Promoção e Organização:

INSTITUTO BRASILEIRO DE PETRÓLEO, GÁS E BIOCOMBUSTÍVEIS

24 - 27 SET
RIOCENTRO - RJ

OTIMIZAÇÃO DE UM CONTROLADOR PID PARA UM TANQUE SEPARADOR BIFÁSICO COM ALGORITMO GENÉTICO

PID CONTROL OPTIMIZATION FOR A BIPHASIC SEPARATOR USING GENETIC ALGORITHM

Alexandre Campos

OBJETIVOS
GOALS

PID CONTROL OPTIMIZATION FOR A BIPHASIC SEPARATOR USING GENETIC ALGORITHM

- Minimize slug effects upon a biphasic separator tank;
- Control variables: liquid level, gas pressure, outlet liquid flow;
- Keep valves opening fraction within desirable values if possible;
- Optimize PID parameters via Genetic Algorithm.

MODELO

MODEL

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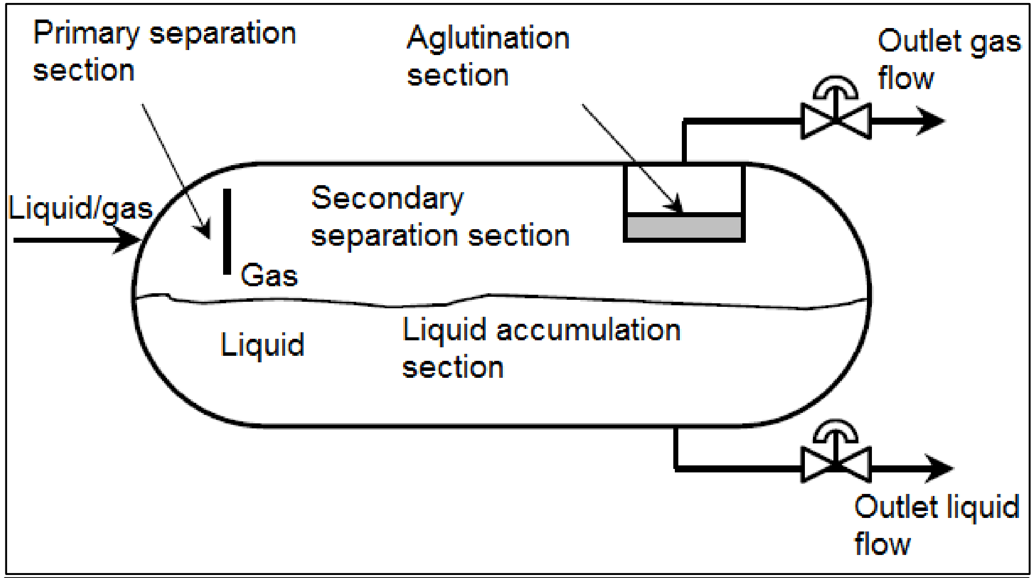
- Liquid and gas flow through the valves described by

$$L_{out}(t) = C_{VL} x_L(t) \sqrt{[P(t) + \rho_L g h_L(t) - P_1] / (\rho_L / \rho_{H_2O})}$$

$$G_{out}(t) = \frac{C_{VG} x_g(t)}{P(t)} \sqrt{[P(t)^2 - P_2^2] T \, MM_{air} / MM_g}$$

- C_V = valve flow coefficient;
- $x(t)$ = valve opening fraction;
- $P_{1,2}$ = downstream pressures.



Source: adapted from SILVA et al. (2007)

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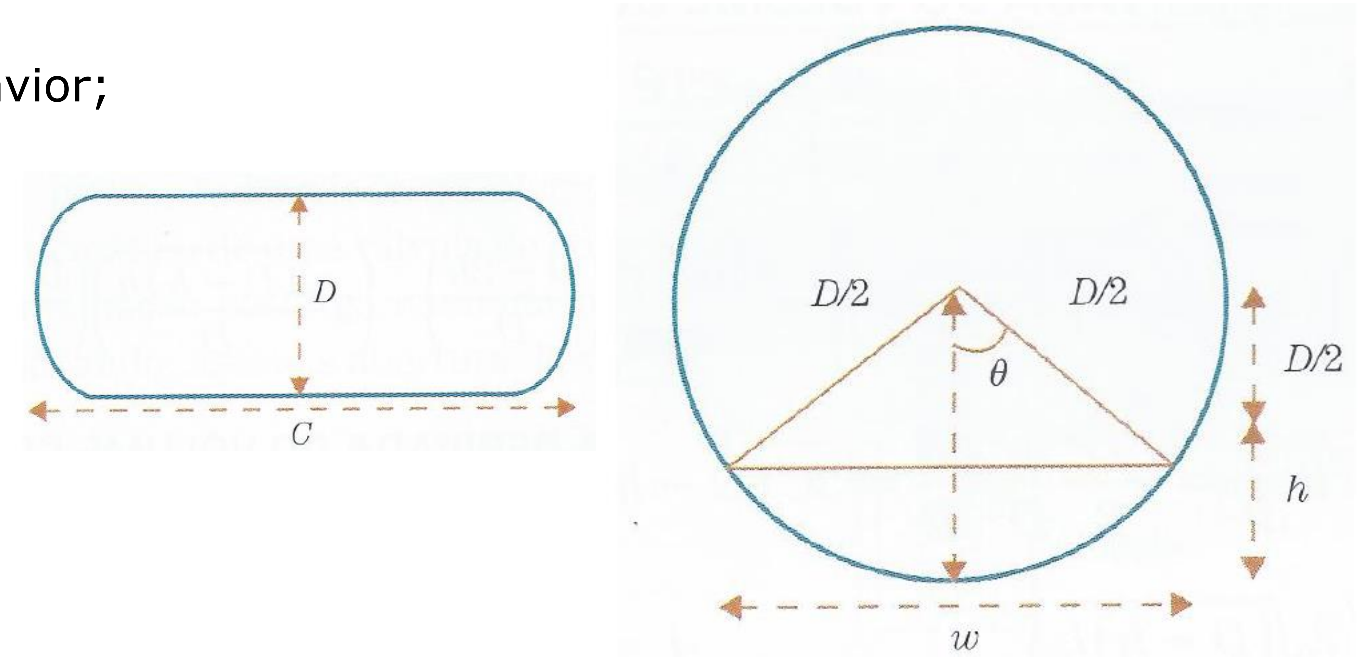
- Tank assumed as horizontal cylinder;
- Conservation of mass and ideal gas behavior;
- Two transfer functions result:

$$H_L'(s) = G_{p11}X_L'(s) + G_{p12}X_G'(s)$$
$$P_L'(s) = G_{p21}X'L(s) + G_{p22}X_G'(s)$$



Source: NUNES et al. (2010)

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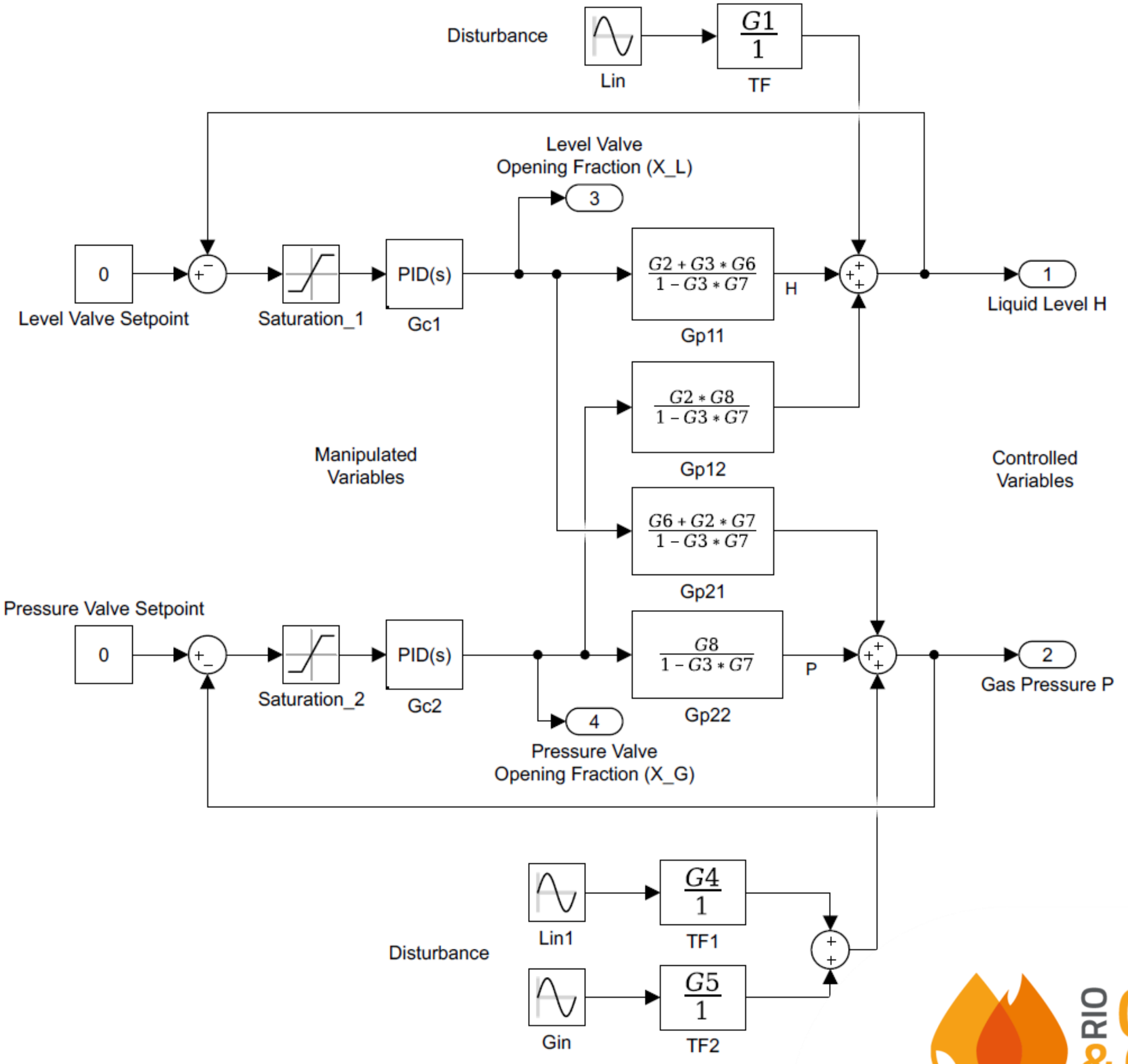
- Block diagram simulates tank behavior;
- Manipulated variables:
  - Liquid valve;
  - Gas valve;
- Controlled variables:
  - Liquid level;
  - Gas pressure;
- Disturbances:
  - Slug effect on inlet liquid flow;
  - Slug effect on inlet gas flow.



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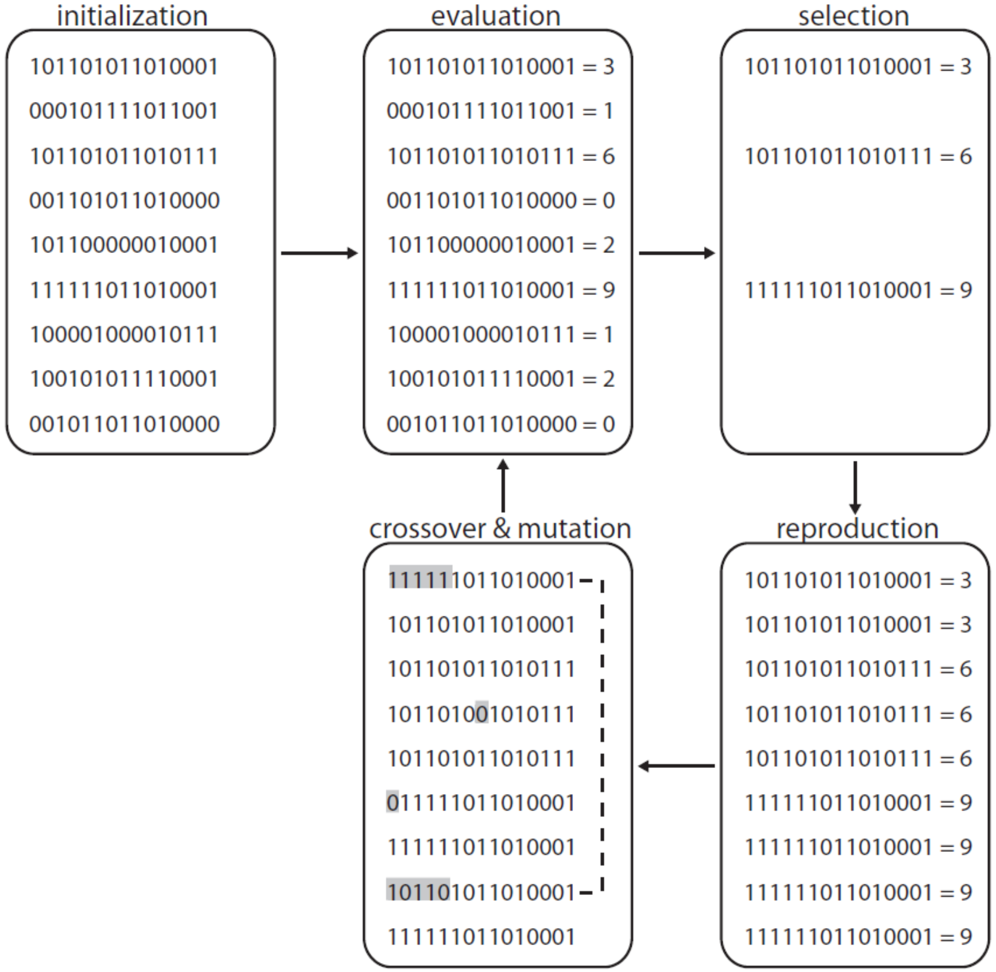
Genetic Algorithm

- Meta-heuristic tool inspired by natural selection and evolution;
- Initializes a population with several individuals;
- Evaluates individuals;
- Select individuals with better results;
- Survivors reproduce and exchange information;
- Process repeats until convergence.



Source: FLOREANO; MATTIUSSI (2008)

PARÂMETROS
PARAMETERS

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Genetic Algorithm	
Population (individuals)	50
Generations (iterations)	30
Mutation Function	*@mutationadaptfeasible*
Plot Function	*@gaplotbestf*

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Initialization Parameters

Simulation time	500 minutes
Downstream pressures ($P_{1,2}$)	6 bar
Liquid valve flow constant (C_{VL})	$1025\ GPM/\sqrt{psi}$
Gas valve flow constant (C_{VG})	120 $GPM/\sqrt{psi}$
Liquid density (ρ_L)	850 kg/m^3
Gas molar mass (MM_g)	0.021 kg/mol
Steady state liquid flow ($\bar{L}_{in}, \bar{L}_{out}$)	0.165 m^3/s
Steady state gas flow ($\bar{G}_{in}, \bar{G}_{out}$)	0.1 m^3/s
Steady state tank pressure ($\bar{P}$)	8 bar
Steady state tank level ($\bar{h}_L$)	1.1 m
Steady state valves opening fraction (x_L, x_g)	0.5

RESULTADOS

RESULTS

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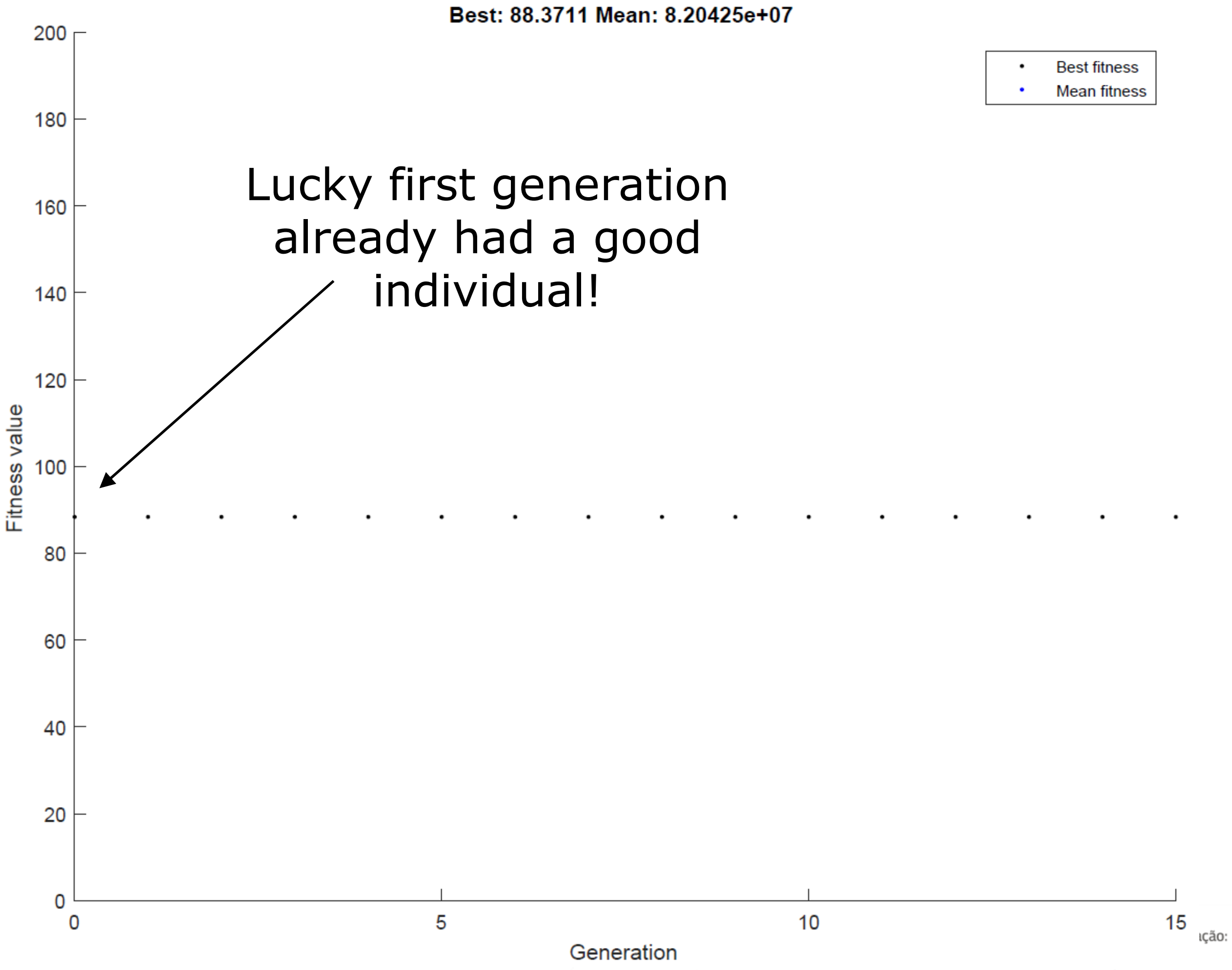
Genetic Algorithm convergence:

- Function to be minimized (fitness value):

$$\max\left(\left|\frac{h'(t)}{\bar{h}_L}\right|,\left|\frac{P'(t)}{\bar{P}}\right|,\left|\frac{x'_L(t)}{\bar{x}_L}\right|,\left|\frac{x'_G(t)}{\bar{x}_G}\right|,\left|\frac{L'_{out}(t)}{\bar{L}_{out}}\right|\right)$$

- Meta-heuristic nature is highly dependent on randomness;
- In this specific simulation, the first generation already contained an individual with good results;
- Not easy to know if final result is global optimum or local optimum.



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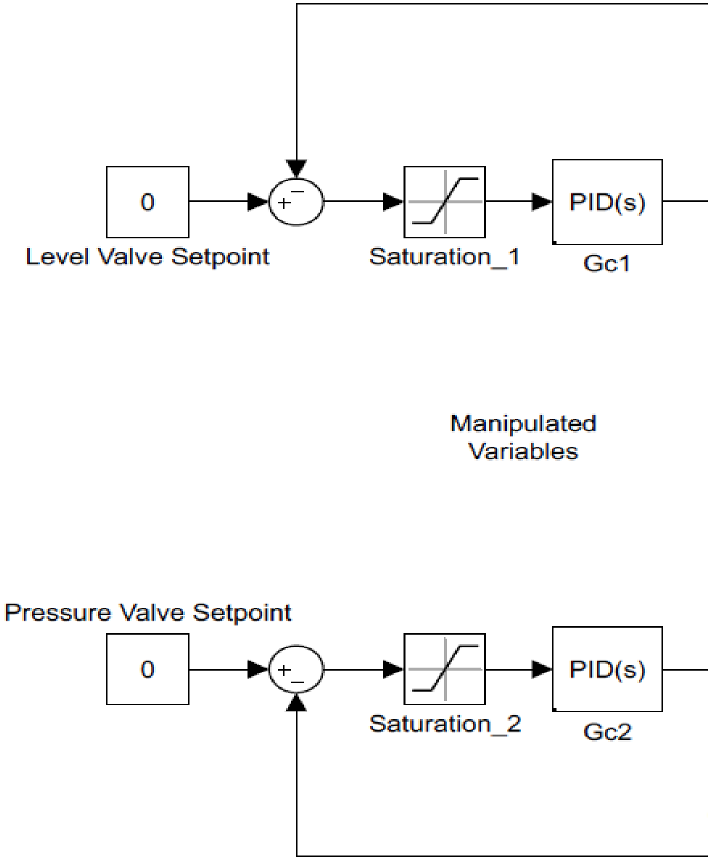
Best individual performance

PID parameters for liquid and gas valves

Optimal Parameters	Liquid	Gas
K	-4.3109	-5.2606
I	-15.0282	-0.4556
D	19.8454	1.0189



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Best individual performance

Controlled parameters	
Outlet liquid flow deviation	88.3711 %
Maximum valve opening fraction	64.8096 %
Pressure deviation	0.0049 %
Level deviation	0.0051 %

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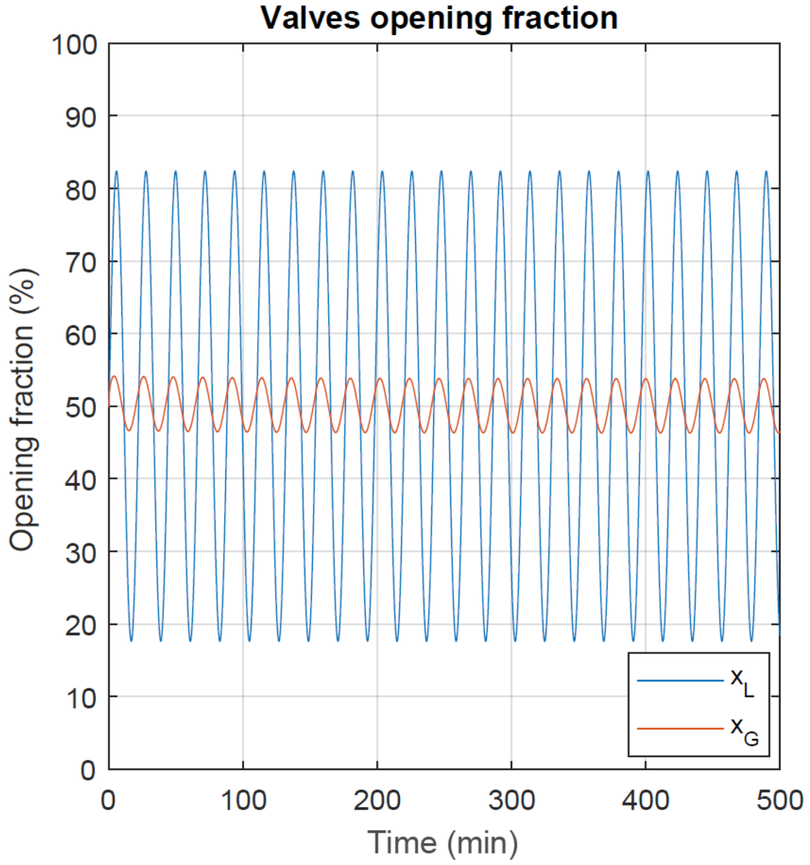
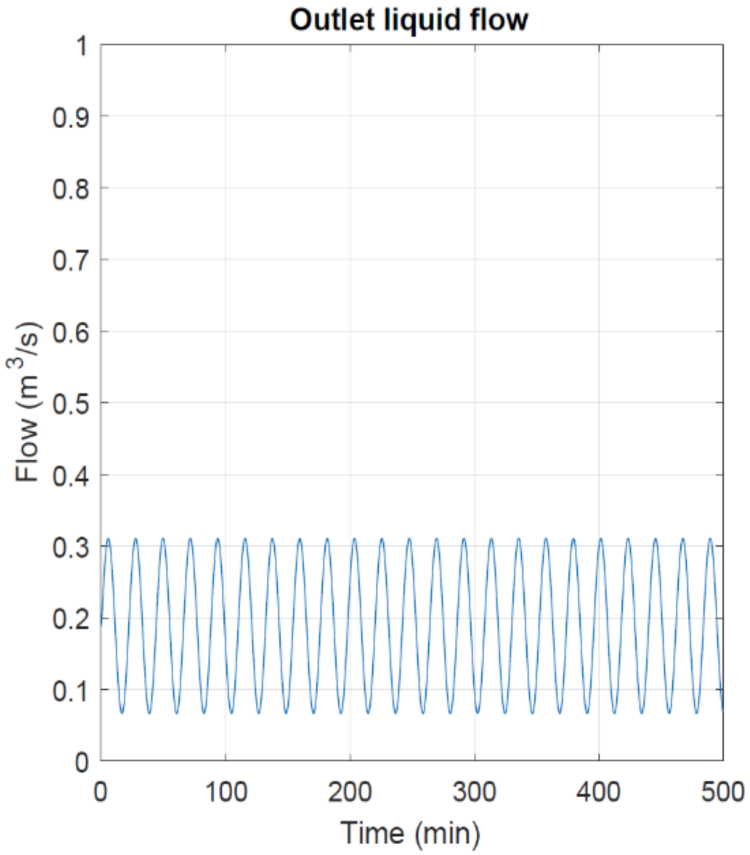
Valves:

- Opening fractions with maximum amplitude of 60%;
- *Poligon* (2014) suggests an optimum interval between 30% and 80%;
- Range exceeded in 10%.

Outlet:

- High amplitude;
- Amplification of 144% compared to disturbance (amplitude of 0.05 m/s^3);





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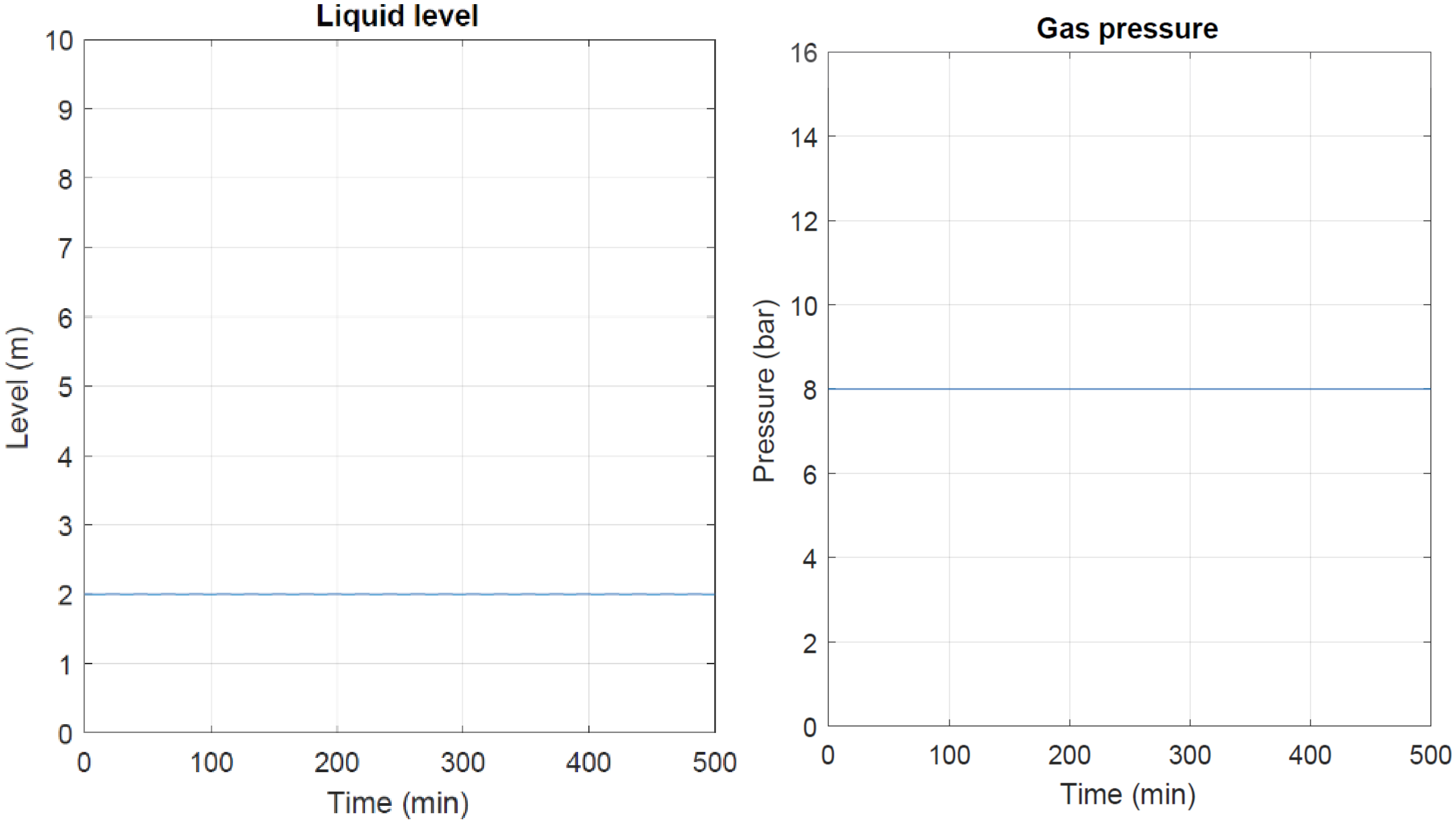
Level and Pressure:

- Unchanged when controller is active;
- Stability reflects on outlet liquid flow behavior;



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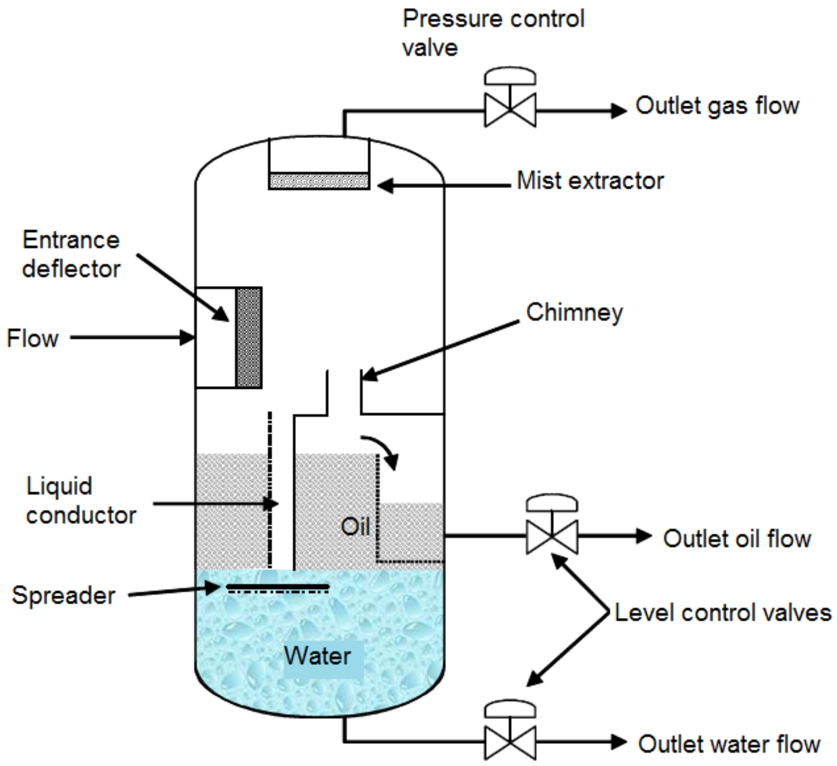
Conclusions:

- Potentially few iterations to reach optimum value;
- Liquid level and gas pressure deviations inexistent;
- Not very good in controlling outlet liquid flow;
- Valves opening fraction within acceptable values.

Topics for further research:

- Controller loops around liquid and gas outlet flows instead of level and pressure;
- Effect of choke valve;
- Effect of tanks in series;
- Three-phase separators;



Source: adapted from SILVA et al. (2007)

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Slides References

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