Optimizing The Process of Liquefying Hydrogen for Storing Purposes

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Problem Statement

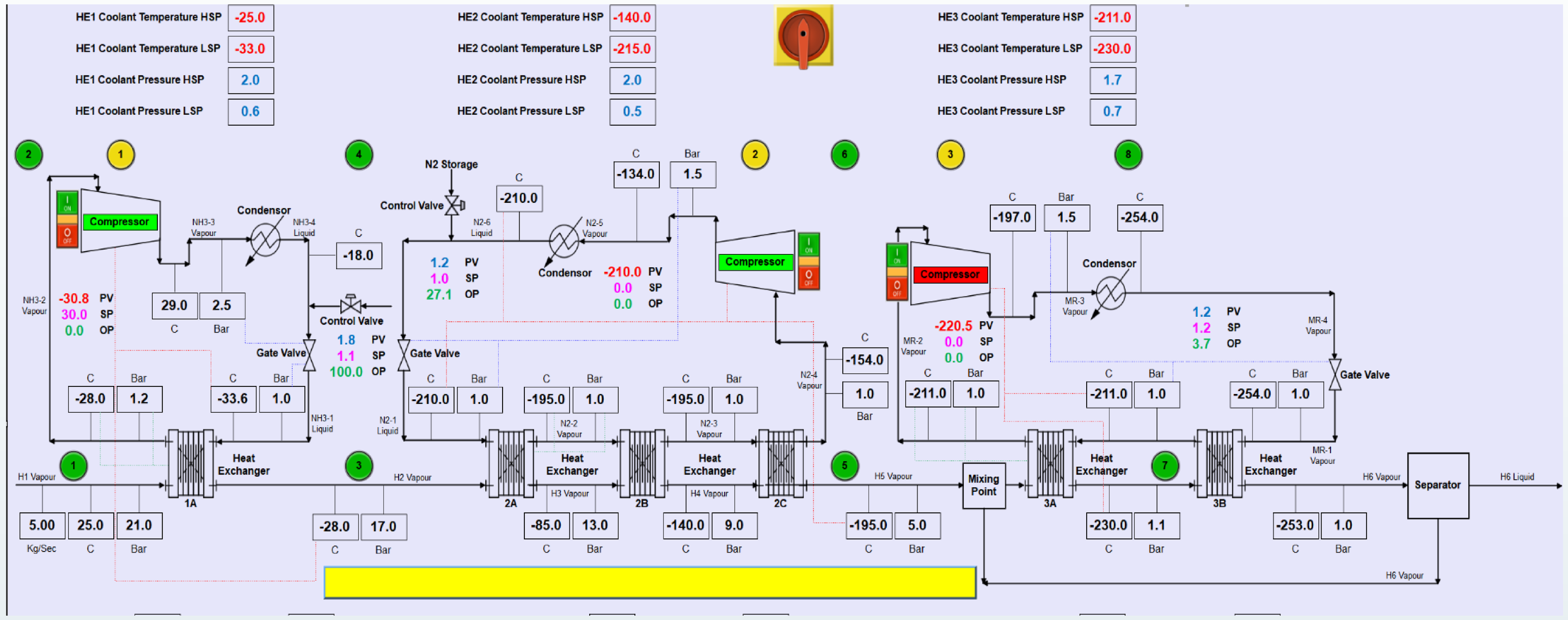
Complete a study of improved hydrogen liquification storage system, which includes analysis of heat loss, energy efficiency and the cost of manufacturing.

Background

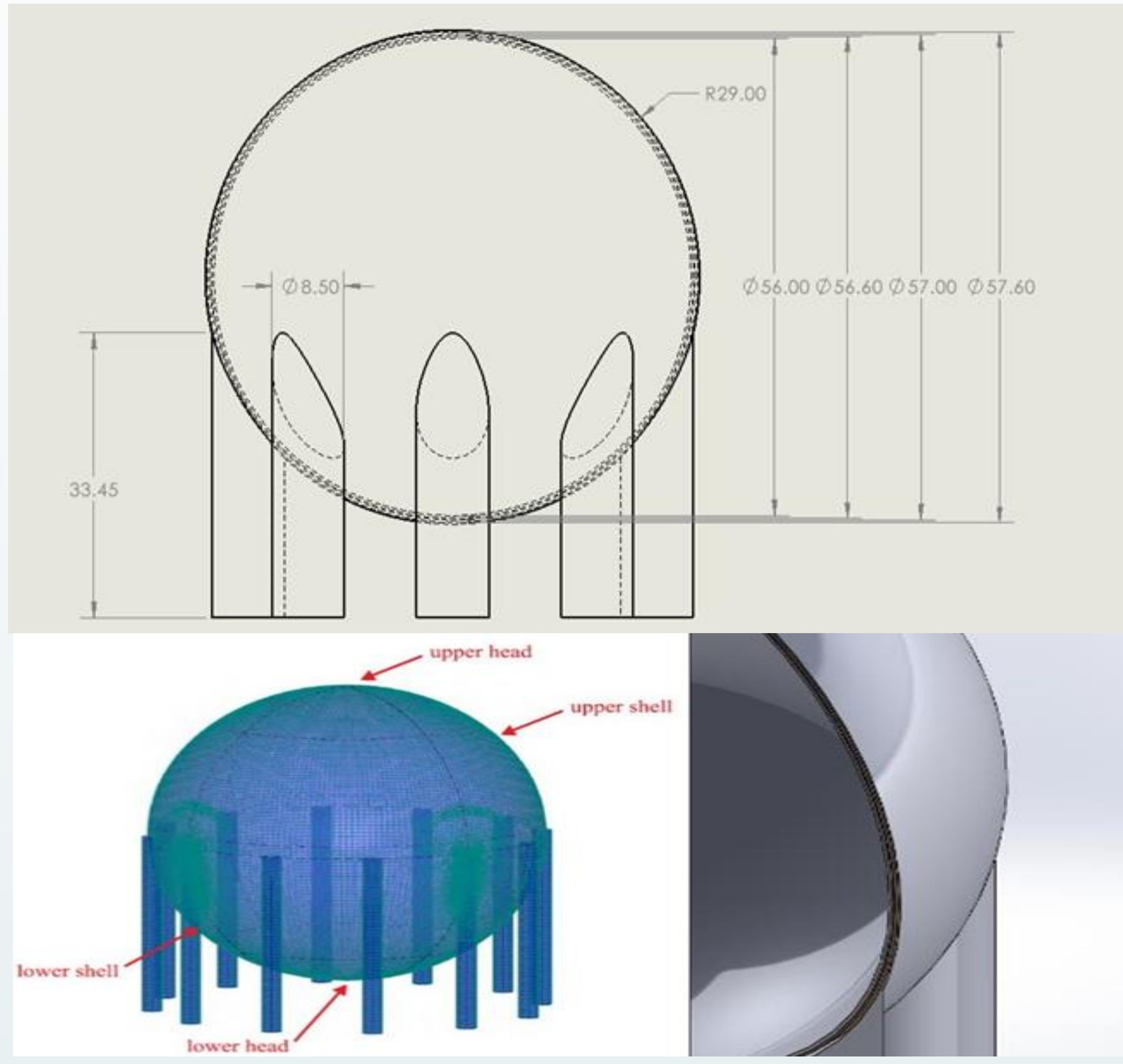
A new hydrogen liquefaction storage system has been proposed with the aim of overcoming the challenges of onboard storage in aviation, energy storage, and transportation.

- The system is designed to offer high energy density and reduced volume, making it suitable for a variety of applications.
- Existing cryogenic storage systems are limited by energy consumption, infrastructure requirements, and safety concerns.

Simulated Design



Tank Design



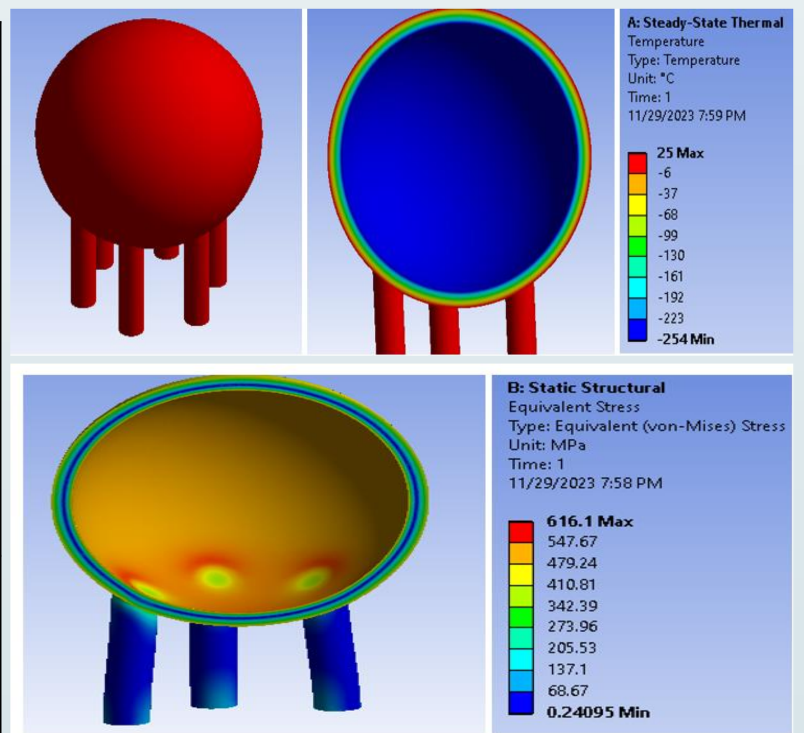
Testing & Validation

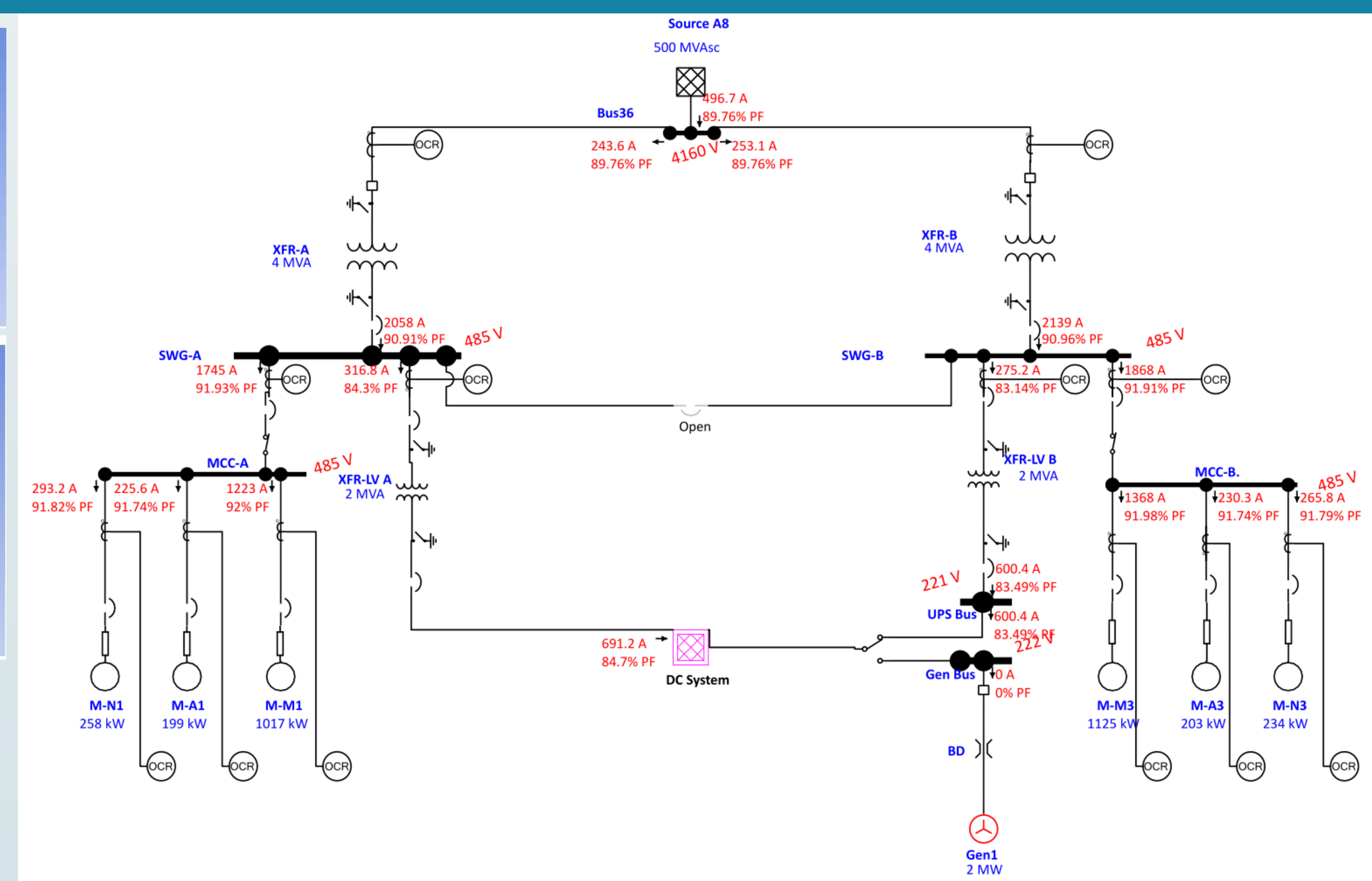
Name	Hydrogen Produ
Vapour	0.0000
Temperature [C]	-252.8
Pressure [bar]	1.000
Molar Flow [kgmole/h]	8929
Mass Flow [kg/s]	5.000
Std Ideal Liq Vol Flow [m3/h]	478.2
Molar Enthalpy [kJ/kgmole]	-7926
Molar Entropy [kJ/kgmole-C]	-107.6
Heat Flow [kJ/h]	-7.077e+007

Temperature & Pressure Specifications

Time to liquify	• **Cannot be determined since our process is a continuous process**
Energy to liquify	• **Power= 24,277.2 kWh,** • **Flow/hr= 18,000 kg/hr** • **24,277.2/18,000 = 1.3 kg/hr_{LH2}**

Storage Tank Design:	• **Reduce thermal diffusivity by minimizing k/a^(1/2) to maximize stored energy.** • **Critical insulation thickness: r_cr = 2k/h_rad.** • **Ideal insulation materials: Aerogel (r > 0.4567 m) or cellular glass foam (r > 0.7177 mm).** • **Structural design: Minimize yield strength while satisfying leak-before-break and yield-before-break criteria.** • **Stress considerations: Hoop stress (σ = ΔpR/2t) and thermal stress (σ_thermal = EαΔT).** • **Appendix simulation: Thermal-static analysis to determine stresses from pressure and temperature.**
Main findings:	• **No optimal insulation thickness, but critical thickness exists (r_cr) above which heat transfer increases.** • **Choice of material depends on detectable crack size.** • **Both pressure and temperature induce stresses in the tank.** • **Simulation results show stresses below yield strength for structural steel.**
Power Factor	• **Due to the KFUPM's license of ETAP software, the analysis needed cannot be done. Hence, the capacitor banks cannot be used in the design and gives an alarm. The Power Factor achieved is 0.91.**





Specifications

Table of specification		
Temperature	-252.8	Celsius
Pressure	1.0 < p < 5.0	Bar
Time of liquification	1.0	hr/kg
Energy to liquify	6	kWh/kg LH2
Power factor	>0.95	-
Capacity of the tank	Up to 3900	tons

Constrains

- The process of hydrogen liquefaction is challenging due to the extremely low temperature required.
- The safety of handling liquid hydrogen is a major concern due to the risk of frostbite, embrittlement, and explosions.
- The energy consumption of hydrogen liquefaction is high due to the need for cooling and compression.
- Finding suitable sensors for liquid hydrogen is difficult due to the extreme temperature.

Safety Measures

- Use of Personal Protective Equipment (PPEs)
- Fire Safety Management
- Chemical Hazards Management for Hydrogen
- Chemical Hazards Management for Ammonia
- Chemical Hazards Management for Nitrogen
- Chemical Hazards Management for Helium
- Reliving system for the tank (P_in<30lbf/in2)
- Valves are cryogenic valves(Extended stem & Vacuum Jacketed)

Cost Estimate

	US DOLLARS $
EQUIPMENT	27,186,660 $
UTILITY	17,550,280 $ / YEAR
OPERATION	21,190,390 $ / YEAR
ELECTRCITY	10,900,050 $ / YEAR

Conclusion

In conclusion in process of liquefying hydrogen there were 6 plate heat exchangers each of them are in cycle. first cycle was consisting of 1 heat exchanger and using ammonia as coolant, in second cycle of 3 heat exchangers uses nitrogen as a coolant and for the final cycle MR were used it was 2 exchangers and the coolant was helium 90% and 10% hydrogen. The hydrogen exists at 252.53 c. The tank was designed to prevent the loss of cool and can store up to 3900 tons (10 days of running continually) The distribution substation of power system was designed and to feed the process with power factor 0.91.