DSOySP

Ejemplo de Modelado de Equipos de una Planta en Estado Dinámico (II)

2024

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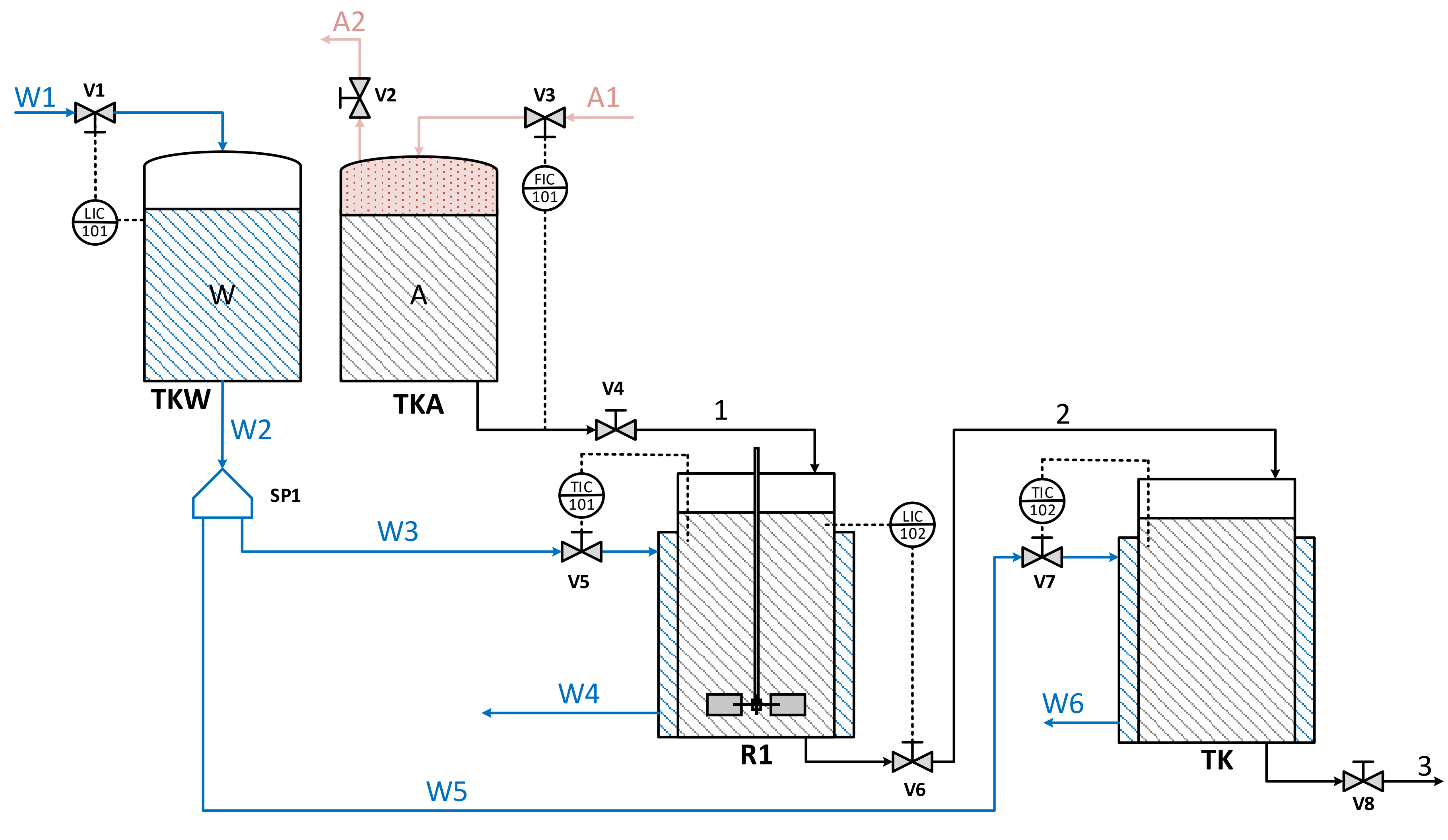
Flowsheet


A2
W1
V1
V2
V3
A1
FIC 101
LIC 101
W
A
TKW
TKA
V4
1
2
W2
SP1
TIC 101
LIC 102
TIC 102
W3
V5
V7
W4
W6
R1
TK
V6
3
V8
W5

Hipótesis – Reactor R1

- Reacción química en fase líquida cuya cinética es:

$$A \underset{k_I}{\overset{k_D}{\rightleftarrows}} B \qquad (r_D) = k_D C_A \quad (r_I) = k_I C_B \qquad k_D = A_D e^{-\frac{E_D}{RT}} \quad k_I = A_I e^{-\frac{E_I}{RT}}$$

- Reacción exotérmica: (ΔHR<0).
- Reactor Mezcla completa de geometría cilíndrica vertical y sección constante.
- Presión sobre la superficie de líquido conocida y constante.
- Camisa de enfriamiento con agua pura:
  - Mezcla completa con Holdup conocido y constante.
  - Caída de presión nula.
  - (UA) conocido y constante.

Hipótesis – Tanque TK

- Mezcla completa
- Cilindro vertical de sección constante.
- Presión sobre la superficie de líquido conocida y constante.
- Debido a la ausencia de catalizador no ocurre reacción química.
- Camisa de enfriamiento con agua pura:
  - Mezcla completa con Holdup conocido y constante.
  - Caída de presión nula.
  - (UA) conocido y constante.

Hipótesis – Tanque TKW

- Tanque de almacenamiento de agua de enfriamiento
- Cilíndrico de sección constante.
- Presión sobre la superficie de líquido conocida y constante.
- Su comportamiento es isotérmico y su temperatura es conocida (e igual a la de entrada).

Hipótesis – Tanque TKA

- Tanque de almacenamiento de reactivo A
- Cilíndrico de sección constante.
- Sin reacción química
- Sobre la superficie del líquido existe una atmosfera de gas inerte de holdup **NO DESPRECIABLE**.
- El gas inerte no es absorbido por el líquido.
- El gas inerte se utiliza para aumentar la presión de manera de controlar el caudal de salida de líquido.
- Se desprecian los efectos de compresión o expansión del gas por lo que podemos considerar la temperatura del gas y del líquido conocida y constante (e idénticas entre sí).

Hipótesis - Varias

Divisor SP1

- Adiabático y sin cambio de fase.
- Caída de presión nula.
- Asumir comportamiento pseudoestacionario.

Válvulas (V1 a V8)

- Válvulas de apertura lineal con todos sus parámetros conocidos.
- Las válvulas V2, V4 y V8 se encuentra en modo manual a una apertura conocida.
- Todas las válvulas no alteran las propiedades del fluido.

Hipótesis - Varias

Controladores

- LIC/101: Controlador de nivel P
- FIC/101: Controlador de flujo PI
- TIC/101: Controlador de temperatura PID
- LIC/102: Controlador de nivel PID
- TIC/102: Controlador de temperatura PI
- Todos los parámetros, incluidos los setpoints, son conocidos.

Corrientes

- Corrientes A2, W4, W6 y 3: Presión conocida y constante.
- Corriente W1: Corriente líquida de agua pura con presión y temperatura conocida y constante.
- Corriente A1: Corriente de gas inerte con presión y temperatura conocida y constante.

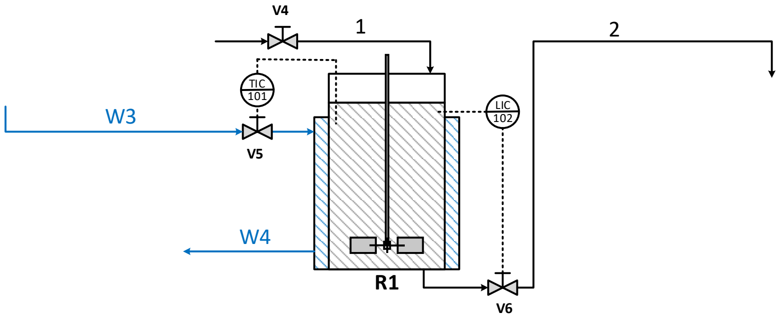
Plantear:

1. El correspondiente sistema de ecuaciones diferenciales.
2. El sistema de ecuaciones algebraicas complementario de tal forma que todas las variables de las ecuaciones diferenciales queden definidas.
3. Explique la estrategia de resolución y demuestre esquemáticamente que el sistema de ecuaciones diferenciales y algebraicas resultante es calculable dadas las condiciones iniciales y los parámetros/datos de entrada del sistema. Detallar la secuencia en que se obtienen las variables del sistema de EDO.

Modelado – Reactor R1

Balance molar por componentes en el reactor

$$\frac{dM_A}{dt} = m_1 x_{A,1} + r_A V_{R1} - m_2 x_{A,2}$$



$$\frac{dC_A A_{R1} h_{R1}}{dt} = m_1 x_{A,1} + r_A A_{R1} h_{R1} - m_2 x_{A,2}$$

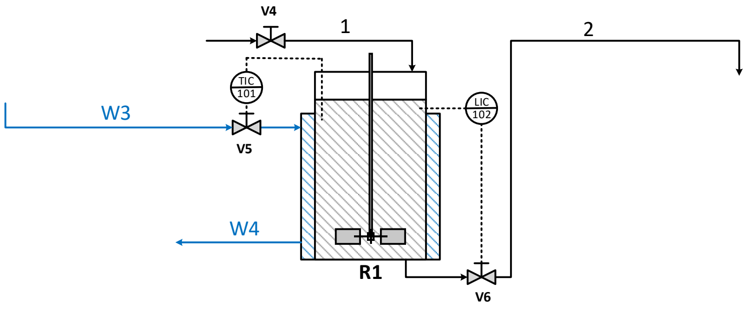
$$A_{R1} C_A \frac{dh_{R1}}{dt} + A_{R1} h_{R1} \frac{dC_A}{dt} = m_1 x_{A,1} + r_A A_{R1} h_{R1} - m_2 x_{A,2}$$

$$A_{R1} C_B \frac{dh_{R1}}{dt} + A_{R1} h_{R1} \frac{dC_B}{dt} = m_1 x_{B,1} + r_B A_{R1} h_{R1} - m_2 x_{B,2}$$

Modelado – Reactor R1

Balance molar total en el reactor

$$\frac{dM}{dt} = m_1 - m_2 + \sum_{i=A}^{C} r_i V_{R1}$$



$$\frac{d\rho_2 A_{R1} h_{R1}}{dt} = m_1 - m_2$$

$$\rho_2 A_{R1} \frac{dh_{R1}}{dt} = m_1 - m_2$$

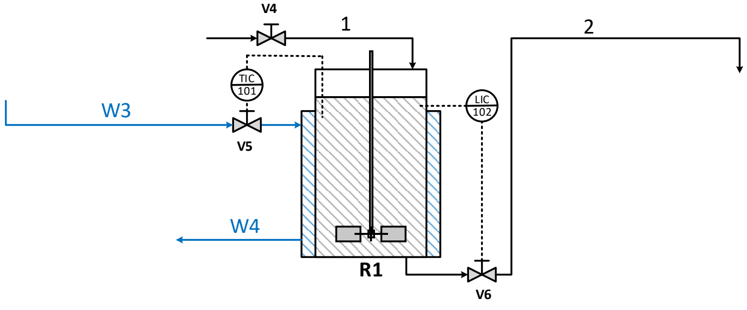
Modelado – Reactor R1

Balance de energía en el reactor

$$\frac{dMH_2}{dt} = m_1 H_1 - m_2 H_2 + (-r_A) V_{R1} (-\Delta H_{rD}) - Q_{R1}$$

$$\frac{d\rho_2 A_{R1} h_{R1} H_2}{dt} = m_1 H_1 - m_2 H_2 + (-r_A) A_{R1} h_{R1} (-\Delta H_{rD}) - Q_{R1}$$

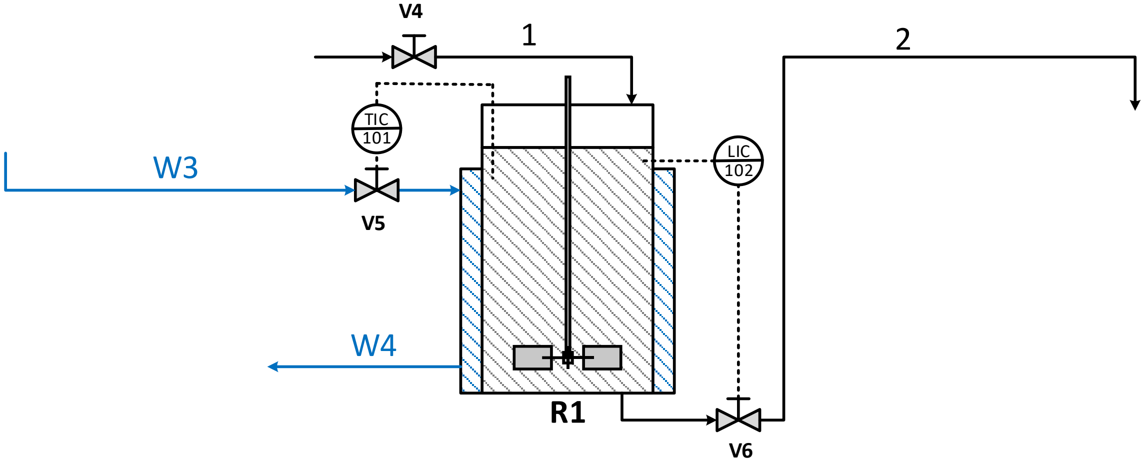
$$\rho_2 A_{R1} h_{R1} \frac{dH_2}{dt} + \rho_2 A_{R1} H_2 \frac{dh_{R1}}{dt} = m_1 H_1 - m_2 H_2 + (-r_A) A_{R1} h_{R1} (-\Delta H_{rD}) - Q_{R1}$$



Modelado – Reactor R1

$$r_A = -k_D C_A + k_I C_B$$

$$r_B = k_D C_A - k_I C_B$$



$$k_D = f\left(T_2\right)$$

$$k_I = f\left(T_2\right)$$

$$x_{A,2} = \frac{C_A}{C_A + C_B} \qquad x_{B,2} = \frac{C_B}{C_A + C_B}$$

$$H_1 = f\left(T_1, x_1\right)$$

$$H_2 = f\left(T_2, x_2\right)$$

$$\rho_2 = f\left(T_2, x_2\right)$$

$$\Delta H_{rD} = f\left(T_2\right)$$

Modelado – Reactor R1 (camisa)

Considerando el hold up y densidad del agua de enfriamiento constantes:

$$m_{W3} = m_{W4}$$

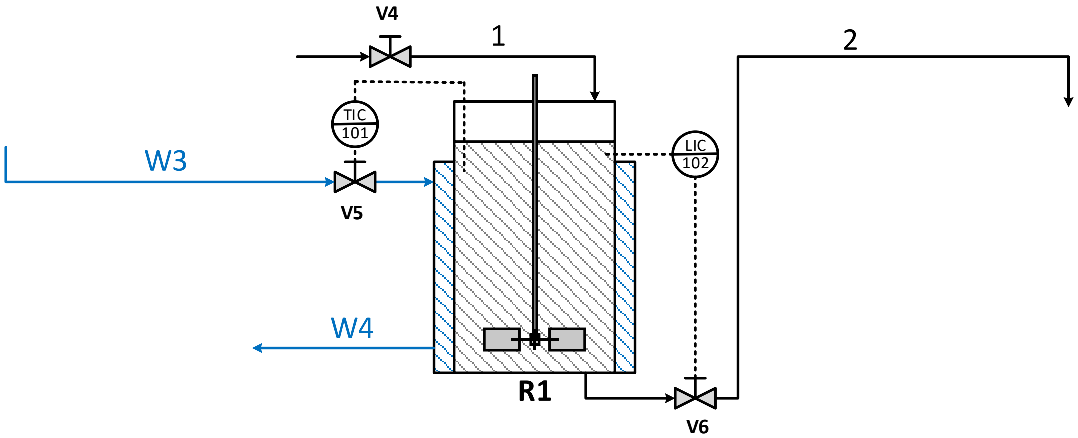
$$\frac{dM_a H_{W4}}{dt} = m_{W3}\left(H_{W3} - H_{W4}\right) + Q_{R1}$$

$$M_a \frac{dH_{W4}}{dt} = m_{W3}\left(H_{W3} - H_{W4}\right) + Q_{R1}$$

$$Q_{R1} = \left(UA\right)_{R1}\left(T_2 - T_{W4}\right)$$

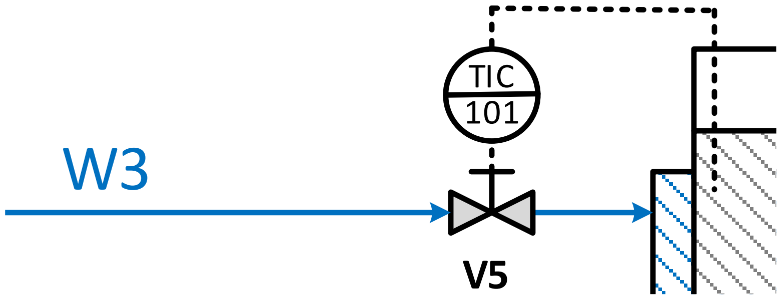
$$H_{W3} = f\left(T_{W3}\right)$$

$$H_{W4} = f\left(T_{W4}\right)$$



Modelado – Reactor R1 (controladores)

$$\varepsilon = T_2 - T_{sp}$$ Control directo



$$A_p = K_p\,\varepsilon$$

$$A_D = K_D \frac{dT_2}{dt}$$

$$\frac{dA_I}{dt} = K_I\,\varepsilon$$

$$m_{W3} = \rho_{W3} x_{V5} K_{V5} \sqrt{\frac{\Delta P_{V5}}{G_{V5}}}$$

$$\Delta P_{V5} = P_{W3} - P_{W4}$$

$$AC = A_P + A_I + A_D + A_0$$

$$x_{V5} = \max\left(0, \min\left(1, AC\right)\right)$$

Modelado – Reactor R1 (controladores)

$$\varepsilon = h_{R1} - h_{sp}$$ Control directo

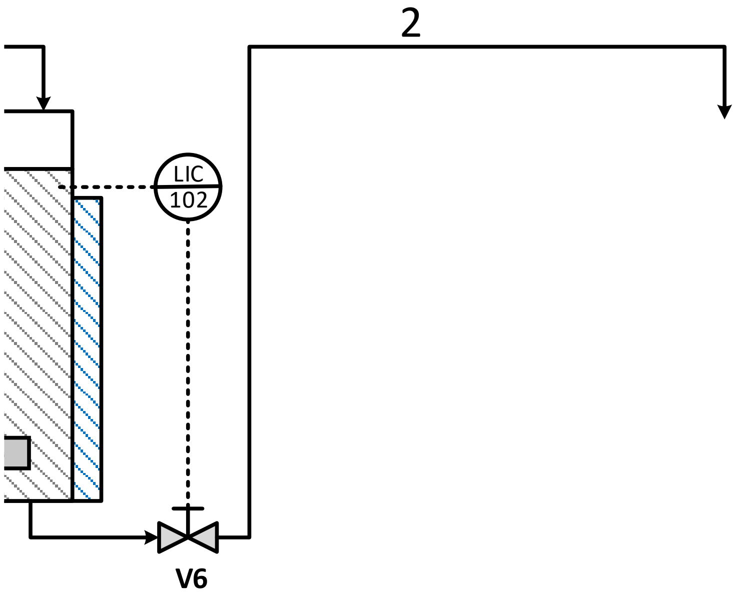
$$A_p = K_p \, \varepsilon_L$$

$$A_D = K_D \frac{dh_{R1}}{dt}$$

$$\frac{dA_I}{dt} = K_I \, \varepsilon$$

$$AC = A_P + A_I + A_D + A_0$$

$$x_{V6} = \max\left(0, \min\left(1, AC\right)\right)$$



$$m_2 = \rho_2 x_{V6} K_{V6} \sqrt{\frac{\Delta P_{V6}}{G_{V6}}}$$

$$\Delta P_{V6} = P_{R1}^0 + \tilde{\rho}_2 g h_{R1} - P_{TK}^0$$

Modelado - Tanque TK

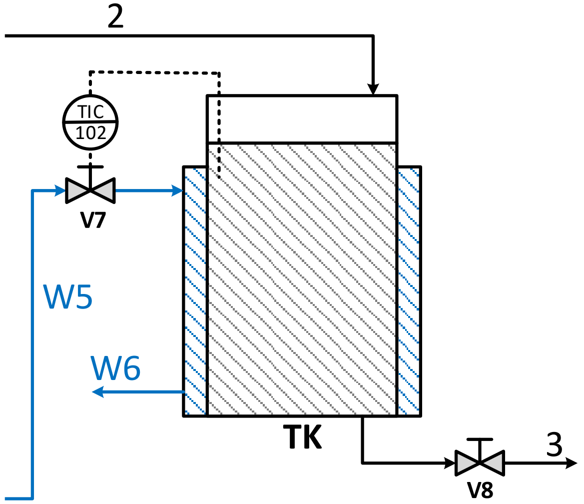
$$\rho_3 A_{TK} \frac{dh_{TK}}{dt} = m_2 - m_3$$

$$A_{TK} C_{A,3} \frac{dh_{TK}}{dt} + A_{TK} h_{TK} \frac{dC_{A,3}}{dt} = m_2 x_{A,2} - m_3 x_{A,3}$$

$$A_{TK} C_{B,3} \frac{dh_{TK}}{dt} + A_{TK} h_{TK} \frac{dC_{B,3}}{dt} = m_2 x_{B,2} - m_3 x_{B,3}$$

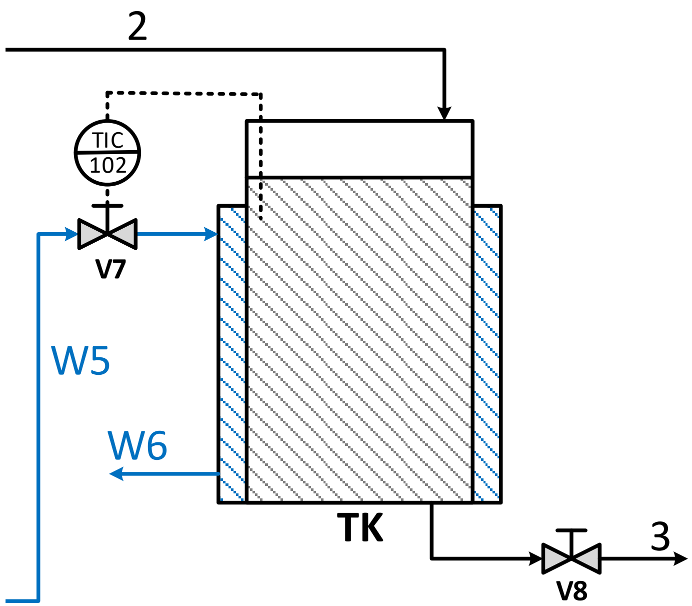
$$m_3 = \rho_3 x_{V8} K_{V8} \sqrt{\frac{\Delta P_{V8}}{G_{V8}}}$$

$$\Delta P_{V8} = P_{TK}^0 + \tilde{\rho}_3 g h_{TK} - P_3$$



Modelado - Tanque TK

$$\rho_3 A_{TK} h_{TK} \frac{dH_3}{dt} + \rho_3 A_{TK} H_3 \frac{dh_{TK}}{dt} = m_2 H_2 - m_3 H_3 - Q_{TK}$$



Modelado - Tanque TK (camisa)

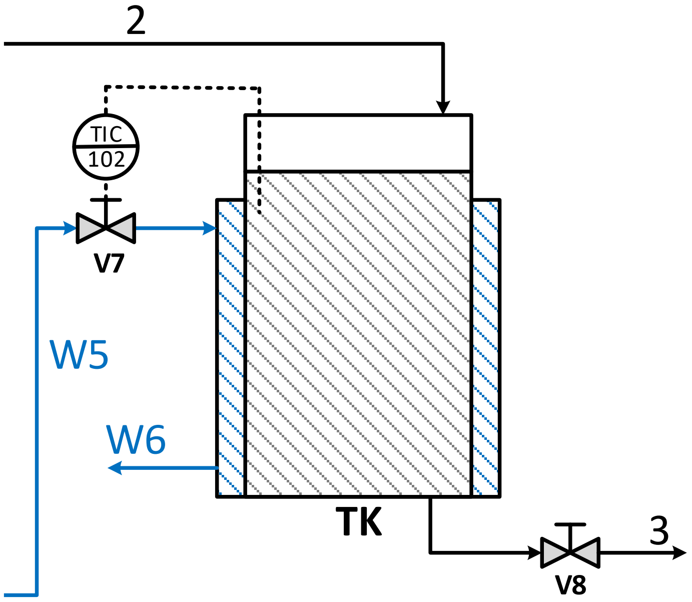
$$m_{W5} = m_{W6}$$

$$M_a \frac{dH_{W6}}{dt} = m_{W5}\left(H_{W5} - H_{W6}\right) + Q_{TK}$$

$$Q_{TK} = (UA)_{TK}\left(T_3 - T_{W6}\right)$$

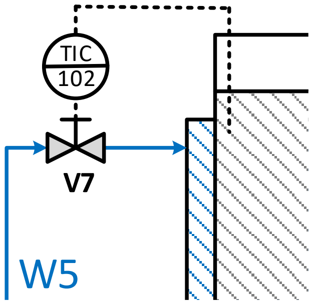
$$H_{W5} = f\left(T_{W5}\right)$$

$$H_{W6} = f\left(T_{W6}\right)$$



Modelado - Tanque TK (controladores)

$$\varepsilon = T_3 - T_{sp}$$ Control directo



$$A_p = K_p \, \varepsilon$$

$$\frac{dA_I}{dt} = K_I \, \varepsilon$$

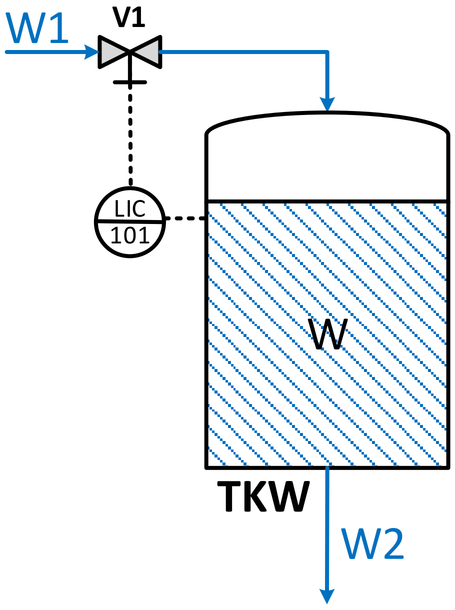
$$AC = A_P + A_I + A_0$$

$$x_{V7} = \max\left(0, \min\left(1, AC\right)\right)$$

$$m_{W5} = \rho_{W5} x_{V7} K_{V7} \sqrt{\frac{\Delta P_{V7}}{G_{V7}}} \qquad \Delta P_{V7} = P_{W5} - P_{W6}$$

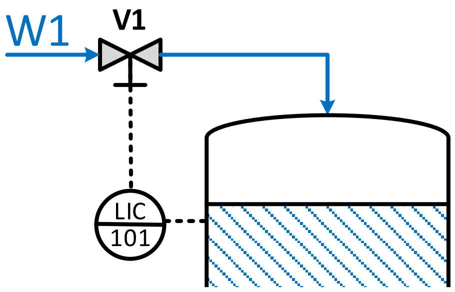
Modelado - Tanque TKW

$$\rho_{W2} A_{TKW} \frac{dh_{TKW}}{dt} = m_{W1} - m_{W2}$$



Modelado - Tanque TKW (controladores)

$$\varepsilon = h_{sp} - h_{R1}$$ Control inverso



$$A_p = K_p\,\varepsilon$$

$$AC = A_P + A_0$$

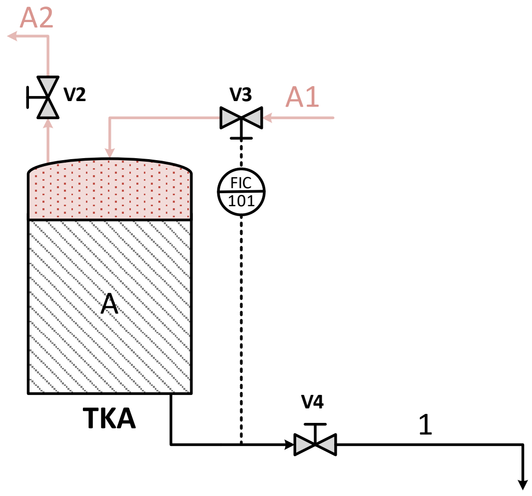
$$x_{V1} = \max\left(0, \min\left(1, AC\right)\right)$$

$$m_{W1} = \rho_{W1} x_{V1} K_{V1} \sqrt{\frac{\Delta P_{V1}}{G_{V1}}}$$

$$\Delta P_{V1} = P_{W1} - P_{TKW}^{0}$$

Modelado - Tanque TKA

$$\rho_1 A_{TKA} \frac{dh_{TKA}}{dt} = -m_1$$



$$m_1 = \rho_1 x_{V4} K_{V4} \sqrt{\frac{\Delta P_{V4}}{G_{V4}}}$$

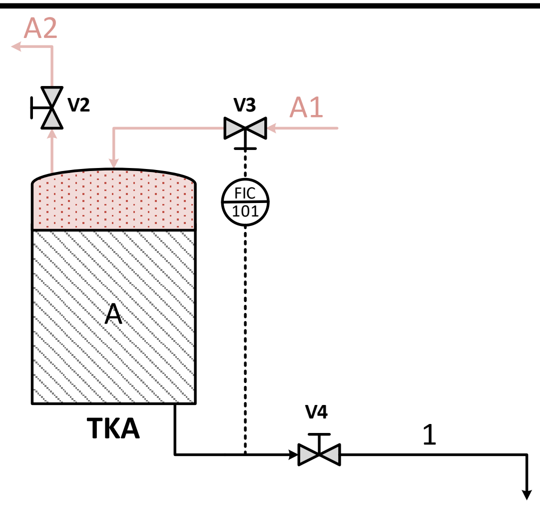
$$\Delta P_{V4} = P_{TKA}^0 + \tilde{\rho}_1 g h_{TKA} - P_{R1}^0$$

Modelado - Tanque TKA

$$\frac{dM_{GI}}{dt} = m_{A1} - m_{A2}$$

$$M_{GI} = \frac{P_{TKA}^0 V_{GI}}{RT_{GI}} = \frac{P_{TKA}^0 \left(V_{TKA} - A_{TKA} h_{TKA}\right)}{RT_{GI}}$$

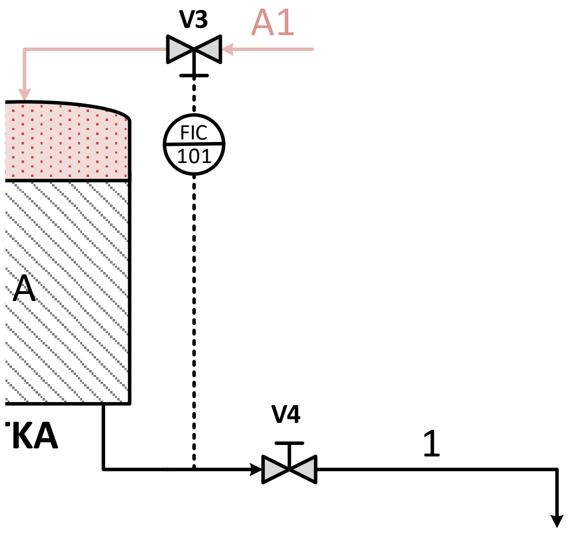
$$m_{A2} = \rho_{A2} x_{V2} K_{V2} \sqrt{\frac{\Delta P_{V2}}{G_{V2}}} \quad \Delta P_{V2} = P_{TKA}^0 - P_{A2}$$



Modelado - Tanque TKA (controladores)

$$\varepsilon = m_{sp} - m_1$$

Control inverso



$$A_p = K_p \, \varepsilon_L$$

$$\frac{dA_I}{dt} = K_I \, \varepsilon_L$$

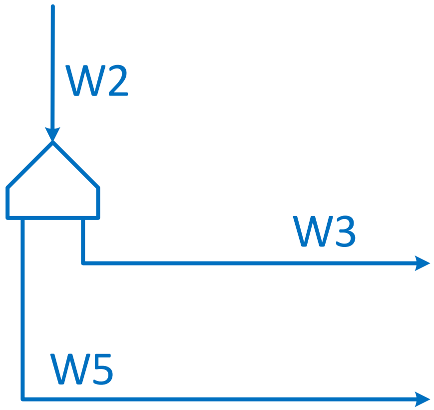
$$AC = A_P + A_I + A_0$$

$$x_{V3} = \max\left(0, \min\left(1, AC\right)\right)$$

$$m_{A1} = \rho_{A1} x_{V3} K_{V3} \sqrt{\frac{\Delta P_{V3}}{G_{V3}}} \qquad \Delta P_{V3} = P_{A1} - P_{TKA}^{0}$$

Modelado – Splitter SP1

$$m_{W2} = m_{W3} + m_{W5}$$



Resumen de EDOS

$$A_{R1}C_A\frac{dh_{R1}}{dt}+A_{R1}h_{R1}\frac{dC_A}{dt}=m_1x_{A,1}+r_AA_{R1}h_{R1}-m_2x_{A,2}\qquad \text{I}$$

$$A_{R1}C_B\frac{dh_{R1}}{dt}+A_{R1}h_{R1}\frac{dC_B}{dt}=m_1x_{B,1}+r_BA_{R1}h_{R1}-m_2x_{B,2}\qquad \text{II}$$

$$\rho_2A_{R1}\frac{dh_{R1}}{dt}=m_1-m_2\qquad \text{III}$$

$$\rho_2A_{R1}h_{R1}\frac{dH_2}{dt}+\rho_2A_{R1}H_2\frac{dh_{R1}}{dt}=m_1H_1-m_2H_2+\left(-r_A\right)A_{R1}h_{R1}\left(-\Delta H_{rD}\right)-Q_{R1}\qquad \text{IV}$$

$$M_a\frac{dH_{W4}}{dt}=m_{W3}\left(H_{W3}-H_{W4}\right)+Q_{R1}\qquad \text{V}$$

Resumen de EDOS

$$\rho_3 A_{TK} \frac{dh_{TK}}{dt} = m_2 - m_3 \quad \text{VI}$$

$$A_{TK} C_{A,3} \frac{dh_{TK}}{dt} + A_{TK} h_{TK} \frac{dC_{A,3}}{dt} = m_2 x_{A,2} - m_3 x_{A,3} \quad \text{VII}$$

$$A_{TK} C_{B,3} \frac{dh_{TK}}{dt} + A_{TK} h_{TK} \frac{dC_{B,3}}{dt} = m_2 x_{B,2} - m_3 x_{B,3} \quad \text{VIII}$$

$$\rho_3 A_{TK} h_{TK} \frac{dH_3}{dt} + \rho_3 A_{TK} H_3 \frac{dh_{TK}}{dt} = m_2 H_2 - m_3 H_3 - Q_{TK} \quad \text{IX}$$

$$M_a \frac{dH_{W6}}{dt} = m_{W5} \left(H_{W5} - H_{W6} \right) + Q_{TK} \quad \text{X}$$

$$\rho_{W2} A_{TKW} \frac{dh_{TKW}}{dt} = m_{W1} - m_{W2} \quad \text{XI}$$

Resumen de EDOS

$$\rho_1 A_{TKA} \frac{dh_{TKA}}{dt} = -m_1 \quad \text{XII}$$

$$\frac{dM_{GI}}{dt} = m_{A1} - m_{A2} \quad \text{XIII}$$

Resumen de EDOS

FIC/101: $$\frac{dA_I}{dt} = K_I \varepsilon$$ (XIV)

TIC/101: $$\frac{dA_I}{dt} = K_I \varepsilon$$ (XV)

LIC/101: $$\frac{dA_I}{dt} = K_I \varepsilon$$ (XVI)

TIC/102: $$\frac{dA_I}{dt} = K_I \varepsilon$$ (XVII)

Sistema de EDOS – Valores iniciales

Condiciones iniciales:

$h_{R1}^{(0)}$ $C_A^{(0)}$ $C_B^{(0)}$ $H_2^{(0)}$ $H_{W4}^{(0)}$

$h_{TK}^{(0)}$ $C_{A,3}^{(0)}$ $C_{B,3}^{(0)}$ $H_3^{(0)}$ $H_{W6}^{(0)}$ $h_{TKW}^{(0)}$ $h_{TKA}^{(0)}$ $M_{GI}^{(0)}$

$A_I^{(0)}$	$A_I^{(0)}$	$A_I^{(0)}$	$A_I^{(0)}$
FIC/101	TIC/101	LIC/102	TIC/102

Sistema de EDOS – Resolución

$$\left.\begin{aligned} x_{A,2} &= \frac{C_A}{C_A + C_B} \\ x_{B,2} &= \frac{C_B}{C_A + C_B} \end{aligned}\right\} \rightarrow x_{A,2}{}^{(0)} \;\; x_{B,2}{}^{(0)} \qquad \left.\begin{aligned} x_{A,3} &= \frac{C_{A,3}}{C_{A,3} + C_{B,3}} \\ x_{B,3} &= \frac{C_{B,3}}{C_{A,3} + C_{B,3}} \end{aligned}\right\} \rightarrow x_{A,3}{}^{(0)} \;\; x_{B,3}{}^{(0)}$$

$$P_{W2} = P_{W3} = P_{W5} = P_{TKW}^{0} + \tilde{\rho}_{W2} g h_{TKW} \rightarrow P_{W2}{}^{(0)} \;\; P_{W3}{}^{(0)} \;\; P_{W5}{}^{(0)}$$

$$H_{W4} = f\left(T_{W4}\right) \rightarrow T_{W4}{}^{(0)}$$

$$H_{W6} = f\left(T_{W6}\right) \rightarrow T_{W6}{}^{(0)}$$

$$H_{2} = f\left(T_{2}, x_{2}\right) \rightarrow T_{2}{}^{(0)}$$

Sistema de EDOS – Resolución

$$M_{GI} = \frac{P^0_{TKA}\left(V_{TKA} - A_{TKA}h_{TKA}\right)}{RT_{GI}} \rightarrow {P^0_{TKA}}^{(0)}$$

$$\Delta P_{V4} = P^0_{TKA} + \tilde{\rho}_1 g h_{TKA} - P^0_{R1} \rightarrow \Delta {P_{V4}}^{(0)}$$

$$m_1 = \rho_1 x_{V4} K_{V4} \sqrt{\frac{\Delta P_{V4}}{G_{V4}}} \rightarrow {m_1}^{(0)}$$

$$\Delta P_{V8} = P^0_{TK} + \tilde{\rho}_3 g h_{TK} - P_3 \rightarrow \Delta {P_{V8}}^{(0)}$$

$$m_3 = \rho_3 x_{V8} K_{V8} \sqrt{\frac{\Delta P_{V8}}{G_{V8}}} \rightarrow {m_3}^{(0)}$$

$$\Delta P_{V2} = P^0_{TKA} - P_{A2} \rightarrow \Delta {P_{V2}}^{(0)}$$

$$m_{A2} = \rho_{A2} x_{V2} K_{V2} \sqrt{\frac{\Delta P_{V2}}{G_{V2}}} \rightarrow {m_{A2}}^{(0)}$$

Sistema de EDOS – Resolución

$$\left.\begin{array}{l} \varepsilon = h_{sp} - h_{R1} \\ A_p = K_p\, \varepsilon \\ AC = A_P + A_0 \\ x_{V1} = \max\left(0, \min\left(1, AC\right)\right) \\ \Delta P_{V1} = P_{W1} - P_{TKW}^{0} \\ m_{W1} = \rho_{W1} x_{V1} K_{V1} \sqrt{\dfrac{\Delta P_{V1}}{G_{V1}}} \end{array}\right\} \rightarrow m_{W1}{}^{(0)}$$

$$\left.\begin{array}{l} \varepsilon = T_3 - T_{sp} \\ A_p = K_p\, \varepsilon \\ AC = A_P + A_I + A_0 \\ x_{V7} = \max\left(0, \min\left(1, AC\right)\right) \\ \Delta P_{V7} = P_{W5} - P_{W6} \\ m_{W5} = \rho_{W5} x_{V7} K_{V7} \sqrt{\dfrac{\Delta P_{V7}}{G_{V7}}} \end{array}\right\} \rightarrow m_{W5}{}^{(0)}$$

$$\left.\begin{array}{l} \varepsilon = m_{sp} - m_1 \\ A_p = K_p\, \varepsilon_L \\ AC = A_P + A_I + A_0 \\ x_{V3} = \max\left(0, \min\left(1, AC\right)\right) \\ \Delta P_{V3} = P_{A1} - P_{TKA}^{0} \\ m_{A1} = \rho_{A1} x_{V3} K_{V3} \sqrt{\dfrac{\Delta P_{V3}}{G_{V3}}} \end{array}\right\} \rightarrow m_{A1}{}^{(0)}$$

Sistema de EDOS – Resolución

$$\left(\frac{dT_2}{dt}\right)^* \rightarrow \left.\begin{aligned} &\varepsilon = T_2 - T_{sp} \\ &A_p = K_p\,\varepsilon \\ &A_D = K_D\left(\frac{dT_2}{dt}\right)^* \\ &AC = A_P + A_I + A_D + A_0 \\ &x_{V5} = \max\left(0, \min\left(1, AC\right)\right) \\ &\Delta P_{V5} = P_{W3} - P_{W4} \\ &m_{W3} = \rho_{W3} x_{V5} K_{V5} \sqrt{\frac{\Delta P_{V5}}{G_{V5}}} \end{aligned}\right\} \rightarrow m_{W3}^{(0)}$$

$$\left(\frac{dh_{R1}}{dt}\right)^* \rightarrow \left.\begin{aligned} &\varepsilon = h_{R1} - h_{sp} \\ &A_p = K_p\,\varepsilon_L \\ &A_D = K_D\left(\frac{dh_{R1}}{dt}\right)^* \\ &AC = A_P + A_I + A_D + A_0 \\ &x_{V6} = \max\left(0, \min\left(1, AC\right)\right) \\ &\Delta P_{V6} = P_{R1}^0 + \tilde{\rho}_2 g h_{R1} - P_{TK}^0 \\ &m_2 = \rho_2 x_{V6} K_{V6} \sqrt{\frac{\Delta P_{V6}}{G_{V6}}} \end{aligned}\right\} \rightarrow m_2^{(0)}$$

Sistema de EDOS – Resolución

$$m_{W2} = m_{W3} + m_{W5} \rightarrow m_{W2}{}^{(0)}$$

$$Q_{R1} = \left(UA\right)_{R1}\left(T_2 - T_{W4}\right) \rightarrow Q_{R1}{}^{(0)}$$

$$Q_{TK} = \left(UA\right)_{TK}\left(T_3 - T_{W6}\right) \rightarrow Q_{TK}{}^{(0)}$$

Sistema de EDOS – Resolución

$$\rho_2 A_{R1}\frac{dh_{R1}}{dt} = m_1 - m_2 \rightarrow \left(\frac{dh_{R1}}{dt}\right)^{(0)} \quad \text{III}$$

$$A_{R1}C_A\frac{dh_{R1}}{dt} + A_{R1}h_{R1}\frac{dC_A}{dt} = m_1 x_{A,1} + r_A A_{R1}h_{R1} - m_2 x_{A,2} \rightarrow \left(\frac{dC_A}{dt}\right)^{(0)} \quad \text{I}$$

$$A_{R1}C_B\frac{dh_{R1}}{dt} + A_{R1}h_{R1}\frac{dC_B}{dt} = m_1 x_{B,1} + r_B A_{R1}h_{R1} - m_2 x_{B,2} \rightarrow \left(\frac{dC_B}{dt}\right)^{(0)} \quad \text{II}$$

$$\rho_2 A_{R1}h_{R1}\frac{dH_2}{dt} + \rho_2 A_{R1}H_2\frac{dh_{R1}}{dt} = m_1 H_1 - m_2 H_2 + (-r_A)A_{R1}h_{R1}(-\Delta H_{rD}) - Q_{R1} \rightarrow \left(\frac{dH_2}{dt}\right)^{(0)} \quad \text{IV}$$

$$C_A^{(1)} = C_A^{(0)} + \Delta t\left(\frac{dC_A}{dt}\right)^{(0)}$$

$$C_B^{(1)} = C_B^{(0)} + \Delta t\left(\frac{dC_B}{dt}\right)^{(0)} \rightarrow \begin{cases} x_{A,2}^{(1)} = \dfrac{C_A^{(1)}}{C_A^{(1)} + C_B^{(1)}} \\ x_{B,2}^{(1)} = \dfrac{C_B^{(1)}}{C_A^{(1)} + C_B^{(1)}} \end{cases} \rightarrow H_2^{(1)} = f\left(T_2^{(1)}, x_2^{(1)}\right) \rightarrow T_2^{(1)}$$

$$H_2^{(1)} = H_2^{(0)} + \Delta t\left(\frac{dH_2}{dt}\right)^{(0)}$$

$$\left(\frac{dT_2}{dt}\right)^{(0)} = \frac{T_2^{(1)} - T_2^{(0)}}{\Delta t}$$

Sistema de EDOS – Resolución

$$G_1 = \left| \left(\frac{dh_{R1}}{dt} \right)^* - \left(\frac{dh_{R1}}{dt} \right)^{(0)} \right| \qquad G_2 = \left| \left(\frac{dT_2}{dt} \right)^* - \left(\frac{dT_2}{dt} \right)^{(0)} \right|$$

$$¿\max\left(G_1, \ldots, G_4\right) < tol\,? \rightarrow Si$$

Continuamos

$$¿\max\left(G_1, \ldots, G_4\right) < tol\,? \rightarrow No$$

$$\left(\frac{dh_{R1}}{dt} \right)^* = \left(\frac{dh_{R1}}{dt} \right)^{(0)}$$

$$\left(\frac{dT_2}{dt} \right)^* = \left(\frac{dT_2}{dt} \right)^{(0)}$$

Remplazamos y recalculamos

Sistema de EDOS – Resolución

$$M_a \frac{dH_{W4}}{dt} = m_{W3}\left(H_{W3} - H_{W4}\right) + Q_{R1} \rightarrow \left(\frac{dH_{W4}}{dt}\right)^{(0)}$$ V

$$\rho_3 A_{TK} \frac{dh_{TK}}{dt} = m_2 - m_3 \rightarrow \left(\frac{dh_{TK}}{dt}\right)^{(0)}$$ VI

$$A_{TK} C_{A,3} \frac{dh_{TK}}{dt} + A_{TK} h_{TK} \frac{dC_{A,3}}{dt} = m_2 x_{A,2} - m_3 x_{A,3} \rightarrow \left(\frac{dC_{A,3}}{dt}\right)^{(0)}$$ VII

$$A_{TK} C_{B,3} \frac{dh_{TK}}{dt} + A_{TK} h_{TK} \frac{dC_{B,3}}{dt} = m_2 x_{B,2} - m_3 x_{B,3} \rightarrow \left(\frac{dC_{B,3}}{dt}\right)^{(0)}$$ VIII

$$\rho_{W2} A_{TKW} \frac{dh_{TKW}}{dt} = m_{W1} - m_{W2} \rightarrow \left(\frac{dh_{TKW}}{dt}\right)^{(0)}$$ XI

$$\rho_3 A_{TK} h_{TK} \frac{dH_3}{dt} + \rho_3 A_{TK} H_3 \frac{dh_{TK}}{dt} = m_2 H_2 - m_3 H_3 - Q_{TK} \rightarrow \left(\frac{dH_3}{dt}\right)^{(0)}$$ IX

$$M_a \frac{dH_{W6}}{dt} = m_{W5}\left(H_{W5} - H_{W6}\right) + Q_{TK} \rightarrow \left(\frac{dH_{W6}}{dt}\right)^{(0)}$$ X

Sistema de EDOS – Resolución

$$\rho_1 A_{TKA} \frac{dh_{TKA}}{dt} = -m_1 \rightarrow \left(\frac{dh_{TKA}}{dt}\right)^{(0)}$$ XII

$$\frac{dM_{GI}}{dt} = m_{A1} - m_{A2} \rightarrow \left(\frac{dM_{GI}}{dt}\right)^{(0)}$$ XIII

Sistema de EDOS – Resolución

FIC/101: $$\frac{dA_I}{dt} = K_I \varepsilon \rightarrow \left(\frac{dA_I}{dt}\right)^{(0)}$$ XIV

TIC/101: $$\frac{dA_I}{dt} = K_I \varepsilon \rightarrow \left(\frac{dA_I}{dt}\right)^{(0)}$$ XV

LIC/101: $$\frac{dA_I}{dt} = K_I \varepsilon \rightarrow \left(\frac{dA_I}{dt}\right)^{(0)}$$ XVI

TIC/102: $$\frac{dA_I}{dt} = K_I \varepsilon \rightarrow \left(\frac{dA_I}{dt}\right)^{(0)}$$ XVII

Sistema de EDOS – Resolución

Aplicando Euler obtenemos:

$$h_{R1}^{(1)} \quad C_A^{(1)} \quad C_B^{(1)} \quad H_2^{(1)} \quad H_{W4}^{(1)}$$

$$h_{TK}^{(1)} \quad x_{A,3}^{(1)} \quad x_{B,3}^{(1)} \quad H_3^{(1)} \quad H_{W6}^{(1)} \quad h_{TKW}^{(1)} \quad h_{TKA}^{(1)} \quad M_{GI}^{(1)}$$

$A_I^{(1)}$	$A_I^{(1)}$	$A_I^{(1)}$	$A_I^{(1)}$
FIC/101	TIC/101	LIC/102	TIC/102

Y resolvemos nuevamente para el nuevo instante (1)…