School of Engineering
Integrated Design Project 2
Assignment 2
Individual Detail Design
2021/22

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Transport and Storage

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TECHNICAL SUMMARY

What part of the facility is simulated by your detailed design?	My simulation models the transport and storage side of the facility
What are the key features of your simulation?	The simulation has realistic power generation with a possible power conversion that could be used if this facility was to be built. It also models the pressure of the CO_2 change from being a gas to a liquid to be pumped into cylinder. It also contains 3 pumps that simulate the power needed to run multiple pumps at the same time
How realistic is your simulation, and how could it be made more realistic?	The simulation can be considered realistic as it uses a 3-phase power generation system that is used in Malaysia. The pumps also have efficiency ratings for both volumetric and mechanical efficiency. However, the actual resistance from the pumping system and compression system have not been modelled which would make the model even more realistic. It also does not contain a proper control system, if this was implemented, this would make the model even more realistic
What did you find were the best approaches to modelling to improve power efficiency?	Using trial and error, I changed the constant of proportionality in the rotational electromechanical converter as well as the displacement amount by each pump.
What obstacles did you encounter and spend the longest time getting to work?	As I had never used Simulink and Simscape, I had no idea how to get the fluid system to work effectively. I also had trouble with producing a realistic power generation system
How would you tackle the simulation differently if you could start again?	I would map out the system on paper first so I had a better idea of how each domain interacted with each other and what component would be needed to do this. I would also research what control system would be needed so this can be implemented to actually read inputs and adjust accordingly

SIMULATION

Qualitative Description:

In my simulation model, I have improved upon the power generation, conversion and load systems. This was done by using a 3-phase voltage system and half wave rectifier bridge. The pumps also consider certain losses from both the fluid and mechanical domains as well as the amount of fluid being pumped through per rotation.

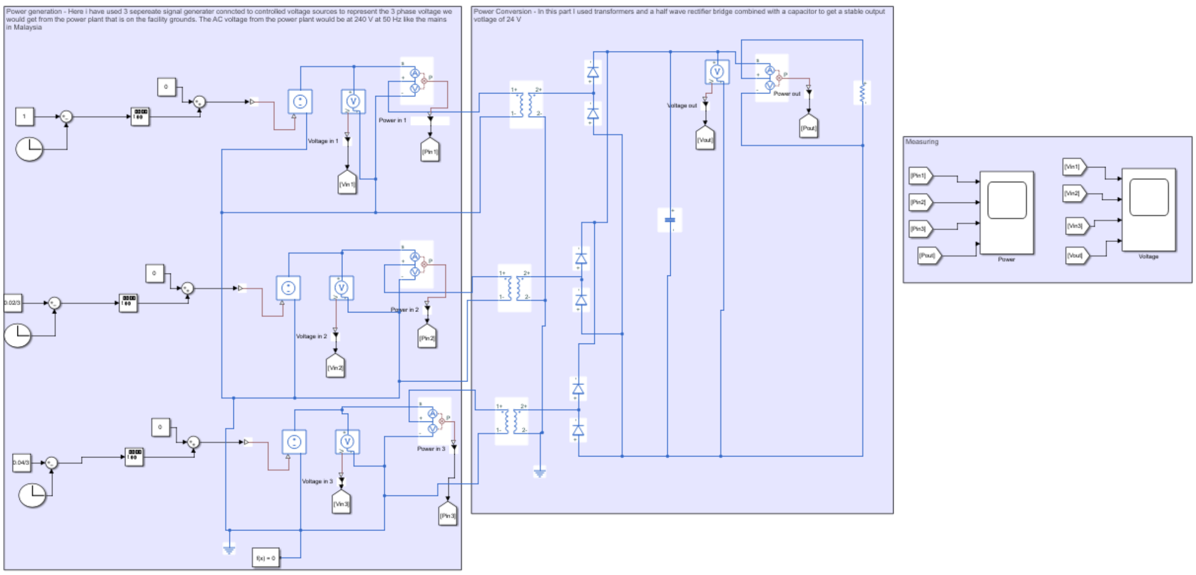
Quantitative Description: Specification Table

Variable	Value
Input AC peak voltage	240 V
Input AC frequency	50 Hz
Winding ratio in transformer(s)	22.8
Average voltage into pump	24 V
Gas pressure into system	101.325 kPa
CO_2 pressure after compression/in pipes	12.5 MPa
CO_2 pressure in canister	5.93 kPa
Volumetric efficiency of pump [(1)]	0.98
Mechanical efficiency of pump [(1)]	0.98
Power delivered to each pump	96 kW
Overall efficiency of system	0.98

(1) At nominal conditions

Model: The Simulation model diagram(s)

Overall Model



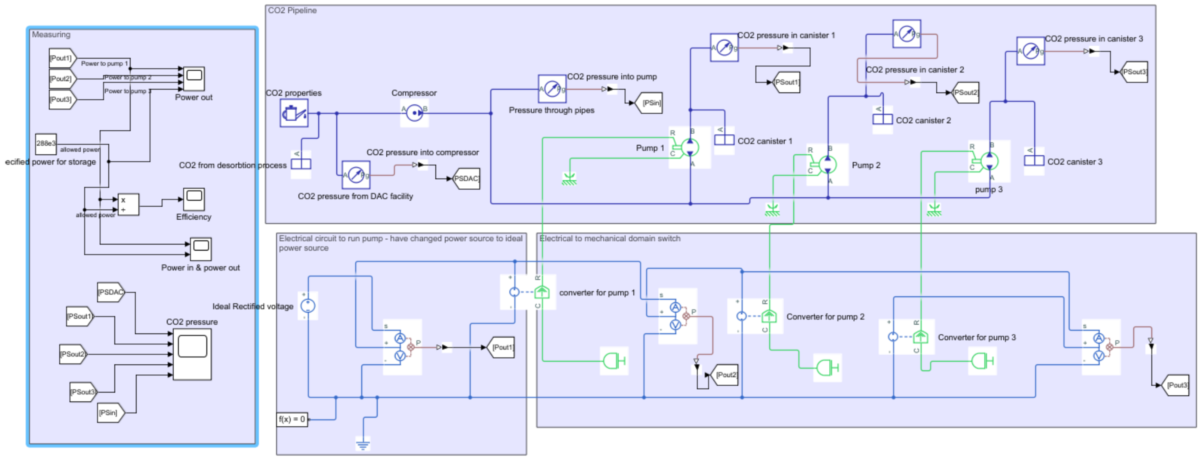


Figure 1: circuit diagram of whole simulation. Power generation and conversion (top) and Load and control (bottom)

Power Generation

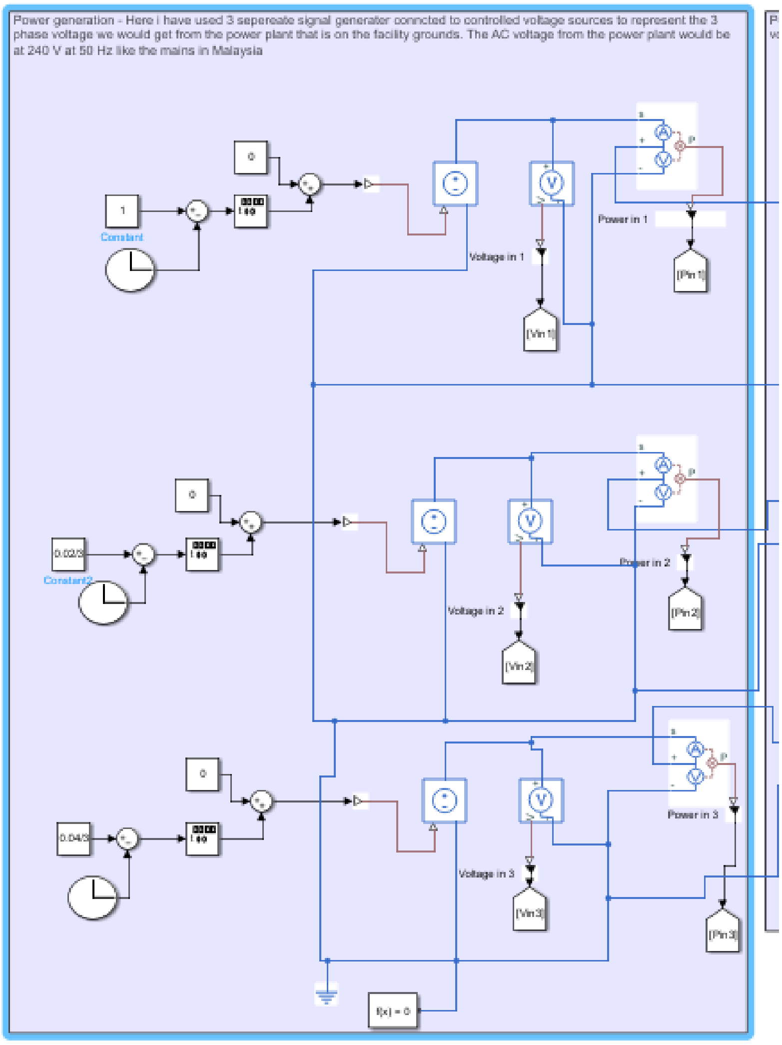


Figure 2: Circuit diagram of power generation

In this power generation model, I simulated a 3-phase voltage system that would be the output of the power station on site. I used a signal generator to generate a sine wave of amplitude (2^1/2*240) that fed a controlled voltage source. I coupled this with two other signal generators that had a delay to create a 3-phase signal when combined. This model is more realistic compared to the basic DC voltage-controlled source as this is the actual way that power is delivered in Malaysia. This allows us to feed the grid left over electricity supplied by the power station.

Power Conversion

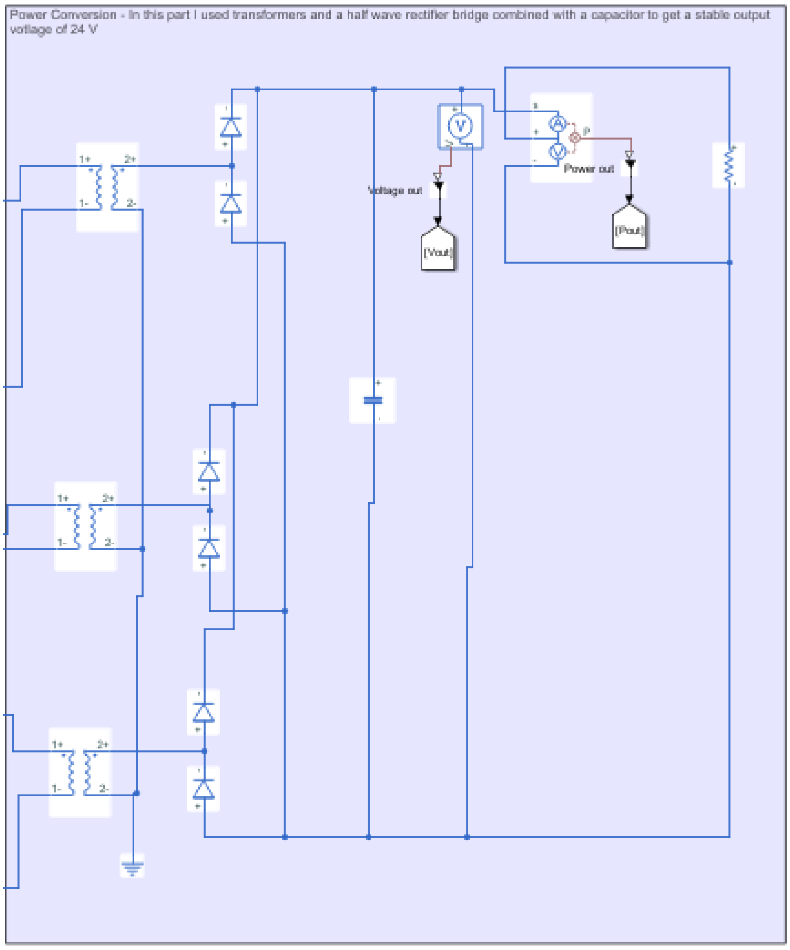


Figure 3: Circuit diagram of power conversion

The power conversion was done using 3 half wave rectifier bridges for each power line. This was combined to give a stable 24 V output that would be used to supply the pumps used to transport the CO2 around the facility and into canisters for transportation. The winding ratio needed for the transformers is 22.8. This enhances on the potential divider as it combined 3 voltages together and smooths out the signal using a capacitor. This allows us to get a much more stable output.

Load

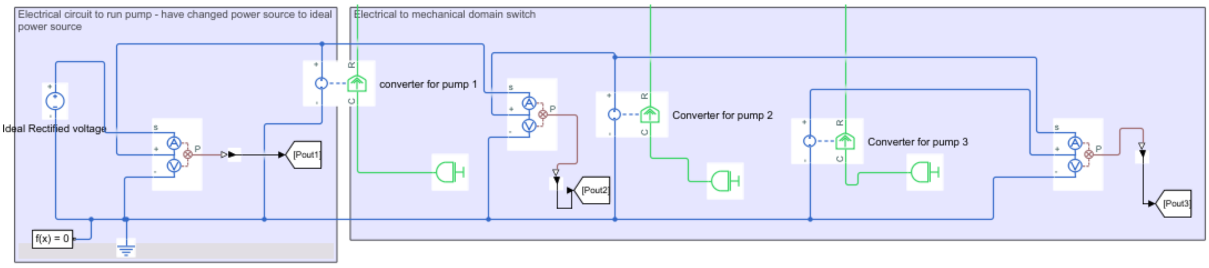


Figure 4: Circuit diagram of 3 electromechanical converters with ideal rectified voltage supplying it

Here I used rotational electromechanical converters to act as the motor in the pump that would force the liquid CO2 round the facility and into canisters and into gas seams to force Methane out that can be used to power the power station. The canisters can also be transported to the necessary places, like the cement factory.

Control

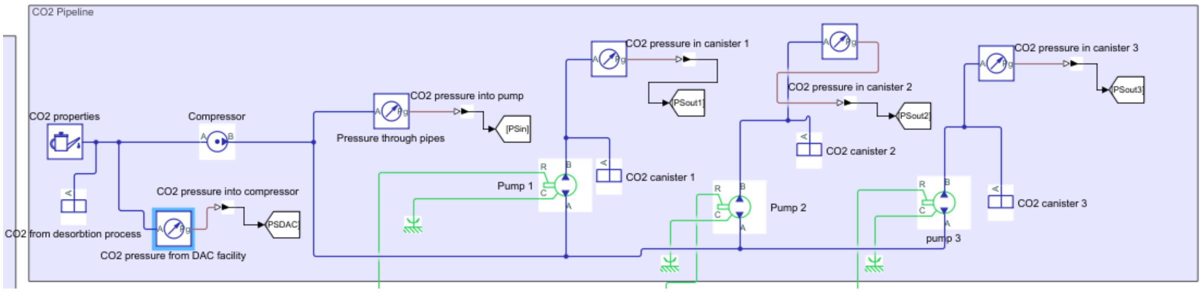


Figure 5: Circuit diagram of CO2 pipeline simulated with CO2 properties, compressor and pumps

The CO2 has been modelled here from the DAC facility to the canisters. The compressor and pumps would be controlled by a PI or PID controller, however it was not possible to model the control and integrate it into the model. The control would monitor the pressure through each part and change the speed of the pumps or the pressure needed to compress the CO2 into liquid form. The temperature of the CO2 would also need to be monitored and cooled as the compression would cause the CO2 to heat up.

Analysis: The Simulation Result

Inputs and Outputs

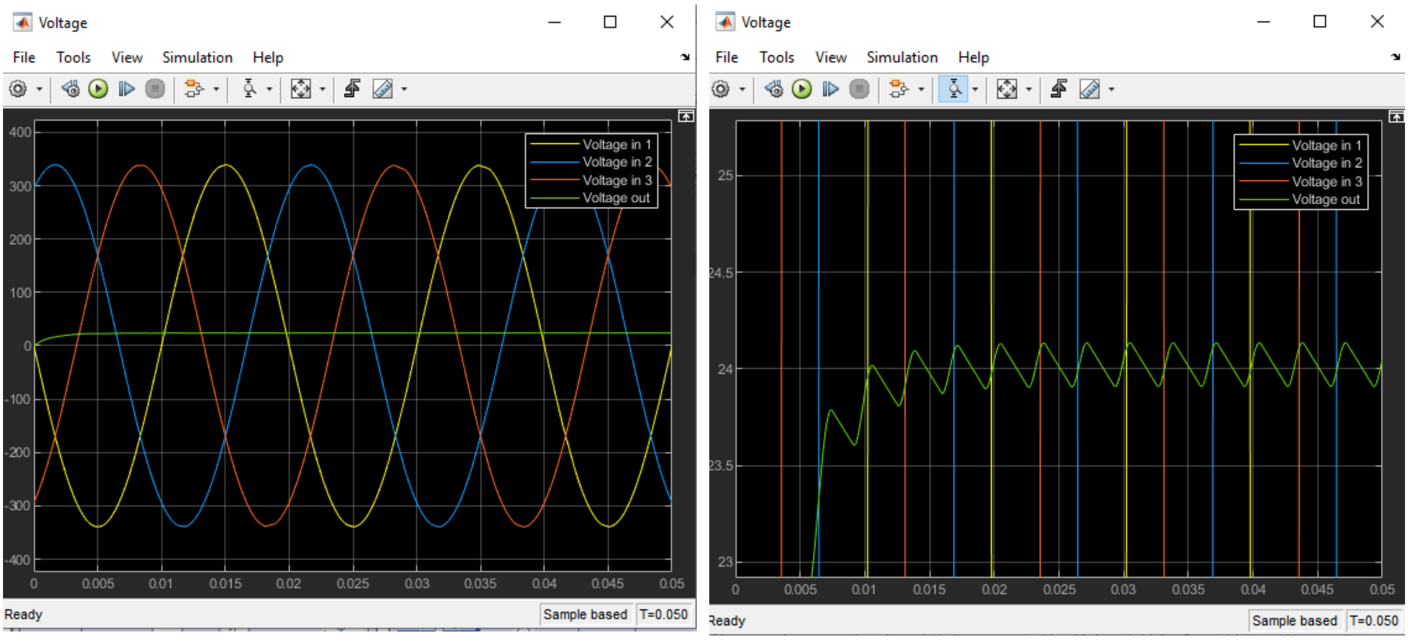


Figure 6: oscilloscope reading of power generation (left) and power conversion (right) to give 24 V

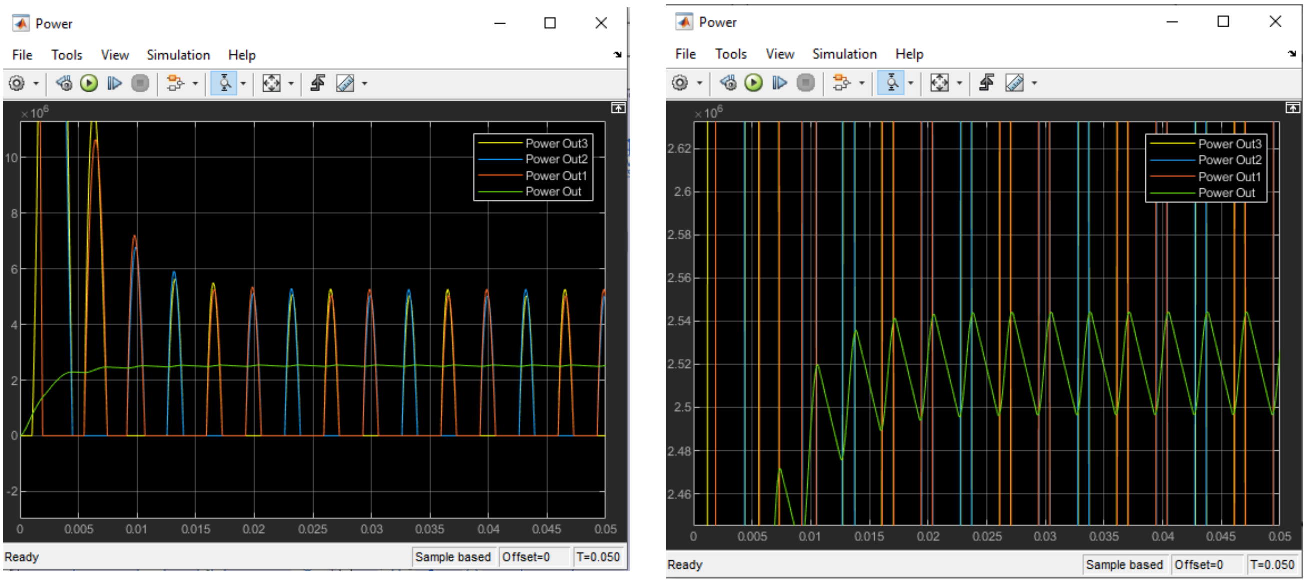


Figure 7: oscilloscope reading of power from generations and conversion – shows total calculated necessary power for entire DAC facility

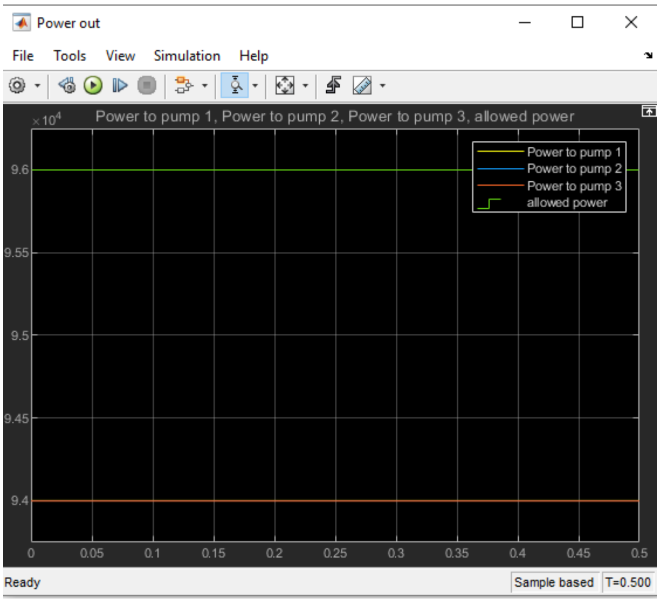


Figure 8: oscilloscope showing power drawn by each pump as well as allowed power for each pump

As seen from figure 6, the power generation and conversion is able to generate a stable 24 V output that can be supplied to each pump, allowing them to operate at their rated voltages. There is a voltage bounce of ±0.1 V, however I do not believe this would affect the overall outcome. The power output from the power generation also shows the 2.52 MW power usage predicted in the report. Each pump uses 94 kW as the predicted power for transportation is 288 kW, therefore each pump can use up to 96 kW

Energy Efficiency

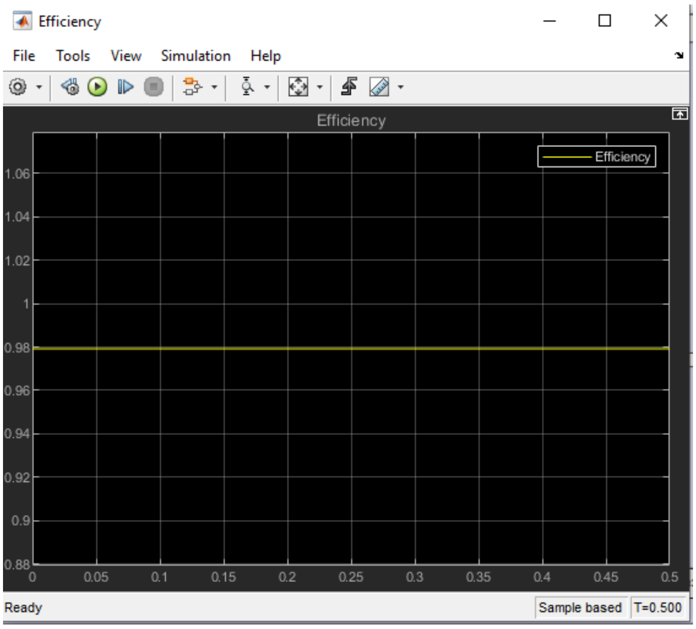


Figure 9: oscilloscope showing efficiency of each pump

As a future project, I modelled the pumps to work at a 0.98 efficiency. The efficiency was calculated by taking the power used by the pump (94 kW) and dividing it by the allowed power for each pump (96kW). Current pumps have an efficiency of 0.75 to 0.93, these losses are due to friction in the rotor and pump, eddy currents in the coils and sound. However, these will hopefully be minimalised in the future. Factors from the fluids that affect the efficiency include flow rate, pressure and flow type which can cause the pump to run less efficiently.

CAD:

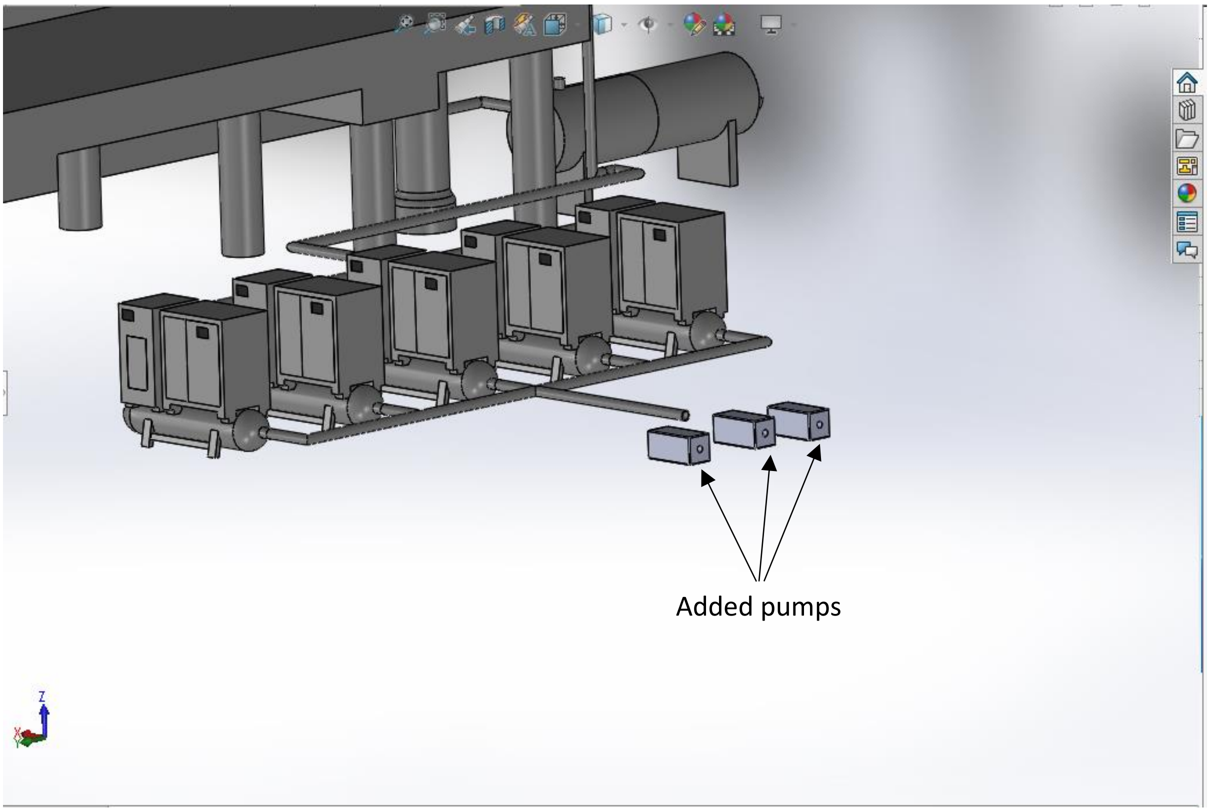


Figure 10: enhanced CAD design for transport and storage

In the above figure, 3 blocks have been added to represent the pumps that would be used in the actual design. These pumps would connect the CO2 from the desorption process to the compressor and finally to the canisters where the CO2 can be transported away to the necessary places.

APPENDIX

<please include all your design evidence in further appendices to support your report. This may include research journal club reports, interim designs, and detailed calculations. There is no page limit. This section will be referred to by markers to clarify/evidence anything you state in the main body of the report. 0% of marks directly allocated for this report section >