Variable frequency drive pump operating two stages Reverse osmosis

T E A M 0 1 - VFD Pump operating 2 stage RO

CHE		ME	
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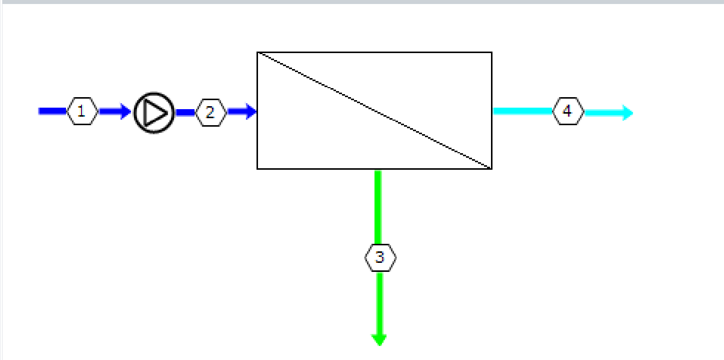
INTRODUCTION

The project aims to use less power at the cost of production to efficiently desalinate water using batch RO system paired with a Variable Frequency Drive Pump. the main customers that can use this product are laboratories, Farms who require larger quantities of fresh water. The system can be scaled up to generate the need of desalination plants.

PROTOTYPE DEVELOPMENT: CHE

Finding the relation between Concentration and pressure was the first role for chemical engineers in this project. By analyzing the Reverse osmosis and performing mass and salt balance on the system an equation was derived to solve for the concentrations of the three streams that are either introduced in the RO or are the output from the RO.



	1	2	3	4
Flow (m3/h)	100	100	40.1	60.0
Pressure (bar)	0	7.64	7.04	0
TDS (mg/l)	3000	3000	7150	227
pH	7.00	7.00	7.35	5.94
Econd (μs/cm)	5490	5490	12160	492

Overall mass balance:

$$Mf = Mb + Mp$$

Salt mass balance:

$$XfMf = XbMb + XpMp$$

So, solving the overall mass balance with the fact that the recovery is 60%

$$Mp = Mf * 0.60 = 100 * 0.60 = 60 m3/h$$

$$Mb = Mf - Mp = 100 - 60 = 40\ m3/h$$

Now to find the brine salt concentration Xb

Xb = $\frac{XfMf - XpMp}{Mb} = \frac{3000*100-120*60}{40}$ =7320PPM or mg/l

This analysis of the salt balance and simulation of Reverse osmosis showed that the system needs a pressure value that matches the concentration of the brine. E.g. 3000 tds feed means 7150 tds of brine which translates to 7 bars approximately.

PROTOTYPE DEVELOPMENT: ME

Pump Calculations:

Given Information

$P_{tank} = P_a$ = 1.01325 bar = 101.325 Kpa

$P_{RO} = P_b$ = 4 bar = 400 Kpa

y = 10.3 KN/m^3 , f = 0.019 , g = 9.81

$D_s = D_d = 25.4\ mm$, L_s =1.25m , L_d =0.75m   Using Bernoulli Equation

$$\frac{P_a}{y} + \frac{V_a^2}{2g} + z_a + H = \frac{P_b}{y} + \frac{V_b^2}{2g} + z_a + \Sigma h_L$$

$$H = \frac{Pb - Pa}{y} + \Sigma h_L$$

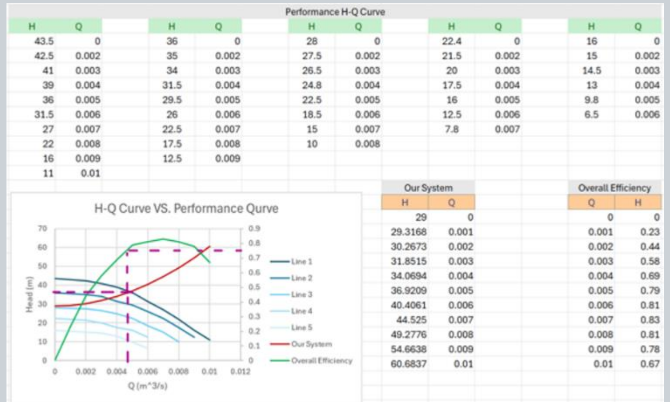
$$H = 29 + 316{,}837\ Q^2$$

From the Graph:

H = 38 m

Q = 0.005 $\frac{m^3}{s}$

η_0 = 0.75 = 75%



Performance H-Q Curve

H	Q	H	Q	H	Q	H	Q	H	Q
43.5	0	36	0	28	0	22.4	0	16	0
42.5	0.002	35	0.002	27.5	0.002	21.5	0.002	15	0.002
41	0.003	34	0.003	26.5	0.003	20	0.003	14.5	0.003
39	0.004	31.5	0.004	24.8	0.004	17.5	0.004	13	0.004
36	0.005	29.5	0.005	22.5	0.005	16	0.005	9.8	0.005
31.5	0.006	26	0.006	18.5	0.006	12.5	0.006	6.5	0.006
27	0.007	22.5	0.007	15	0.007	7.8	0.007		
22	0.008	17.5	0.008	10	0.008				
16	0.009	12.5	0.009						
11	0.01								

Our System

H	Q
29	0
29.3168	0.001
30.2673	0.002
31.8515	0.003
34.0694	0.004
36.9209	0.005
40.4061	0.006
44.525	0.007
49.2776	0.008
54.6638	0.009
60.6837	0.01

Overall Efficiency

Q	H
0	0
0.001	0.23
0.002	0.44
0.003	0.58
0.004	0.69
0.005	0.79
0.006	0.81
0.007	0.83
0.008	0.81
0.009	0.78
0.01	0.67

B.P. = $\frac{yQH}{\eta_0} = \frac{10.3(0.005)(38)}{0.75}$ = 2.5 KW = 3.36 Hp

Speed and Frequency of the Motor

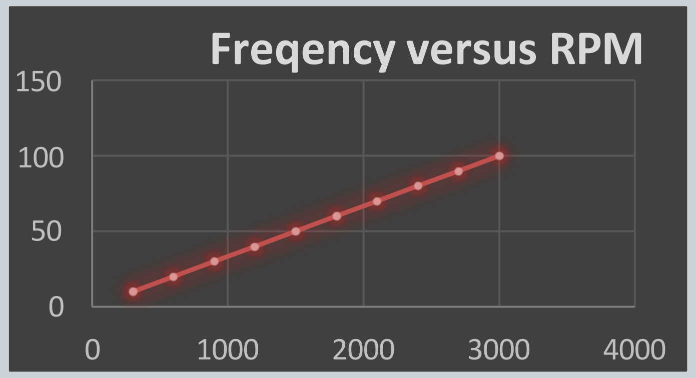
$$Ns = \frac{120*f}{P}$$

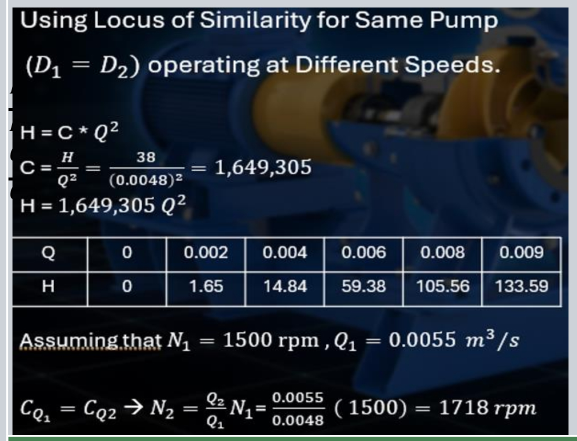
Ns: Synchronous Speed

F: frequency

P: Number of Poles

$$BHP = \frac{\text{Head x Flow x Specific Gravity}}{3960\ \text{x efficiency}}$$





Using Locus of Similarity for Same Pump ($D_1 = D_2$) operating at Different Speeds.

H = C * Q^2

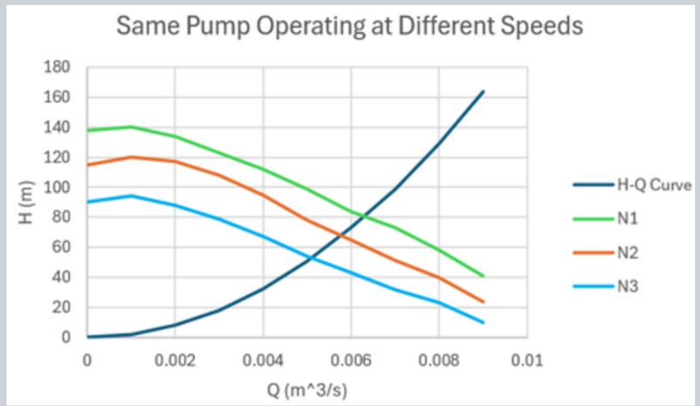
C = $\frac{H}{Q^2} = \frac{38}{(0.0048)^2}$ = 1,649,305

H = 1,649,305 Q^2

Q	0	0.002	0.004	0.006	0.008	0.009
H	0	1.65	14.84	59.38	105.56	133.59

Assuming that $N_1 = 1500$ rpm , $Q_1 = 0.0055\ m^3/s$

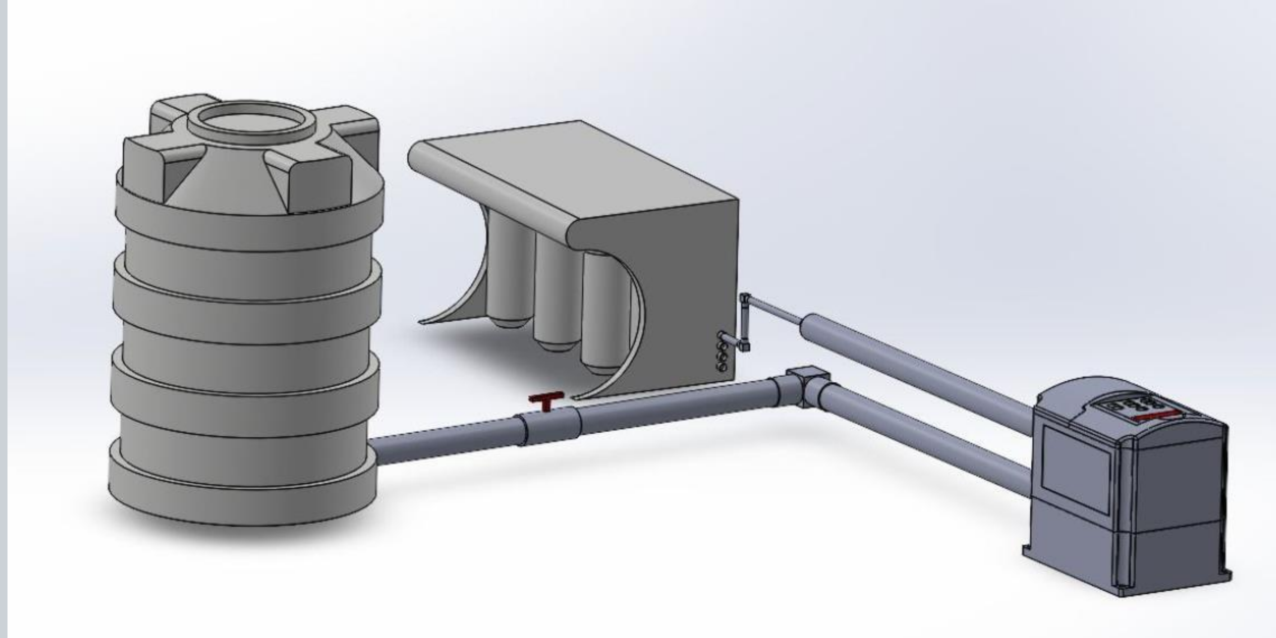
$C_{Q_1} = C_{Q2} \rightarrow N_2 = \frac{Q_2}{Q_1} N_1 = \frac{0.0055}{0.0048}(1500) = 1718\ rpm$



ANALYSIS

Combining the mechanical and chemical sections to systematically identify the pressure needed at each concentration then adjusting with the frequency that correlates the speed of the motor and pressure through the variable frequency drive at each batch.

Prototype Design



the Prototype is scaled down to brackish water feed of 3000tds approximately since seawater will need high pressure and more membranes. It consists of a tank, pump and Commercial Reverse osmosis system. The pipes are made from PVC that is corrosion resistant.

The Prototype constraints are

- 1-Pump Discharge pressure ≤10 Bar
- 2-Feed Salinity ≤5000PPM
- 3-Membrane size ≤8"
- 4-Budget ≤6000 SAR

Specifications are

- 1-Product TDS of 80-120 PPM
- 2-Overall recovery of 80%
- 3-Salt rejection of 98%
- 4-energy consumption <1kWh/m^3 product

TESTING

The prototype functionality is tested by the power consumption of the pump and the TDS in the brine and product by using a Concentration Element. The prototype works according to specifications

RESULTS

The Project prototype shows that for a small scale, brackish water it achieves the original objective of desalting the water using less power than usual. However, now it is not practical at large scale without a control system to control the level of the brine and feed tanks to switch feed efficiently without shutting down the pump.