24th Pump Users Symposium

Adequacy of Flow Loop Control of Pumps Operating in a Parallel Configuration Whenever Any of the Pumps are Tripped

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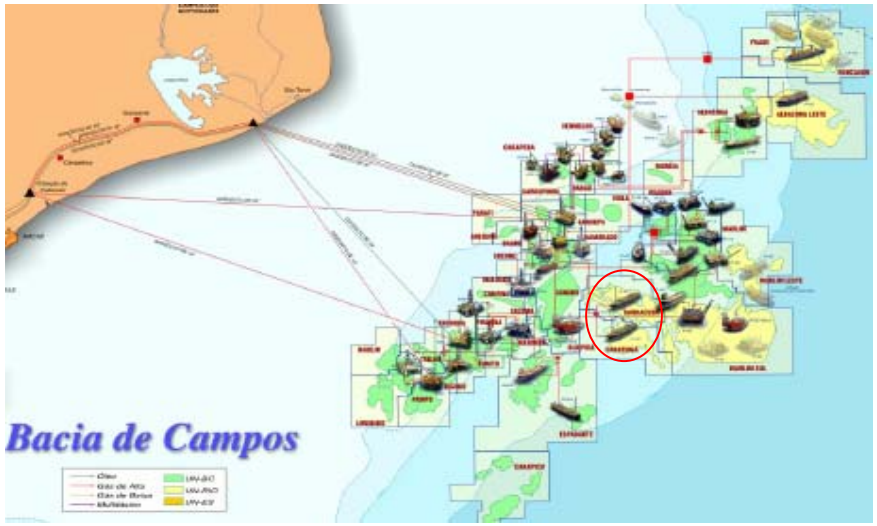
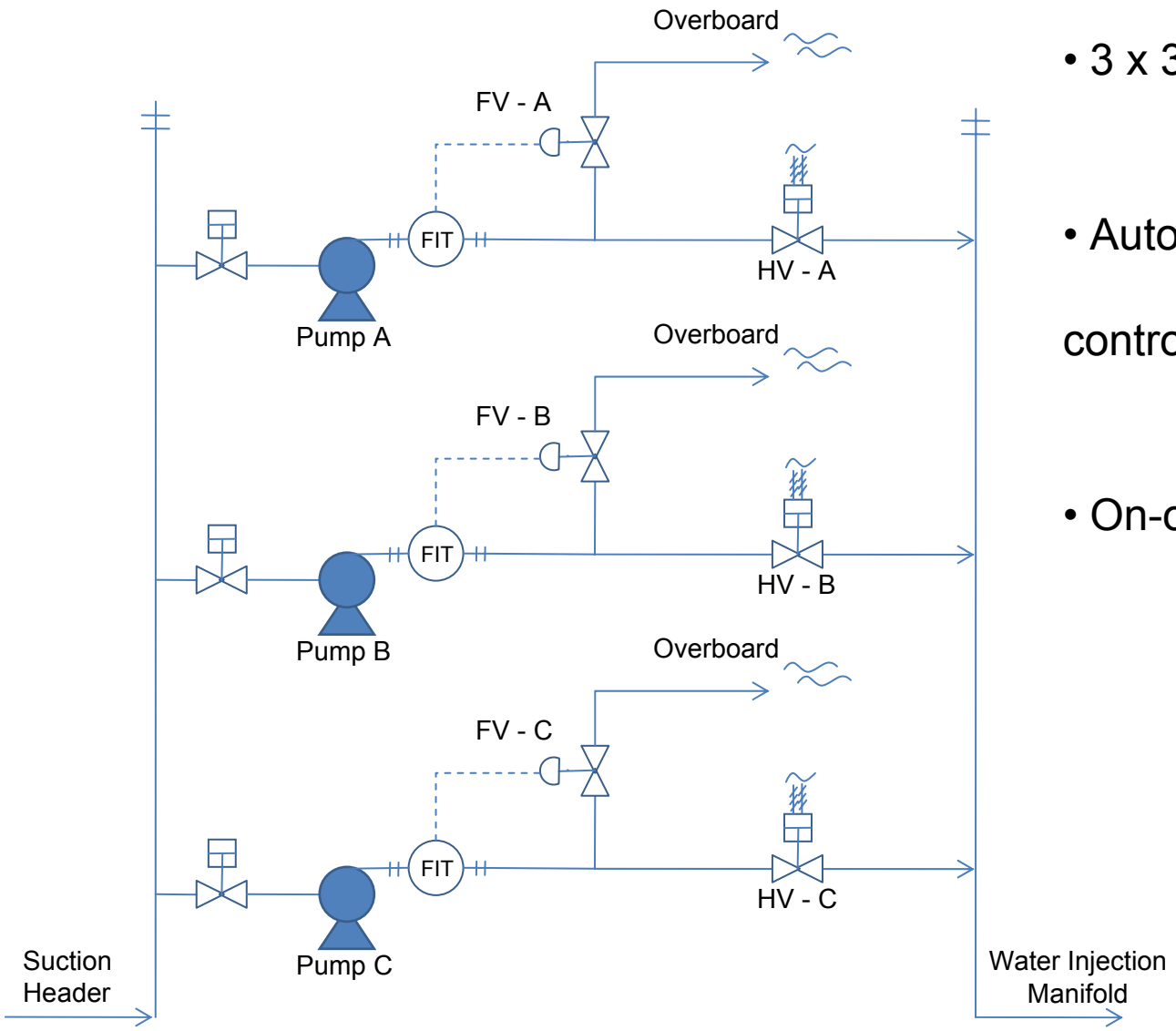
System Description

P-43 and P-48 are FPSO Platforms in Campo's Basin offshore Brazil.



- Processing capacity of 150,000 bpd each;
- Water injection facilities for 40,000 m3/day each.

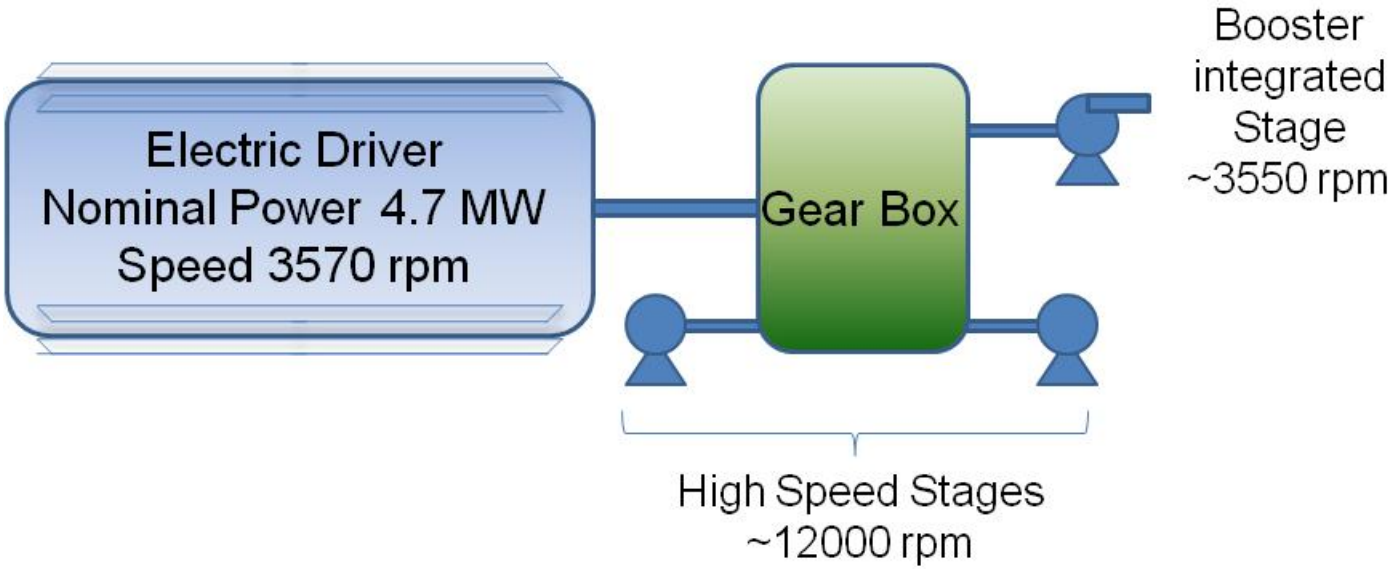
Water Injection System Description



- 3 x 33% pumps;
- Automatic minimum flow control (FVs);
- On-off discharge valves (HVs)

System Description

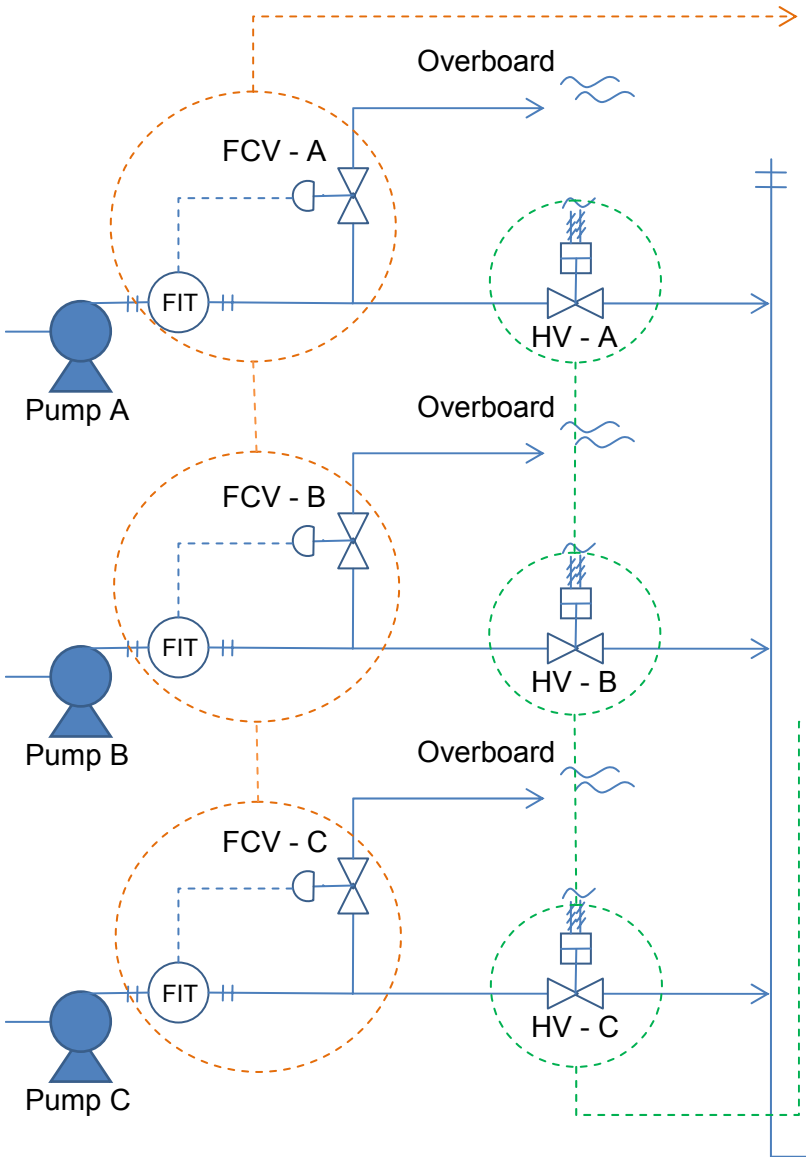
Pumps Features:



Pump Operational Data	
Nominal Capacity	2465 GPM (560 m3/h)
Discharge Pressure	2900 PSI (20,000 kPa)
Minimum Continuous outflow	880 GPM (200 m3/h)
Maximum Continuous outflow	3080 GPM (700 m3/h)
Trip – Minimum Outflow	660 GPM, 3s later (150 m3/h)
Trip – Maximum Outflow	3300 GPM (750 m3/h)

System Description

System characteristics:



Valves	Control Parameters		Set-Point	Stroke Time	ΔP
FCV A/C	Proportional	Integral time	880 GPM 200 m3/h	5 s	2870 PSI 19800 kPa
	3	0.1s			
Pneumatic driven					
Linear Closing Curves					

Valve	Nominal Ø (in)	Closing time
HV - A	14”	16s
HV - B		17s
HV - C		13s
Hydraulic driven		
Equal Percentage Closing Curves		

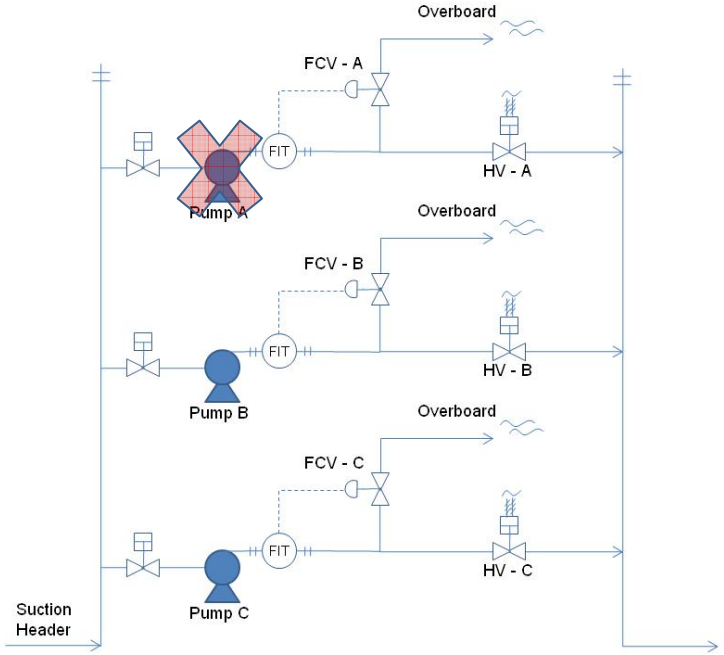
System Loop Control

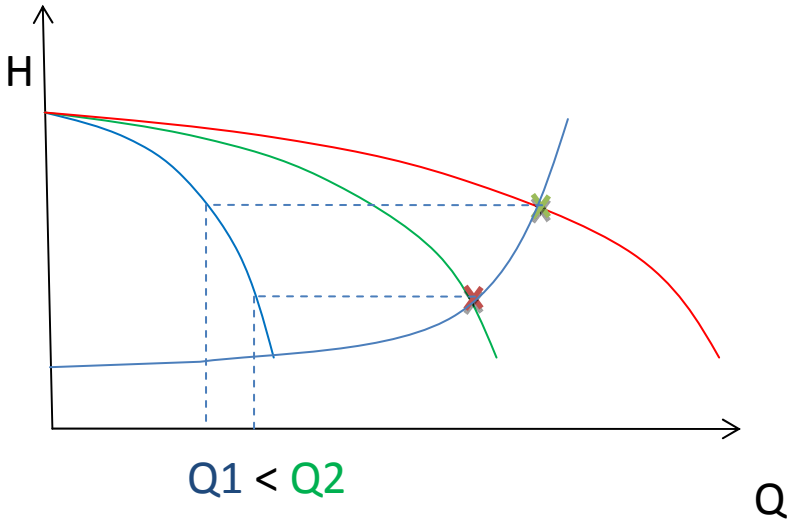
Main Control Constrains:

- Maximum flow pump trip - 3300 GPM (750 m3/h);
- Minimum flow pump trip - 660 GPM (150 m3/h) – 3s delay;
- Discharge valves open if pressure exceeds 3550 PSI (24500 kPa);

Problem Description

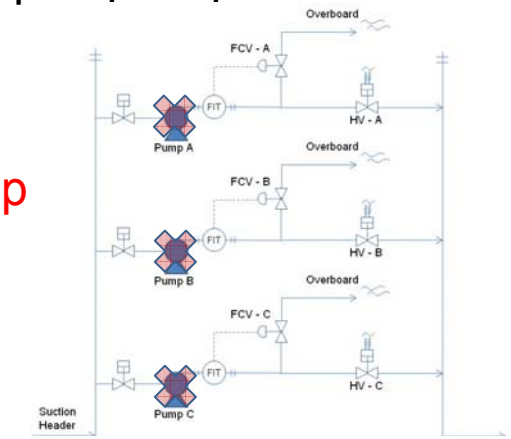
When one pump trips, the outflow of the other pumps rise due to parallel configuration.





The increase in the outflow of the remaining pumps often reaches the maximum allowed outflow, as a result all pumps trip.

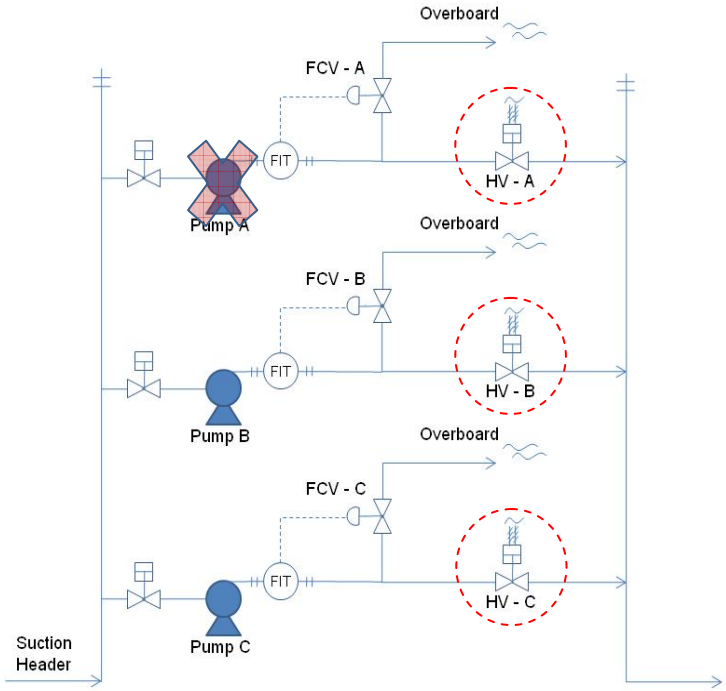
Q2 > 3300 GPM
(750 m3/h)



Cascade trip

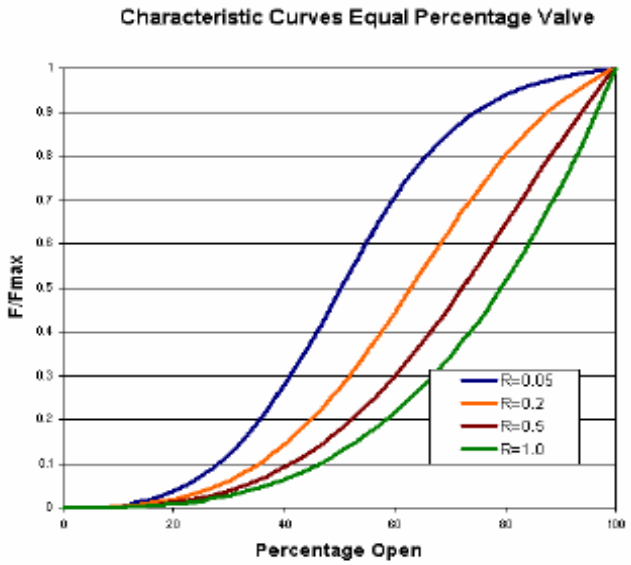
1st Solution Proposal

To prevent the pumps maximum flow, an automatic closing signal is given to the discharge valves of the three pumps whenever any of the pumps is tripped.



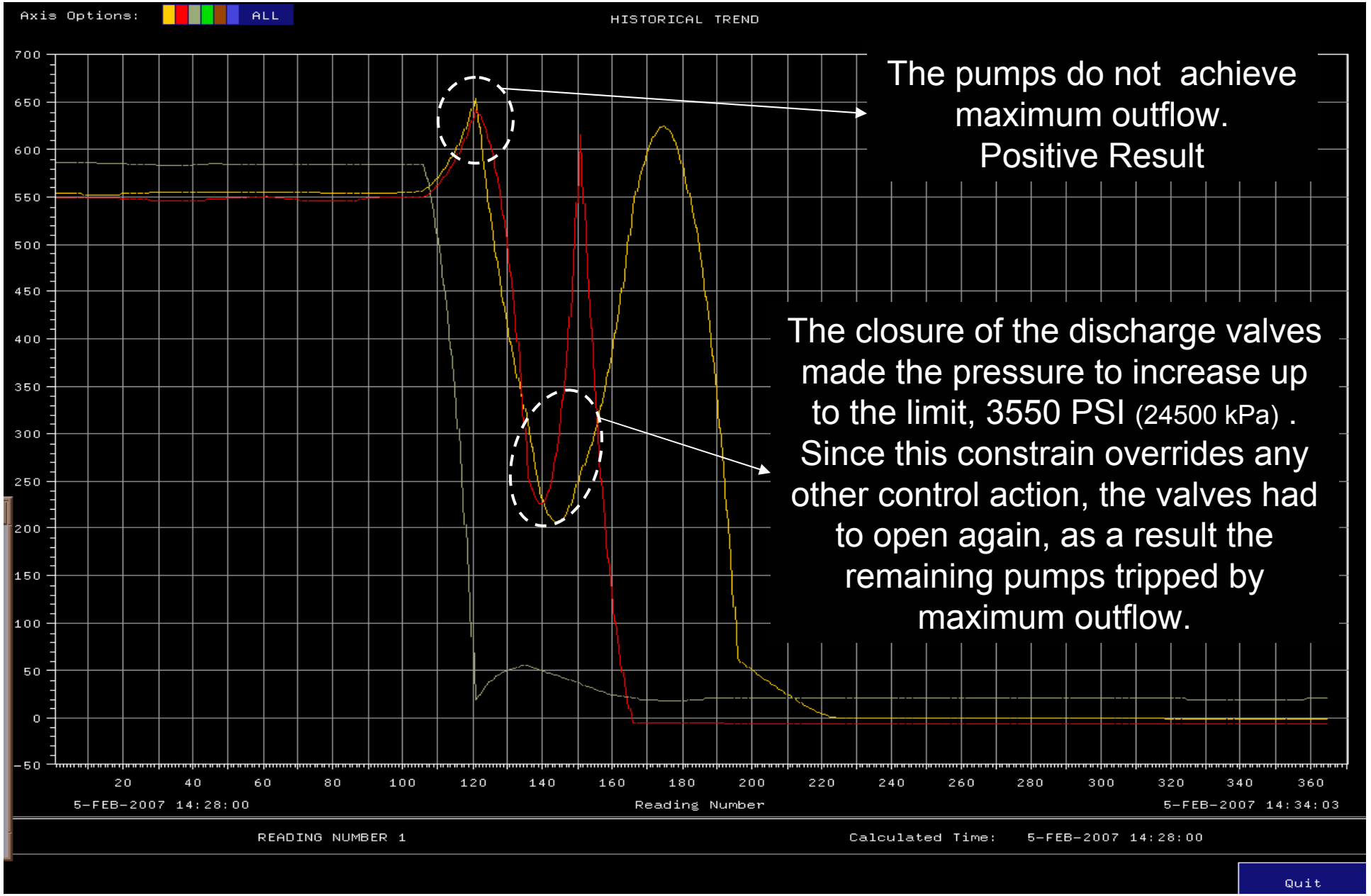
• The expected result was keeping the remaining pumps running in minimum flow;

• However, the response time of the minimum flow controller is not fast enough to prevent trip due to the on-off characteristic of the discharge valves.



1st Solution Proposal

Observed result.

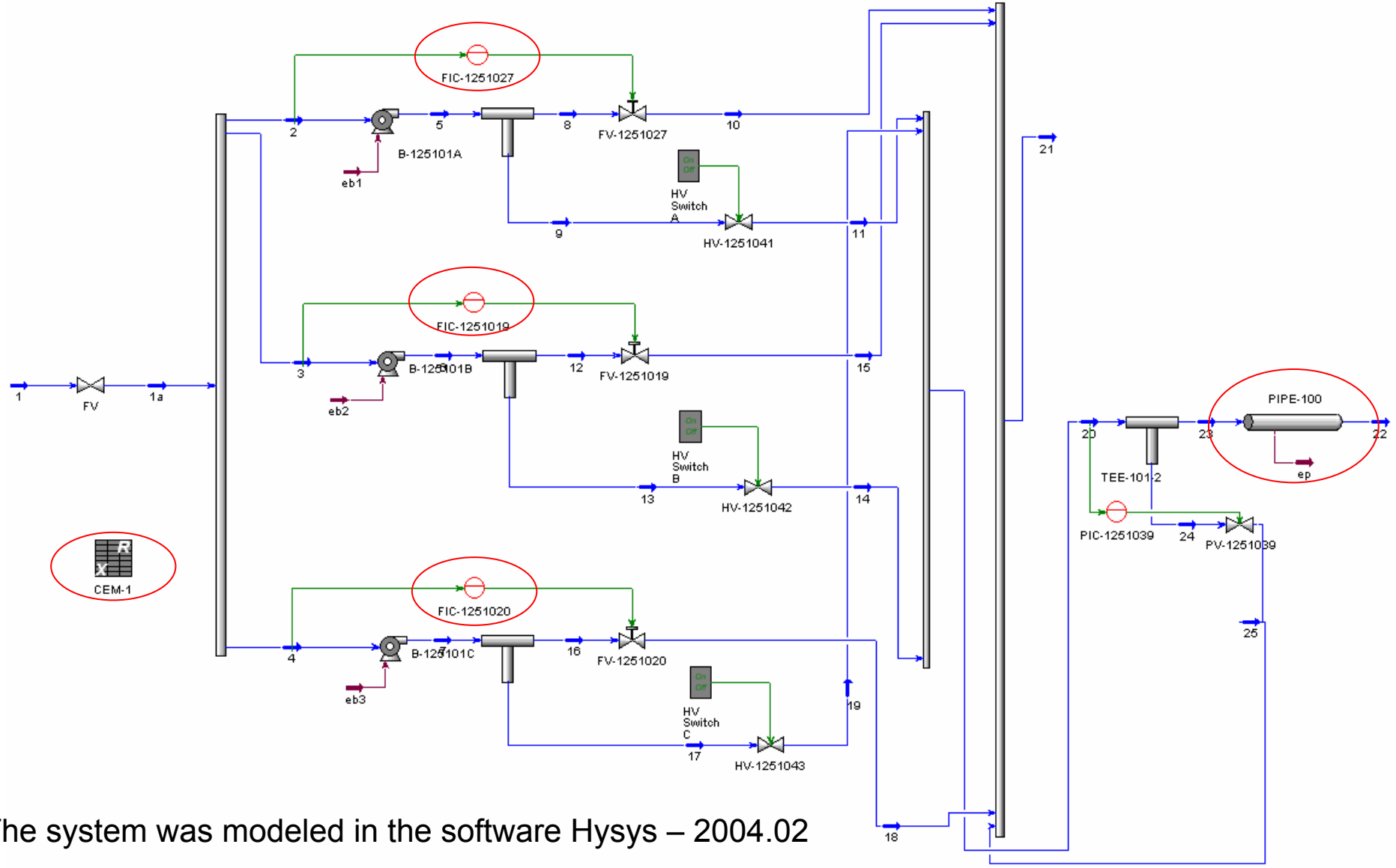


The pumps do not achieve maximum outflow.
Positive Result

The closure of the discharge valves made the pressure to increase up to the limit, 3550 PSI (24500 kPa) . Since this constrain overrides any other control action, the valves had to open again, as a result the remaining pumps tripped by maximum outflow.

System Modeling

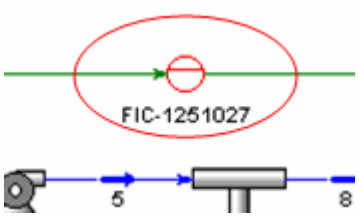
• A computer simulation study was carried out in order to try different control strategies before field application.



The system was modeled in the software Hysys – 2004.02

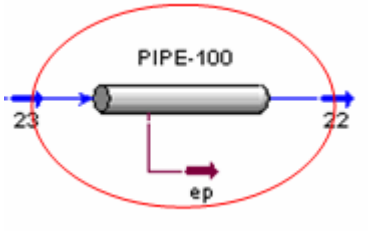
System Modeling

- The minimum flow valves loop control were set according to field values;



PI Parameters		Set-Point	Stroke Time	Cv (USGPM) Calculated by Hysys
Proportional	Integral time	880 GPM (200 m3/h)	5 s	24
3	0.1s			

- Pipe included to simulate flowlines;



Length (ft)	Diameter (in)	Elevation (ft)
13120 (4000 m)	10 (254 mm)	-6560 (-2000 m)

- Constrains included in C&E Matrix;

CEM-1

Cause and Effect Help...

Outputs (Effects)

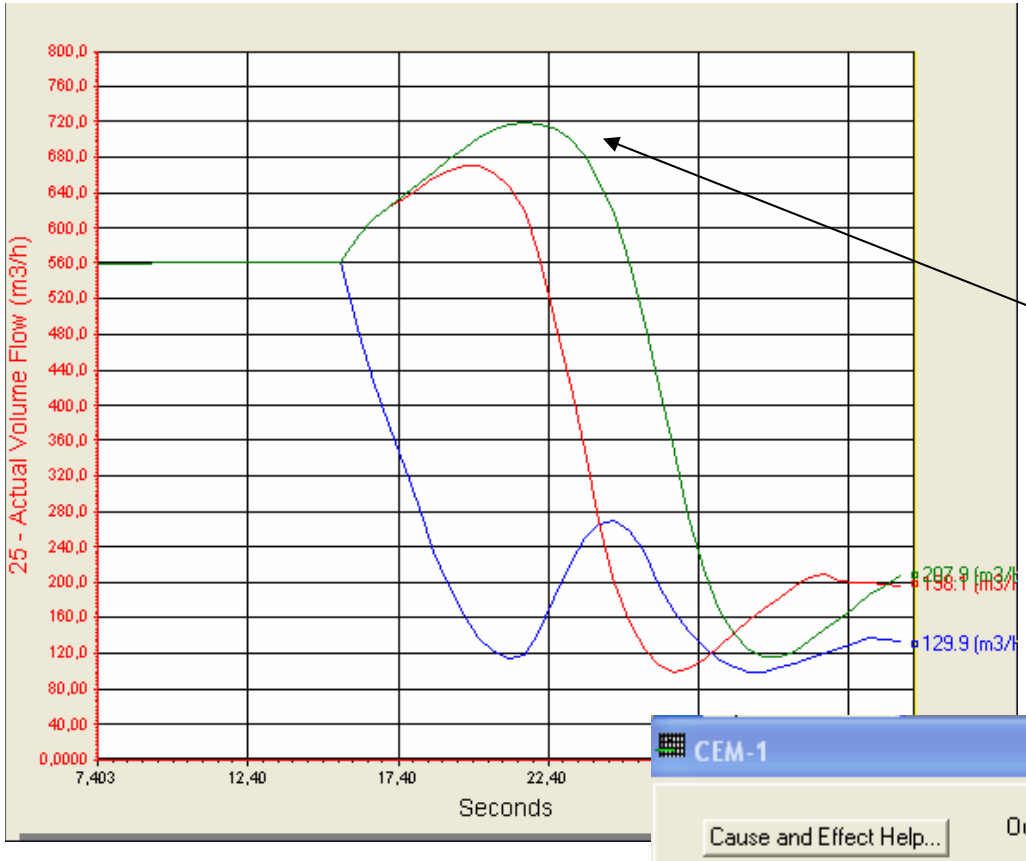
Inputs (Causes)

Effect #	1	2	3	4	5	6
Bypass	☐	☐	☐	☐	☐	☐
Reset	☐	☐	☐	☐	☐	☐
Local Switch	☐	☐	☐	☐	☐	☐
	✓	✓	✓	✓	✓	✓

#	Description	Tag	Value	Sw	OR							
1	Vazão de Água Mínima	FIT-1251027	561,2	☐	☐	✓	X			X	X	X
2	Vazão de Água Mínima	FIT-1251019	561,2	☐	☐	✓		X		X	X	X
3	Vazão de Água Mínima	FIT-1251020	561,2	☐	☐	✓			X	X	X	X
4	Vazão de Água Máxima	FIT-1251027	561,2	☐	☐	✓	X			X	X	X
5	Vazão de Água Máxima	FIT-1251019	561,2	☐	☐	✓		X		X	X	X
6	Vazão de Água Máxima	FIT-1251020	561,2	☐	☐	✓			X	X	X	X
7	Pressão mont HV	PIT-1251041	1,871e+004	☐	☐	✓	X					
8	Pressão mont HV	PIT-1251042	1,871e+004	☐	☐	✓		X				
9	Pressão mont HV	PIT-1251047	1,871e+004	☐	☐	✓			X			

Model Result

- The model fairly represented the field behavior;



Pump A was tripped manually

No trip - high flow

Trip - low flow

CEM-1

Cause and Effect Help...

Outputs (Effects)

Inputs (Causes)

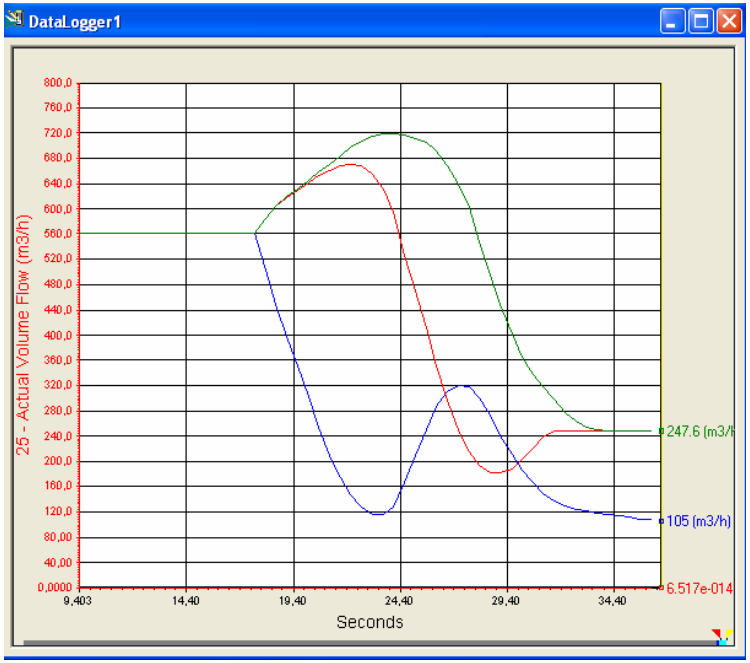
Effect #	1	2	3	4	5	6
Bypass						
Reset						
Local Switch						

#	Description	Tag	Value	Sw	OR		1	2	3	4	5	6
1	Vazão de Água Mínima	FIT-1251027	0,0000	☑	☐	✗	X			X	X	X
2	Vazão de Água Mínima	FIT-1251019	198,5	☐	☐	⚡		X		X	X	X
3	Vazão de Água Mínima	FIT-1251020	203,8	☐	☐	✓			X	X	X	X
4	Vazão de Água Máxima	FIT-1251027	129,4	☐	☐	✓	X			X	X	X
5	Vazão de Água Máxima	FIT-1251019	198,5	☐	☐	✓		X		X	X	X
6	Vazão de Água Máxima	FIT-1251020	203,8	☐	☐	✓			X	X	X	X
7	Pressão mont HV	PIT-1251041	3982	☐	☐	✓	X					
8	Pressão mont HV	PIT-1251042	1,174e+004	☐	☐	✓		X				
9	Pressão mont HV	PIT-1251047	1,609e+004	☐	☐	✓			X			

Two Loop Control Strategies

Delayed FV Open:

1. First pump trips;
2. Closing signal for 3 discharge valves;
3. 7s later, FV opens at 80%



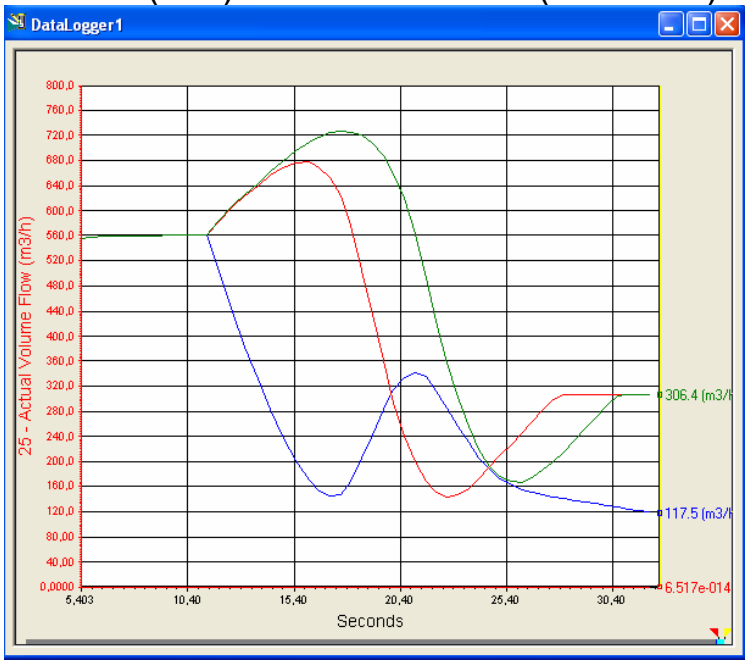
Conclusion:

1. Strategy works;
2. Difficult implementation, field tests needed;

Set Point Change:

1. First pump trips;
2. Closing signal for 3 discharge valves;
3. FV controllers' Set-Point changes:

880 (200)⟶ 1660 GPM (400 m3/h)

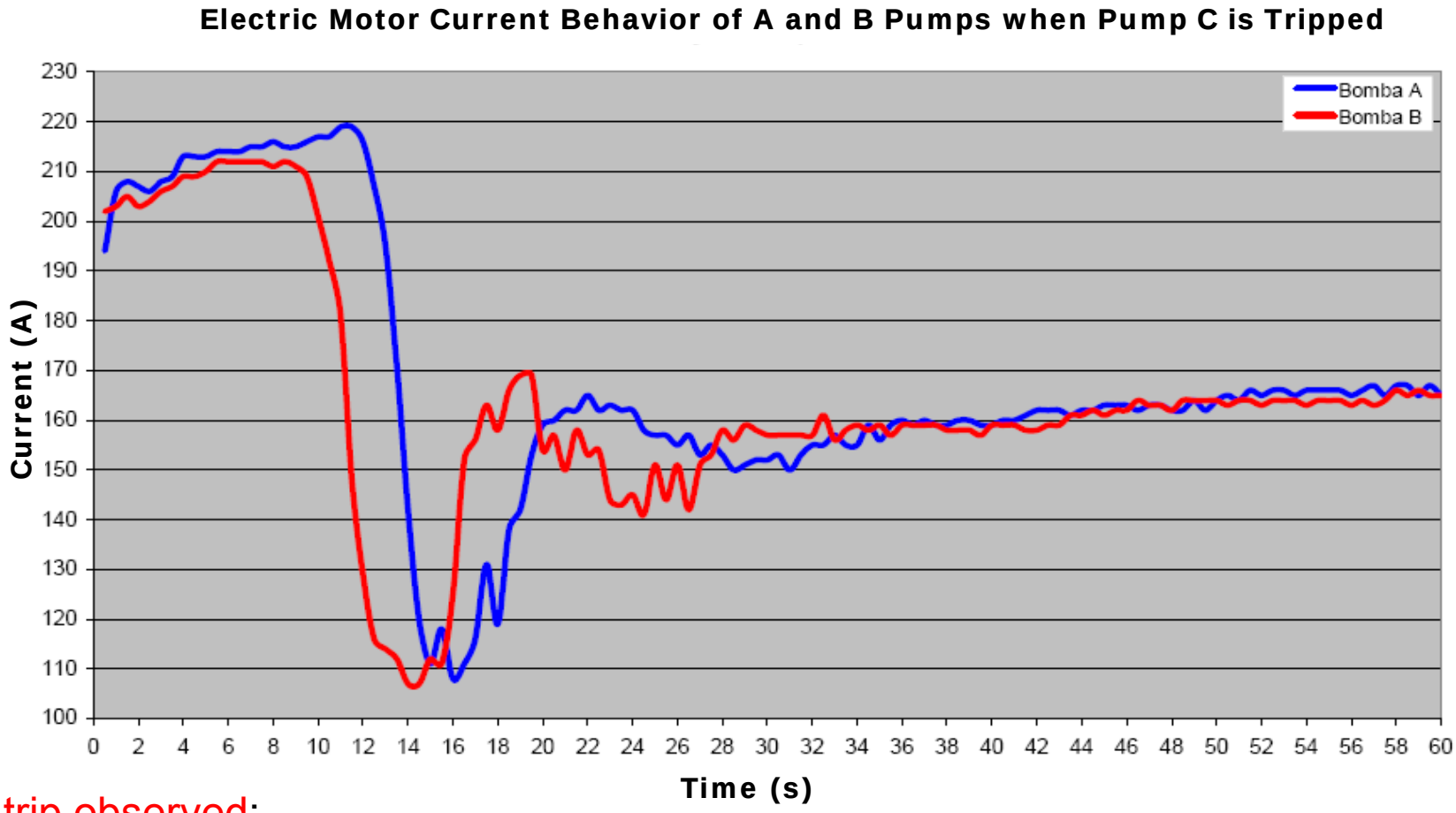


Conclusion:

1. Strategy works as well;
2. Easier implementation;
3. Chosen!

Field results

- PI trend: Pump C Tripped;



- No trip observed;
- Simulation was feedbacked by field results for fine tuning;
- New setpoint: 1980 GPM (450m3/h) ;
- Loop control also worked when only 2 off 3 pumps were running.

Conclusion

Dynamic Simulation Proved to be a Valuable Tool to Solve Control Problems in large Pumping Systems

- Simulations allow to test a large number of ideas before field application;
- Reliable results;
- Model can be used to solve other problems.