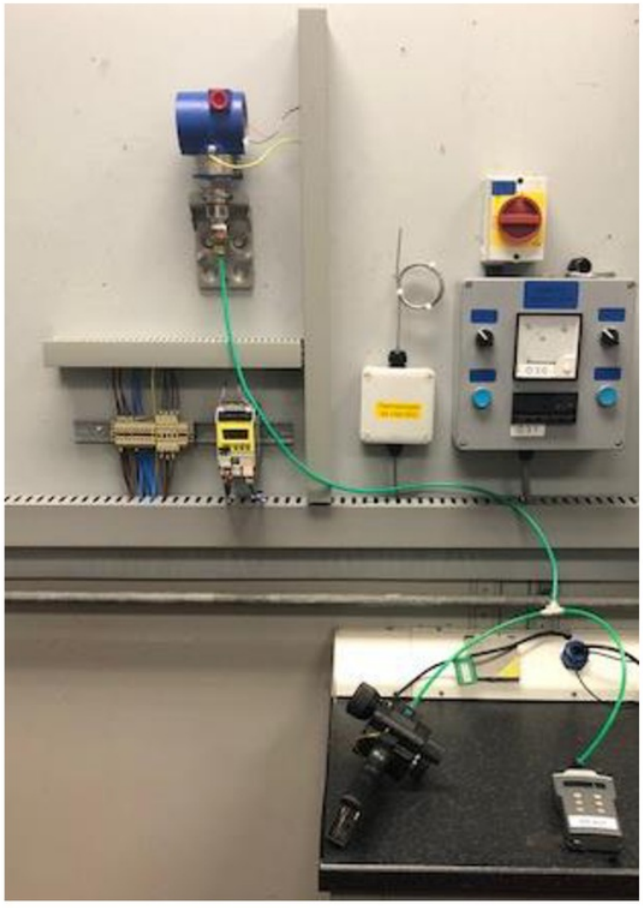


Figure 55: Project prototype set up for test

It would have been useful to see the PLC and HMI connected as a complete system

7.1.1 Calibration Checks

To ensure that the results were accurate, it was also necessary for the pressure meter to be within calibration. The calibration sticker is shown in Figure 56, and the date shown in March 2017. This means that the due date for the next calibration would be around March 2018.

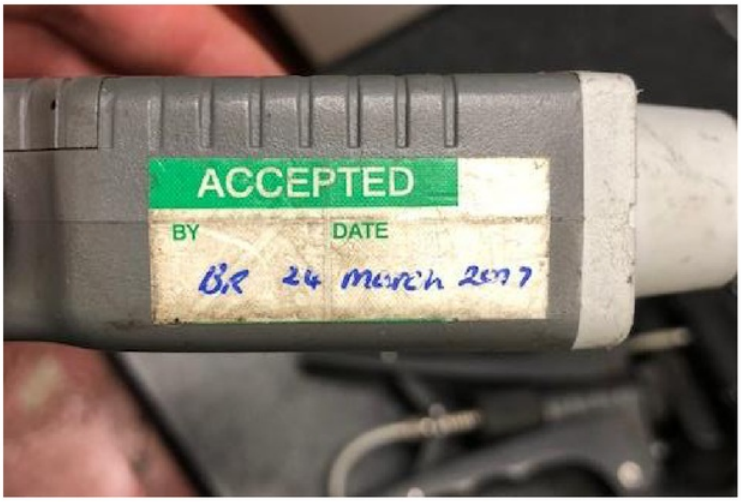


Figure 56: Pressure meter calibration sticker

Figure 57 shows the display on the transmitter at 0psi. There is an offset present, but this is negligible. The meter display is shown in Figure 58, which clearly shows that the pressure is at zero.



Figure 57: Transmitter display at 0psi

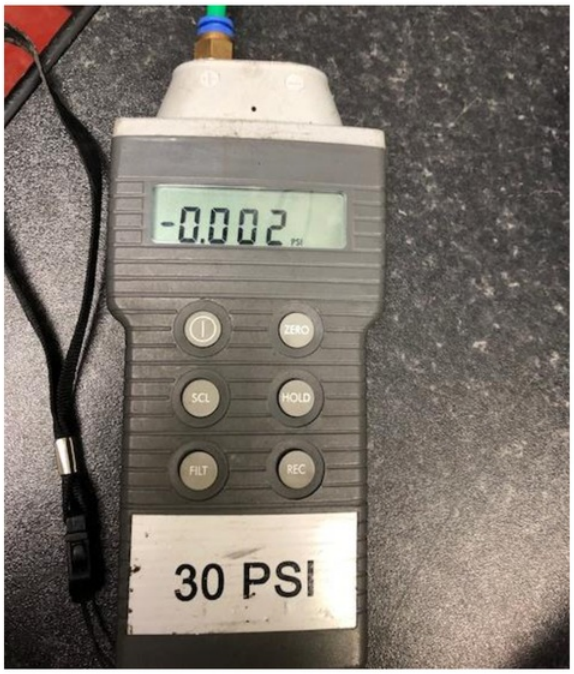


Figure 58: Meter display at 0psi

The next test was performed at 5psi. The transmitter display is shown in Figure 60, and the meter display in Figure 59. Both images show a reading of 5psi.



Figure 60: Transmitter display at 5psi



Figure 59: Meter display at 5psi

The final test on the transmitter was performed at 10psi. the transmitter reading is shown in Figure 61, and the meter display is shown in



Figure 61: Transmitter display at 10psi

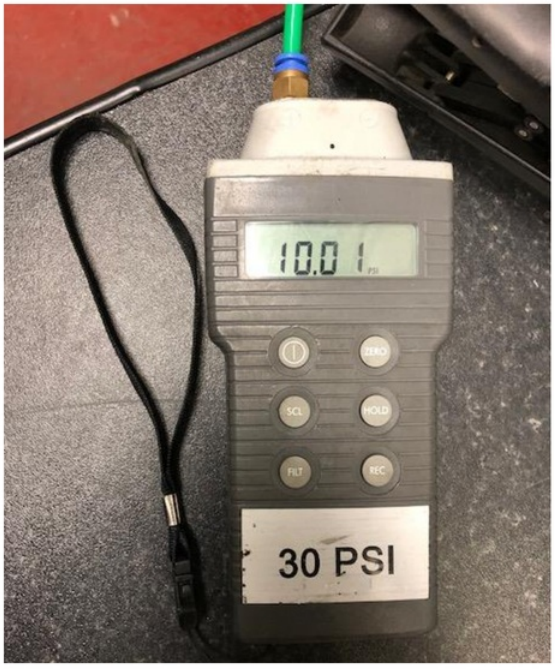


Figure 62: Meter display at 10psi

Table 4: Calibratrion results

Test no.	Transmitter value (psi)	Meter value (psi)	Transmitter error(%)
1	0.00	0.00	0
2	5.00	5.00	0
3	10.00	10.00	0

Table 4 shows the calibration results. It can clearly be seen that the transmitter is properly calibrated as the results are close to those on the meter.

7.1.2 IO Testing

The next series of tests to undertake were to determine whether the IO status page on the web server was operating correctly. In order to do this, toggle switches were used on the inputs of the PLC as shown in Figure 63.

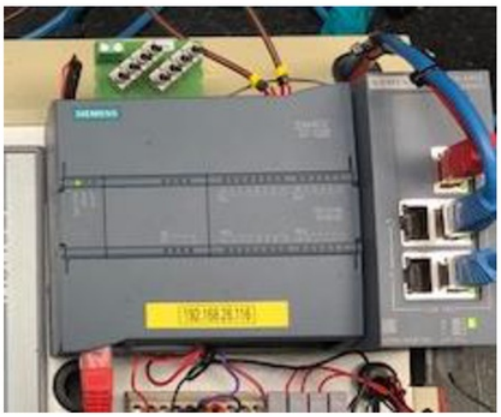


Figure 63: Toggle switch setup

Figure 64 shows the test with no toggle switch active.

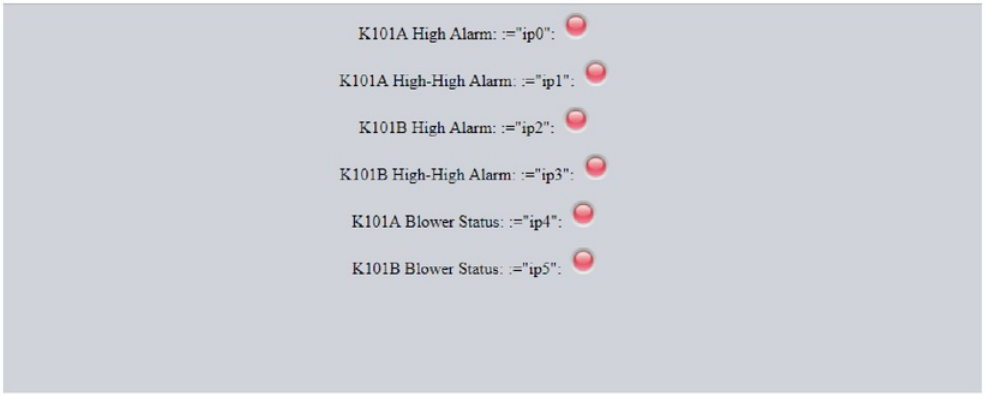


Figure 64: Test with no switch active

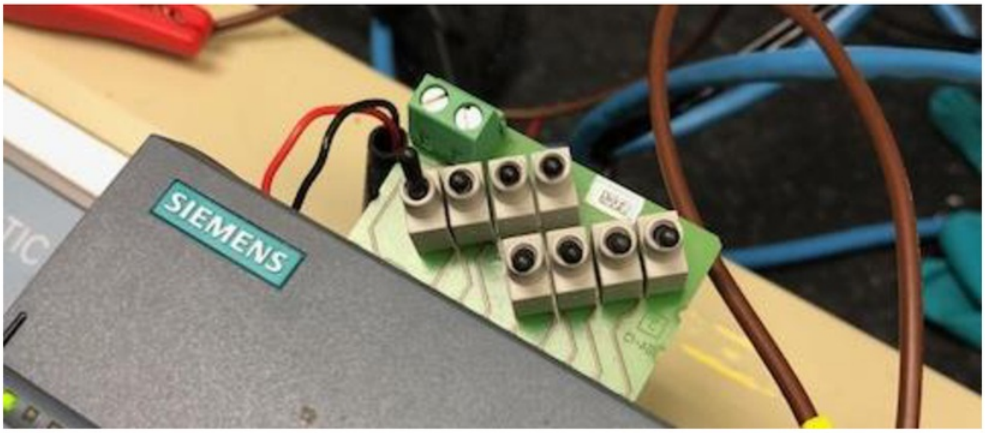


Figure 65: Switch 1 active

Figure 65 shows toggle switch 1 as active. The web page is shown in Figure 66, where it is clear that lamp 1 is also showing a high state. This indicates that the system is working as intended.

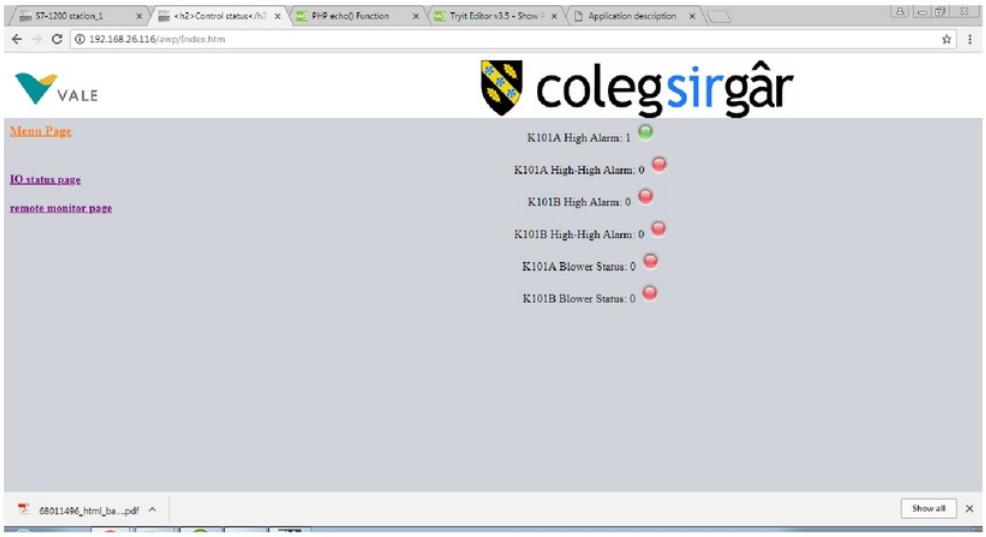


Figure 66: Input 1 high

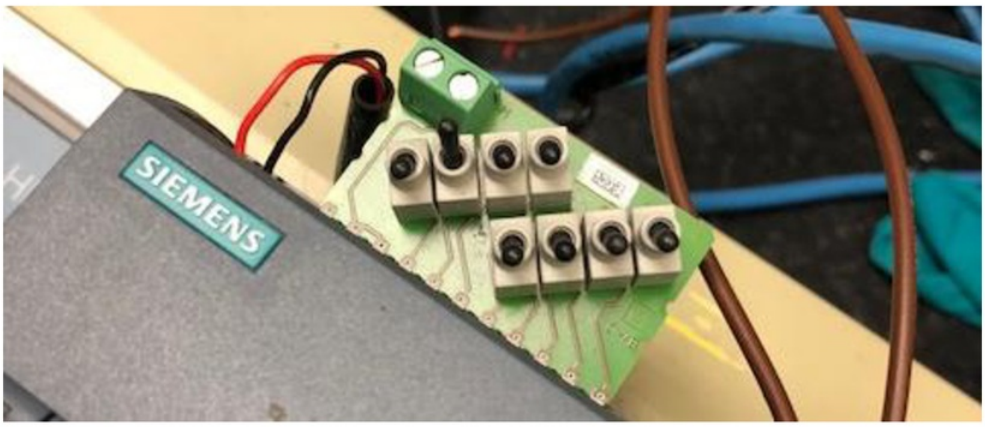


Figure 67: Toggle switch 2 active

Figure 67 shows the second toggle switch as active. As expected, the corresponding lamp on the web page also became active as shown in Figure 68. This proves the correct operation of the system.

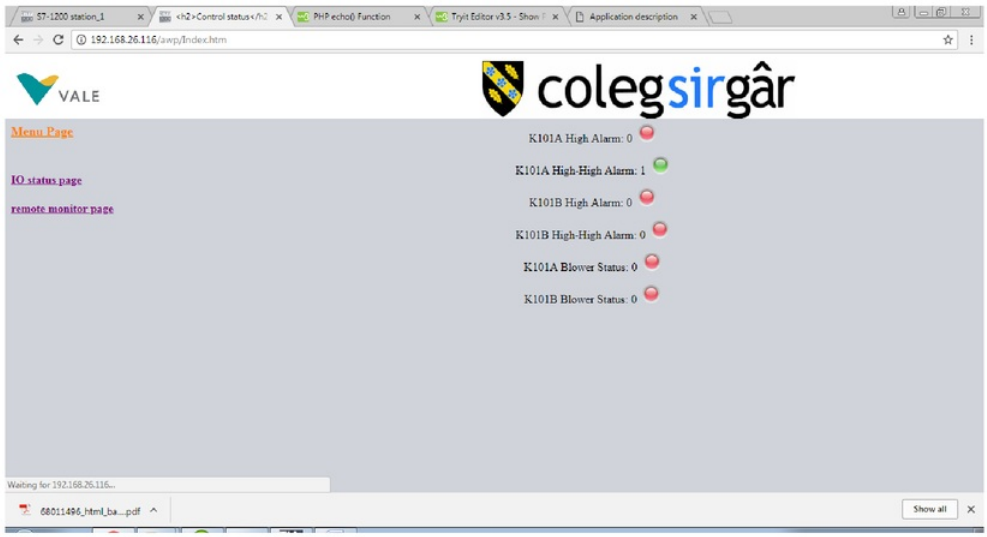


Figure 68: Input 2 high

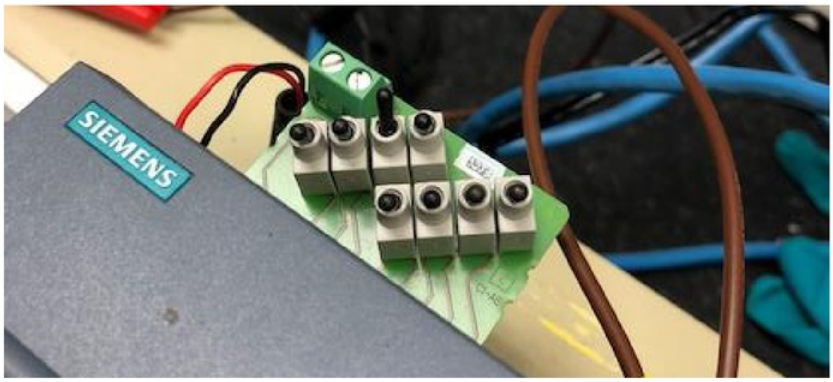


Figure 69: Toggle switch 3 active

The third toggle is shown as active in Figure 69. The web page is shown in Figure 70, and the lamp is clearly in a high state. This indicates the correct operation of the system.

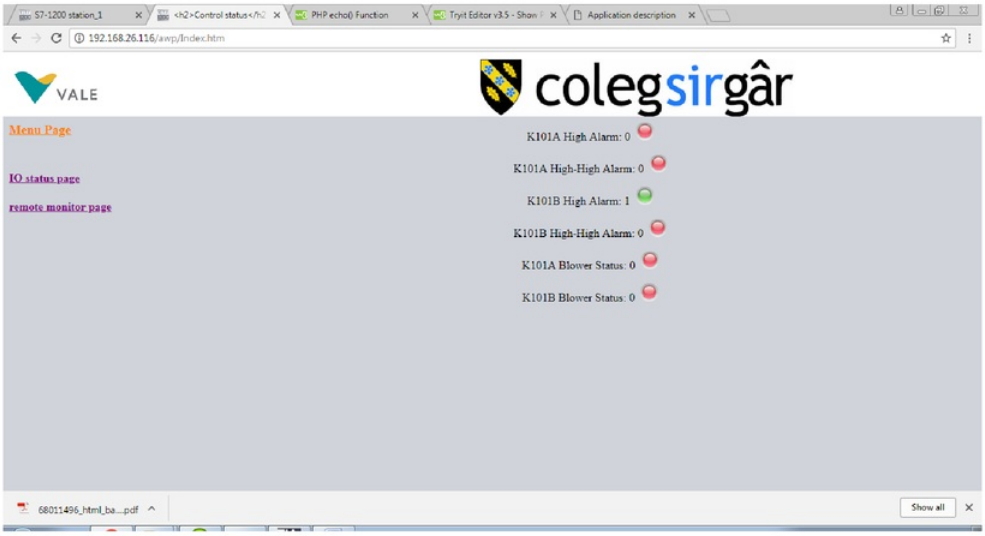


Figure 70: Input 3 high

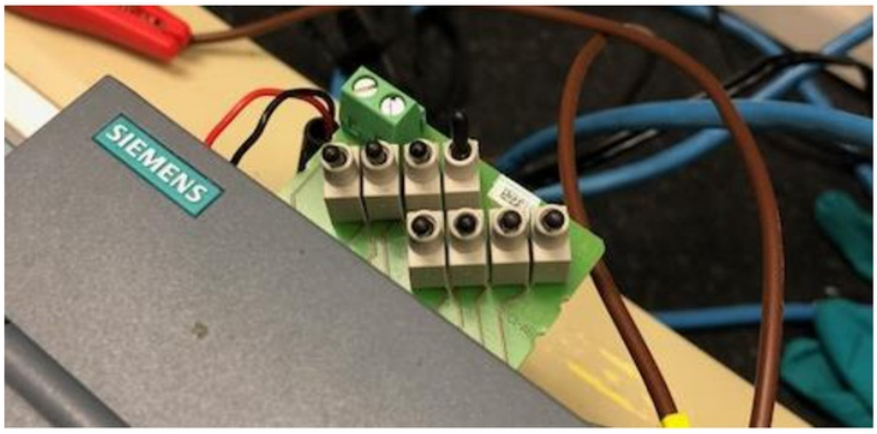


Figure 71: Toggle switch 4 active

Toggle switch 4 is shown as active in Figure 71. The web page in Figure 72 then shows that the fourth lamp is active as expected.

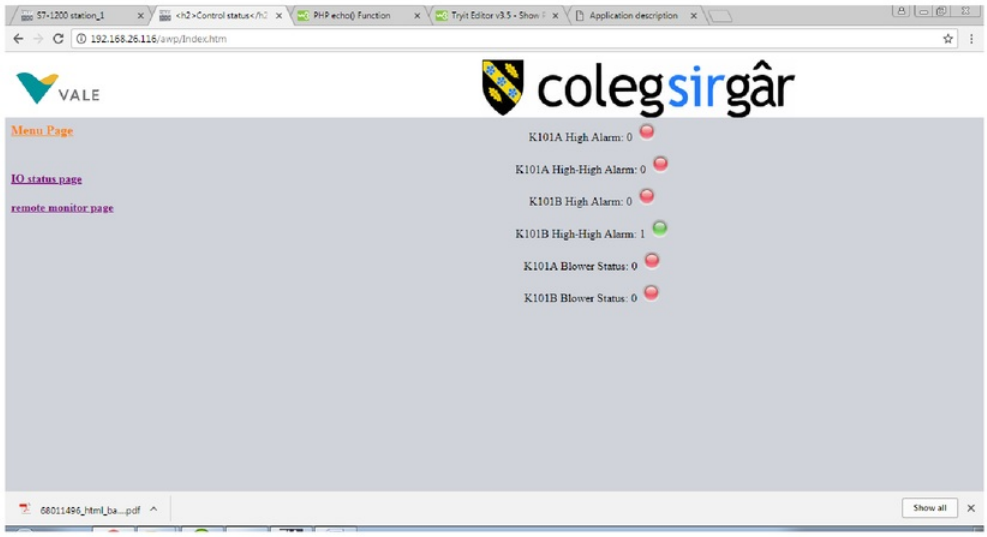


Figure 72: Input 4 high

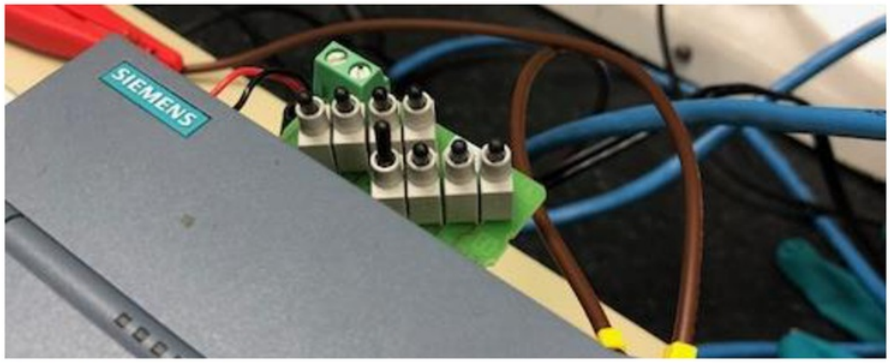


Figure 73: Toggle switch 5 active

The fifth toggle switch in Figure 73 is shown as active. Figure 74 shows the fifth lamp in the browser as being high. This is further proof that the page works correctly.

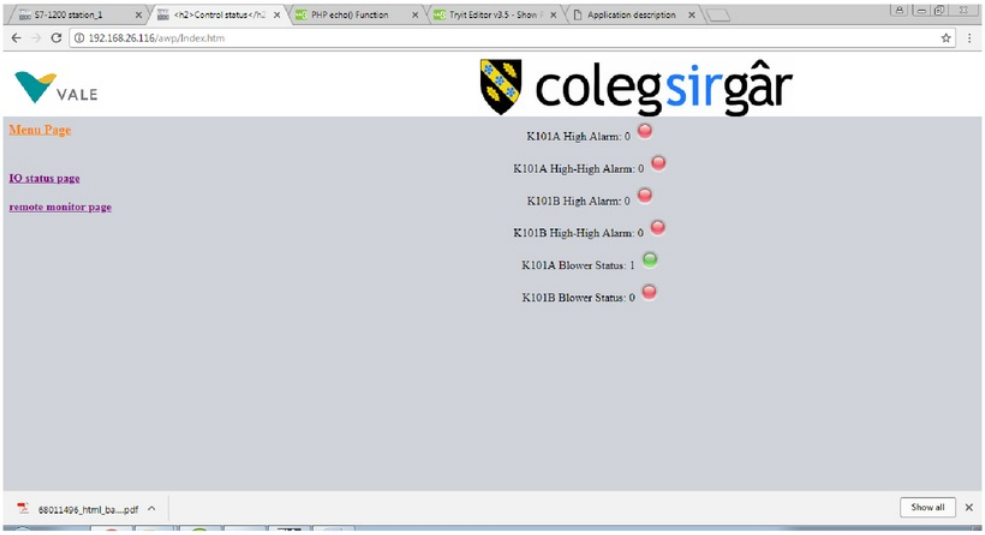


Figure 74: Input 5 high

The PLC analogue input could have been used to test the alarm levels

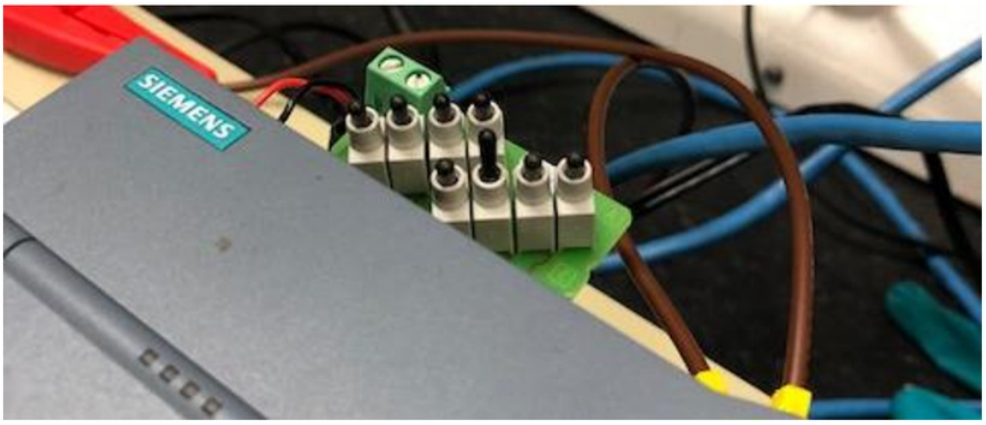


Figure 75: Toggle switch 6 active

Finally, toggle switch 6 is shown in Figure 75. It is active, and as can clearly be seen in the web browser shown in Figure 76, the sixth lamp is active.

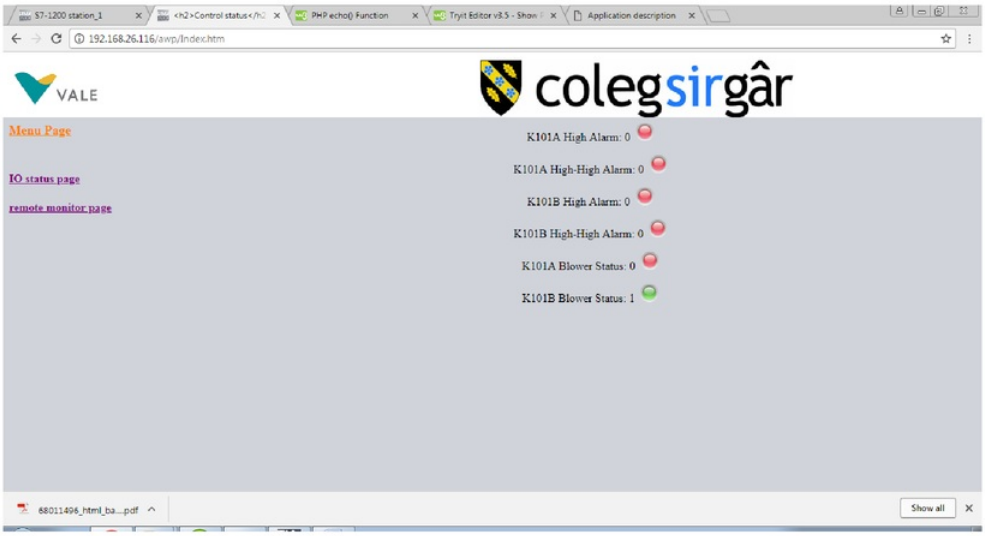


Figure 76: Input 6 high

Table 5: IO tests

Test no.	Switch active	Expected Result	Actual Result
1	None	No active lamps on the web page	No active lamps on the web page
2	1	K101A High Alarm lamp active	K101A High Alarm lamp active
3	2	K101A High-High Alarm lamp active	K101A High-High Alarm lamp active
4	3	K101B High Alarm lamp active	K101B High Alarm lamp active
5	4	K101B High-High Alarm lamp active	K101B High-High Alarm lamp active
6	5	K101A Blower Status lamp active	K101A Blower Status lamp active
7	6	K101B Blower Status lamp active	K101B Blower Status lamp active

With all of the tests on the IO complete, it is possible to input the results into Table 5. It can clearly be seen that each test was successful. This is because when the toggle switches are active, the appropriate lamp is active in the web page.

7.1.3 Web Page Pressure Testing

The next series of tests were to confirm whether the correct pressure could be displayed on the web page. To begin, a Druck genii calibrator was set up to provide a 0-10V signal in order to obtain quick test results with a stable voltage. It was first necessary to set the maximum ADC values in the PLC program. The PLC web server has an in-built data monitor that was used to see the value at %IW64. This memory location holds the value at the ADC. Figure 77 shows the reading at 0V. It is clear that there is no offset here, which means that it is no concern. Figure 78 shows the ADC value at 10V, which is at 27578. This value was put into the PLC, and the tests could then be carried out.

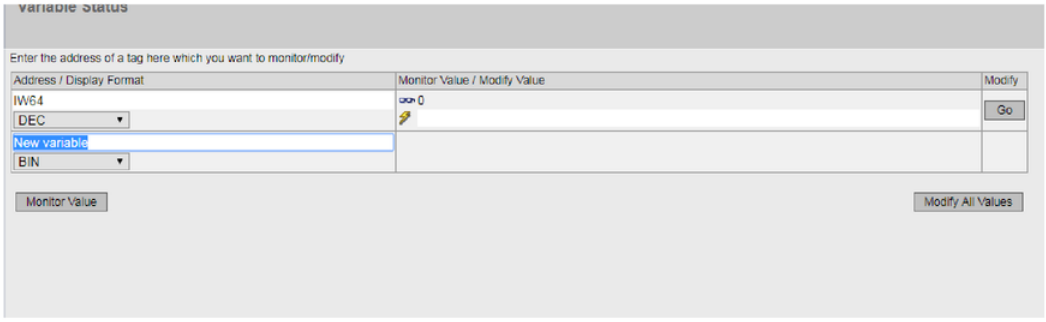


Figure 77: Analog input at 0V

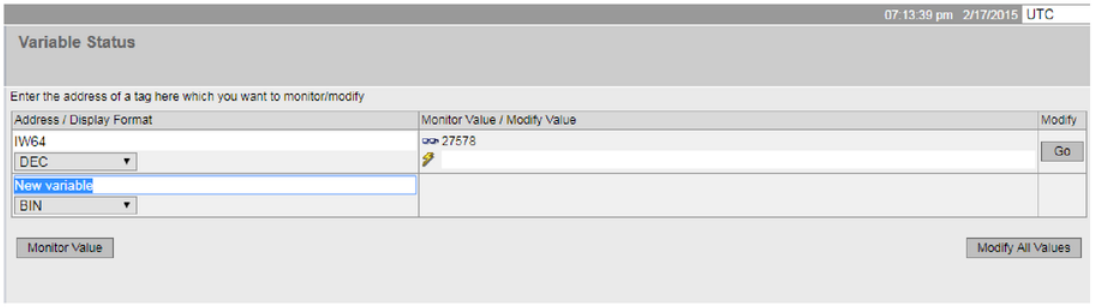


Figure 78: Analogue input at 10V

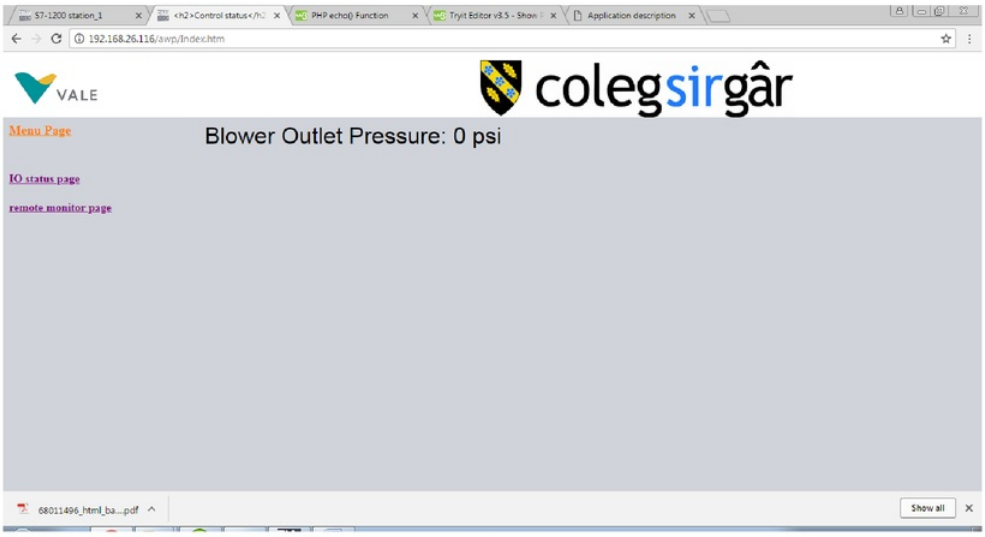


Figure 79: Web page reading at 0 psi

Figure 79 shows the webpage display at 0 psi. It is clear that the correct reading is shown here. The Druck display is shown in Figure 80 and it is set to output 0V.



Figure 80: Druck reading at 0 psi

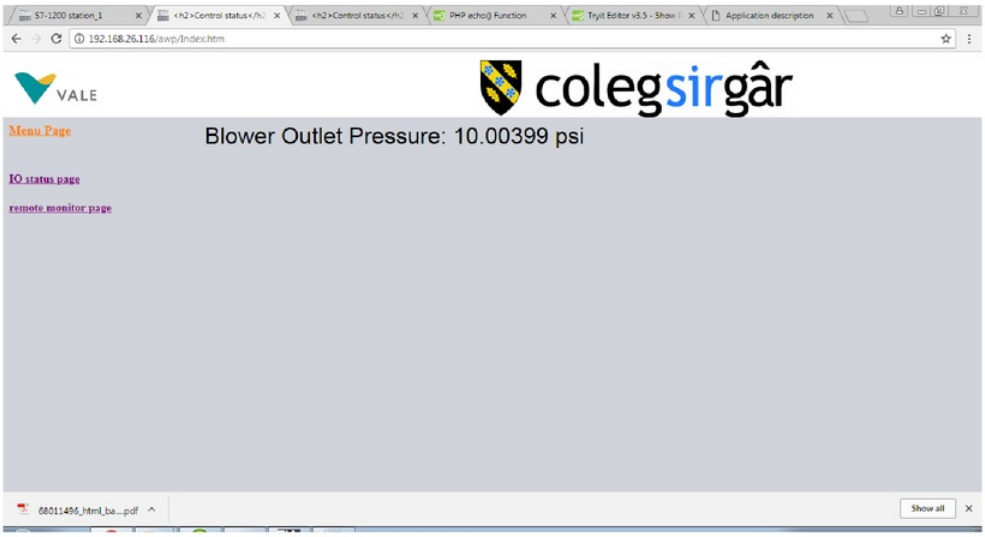


Figure 81: Web page reading at 0 psi

A second test at 10 psi is shown in Figure 81. Here, the web page clearly shows the correct figure. Again, the Druck has been shown in Figure 82, and displays an output of 10V.

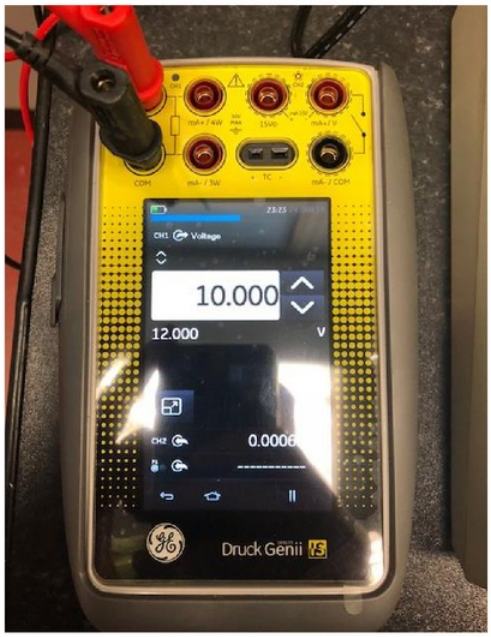


Figure 82: Druck reading at 10 psi

For the test with actual pressure, the ADC value at the top of the range was taken again. This time, a value of approximately 27600 was obtained, and this was then fed into the PLC program. There was no need to test the value with no pressure as it would be identical to the previous set of tests.

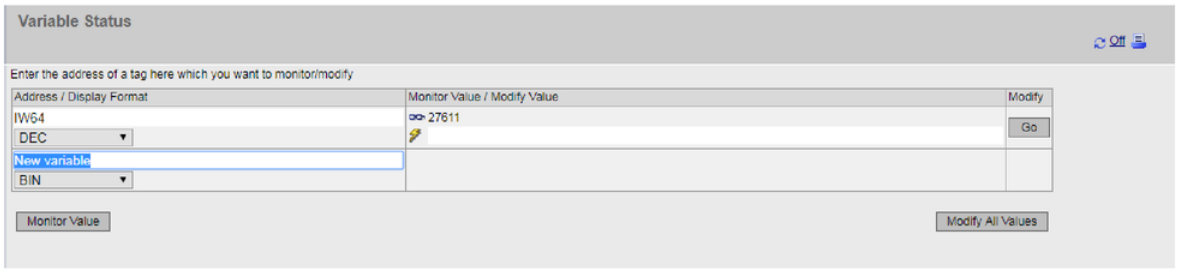


Figure 83: Analogue input at 10 psi from transmitter

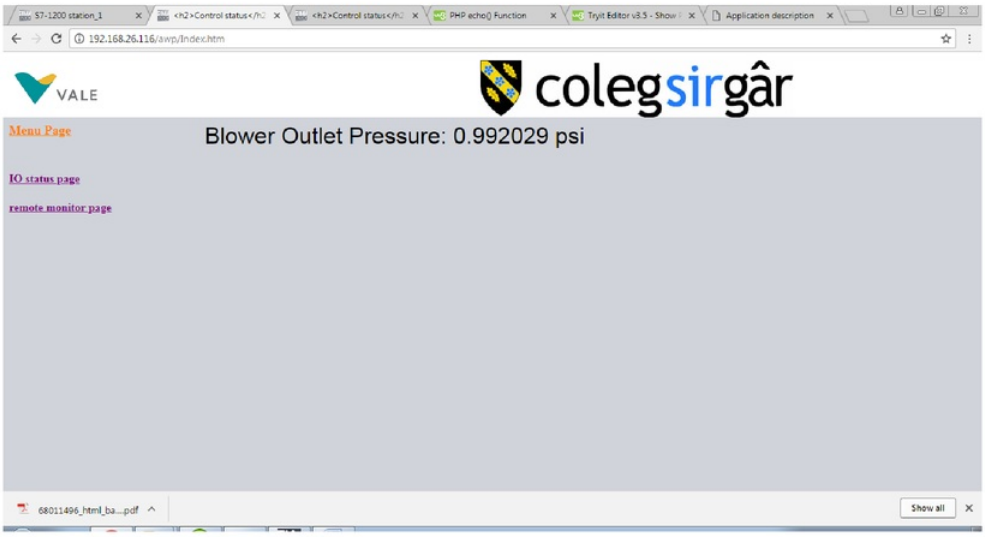


Figure 84: Web page reading at 1 psi

The first test was performed at 1 psi. Figure 84 shows the reading in the web browser, and a value of 0.99 psi is displayed. The pressure meter in Figure 85 displays a pressure of 1.003 psi.



Figure 85: Meter reading at 1 psi

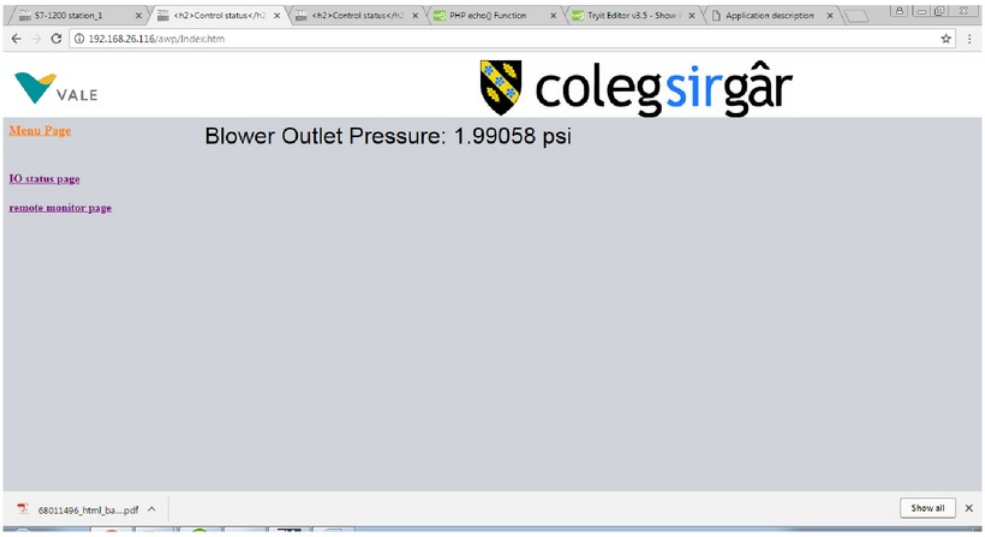


Figure 86: Web page reading at 2 psi

Figure 86 shows the result of the second test at 2 psi. A value of 1.99 psi is shown on the web page, and 1.99 psi is shown on the pressure meter in Figure 87.

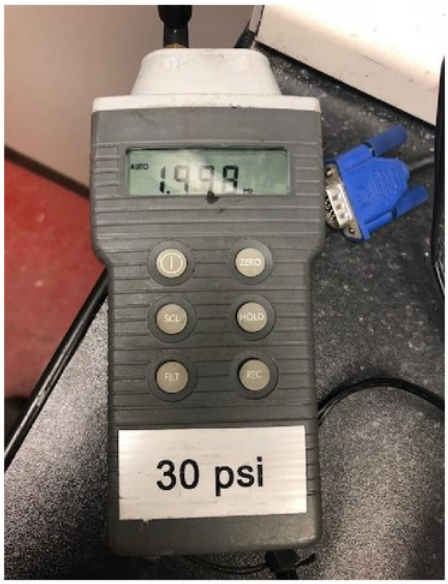


Figure 87: Meter reading at 2 psi



Figure 88: Web page reading at 3 psi

The third test was conducted at 3 psi. The web page shown in Figure 87 displayed a figure of 2.99 psi, and the pressure meter shown in Figure 89 showed 3.00 psi.



Figure 89: Meter reading at 3 psi

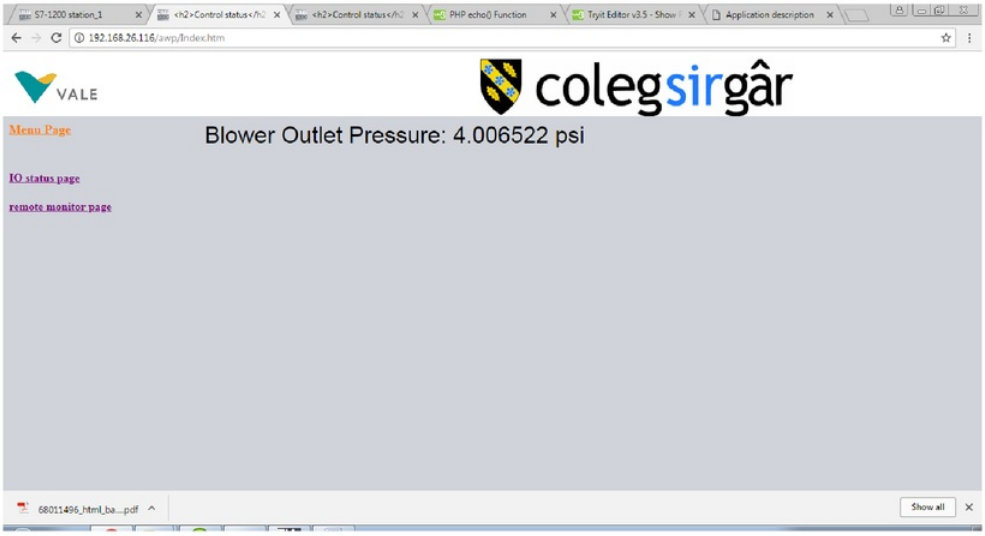


Figure 90: Web page reading at 4 psi

The next test was taken at 4 psi. The web page displays a value of 4.00 psi as shown in Figure 90. The meter is shown in Figure 91 and a figure of 4.00 psi is displayed.

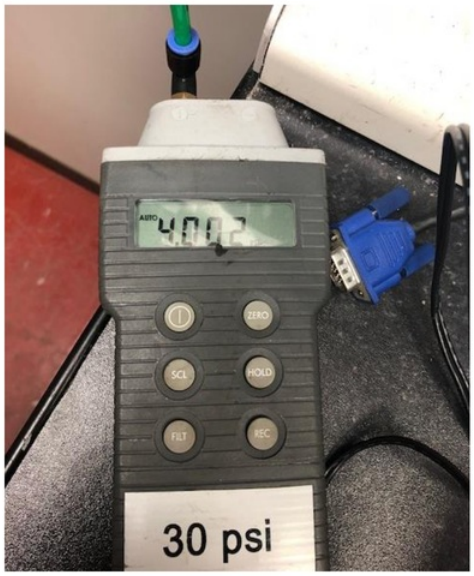


Figure 91: Meter reading at 4 psi



Figure 92: Web page reading at 5 psi

The web page result for the 5 psi test is shown in Figure 92. A value of 4.99 psi was obtained, and the meter shown in Figure 93 displays a reading of 4.99 psi.

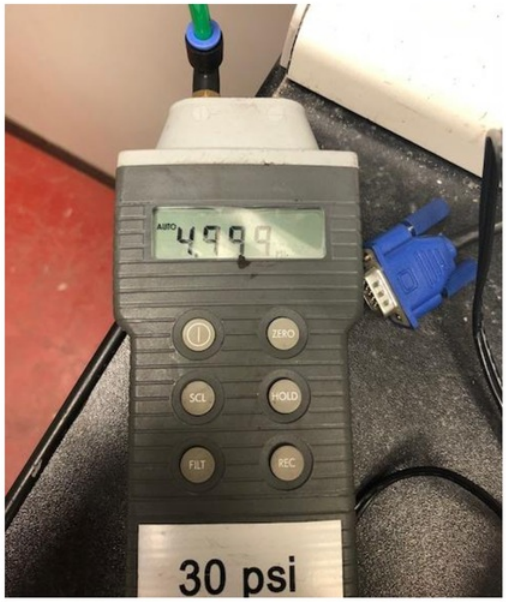


Figure 93: Meter reading at 5 psi

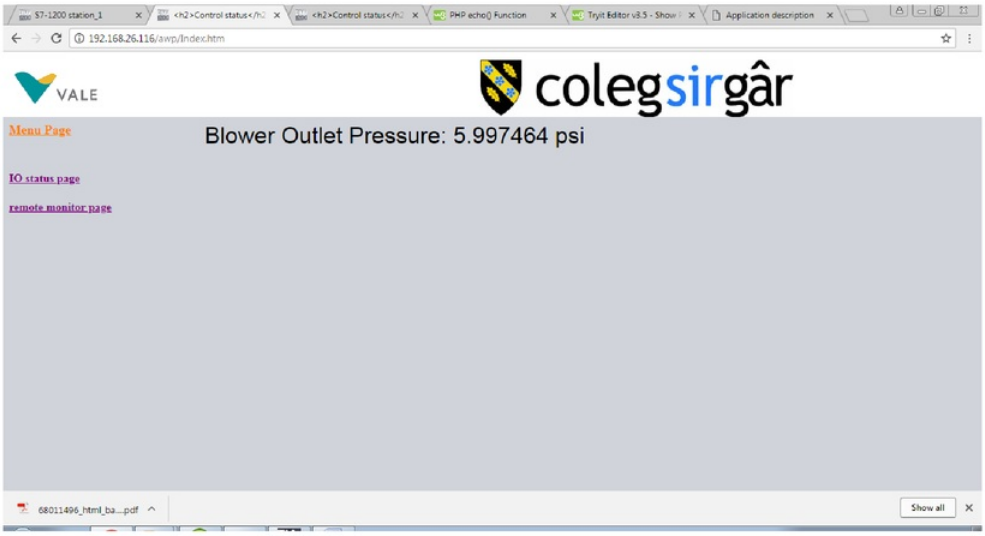


Figure 94: Web page reading at 6 psi

Test six took place at 6 psi. The web page displayed a value of 5.99 psi as shown in Figure 94, and the meter displayed 5.99 psi as shown in Figure 95.



Figure 95: Meter reading at 6 psi



Figure 96: Web page reading at 7 psi

The seventh test was carried out at 7 psi. The web page shown in Figure 96 displays a value of 6.99 psi. The meter shown in Figure 97 displays a value of 6.99 psi.

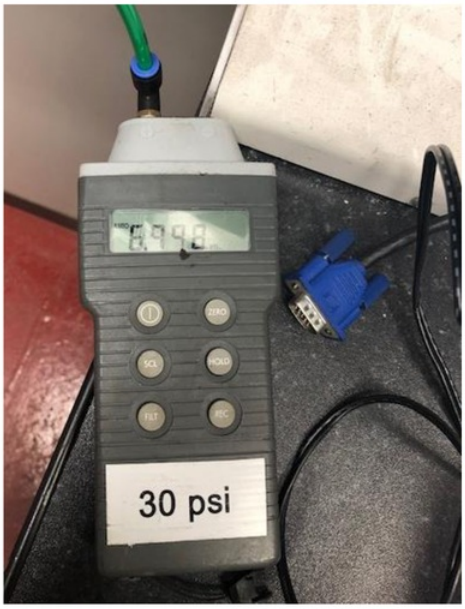


Figure 97: Meter reading at 7 psi

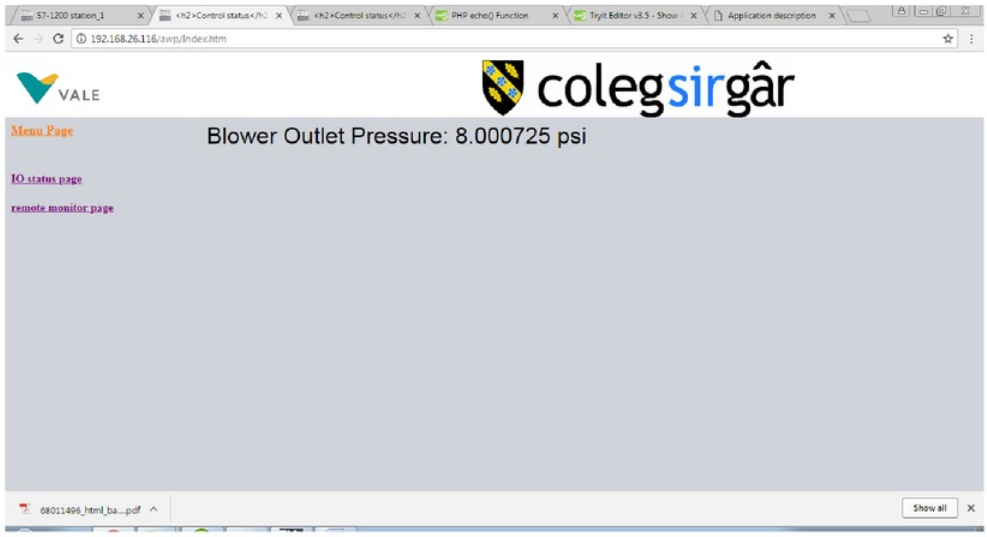


Figure 99: Web page reading at 8 psi

Figure 99 shows the web page reading for the 8 psi test. A value of 8.00 psi was obtained, and the meter shown in Figure 98 displays a value of 8.00 psi.

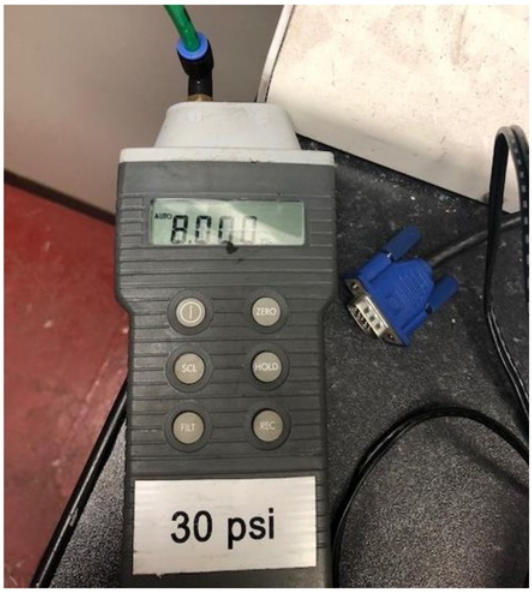


Figure 98: Meter reading at 8 psi

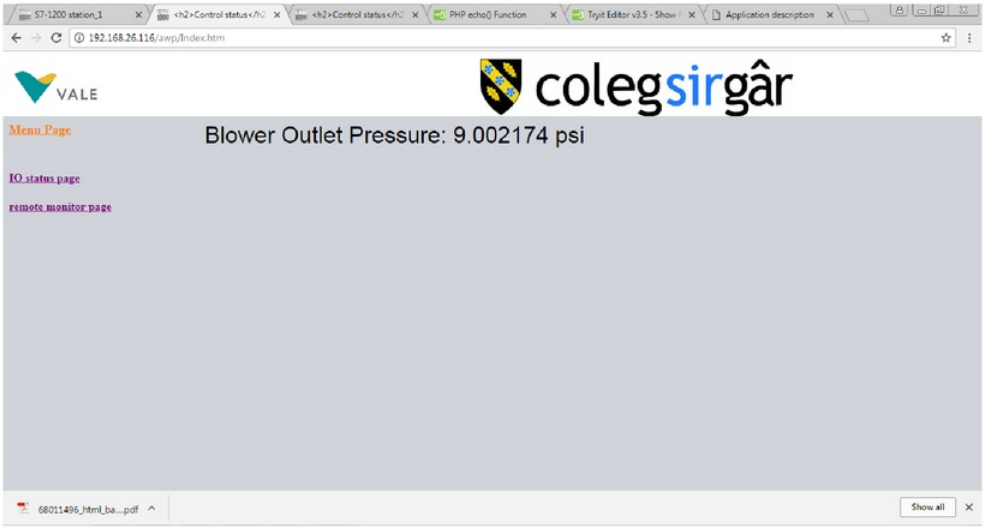


Figure 100: Web page reading at 9 psi

The web page for the 9 psi test is shown in Figure 100. A value of 9.00 psi was obtained, with the pressure meter in Figure 101 displaying 9.00 psi.

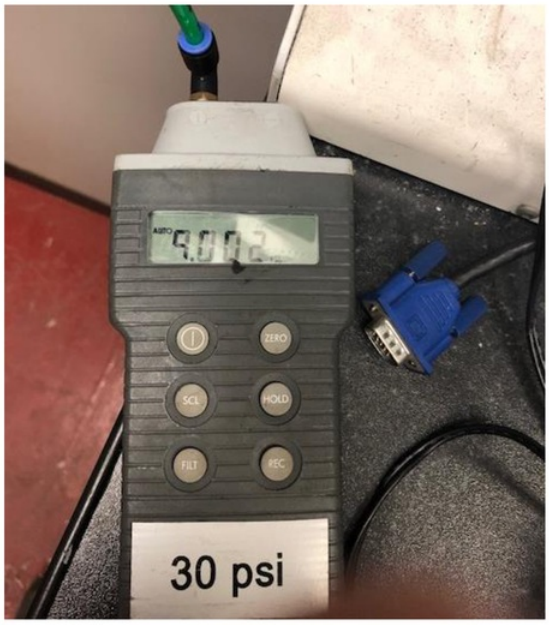


Figure 101: meter reading at 9 psi

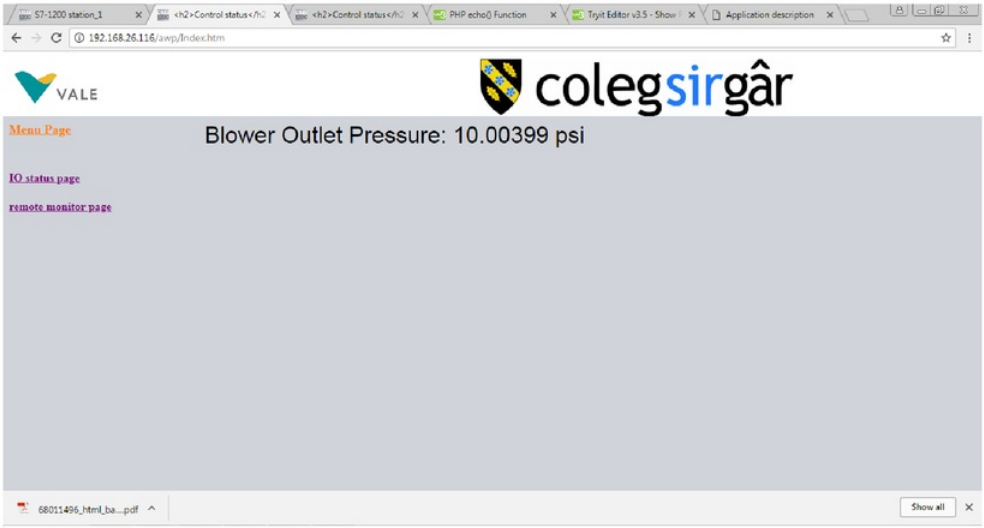


Figure 102: Web page reading at 10 psi

The final test was taken at 10 psi. Figure 102 shows the web page reading, which has a value of 10.00 psi. The meter is shown in Figure 103, and has a reading of 10.00 psi.



Figure 103: Meter reading at 10 psi

Table 6: Pressure test results

Test no.	Web page value (psi)	Meter value (psi)	Web page error(%)
1	0.99	1.00	1
2	1.99	1.99	0.5
3	2.99	3.00	0.333333333
4	4.00	4.00	0
5	4.99	4.99	0.2
6	5.99	5.99	0.166666667
7	6.99	6.99	0.142857143
8	8.00	8.00	0
9	9.00	9.00	0
10	10.00	10.00	0

Table 6 shows the test results from the pressure testing. It can clearly be seen that for test, there is an error of less than 1%. This is proof that the PLC is accurately reading the pressure, and it is being conditioned properly.

This test was successful in demonstrating that a web page would be a suitable means for conveying the system pressure. There is only one pressure shown, but is would be possible to display multiple reading with more analogue input cards.

Because the error is so small, this is an accurate measure of the pressure. This would allow an engineer or technician to make informed judgments on the system status. It also conforms to the specification set out earlier in the report.

7.1.4 STA trip testing

The final series of tests were made in order to show the STA trip. This would prove that the circuit would trip at the correct pressure. To do this, the system was pumped to just below 5.5 psi as shown in Figure 104. The meter displays a reading of 5.494 psi, and the STA displays a reading of 12.796mA as shown in Figure 105. This is slightly below the trip value of 12.80mA



Figure 104: Pressure below trip point



Figure 105: STA active

Once the pressure goes above 5.5 psi, and the STA displays a value above 12.80mA, the system will trip. Figure 106 shows the STA after tripping. The reading displayed is 12.808 mA, and the LED for trip 1 has turned red to indicate a trip.



Figure 106: STA tripped

When the pressure was taking beyond 10 psi, a fault would occur on the STA. The display will show an error stating it is out of range as shown in Figure 107.

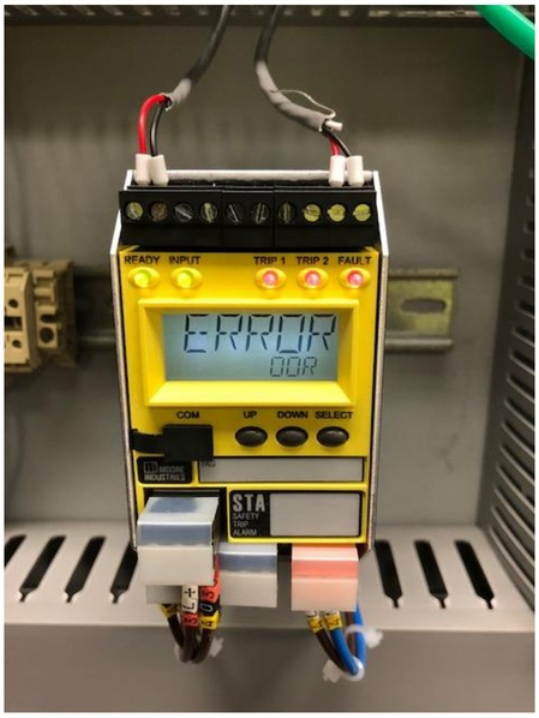


Figure 107: Out of range fault

7.2 Evaluation of Specification

The project requirements are shown in Table 7. A short discussion has been made to demonstrate how each specification has been met in the project. A result has been added to state whether the specification has [assed or failed.

Table 7: Project requirements

Customer Requirements	Discussion	Result
1. Pressure to be continuously monitored	Presure is continuously monitored by STA and PLC	Pass
2. Trip to occur at 5.5 psi	Trip set at 5.5psio, which corresponds to 12.80 mA in the STA	Pass
3. Must conform to the following regulations:		
a. DSEAR	Pressure transmitter rated for zone it is in	Pass
b. IEC 61511 and 61508 functional safety regulations	SIL assessment made, and design complies with that level	Pass
c. Low voltage directive	all voltages used at 24V	Pass
4. Design must conform to SIL rating, to encompass the following:		
a. Hardware Fault Tolerance	Assessment made on HFT	Pass
b. Safe Failure Fraction	Assesment made on SFF	Pass
5. Must not exceed budget of £15,000	Total spending amounts to approximately £9,286.96. This price includes the PLC and its associated peripherals, the four STAs and the four transmitters. This is within budget.	Pass
6. Accuracy of 1% to be achieved across the full range	Accuracy received during testing	Pass
7. Trip signal supplied by volt-free contact at 24VDC	Relay output on STA supplies this signal	Pass
Added Requirements	**Discussion**	**Result**
1. Provide local and remote monitoring	Local monitoring provided by HMI, and remote monitoring provided by web server	Pass
2. User interface to display blower outlet pressure and trip alarms	Alarms and outlet pressure displayed in the interfaces	Pass
3. Basic blower control to be implemented	Not implemented due to time constraints, will be recommended in conclusion	Failed
4. System to communicate via Local Area Network (LAN)	LAN established between PLC and laptop. Communication took place of TCP/IP	Pass
5. Web server must be implemented to allow information to be displayed remotely	Web server implemented	Pass
6. HMI must be used for local display	HMI used	Pass

Table 8 shows the technical specifications of the project. Again, a discussion has been had and the results have been shown.

Table 8: Technical specifications

Technical Specifications	Discussion	Result
1. All equipment installed must work at 24VDC	All equipment works at 24VDC	Pass
2. Foxboro IGP10 pressure transmitter to be used	This pressure transmitter used in circuit	Pass
3. Pressure transmitter must be calibrated to provide 12.80mA output at 5.5psi	Calibration carried out, and specified current provided at 5.5psi	Pass
4. Pressure transmitter to provide analogue signal to the STA, and STA Aout to provide signal to PLC	STA receives 4-20mA signal from the transmitter. STA will then output 0-10V to the PLC	Pass
5. Correct wire colouring and numbering scheme to be followed	Wire colour and numbering scheme followed	Pass
6. STA output relays to be configured as a redundant pair	Not implemented on prototype, but will be implemented on site	Pass
7. All equipment used must have a CE rating to show conformity to European regulations	All equipment is CE marked	Pass
8. Conform to cyber security guidelines to prevent system from being compromised	Cyber security guidelines followed	Pass
9. Ensure all drawings are properly updated in the system	Drawings handed over to appropriate personnel to update the system	Pass
10. 12 digital inputs required	PLC provides an adequate number of IO	Pass
a. High alarm for each blower	High alarm present on web page	Pass
b. High-high alarm for each blower	High-High alarm present on web page	Pass
c. Status of each blower	Blower status present on web page	Pass
11. 4 analogue inputs required to show blower pressure	Only one pressure tested. However; PLC is expandable to 4 analogue inputs	Pass
12. Network connection required	Netwrok connection available on PLC	Pass

Finally, Table 9 shows the environmental and safety specifications.

Table 9: Environmental and safety specification

Environmental Specification	**Discussion**	**Result**
1. Ensure that all waste is properly recycled	All waste disposed of in the appropriate refuse area	Pass
2. Ensure that any effluent is directed to the proper processing facilities	All effluent directed to the proper facilities	Pass
3. Ensure any spills are properly managed	Spill management procedure discussed in report	Pass
Safety Specification	**Discussion**	**Result**
1. Ensure that all work procedures conform to the Health and Safety at Work Act 1974	All work carried out on site must conform to HaSaWa 1974 by law	Pass
2. Ensure correct PPE is provided to the technicians installing the project	PPE is mandatory on site for all personnel. This is enforced by the Site safety representative and failure to abide to the rules will result in disciplinary action	Pass
3. Ensure the correct isolation procedures are followed in order to prevent electrocution and gas leaks when implementing the new transmitters	All engineers trained in the correct isolation procedures.	Pass
4. Ensure risk assessment is carried out for the work being undertaken	Risk assessment provided in appendix	Pass

What was the total cost and how does your reader know that your project was within budget?

8. Conclusions and Recommendations

In conclusion, the project had been successful in developing a solution, and the functional tests had proven the correct operation. Design choices had been backed by extensive research, as well as regulations surrounding safety. The focus on a safe workplace has become critical nowadays, and the consequences of poor safety management can be dire for the employer. Large fines and imprisonment are at the extreme end of the spectrum, but fines that are more moderate can leave a company in financial trouble. This is without mention of the emotional impact brought ton to the victim and their families due to an incident.

This report covers elements of the functional safety regulations, which are vital in preventing incidents from happening through careful consideration of the design. This project was only required to meet a SIL 1 rating, which is a low level. For higher ratings, the design process becomes increasingly more involved, and the cost of the project will increase. This is worth considering when implementing a safety mechanism, as well as for project planning.

It is also important to discuss the sustainability and environmental impact of this project. With increasing focus on these matters, it is important that good environmental practice is followed at all times, and recyclable materials are used.

In terms of the communications, the web server built into the Siemens PLC was a satisfactory solution. For the tests that took place on the prototype, the network only consisted of the PLC and a single laptop, but if it had been connected to the LAN, it would be possible to access the server from across the globe. The HMI also provided a means to observe what the status of the system was.

On reflection, the implementation of the project had been successful. There had been no major time or budgetary constraints, which led to an easy installation of the prototype. Unfortunately, it was not possible to install the equipment in the plant before the shutdown. Doing so would have meant having to shut down part of the process, and this would affect company profits.

The prototype that was built allowed for full functional testing to be conducted. This meant that all aspects of the specification could be met, and design to be trialed before being installed. The test results clearly demonstrate the effectiveness of this prototype, and integration of the design into the existing system would be a straightforward task. It was made sure that enough tests were performed to encompass every aspect of the specification.

There have been many concepts introduced in this report. Through research, a great deal has been learned about the operation of TCP/IP communications, as well as the HTML language

used to program them. An important area covered by the research concerns cyber security, and the threats that are posed on process networks. Furthermore, it also forbids the use of web technology from controlling safety critical systems.

What was the budget?

Gantt chart could have been referred to and explained

In terms of budget and timing, the project was successful. The specification evaluation shows the budget is met, and the timing plan has been included in the appendix. The invoice for the pressure transmitter has also been included in the appendix.

The recommendations for the future of this project would first be to incorporate complex control to the system. As stated in the research of the existing system, there is a bypass valve on the outlets of the hydrogen blowers. It is a hand-cranked system, but it would be possible to replace the existing valve with an electronic one, and set up a control loop to open and close it.

To do this, another pressure transmitter would be required on the outlet. The reason for this is due to the failure modes of the system. If a single transmitter were used for a trip and control function, the trip would cease to engage at the required pressure, and the demand for the valve would continue to increase. This could lead to a catastrophic event.

If a control loop were to be implemented, Proportional, Integral and Derivative (PID) control would likely be used. This would allow the loop to be tuned in order to achieve the most stable process reaction curve. Using software such as the Simulink package in Matlab, the system could be modeled in order to experiment without affecting the real life process.

The second recommendation for the project would be to implement JavaScript to the web pages. Whilst PHP performs to the specification, it has the downfall of running on the server. In order to poll the data, it is necessary to refresh the web page continually. This brings on the issue of a flickering screen, which can be annoying and unprofessional. JavaScript runs on the client side, and only the desired elements will update, leaving the remainder of the web page intact.

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Appendix

1. Risk assessment

VALE

Clydach Refinery Occupational Risk Assessment Record Form

SAFE PRODUCTION

RAP06/ WI01/SF04 (v4) Nov 2015

Department / Location:	**HR / Training - Electrical Installation**											
Description of Subject / job / task to be assessed:												
Reference No:												
Version No:		**Task No:**										
Date of this assessment:		**ORA Team Leader:**				**ORA Team Members:**						
Next scheduled review:		**Approved By:**										

Likelihood / Impact Severity	Rare	Unlikely	Occasional	Likely	Frequent	Risk Levels
Catastrophic (E)						
Critical (D)						
Severe (C)						73 - 160
Moderate (B)						35 - 72
Minor (A)						<35

	Activity / Step / Area / component	Hazard	Hazardous Event and Impact	Potential Risk (assuming no control's in place)			Existing Control Measures	Residual Risk (Taking into account existing controls and their effectiveness)			Further Actions
No:	Subject broken down into manageable components, sections or steps	What has the potential to cause harm?	How could it go wrong? What would be the likely impacts?	Impact	Like'd	Risk	Describe the existing control measures relevant to each hazard	Impact	Like'd	Risk	Number and transfer to Action tab
Consider if there is a risk of exposure to asbestos (mandatory field)											
	LINK TO ASBESTOS REGISTERS										
						0				0	
Consider the risk of the environmental impact of the job (mandatory field)											
E1	Eqipment installation	Emission to Land	Uncontrolled disposal of waste materials	4	3	12	Technicians to follow site protocol for waste disposal	4	2	8	
Consider the manual handling risks associated with the task (Mandatory Field)											
M1	Eqipment installation	Load	Muscular Problem, Back Problem	4	5	20	Ensure personnel present have undergone manual handling training and adhere to good manual handling practices/procedures.	4	2	8	
M2	Eqipment installation	Stretching	Muscular Problem, Back Problem	4	5	20	No over stretching, ensure enough personnel present when installing supply cable.	4	2	8	
M3	Eqipment installation	Sharp Edges	Cuts to Hands	4	5	20	Ensure all brackets are filed smoothly and gloves worn when installing cable.	4	2	8	
Consider the work at height risks associated with the task (Mandatory Field) NB: EMERGENCY ARRANGEMENTS MUST BE IN PLACE BEFOR WORK AT HEIGHT COMENCES											
H1	Eqipment installation	Falling from height whilst working off a step ladder.	Falling could cause injuries raging from bruising through to broken bones.	16	5	80	Ladder to be checked for defects prior to use and to be footed at all times.	16	2	32	
						0				0	
						0				0	
						0				0	
Consider the risk of exposure to hazardous substances (mandatory field) - Please inform Safety & Hygiene Coordinator of all tasks with signif cant hazardous substance r sks											
	Eqipment installation	Exposure to gases	Breathing of gases on site could cause a range of symptoms from mild irritation through to asphyxiation	16	2	32	Atmospheric monitoring is in place in areas of increased risk. All staff to wear personal CO monitors on site (TBA at site kick off meeting) and report to Plant team leaders before work commences. Any work which could result in the release of harmfull gases must be controlled by PTW.	16	2	32	
S1	Eqipment installation	Exposure to chemicals	Can cause issues with skin tissue, from irritations and rashes through to severe burns	16	5	80	All chemicals on site must have the correct COSHH assessment. Substances must be stored in correct labelled containers and kept in the designated location.The correct PPE, as directed by COSHH assessment, must be used when working with any chemicals.	16	2	32	
	Eqipment installation	Road Traffic	Contact with: Refinery Pedestrians, Other Road Traffic or Bildings/Structures/ Equipment	8	5	40	Compliance with: Refinery Access Control Procedures, Refinery traffic control measures, Designated access route to work area, Refinery speed limits and road signs. Approved parking locations Work area to be coned off	8	2	16	

Activity / Step / Area / component		Hazard	Hazardous Event and Impact	Potential Risk (assuming no controls in place)			Existing Control Measures	Residual Risk (Taking into account existing controls and their effectiveness)			Further Actions
No:	Subject broken down into manageable components, sections or steps	What has the potential to cause harm?	How could it go wrong? What would be the likely impacts?	Impact	Like'd	Risk	Describe the existing control measures relevant to each hazard	Impact	Like'd	Risk	Number and transfer to Action tab
	Eqipment installation	Hand Tools	Cuts and bruising to hands. Possible broken fingers.	4	5	20	All tools are to be used as the manufacturer intended, shall be in good condition and visually inspected before use. Personnel have served relevant apprenticeships.	4	2	8	
	Eqipment installation	Obstacles and trip hazards	Falls and impact injuries	4	5	20	SLAM, maintain situational awareness and good housekeeping to be kept at all times	4	2	8	
	Eqipment installation	Hazardous area working.	Providing energy source which could interact with dangerous substances or explosive atmospheres, causing explosions.	16	5	80	Where applicable all personnel have been COMPEX trained. Area to be gas tested before opening boxes. Tools and equipment to be ATEX rated. All installations are to ATEX standard, have documented Risk Assessments and are maintained as per scheduled.	16	2	32	
	Eqipment installation	Noise	Temporary or permenant damage to hearing	8	5	40	Noise surveys regularly conducted. Hearing protection is mandatory in some areas. These areas are clearly marked.	8	2	16	
	Eqipment installation	Pedestrians passing work area	Items falling on heads	8	5	40	Work area to be coned off	8	2	16	
	Eqipment installation	Falling objects	Falling object contact with personnel	8	5	40	PPE - Hard Hat Work area to be coned off	8	2	16	
	Eqipment installation	Moving Parts	Body parts could get caught in the blower drive belt	16	5	80	Ensure guarding remains in place when blower is running	16	2	32	
	Eqipment installation	Integrity of supports (permanent, temporary, lifting, etc.)	Brackets used to secure pressure transmitters could fail	8	5	40	Ensure hard hats are worn and brackets are securely fastened.	8	2	16	
	Eqipment installation	Exposure to the elements	Severe conditions could lead to illness	8	5	40	Ensure appropriate clothing is worn for the work conditions	8	2	16	
						0				0	
						40				16	
	Isolation of Plant equipment	Unintentional Production plant equipment isolation	Loss of production	4	2	8	Co-ordination with production staff	4	2	8	
						0				0	

NOTE - This risk assessment is a dynamic document based on how the work is envisaged at the time of production. Things can change and this ORA should be reviewed in light of any changes.
It is important that all stakeholders cooperate and work with on-going risk management in mind. Please use our SafeProduction tools (such as SLAM, interactive discussion and coaching), our Behavioural Standards and maintain situational awareness to identify changes and unforeseen hazards and risks, to challenge unsafe practices and to stop work and report issues to ensure continued risk control.

2. Foxboro policy document

Foxboro.
by Schneider Electric

B0799DD

Environmental Compliance Documentation for Foxboro Pressure Products

Product Disposal and Recycling

International concern about environmental pollution resulting from improper disposal of products and materials at the end of their useful life has resulted in an increase in legislation to control the methods and procedures used to handle waste electrical and electronic equipment. While the regulatory status in some regions of the world has progressed to the point where formal legislation is already in effect, many other regions are in the process of creating similar legislation or adopting legislation already in existence in other areas. The result in the years ahead will be more stringent control over disposal of products and recycling of their components once they are withdrawn from use.

Since regulations governing the disposal of your instrument and accessories may vary depending upon your geographic location, the following guidelines are provided to assist you in identifying the options available to you once the decision has been made to replace or dispose of this product:

Since regulations governing the disposal of your instrument and accessories may vary depending upon your geographic location, the following guidelines are provided to assist you in identifying the options available to you once the decision has been made to replace or dispose of this product:

- Continue following your company's established product disposal and recycling procedures, particularly if they already comply with government and industry regulations. This document contains information on certain substances that are contained in the product that should be given appropriate consideration during product disposal or recycling. You can use this information yourself, or forward it to assist your external contractor who may handle disposal and recycling of your products per your current procedures.
- Contact your local government agency responsible for waste collection and disposal. They can identify procedures and restrictions in effect to ensure proper disposal, and available locations where products can be sent.
- Contact the supplier who sold you the product. Whether this is Schneider Electric itself, or one of its authorized representatives, they can assist you in evaluating the available options. In some cases, the supplier may be legally obligated to accept the product from you and arrange for proper disposal or recycling with no further involvement on your part.
- Contact Schneider Electric Global Customer Support:

  Inside U.S.: 1-866-746-6477
  Outside U.S.: 1-508-549-2424
  Website: http://support.ips.invensys.com.

Cutomer Support personnel can assist you in evaluating your options, and based on your decision, will provide you with instructions and the appropriate classification for returning the product directly to Schneider Electric for disposal and recycling.

3. Vale wiring colours

VALE INCO

EQUIPMENT – PANEL WIRE COLOUR CODING

The following notations and table are representative of the wire colour coding adopted as a site standard and in accordance with the 16th &17th Edition wiring regulation BS EN 7671.

The following notes are intended to clarify the table and differentiate between Power and Control colour coding. Table 01 applies to all control panels and equipment manufactured on and off site. Any deviation from this specification MUST be submitted and approved by Vale Inco prior to work commencing.

Colour codes referred to in the notes are those applied in Table 01.

Note 1. A.C. Power .

Three phase colours as per BS Standard.

Both 110Vac & 240Vac are of the same colour coding.

Where control equipment is powered from the secondary side of a transformer or PSU, then the wire colour coding between the transformer/PSU and the first protective device (MCB/Fuse) shall retain the power colour coding (Brown/Blue).

Control circuits after the protective device shall conform to the control colour coding indicated in the Table 01.

Where a 415Vac phase is used to power a secondary power source (Tx, PSU etc) then the 3 Phase colour coding will be retained on the primary side of the equipment.

Note 2. D.C. Power

Where the power source is on the secondary side of the Transformer/Psu or circuit breaker then the colour code will change to reflect the type of circuit being supplied :-

Control	110Vac	Red.
	Neutral	Blue
	+24VDC	Violet
	0VDC	Blue
Analogue	As per Table 01	
E/Stop	Yellow	
External	Where a circuit is powered externally to the panel and therefore the conductor may still be LIVE when the panel isolator is OFF.	

VALE INCO

TABLE 01 PANEL WIRING COLOUR CODES

Power

VOLTAGE:	COLOUR:	ID MARK
415Vac Phase 1	BROWN	L1
415Vac Phase 2	BLACK	L2
415Vac Phase 3	GREY	L3
110 Volts AC - Live	BROWN	L
110 Volts AC - Neutral	BLUE	N
240 Volts AC - Live	BROWN	L
240 Volts AC - Neutral	BLUE	N
Earth	GRN / YELL	E

Earthed DC

Any DC Voltage – Positive (+)	BROWN	L+
0VDC (Earthed)	BLUE	M
Any DC Voltage – Negative (-)	GREY	L-

UNEARTHED DC

Any DC Voltage – Positive (+)	BROWN	L+
0VDC – Negative (-) (NOT Earthed)	GREY	L-

Control

110VAC	RED	Ferrule ID
24VDC	VIOLET	Ferrule ID
Analogue	PINK +	Ferrule ID
Analogue	GREY -	Ferrule ID
Shutdown	TBA	
E-Stop	YELLOW	Ferrule ID
Contact Input (Internal voltage source)	WHITE	Ferrule ID ?
Contact Input (External voltage source)	ORANGE	Ferrule ID

NOTE : Control circuit neutral or 0V (M) conductor shall be BLUE

4. STA exida document



exida

The manufacturer may use the mark:

exida • CERTIFIED • IEC 61508 • SIL 3 CAPABLE •

Revision 1.4 October 30, 2017
Surveillance Audit Due
November 1, 2018

IAF ANSI

ANSI Accredited Program
ISO/IEC 17065
PRODUCT CERTIFICATION BODY
#1004

Certificate / Certificat
Zertifikat / 合格証

MII 1103026 C001

exida hereby confirms that the:

STA Safety Trip Alarm Relay Output

Moore Industries-International, Inc.
North Hills, CA - USA

Has been assessed per the relevant requirements of:

IEC 61508 : 2010 Parts 1-7

and meets requirements providing a level of integrity to:

Systematic Capability: SC 3 (SIL 3 Capable)

Random Capability: Type B Element

PFD_{AVG} and Architecture Constraints must be verified for each application

Safety Function:
The Safety Trip Alarm will act as a logic solver and perform a preconfigured algorithm to operate a relay output based on either a RTD, thermocouple, millivolt source, resistance or potentiometer, current, or voltage input.

Application Restrictions:
The unit must be properly designed into a Safety Instrumented Function per the Safety Manual requirements.

exida Certification

Evaluating Assessor

Certifying Assessor

Page 1 of 2

STA Safety Trip Alarm Relay Output

Certificate / Certificat / Zertifikat / 合格証

MII 1103026 C001

Systematic Capability: SC 3 (SIL 3 Capable)

Random Capability: Type B Element

PFD_{AVG} and Architecture Constraints must be verified for each application

Systematic Capability:

The product has met manufacturer design process requirements of Safety Integrity Level (SIL) 3. These are intended to achieve sufficient integrity against systematic errors of design by the manufacturer.

A Safety Instrumented Function (SIF) designed with this product must not be used at a SIL level higher than stated.

Random Capability:

The SIL limit imposed by the Architectural Constraints must be met for each element. This device meets *exida* criteria for Route 2_H.

IEC 61508 Failure Rates in FIT*

Element	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF
STA/TPRG/3PRG/24DC/-AO [DIN] Relay Output	0	669.8	174.2	89.5	90.40%
STA/TPRG/3PRG/24DC [DIN] Relay Output	0	663.7	167.1	85.6	90.70%
STA/TPRG/3PRG/UAC/-AO [DIN] Relay Output	0	758.6	174.5	89.6	91.20%
STA/TPRG/3PRG/UAC [DIN] Relay Output	0	752.5	167.4	85.8	91.50%
STA/TPRG/3PRG/U/-AO [DIN] Relay Output	0	708.4	214.2	92.3	90.90%
STA/TPRG/3PRG/U [DIN] Relay Output	0	703.1	207.2	90.4	91.00%
STA/HLPRG/3PRG/24DC/-AO [DIN] Relay Output	0	679.8	175.8	84.9	91.00%
STA/HLPRG/3PRG/24DC [DIN] Relay Output	0	673.7	168.7	81	91.20%
STA/HLPRG/3PRG/UAC/-AO [DIN] Relay Output	0	776.1	176.1	85.2	91.80%
STA/HLPRG/3PRG/UAC [DIN] Relay Output	0	770	169	81.2	92.00%
STA/HLPRG/3PRG/U/-AO [DIN] Relay Output	0	719.3	215.1	88.2	91.40%
STA/HLPRG/3PRG/U [DIN] Relay Output	0	714	208.1	86.2	91.40%

* FIT = 1 failure / 10^9 hours

SIL Verification:

The Safety Integrity Level (SIL) of an entire Safety Instrumented Function (SIF) must be verified via a calculation of PFD_{AVG} considering redundant architectures, proof test interval, proof test effectiveness, any automatic diagnostics, average repair time and the specific failure rates of all products included in the SIF. Each subsystem must be checked to assure compliance with minimum hardware fault tolerance (HFT) requirements.

The following documents are a mandatory part of certification:

Assessment Report: MII 11/03-026 R001 V1 R6

Safety Manual: 225-748-00J or 225-748-01L

80 N Main St
Sellersville, PA 18960

5. Transmitter invoice

Foxboro.
by Schneider Electric

To:	Darren Paddison	Date:	22/01/2018
Company:	Vale Europe Limited		
Tel:	01792 841236		
E-Mail:	Darren.Paddison@vale.com		
From:	Michael Davis	Your Reference:	E-Mail 22nd January 18
Group:	Field Measurement & Control	**Proposal No.:**	**QUK-0118-10037**
Copies:	Jonathan Cowley	Pages including cover sheet:	5

Thank you for the above referenced enquiry for which we now have pleasure in submitting our attached proposal **QUK-0118-10037** for your consideration.

This proposal supersedes any previous offer that has been made against our proposal reference shown above.

To place an order for the items shown in this proposal please contact our sales team at the address shown below quoting our proposal number shown above.

Any pictures shown in this proposal are for illustration purposes only and may differ to the product supplied.

We trust that the attached proposal meets with your approval. However if you require any further information please do not hesitate to contact me at the address shown below or alternatively our Account Manager Mr. Jonathan Cowley on 07795 496517.

Yours sincerely,

Michael Davis

Michael Davis
EMEA Field Devices Sales Operations Manager
Schneider Electric Systems UK Limited
E-mail: mick.davis@schneider-electric.com
Phone: 01293 643 252 Mobile: 07917 597 068

Schneider Electric UK Limited is an ISO9001 certified company

PROPOSAL SUMMARY

Description	Total
Total Instruments Nett	£4,008.96
Documentation / Certification • CERT-S - SIL 2-TUV Certificate	Inclusive
Total Delivery DDP to UK Mainland Site	Inclusive
Packing (Foxboro Standard carton)	Inclusive
TOTAL PROPOSAL VALUE:	**£4,008.96**

Pricing: Prices quoted are NETT, exclude VAT and are in Pounds Sterling and shall remain fixed and firm for the duration of the contract.

Commercial Terms: The prices shown are based upon your acceptance of Schneider Electric Systems UK Limited Short form General Terms & Conditions of Sale of Goods and Services and License of Software (English law version - 2547Gs) – M&I Products (April 2010). A copy is included at the end of the proposal.

Payment Terms: 100% NETT cash, 30 days from date of invoice (Subject to satisfactory credit checks, where appropriate).

Delivery Terms: DDP to UK mainland site as per Inco terms 2010.

Delivery: 6 working weeks 9to be confirmed) from receipt of a firm order and all information to enable manufacturing to proceed, including all relevant drawings/documentation approved for manufacture, and a completed 'Request for End User Information' form.

Country of Origin: United States of America

Proposal Validity: 30 Days from the date of our proposal.

Export License: Any order received as a result of this proposal, will be subject to the granting of any U.K. and U.S.A. Export Licenses that may be required. Diversion contrary to U.K. and U.S.A law is prohibited.

It is further understood that the goods will not be used in Nuclear related industries or in the production of Chemical or Biological Warfare substances.

Any resultant PO will require a completed 'Request for End User Information' form to be provided with the PO (copy attached).

Nuclear End Use: If goods are for civil Nuclear Use at a site within the United Kingdom, then supply will be subject to Schneider's special condition Nuclear Liability Protection reference BSF 7.2.1.6.Schneider Electric Nuclear Liability Clause UK Apr 10, copy available on request.

Inspection: Available at extra cost, contact Schneider Electric for more details.

Warranty: 5 Years for I/A Series Pressure Products (IAP, IDP, IGP & IMV Series, excluding chemical seal(s) which are 2 years)
5 Years for RTT15 Series Temperature Transmitters
2 Years for all other Foxboro Instrumentation
1 Year for disposable pH and ORP Sensors
3 Months for Spare Parts

An optional 17 years is available for our premium performance transmitters.

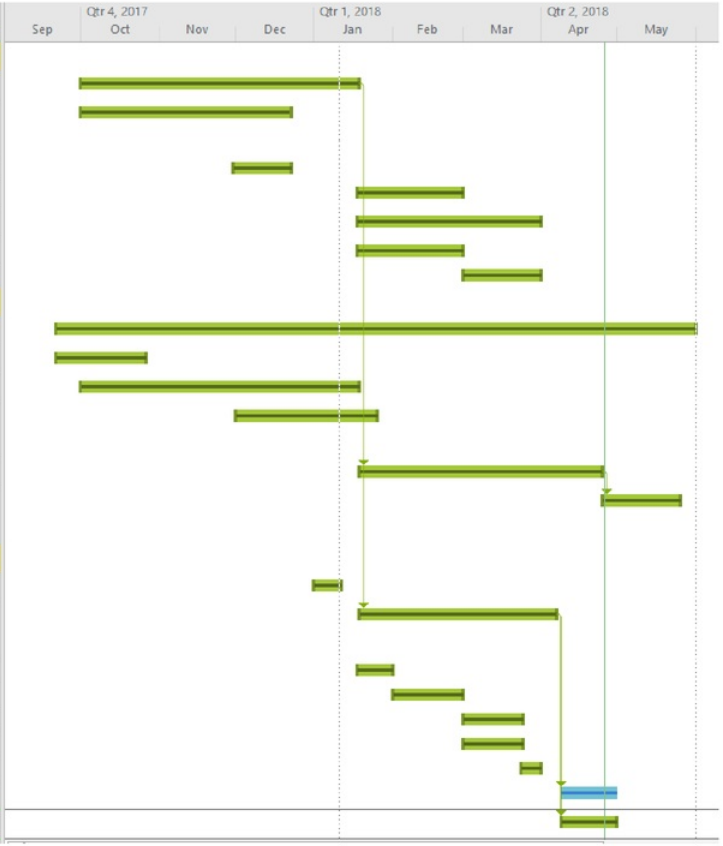
For full details of our warranty please refer to General Terms & Conditions of Sale of Goods and Services and License of Software (English law version - 2547Gs) – M&I Products dated April 2010.

6. Timing plan

You could have explained how the actual timing compared with the planned times.

GANTT CHART

	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		1. Planning				
2	✓	1.1 Project Planning	80 days	Sun 01/10/17	Thu 18/01/18	
3		1.2 Background Research	61 days	Sun 01/10/17	Fri 22/12/17	
4	✓	1.2.1 SIL rating Calculation	17 days	Thu 30/11/17	Fri 22/12/17	
5	✓	1.3 Design	30 days	Thu 18/01/18	Wed 28/02/18	
6	✓	1.4 Control Valve Investigation	53 days	Thu 18/01/18	Sat 31/03/18	
7	✓	1.4.1 Modelling System	30 days	Thu 18/01/18	Wed 28/02/18	
8	✓	1.4.2 Simulation	23 days	Thu 01/03/18	Sat 31/03/18	
9		2. Reports				
10	✓	2.1 Log Book	181 days	Thu 21/09/17	Thu 31/05/18	
11	✓	2.2 Proposal	26 days	Thu 21/09/17	Thu 26/10/17	
12	✓	2.3 Interim Report	80 days	Sun 01/10/17	Thu 18/01/18	
13	✓	2.4 Interim Presentation	40 days	Fri 01/12/17	Thu 25/01/18	
14	✓	2.5 Final Report	68 days	Fri 19/01/18	Tue 24/04/18	2
15	✓	2.6 Final Presentation	23 days	Wed 25/04/18	Fri 25/05/18	14
16		3. Implementation				
17	✓	3.1 Prototype Test	9 days	Mon 01/01/18	Thu 11/01/18	
18	✓	3.2 Design Implementation	56 days	Fri 19/01/18	Fri 06/04/18	2
19	✓	3.2.1 Gather Components	10 days	Thu 18/01/18	Wed 31/01/18	
20	✓	3.2.2 Functional Prototype Test	20 days	Thu 01/02/18	Wed 28/02/18	
21	✓	3.3.3 Install Components	18 days	Thu 01/03/18	Sat 24/03/18	
22	✓	3.3.4 Install Wiring	18 days	Thu 01/03/18	Sat 24/03/18	
23	✓	3.3.5 Test System	7 days	Sat 24/03/18	Sat 31/03/18	
24	✓	3.3 Testing	16 days	Mon 09/04/18	Mon 30/04/18	18
25	✓	3.4 Verification	16 days	Mon 09/04/18	Mon 30/04/18	18



Major Project - Final Report

GRADEMARK REPORT

FINAL GRADE

61 /100

GENERAL COMMENTS

Instructor

PAGE 1

Text Comment. UWTSD/Coleg SirGar

PAGE 2

Text Comment. An abstract of this nature should state the company in which the project was carried out, give a brief overview of the problem and should end with a clear statement of whether the project was successful or not. This abstract leaves the reader wondering. No budget mentioned.

PAGE 3

PAGE 4

Text Comment. Use of heading style 1 on the front covering gives the impression that this is a section

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

Text Comment. This section provides useful background information while setting out the aims and objectives of the project

PAGE 10

PAGE 11

PAGE 12

Text Comment. do you mean photographed?

Text Comment. of

PAGE 13

PAGE 14

Text Comment. ?

Text Comment. Good background information

PAGE 15

Text Comment. Was there a source that you could have cited your source for this drawing?

PAGE 16

Text Comment. this would have been a good place to explain Ex rating in more detail with citations

PAGE 17

Text Comment. more to say ?

PAGE 18

PAGE 19

PAGE 20

PAGE 21

PAGE 22

Text Comment. You could have combined the two systems into one block diagram with three solutions.

QM

Spelling

Spelling error

PAGE 23

PAGE 24

PAGE 25

Text Comment. You could have used a rating system to score the solutions to allow a choice to be made.

PAGE 26

PAGE 27

PAGE 28

PAGE 29

PAGE 30

Text Comment. The budget has not yet been stated.

PAGE 31

Text Comment. A good choice made. However, there appears to be a contradiction in that the Siemens PLC was rejected from system 1 on the grounds that it was not a standard item yet it was the preferred option for the monitoring part.

PAGE 32

PAGE 33

Text Comment. A good, detailed section

PAGE 34

Text Comment. SIL rating could have been mentioned here.

PAGE 35

QM

Spelling

Spelling error

PAGE 36

PAGE 37

PAGE 38

PAGE 39

PAGE 40

PAGE 41

PAGE 42

PAGE 43

PAGE 44

PAGE 45

PAGE 46

PAGE 47

Text Comment. How does this relate to your project?

PAGE 48

PAGE 49

Text Comment. The focus of this section should have been on the environmental impact of your project rather than company procedures only.

PAGE 50

Text Comment. This has no bearing on your project.

PAGE 51

Text Comment. You could have included the MoFC document in the appendix.

Text Comment. Management ?

Text Comment. was

PAGE 52

PAGE 53

Text Comment. The result is a Real which usually occupies at least 32 bits

PAGE 54

PAGE 55

Text Comment. How was it configured?

PAGE 56

Text Comment. Helpful information

PAGE 57

PAGE 58

PAGE 59

PAGE 60

PAGE 61

PAGE 62

Text Comment. incomplete sentence

PAGE 63

PAGE 64

PAGE 65

PAGE 66

Text Comment. You could have included the drawing in the report.

PAGE 67

PAGE 68

PAGE 69

PAGE 70

PAGE 71

PAGE 72

PAGE 73

Text Comment. Which drawing applies to your project?

PAGE 74

Text Comment. It would have been good to see a screenshot of the Packware software running.

PAGE 75

PAGE 76

Text Comment. It would have been useful to see the PLC and HMI connected as a complete system

PAGE 77

PAGE 78

PAGE 79

PAGE 80

PAGE 81

PAGE 82

PAGE 83

PAGE 84

PAGE 85

PAGE 86

PAGE 87

Text Comment. The PLC analogue input could have been used to test the alarm levels

PAGE 88

PAGE 89

PAGE 90

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PAGE 100

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PAGE 102

PAGE 103

PAGE 104

PAGE 105

PAGE 106

PAGE 107

PAGE 108

Text Comment. not at the same time

PAGE 109

PAGE 110

Text Comment. What was the total cost and how does your reader know that your project was within budget?

PAGE 111

PAGE 112

Text Comment. Gantt chart could have been referred to and explained

Text Comment. What was the budget?

PAGE 113

Text Comment. Comprehensive range of sources listed correctly.

PAGE 114

PAGE 115

PAGE 116

PAGE 117

PAGE 118

PAGE 119

PAGE 120

PAGE 121

PAGE 122

PAGE 123

PAGE 124

PAGE 125

PAGE 126

Text Comment. You could have explained how the actual timing compared with the planned

times.

GRADING FORM: MAJOR PROJECT 2017_18

JAMES DAVIES	**60.80**

RESEARCH (20%)

Research Informed Literature: 1. Abstract, acknowledgements, introduction and setting out of aims and objectives. (/20) 2. Background research, setting the context of the project, statement of user or customer needs. (/30) 3. Literature review, solutions considered and choice made. (/40) 4. Use of Harvard Referencing for citing and listing sources. (/10)

12.8

1. A good abstract covering most of the project. However, there is no mention of the budget or if the project was successful. Acknowledgements briefly stated and introduction clearly sets out the aims and objectives of the project. (13) 2. Very good evidence of background reading setting the project in context and providing useful information for the reader. User/customer need are not contained in this section but in the previous one. (19) 3. Good choices made for each subsystem with clear evidence of research. However, a rating system could have been used to select the final choices and the subsystems could have been combined together and treated as one system with 3 solutions. There also appears to be a discrepancy between selection of equipment (the PLC was rejected for subsystem 1 yet accepted in subsystem 2). Block diagrams of each solution a bit primitive. (24) 4. Comprehensive

range of sources consulted (particularly related to safety), cited and listed correctly. (8)

KNOWLEDGE (20%)

Knowledge & Understanding of Subject: 1. Specification, design requirements and project outcomes, time and financial constraints. (/30) 2. Test planning and procedures. (/20) 3. Formal project planning and identification of milestones. (/25) 4. Consideration of maintenance and reliability. (/25)

1. Specifications are clearly stated and detailed. Budget is mentioned and Gantt chart provided in the appendix but timing should have been mentioned in this section. (20) 2. No test planning included. (0) 3. Gantt chart provided in the appendix but no explanation or discussion of milestone or actually timing. (10) 4. Good consideration given. (20)

10

ANALYSIS (20%)

Analysis: 1. Evaluation of Implementation stage, monitoring of progress and milestone activities. (/20) 2. Testing & test results. (/30) 3. Comparison of project outcomes to specification. (/20) 4. Conclusions, recommendations and reflections. (/30)

1. Implementation stage has been evaluated briefly but no explanation given in relation to Gantt chart or milestones. (8) 2. Good evidence of testing of subsystems but they should have been combined as one system with overall testing including the website and HMI screens. No need for the amount of test results shown. (19) 3. Detailed testing table with results and comparison with specification. However, cost has not been considered. (13) 4. A good section provided in the report. (20)

12

PRACTICAL APPLICATION (20%)

Practical Application & Deployment: 1. Quality, innovation and creativity of design solution. (/20) 2. Implementation stage, working independently with limited supervision. (/30) 3. Meeting customer or user needs, fitness of solution to purpose, working within time and financial constraints. (/20) 4. Log book. (/30)

1. There is clear evidence of creativity in the design of the webserver page, PLC program and HMI screen. However, there is a lack of drawings provided for the instrument connections and no overall diagram of the system. (16) 2. Both subsystems have been implemented with limited supervision but should have been connected together as one system. (18) 3. Solution meets the customer needs as a prototype but is yet to be installed on plant. The monitoring aspect has been demonstrated but it is unclear how this would be implemented on plant as the manufacturer of the PLC/HMI is not a standard company item. Total cost has not been stated and it is unclear what the actual timing was. (12) 4. Good evidence presented of development of the project (18)

12.8

PROFESSIONAL PRACTICE (20%)

Skills for Professional Pracice: 1. Professionalism and ethical conduct. (/25) 2. Health and safety, assessment of risk. (/25) 3. Sustainability and environmental protection.. (/25) 4. Presentation and organisational quality of report. (/25)

1. Standard company procedures have been mentioned though not all documents are contained in the appendix. (16) 2. A very good section has been included, safety is a major part of the project. (19) 3. These issues have been explained but the focus should have been on the project rather than

13.2

company policies what are not directly linked to the project. (13) 4. Report is well structured and presented, good figures. There are some spelling and punctuation errors. (18)