

SGEL6000 Independent Project

2020-2021

DOUBLE MARKING SHEET AND COMBINED STUDENT FEEDBACK

Assessment 1 of 4

Assignment 1: Project Definition, Research and Quality Planning

Agreed mark

68

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Generic Assessment Criteria	Marks available	1st Marker (RD)	2nd Marker (MH)	Agreed Mark
1. Engagement with Literature Skills.				
Section 5: Engagement in research, judicial use and critical evaluation sources, depth of literature review of solutions (7/10) Good engagement in research throughout with evidence contained in literature review. (RD) Evidence of extensive research was demonstrated (MH)	10	7	8	7
Sections 3, 5 and 8: Extent of reading, use of credible sources, use of Harvard method for listing and citing (4/5) Excellent evidence of reading, citations are mostly correct and a good range of sources used. (RD) A wide range of reliable technical sources were used. (MH)	5	4	4	4
Total	15	11	12	11
2. Knowledge and Understanding Skills				
Section 3: Project background and context, commercial, economic and social context (8/10) Project has been set in context, all relevant areas have been covered. (RD) Project explained as a control system upgrade for a VRU compressor (MH)	10	8	7	8
Section 3: Project constraints, professional and ethical conduct, codes of practice, standards, security, intellectual property, legal requirements etc. (5/10) All relevant areas have been covered in a professional way according to company standards. (RD) Some consideration of some aspects of ethical engineering were explained in detail, however others were too generic and didn't relate directly to the project (MH)	10	6	5	5
Section 3: Environmental and sustainability limitations and promotion of sustainable development (4/5) Clear evidence shows consideration to these issues. (RD) Some consideration given (MH)	5	4	3	4
Section 3: Project risks, health and safety etc. (3/5) All risks have been considered, good summary of risk assessment. (RD) Consideration of risks to the project's success (MH)	5	4	3	3
Total	30	22	18	20

3. Cognitive and Intellectual Skills					
Section 3: Problem Definition (3/5) Clearly defined, but some details were unnecessary. (RD) Clearly, but excessively defined and explained (MH)		5	3	4	3
Section 4: Functional Design Specification (7/10) Good level of coverage but some details were missing. (RD) Detailed and clear, but excessive in the detail of setting out the requirement of the project.(MH)		10	7	7	7
Section 4: Test planning (5/5) Very detailed, excellent standard of work. (RD) Detailed testing plan included with success metrics, some were undefined though e.g. prompt (MH)		5	5	4	5
Section 7: Conclusions and Recommendations (3/5) A helpful and objective section clearly outlining what has been achieved and what now is required to complete the project. (RD) More descriptive than evaluative (MH)		5	3	2	3
Total		25	18	17	18
4. Practical Application Skills					
Section 5: Critical choice and justification of final solution (4/5) Good range of techniques used to justify choice. (RD) Detailed scoring system used to assess each solution (MH)		5	4	5	4
Section 6: Project Planning, working breakdown structure and management techniques. (7/10) Good evidence of use of these methods contained in the report. (RD) Detailed 4 layer WBS was devised, Gantt chart was linear and basic (MH)		10	7	7	7
Total		15	11	12	11
5. Transferable Skills for Life and Professional Practice					
Section 1: Executive summary (3/5) A good summary covering all aspects of the project. (RD) A basic understanding of the project could be gleaned (MH)		5	3	2	3
All Sections: Quality of the report – (5/5) Excellent, well written in a flowing style. (RD) Generally very well written and presented (MH)		5	5	5	5
Word count – (0/5) Exceeded significantly (RD) 6000 words declared – word counts should be respected (MH)		5	0	0	0
Total		15	8	7	8
Grand Total		100	70	66	68

Assignment 1 1602836 DI

by Daniel Ince

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TIME SUBMITTED	11-DEC-2020 04:14PM (UTC+0000)	WORD COUNT	8655
SUBMISSION ID	139284468	CHARACTER COUNT	51620

Course: BSc (Hons) Electrical and Electronic Engineering
Module: SGEL6000 Independent Project
Assignment: 1. Project Definition, Research and Quality Planning
Name: Daniel Ince
University number: 1602836
Date submitted: 11/12/2020
Word count: 6000

*word count exceeded, should be no
more than 3850 (RD)*

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Well structure report (RD)

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1. Executive Summary

The proposed project upgrade on the Vapour Recovery Unit (VRU) compressor control system has been evaluated and planned. Work order history and faults have been analysed to provide evidence for the project justification, with the existing system weak points being found as; Relay reliability, set point control and compressor loading.

Following approval, three potential solutions were considered; these included using the existing DeltaV Distributed Control System (DCS) to build control logic, using a Programmable Logic Controller (PLC) or upgrading to a modern relay logic bank. On analysis, the relay solution was the weakest scoring followed jointly by PLC and DCS solutions. These are more advanced and provide higher levels of protection and reliability. The chosen solution, DCS, will be implemented providing there is a reduction in the risks presented by the analysed threats.

The project implementation process has been broken down and planned with consideration given to topics such as ethics, safety and environmental concerns. A Gantt chart was derived from the work breakdown structure and an initial costing plan drawn up. The report concludes with an evaluation of progress so far throughout the VRU control system project leaving the system ready for implementation.

*This is a good executive summary
that covers all that was done. (RD)*

2. Introduction

The project will be a control system upgrade for VRU compressors situated on the site, with the aim of improving unit reliability and operation. The project is to be justified through evidence analysis, and from that, three main potential solutions to the problem will be researched, costed and considered. A design specification will be compiled to highlight the criteria the upgrade must meet, and from this a test plan will be devised. An ideal solution will be chosen as the one which best fits the functional specification and will be planned for implementation. Relevant company and engineering policies will be considered throughout to plan the process to the highest level.

*Well done, you have set the aims and objectives of the project out clearly
(RD)*

3. Project Background, Problem Definition and Constraints

3.1 Process overview

The propane vapour recovery compressors (VRU 1 & 2) are designed to control the pressure within the propane spheres. Each compressor is responsible for a set of different spheres, with a pressure controller on each bank.

If a single compressor is offline, the other online compressor can control the pressure in both sphere banks with the vapour lines combined.

This pressure control is necessary as the optimum propane operating temperature is between 2 and 4°C. The ambient temperature has a large influence on the control and if the temperature climbs too high, the liquid is prone to 'flashing off', expanding and forming vapour, increasing the pressure. The compressors cut in at 4.4kg/cm² and load as the pressure increases, at maximum load at 4.7kg/cm², maintaining the correct pressure to prevent the temperature dropping to 0°C.



Figure 1: VRU Compressor and instrument panel

The two VRU systems are identical, depending on which VRU is online.

3.2 Existing system operation

The VRU trains obtain their set point and cut in/out times from two pneumatic pressure controllers in the field and are located approximately 30 metres from the VRU and measure the sphere line process pressure.

Each compressor loading sequence is controlled by its own respective pneumatic controller. These output a 3-15psi air signal based on the process pressure across a range of 4.3 to 4.7kg/cm².

Subsequent loading is then performed by operation of three pressure switches, PS-1577B/C/D for 50%, 75% and 100% respectively. Following a review of compressor relay logic documents JA08/4585/Z Sheets 1 & 2, Appendix 1 table was compiled to display the SOV switching and loading order.

During start-up, time delay relay is energised for 60 seconds, this starts a timer to open the contacts that bypass the trip for the low lube oil pressure. This hold out allows the machine to start and get up to speed to hold out the trip until the 60 second timer is up. By this point the machine will have a healthy lube oil pressure from its own mechanical pump. If this is not the case, the machine will trip following completion of the timer.

*There is probably too
much detail at this
point (RD)*

3.3 Problem definition

The existing system is controlled through an aging relay logic panel and pneumatic controllers, faults frequently plague the operation.

Multiple reoccurring issues regarding cut in and out of the compressors have become apparent, shown by the work requests in appendix 2 & 3. The rectifications involved troubleshooting the pneumatic pressure controller set points and adjustment as the existing tolerance had slipped over time. Failure for the compressor to cut out can result in cavitation and damage to the machine, potentially rendering it unusable for a long period of time.

Appendix 3 shows other issues rectified involving the timing relays not seating correctly. Losses such as this are costing the company money as useful product is being flared unnecessarily. Flare line gas flows are tightly regulated, and increased emissions will also mean a higher environmental tax for the company. Another risk has been highlighted in that continued pressure increases as a result of the VRU being down could result in a PSV lifting and process gas releasing to atmosphere. Even with no further consequences, this will be recorded as an environmental incident and mean costs and

potential fines from the HSE, incidents such as these will also have an impact on company PR and reputation.

3.4 Target issues

After reviewing work requests and history in the system it can be deduced that the three main targets for improvement are:

- Set point adjustment and pneumatic controller
- Relay logic and timers
- Compressor selection and loading

The project will aim to remove the existing problems associated with these and address the issues. This will increase the mean time between repair, minimise compressor downtime, reduce costs imposed by poor compressor control and reduce the risk of an environmental incident through safer operation. The need for this upgrade is further highlighted by the preventative maintenance work carried out on this system yearly.

3.5 Constraints

3.5.1 Safety

The refinery is a high consequence listed site and so is under regulation by the Health and Safety Executive. The scope of work falls under the Health and Safety at Work Act 1974, other regulations apply for this design such as Electricity at Work 1989.

The internal company policies such as Life Saving Rules and PPE requirements set out by the Permit to Work system will also need to be adhered to for work to be allowed to commence. Each permit will be risk assessed specific to the job and authorised by maintenance and operations before issuing.

3.5.1.1 Risk assessment and MOC

A risk assessment was performed as part of the Management of Change process (MOC). This involves a review of any new potential hazards presented by the upgrade and must be completed in line with the oil company's internal policies as this is not 'a like-for-like change'. The risk assessment PP-PEM-FRM-0027 builds upon a Process Hazard Analysis previously carried out on the existing installation. These documents refer to a risk matrix PP-HES-GUI-0009 (Valero, 2020) that classifies the different levels of risks presented by comparing severity verses likelihood levels.

To summarise, the outcome of the MOC risk assessment addressed three main hazards:

- *Sphere vapour line over pressure to above 5.3 kg/cm² and lifting of PSV, releasing propane gas to atmosphere.*
- *Pressure increasing past 4.7kg/cm² with no indication shown to highlight the increase.*
- *Compressor cut-in is reached, however it fails to start, whilst second VRU is not commissioned.*

The consequences of these occurring included pressure being allowed to exceed 4.7kg/cm² as indication is topped out causing the flare valve to open. As a result, environmental fines for the company and damage to plant/personnel along with potential loss of containment.

Therefore, the following controls were implemented:

- *Cut-in of selected VRU compressor should the pressure reach the set point along with appropriate loading to reduce pressure before flare valve operation.*
- *Expanding of measurement range of VRU cut-in indication to 6kg/cm². High pressure alarm to be set at 4.6kg/cm² to indicate pressure has begun flaring. This is also to include NAMUR alarm saturation standards.*

- Compressor 'failure to start' alarm to be implemented to provide a notification to operations, allowing them enough time to act. (Valero, 2020)

3.5.2 Environment and sustainability

The improvements to this system will allow proper control of the compressors with successful operation preventing flaring as a result of high propane pressure in all normal plant operation scenarios. This also applies to the further risk of atmospheric release of hydrocarbon due to this increase in pressure.

Relevant points made (RD)

The upgrade will utilise modern components and equipment to replace the old system, these replacements will be more reliable and thus need to be changed out less-often, resulting in less waste. Components will initially be sourced from the company stores where possible as these have already been delivered and will not need freight and packaging. This will also result in fewer components ordered separately and so less waste. The design of this system should result in a reduction in maintenance resources and parts when under normal operating conditions, one which greatly improves upon the old design.

citations needed (RD)

In keeping with the hazardous area drawing 50-ZA-003-05 the compressor and spheres come under the rating of Zone 2 IIC T3. This means all equipment selected for the field must have an ATEX rating equivalent or higher for this location. Racking room equipment will be kept within a safe environment and will house any energy limiting barriers.

3.5.3 Professionalism, legality and ethics

will be (RD)

Throughout the project process, professionalism was maintained through following approved codes of practice and consulting the project with management. Company rules and guidelines have been followed and sensitive company information has been withheld and kept confidential. Failings of the design can result in a breach of safety regulations and fines and restrictions put into place by the HSE for the company and individual if they are found liable.

Engineering must always be carried out with consideration towards ethics, with consideration given to where materials and labour are sourced. To ensure this, only approved vendors have been used throughout the project.

citations needed (RD)

4. Functional Design Specification and Test Plan

4.1 Performance

4.1.1 Functionality

The upgrade needs to control both VRU compressors, maintaining the correct line pressure and preventing it from reaching the flare valve set point or higher. Should any abnormal circumstances occur, the compressors should promptly trip, preventing a restart until the fault has cleared and has been manually reset.

4.1.1.1 System must be able to reliably operate both VRU compressors through use of either hardwired or software-based control logic.

4.1.1.2 VRU1 & 2 compressors must trip on the following corresponding unhealthy conditions:

4.1.1.2.1 Extra high temperature TSHH-1569 [1669].

4.1.1.2.2 High delivery pressure PSHH-1574 [1674].

4.1.1.2.3 Low suction pressure PSL-1571 [1671].

4.1.1.2.4 Low oil pressure (following completion of start-up timer) PDSLL-1571 [1671].

4.1.1.2.5 High fin-fan vibration FAN-1 [FAN-2].

4.1.1.2.6 High suction separator level LSHH-1561 [1661].

4.1.1.3 Compressors must cut in at the desired set point of 4.4kg/cm² using a pressure value from sphere vapour line pressure controllers.

4.1.1.4 Compressor start procedure must energise fin-fans EAM-101A&B [102A&B] prior to output to compressor motor starter EAM-101C [102C].

4.1.1.5 Interlocks must force the start procedure to wait for a healthy run signal from the output of compressor fin-fan starters EAM-101A [102A] & 101B [102B].

4.1.1.6 Compressors must load accordingly based on the sphere vapour line pressure, increasing and decreasing.

4.1.1.7 System must delay compressor loading for 10 seconds after start.

4.1.1.8 Loading must be achieved through operation of SOV-1578 [1678], 1579 [1679] & 1580 [1680].

4.1.1.9 System must hold out low lube oil trip during start-up for 60 seconds.

4.1.2 Operation and indication

Indication should be provided through use of either communication through DCS, a HMI or local annunciator panel. Provision must also be made for an analogue indication of the set point controller pressures. The indication must provide operations with information of the current running status and any standing trips or alarms.

- 4.1.2.1 System must be able to be stopped through use of a local physical ESD button for each compressor that latches and prevents starting.
- 4.1.2.2 System must be able to be reset through use of a local physical reset button.
- 4.1.2.3 A manual override must be available to prevent compressor loading.
- 4.1.2.4 Indication must be present through either HMI, DCS system or hardwired LEDs and must include:
 - 4.1.2.4.1 Compressor running light.
 - 4.1.2.4.2 Any standing trips documented in section 1.1.2.
 - 4.1.2.4.3 Current state of compressor loading.
 - 4.1.2.4.4 Fin-Fan start signal light.
 - 4.1.2.4.5 Sphere vapour line pressure indication.
 - 4.1.2.4.6 Bypass engaged light.
 - 4.1.2.4.7 Power supply failure indication.
 - 4.1.2.4.8 Current pressure indication

4.2 Ergonomics

The project design is for a prototype workshop-based system prior to field implementation and is required to be designed to meet the field size and weight restrictions. The location is within an existing cabinet of 1m wide, 2m long and 1m deep. All supplementary equipment such as power supplies and barriers will also be stored inside.

4.2.1 Size

- 4.2.1.1 Panel must be appropriately sized as to fit in the Plant 29 & RTW racking room cabinet whilst still having enough room for all control equipment.

4.2.2 Weight

- 4.2.2.1 Panel must be able to be supported to back plate of racking room cabinet.
- 4.2.2.2 Should the weight prevent wall mounting support, legs must be fitted.

4.2.3 Design

- 4.2.3.1 The system must be designed with operation and maintenance in mind. Buttons and indication must be in a position where viewing and operation is comfortable and reduces the chance for the user to look for potentially unsafe workarounds.
- 4.2.3.2 System bypasses must need either a key or some form of tool to be consciously negotiated around or operated.

4.3 Safety

- 4.3.1 As stated in 1.1.2, the system must feature safety trip systems and interlocks to prevent starting in the event of a trip standing.
- 4.3.2 Power to the system must be able to be isolated and locked out.
- 4.3.3 System must be suitably fused for the correct power rating.
- 4.3.4 Control transmitter range must be appropriate for measuring application to include indication below and above compressor cut in and out points. *you could have given the range here (RD)*
- 4.3.5 All parts of the system must be tested prior to site commissioning.
- 4.3.6 The design of the system must be such that it reduces the chance of human error in high pressure critical situations. All emergency stops and isolations must be clear, accessible and locations keeping within traditionally expected patterns.

4.4 Reliability

4.4.1 Redundancy and protection

- 4.4.1.1 The system must have appropriate dual power supply redundancy measures with diodes.
- 4.4.1.2 The power supply must be suitable fused to protect from overcurrent. *what values ? (RD)*

4.4.2 Maintenance

- 4.4.2.1 The system must be able to run uninterrupted for extended periods of time with very little maintenance. *How long ? (RD)*
- 4.4.2.2 The system must be designed with maintenance access in mind.
- 4.4.2.3 Parts used must be serviceable and replacements easily sourced.
- 4.4.2.4 The preventative maintenance procedure must be adjusted to include the upgrade for this system.
- 4.4.2.5 Pressure indication and control needs to be done through an electronic transmitter in order to provide more accurate and reliable control over the existing pneumatic set point controller.

4.4.3 Product life span

- 4.4.3.1 System must be of a design and use components that enables the system to run for at least 5 years with minimal maintenance. The system should not need replacement and should last the life of the business unit provided no major changes are required.
- 4.4.3.2 The system needs to be reliably operating as the VRU compressors are in daily use, especially true during the warmer months. *How do you define reliable? (RD)*

4.5 Hardware

- 4.5.1 Suitable barrier protection must be used to provide adequate hazardous area energy limiting protection for any intrinsically safe equipment.
- 4.5.2 Any intrinsically safe wiring must satisfy the ATEX Directive and be separate from any non-IS loops
- 4.5.3 Field equipment and instruments must be suitably rated for the hazardous area zone and classification in which it is to be located. *what is the classification?*
- 4.5.4 Where electronic transmitters are used, failure modes and detection must be configured and must follow NAMUR alarm standards and saturation points.

4.6 Environment

4.6.1 Cabinet equipment

- 4.6.1.1 Cabinet equipment must be suitable for operation within a high electromagnetic background environment.
- 4.6.1.2 Equipment will be located within a humidity-controlled environment.
- 4.6.1.3 Temperature will be ambient at around 20 degrees Celsius.

4.6.2 Field equipment

- 4.6.2.1 Must have enough Ingress Protection for use outside where rain will be a common occurrence.

4.7 Applicable standards

- 4.7.1 IEC 61131-3 Programming standard
- 4.7.2 IEC 61511 Functional safety – Safety instrumented systems for the process industry sector
- 4.7.3 BS 7671 Requirements for electrical installations
- 4.7.4 PCLT-S 003 Valero alarm management standard
- 4.7.5 CTEMS INST-MGT-1 Valero Management of critical instrumentation
- 4.7.6 DEP 32.80.10.10 Design and installation of critical instrumentation
- 4.7.7 ATEX directive 95

A testing plan for this specification can be found in appendix 5.

5. Literature Review

Each of these potential solutions aims to conform to the company policy and approved manufacturer standards, whilst maintaining a different approach at improving the system.

5.1 Continuous equipment

Here selected equipment will be detailed that do not change throughout the potential solutions due to the specification and company requirements.

5.1.1 Pressure controller

The two VRU systems require an electronic form of pressure measurement and indication meet the specification. The instruments will be mounted in the field on the sphere vapour line, mounted on the access platform to the pipe track. They will be subject to coastal weather conditions and require a suitable ingress protection rating. *this belongs in the background or FDS (RD)*

The Rosemount 2051 pressure transmitter will be reviewed to find if deemed suitable. This analogue transmitter is manufactured by Emerson and is already widely used on site, and so meets company standards.

This transmitter comes in a variety of different ranges and can be specified up to the exact requirements of the scenario. For the purpose of this installation a range 4 will be required (-20.7 to 20.7bar) as this is the smallest range that still allows for 0 to 6kg/cm². This instrument can output 4-20mA current with HART capability whilst running off a 24V power supply. The accuracy is stated by Emerson, *"Performance up to 0.05% of span accuracy."* (2020) This provides a tolerance of 0.003kg/cm² across the given range. *direct quotations need a page number (RD)*

Strengths	Weaknesses
Very accurate.	Will need IS barriers to be implemented in racking room before use.
Powered by 24V supply and outputs 4-20mA, compatible with DCS and PLC options.	
ATEX rated to be intrinsically safe and has a more than sufficient IP rating (66).	
Very reliable and maintenance friendly.	
Complies with company standards.	
Opportunities	Threats
HART Compatibility and can be configured into AMS suite.	More expensive than other market alternatives.
SIL Rated.	
Can be specified for each application.	

A SWOT analysis was compiled to briefly highlight the main benefits of this transmitter versus any potential issues. As this is already widely used on site, the reliability is proven along with its integration into the existing control system along with part availability on stores stock.

The cost per item of these are £1248.35 for a Rosemount 2051CD4 and two are required.

5.2 Distributed control system solution

5.2.1 DeltaV Architecture

Utilising the already established Distributed Control system (DCS) system for the control side of the upgrade is also a consideration. The Emerson DeltaV DCS is modern and proven reliable, whilst also having the ability to contain both trip and control elements.

The architecture of the Emerson system is displayed in figure 4, with the base processing being performed on a main server and processor. These then communicate through a high-speed ethernet control network with the operator stations and the input/output modules. A current signal with HART functionality is used between the I/O modules for communication and operation of the analogue primary elements.

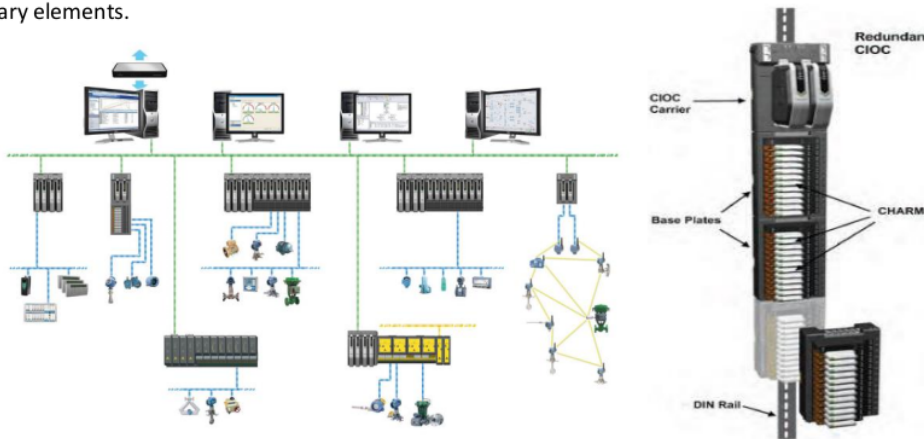


Figure 2: DeltaV Architecture (Emerson, 2010)

: CIOC layout (Lyndon, 2020)

5.2.2 Benefits and application

The DeltaV system would incorporate the use of CHARM I/O to connect the field equipment to the DCS. As stated by Emerson, “Electronic Marshalling provides I/O type connectivity in a single channel component – called a CHARacterization Modules (CHARM)” (2020) These can be specified to be intrinsically safe to act as energy limiting protection to save the need for implementing a barrier.

The Emerson DeltaV Characterisation Modules have a built in 250Ω for resistor and are 30mA current limiting, this applies to the 24V loops for the two wire analogue inputs suggested with this design. Here there is enough allowed current for the NAMUR alarm saturation limits whilst also preventing overcurrent of the instrument. (Emerson, 2020)

The advantages of the DeltaV CHARM marshalling has over traditional cabinet wiring. They estimate that over 1000 termination points, 400 to 600 hours of labour are saved by the reduction in field

wiring. This also leaves more space within the cabinet for extra terminations. (Lyndon, 2020) Space is tight within the cabinet and so space conservation will prove crucial.

The controllers for DeltaV feature a built-in redundancy, this satisfies the project specification and complements the overall reliability and safety of the system. Emerson explain how I/O communication or controller hardware failure detected by the continuous self-tests will trigger an automatic switchover to the second redundancy controller. (2017)

The power supply data sheet displays the performance of the supply this solution would use, with a 24V with minimal fluctuation and 5A current output and the correct specification for connecting to the mains input. This supply would be adequate in supplying the 24V DC power to the instruments required. Although only rated at IP20, the DIN rail mounting environment will be indoors and humidity controlled so will not present a problem. (Emerson, 2019)

Advantages of DeltaV are explained by Bai, Hongyu et al., such as the expansion of DeltaV by connecting another controller or workstation. This is automatically detected by the system and is useful for the project application as this will be the installation method for the VRU controllers. (2006)

It is the company policy to attempt to use the DCS for control options where possible if the infrastructure is available. This is due to factors such as:

- Operator familiarity
- Control and trip functionality
- No programme version management required
- Visibility to operations

5.2.3 Design and costing

The design of the system is shown in figure 5, this highlights the three main areas within the instrument loop:

- Existing infrastructure
Shown by the blue dashed box; this equipment already exists, and the upgrade will be merging into this system.
- New installation
Shown by the green dashed box; this is to be the new equipment installed within the blending and shipping racking room cabinet. Two I/O CHARM drops coupled with a pair of CIOC controllers each, including the extra for redundancy.
- Field equipment
Shown by the red dashed box; the primary elements located in the field. The two analogue inputs are new and will output 4-20mA through a HART loop to the NAMUR IS AI CHARMS. All others are 24V DC discrete signal outputting to IS DI and DO CHARMS.

After liaising with the DCS Project Engineer Dan Belli – a price estimate was provided for the DeltaV setup, this includes various charms, the rest have been costed as extra.

Item	Manufacturer	Vendor	Price each	Quantity	Total
48 CHARM box	Emerson	Emerson	£15,000	1	£15,000
DI CHARM	Emerson	Emerson	£100	10	£1,000
DO CHARM	Emerson	Emerson	£100	12	£1,200
AI CHARM	Emerson	Emerson	£300	2	£600
				Total:	£17,800

Figure 3: DCS costing

Further details can be found on the Emerson document EU-FE-48-AC-CIOC-HA-DEMO, which includes additional options for cabinet heaters and fans if required. (2020)

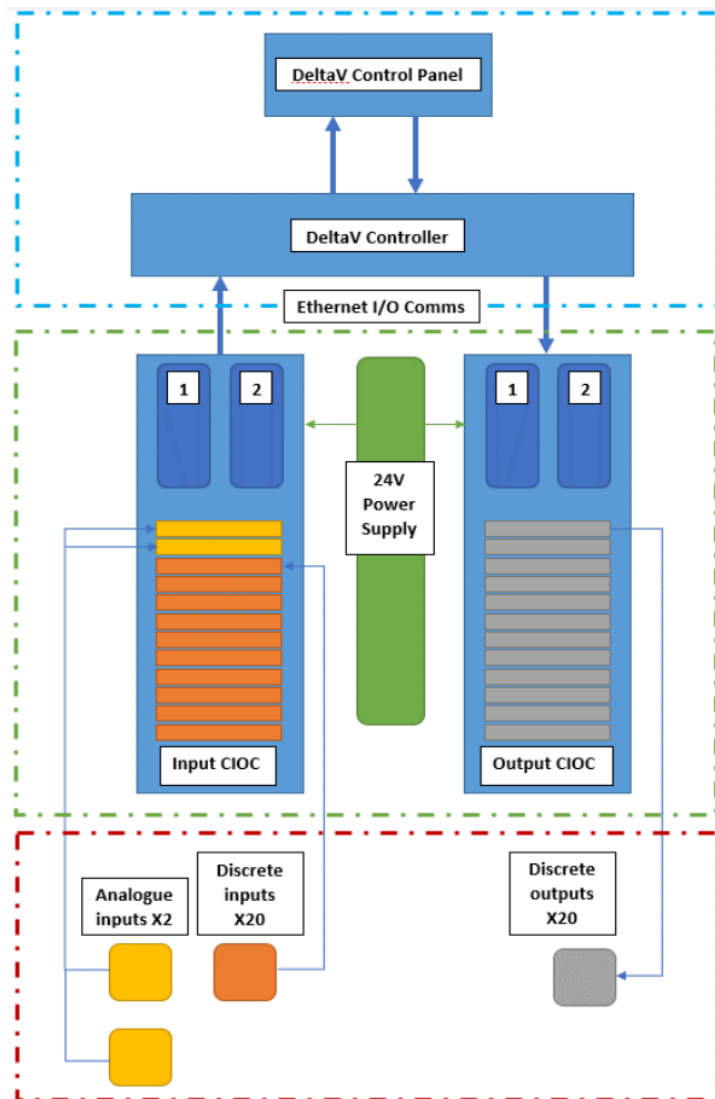


Figure 4: DCS solution block diagram

5.2.4 DCS method analysis and scoring

Strengths	Weaknesses
Merges into existing infrastructure, easily connected. Cabinet comes default fabricated from Emerson.	Very expensive. Any additional CHARMS required will quickly rack up cost.
Power supply included into cost and some CHARMS provided with quotation. Barriers not required.	Quotation does not include commissioning, Site Acceptance Test, Software documentation, cabling design or loop drawings.
System already familiar to operations and no programme version management required.	
Minimal cable marshalling required, saving labour costs.	
Preferred company standard option and replacement parts already on stores stock. Familiarity with maintenance department.	
Reliable and features a controller and CIOC redundancy system.	
Opportunities	Threats
Control and trip functionality on DCS system. System can also be SIL rated if desired.	If additional controllers are required due to lack of existing controller capacity and infrastructure. Cost will be triple.
CIOC cabinet can also be fitted in Zone 2 hazardous area locations if required.	COVID-19 company restriction and policy may prevent use of DeltaV hot rig.

Figure 5: DCS SWOT Analysis

5.3 Programmable logic controller

5.3.1 PLC review and design

This solution will involve the main bulk of the control performed through a programmable logic controller.

To be approved for use on site, the PLC must be chosen from the company approved manufacturers list, which for non Triconex systems, is the Allen Bradley ControlLogix. This PLC will allow the VRU control software to be programmed into the controller whilst maintaining a compact design. The chassis can be customised to include as many I/O or communication modules as required. This design will utilise a communication module to set up ethernet comms to the DCS control system to provide indication on the operator stations.

As explained by PLCHardware, the processor features 2048Kb internal memory with 478Kb I/O memory with the option for expansion memory cards if desired. It is also specified that to establish communication, an interface module must be installed. (2020) The program for the VRU upgrade will not utilise a large amount of memory so 2MB will suffice, however if required larger memory processors can be purchased at additional cost.

The Allen Bradley ControlLogix 5561 PLC is widely used on site in a variety of application and its reliability is proven through industrial usage. The company stores already hold spare cards and module for this particular PLC making maintenance and part sourcing easier. However, the company standard currently discourages PLC use for new projects unless deemed necessary.

An advantage of using a PLC over the existing system reduces the amount of failure points within the system, they also do not wear in the same way as the relays currently installed and will fail to a desired safe state. As stated by V. Segovia and Theorin, *"Additionally, due to the solid-state nature they offer greater reliability, require less maintenance, have a longer life than mechanical relays or other analog equipment, and can withstand extreme industrial environmental conditions."* (2013) [page number? \(RD\)](#)

Reviewing a comparison, it is explained by Fauci that the initial cost of a PLC eventually becomes offset by savings in maintenance and downtime later down the line. The cost of the software is traditionally higher than the equivalent hardware of a different system but ultimately helps to reduce long term costs. (1997)

[This is a very good point \(RD\)](#)

A diagram of how the PLC will be connected to the system is shown in figure 7.

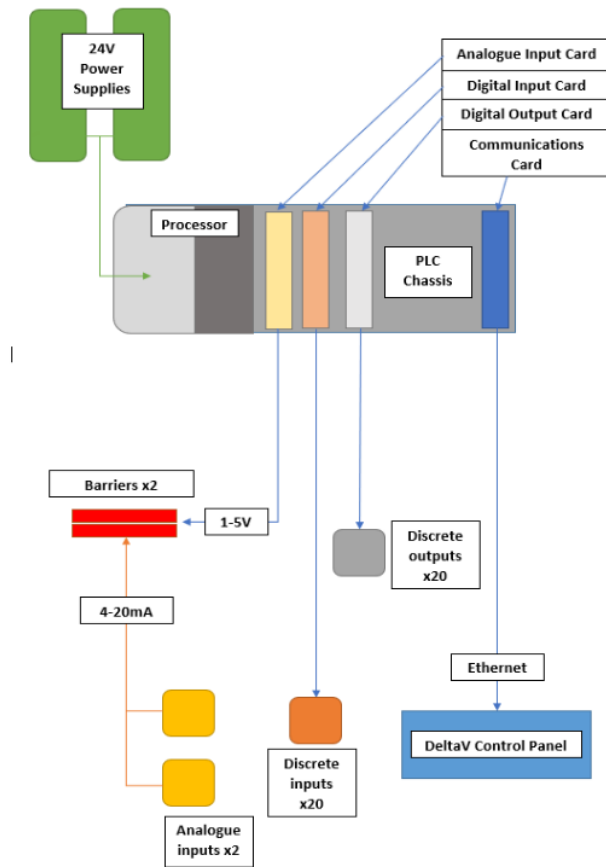


Figure 6: PLC design block diagram

The dual 24V power supplies will power the PLC rack containing the I/O cards and communication modules. Barriers will be used to keep the analogue input loops intrinsically safe, whilst the Discrete I/O will be powered through the PLC. Control and indication with the DCS/HMI will be established through ethernet from the communication card.

5.3.2 Analysis and costing

To install the PLC solution, 24V power supplies must be included with a redundancy feature should one fail. This system will also require barrier to be fitted to the analogue input loops to maintain the ATEX and intrinsically safe rating of the system.

The selected barrier for a 2-wire SMART 4-20mA analogue input is the MTL7787+, the details of this are documented in appendix 7. This barrier includes the 250Ω resistor and 50mA fuse rating required for the Rosemount 2051. The energy is limited through the Zener diode to protect the safe area terminals in event of excess current. (MTL, 2018)

The 24V DC power supply will be powered by 240V AC mains supply, two of these supplies will be required. Reviewing the datasheet, the Phoenix Contact Quint 24V DC supply allows for redundancy connection between two units and ensures 12ms trip at six times the nominal current. This circuit protection ensures the barrier fuses are not blown and prevents damage to the PLC processor. IP is listed at IP20 and the ambient condition data matches the suitability for racking room usage.

A costing spreadsheet and SWOT analysis was compiled for this solution, shown in figures 8 and 9.

Item	Product code	Manufacturer	Vendor	Price each	Quantity	Total
13-slot ControlLogix Chassis	1756-A13	Allen Bradley	Routecco	£507	1	£507
Power supply 120/220V ControlLogix	1756-PA72	Allen Bradley	Routecco	£622	1	£622
2-Port Ethernet module	1756-EN3TR	Allen Bradley	Routecco	£2,640	1	£2,640
Processor 2MB memory	1756-L71	Allen Bradley	Routecco	£3,640	1	£3,640
Empty slot cover	1756-N2	Allen Bradley	Routecco	£19.40	2	£39
Isolated input 16 pts 10-30VDC	1756-IB16I	Allen Bradley	Routecco	£380	2	£760
DeviceNet module	1756-DNB	Allen Bradley	Routecco	£841	1	£841
Analogue input module isolated w/HART	1756-IF8IH	Allen Bradley	Routecco	£1,630	1	£1,630
Digital output module 16 pts 24VDC	1756-OB16D	Allen Bradley	Routecco	£557	2	£1,114
Relay output module NO 16 pts	1756-OW16I	Allen Bradley	Routecco	£428	2	£856
Terminal block 36pin	1756-TBCH	Allen Bradley	Routecco	£58.40	8	£467
1 Channel 7787+ barrier	MTL7787+	MTL	RSComponents	£112.20	2	£224
Quint switch mode PSU 264VAC input 24VDC output 10A	2866763	Phoenix Contact	RSComponents	£249	2	£497
					Total:	£13,837

Figure 7: PLC solution cost

Strengths	Weaknesses
Cheaper than a DCS alternative.	Company standpoint prefers usage of DCS for control where possible.
HART capability for analogue inputs.	PLC program version will need to be managed and updated.
Power supply redundancy and failsafe options.	PLC must be kept in racking room or Exd enclosure.
Separate I/O cards for each VRU to prevent common failure for both units.	
Equipment already on stores stock and familiar with maintenance department.	
Reliability proven through existing ControlLogix PLC usage already on site.	
Opportunities	Threats
Potential for expansion with additional modules	
Communication ports for either DeltaV or HMI	

Figure 8: PLC Solution SWOT analysis

5.4 Relay logic and trip amplifiers

5.4.1 Review and design

Building upon the existing system and replacing the older style relays with modern ones that are more reliable and versatile is another potential option. To improve the control system the electronic pressure transmitter will need to be utilised in conjunction with a series of trip amplifiers to control the compressor start and stop.

These new relays will need to be an upgrade from the old in order to reduce the failure rate and make the upgrade worthwhile.

Advantages of the traditional relay are documented by Karl Zimmerman, explaining how the single-purpose relay can be tested and commissioned far more easily than that of programmable logic. The resultant logic drawing of the system allows thorough testing. Zimmerman states *“A technician can have a blueprint of the design and systematically highlight each device and interconnection until the entire system is tested.”* (2008) This makes fault finding easier and faster, it also means a single part can be swapped out swiftly to restore functionality to the system, whereas a whole microprocessor may fail. D. Baradi and J. Xavier also explain how the success of fault-finding relay logic relies largely on the quality of the logic documentation. (2018)

This system will involve new relays being added along with new logic documentation to suit. The replacement Phoenix Contact 24V relays are fitted with power indication to aid with troubleshooting, as this is a large disadvantage with this design. A 6A fuse is also incorporated for circuit protection and as this will not be required to rapidly switch repeatedly, the response time and life cycle is enough. (Phoenix Contact, 2019) The design of this relay prevents the main switching block from coming loose as found with the existing setup as it is all a single piece.

The analogue inputs from the field pressure controllers will feed back to a series of trip amplifiers that will operate the loading SOVs at set current limits. Therefore, two sets of four trip amplifiers will be needed. The Pepperl & Fuchs transmitter amplifier will be utilised to detect line faults, switch the relay outputs to the SOV and allow configured alarms. (Pepperl+Fuchs, 2020)

The design of the system can be seen in figure 10.



Figure 9: Relay and trip amplifier solution design

5.4.2 Analysis and costing

A costing spreadsheet and SWOT analysis was compiled for this solution, shown in figures 11 and 12.

Item	Product code	Manufacturer	Vendor	Price each	Quantity	Total
Phoenix Contact, 24V dc Coil Non-Latching Relay 5PNO, DPST	2963747	Phoenix Contact	RSComponents	£62	20	£1,240
Transmitter Power Supply	KFD2-CRG2-1.D	Pepperl&Fuchs	Pepperl&Fuchs	£262	2	£524
Current/Voltage trip amplifier	KFD2-GS-1.2W	Pepperl&Fuchs	Pepperl&Fuchs	£197	8	£1,579
					Total:	£3,344

Figure 10: Relay logic costing

Strengths	Weaknesses
Simple design and installation.	Inherent problems with electromechanical relays still exist.
Improves upon old method through electronic analogue input loading and relay power and fault indication.	No analogue indication or feedback to DCS or local indicator.
Very inexpensive.	Lots of wiring required taking up a lot of space within cabinet.
Opportunities	Threats
	Updated design is very similar to existing system.

Figure 11: Relay logic SWOT analysis

5.5 Overall comparison and conclusion

The three main solutions will be broken down into a decision matrix and scored against various categories up to a maximum of 10:

- Reliability – How the solution meets expectations regarding successful operation and failure rate.
- Redundancy and protection – How well the solution protects against complete failure or fails in a safe manner.
- Overall cost – Based on the cost estimates provided (higher score for less cost).
- Maintenance difficulty – How easily parts can be swapped or repaired on the solution.
- Part sourcing – How easy it is to source replacement parts or equipment.
- Development – How compatible the solution is to additional installations/modifications and new equipment.
- Testing – The ease at which the system can be thoroughly tested during commissioning or preventative maintenance.
- Company requirements – The level at which the solution satisfies company preferred methods.
- Ergonomics – The size and weight suitability of the solution.
- SWOT – Scoring based off the SWOT analysis outcome.

Solution	DCS	PLC	Relay
Strengths (+)	6	6	3
Opportunities (+)	2	2	0
Weaknesses (-)	-2	-3	-3
Threats (-)	-2	0	-1
Total	4	5	-1

Figure 12: SWOT score

The SWOT analysis positives verses negatives were totalled in figure 13, these will be used within the final scoring matrix.

5.5.1 Scoring matrix

The resulting scoring table can be seen in figure 14, with the DCS solution providing the highest score.

Category	Solution score		
	DCS	PLC	Relay
Reliability	9	7	4
Redundancy and protection	8	7	4
Overall cost	3	5	9
Maintenance difficulty	6	6	6
Part sourcing	5	6	3
Development	7	7	4
Testing	6	6	5
Company requirements	8	6	3
Ergonomics	8	6	4
SWOT score	4	5	-1
Total	64	61	41

Table 1: Decision matrix

5.5.2 Decision conclusion

Reviewing the decision matrix table, the best fit for the project is the DCS solution, however it scored very similarly overall to the PLC solution. The reason for this is both these methods are very similar with only a slight cost difference. The DCS solution scored higher mainly due to the reliability and ease of integration and development of the system into the infrastructure. It is also the most modern and is kept up-to-date automatically as it merges with the DeltaV system. The relay solution scored far lower because it is not a substantial enough development on the original system, it also does not have functionality such as HART and DCS integration.

The DCS solution will be chosen under the conditions that the threats noted in section 5.2.4 do not pose an issue.

- Approval is currently pending for use of the DeltaV hot rig during company COVID-19 restrictions. Having this denied will prevent use of the Emerson control software.
- Pending availability check of DeltaV infrastructure controller free space, failure of space availability means the budget will drastically increase.

If the threat of these issues is not removed, the PLC solution will be chosen as it scored very highly and similarly to the DCS solution but without any threats.

6. Project Planning, Work Breakdown and Management Techniques

6.1 Work breakdown structure

A work breakdown structure was compiled to aid with project planning, all sections were split up until the lowest level was detailed, shown in figure 13.

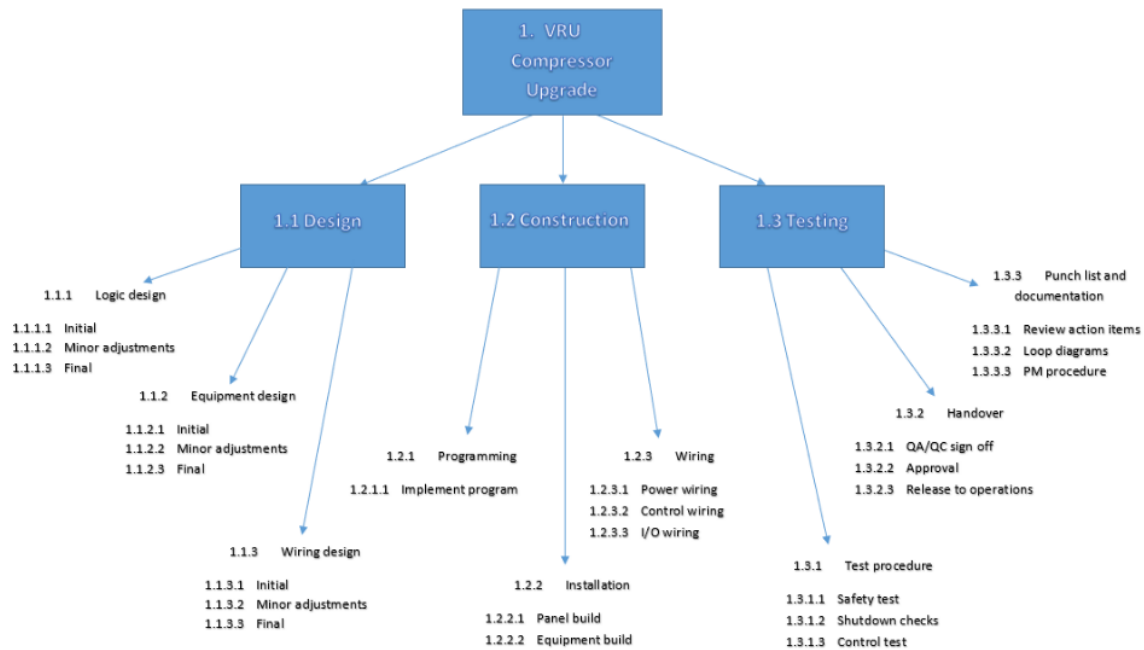


Figure 13: Work breakdown structure

6.2 Gantt chart and contingencies

The project has been planned from the start date of 08/12/2020 to completion on 25/01/2021, this is due to a company turnaround starting end of January so all project work must aim to be completed by that date. The project tasks are broken down and will be updated as percentages complete or deviate from plan. The Gantt chart can be seen in appendix 6.

To achieve this plan, various actions and considerations have been given to potential project threats. These contingencies will help reduce the consequences or risk of the issues.

Threat	Potential Consequences	Actions and Considerations
Company shutdown starting end of February for two months.	Large reduction in available man hours for project execution and construction.	Begin construction in December and allocate more manhours within this time.
COVID-19 reduces availability of manufacturer items.	Reduction in vendor stock and increased delivery times.	Order equipment a month earlier than normal, move budget to the preceding month to account for this. Company stores to be utilised where possible.
Overhead costs from other priority projects take budget from this one. (Large cogeneration project currently ongoing and TAR work are big expenses.)	Loss of budget, delay of project start date.	Begin project construction earlier than originally planned. Obtain budget approval from supervisor prior to commencing.

Table 2: Contingencies

As this is a project with a budget under £100,000 the company specific small project cost spreadsheet was used. Here the two applicable categories had costs allocated to them on a monthly basis based upon the overall budget. The costing plan can be found in appendix 7.

- *Manhours*

The manhour costs were taken as a predicted total of 400 hours across the project timeline. Here the given labour rate is taken at £15 per hour to calculate the figures.

- *Materials*

Materials have been split into two months to account for purchasing/acquisition of the main control unit (December) and remaining materials (January). This has been chosen as a result of an action deduced within the *Threats and Vulnerabilities* section.

These figures can be further added into the three budget categories shown;

- Original – This is the original budget initially stated, detailed within the project proposal. This has not changed and will remain at £20,000 total for materials, split across the months.
- Current – This figure will change based upon any budget adjustments, allocation or removal.
- Forecasted – The forecast is based upon the prediction of material or resource delivery and can change if manufacturer delivery times or quotes change. Any adjustment here may mean budget has to be taken from one month and added to the next.

6.3 Management techniques and milestones

The management technique adapted for this project is the agile style, this involves continually working towards smaller goals, such as the ones detailed in the work breakdown structure. This has been chosen due to the current climate and shifting environment. Maintaining frequent short-term goals ensures progress is continually achieved and reduces the chance of these goals being impacted as the plan is always up to date with the situation. As explained by D. Rigby et al., utilising this method ensures everyone in the process is kept up to date through daily meetings and any new problems can be quickly identified. (2006)

To manage the process, delegation of authority has been used to obtain information from different sources, this includes fault history, budget approval and instrument data.

Various milestones have been set in place by analysing the work breakdown structure to maintain the agile style:

- Material acquisition – 11/12/2020
- Logic design – 16/12/2020
- Logic implementation – 05/01/2020
- Equipment installation – 10/01/2020
- Build completion – 12/01/2020
- Testing completion – 21/01/2020
- Handover – 23/01/2020

7. Conclusions and Recommendations

The project process has been planned as far as possible at this stage with any potential development threats considered to a reasonable level. The initial stages of background research and problem investigation have cemented the justification behind the necessity for this upgrade. The target areas have been highlighted for improvement to ensure the chosen solution solves the issues.

In order to develop further, approval will need to be sought for the threats documented in section 5.5.2. All steps have been taken to include a contingency solution should this approval not be granted, and any delays here may affect the plan slightly. The selected and contingency solutions scored very high and clearly outclassed the more traditional relay logic method. Selection methods have been thorough, and all effort has been made to consider all relevant aspects of the system.

To have this project carried out in an industrial environment, the steps throughout the project process and to obtain authorisation have been carried out in a professional manner. Various company practices and standards have been followed, this includes safety related documentation and standards. Relevant personnel have been informed and consideration given to ethical and environmental aspects, along with implications on the wider world.

Overall, all attempts have been made to breakdown and plan every element of the project to within a reasonable level. Although due to the current changing climate with respect to COVID-19, some conditions have caused difficulties with the planning process.

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9. Appendix

Appendix 1: Compressor loading logic table

Loading	Switch Point Rising (Falling)	Pressure Switch VRU1 (VRU2)	Loading SOVs Energised VRU1 (VRU2)	Cylinders Active
0%	6.5psi (3.5psi)	PS-1577A (1677A)		
25%	6.5psi 10sec delay (3.5psi)	PS-1577A (1677A)	SOV-1578 (1678)	1 & 5
50%	10psi (7.8psi)	PS-1577B (1677B)	SOV-1578 (1678) SOV-1580 (1680)	1 & 5 2 & 6
75%	12.3psi (10.3psi)	PS-1577C (1677C)	SOV-1578 (1678) SOV-1579 (1679)	1 & 5 3 & 7 and 4 & 8
100%	15psi (13psi)	PS-1577D (1677D)	SOV-1578 (1678) SOV-1579 (1679) SOV-1580 (1680)	1 & 5 3 & 7 and 4 & 8 2 & 6

Appendix 2: Cut in/out work orders

Work Request

Work Request #: 940196

Status: Approved

Work Category: Maintenance Repair

Notification #: 14905175

Work Order #: 6138729

Created By: [Redacted] Tim

Reported By: [Redacted] Tim

Changed By: Sutton, Marcus

Changed On: 10/01/2020 12:06 PM

Approved By: [Redacted] Marcus

Expand All

Collapse All

Short Description: 21-C-101 & 102: CHECK CUT IN/OUT POINTS

Detailed Description:

21-C-101 & 102: CHECK CUT IN/OUT POINTS:
21-C-101 & 102 RTW C3 VRU - NOT CUTTING IN UNTIL WELL ABOVE THE SETPOINT, AND NOT CUTTING OUT UNTIL WELL BELOW - PLEASE INSPECT AND REPAIR.
PLEASE CHECK FOR BOTH COMPRESSORS.

Asset Information

Plant: PL25 - Pembroke

Functional Location: PL25-02-0640-18-21C101
21C101, RTW E Corner

Planner Group: IN

Equipment: 10960973
21C101, Comp (965 RPM)

Main Work Center: IN-COR

Safety & Environmental

Safety Considerations

Work Request

Work Request #: 928599

Status: Fix it Myself

Notification #: 14867771

Created By: [Redacted] Karl

Reported By: [Redacted] Karl

Changed By: [Redacted] Jacobb

Changed On: 08/07/2020 05:35 PM

Expand All

Collapse All

Short Description: 21-C-101 Not cutting out on low pressure

Detailed Description:

21-C-101: Not Stopping On Low Pressure:
21-C-101, not cutting out at set pressure. Pressure reading 3.8 but VRU not cutting out. If you stop the compressor, when the pull the stop button out, it restarts, Please investigate and repair.

Asset Information

Plant: PL25 - Pembroke

Functional Location: PL25-02-0640-18-21C101
21C101, RTW E Corner

Planner Group: IN

Equipment: 10956910
21CM101, Motor 3.3KV - Propane Comp

Main Work Center: IN-COR

Actions Taken/Troubleshooting

21-PC-1677 set point too low, adjusted according to data sheet.

Work Request

Work Request #: 899146

Status: Fix it Myself

Notification #: 14794234

Created By: Meredith

Reported By: Meredith

Changed By: Ince, Daniel

Changed On: 05/03/2020 09:58 AM

Expand All Collapse All

Short Description: 21C101 PROPANE COMP NOT CUTING IN

Detailed Description: 21-C-101 NOT CUTTING IN . PROPANE VRU 1 RTW. PLEASE INVESTIGATE FAULT AND REPAIR

Asset Information

Plant: PL25 - Pembroke

Functional Location: PL25-02-0640-18-21C101

21C101, RTW E Corner

Planner Group: IN

Equipment:

Main Work Center: IN-COR

Actions Taken/Troubleshooting

Relay logic checked, found TR2 not seating correctly, rectified, however motor still not starting. C1X relay blown fuse replaced. Resistor also found shorted inside starter. Rectified and compressor now starts.

Work Request

Work Request #: 773569

Status: Approved

Work Category: Maintenance Repair

Notification #: 14494298

Work Order #: 5610070

Created By: Lance

Reported By: Lance

Changed By: Marcus

Changed On: 05/15/2019 07:57 AM

Approved By: Marcus

Expand All Collapse All

Short Description: 21-PC-1677: VRU: Replace Selector Switch

Detailed Description: 21-PC-1677: VRU: Replace Pneumatic Selector Switch: Replace selector switch on pneumatic controller 21-PC-1677 for sphere vapour recovery. This is off the back of a call out where the switch got stuck and vru wasnt working correctly and venting gas to flare. the external of the switch is in poor condition but looks to be something along the lines of a fairchilds selector, unsure weather its hi or low.

Asset Information

Plant: PL25 - Pembroke

Functional Location: PL25-02-0051-32-P-21P1677

21P1677, Propane To Vapour Recovery

Planner Group: IN

Equipment: 11019739

21PC1677, Press Cntrlr

Main Work Center: IN-COR

Safety & Environmental

Safety Considerations

Environmental Considerations

Reliability

Is this Rework?

No

Was this discovered during preventive or predictive maintenance?

No

Can the repair be made while the asset is online?

Yes

Is the asset currently operable?

Yes

Should a preventive or predictive maintenance plan be created for this task?

No

Finalization Information

Priority: Urgent

Suggested Start Date: 04/29/2019

Reason

loss of gas to flare is a business loss, incorrect propane recovery can lead to excessive pressure in the sphere and possibly lift an atmospheric psv....

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PROJECT PROPOSAL DOCUMENT

Student Name: Daniel Ince

Project Title: Propane VRU Compressor Control System Upgrade

Date: 15/10/2020

Budget: £20000

Description of Project

This is a company-based project that involves the design and testing of an upgrade to an existing control system that is decades old, and has been the cause of repeated maintenance call outs, in order to establish working compressors within the work site.

The aim of the project is to produce a system modification for the control and operation of a pair of propane compressors within the company site. These compressors are responsible for maintaining the correct pressure of propane across the spheres through automatic cut-in and cut-out around a set point; this is required as the pressure can increase by the flashing off of the liquid propane into a vapour. This becomes more likely as the ambient temperature increases and affects the amount of expansion.

To permit a compressor to start, there are multiple parameters that need to be in a healthy state, such as, the operation of the fin fans, and at a healthy state of instrumentation within compressor peripheral vessels. The operation is controlled via two banks of relay logic, one for each compressor, located within the main pumphouse racking room.

The new system must be able to control the operation of both compressors, ideally through one unit, whilst ensuring reliability over an extended period, to save the company money in maintenance call outs and compressor downtime. The system must also run the compressors more efficiently, further saving money. The existing system is known to occasionally prevent the compressors from cutting out when required, thereby wasting energy and allowing the pressure to deviate too far from the set point. As it will be a new upgrade, it will have to conform to various regulations and meet the company's own standards and requirements particularly for shutdown and safety instrumentation.

To achieve this outcome, a demonstration rig will need to be constructed within the workshop and will be subject to FAT testing. This will prove the system's functionality ready for implementation onto site.

The project will involve myself, the I&E Maintenance Supervisor (Chris Scott), the Instrument SME (Wayne Brickle) and SIS Engineer (Leon Trunecka), along with the PLC and Electronics Sr Analyser Technician (Matthew Roberts) for assistance with appropriate risk assessments and MOC processes.

The budget stated is for the demonstration rig and panel only and will not include the final installation of the system onto site. This will be included in the final recommendations should the project functionality prove successful. The given budget is £20,000.

Agreement for project proposal

Student Signature: _____ Daniel Ince _____ Date: ____28/10/2020

Industrial Supervisor Signature: _____ Chris Scott _____ Date: ____28/10/2020

Academic Tutor Signature: _____ Robert Davies _____ Date: _06/11/20_

Appendix 5: Testing plan

FDS item	Test	Expected result	Actual result	Pass (Y/N)	Amendment required
4.1.1.2, 4.1.2.4	Simulate an open circuit trip condition during healthy VRU1 compressor operation for TSHH-1569. Repeat for all VRU1 trips. PSHH-1574 PSLL-1571 PDSLL-1571 FAN-1 Vibration LSHH-1561	Output to VRU1 compressor immediately de-energises to shutdown equipment. VRU1 loading SOV outputs de-energise. Compressor will not start until trip made healthy again. Indication for each alarm and trip must operate			
	Simulate an open circuit trip condition during healthy VRU2 compressor operation for TSHH-1669. Repeat for all VRU2 trips. PSHH-1674 PSLL-1671 PDSLL-1671 FAN-2 Vibration LSHH-1661	Output to VRU2 compressor immediately de-energises to shutdown equipment. VRU2 loading SOV outputs de-energise. Compressor will not start until trip made healthy again. Indication for each alarm and trip must operate.			
4.1.1.3	Increase pressure of VRU1 set point controller to 4.4kg/cm2 whilst all states healthy and compressor offline. Increase pressure of VRU2 set point controller to 4.4kg/cm2 whilst all states healthy and compressor offline.	VRU1 compressor should promptly cut in following start sequence. VRU2 compressor should promptly cut in following start sequence.			
4.1.1.4	Begin VRU1 compressor start sequence.	Fin-fans EAM-101A&B outputs should cut in instantly.			

	Begin VRU2 compressor start sequence.	Fin-fans EAM-102A&B outputs should cut in instantly.			
4.1.1.5	Force VRU1 fin-fan outputs open and attempt to begin start sequence on VRU1. Force VRU2 fin-fan outputs open and attempt to begin start sequence on VRU2.	VRU2 compressor output should not energise. VRU2 compressor output should not energise.			
4.1.1.6	Increase VRU1 controller pressure throughout range. Increase VRU2 controller pressure throughout range.	VRU1 loading SOVs should trigger as per loading table. VRU2 loading SOVs should trigger as per loading table.			
4.1.1.7, 4.1.1.9	Begin VRU1 compressor start sequence. Begin VRU2 compressor start sequence.	VRU1 must not load until 10 seconds after start. Lube oil trip must be bypassed for 60 seconds after start. VRU2 must not load until 10 seconds after start. Lube oil trip must be bypassed for 60 seconds after start.			
4.1.2.1	Test ESD buttons during compressor operation	Corresponding compressor must shutdown and not restart while latched.			
4.1.2.2	Test compressor resets.	Corresponding compressor alarms and trips should clear and compressor start when reset operated if all trips are healthy and pressure above set point.			
4.1.2.3	Operate loading bypasses.	Compressors must not load when bypass is engaged.			
4.4.1.1	Disconnect one power supply.	System should still maintain power from redundant supply.			
4.4.2.5	Check full range of electronic pressure transmitters.	Range should output 4-20mA as per specification.			
4.4.1.2	Check power supply output voltage.	Output should be 24V.			

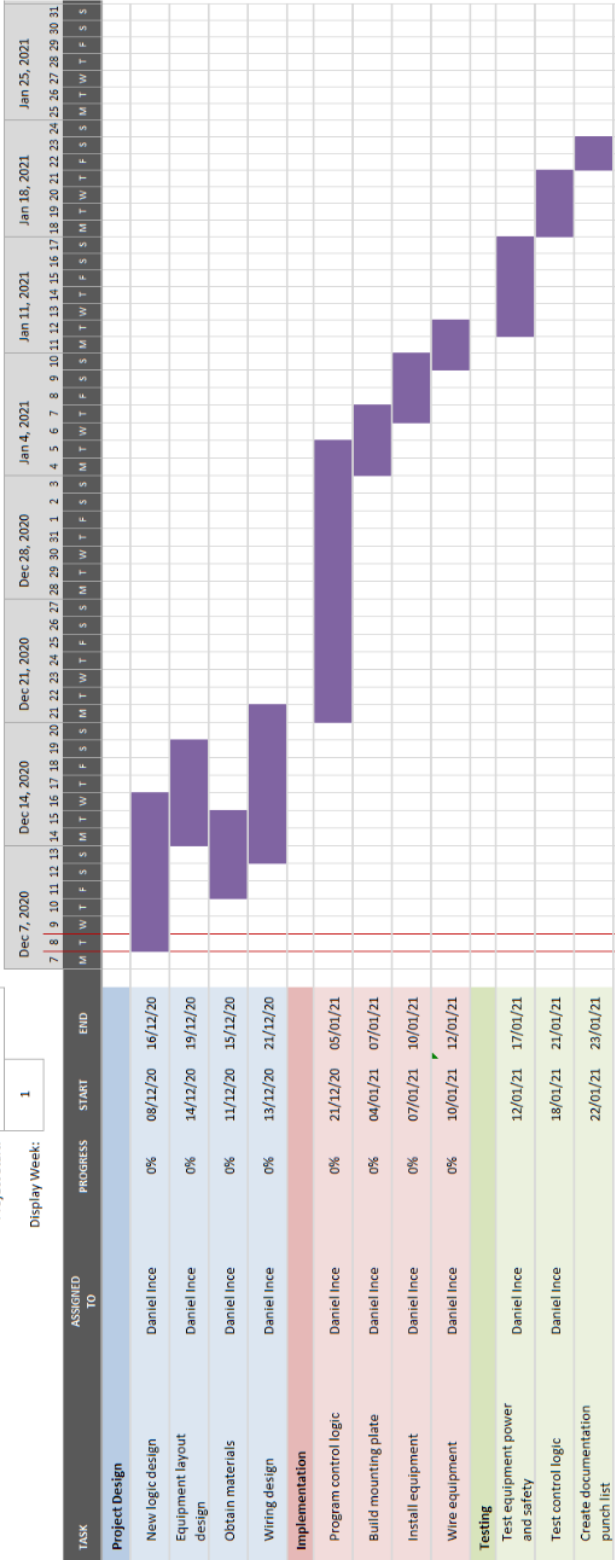
Appendix 6: Gantt chart plan

VRU Compressor Upgrade

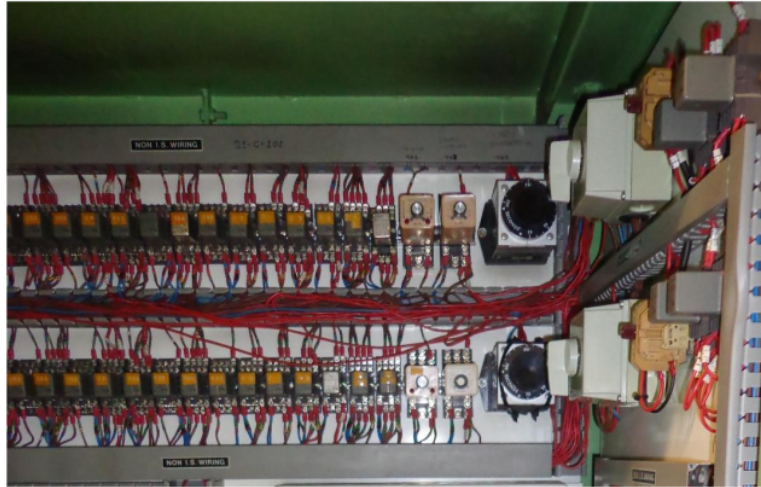
Daniel Ince

Project Start: Tue, 12/8/2020

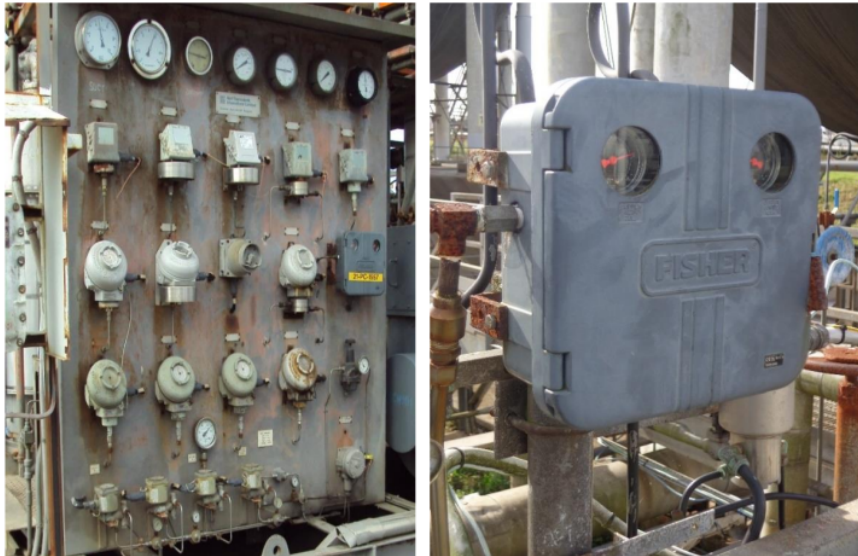
Display Week: 1



Appendix 8: Relay cabinet



Appendix 9: Instrument panel and pneumatic controller



Appendix 10: Loading SOVs



Appendix 11: Risk assessment

The document PP-PEM-FRM-0027 has been omitted for confidentiality reasons, an overview of the risk assessment can be seen in section 3.5.1.1.

Assignment 1 1602836 DI

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

68/100

PAGE 1

Text Comment. word count exceeded, should be no more than 3850 (RD)

PAGE 2

PAGE 3

Text Comment. Well structure report (RD)

PAGE 4

PAGE 5

Text Comment. This is a good executive summary that covers al that was done. (RD)

PAGE 6

Text Comment. Well done, you have set the aims and objectives of the project out clearly (RD)

PAGE 7

PAGE 8

Text Comment. There is probably too much detail at this point (RD)

PAGE 9

PAGE 10

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PAGE 12

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GRADING FORM: NEW CSG-RUBRIC

DANIEL INCE**68****1. ENGAGEMENT WITH LITERATURE**

Section 5: Engagement in research, judicial use and critical evaluation sources, depth of literature review of solutions (7/10) Good engagement in research throughout with evidence contained in literature review. (RD) Evidence of extensive research was demonstrated (MH) Sections 3, 5 and 8: Extent of reading, use of credible sources, use of Harvard method for listing and citing (4/5) Excellent evidence of reading, citations are mostly correct and a good range of sources used. (RD) A wide range of reliable technical sources were used. (MH)

11**2. KNOWLEDGE AND UNDERSTANDING**

Section 3: Project background and context, commercial, economic and social context (8/10) Project has been set in context, all relevant areas have been covered. (RD) Project explained as a

20

control system upgrade for a VRU compressor (MH) Section 3: Project constraints, professional and ethical conduct, codes of practice, standards, security, intellectual property, legal requirements etc. (5/10) All relevant areas have been covered in a professional way according to company standards. (RD) Some consideration of some aspects of ethical engineering were explained in detail, however others were too generic and didn't relate directly to the project (MH) Section 3: Environmental and sustainability limitations and promotion of sustainable development (4/5) Clear evidence shows consideration to these issues. (RD) Some consideration given (MH) Section 3: Project risks, health and safety etc. (3/5) All risks have been considered, good summary of risk assessment. (RD) Consideration of risks to t

3. COGNITIVE AND INTELLECTUAL



Section 3: Problem Definition (3/5) Clearly defined, but some details were unnecessary. (RD) Clearly, but excessively defined and explained (MH) Section 4: Functional Design Specification (7/10) Good level of coverage but some details were missing. (RD) Detailed and clear, but excessive in the detail of setting out the requirement of the project. (MH) Section 4: Test planning (5/5) Very detailed, excellent standard of work. (RD) Detailed testing plan included with success metrics, some were undefined though e.g. prompt (MH) Section 7: Conclusions and Recommendations (3/5) A helpful and objective section clearly outlining what has been achieved and what now is required to

complete the project. (RD) More descriptive than evaluative (MH)

4. PRACTICAL APPLICATION



Section 5: Critical choice and justification of final solution (4/5) Good range of techniques used to justify choice. (RD) Detailed scoring system used to assess each solution (MH) Section 6: Project Planning, working breakdown structure and management techniques. (7/10) Good evidence of use of these methods contained in the report. (RD) Detailed 4 layer WBS was devised, Gantt chart was linear and basic (MH)

11

5. TRANSFERABLE SKILLS



Section 1: Executive summary (3/5) A good summary covering all aspects of the project. (RD) A basic understanding of the project could be gleaned (MH) All Sections: Quality of the report – (5/5) Excellent, well written in a flowing style. (RD) Generally very well written and presented (MH) Word count – (0/5) Exceeded significantly (RD) 6000 words declared – word counts should be respected (MH)

8

SECOND MARKER - MH

Course: BSc (Hons) Electrical and Electronic Engineering
Module: SGEL6000 Independent Project
Assignment: 1. Project Definition, Research and Quality Planning
Name: Daniel Ince
University number: 1602836
Date submitted: 11/12/2020
Word count: 6000

2000 over
word limit.

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BRIEF MENTION OF THE PROTECT AIMS. NEED

1. Executive Summary

The proposed project upgrade on the Vapour Recovery Unit (VRU) compressor control system has been evaluated and planned. Work order history and faults have been analysed to provide evidence for the project justification, with the existing system weak points being found as; Relay reliability, set point control and compressor loading.

Following approval, three potential solutions were considered; these included using the existing DeltaV Distributed Control System (DCS) to build control logic, using a Programmable Logic Controller (PLC) or upgrading to a modern relay logic bank. On analysis, the relay solution was the weakest scoring followed jointly by PLC and DCS solutions. These are more advanced and provide higher levels of protection and reliability. The chosen solution, DCS, will be implemented providing there is a reduction in the risks presented by the analysed threats.

The project implementation process has been broken down and planned with consideration given to topics such as ethics, safety and environmental concerns. A Gantt chart was derived from the work breakdown structure and an initial costing plan drawn up. The report concludes with an evaluation of progress so far throughout the VRU control system project leaving the system ready for implementation.

2. Introduction

The project will be a control system upgrade for VRU compressors situated on the site, with the aim of improving unit reliability and operation. The project is to be justified through evidence analysis, and from that, three main potential solutions to the problem will be researched, costed and considered. A design specification will be compiled to highlight the criteria the upgrade must meet, and from this a test plan will be devised. An ideal solution will be chosen as the one which best fits the functional specification and will be planned for implementation. Relevant company and engineering policies will be considered throughout to plan the process to the highest level.

3. Project Background, Problem Definition and Constraints

3.1 Process overview

The propane vapour recovery compressors (VRU 1 & 2) are designed to control the pressure within the propane spheres. Each compressor is responsible for a set of different spheres, with a pressure controller on each bank.

If a single compressor is offline, the other online compressor can control the pressure in both sphere banks with the vapour lines combined.

This pressure control is necessary as the optimum propane operating temperature is between 2 and 4°C. The ambient temperature has a large influence on the control and if the temperature climbs too high, the liquid is prone to 'flashing off', expanding and forming vapour, increasing the pressure. The compressors cut in at 4.4kg/cm² and load as the pressure increases, at maximum load at 4.7kg/cm², maintaining the correct pressure to prevent the temperature dropping to 0°C.



Figure 1: VRU Compressor and instrument panel

The two VRU systems are identical, depending on which VRU is online.

3.2 Existing system operation

The VRU trains obtain their set point and cut in/out times from two pneumatic pressure controllers in the field and are located approximately 30 metres from the VRU and measure the sphere line process pressure.

Each compressor loading sequence is controlled by its own respective pneumatic controller. These output a 3-15psi air signal based on the process pressure across a range of 4.3 to 4.7kg/cm².

Subsequent loading is then performed by operation of three pressure switches, PS-1577B/C/D for 50%, 75% and 100% respectively. Following a review of compressor relay logic documents JA08/4585/Z Sheets 1 & 2, Appendix 1 table was compiled to display the SOV switching and loading order.

During start-up, time delay relay is energised for 60 seconds, this starts a timer to open the contacts that bypass the trip for the low lube oil pressure. This hold out allows the machine to start and get up to speed to hold out the trip until the 60 second timer is up. By this point the machine will have a healthy lube oil pressure from its own mechanical pump. If this is not the case, the machine will trip following completion of the timer.

3.3 Problem definition

The existing system is controlled through an aging relay logic panel and pneumatic controllers, faults frequently plague the operation.

Multiple reoccurring issues regarding cut in and out of the compressors have become apparent, shown by the work requests in appendix 2 & 3. The rectifications involved troubleshooting the pneumatic pressure controller set points and adjustment as the existing tolerance had slipped over time. Failure for the compressor to cut out can result in cavitation and damage to the machine, potentially rendering it unusable for a long period of time.

Appendix 3 shows other issues rectified involving the timing relays not seating correctly. Losses such as this are costing the company money as useful product is being flared unnecessarily. Flare line gas flows are tightly regulated, and increased emissions will also mean a higher environmental tax for the company. Another risk has been highlighted in that continued pressure increases as a result of the VRU being down could result in a PSV lifting and process gas releasing to atmosphere. Even with no further consequences, this will be recorded as an environmental incident and mean costs and

potential fines from the HSE, incidents such as these will also have an impact on company PR and reputation.

3.4 Target issues

After reviewing work requests and history in the system it can be deduced that the three main targets for improvement are:

- Set point adjustment and pneumatic controller
- Relay logic and timers
- Compressor selection and loading

The project will aim to remove the existing problems associated with these and address the issues. This will increase the mean time between repair, minimise compressor downtime, reduce costs imposed by poor compressor control and reduce the risk of an environmental incident through safer operation. The need for this upgrade is further highlighted by the preventative maintenance work carried out on this system yearly.

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3.5 Constraints

3.5.1 Safety

The refinery is a high consequence listed site and so is under regulation by the Health and Safety Executive. The scope of work falls under the Health and Safety at Work Act 1974, other regulations apply for this design such as Electricity at Work 1989.

The internal company policies such as Life Saving Rules and PPE requirements set out by the Permit to Work system will also need to be adhered to for work to be allowed to commence. Each permit will be risk assessed specific to the job and authorised by maintenance and operations before issuing.

3.5.1.1 Risk assessment and MOC

A risk assessment was performed as part of the Management of Change process (MOC). This involves a review of any new potential hazards presented by the upgrade and must be completed in line with the oil company's internal policies as this is not 'a like-for-like change'. The risk assessment PP-PEM-FRM-0027 builds upon a Process Hazard Analysis previously carried out on the existing installation. These documents refer to a risk matrix PP-HES-GUI-0009 (Valero, 2020) that classifies the different levels of risks presented by comparing severity verses likelihood levels.

To summarise, the outcome of the MOC risk assessment addressed three main hazards:

- *Sphere vapour line over pressure to above 5.3 kg/cm² and lifting of PSV, releasing propane gas to atmosphere.*
- *Pressure increasing past 4.7kg/cm² with no indication shown to highlight the increase.*
- *Compressor cut-in is reached, however it fails to start, whilst second VRU is not commissioned.*

The consequences of these occurring included pressure being allowed to exceed 4.7kg/cm² as indication is topped out causing the flare valve to open. As a result, environmental fines for the company and damage to plant/personnel along with potential loss of containment.

Therefore, the following controls were implemented:

- *Cut-in of selected VRU compressor should the pressure reach the set point along with appropriate loading to reduce pressure before flare valve operation.*
- *Expanding of measurement range of VRU cut-in indication to 6kg/cm². High pressure alarm to be set at 4.6kg/cm² to indicate pressure has begun flaring. This is also to include NAMUR alarm saturation standards.*

- *Compressor ‘failure to start’ alarm to be implemented to provide a notification to operations, allowing them enough time to act. (Valero, 2020)*

3.5.2 Environment and sustainability

The improvements to this system will allow proper control of the compressors with successful operation preventing flaring as a result of high propane pressure in all normal plant operation scenarios. This also applies to the further risk of atmospheric release of hydrocarbon due to this increase in pressure.

The upgrade will utilise modern components and equipment to replace the old system, these replacements will be more reliable and thus need to be changed out less-often, resulting in less waste. Components will initially be sourced from the company stores where possible as these have already been delivered and will not need freight and packaging. This will also result in fewer components ordered separately and so less waste. The design of this system should result in a reduction in maintenance resources and parts when under normal operating conditions, one which greatly improves upon the old design.

In keeping with the hazardous area drawing 50-ZA-003-05 the compressor and spheres come under the rating of Zone 2 IIC T3. This means all equipment selected for the field must have an ATEX rating equivalent or higher for this location. Racking room equipment will be kept within a safe environment and will house any energy limiting barriers.

3.5.3 Professionalism, legality and ethics

Throughout the project process, professionalism was maintained through following approved codes of practice and consulting the project with management. Company rules and guidelines have been followed and sensitive company information has been withheld and kept confidential. Failings of the design can result in a breach of safety regulations and fines and restrictions put into place by the HSE for the company and individual if they are found liable.

Engineering must always be carried out with consideration towards ethics, with consideration given to where materials and labour are sourced. To ensure this, only approved vendors have been used throughout the project.

4. Functional Design Specification and Test Plan

4.1 Performance

4.1.1 Functionality

The upgrade needs to control both VRU compressors, maintaining the correct line pressure and preventing it from reaching the flare valve set point or higher. Should any abnormal circumstances occur, the compressors should promptly trip, preventing a restart until the fault has cleared and has been manually reset.

4.1.1.1 System must be able to reliably operate both VRU compressors through use of either hardwired or software-based control logic.

4.1.1.2 VRU1 & 2 compressors must trip on the following corresponding unhealthy conditions:

4.1.1.2.1 Extra high temperature TSHH-1569 [1669].

4.1.1.2.2 High delivery pressure PSHH-1574 [1674].

4.1.1.2.3 Low suction pressure PSL-1571 [1671].

4.1.1.2.4 Low oil pressure (following completion of start-up timer) PDSL-1571 [1671].

4.1.1.2.5 High fin-fan vibration FAN-1 [FAN-2].

4.1.1.2.6 High suction separator level LSHH-1561 [1661].

4.1.1.3 Compressors must cut in at the desired set point of 4.4kg/cm² using a pressure value from sphere vapour line pressure controllers.

4.1.1.4 Compressor start procedure must energise fin-fans EAM-101A&B [102A&B] prior to output to compressor motor starter EAM-101C [102C].

4.1.1.5 Interlocks must force the start procedure to wait for a healthy run signal from the output of compressor fin-fan starters EAM-101A [102A] & 101B [102B].

4.1.1.6 Compressors must load accordingly based on the sphere vapour line pressure, increasing and decreasing.

4.1.1.7 System must delay compressor loading for 10 seconds after start.

4.1.1.8 Loading must be achieved through operation of SOV-1578 [1678], 1579 [1679] & 1580 [1680].

4.1.1.9 System must hold out low lube oil trip during start-up for 60 seconds.

4.1.2 Operation and indication

Indication should be provided through use of either communication through DCS, a HMI or local annunciator panel. Provision must also be made for an analogue indication of the set point controller pressures. The indication must provide operations with information of the current running status and any standing trips or alarms.

- 4.1.2.1 System must be able to be stopped through use of a local physical ESD button for each compressor that latches and prevents starting.
- 4.1.2.2 System must be able to be reset through use of a local physical reset button.
- 4.1.2.3 A manual override must be available to prevent compressor loading.
- 4.1.2.4 Indication must be present through either HMI, DCS system or hardwired LEDs and must include:
 - 4.1.2.4.1 Compressor running light.
 - 4.1.2.4.2 Any standing trips documented in section 1.1.2.
 - 4.1.2.4.3 Current state of compressor loading.
 - 4.1.2.4.4 Fin-Fan start signal light.
 - 4.1.2.4.5 Sphere vapour line pressure indication.
 - 4.1.2.4.6 Bypass engaged light.
 - 4.1.2.4.7 Power supply failure indication.
 - 4.1.2.4.8 Current pressure indication

4.2 Ergonomics

The project design is for a prototype workshop-based system prior to field implementation and is required to be designed to meet the field size and weight restrictions. The location is within an existing cabinet of 1m wide, 2m long and 1m deep. All supplementary equipment such as power supplies and barriers will also be stored inside.

4.2.1 Size

- 4.2.1.1 Panel must be appropriately sized as to fit in the Plant 29 & RTW racking room cabinet whilst still having enough room for all control equipment.

4.2.2 Weight

- 4.2.2.1 Panel must be able to be supported to back plate of racking room cabinet.
- 4.2.2.2 Should the weight prevent wall mounting support, legs must be fitted.

4.2.3 Design

- 4.2.3.1 The system must be designed with operation and maintenance in mind. Buttons and indication must be in a position where viewing and operation is comfortable and reduces the chance for the user to look for potentially unsafe workarounds.
- 4.2.3.2 System bypasses must need either a key or some form of tool to be consciously negotiated around or operated.

4.3 Safety

- 4.3.1 As stated in 1.1.2, the system must feature safety trip systems and interlocks to prevent starting in the event of a trip standing.
- 4.3.2 Power to the system must be able to be isolated and locked out.
- 4.3.3 System must be suitably fused for the correct power rating.
- 4.3.4 Control transmitter range must be appropriate for measuring application to include indication below and above compressor cut in and out points.
- 4.3.5 All parts of the system must be tested prior to site commissioning.
- 4.3.6 The design of the system must be such that it reduces the chance of human error in high pressure critical situations. All emergency stops and isolations must be clear, accessible and locations keeping within traditionally expected patterns.

4.4 Reliability

4.4.1 Redundancy and protection

- 4.4.1.1 The system must have appropriate dual power supply redundancy measures with diodes.
- 4.4.1.2 The power supply must be suitable fused to protect from overcurrent.

4.4.2 Maintenance

- 4.4.2.1 The system must be able to run uninterrupted for extended periods of time with very little maintenance.
- 4.4.2.2 The system must be designed with maintenance access in mind.
- 4.4.2.3 Parts used must be serviceable and replacements easily sourced.
- 4.4.2.4 The preventative maintenance procedure must be adjusted to include the upgrade for this system.
- 4.4.2.5 Pressure indication and control needs to be done through an electronic transmitter in order to provide more accurate and reliable control over the existing pneumatic set point controller.

4.4.3 Product life span

- 4.4.3.1 System must be of a design and use components that enables the system to run for at least 5 years with minimal maintenance. The system should not need replacement and should last the life of the business unit provided no major changes are required.
- 4.4.3.2 The system needs to be reliably operating as the VRU compressors are in daily use, especially true during the warmer months.

4.5 Hardware

- 4.5.1 Suitable barrier protection must be used to provide adequate hazardous area energy limiting protection for any intrinsically safe equipment.
- 4.5.2 Any intrinsically safe wiring must satisfy the ATEX Directive and be separate from any non-IS loops
- 4.5.3 Field equipment and instruments must be suitably rated for the hazardous area zone and classification in which it is to be located.
- 4.5.4 Where electronic transmitters are used, failure modes and detection must be configured and must follow NAMUR alarm standards and saturation points.

4.6 Environment

4.6.1 Cabinet equipment

- 4.6.1.1 Cabinet equipment must be suitable for operation within a high electromagnetic background environment.
- 4.6.1.2 Equipment will be located within a humidity-controlled environment.
- 4.6.1.3 Temperature will be ambient at around 20 degrees Celsius.

4.6.2 Field equipment

- 4.6.2.1 Must have enough Ingress Protection for use outside where rain will be a common occurrence.

4.7 Applicable standards

- 4.7.1 IEC 61131-3 Programming standard
- 4.7.2 IEC 61511 Functional safety – Safety instrumented systems for the process industry sector
- 4.7.3 BS 7671 Requirements for electrical installations
- 4.7.4 PCLT-S 003 Valero alarm management standard
- 4.7.5 CTEMS INST-MGT-1 Valero Management of critical instrumentation
- 4.7.6 DEP 32.80.10.10 Design and installation of critical instrumentation
- 4.7.7 ATEX directive 95

A testing plan for this specification can be found in appendix 5.

5. Literature Review

Each of these potential solutions aims to conform to the company policy and approved manufacturer standards, whilst maintaining a different approach at improving the system.

5.1 Continuous equipment

Here selected equipment will be detailed that do not change throughout the potential solutions due to the specification and company requirements.

5.1.1 Pressure controller

The two VRU systems require an electronic form of pressure measurement and indication meet the specification. The instruments will be mounted in the field on the sphere vapour line, mounted on the access platform to the pipe track. They will be subject to coastal weather conditions and require a suitable ingress protection rating.

The Rosemount 2051 pressure transmitter will be reviewed to find if deemed suitable. This analogue transmitter is manufactured by Emerson and is already widely used on site, and so meets company standards.

This transmitter comes in a variety of different ranges and can be specified up to the exact requirements of the scenario. For the purpose of this installation a range 4 will be required (-20.7 to 20.7bar) as this is the smallest range that still allows for 0 to 6kg/cm². This instrument can output 4-20mA current with HART capability whilst running off a 24V power supply. The accuracy is stated by Emerson, *"Performance up to 0.05% of span accuracy."* (2020) This provides a tolerance of 0.003kg/cm² across the given range.

Strengths	Weaknesses
Very accurate.	Will need IS barriers to be implemented in racking room before use.
Powered by 24V supply and outputs 4-20mA, compatible with DCS and PLC options.	
ATEX rated to be intrinsically safe and has a more than sufficient IP rating (66).	
Very reliable and maintenance friendly.	
Complies with company standards.	
Opportunities	Threats
HART Compatibility and can be configured into AMS suite.	More expensive than other market alternatives.
SIL Rated.	
Can be specified for each application.	

A SWOT analysis was compiled to briefly highlight the main benefits of this transmitter versus any potential issues. As this is already widely used on site, the reliability is proven along with its integration into the existing control system along with part availability on stores stock.

The cost per item of these are £1248.35 for a Rosemount 2051CD4 and two are required.

5.2 Distributed control system solution

5.2.1 DeltaV Architecture

Utilising the already established Distributed Control system (DCS) system for the control side of the upgrade is also a consideration. The Emerson DeltaV DCS is modern and proven reliable, whilst also having the ability to contain both trip and control elements.

The architecture of the Emerson system is displayed in figure 4, with the base processing being performed on a main server and processor. These then communicate through a high-speed ethernet control network with the operator stations and the input/output modules. A current signal with HART functionality is used between the I/O modules for communication and operation of the analogue primary elements.

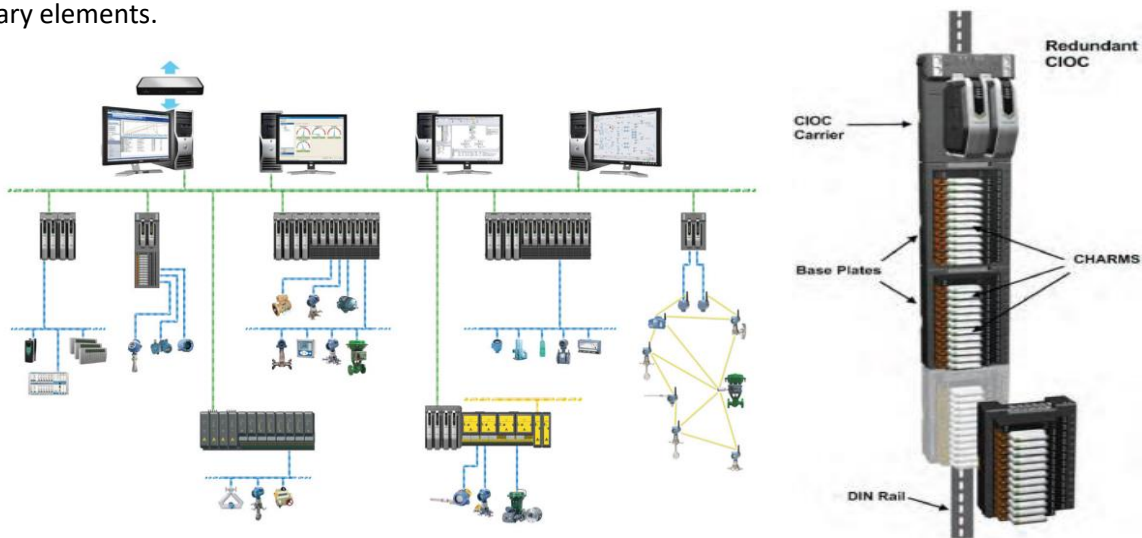


Figure 2: DeltaV Architecture (Emerson, 2010)

: CIOC layout (Lyndon, 2020)

5.2.2 Benefits and application

The DeltaV system would incorporate the use of CHARM I/O to connect the field equipment to the DCS. As stated by Emerson, *“Electronic Marshalling provides I/O type connectivity in a single channel component – called a CHARacterization Modules (CHARM)”* (2020) These can be specified to be intrinsically safe to act as energy limiting protection to save the need for implementing a barrier.

The Emerson DeltaV Characterisation Modules have a built in 250Ω for resistor and are 30mA current limiting, this applies to the 24V loops for the two wire analogue inputs suggested with this design. Here there is enough allowed current for the NAMUR alarm saturation limits whilst also preventing overcurrent of the instrument. (Emerson, 2020)

The advantages of the DeltaV CHARM marshalling has over traditional cabinet wiring. They estimate that over 1000 termination points, 400 to 600 hours of labour are saved by the reduction in field

wiring. This also leaves more space within the cabinet for extra terminations. (Lyndon, 2020) Space is tight within the cabinet and so space conservation will prove crucial.

The controllers for DeltaV feature a built-in redundancy, this satisfies the project specification and complements the overall reliability and safety of the system. Emerson explain how I/O communication or controller hardware failure detected by the continuous self-tests will trigger an automatic switchover to the second redundancy controller. (2017)

The power supply data sheet displays the performance of the supply this solution would use, with a 24V with minimal fluctuation and 5A current output and the correct specification for connecting to the mains input. This supply would be adequate in supplying the 24V DC power to the instruments required. Although only rated at IP20, the DIN rail mounting environment will be indoors and humidity controlled so will not present a problem. (Emerson, 2019)

Advantages of DeltaV are explained by Bai, Hongyu et al., such as the expansion of DeltaV by connecting another controller or workstation. This is automatically detected by the system and is useful for the project application as this will be the installation method for the VRU controllers. (2006)

It is the company policy to attempt to use the DCS for control options where possible if the infrastructure is available. This is due to factors such as:

- Operator familiarity
- Control and trip functionality
- No programme version management required
- Visibility to operations

5.2.3 Design and costing

The design of the system is shown in figure 5, this highlights the three main areas within the instrument loop:

- Existing infrastructure
Shown by the blue dashed box; this equipment already exists, and the upgrade will be merging into this system.
- New installation
Shown by the green dashed box; this is to be the new equipment installed within the blending and shipping racking room cabinet. Two I/O CHARM drops coupled with a pair of CIOC controllers each, including the extra for redundancy.
- Field equipment
Shown by the red dashed box; the primary elements located in the field. The two analogue inputs are new and will output 4-20mA through a HART loop to the NAMUR IS AI CHARMS. All others are 24V DC discrete signal outputting to IS DI and DO CHARMS.

After liaising with the DCS Project Engineer Dan Belli – a price estimate was provided for the DeltaV setup, this includes various charms, the rest have been costed as extra.

Item	Manufacturer	Vendor	Price each	Quantity	Total
48 CHARM box	Emerson	Emerson	£15,000	1	£15,000
DI CHARM	Emerson	Emerson	£100	10	£1,000
DO CHARM	Emerson	Emerson	£100	12	£1,200
AI CHARM	Emerson	Emerson	£300	2	£600
				Total:	£17,800

Figure 3: DCS costing

Further details can be found on the Emerson document EU-FE-48-AC-CIOC-HA-DEMO, which includes additional options for cabinet heaters and fans if required. (2020)

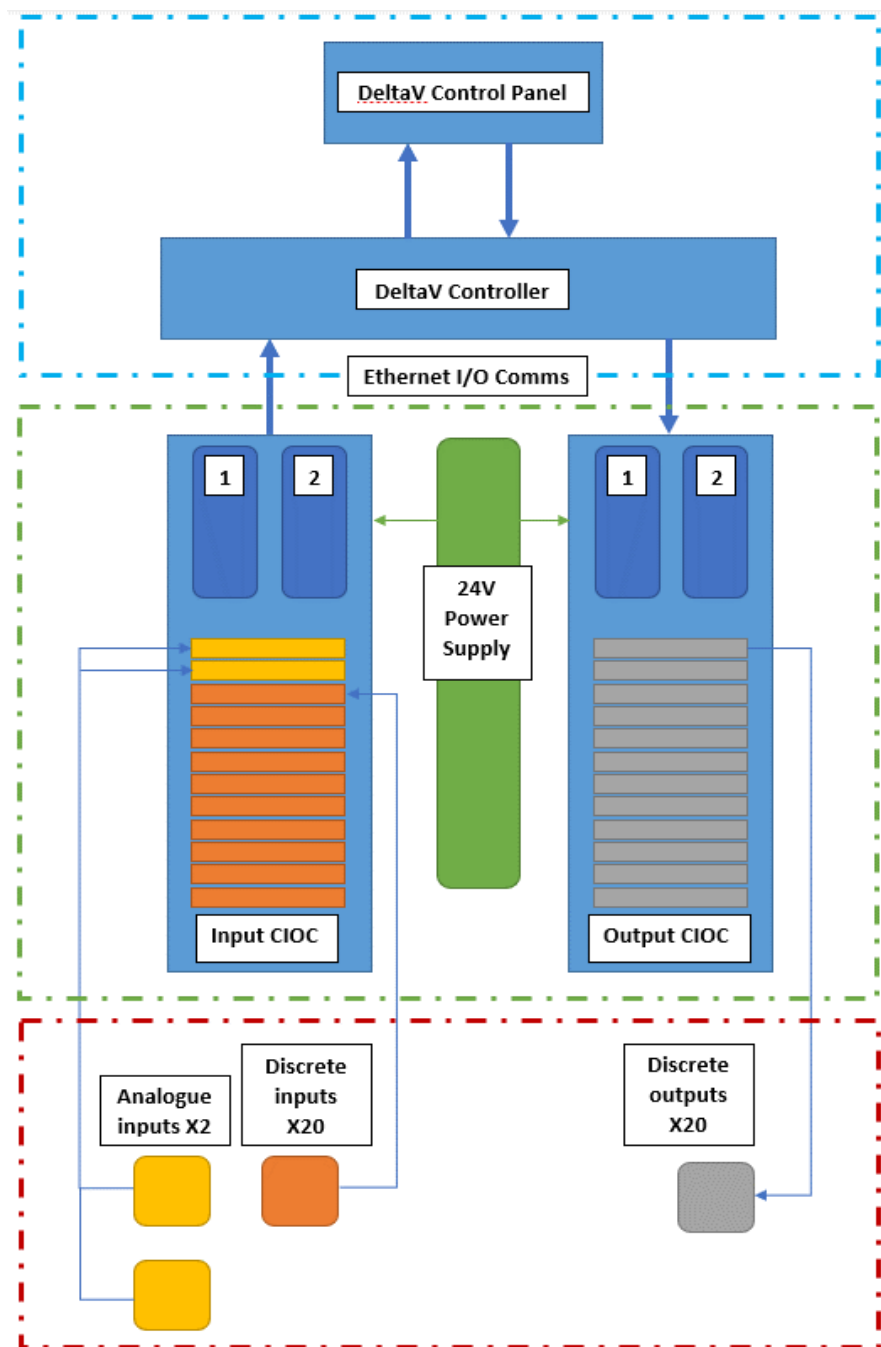


Figure 4: DCS solution block diagram

5.2.4 DCS method analysis and scoring

Strengths	Weaknesses
Merges into existing infrastructure, easily connected. Cabinet comes default fabricated from Emerson.	Very expensive. Any additional CHARMS required will quickly rack up cost.
Power supply included into cost and some CHARMS provided with quotation. Barriers not required.	Quotation does not include commissioning, Site Acceptance Test, Software documentation, cabling design or loop drawings.
System already familiar to operations and no programme version management required.	
Minimal cable marshalling required, saving labour costs.	
Preferred company standard option and replacement parts already on stores stock. Familiarity with maintenance department.	
Reliable and features a controller and CIOC redundancy system.	
Opportunities	Threats
Control and trip functionality on DCS system. System can also be SIL rated if desired.	If additional controllers are required due to lack of existing controller capacity and infrastructure. Cost will be triple.
CIOC cabinet can also be fitted in Zone 2 hazardous area locations if required.	COVID-19 company restriction and policy may prevent use of DeltaV hot rig.

Figure 5: DCS SWOT Analysis

5.3 Programmable logic controller

5.3.1 PLC review and design

This solution will involve the main bulk of the control performed through a programmable logic controller.

To be approved for use on site, the PLC must be chosen from the company approved manufacturers list, which for non Triconex systems, is the Allen Bradley ControlLogix. This PLC will allow the VRU control software to be programmed into the controller whilst maintaining a compact design. The chassis can be customised to include as many I/O or communication modules as required. This design will utilise a communication module to set up ethernet comms to the DCS control system to provide indication on the operator stations.

As explained by PLCHardware, the processor features 2048Kb internal memory with 478Kb I/O memory with the option for expansion memory cards if desired. It is also specified that to establish communication, an interface module must be installed. (2020) The program for the VRU upgrade will not utilise a large amount of memory so 2MB will suffice, however if required larger memory processors can be purchased at additional cost.

The Allen Bradley ControlLogix 5561 PLC is widely used on site in a variety of application and its reliability is proven through industrial usage. The company stores already hold spare cards and module for this particular PLC making maintenance and part sourcing easier. However, the company standard currently discourages PLC use for new projects unless deemed necessary.

An advantage of using a PLC over the existing system reduces the amount of failure points within the system, they also do not wear in the same way as the relays currently installed and will fail to a desired safe state. As stated by V. Segovia and Theorin, *“Additionally, due to the solid-state nature they offer greater reliability, require less maintenance, have a longer life than mechanical relays or other analog equipment, and can withstand extreme industrial environmental conditions.”* (2013)

Reviewing a comparison, it is explained by Fauci that the initial cost of a PLC eventually becomes offset by savings in maintenance and downtime later down the line. The cost of the software is traditionally higher than the equivalent hardware of a different system but ultimately helps to reduce long term costs. (1997)

A diagram of how the PLC will be connected to the system is shown in figure 7.

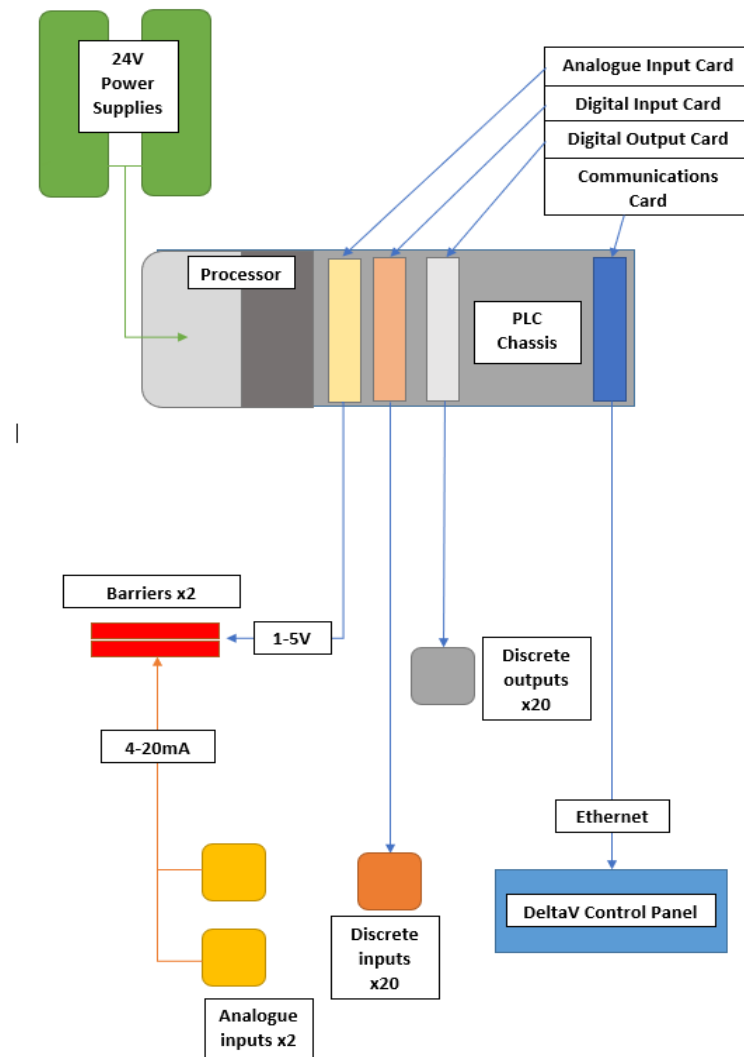


Figure 6: PLC design block diagram

The dual 24V power supplies will power the PLC rack containing the I/O cards and communication modules. Barriers will be used to keep the analogue input loops intrinsically safe, whilst the Discrete I/O will be powered through the PLC. Control and indication with the DCS/HMI will be established through ethernet from the communication card.

5.3.2 Analysis and costing

To install the PLC solution, 24V power supplies must be included with a redundancy feature should one fail. This system will also require barrier to be fitted to the analogue input loops to maintain the ATEX and intrinsically safe rating of the system.

The selected barrier for a 2-wire SMART 4-20mA analogue input is the MTL7787+, the details of this are documented in appendix 7. This barrier includes the 250Ω resistor and 50mA fuse rating required for the Rosemount 2051. The energy is limited through the Zener diode to protect the safe area terminals in event of excess current. (MTL, 2018)

The 24V DC power supply will be powered by 240V AC mains supply, two of these supplies will be required. Reviewing the datasheet, the Phoenix Contact Quint 24V DC supply allows for redundancy connection between two units and ensures 12ms trip at six times the nominal current. This circuit protection ensures the barrier fuses are not blown and prevents damage to the PLC processor. IP is listed at IP20 and the ambient condition data matches the suitability for racking room usage.

A costing spreadsheet and SWOT analysis was compiled for this solution, shown in figures 8 and 9.

Item	Product code	Manufacturer	Vendor	Price each	Quantity	Total
13-slot ControlLogix Chassis	1756-A13	Allen Bradley	Routeco	£507	1	£507
Power supply 120/220V ControlLogix	1756-PA72	Allen Bradley	Routeco	£622	1	£622
2-Port Ethernet module	1756-EN3TR	Allen Bradley	Routeco	£2,640	1	£2,640
Processor 2MB memory	1756-L71	Allen Bradley	Routeco	£3,640	1	£3,640
Empty slot cover	1756-N2	Allen Bradley	Routeco	£19.40	2	£39
Isolated input 16 pts 10-30VDC	1756-IB16I	Allen Bradley	Routeco	£380	2	£760
DeviceNet module	1756-DNB	Allen Bradley	Routeco	£841	1	£841
Analogue input module isolated w/HART	1756-IF8IH	Allen Bradley	Routeco	£1,630	1	£1,630
Digital output module 16 pts 24VDC	1756-OB16D	Allen Bradley	Routeco	£557	2	£1,114
Relay output module NO 16 pts	1756-OW16I	Allen Bradley	Routeco	£428	2	£856
Terminal block 36pin	1756-TBCH	Allen Bradley	Routeco	£58.40	8	£467
1 Channel 7787+ barrier	MTL7787+	MTL	RSComponents	£112.20	2	£224
Quint switch mode PSU 264VAC input 24VDC output 10A	2866763	Phoenix Contact	RSComponents	£249	2	£497
					Total:	£13,837

Figure 7: PLC solution cost

Strengths	Weaknesses
Cheaper than a DCS alternative.	Company standpoint prefers usage of DCS for control where possible.
HART capability for analogue inputs.	PLC program version will need to be managed and updated.
Power supply redundancy and failsafe options.	PLC must be kept in racking room or Exd enclosure.
Separate I/O cards for each VRU to prevent common failure for both units.	
Equipment already on stores stock and familiar with maintenance department.	
Reliability proven through existing ControlLogix PLC usage already on site.	
Opportunities	Threats
Potential for expansion with additional modules	
Communication ports for either DeltaV or HMI	

Figure 8: PLC Solution SWOT analysis

5.4 Relay logic and trip amplifiers

5.4.1 Review and design

Building upon the existing system and replacing the older style relays with modern ones that are more reliable and versatile is another potential option. To improve the control system the electronic pressure transmitter will need to be utilised in conjunction with a series of trip amplifiers to control the compressor start and stop.

These new relays will need to be an upgrade from the old in order to reduce the failure rate and make the upgrade worthwhile.

Advantages of the traditional relay are documented by Karl Zimmerman, explaining how the single-purpose relay can be tested and commissioned far more easily than that of programmable logic. The resultant logic drawing of the system allows thorough testing. Zimmerman states *“A technician can have a blueprint of the design and systematically highlight each device and interconnection until the entire system is tested.”* (2008) This makes fault finding easier and faster, it also means a single part can be swapped out swiftly to restore functionality to the system, whereas a whole microprocessor may fail. D. Baradi and J. Xavier also explain how the success of fault-finding relay logic relies largely on the quality of the logic documentation. (2018)

This system will involve new relays being added along with new logic documentation to suit. The replacement Phoenix Contact 24V relays are fitted with power indication to aid with troubleshooting, as this is a large disadvantage with this design. A 6A fuse is also incorporated for circuit protection and as this will not be required to rapidly switch repeatedly, the response time and life cycle is enough. (Phoenix Contact, 2019) The design of this relay prevents the main switching block from coming loose as found with the existing setup as it is all a single piece.

The analogue inputs from the field pressure controllers will feed back to a series of trip amplifiers that will operate the loading SOVs at set current limits. Therefore, two sets of four trip amplifiers will be needed. The Pepperl & Fuchs transmitter amplifier will be utilised to detect line faults, switch the relay outputs to the SOV and allow configured alarms. (Pepperl+Fuchs, 2020)

The design of the system can be seen in figure 10.



Figure 9: Relay and trip amplifier solution design

5.4.2 Analysis and costing

A costing spreadsheet and SWOT analysis was compiled for this solution, shown in figures 11 and 12.

Item	Product code	Manufacturer	Vendor	Price each	Quantity	Total
Phoenix Contact, 24V dc Coil Non-Latching Relay 5PNO, DPST	2963747	Phoenix Contact	RSComponents	£62	20	£1,240
Transmitter Power Supply	KFD2-CRG2-1.D	Pepperl&Fuchs	Pepperl&Fuchs	£262	2	£524
Current/Voltage trip amplifier	KFD2-GS-1.2W	Pepperl&Fuchs	Pepperl&Fuchs	£197	8	£1,579
					Total:	£3,344

Figure 10: Relay logic costing

Strengths	Weaknesses
Simple design and installation.	Inherent problems with electromechanical relays still exist.
Improves upon old method through electronic analogue input loading and relay power and fault indication.	No analogue indication or feedback to DCS or local indicator.
Very inexpensive.	Lots of wiring required taking up a lot of space within cabinet.
Opportunities	Threats
	Updated design is very similar to existing system.

Figure 11: Relay logic SWOT analysis

5.5 Overall comparison and conclusion

The three main solutions will be broken down into a decision matrix and scored against various categories up to a maximum of 10:

- Reliability – How the solution meets expectations regarding successful operation and failure rate.
- Redundancy and protection – How well the solution protects against complete failure or fails in a safe manner.
- Overall cost – Based on the cost estimates provided (higher score for less cost).
- Maintenance difficulty – How easily parts can be swapped or repaired on the solution.
- Part sourcing – How easy it is to source replacement parts or equipment.
- Development – How compatible the solution is to additional installations/modifications and new equipment.
- Testing – The ease at which the system can be thoroughly tested during commissioning or preventative maintenance.
- Company requirements – The level at which the solution satisfies company preferred methods.
- Ergonomics – The size and weight suitability of the solution.
- SWOT – Scoring based off the SWOT analysis outcome.

Solution	DCS	PLC	Relay
Strengths (+)	6	6	3
Opportunities (+)	2	2	0
Weaknesses (-)	-2	-3	-3
Threats (-)	-2	0	-1
Total	4	5	-1

Figure 12: SWOT score

The SWOT analysis positives verses negatives were totalled in figure 13, these will be used within the final scoring matrix.

5.5.1 Scoring matrix

The resulting scoring table can be seen in figure 14, with the DCS solution providing the highest score.

Category	Solution score		
	DCS	PLC	Relay
Reliability	9	7	4
Redundancy and protection	8	7	4
Overall cost	3	5	9
Maintenance difficulty	6	6	6
Part sourcing	5	6	3
Development	7	7	4
Testing	6	6	5
Company requirements	8	6	3
Ergonomics	8	6	4
SWOT score	4	5	-1
Total	64	61	41

Table 1: Decision matrix

5.5.2 Decision conclusion

Reviewing the decision matrix table, the best fit for the project is the DCS solution, however it scored very similarly overall to the PLC solution. The reason for this is both these methods are very similar with only a slight cost difference. The DCS solution scored higher mainly due to the reliability and ease of integration and development of the system into the infrastructure. It is also the most modern and is kept up-to-date automatically as it merges with the DeltaV system. The relay solution scored far lower because it is not a substantial enough development on the original system, it also does not have functionality such as HART and DCS integration.

The DCS solution will be chosen under the conditions that the threats noted in section 5.2.4 do not pose an issue.

- Approval is currently pending for use of the DeltaV hot rig during company COVID-19 restrictions. Having this denied will prevent use of the Emerson control software.
- Pending availability check of DeltaV infrastructure controller free space, failure of space availability means the budget will drastically increase.

If the threat of these issues is not removed, the PLC solution will be chosen as it scored very highly and similarly to the DCS solution but without any threats.

6. Project Planning, Work Breakdown and Management Techniques

6.1 Work breakdown structure

A work breakdown structure was compiled to aid with project planning, all sections were split up until the lowest level was detailed, shown in figure 13.

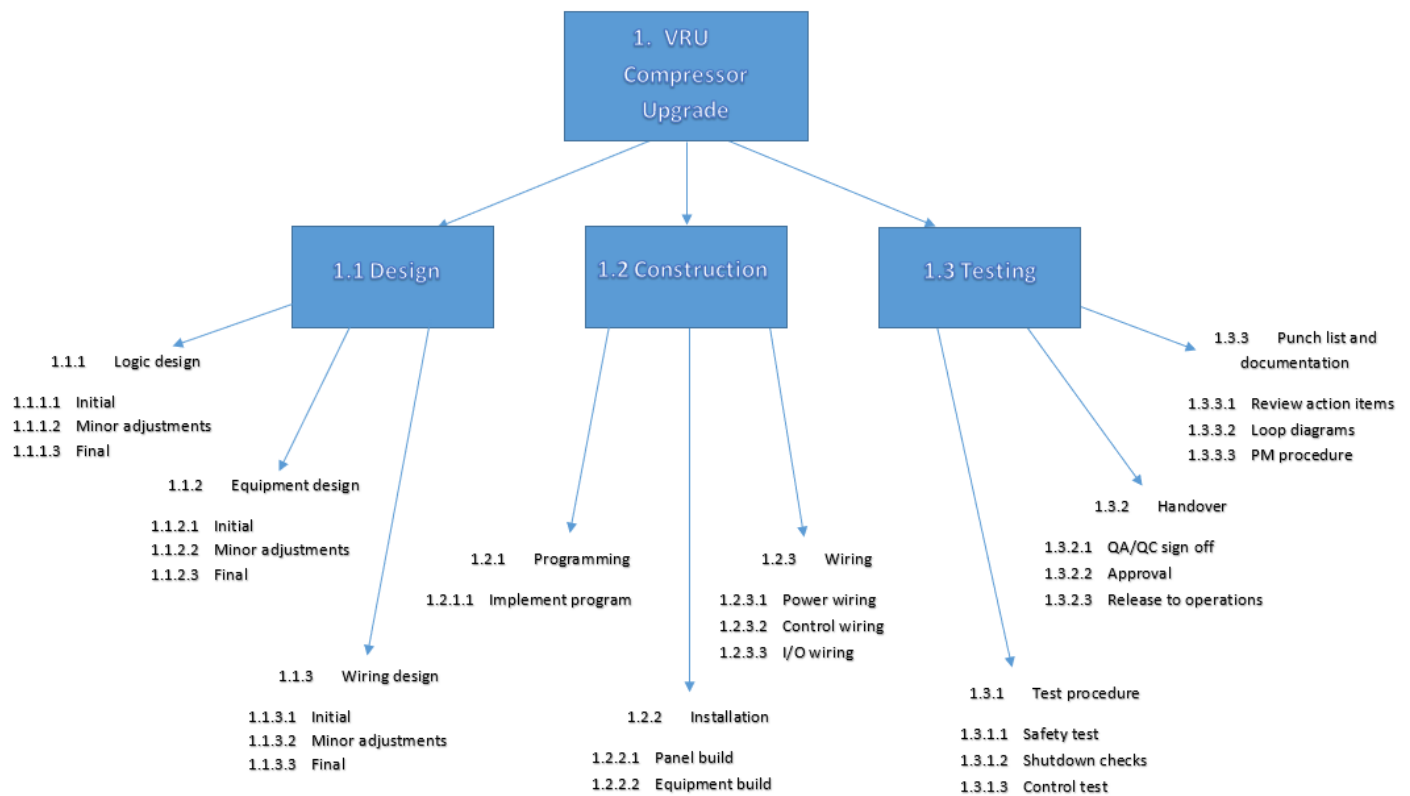


Figure 13: Work breakdown structure

6.2 Gantt chart and contingencies

The project has been planned from the start date of 08/12/2020 to completion on 25/01/2021, this is due to a company turnaround starting end of January so all project work must aim to be completed by that date. The project tasks are broken down and will be updated as percentages complete or deviate from plan. The Gantt chart can be seen in appendix 6.

To achieve this plan, various actions and considerations have been given to potential project threats. These contingencies will help reduce the consequences or risk of the issues.

Threat	Potential Consequences	Actions and Considerations
Company shutdown starting end of February for two months.	Large reduction in available man hours for project execution and construction.	Begin construction in December and allocate more manhours within this time.
COVID-19 reduces availability of manufacturer items.	Reduction in vendor stock and increased delivery times.	Order equipment a month earlier than normal, move budget to the preceding month to account for this. Company stores to be utilised where possible.
Overhead costs from other priority projects take budget from this one. (Large cogeneration project currently ongoing and TAR work are big expenses.)	Loss of budget, delay of project start date.	Begin project construction earlier than originally planned. Obtain budget approval from supervisor prior to commencing.

Table 2: Contingencies

As this is a project with a budget under £100,000 the company specific small project cost spreadsheet was used. Here the two applicable categories had costs allocated to them on a monthly basis based upon the overall budget. The costing plan can be found in appendix 7.

- *Manhours*

The manhour costs were taken as a predicted total of 400 hours across the project timeline. Here the given labour rate is taken at £15 per hour to calculate the figures.

- *Materials*

Materials have been split into two months to account for purchasing/acquisition of the main control unit (December) and remaining materials (January). This has been chosen as a result of an action deduced within the *Threats and Vulnerabilities* section.

These figures can be further added into the three budget categories shown;

- Original – This is the original budget initially stated, detailed within the project proposal. This has not changed and will remain at £20,000 total for materials, split across the months.
- Current – This figure will change based upon any budget adjustments, allocation or removal.
- Forecasted – The forecast is based upon the prediction of material or resource delivery and can change if manufacturer delivery times or quotes change. Any adjustment here may mean budget has to be taken from one month and added to the next.

6.3 Management techniques and milestones

The management technique adapted for this project is the agile style, this involves continually working towards smaller goals, such as the ones detailed in the work breakdown structure. This has been chosen due to the current climate and shifting environment. Maintaining frequent short-term goals ensures progress is continually achieved and reduces the chance of these goals being impacted as the plan is always up to date with the situation. As explained by D. Rigby et al., utilising this method ensures everyone in the process is kept up to date through daily meetings and any new problems can be quickly identified. (2006)

To manage the process, delegation of authority has been used to obtain information from different sources, this includes fault history, budget approval and instrument data.

Various milestones have been set in place by analysing the work breakdown structure to maintain the agile style:

- Material acquisition – 11/12/2020
- Logic design – 16/12/2020
- Logic implementation – 05/01/2020
- Equipment installation – 10/01/2020
- Build completion – 12/01/2020
- Testing completion – 21/01/2020
- Handover – 23/01/2020

7. Conclusions and Recommendations

The project process has been planned as far as possible at this stage with any potential development threats considered to a reasonable level. The initial stages of background research and problem investigation have cemented the justification behind the necessity for this upgrade. The target areas have been highlighted for improvement to ensure the chosen solution solves the issues.

In order to develop further, approval will need to be sought for the threats documented in section 5.5.2. All steps have been taken to include a contingency solution should this approval not be granted, and any delays here may affect the plan slightly. The selected and contingency solutions scored very high and clearly outclassed the more traditional relay logic method. Selection methods have been thorough, and all effort has been made to consider all relevant aspects of the system.

To have this project carried out in an industrial environment, the steps throughout the project process and to obtain authorisation have been carried out in a professional manner. Various company practices and standards have been followed, this includes safety related documentation and standards. Relevant personnel have been informed and consideration given to ethical and environmental aspects, along with implications on the wider world.

Overall, all attempts have been made to breakdown and plan every element of the project to within a reasonable level. Although due to the current changing climate with respect to COVID-19, some conditions have caused difficulties with the planning process.

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9. Appendix

Appendix 1: Compressor loading logic table

Loading	Switch Point Rising (Falling)	Pressure Switch VRU1 (VRU2)	Loading SOVs Energised VRU1 (VRU2)	Cylinders Active
0%	6.5psi (3.5psi)	PS-1577A (1677A)		
25%	6.5psi 10sec delay (3.5psi)	PS-1577A (1677A)	SOV-1578 (1678)	1 & 5
50%	10psi (7.8psi)	PS-1577B (1677B)	SOV-1578 (1678) SOV-1580 (1680)	1 & 5 2 & 6
75%	12.3psi (10.3psi)	PS-1577C (1677C)	SOV-1578 (1678) SOV-1579 (1679)	1 & 5 3 & 7 and 4 & 8
100%	15psi (13psi)	PS-1577D (1677D)	SOV-1578 (1678) SOV-1579 (1679) SOV-1580 (1680)	1 & 5 3 & 7 and 4 & 8 2 & 6

Appendix 2: Cut in/out work orders

Work Request

Work Request #: 940196

Status: Approved

Work Category: Maintenance Repair

Notification #: 14905175

Work Order #: 6138729

Created By: [redacted] Tim

Reported By: [redacted] Tim

Changed By: Sutton, Marcus

Changed On: 10/01/2020 12:06 PM

Approved By: [redacted] Marcus

Expand All Collapse All

Short Description: 21-C-101 & 102: CHECK CUT IN/OUT POINTS

Detailed Description:

21-C-101 & 102: CHECK CUT IN/OUT POINTS:
21-C-101 & 102 RTW C3 VRU - NOT CUTTING IN UNTIL WELL ABOVE THE SETPOINT, AND NOT CUTTING OUT UNTIL WELL BELOW - PLEASE INSPECT AND REPAIR.
PLEASE CHECK FOR BOTH COMPRESSORS.

Asset Information

Plant: PL25 - Pembroke

Functional Location: PL25-02-0640-18-21C101
21C101, RTW E Corner

Planner Group: IN

Equipment: 10960973
21C101, Comp (965 RPM)

Main Work Center: IN-COR

Safety & Environmental

Safety Considerations

Work Request

Work Request #: 928599

Status: Fix it Myself

Notification #: 14867771

Created By: [redacted] Karl

Reported By: [redacted] Karl

Changed By: [redacted] Jacobb

Changed On: 08/07/2020 05:35 PM

Expand All Collapse All

Short Description: 21-C-101 Not cutting out on low pressure

Detailed Description:

21-C-101: Not Stopping On Low Pressure:
21-C-101, not cutting out at set pressure. Pressure reading 3.8 but VRU not cutting out. If you stop the compressor, when the pull the stop button out, it restarts, Please investigate and repair.

Asset Information

Plant: PL25 - Pembroke

Functional Location: PL25-02-0640-18-21C101
21C101, RTW E Corner

Planner Group: IN

Equipment: 10956910
21CM101, Motor 3.3KV - Propane Comp

Main Work Center: IN-COR

Actions Taken/Troubleshooting

21-PC-1677 set point too low, adjusted according to data sheet.

Work Request	
Work Request #: 899146 Status: Fix it Myself Notification #: 14794234	Created By: Meredith Reported By: Meredith Changed By: Ince, Daniel Changed On: 05/03/2020 09:58 AM Expand All Collapse All
Short Description: 21C101 PROPANE COMP NOT CUTING IN Detailed Description: 21-C-101 NOT CUTTING IN . PROPANE VRU 1 RTW. PLEASE INVESTIGATE FAULT AND REPAIR	
Asset Information	
Plant: PL25 - Pembroke Functional Location: PL25-02-0640-18-21C101 21C101, RTW E Corner Planner Group: IN	Equipment: Main Work Center: IN-COR
Actions Taken/Troubleshooting Relay logic checked, found TR2 not seating correctly, rectified, however motor still not starting. C1X relay blown fuse replaced. Resistor also found shorted inside starter. Rectified and compressor now starts.	

Work Request	
Work Request #: 773569 Status: Approved Work Category: Maintenance Repair Notification #: 14494298 Work Order #: 5610070	Created By: Lance Reported By: Lance Changed By: Marcus Changed On: 05/15/2019 07:57 AM Approved By: Marcus Expand All Collapse All
Short Description: 21-PC-1677: VRU: Replace Selector Switch Detailed Description: 21-PC-1677: VRU: Replace Pneumatic Selector Switch: Replace selector switch on pneumatic controller 21-PC-1677 for sphere vapour recovery. This is off the back of a call out where the switch got stuck and vru wasnt working correctly and venting gas to flare. the external of the switch is in poor condition but looks to be something along the lines of a fairchilds selector, unsure weather its hi or low.	
Asset Information	
Plant: PL25 - Pembroke Functional Location: PL25-02-0051-32-P-21P1677 21P1677, Propane To Vapour Recovery Planner Group: IN	Equipment: 11019739 21PC1677, Press Cntrlr Main Work Center: IN-COR
Safety & Environmental	
Safety Considerations	
Environmental Considerations	
Reliability	
Is this Rework? No Was this discovered during preventive or predictive maintenance? No Can the repair be made while the asset is online? Yes Is the asset currently operable? Yes Should a preventive or predictive maintenance plan be created for this task? No	
Finalization Information	
Priority: Urgent Suggested Start Date: 04/29/2019 Reason loss of gas to flare is a business loss, incorrect propane recovery can lead to excessive pressure in the sphere and possibly lift an atmospheric psv....	

PROJECT PROPOSAL DOCUMENT

Student Name: Daniel Ince

Project Title: Propane VRU Compressor Control System Upgrade

Date: 15/10/2020

Budget: £20000

Description of Project

This is a company-based project that involves the design and testing of an upgrade to an existing control system that is decades old, and has been the cause of repeated maintenance call outs, in order to establish working compressors within the work site.

The aim of the project is to produce a system modification for the control and operation of a pair of propane compressors within the company site. These compressors are responsible for maintaining the correct pressure of propane across the spheres through automatic cut-in and cut-out around a set point; this is required as the pressure can increase by the flashing off of the liquid propane into a vapour. This becomes more likely as the ambient temperature increases and affects the amount of expansion.

To permit a compressor to start, there are multiple parameters that need to be in a healthy state, such as, the operation of the fin fans, and at a healthy state of instrumentation within compressor peripheral vessels. The operation is controlled via two banks of relay logic, one for each compressor, located within the main pumphouse racking room.

The new system must be able to control the operation of both compressors, ideally through one unit, whilst ensuring reliability over an extended period, to save the company money in maintenance call outs and compressor downtime. The system must also run the compressors more efficiently, further saving money. The existing system is known to occasionally prevent the compressors from cutting out when required, thereby wasting energy and allowing the pressure to deviate too far from the set point. As it will be a new upgrade, it will have to conform to various regulations and meet the company's own standards and requirements particularly for shutdown and safety instrumentation.

To achieve this outcome, a demonstration rig will need to be constructed within the workshop and will be subject to FAT testing. This will prove the system's functionality ready for implementation onto site.

The project will involve myself, the I&E Maintenance Supervisor (Chris Scott), the Instrument SME (Wayne Brickle) and SIS Engineer (Leon Trunecka), along with the PLC and Electronics Sr Analyser Technician (Matthew Roberts) for assistance with appropriate risk assessments and MOC processes.

The budget stated is for the demonstration rig and panel only and will not include the final installation of the system onto site. This will be included in the final recommendations should the project functionality prove successful. The given budget is £20,000.

Agreement for project proposal

Student Signature: _____ Daniel Ince _____ Date: ____28/10/2020

Industrial Supervisor Signature: _____ Chris Scott _____ Date: ____28/10/2020

Academic Tutor Signature: _____ Robert Davies _____ Date: _06/11/20_

Appendix 5: Testing plan

FDS item	Test	Expected result	Actual result	Pass (Y/N)	Amendment required
4.1.1.2, 4.1.2.4	Simulate an open circuit trip condition during healthy VRU1 compressor operation for TSHH-1569. Repeat for all VRU1 trips. PSHH-1574 PSLL-1571 PDSLL-1571 FAN-1 Vibration LSHH-1561	Output to VRU1 compressor immediately de-energises to shutdown equipment. VRU1 loading SOV outputs de-energise. Compressor will not start until trip made healthy again. Indication for each alarm and trip must operate			
	Simulate an open circuit trip condition during healthy VRU2 compressor operation for TSHH-1669. Repeat for all VRU2 trips. PSHH-1674 PSLL-1671 PDSLL-1671 FAN-2 Vibration LSHH-1661	Output to VRU2 compressor immediately de-energises to shutdown equipment. VRU2 loading SOV outputs de-energise. Compressor will not start until trip made healthy again. Indication for each alarm and trip must operate.			
4.1.1.3	Increase pressure of VRU1 set point controller to 4.4kg/cm2 whilst all states healthy and compressor offline. Increase pressure of VRU2 set point controller to 4.4kg/cm2 whilst all states healthy and compressor offline.	VRU1 compressor should promptly cut in following start sequence. VRU2 compressor should promptly cut in following start sequence.			
4.1.1.4	Begin VRU1 compressor start sequence.	Fin-fans EAM-101A&B outputs should cut in instantly.			

	Begin VRU2 compressor start sequence.	Fin-fans EAM-102A&B outputs should cut in instantly.			
4.1.1.5	Force VRU1 fin-fan outputs open and attempt to begin start sequence on VRU1. Force VRU2 fin-fan outputs open and attempt to begin start sequence on VRU2.	VRU2 compressor output should not energise. VRU2 compressor output should not energise.			
4.1.1.6	Increase VRU1 controller pressure throughout range. Increase VRU2 controller pressure throughout range.	VRU1 loading SOVs should trigger as per loading table. VRU2 loading SOVs should trigger as per loading table.			
4.1.1.7, 4.1.1.9	Begin VRU1 compressor start sequence. Begin VRU2 compressor start sequence.	VRU1 must not load until 10 seconds after start. Lube oil trip must be bypassed for 60 seconds after start. VRU2 must not load until 10 seconds after start. Lube oil trip must be bypassed for 60 seconds after start.			
4.1.2.1	Test ESD buttons during compressor operation	Corresponding compressor must shutdown and not restart while latched.			
4.1.2.2	Test compressor resets.	Corresponding compressor alarms and trips should clear and compressor start when reset operated if all trips are healthy and pressure above set point.			
4.1.2.3	Operate loading bypasses.	Compressors must not load when bypass is engaged.			
4.4.1.1	Disconnect one power supply.	System should still maintain power from redundant supply.			
4.4.2.5	Check full range of electronic pressure transmitters.	Range should output 4-20mA as per specification.			
4.4.1.2	Check power supply output voltage.	Output should be 24V.			

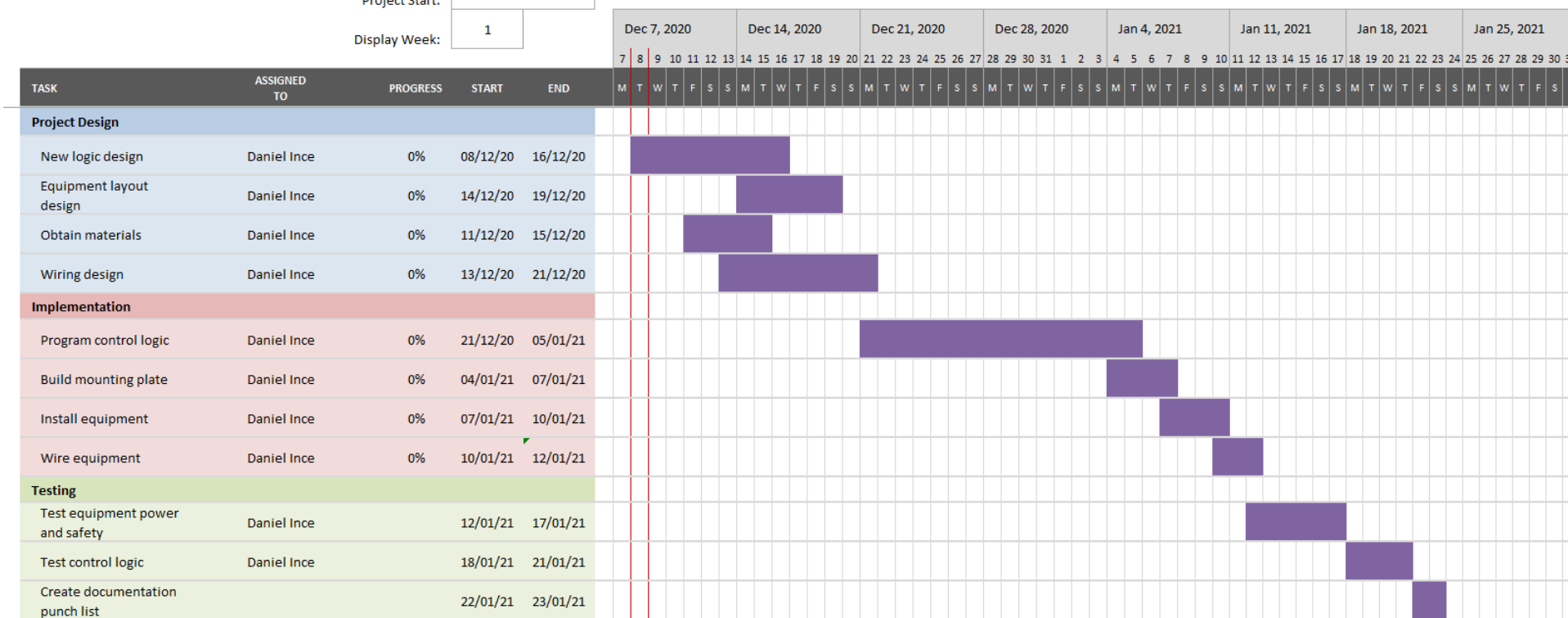
Appendix 6: Gantt chart plan

VRU Compressor Upgrade

Daniel Ince

Project Start: Tue, 12/8/2020

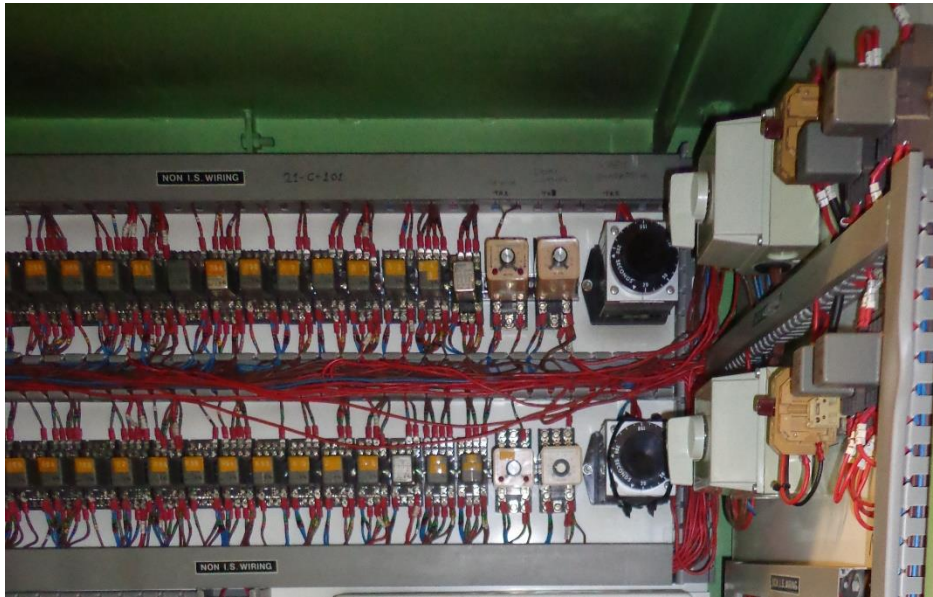
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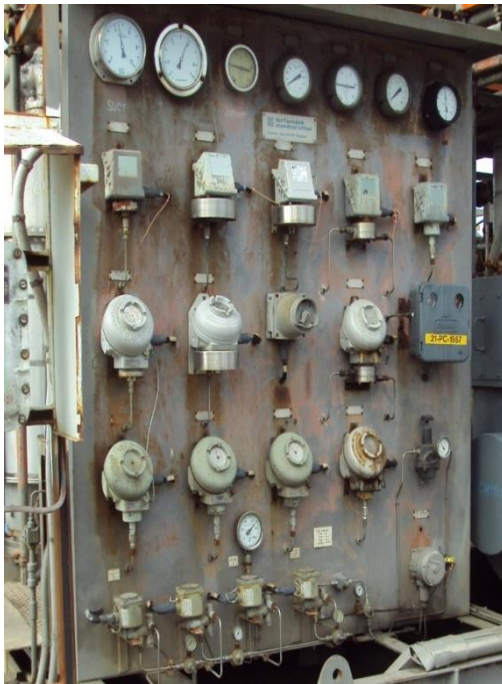
Appendix 7: Costing plan

Description	MVO No.	Original Budget	Current Budget	Current Forecast	2020				2021				
					Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21
Construction Total	Various	£0	£0	£0									
Manhour Costs Total	Various	£6,000	£6,000	£6,000		600	750	750	750	1,050	1,050	1,050	
						600	750	1,050	1,050	1,050	750	750	
						600	750	1,050	1,050	1,050	750	750	
Materials Total	Various	£20,000	£20,000	£20,000					12,000	8,000			
								12,000	8,000				
								12,000	8,000				
Overall Total		£26,000	£26,000	£26,000	0	600	750	750	12,750	9,050	1,050	1,050	0
					0	600	750	13,050	9,050	1,050	750	750	0
					0	600	750	13,050	9,050	1,050	750	750	0
Accumulative Total					0	600	1,350	2,100	14,850	23,900	24,950	26,000	26,000
					0	600	1,350	14,400	23,450	24,500	25,250	26,000	26,000
					0	600	1,350	14,400	23,450	24,500	25,250	26,000	26,000
					Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21
Original Commitment					0	600	1,350	2,100	14,850	23,900	24,950	26,000	26,000
Current Commitment					0	600	1,350	14,400	23,450	24,500	25,250	26,000	26,000
Actuals Commitment					0	600	1,350	14,400	23,450	24,500	25,250	26,000	26,000
Frozen Forecast Commitment					0	600	1,350	14,400	23,450	24,500	25,250	26,000	26,000

Appendix 8: Relay cabinet



Appendix 9: Instrument panel and pneumatic controller



Appendix 10: Loading SOVs



Appendix 11: Risk assessment

The document PP-PEM-FRM-0027 has been omitted for confidentiality reasons, an overview of the risk assessment can be seen in section 3.5.1.1.