UNIVERSIDAD DE LAS FUERZAS ARMADAS ESPE

DEPARTAMENTO DE ELÉCTRICA Y ELECTRÓNICA

CARRERA DE INGENIERÍA EN ELECTRÓNICA E INSTRUMENTACIÓN

Artículo Académico Previo a la Obtención del Título de Ingeniero en Electrónica e Instrumentación

International Conference on Applied Technologies 2022 – ICAT 2022

Design of a Model Based Predictive Control (MPC) Strategy for a Desalination Plant in a Hardware in the Loop (HIL) Environment.

Authors:

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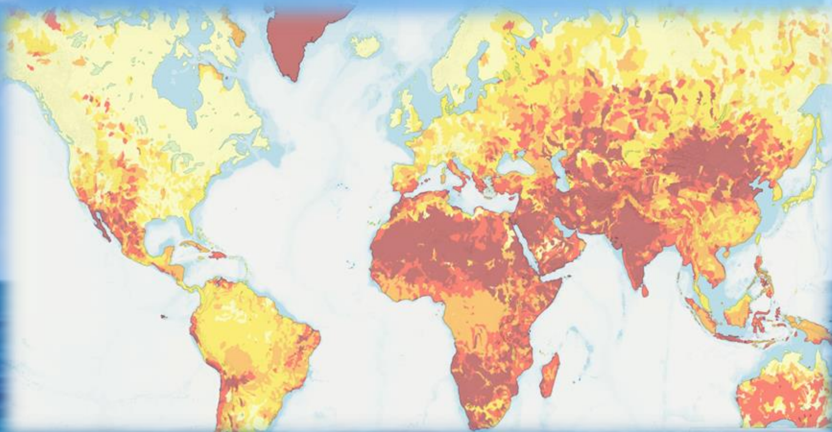
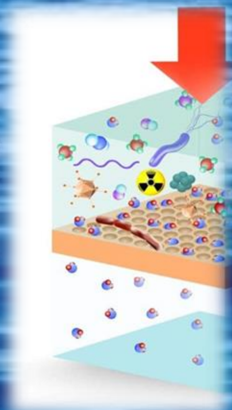
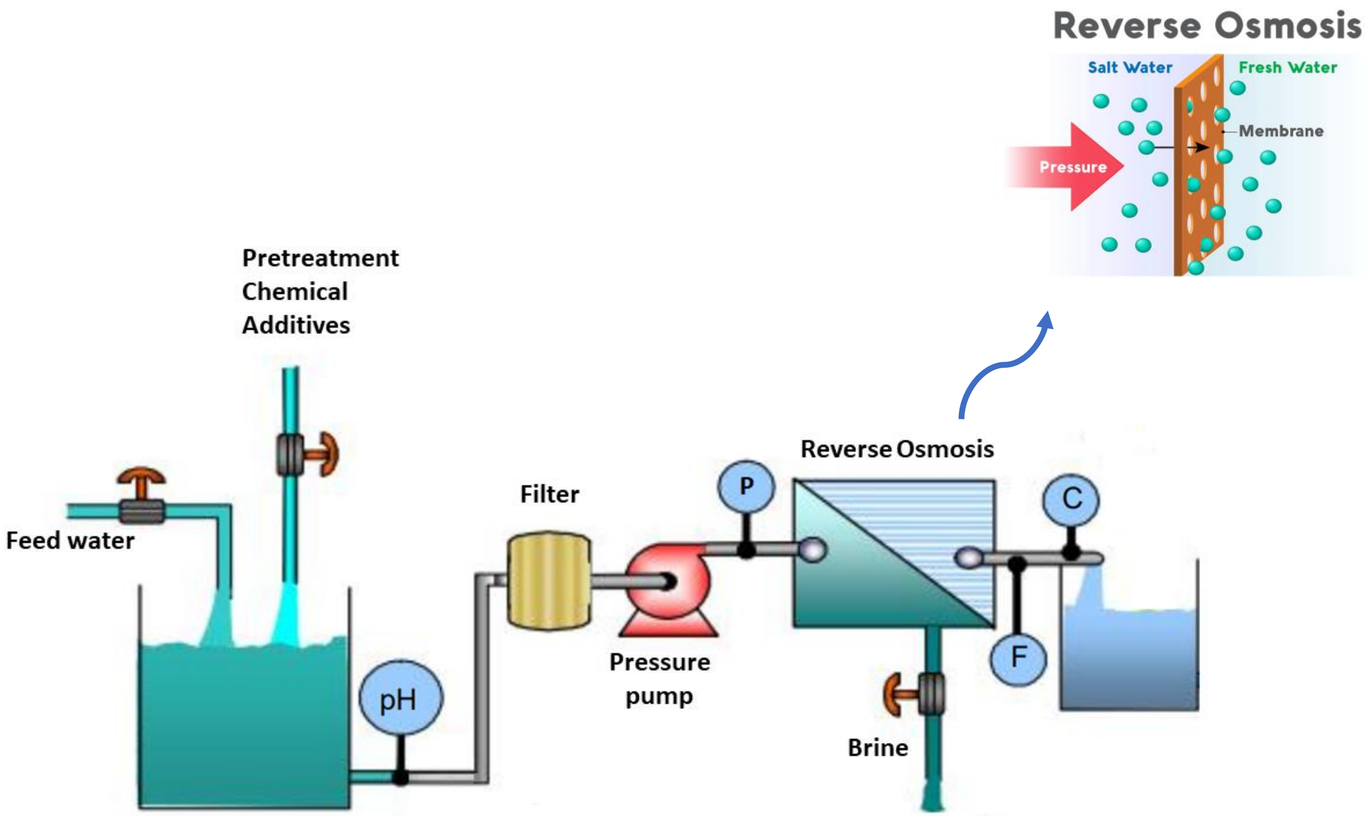




INTRODUCTION



INTRODUCTION

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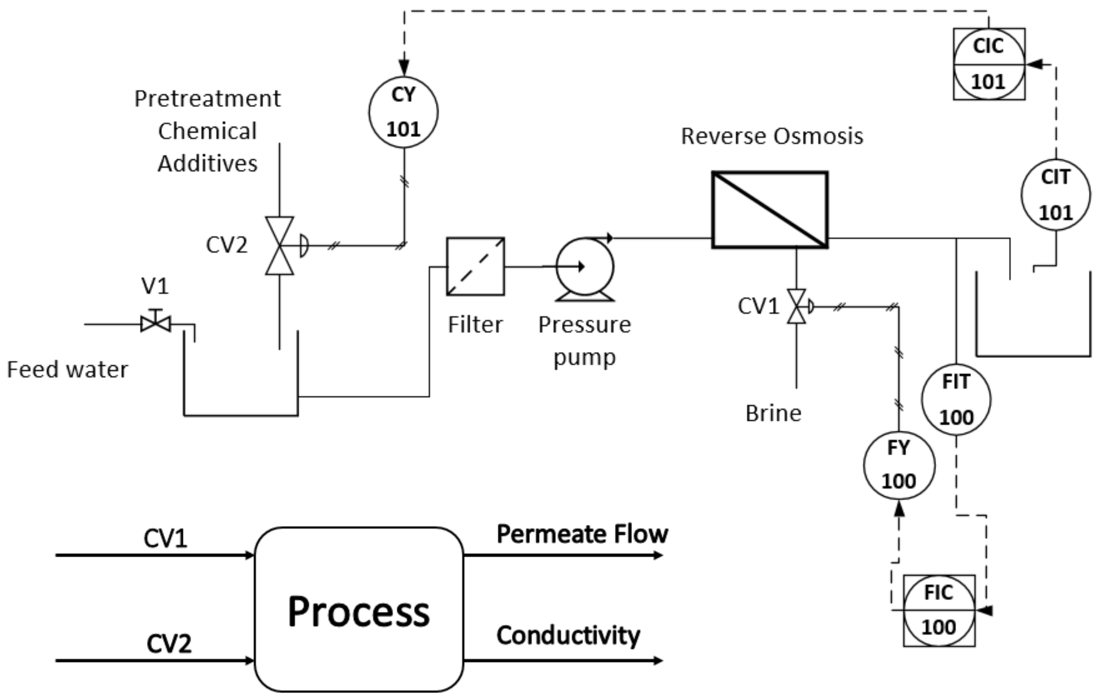
PROCESS MODELING

REVERSE OSMOSIS PROCESS



$$\frac{F}{P} = G_{p11} = \frac{0.002(0.56s+1)}{0.003s^2+0.1s+1}$$

$$\frac{F}{pH} = G_{p12} = 0$$

$$\frac{C}{P} = G_{p21} = \frac{-0.51(0.35s+1)}{0.213s^2+0.7s+1}$$

$$\frac{C}{pH} = G_{p22} = \frac{-57(0.32s+1)}{0.6s^2+1.8s+1}$$

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CONTROL STRATEGIES

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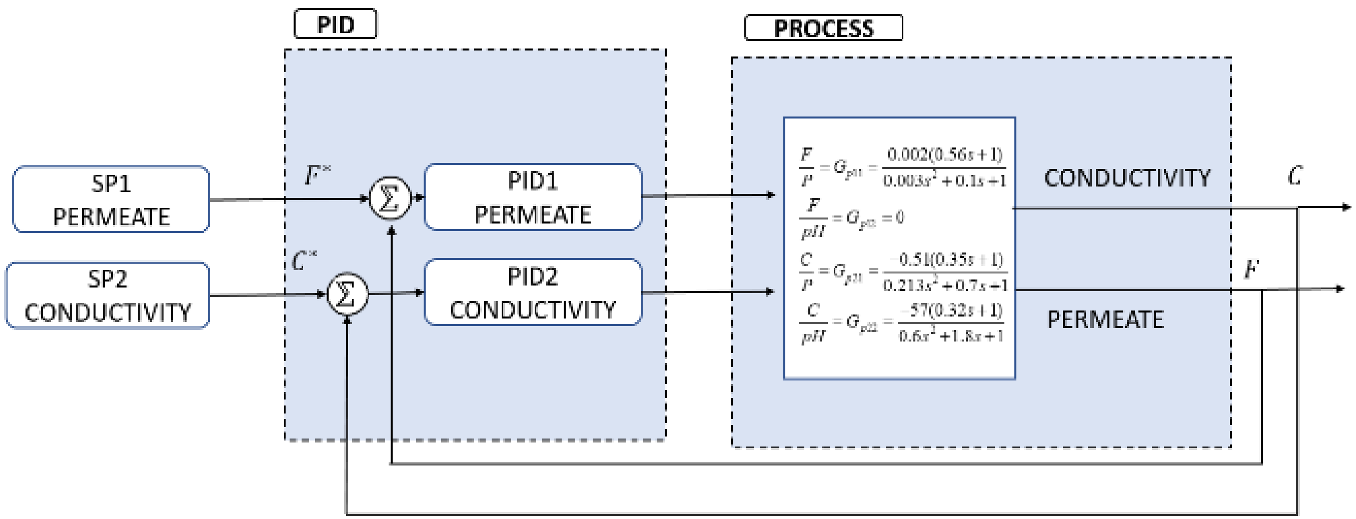

$$u(t) = K_p \left[e(t) + \frac{1}{T_i} \int_0^t e(t)\,dt + T_d \frac{de(t)}{dt} \right]$$

CONTROL STRATEGIES

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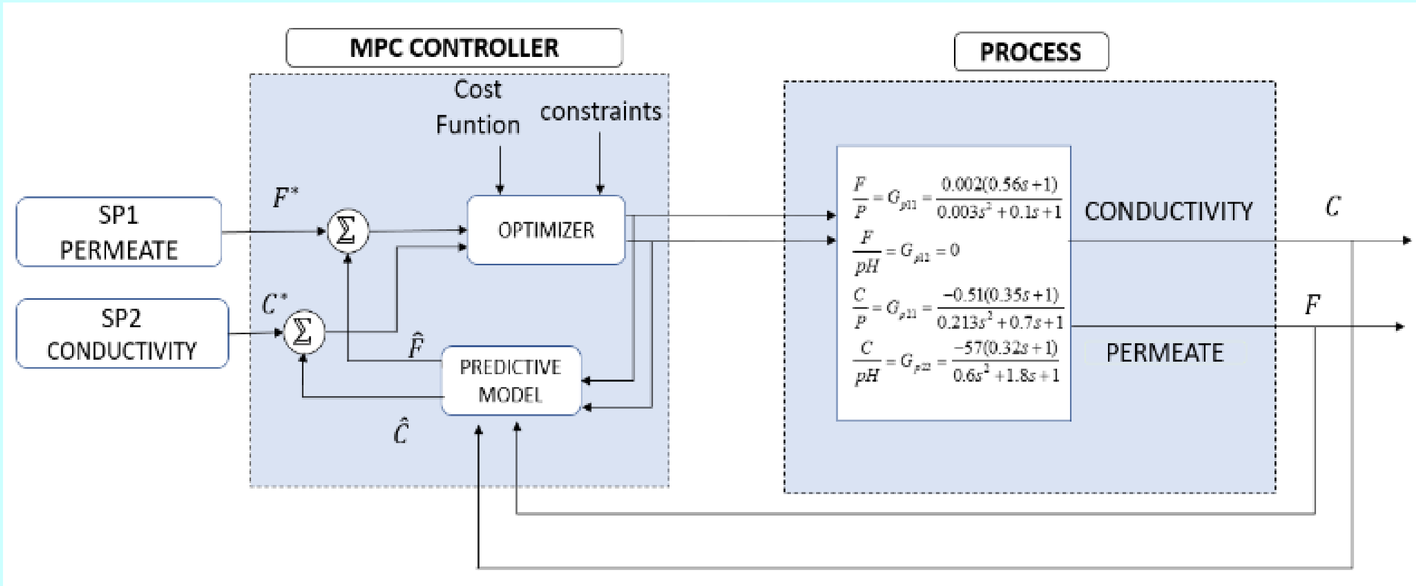

$$J(k) = \sum_{i=N_f}^{N_p} \delta_1(k)\left[\hat{F}\left(k+i|k\right) - F^*\left(k+i|k\right)\right]^2 + \delta_2(k)\left[\hat{C}\left(k+i|k\right) - C^*\left(k+i|k\right)\right]^2 +$$

$$\sum_{i=0}^{N_{c-1}} \lambda_1(k)\left[\Delta u_1(k+i-1)\right]^2 + \lambda_2(k)\left[\Delta u_2(k+i-1)\right]^2$$

$\Delta u_{1\min} = 0$ $\quad \Delta u_{1\max} = 1000$ $\quad \delta_1, \delta_2 = 11$

$\Delta u_{2\min} = 0$ $\quad \Delta u_{2\max} = 14$ $\quad \lambda_1, \lambda_2 = 0.07$

$F_{\min} = 0.85[gpm]$ $\quad F_{\max} = 2[gpm]$ $\quad N_p = 10$

$C_{\min} = 400[uS/cm]$ $\quad C_{min} = 1000[uS/cm]$ $\quad N_c = 3$

CONTROL STRATEGIES

mpc1_plant 2x2 ss

A =

	Transfer Fcn	Transfer Fcn	Transfer Fcn	Transfer Fcn	Transfer Fcn	Transfer Fcn
Transfer Fcn	-33.33	-333.3	0	0	0	0
Transfer Fcn	1	0	0	0	0	0
Transfer Fcn	0	0	-3.286	-4.695	0	0
Transfer Fcn	0	0	1	0	0	0
Transfer Fcn	0	0	0	0	-3	-1.667
Transfer Fcn	0	0	0	0	1	0

B =

	MPC Controll	MPC Controll
Transfer Fcn	1	0
Transfer Fcn	0	0
Transfer Fcn	1	0
Transfer Fcn	0	0
Transfer Fcn	0	1
Transfer Fcn	0	0

C =

	Transfer Fcn	Transfer Fcn	Transfer Fcn	Transfer Fcn	Transfer Fcn	Transfer Fcn
PV(1)	0.03733	0.6667	0	0	0	0
PV(2)	0	0	-0.838	-2.394	30.4	95

D =

	MPC Controll	MPC Controll
PV(1)	0	0
PV(2)	0	0

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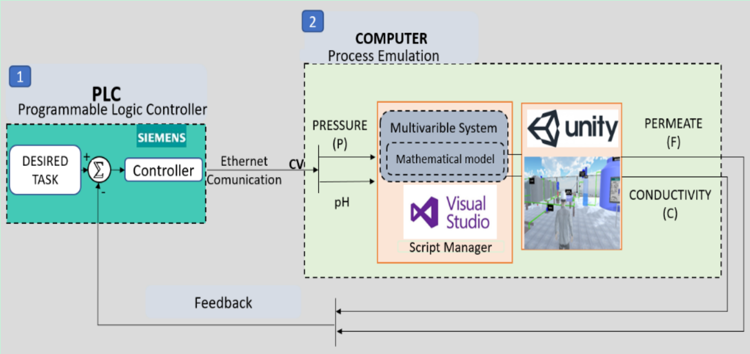
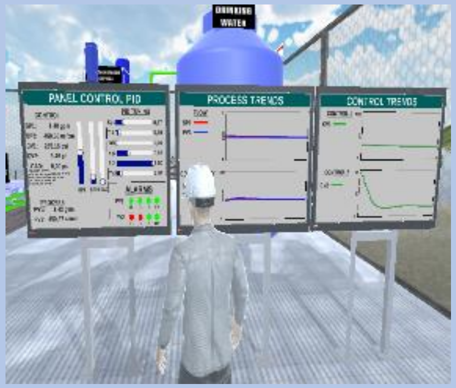
EXPERIMENTAL RESULTS

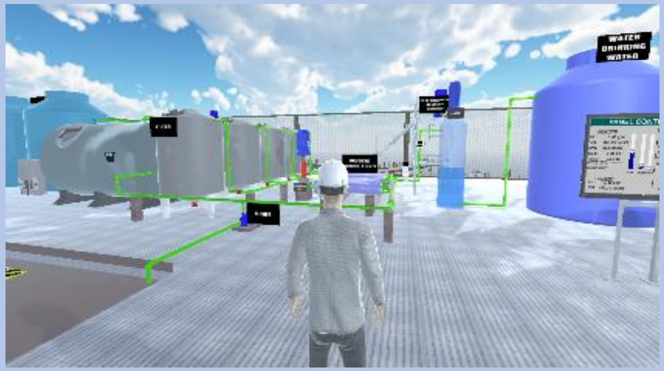
COMMUNICATION



VIRTUALIZED PROCESS

unity





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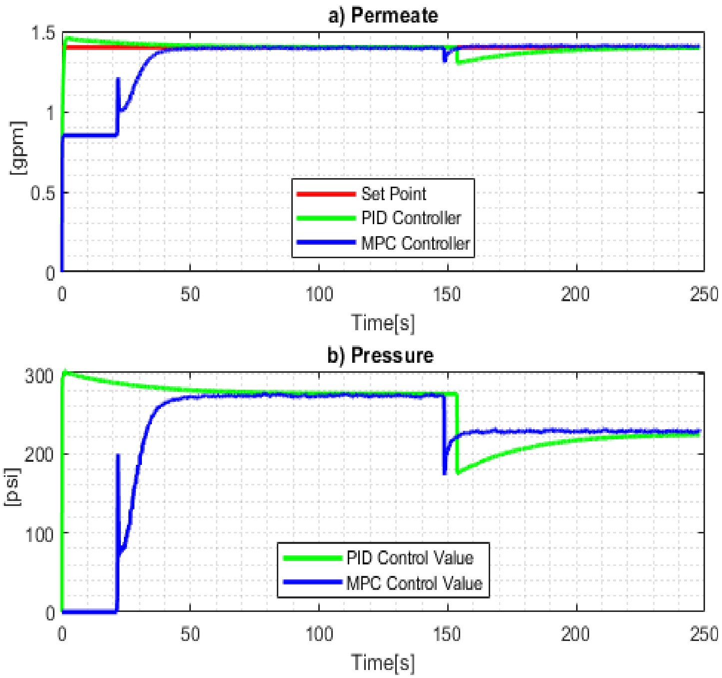

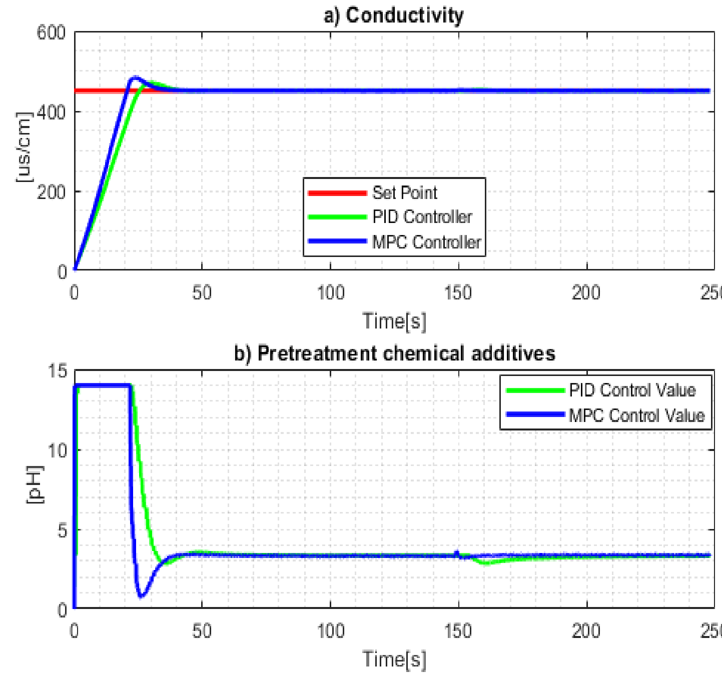

CONTROLLER

CONTROLLER

Parameters	PID Controller Permeate	MPC Controller Permeate
Overshoot [%]	3.57	0
Settling time [s]	62	60
Steady-state error [gpm]	1×10^{-3}	6.4×10^{-5}

Parameters	PID Controller Conductivity	MPC Controller Conductivity
Overshoot [%]	4.23	6
Settling time [s]	60	46
Steady-state error [uS/cm]	8×10^{-3}	7×10^{-3}

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CONCLUSIONS

- ✓ The HIL technique allows the integration of PLC-programmed control algorithms operating in real-time with virtual environments of industrial processes in this case of reverse osmosis, which works in conjunction with the implemented control algorithms, reducing the cost to real processes in laboratory environments.
- ✓ Input-output models based on real industrial plant measurements allow the implementation of a virtual environment similar to the industrial process with equal dynamics of the variables to be controlled within an immersive environment.
- ✓ The MPC controller shows a better performance in the operation of the controlled variables permeate flow and conductivity for the PID control strategy, for parameters such as overshoot, settling time, and steady-state error.

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