

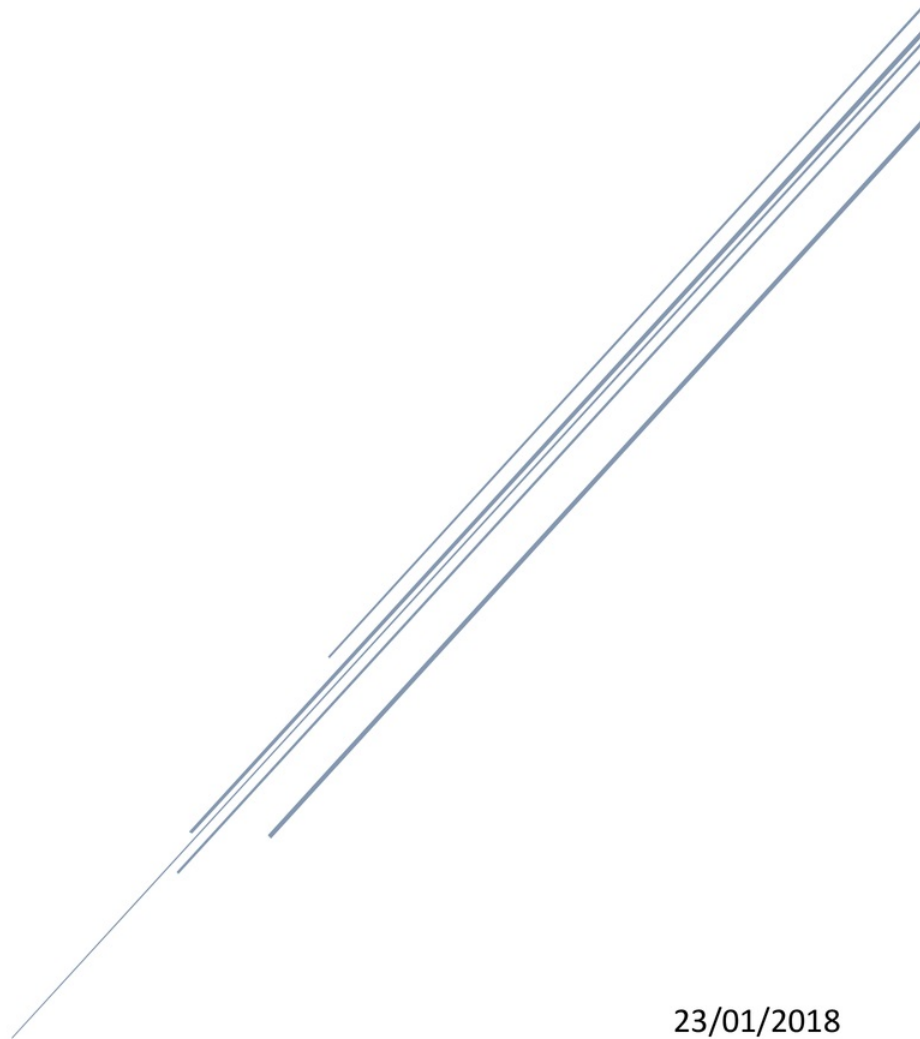
PSDE5007 Assignment 1 Interim Report

by Daniel Ince

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PROJECT INTERIM REPORT

PSDE5007



23/01/2018

Daniel Ince

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1. Project Proposal

1.1 Overview

The project in question is to centre on a control system. This system will involve a PLC with bespoke program written to provide the control aspect.

The outcome is to achieve an effective way of performing a valve sequence for a section of plant. A control aspect will be incorporated to regulate the sequence of events and keep it well within operating limits. This aspect will include a form of timing and sequential control to keep the process variable as close to the set point as possible. This set point will be able to be modified through interacting with a control panel installed through hardwiring and with the assistance of a HMI connected to the PLC.

The system is also to include a hardwired and software safety system in order to trip the system should it stray too far from the acceptable limits. The hardwired system will be an emergency stop to physically break the circuit and cut out the equipment should there be a failure of the software. A manual and automatic switch will be incorporated, along with a maintenance bypass to allow work to be carried out, such as live calibration, without the system needing to be shut down.

Investigation will be carried out in order to determine the most effective way of achieving this while being as cost effective as reasonably practicable. The different methods will be looked into through a variety of techniques, such as gant chart, direct comparison and SWOT analysis. These will aid in the decision of how to achieve the control system and make it clear which is most cost effective and includes the most layers of protection with regards to safety integrity.

The project work will be carried out predominantly at Valero, along with the use of resources during time spent at Coleg Sir Gar. Testing will be carried out using specialist test equipment found at Valero and calibration of any equipment will be completed there. The college software will be used to write and compile the program for the PLC.

The budget is to be £800 as the system will require use of a PLC, valves and sensing instrumentation.

Testing of the project will be done to determine whether or not the system conforms to the product design specification and thoroughly test all aspects of control within the system. Each instrument will be calibrated and loop checked to ensure adequate signal transmission and functionality. The program and software aspect will be set up and input/output configurations checked. This will include testing of the trip setting and adjustments to the set point to determine the optimum operation while remaining as safe as reasonably practicable. The safety system is important on the refinery as it is critical that the control measures are in place to prevent a process upset or dangerous occurrence.

The project will run from October 2017 to the 25th of April 2018 and will be planned throughout these dates with all information and activities being recorded in a log book.

1.2 Detailed Objective

The specified valve sequence will be the PSA (Pressure Swing Adsorption) skid on the HRU (Hydrogen Recovery Unit) of Pembroke Refinery. A system to control the systematic opening and closing of the many valves on the unit will need to be designed to suit accordingly to ensure correct unit operation.

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Methods will be investigated and chosen until the most effective solution for controlling the system is determined. The method will need to be able to run the system flawlessly error free for at least 10 years with minimal maintenance on the control system itself.

2. Background Research

Research will be performed to gain an insight onto Pembroke Refinery, the HRU unit, the PSA skid and the existing control system.

2.1 Pembroke Refinery

Pembroke Refinery opened in 1964 and one of the largest refineries in Europe. Taken over by Valero in 2011, it processes 270,000 barrels of crude oil per day.

As stated on Valero's website:

- *Built in 1964 as a hydroskimmer, with cat-cracking capacity added in 1982*
- *Acquired from Chevron in 2011*
- *Occupies approximately 450 acres of a 1,275-acre site on the southern shore of the Milford Haven Waterway in Pembrokeshire, Wales*
- *Deep-water port and docks with capacity to handle very large ships, without reliance on third-party terminals or pipelines*
- *Total throughput capacity of 270,000 barrels per day, including 220,000 barrels per day of crude oil, plus 50,000 barrels per day of other feedstocks*
- *Approximately 10.5 million barrels of storage, about half used for feedstocks*
- *Large FCC and alkylation units providing significant volumetric production gains*
- *Nelson complexity rating of 11.6 ranking among the top refineries in Western Europe*
- *Refinery scale, flexibility, location and logistical advantages enhancing Valero's optimization and trading strategy in the Atlantic Basin*
- *Major national employer in Wales, including about 550 employees and 400 term contractors;*
- *50th anniversary of the refinery celebrated in 2014 by a visit from Their Royal Highness The Duke and Duchess of Cambridge*

(Valero, n.d.)

2.2 Hydrogen Recovery Unit

The HRU was implemented at Pembroke Refinery in order to recover hydrogen to supply additional reactors needed to reduce the sulphur levels of product. It uses gas feed from the CCR unit which passes through the LPGRU and then onto the HRU. This feed contains around 80% hydrogen content and is increased in pressure before being sent to the Pressure Swing Adsorption section and then the resultant pure hydrogen is sent to the hydrotreaters.

2.3 PSA Skid

The PSA skid consists of 4-bed adsorbers and is designed to remove impurities from the gas to produce high purity hydrogen. The process involves a cycle which varies the pressure of the feed and then regenerates the adsorbent of any impurities. Each cycle is staggered to ensure one adsorber is always online while the others are in the regeneration phase in order to provide a continuous flow. The PSA can also function using 3 beds if required but this is generally undesired as it can produce a lot of flaring if the resid gas purity drops. The adsorption phase timing can be increased to increase the purity of the hydrogen produced, and vice-versa depending on demand.

The entire cycle of each adsorber consists of four subcycles, adsorption, de-pressurisation, purging, and re-pressurisation ready for the cycle repeat.

Adsorption

The feed gas enters the adsorber at a pressure of 42.7kg/cm²g entering through 11-KV-0211 and flowing upwards into the vessel 02-F-201. As it passes over the bed, the adsorbent removes impurities from the gas through adsorbing them onto the bed surface. This subcycle is undergone for 135 seconds before moving on to the regeneration subcycle. The cycle time varies depending on flow rate and capacity and is controlled automatically by logic.

At the completion of adsorption on the first bed, the next bed begins the process to ensure continual flow.

Regeneration

The bed is now coated in impurities removed from the hydrogen and needs to be regenerated before the next cycle. The impurity concentration varies throughout the height of the vessel, with the lowest part containing the highest concentration with this decreasing as you move up the adsorber. The regeneration process is carried out in three stages.

These impurities are to be removed through desorption at low pressure, this is carried out by a two stage depressurisation of the adsorber through the top using co-current direction. This allows hydrogen to be recovered which is still in the bed before dumping the impurities. Initially the vessel is de-pressurised to the resid gas pressure and the hydrogen stored is used to pressurise and purge other adsorbers in the second and third stages of the regeneration cycle respectively.

Hydrogen from another adsorber is then used to purge the current one at a low pressure. The impurities are desorbed and removed through the bottom of the adsorber. The adsorber is then re-pressurised prior to adsorption using purified hydrogen from other adsorbers in regeneration to prepare it.

The stages are described in detail below.

Equalisation – This is a 30 second process which uses the high pressure hydrogen from adsorber 1 to partially repressurise adsorber 3. Valves 11-KCV-213 and 233 open in order to allow the flow from adsorber 1 to 3. The 30 second timer lasts to allow the pressure of adsorbers 1 and 3 to have equalised at 25.89kg/cm²g.

Purge providing – This is a 90 second step which uses the remaining hydrogen in adsorber 1 to purge adsorber 4. The gas exits the vessel through KCV-213 and then enters adsorber 4 through KCV-243. This process drops the pressure in the first adsorber to 14.39 kg/cm²g. This purge for adsorber 4 allows the remaining impurities to be forced out of the vessel downwards out of KCV-244.

Depressurisation dump – This is a 45 second step which reduces the pressure of adsorber 1 to 5.7 kg/cm²g through depressurising the gas downwards out of KCV-214. The opening of this valve is adjusted and used to control the rate of depressurisation within the allocated time.

Purge – Adsorber 1 is purged for 90 seconds from top to bottom using the hydrogen gas from adsorber 2. KCV-223 and 213 open to allow and control the purge gas flow to enter the vessel and desorb the impurities from the bed. The gas takes the impurities with it as it passes through KCV-214 which is fully open to maintain the low pressure in the system.

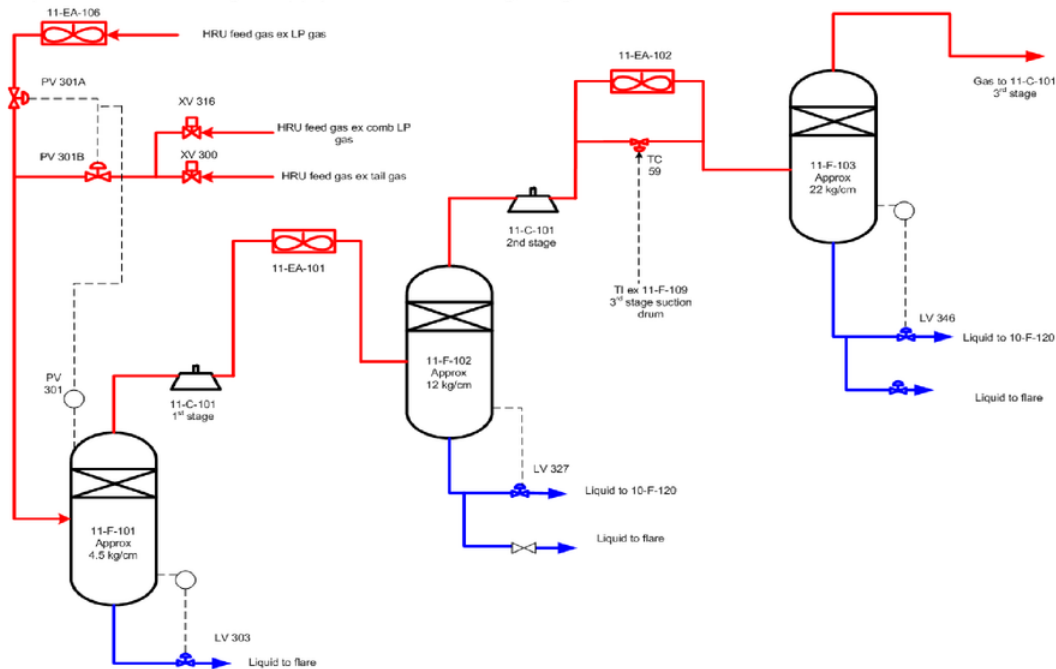
Re-pressurisation – The first adsorber then needs to be re-pressurised to prepare for the next cycle. To do this, two sources of hydrogen are used to pressure up the vessel, taken from the equalisation stage of adsorber 3 and pure hydrogen product through KCV-212. Once the pressure has equalised this first re-pressurisation stage ends and the next re-pressurisation begins using only purified hydrogen product. The maximum pressure reached is 42.7 kg/cm²g and allows the beginning of the next cycle.

The adsorber subcycle time can be modified depending on what is demanded. Using 4-beds and at 100% load, the subcycle is set at 135 seconds, should only 50% flow be required, the cycle time is set to 270 seconds. This is because the adsorbent can only remove a fixed amount of purities and so the larger the capacity of the adsorber, the shorter the subcycle time. The flow used for repressurisation is constant to maintain a stable product flow. The sequence is designed to have the adsorber complete the repressure stage at the end of the subcycle time, this is then switched to the adsorption stage and another adsorber begins repressurising.

PSA feed

In order to provide a feed gas to the PSA skid, the reciprocating compressor 11-C-101 is used to increase the pressure of the feed gas from the LPGRU and CRU containing approximately 80% of hydrogen. The pressure is stepped up from 4.7 kg/cm²g to the 42.7 kg/cm²g required for the PSA skid. The unit is designed to process a maximum of 22000 sm³/h of gas and if this maximum flow is not met, then additional gas is taken from the LPGRU HP gas header to make up.

The compressor is designed to adjust its volumetric capacity to control the flow and this is done through a step-less control system known as Hydrocom. The loading on the compressor is controlled 11-FC-371 which sends a signal to the Hydrocom system. Upon start up, this output is set to 20% and can be increased from here in order to take in more LP feed gas. As this happens, the upstream pressure decreases as more gas is sent to the HRU and so the pressure controller 11-PV-391 closes off in response to maintain the upstream pressure and route the gas to the HRU. The ratio of feed gas between LP and HP gas is controlled through 11-PV-301A and 301B valves respectively, responding to the split pressure controller PC-301, in order to keep the feed gas to the compressor at 4.5 kg/cm²g. The controller opens 301A fully as the flow demand increases before opening the HP gas valve 301B to respond to any further increases. The compressor will trip upon a low suction pressure should the gas supply falter below 3.8 kg/cm²g.



The compressor uses three stages to achieve the 42.7 kg/cm²g as shown in the above process diagram taken from the HTU/HRU Operating Manual.

Stage 1 increases the pressure from 4.7 to 12.2 kg/cm²g, stage 2 then brings this up to 22.7 kg/cm²g and the final stage increases it to 42.7 kg/cm²g.

The loading is achieved through the use of the 22 Hydrocom suction valves and actuators. The valves are designed to spill back gas internally within the compressor. Depending on what load is needed,

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the suction valves open and allow a certain amount of gas to exit the cylinder before closing, leaving only some to be compressed during the compression stroke. The combination of these suction valves and the amount of time they are left open changes depending on the compressor loading chosen by the Hydrocom system.

Following the completion of the third compression stage, the high pressure gas is sent to 11-F-104A to allow any liquid butane to condense out and be removed from the system. This prevents the butane from entering the PSA skid and is instead exported to the butamer unit or spheres.

Should the PSA unit trip for any reason, the compressor can be used to send hydrogen of reduced purity (about 80%) to the hydrogen header at a reduced rate.

Product

The hydrogen product exits the PSA skid through a 4" line where it is sent to the LPGRU unit limits and then on to primarily Hydrotreater 1 and then Hydrotreater 2, depending on demand. If the PSA has tripped it can be bypassed and the compressor will send the mixed LP and HP gas directly into this line.

3. Specification

As The project is to be based on Pembroke refinery, it must follow the site-specific guidelines and regulations for projects on this refinery.

3.1 Detailed Design Specification

- The project must satisfy the ability to control the core features of the PSA unit.
- The adsorption stage must last for 135 seconds.
- A supply pressure of 4.2kg must be achieved for the hydrogen supply pressure, this is because the actual 42.7kg supply pressure used in the field is extremely high. For testing purposes and to satisfy health and safety, the pressure within the skid will be dropped by a factor of 10 for this equipment.
- The 4-bed system must operate continuously with staggered cycles. A manual ESD stop and start must be present. The stop button must vent out excess pressure and return the system to the start of the first cycle.
- The pressure of each vessel must be monitored by four pressure transmitters. Each pressure transmitter must act as indication and a trip system to prevent over-pressuring of the vessels.
- If a trip function is activated, the system will perform the same function of activating the ESD (Emergency Shutdown) button.
- Whilst a bed is in the adsorption stage, the other three beds must be performing the other sub-cycles of the process. (Equalisation, Providing Purge, Depressurising, Purging and Re-pressurising.
- The system must be able to control the sequence of opening and closing all 16 valves on the four vessels.
- Indication of the valve positions must be present to understand what current cycle the system is on.
- The system must be ergonomic enough to be functional within the workshop environment.

3.2 Timing and Budget

The project will need to be completed by April 2018 with all design, construction and testing finalised. The main bulk of the design will be research into how the system operates. Once this is determined, a method of achieving this operation will need to be chosen, details of this will be in the project plan section.

The budget has been set to £800 for the cost of all parts, including parts and equipment to be used but not time.

4. Testing Plan

Following project construction, the system will need to be tested against the Detailed Design Specification. Points that are conformed to will be noted and any failed points highlighted. From here, any improvements that could be made to achieve the complete DDS will be investigated. Any problems will become apparent during the test and an effort to rectify these will be made.

The first test will be to ensure that each vessel can make one complete cycle. At various stages during the cycle the valve positions will be checked against the valve position sheet to ensure correct functionality.

The second test will be to allow the system to run continuously for 10 cycles without faltering. Once this is complete, the ESD button will be pressed to ensure the system shuts down appropriately into what would be a safe condition.

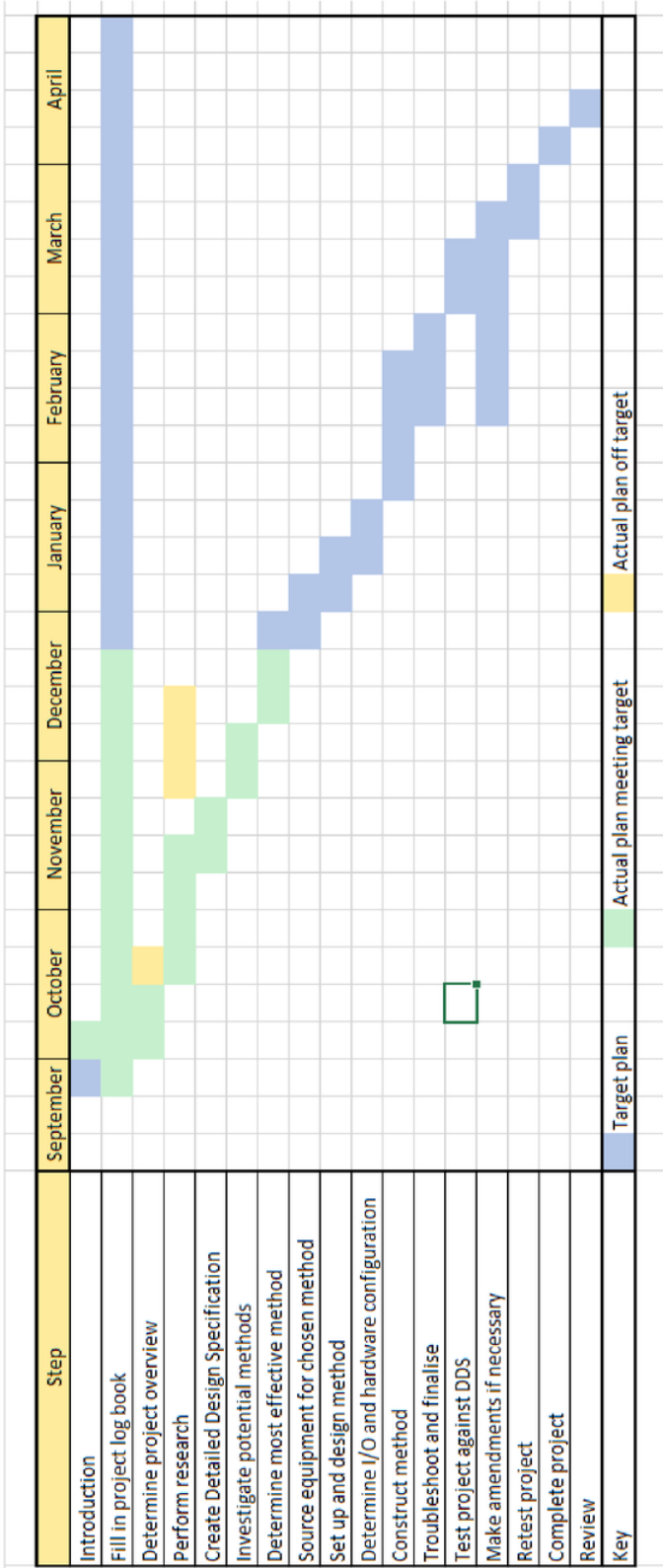
The third test will include testing the high pressure trip settings on all four vessels. On activation of the trip, the vessel in question should vent all excess gas out the flare line.

Throughout the testing process, the indication and start functions will be checked and each cycle/subcycle timed to ensure it is correct. Failing to meet the correct valve timing will mean the pressure cannot be effectively 'swung' between vessels and results in a system failure.

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5. Project Plan

In order to plan accordingly, a gant chart was made to show progress throughout the project. The chart is shown below with a key at the bottom for differentiating between the plan.



6. Potential Project Methods

6.1 Method One – Relay Logic

The first method is to carry out the control using relay logic. This will involve hardwiring the entire valve sequencing system, using timers and relays to cycle the adsorber beds through the different stages.

6.1.1 Advantages

The advantages of such a system as this is the ability to physically see the changes and the switching of the relays. It also gives an indication of what point in the sequence the valves are in as each state of the relay can physically be seen without the need of travelling into the field to look at each valve individually. This would typically be based with an array of relays and timers in the racking room.

Should any problems arise after system commissioning, the maintenance team would be able to individually swap out relays that fail. Identifying the faulty relay could be performed by referencing a relay state diagram, showing the switch state of each relay at every point during the cycle.

6.1.2 Disadvantages

Due to the nature of the system, all four beds require four valves each, with an open and close for each. This leads to 32 separate discrete input/outputs required. Multiple relays and timers will be needed for each one of those i/o to create the logic gates needed for the cycle. The complexity means a lot of physical hardwiring and the space that this will take up is far greater than the space available in the workshop.

The reliability of the system will become questionable due to the large number of components, if one fails, the complexity of the system would slow down fault finding and increase down time of the PSA skid. As the PSA skid provides 99.9% pure hydrogen to multiple other units on the refinery, failing to provide the gas greatly affects the overall refinery performance. A lower mean time between repair and higher downtime means this impact is more frequent and for longer periods of time.

6.1.3 SWOT Analysis

Strengths	Weaknesses
Visible indication of switching.	Very complex and occupies a lot of space.
	Lots of Hardwiring.
	Lots of components to fail.
Opportunities	Threats
Can be developed and expanded with more hardwiring.	A PLC performs the same task but better and in a much more compact form.

6.2 Method Two – PLC Ladder Logic

This method involves using a programmable logic controller to control the large amount of inputs and outputs required by this project. This will eliminate the need for relays and a lot of the hardwiring.

6.2.1 Advantages

A PLC is very small in comparison to a large array of relays and allows an entire program to be contained within a very small space, the only hard wiring is to the inputs and outputs. The PLC can also communicate with other controllers nearby and pass information to and from equipment such as a HMI (Human Machine Interface).

The PLC program is fully customisable and improvements can be made over time, security settings can also be placed to prevent it from being tampered with.

Trip amplifiers will not be needed as an analogue input card can be mounted.

6.2.2 Disadvantages

Using purely ladder logic to achieve the outcome means the program will be very complex and occupy a lot of memory within the PLC itself.

6.2.3 SWOT Analysis

Strengths	Weaknesses
Compact within the PLC.	If the PLC itself fails, the entire system fails.
Less hardwiring.	Very complex program.
Less components to fail.	
Opportunities	Threats
Ability to modify the program with ease.	Could be come outdated by better PLC systems.

6.3 Method Three – PLC Sequencer

This method is similar to method two as a PLC is used, however the programming will be done slightly differently and will be in the form of a sequencer. A table of inputs and outputs is sequenced through and translated into the physical inputs and outputs of the PLC. Different parameters and conditions can be set for each set in the sequence and it can allow for a timer between steps.

6.3.1 Advantages

Advantages are similar to that of method two, however the main benefit of this method is that the program is much smaller and less complex. This means that it takes up less memory and is easier to fault find if maintenance personnel are called to fault find an issue at a later date.

6.3.2 Disadvantages

If the PLC fails, the entire system fails.

6.3.3 SWOT Analysis

Strengths	Weaknesses
Compact program uses less memory.	If the PLC itself fails, the entire system fails.
Not as complex a program to fault find.	
Less hardwiring.	
Less components to Fail.	
Opportunities	Threats
Ability to modify the program with ease.	Could become outdated by better PLC systems.

6.4 Conclusion

Overall, when reviewing the SWOT analysis, method three comes out on top as the most efficient, compact and long lasting option. Developing a PLC program to incorporate the best traits of ladder logic along with a sequencer provides versatility and efficiency. It also severely reduces the amount of logic gates needed within the program and makes it easier for fault finding.

This method will be chosen and the program will be designed to suit.

7. References

7.1 Works Cited

Valero, n.d. *Valero*. [Online]

Available at: <https://www.valero.com/en-us/Pages/Pembroke.aspx>

[Accessed 25 November 2017].

7.2 Reference List

1. REFINING PLANT OPERATOR HYDROTREATER UNIT 2 MODULE 1 (PART 1) PLANT AND PROCESS KNOWLEDGE.
2. Valero P&ID 11-AA-506 Hydrogen Recovery Unit PSA Unit

8. Appendix

PSDE5007 Assignment 1 Interim Report

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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RESEARCH-INFORMED LITERATURE



Good start with research and refs included. Use more refs in final report about 4 for every 1000 words. - 5/10 Research good - 10/15

15/25

KNOWLEDGE AND UNDERSTANDING



Good in all areas. Refs will help this further. Proposal is clearly defined - 7/10 Spec is good - 3/5 Design requirements - a good start - 7/10

17/25

ANALYSIS



Conclusion needs to improve. 5/10 Testing plan looks good - 7/10

12/20

PRACTICAL APPLICATION AND DEP.



Good application demonstrated. Project plan is good - Gant chart used for comparison - 3.5/5 Quality of work is good - 3.5/5

7/10

SKILLS FOR PROFESSIONAL PRAC.



Good all round report - 8/10 Presentation - 7/10

15/20

