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UNIVERSIDAD DE LAS FUERZAS ARMADAS
INNOVACIÓN PARA LA EXCELENCIA

UNIVERSIDAD DE LAS FUERZAS ARMADAS ESPE

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CARRERA DE INGENIERIA EN ELECTRÓNICA E INSTRUMENTACIÓN

Artículo Académico previo a la obtención del Título de Ingeniero en Electrónica e Instrumentación

“DISEÑO DE ESTRATEGIAS DE CONTROL PID Y MPC PARA UN CAMPO DE COLECTORES SOLARES DISTRIBUIDOS VIRTUAL.”

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CONTENIDOS

I. INTRODUCCIÓN

II. MODELO MATEMÁTICO

III. VIRTUALIZACIÓN

IV. ESTRATEGIAS DE CONTROL

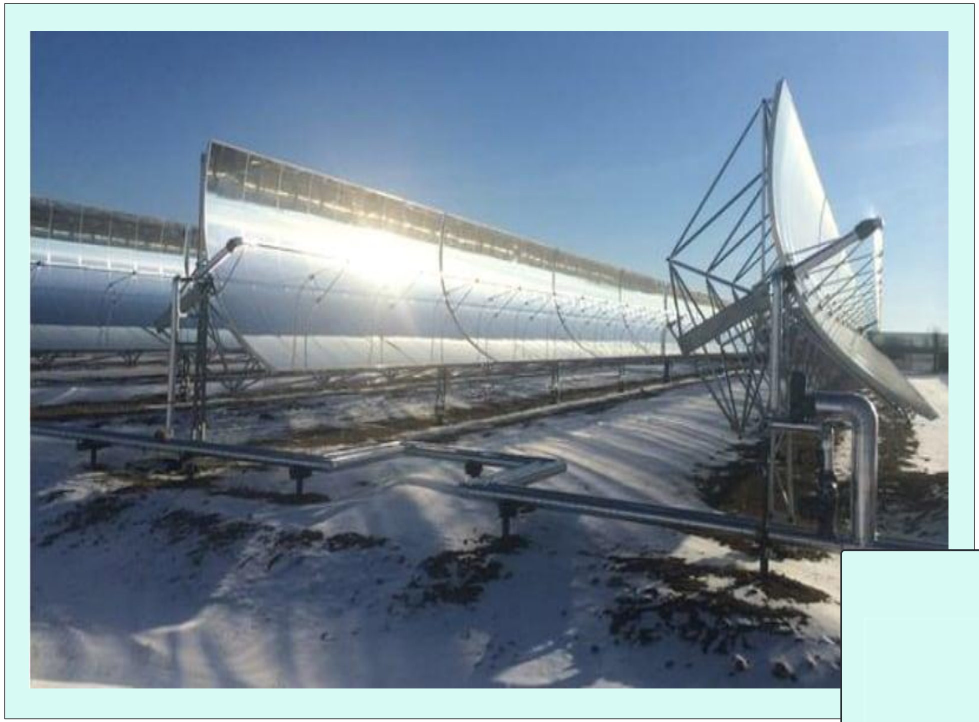
V. RESULTADOS

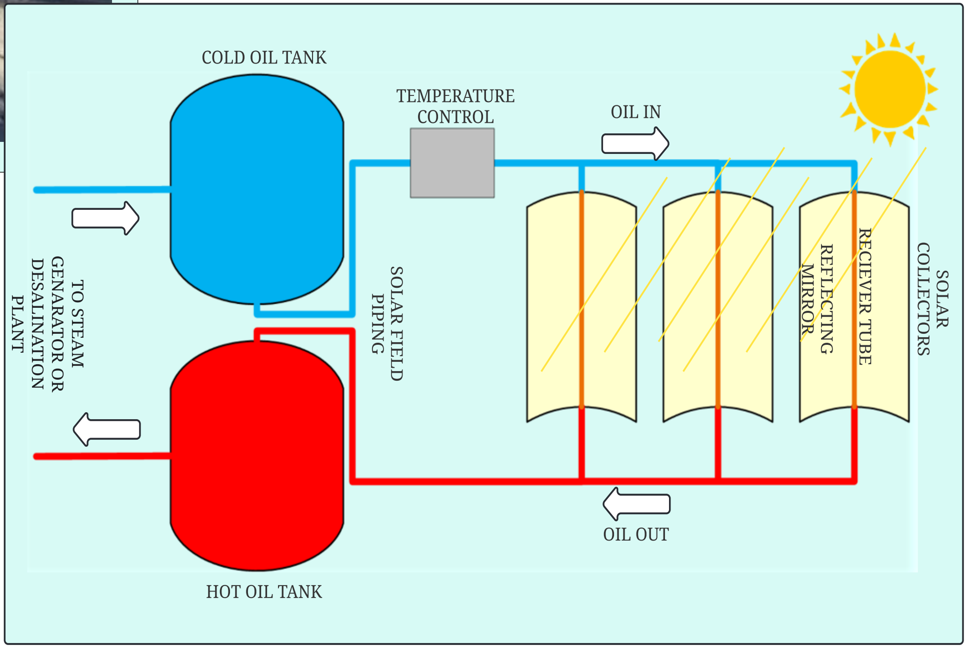
VI. CONCLUSIONES

INTRODUCCIÓN

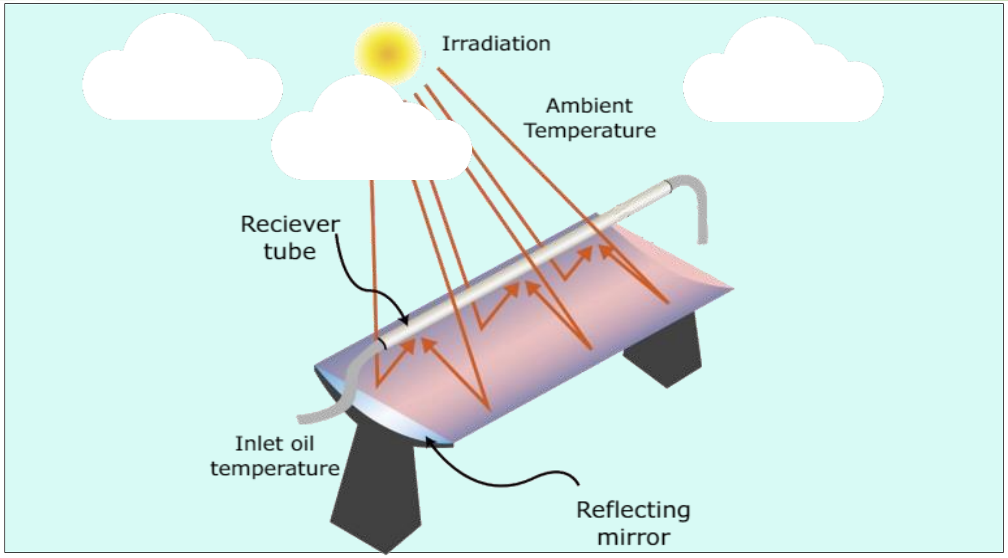
INTRODUCTION

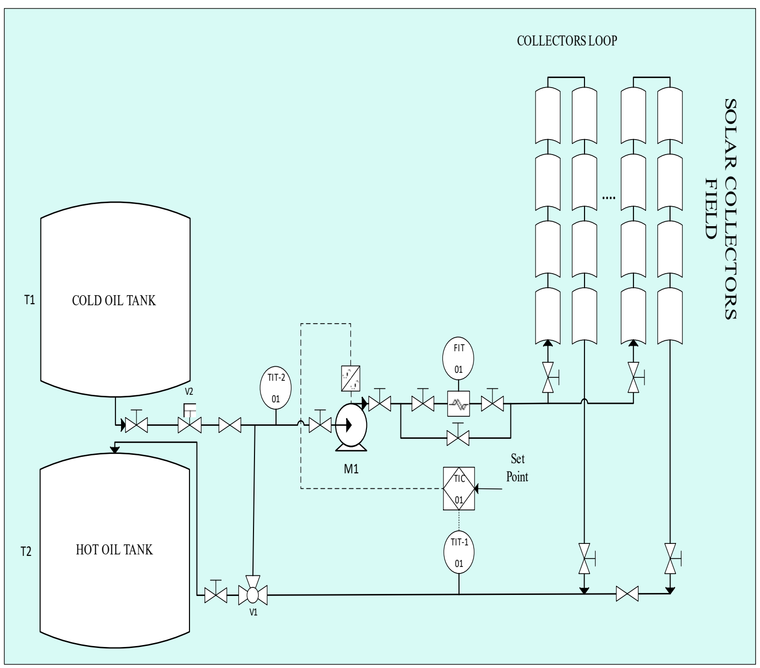
INTRODUCCIÓN





INTRODUCCIÓN

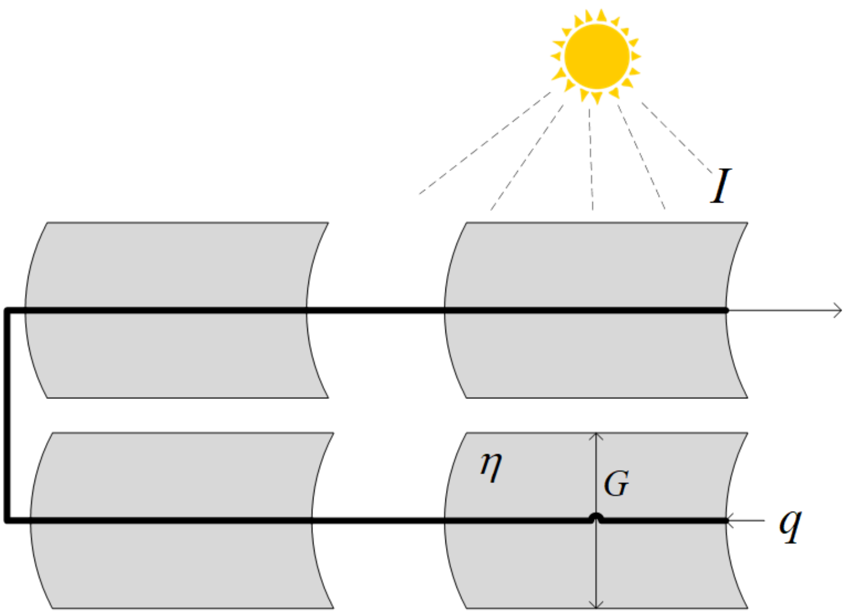


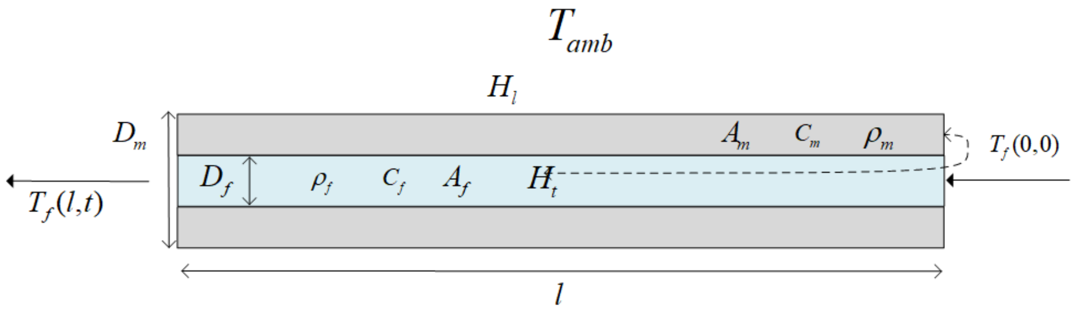


MODELO MATEMÁTICO

$$A_m\rho_m C_m \frac{dT_m(t,l)}{dt} = \eta G I(t) - D_m\pi H_l(T_m(t,l)-T_{amb}(t,l)) - D_f\pi H_t(T_m(t,l)-T_f(t,l))$$

$$A_f\rho_f C_f \frac{dT_f(t,l)}{dt} + \rho_f C_f q(t)\frac{dT_f(t,l)}{dl} = D_f\pi H_t(T_m(t,l)-T_f(t,l))$$



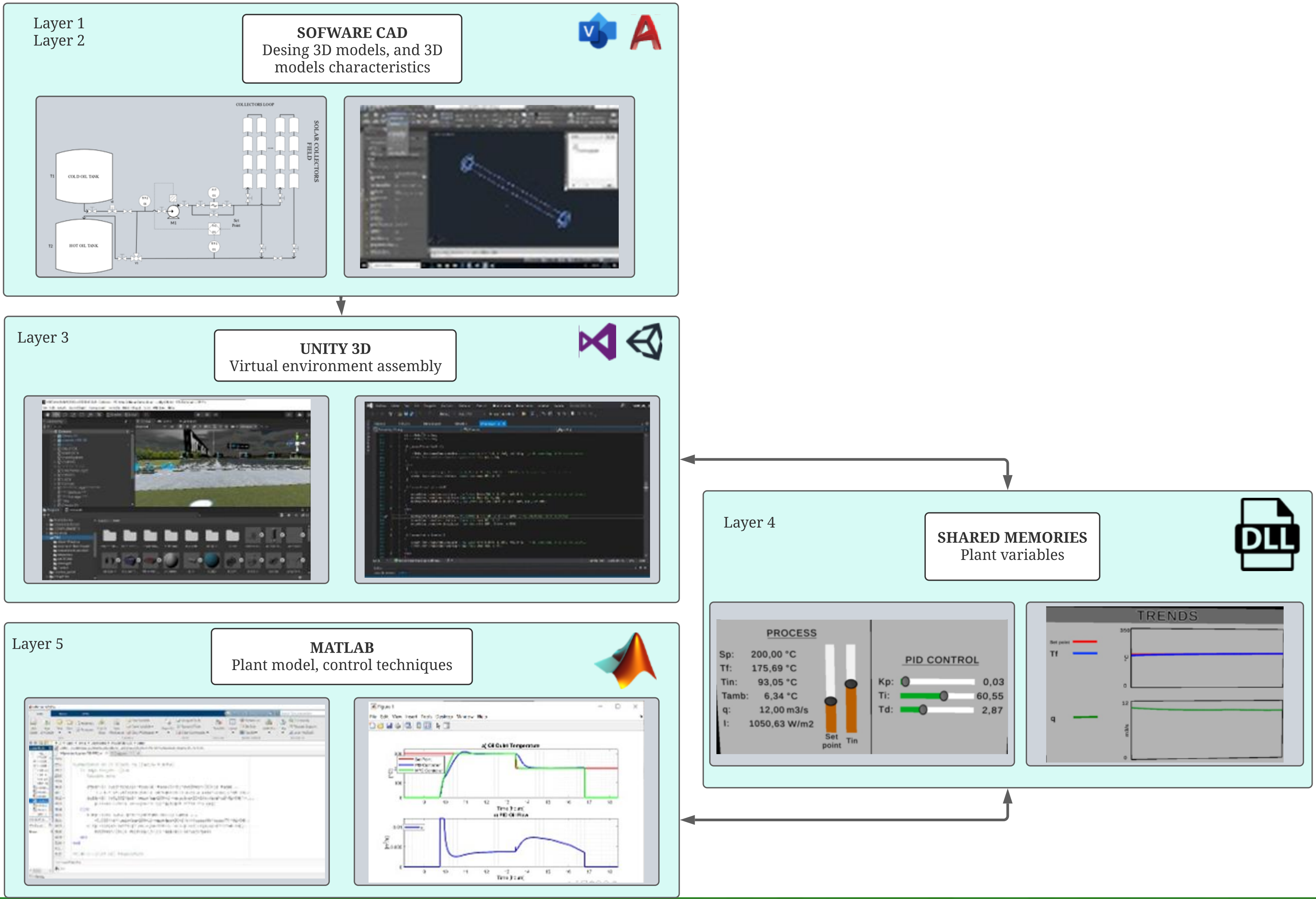


$$0.002\, m^3/s \leq q \leq 0.012\, m^3/s$$

$$T_f \max = 305°C \qquad I \min = 400\, W/m^2$$

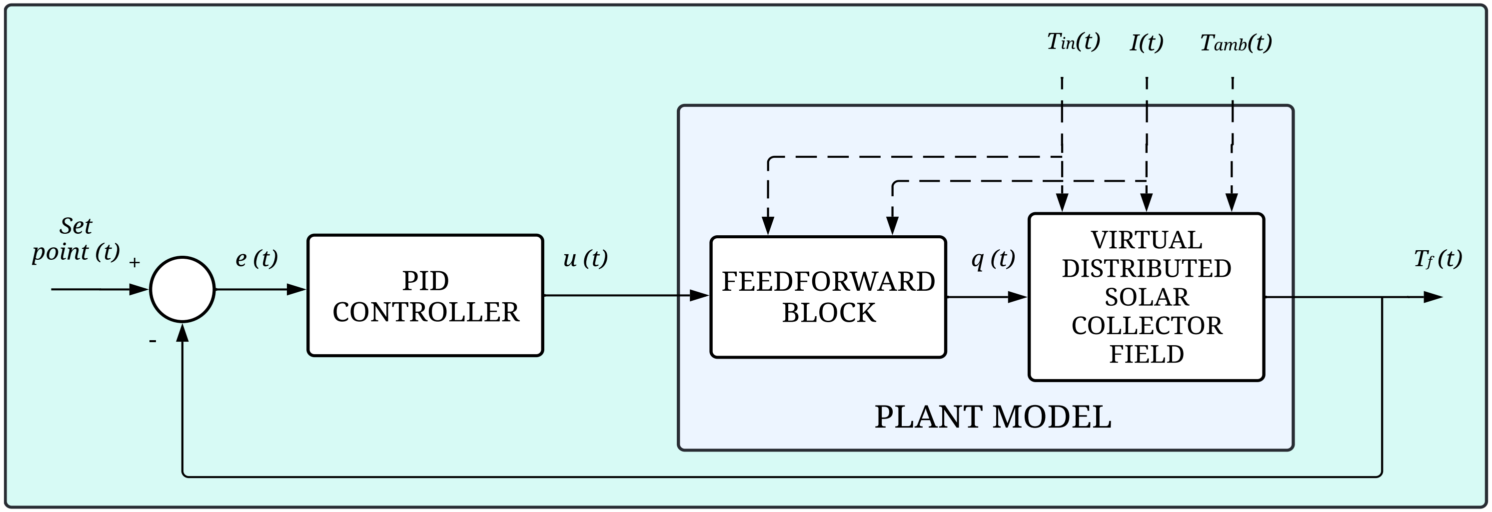
VIRTUALIZACIÓN

VIRTUALIZACIÓN



ESTRATEGIAS DE CONTROL

ESTRATEGIA DE CONTROL PID



Algoritmo PID

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

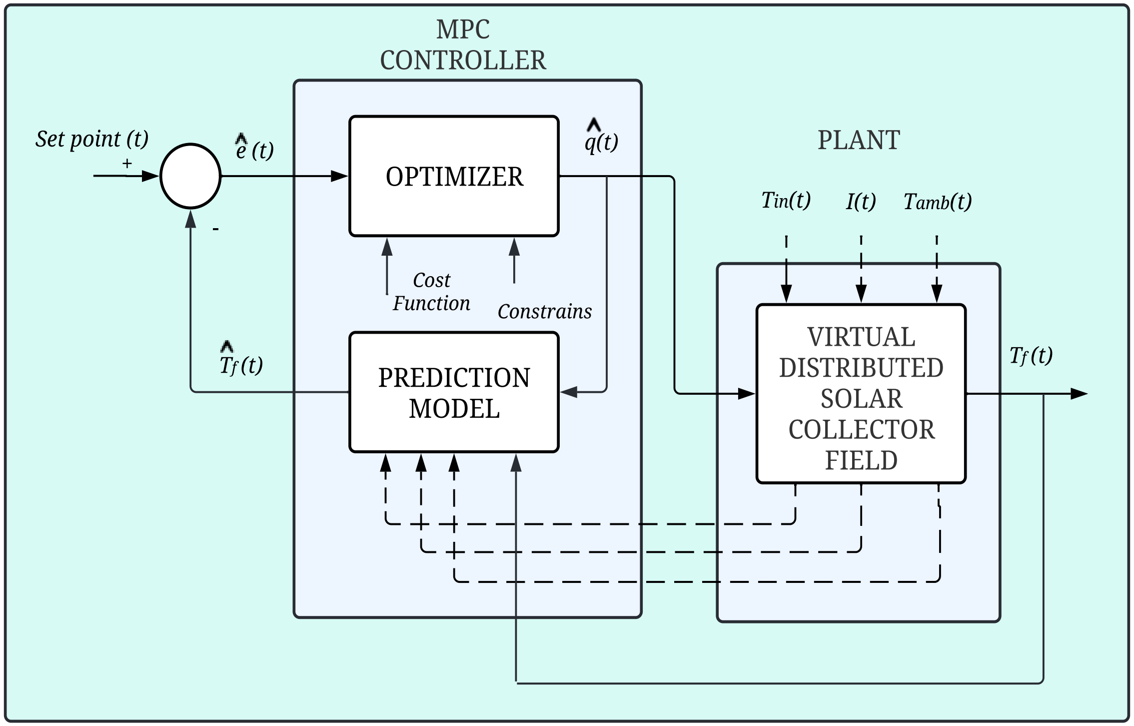
Parámetros de sintonía

$K_p=0.03$ $T_i=70.55$ $T_d=2.86$

Bloque Feedforward

$$q=\frac{0.7869I-0.485(u-151.5)-80.7}{u-T_{in}}$$

ESTRATEGIA MPC



Restricciones

$$q_{\min} \leq q \leq q_{\max}$$

$$0.002\, {m^3}/{s} \leq q \leq 0.012\, {m^3}/{s}$$

Parámetros

$$\delta = 10000$$

$$\lambda = 1$$

$$N_w = 10$$

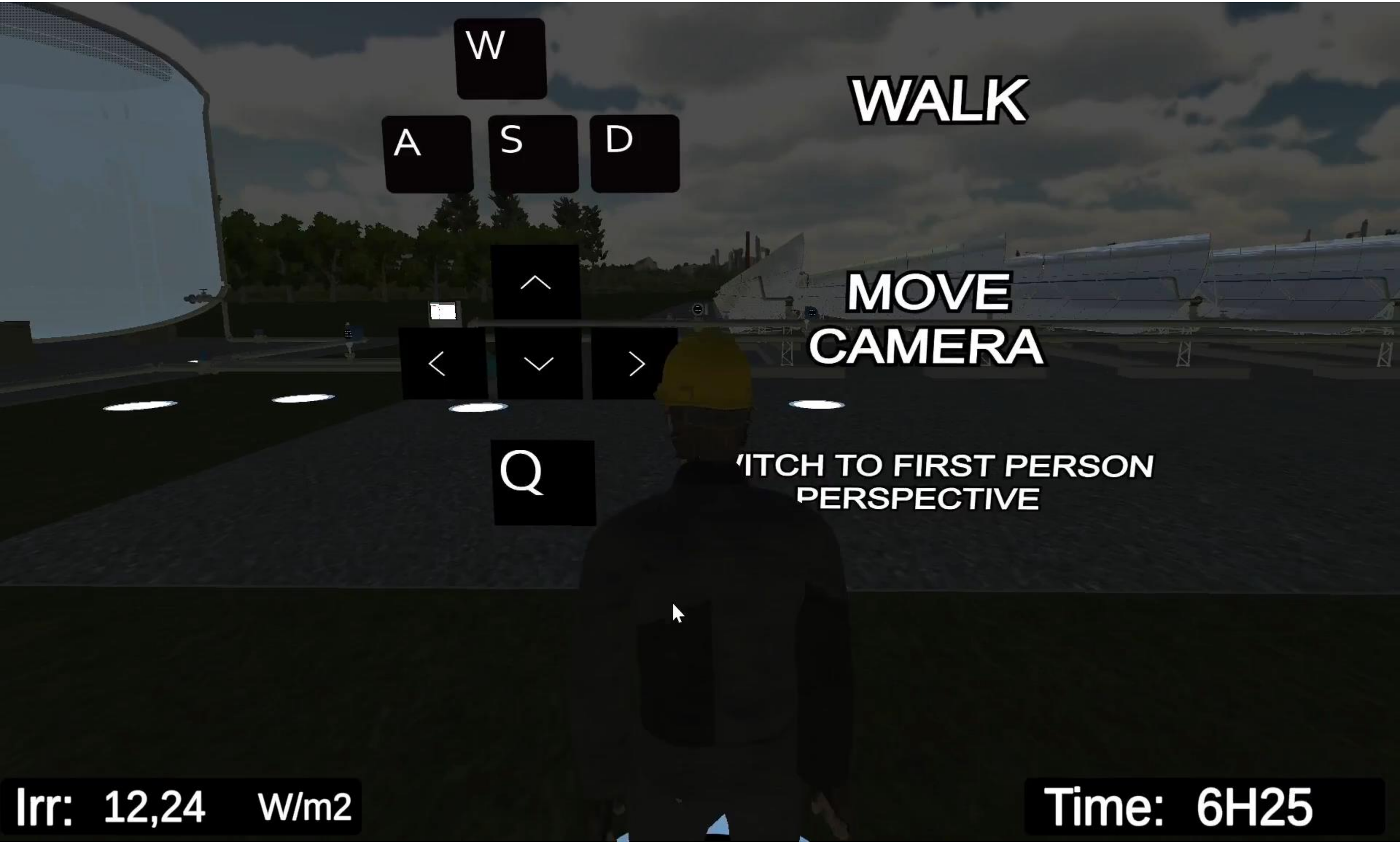
$$N_c = 5$$

Algoritmo MPC

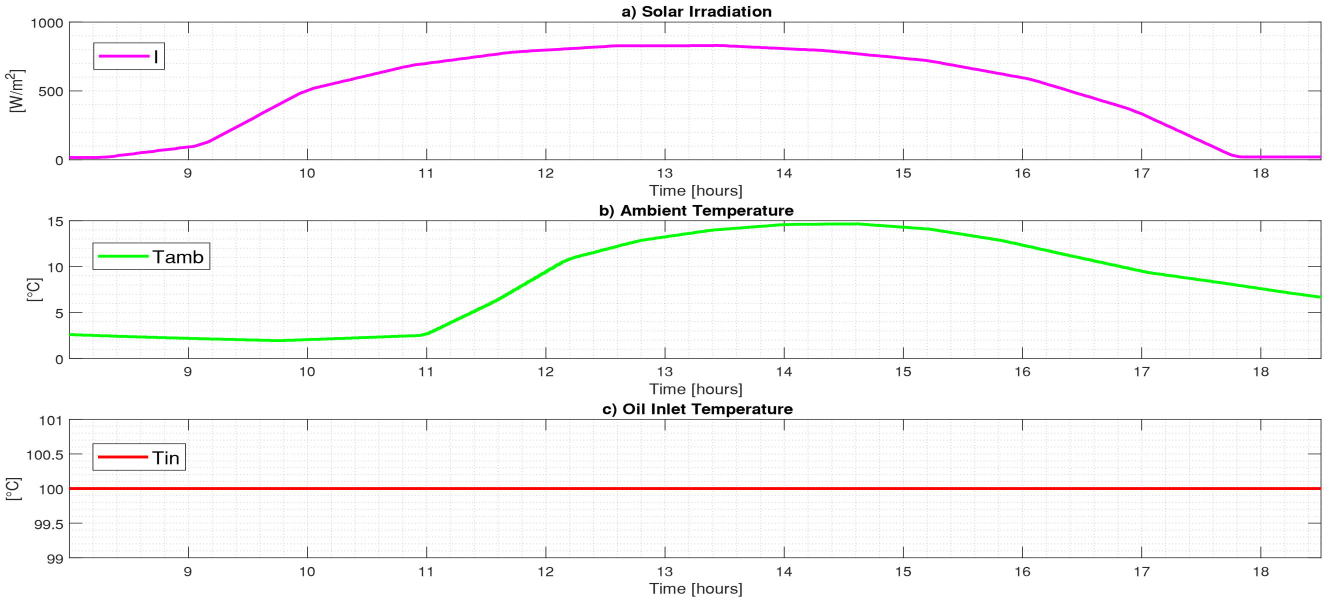
$$J(k)_{u} = \sum_{i=N_w}^{N_p} \delta(k) \left[\hat{T}_f(k+i|k) - T_{fd}(k+i|k) \right]^2 + \sum_{i=0}^{N_{c-1}} \lambda(k) [\Delta u(k+i-1)]^2$$

RESULTADOS

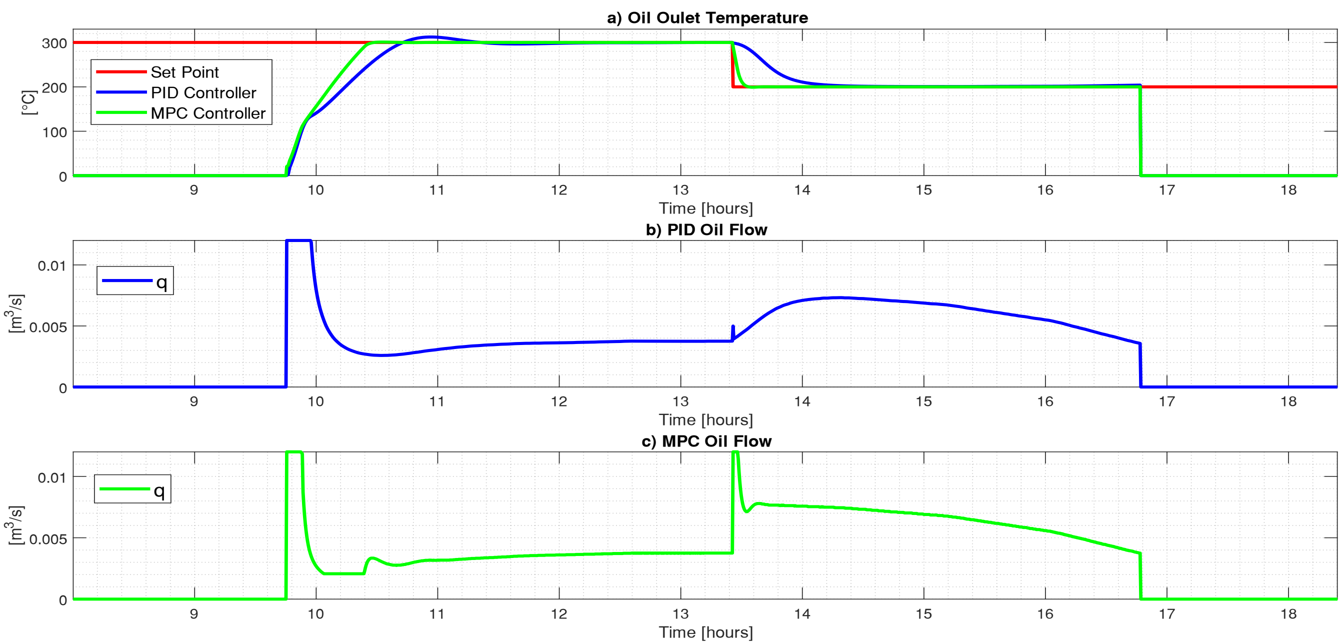
VIRTUALIZACIÓN



RESULTADOS



PERTURBACIONES



CONTROLADORES

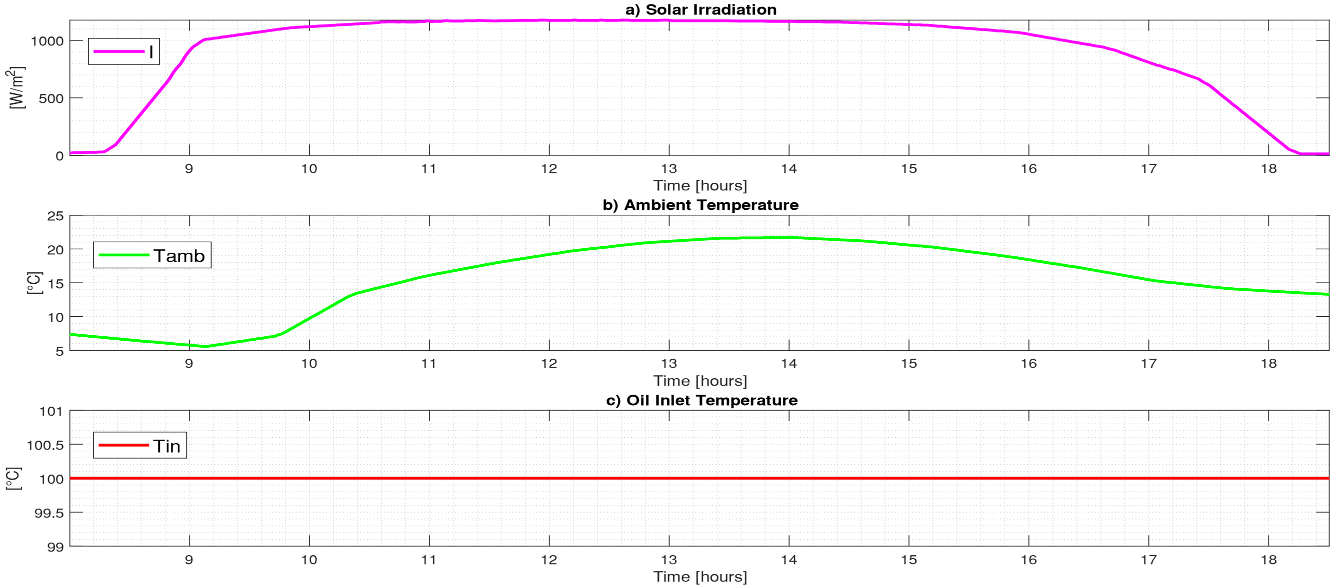
PID

Overshoot: 4%
Settling time: 2h21m
Steady State error: 2.33×10^{-3}

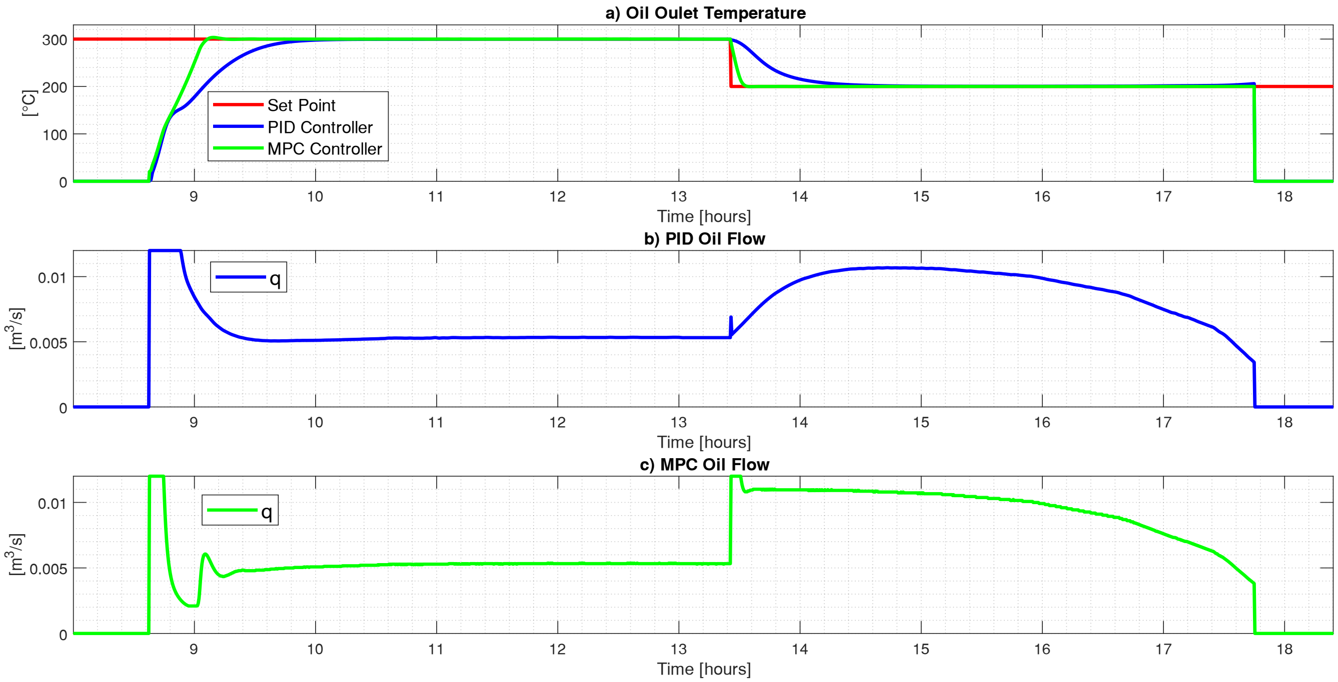
MPC

Overshoot: 0.3%
Settling time: 1h
Steady State error: 1.10×10^{-3}

RESULTADOS



PERTURBACIONES



CONTROLADORES

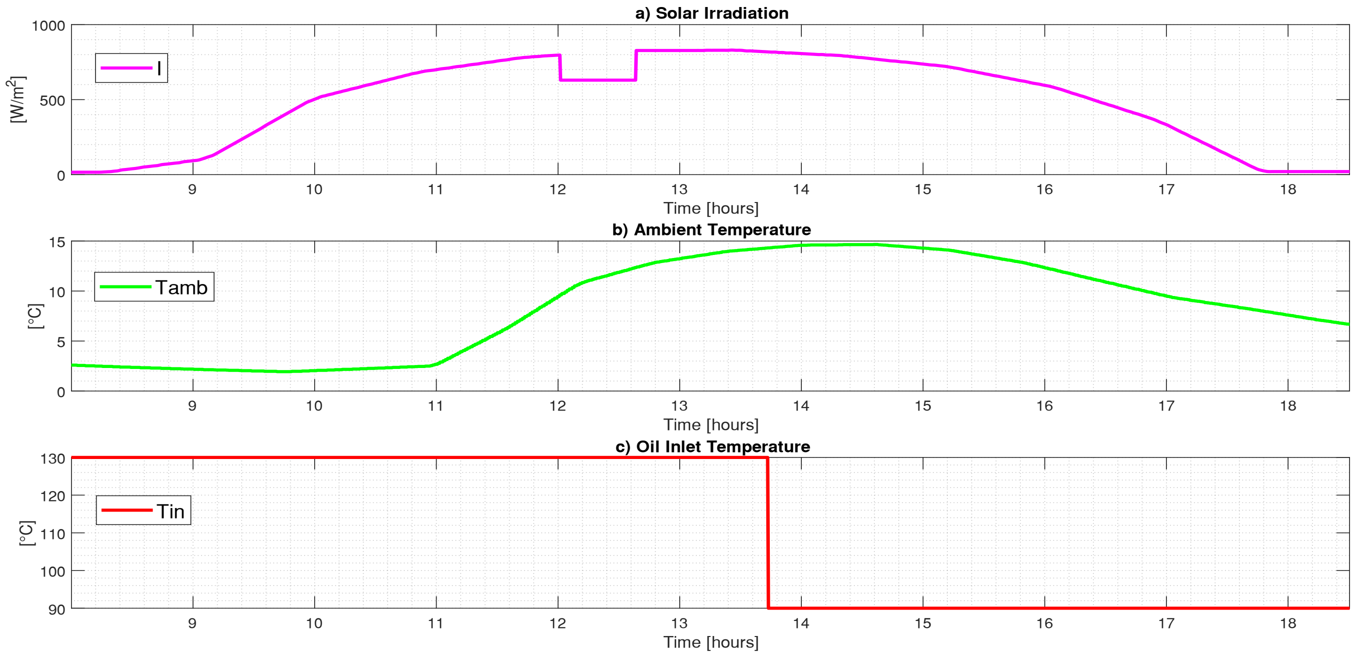
PID

Overshoot:	0%
Settling time:	1h24m
Steady State error:	6.66×10^{-4}

MPC

Overshoot:	1.17%
Settling time:	33m
Steady State error:	1.66×10^{-4}

RESULTADOS



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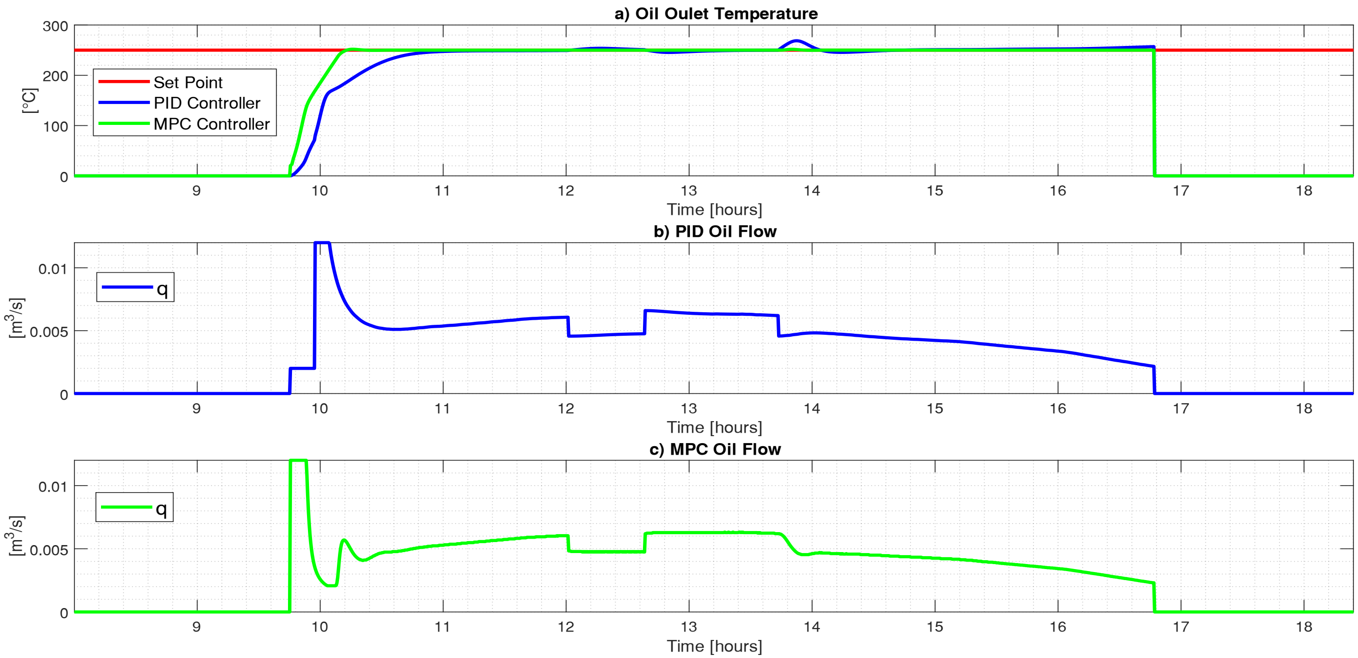

CONTROLADORES

PID

Overshoot: 0%, 1.45%, 7%

Settling time: 1h22m, 1h, 43m

Steady State error: 3.6×10^{-3}

MPC

0. 72%, 0.48%, 0.68

28m, 0m, 0m

Overshoot:

Settling time:

Steady State error: 1.2×10^{-4}

CONCLUSIONES

- The implemented virtual environment presents a high realism, it is interactive and immersive. The virtual plant allows the interaction with the components that conform the plant, the visualization of the evolution and state of the variables of interest, as well as allowing the operator to insert disturbances and manipulate the tuning constants of the MPC and PID controllers.

- The distributed solar collector field requires efficient controls due to solar irradiation which is its main disturbance and source of energy. It is observed that the MPC has a better performance in the scenarios of high and medium irradiation and in the presence of clouds compared with the PID control, since it has on average less overshoot, settling time and steady-state error.

- The MPC, due to its shorter settling time, better optimizes the use of solar irradiation available throughout the day. In addition, because it has a low overshoot, it does not exceed the maximum safe temperature of $305°C$, which the PID control does at certain points of operation. The MPC performs better than the PID control when faced with sudden changes in the oil inlet temperature and the solar irradiation caused by the presence of clouds.

GRACIAS