Lugar Geométrico de Las Raíces de la Función en L.D. kgr(s)

Problema Graficar el root locus de una función kgr(s) en función de k positivo y negativo.

Parametros

$$gr(s,k) := k\cdot\frac{(s+4+j\cdot3)\cdot(s+4-j\cdot3)}{s\cdot(s+2)\cdot(s+6)\cdot(s+5+j\cdot6)\cdot(s+5-j\cdot6)}$$

$$s^5 + 18\cdot s^4 + 153\cdot s^3 + (K+608)\cdot s^2 + (732+8\cdot K)\cdot s + 25\cdot K = 0$$

$$n := 5$$

Solución A continuación se grafica el locus requerido.

$$j := 1 .. n-1 \qquad C_{j+1,j} := 1$$

$$coeff_p(k) := (25\cdot k \quad 732+8\cdot k \quad k+608 \quad 153 \quad 18)^T \qquad k_{max} := 2.9$$

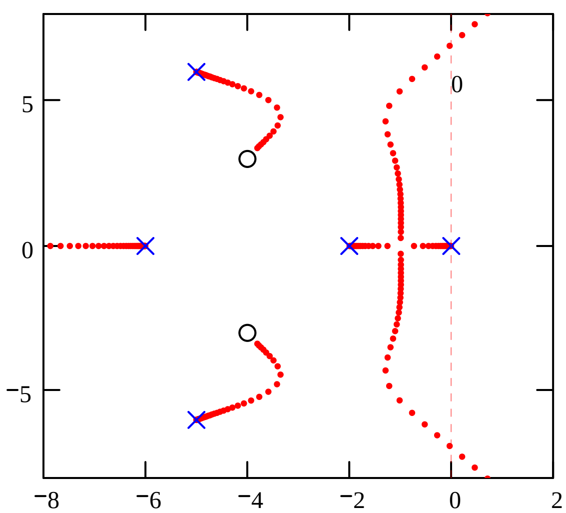
$$coeff_n(k) := (25\cdot -k \quad 732+8\cdot -k \quad -k+608 \quad 153 \quad 18)^T$$

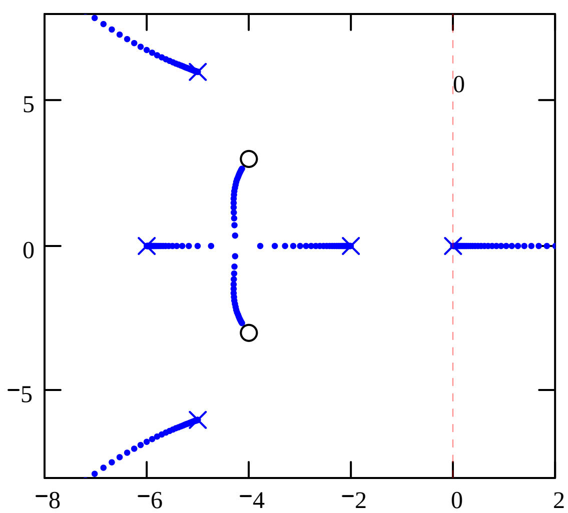
$$m := 1 .. n \qquad i_{max} := 50 \qquad i := 1 .. i_{max} \qquad k_i := 10^{\left(\frac{i}{i_{max}}\cdot k_{max}\right)} - 1$$

$$R_p^{\langle i\rangle} := eigenvals\left(augment\left(C, -coeff_p\left(k_i\right)\right)\right) \qquad Q_p(k) := eigenvals\left(augment\left(C, -coeff_p(k)\right)\right)$$

$$R_n^{\langle i\rangle} := eigenvals\left(augment\left(C, -coeff_n\left(k_i\right)\right)\right) \qquad Q_n(k) := eigenvals\left(augment\left(C, -coeff_n(k)\right)\right)$$

$$k_{ol} := 0 \qquad k_{cer} := 10^{10\cdot k_{max}}$$





L.G.R.

Problema Estudiar la aplicabilidad del LGR a sistemas en ingeniería.

Fuente DC/DC

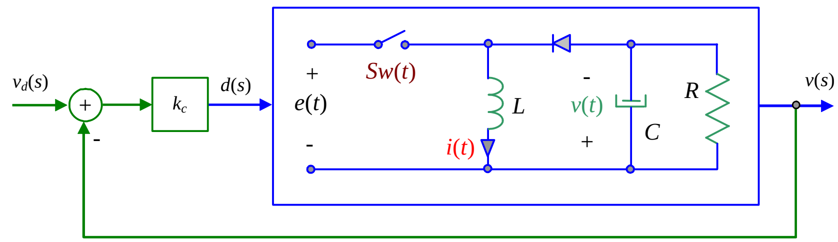
Parámetros

$L := 12\cdot 10^{-3}$ $\quad C := 250\cdot 10^{-6}$ $\quad R := 10$

$d_o := 0.5$ $\quad e_o := 10$ $\quad \Delta e := 0.5$

Variables de Estado

$x_1 = v$ $\quad x_2 = i$



Punto de operación

$v_o := \dfrac{d_o}{1-d_o}\cdot e_o$ $\quad v_o = 10$ $\quad i_o := \dfrac{v_o}{R\cdot(1-d_o)}$ $\quad i_o = 2$ $\quad u_o := d_o$ $\quad p_o := e_o$

Modelo Lineal Normalizad-o.

$$A_n := \begin{bmatrix} \dfrac{-1}{R\cdot C} & \dfrac{1}{R\cdot C} \\ \dfrac{-R}{L}\cdot(1-d_o)^2 & 0 \end{bmatrix} \quad b_n := \begin{bmatrix} \dfrac{-d_o}{R\cdot C\cdot(1-d_o)} \\ \dfrac{R}{L}\cdot(1-d_o) \end{bmatrix} \quad e_n := \begin{bmatrix} 0 \\ \dfrac{R}{L}\cdot(1-d_o)^2 \end{bmatrix} \quad c_n := (1 \quad 0)$$

F. de T. en L.A.

$$h_{vndn}(s) := \frac{1}{1-d_o}\cdot\frac{s\cdot\dfrac{-1}{R\cdot C}\cdot d_o + \dfrac{(1-d_o)^2}{L\cdot C}}{s^2 + s\cdot\dfrac{1}{R\cdot C} + \dfrac{(1-d_o)^2}{L\cdot C}}$$

cero $\quad s\cdot\dfrac{-1}{R\cdot C}\cdot d_o + \dfrac{(1-d_o)^2}{L\cdot C} = 0$

polos $\quad s^2 + s\cdot\dfrac{1}{R\cdot C} + \dfrac{(1-d_o)^2}{L\cdot C} = 0$

$$pp := \lambda^2 + \lambda\cdot\frac{1}{R\cdot C} + \frac{(1-d_o)^2}{L\cdot C} \text{ coeffs}, \lambda \rightarrow \begin{pmatrix} 83333.333333333333333 \\ 400 \\ 1 \end{pmatrix}$$

$$\text{polyroots}(pp) = \begin{pmatrix} -200 - 208.167i \\ -200 + 208.167i \end{pmatrix}$$

$$zz := \lambda\cdot\frac{-1}{R\cdot C}\cdot d_o + \frac{(1-d_o)^2}{L\cdot C} \text{ coeffs}, \lambda \rightarrow \begin{pmatrix} 83333.333333333333333 \\ -200.0 \end{pmatrix}$$

$$\text{polyroots}(zz) = 416.667$$

F. de T. en L.C.

$$h_{vnvnd}(s, k_c) := \frac{\dfrac{k_c}{1-d_o}\cdot\left[s\cdot\dfrac{-1}{R\cdot C}\cdot d_o + \dfrac{(1-d_o)^2}{L\cdot C}\right]}{s^2 + s\cdot\dfrac{1}{R\cdot C}\cdot\left(1 - k_c\cdot\dfrac{d_o}{1-d_o}\right) + \dfrac{(1-d_o)^2}{L\cdot C}\cdot\left(1 + k_c\cdot\dfrac{1}{1-d_o}\right)}$$

$$h_{vnvnd}(0, 0.16667) = 0.25$$

$$pp(k_c) := \lambda^2 + \lambda\cdot\frac{1}{R\cdot C}\cdot\left(1 - k_c\cdot\frac{d_o}{1-d_o}\right) + \frac{(1-d_o)^2}{L\cdot C}\cdot\left(1 + k_c\cdot\frac{1}{1-d_o}\right) \left|\begin{matrix}\text{coeffs}, \lambda \\ \text{float}, 5\end{matrix}\right. \rightarrow \begin{pmatrix} 83333. + 1.6667\cdot 10^5\cdot k_c \\ 400. - 400.00\cdot k_c \\ 1. \end{pmatrix}$$

Error en S.S. Entrada Escalón - Sistema en L.C. de Voltaje - Controlador k_c, con k_a = 1, y k_{st} = 1.

$\Delta e_{esc\_ss} := 0.75 \qquad k_c := \mathrm{Re}\left[\frac{-(\Delta e_{esc\_ss} - 1)}{\Delta e_{esc\_ss} \cdot h_{vndn}(0)}\right] \qquad k_c = 0.167 \qquad k_a := 1 \qquad k_{st} := 1$

$h_c(s,k) := k \qquad l(s) := h_{vndn}(s) \qquad h_{vnvnd}(0, k_c) = 0.25$

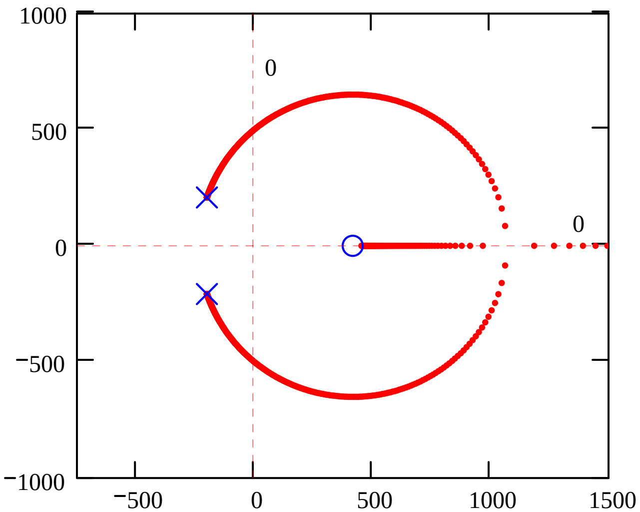
Polos y ceros en L.C. para k_c calculado.

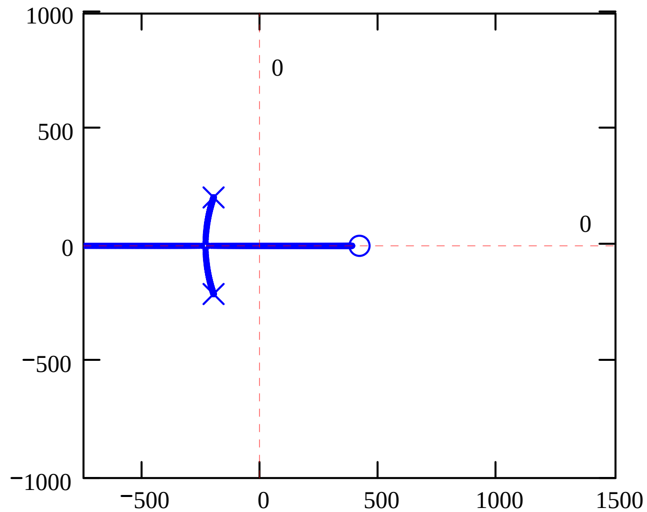
$pol := \mathrm{polyroots}(pp(k_c)) \qquad pol = \begin{pmatrix} -166.667 + 288.676i \\ -166.667 - 288.676i \end{pmatrix} \qquad cer := h_{vnvnd}(s, k_c) \left| \begin{matrix} \text{solve}, s \\ \text{float}, 10 \end{matrix} \right. \rightarrow 416.6666667$

Se grafica el L.G.R.

$\beta m := -4 \qquad \beta M := 1.5 \qquad \beta c := 10 \cdot \beta M \qquad re_{min} := -750 \qquad re_{max} := 1500$

$m := 1..2 \quad d := \beta m, \beta m + 0.005 .. \beta M \qquad P(d) := \mathrm{polyroots}(pp(10^d)) \qquad N(d) := \mathrm{polyroots}(pp(-10^d))$



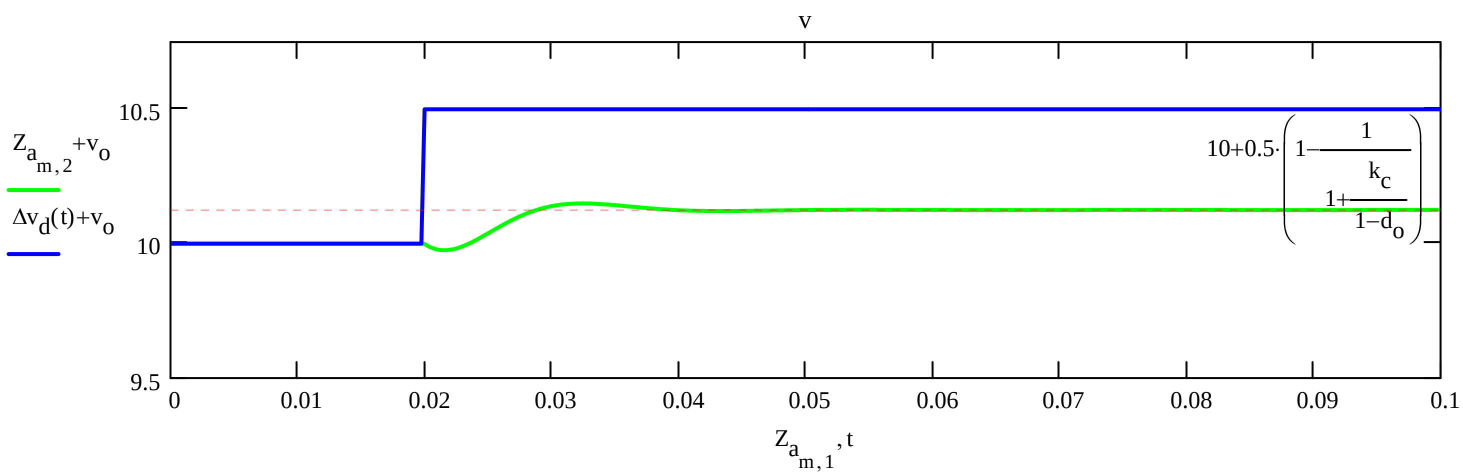


Simulación en L.C.

Caso 1

$\Delta v_d(t) := 0.5\cdot\Phi(t - 0.02)$ $\quad \Delta e(t) := 0$ $\quad n_f := 400$ $\quad t_f := 0.1$ $\quad t := 0, \frac{t_f}{n_f} .. t_f$ $\quad m := 0 .. n_f$

$D(t, \Delta x) := A_n\cdot(\Delta x_1 \;\; \Delta x_2)^T + b_n\cdot(k_c\cdot k_a)\cdot(\Delta v_d(t) - \Delta x_1) + e_n\cdot\Delta e(t)$ $\quad CI := (0 \;\; 0)^T$ $\quad Z_a := \text{rkfixed}(CI, 0, t_f, n_f, D)$



$h_{vnvnd}(0, k_c) = 0.25$

$k_c = 0.167$

Root Locus de una Función en L.D. gr(s)

Problema Graficar el root locus de una F. de T. en L.D. arbitraria.

Parametros

$$gr(s) := \frac{2s + 4}{s\cdot(s+4)} \qquad 1 + k\cdot\frac{2s+4}{s\cdot(s+4)} = 0 \qquad \frac{s^2 + (4 + 2\cdot k)\cdot s + 4\cdot k}{s\cdot(s+4)} = 0$$

$$s^2 + (4 + 2\cdot k)\cdot s + 4\cdot k = 0$$

$$n := 2$$

Solución A continuación se grafica el locus requerido.

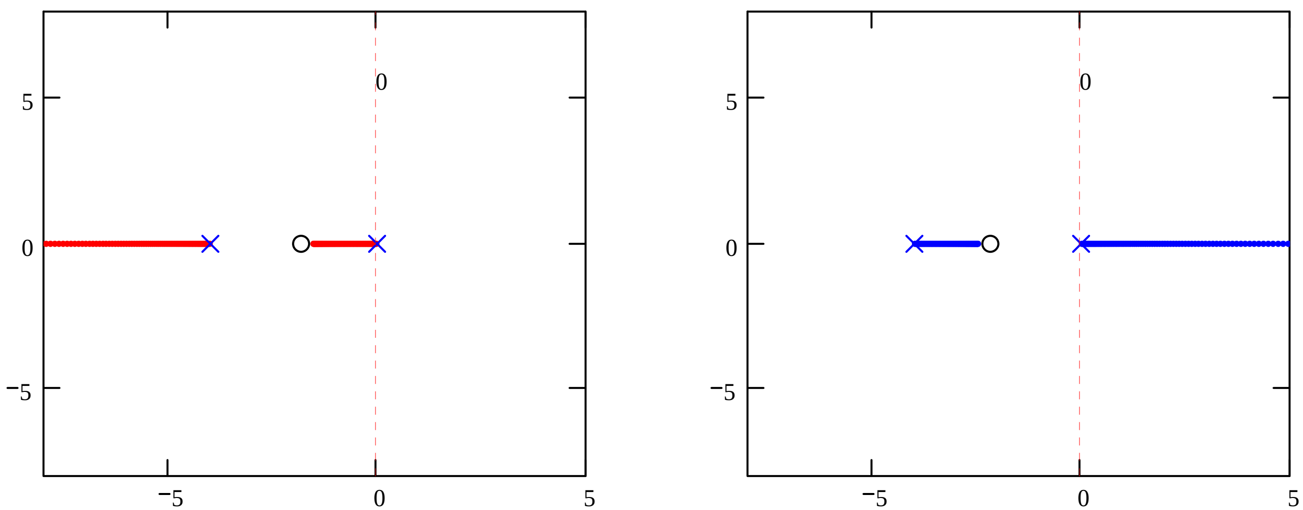
$$coeff_p(k) := (4\cdot k \quad 4 + 2\cdot k \quad 1)^T \qquad \beta_{ol} := 0 \qquad \beta_{max} := 0.7 \qquad \beta_{cer} := 10^{1.5\cdot\beta_{max}}$$

$$coeff_n(k) := (-4\cdot k \quad 4 + 2\cdot -k \quad 1)^T$$

$$m := 1 .. n \qquad i_{max} := 100 \qquad i := 1 .. i_{max} \qquad \beta_i := 10^{\left(\frac{i}{i_{max}}\cdot\beta_{max}\right)} - 1$$

$$R_p^{\langle i\rangle} := polyroots\left(coeff_p(\beta_i)\right) \qquad Q_p(\beta) := polyroots\left(coeff_p(\beta)\right)$$

$$R_n^{\langle i\rangle} := polyroots\left(coeff_n(\beta_i)\right) \qquad Q_n(\beta) := polyroots\left(coeff_n(\beta)\right)$$



Root Locus de una Función en L.D. gr(z)

Problema Graficar el root locus de una F. de T. en L.D. arbitraria.

Parametros

$$gr(z) := \frac{4\cdot(z+0.5)}{3\cdot z\cdot(z-0.4)} \qquad 1 + k\cdot\frac{4\cdot(z+0.5)}{3\cdot z\cdot(z-0.4)} = 0 \qquad \frac{1}{3}\cdot\frac{3\cdot z^2 + (4\cdot k - 1.2)\cdot z + 2\cdot k}{z\cdot(z-0.4)} = 0$$

$$3\cdot z^2 + (4\cdot k - 1.2)\cdot z + 2\cdot k = 0$$

$$n := 2$$

Solución A continuación se grafica el locus requerido.

$$coeff_p(k) := (2\cdot k \;\; 4\cdot k - 1.2 \;\; 3)^T \qquad \beta_{ol} := 0 \qquad \beta_{max} := 0.75 \qquad \beta_c := 10^{1.5\cdot\beta_{max}}$$

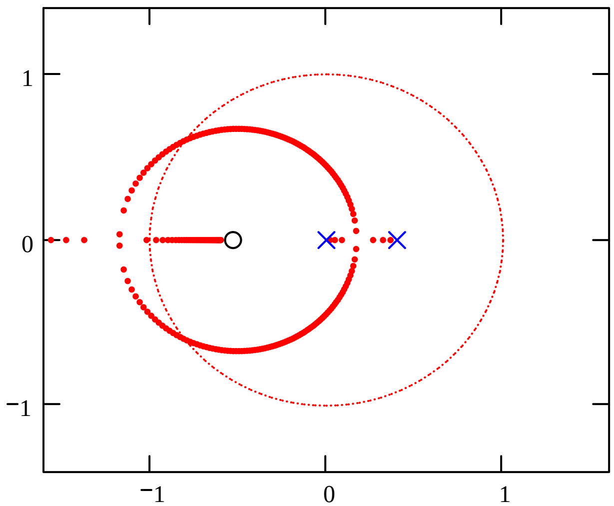
$$coeff_n(k) := (2\cdot -k \;\; -4\cdot k - 1.2 \;\; 3)^T$$

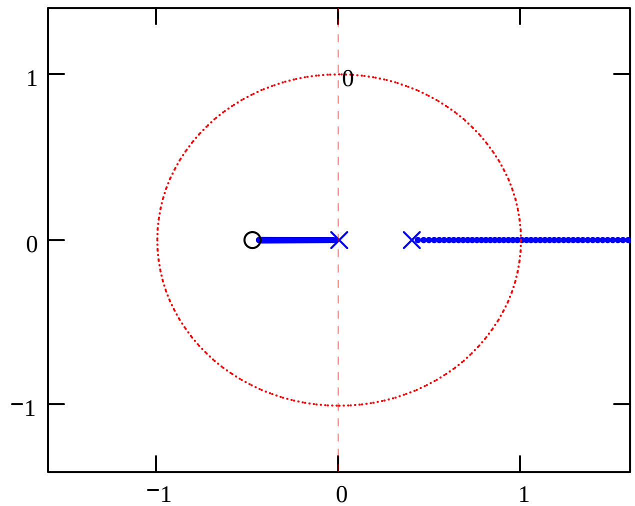
$$m := 1..n \qquad i_{max} := 150 \qquad i := 1..i_{max} \qquad \beta_i := 10^{\left(\frac{i}{i_{max}}\cdot\beta_{max}\right)} - 1 \qquad x(\theta) := \cos(\theta)$$

$$y(\theta) := \sin(\theta)$$

$$R_p^{\langle i\rangle} := polyroots\left(coeff_p\left(\beta_i\right)\right) \qquad Q_p(\beta) := polyroots\left(coeff_p(\beta)\right)$$

$$R_n^{\langle i\rangle} := polyroots\left(coeff_n\left(\beta_i\right)\right) \qquad Q_n(\beta) := polyroots\left(coeff_n(\beta)\right) \qquad \theta := 0, \frac{\pi}{50}..2\pi$$





Root Locus de una Función en L.D. gr(s)

Problema Graficar el root locus de una F. de T. en L.D. arbitraria.

Parametros

$$gr(s) := \frac{6}{s\cdot(s+1)\cdot(s+2)} \qquad 1 + k\cdot\frac{6}{s\cdot(s+1)\cdot(s+2)} = 0 \qquad \frac{s^3 + 3\cdot s^2 + 2\cdot s + 6\cdot k}{s\cdot(s+1)\cdot(s+2)} = 0$$

$$s^3 + 3\cdot s^2 + 2\cdot s + 6\cdot k = 0$$

$$n := 3$$

Solución A continuación se grafica el locus requerido.

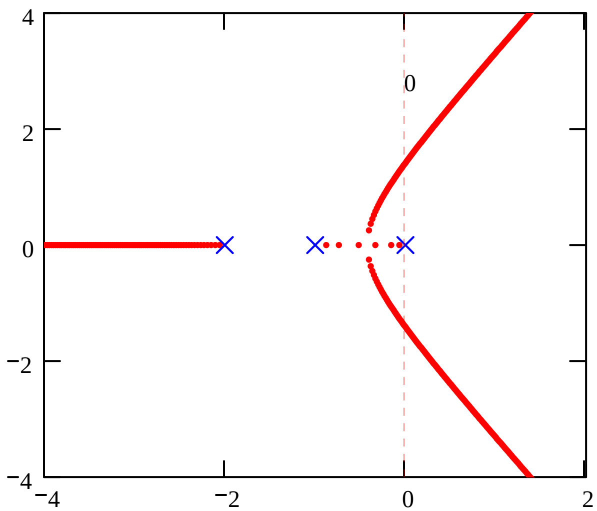
$$coeff_p(k) := (6\cdot k \;\; 2 \;\; 3 \;\; 1)^T \qquad \beta_{ol} := 0 \qquad \beta_{max} := 1.3 \qquad \beta_{cer} := 10^{1.5\cdot\beta_{max}}$$

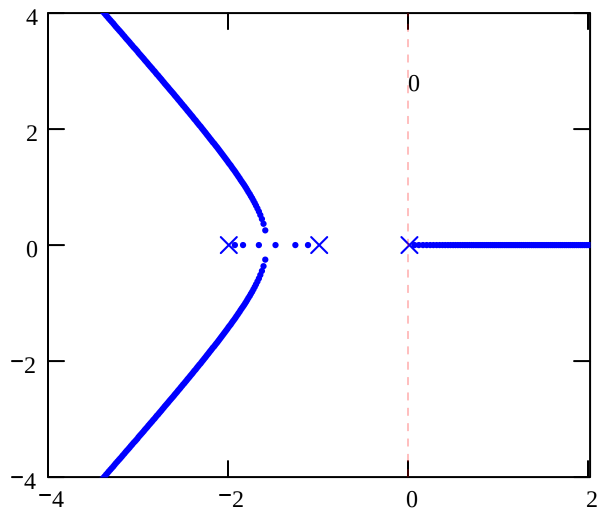
$$coeff_n(k) := (6\cdot -k \;\; 2 \;\; 3 \;\; 1)^T$$

$$m := 1 .. n \qquad i_{max} := 150 \qquad i := 1 .. i_{max} \qquad \beta_i := 10^{\left(\frac{i}{i_{max}}\cdot\beta_{max}\right)} - 1$$

$$R_p^{\langle i\rangle} := polyroots\left(coeff_p\left(\beta_i\right)\right) \qquad Q_p(\beta) := polyroots\left(coeff_p(\beta)\right)$$

$$R_n^{\langle i\rangle} := polyroots\left(coeff_n\left(\beta_i\right)\right) \qquad Q_n(\beta) := polyroots\left(coeff_n(\beta)\right)$$





Root Locus de una Función en L.D. gr(z)

Problema Graficar el root locus de una F. de T. en L.D. arbitraria.

Parametros

$$gr(z) := \frac{z^2 + z + 0.5}{z^2 - z + 0.5} \qquad 1 + k\cdot\frac{z^2 + z + 0.5}{z^2 - z + 0.5} = 0 \qquad \frac{(2\cdot k + 2)\cdot z^2 + (2\cdot k - 2)\cdot z + k + 1}{2\cdot z^2 - 2\cdot z + 1} = 0$$

$$(2\cdot k + 2)\cdot z^2 + (2\cdot k - 2)\cdot z + k + 1 = 0$$

$$n := 2$$

Solución A continuación se grafica el locus requerido.

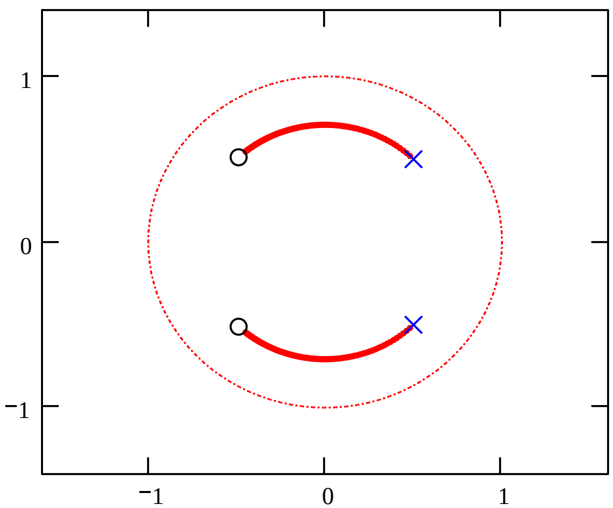
$$coeff_p(k) := (k + 1 \;\; 2\cdot k - 2 \;\; 2\cdot k + 2)^T \qquad \beta_{ol} := 0 \qquad \beta_{max} := 1.3 \qquad \beta_c := 10^{1.5\cdot\beta_{max}}$$

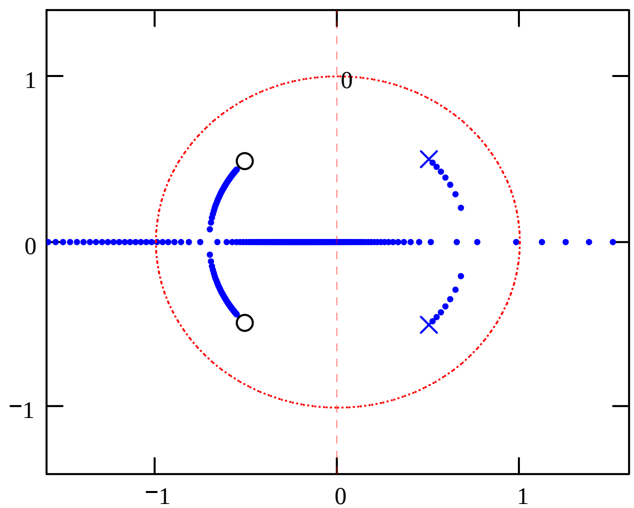
$$coeff_n(k) := (-k + 1 \;\; 2\cdot -k - 2 \;\; 2\cdot -k + 2)^T$$

$$m := 1 .. n \qquad i_{max} := 150 \qquad i := 1 .. i_{max} \qquad \beta_i := 10^{\left(\frac{i}{i_{max}}\cdot\beta_{max}\right)} - 1 \qquad x(\theta) := \cos(\theta)$$

$$R_p^{\langle i\rangle} := polyroots\left(coeff_p(\beta_i)\right) \qquad Q_p(\beta) := polyroots\left(coeff_p(\beta)\right) \qquad y(\theta) := \sin(\theta)$$

$$R_n^{\langle i\rangle} := polyroots\left(coeff_n(\beta_i)\right) \qquad Q_n(\beta) := polyroots\left(coeff_n(\beta)\right) \qquad \theta := 0, \frac{\pi}{50} .. 2\pi$$





Problema Graficar el root locus de una F. de T. en L.D. arbitraria.

Parametros

$$gr(s) := \frac{1}{(s+\alpha)\cdot(s+2)\cdot(s+3)} \qquad 1 + \frac{1}{(s+\alpha)\cdot(s+2)\cdot(s+3)} = 0 \qquad \frac{s^3 + (\alpha+5)\cdot s^2 + (5\cdot\alpha+6)\cdot s + 6\cdot\alpha + 1}{(s+\alpha)\cdot(s+2)\cdot(s+3)} = 0$$

$$s^3 + (\alpha+5)\cdot s^2 + (5\cdot\alpha+6)\cdot s + 6\cdot\alpha + 1 = 0$$

$$n := 3$$

Solución A continuación se grafica el locus requerido.

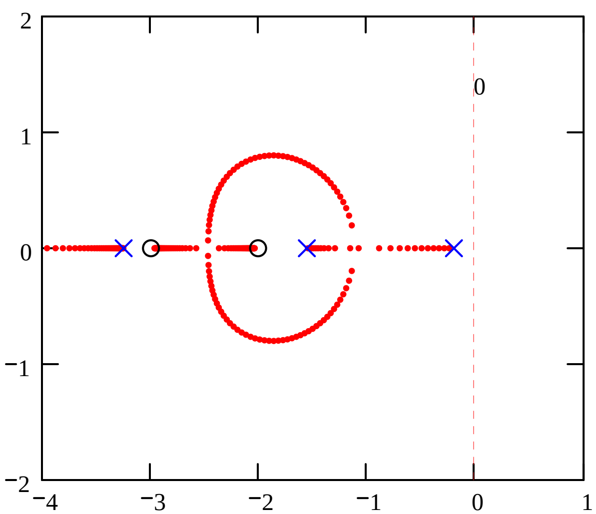
$$coeff_p(\alpha) := (6\cdot\alpha+1 \quad 5\cdot\alpha+6 \quad \alpha+5 \quad 1)^T \qquad \beta_{ol} := 0 \qquad \beta_{max} := 1.5 \qquad \beta_{cer} := 10^{1.5\cdot\beta_{max}}$$

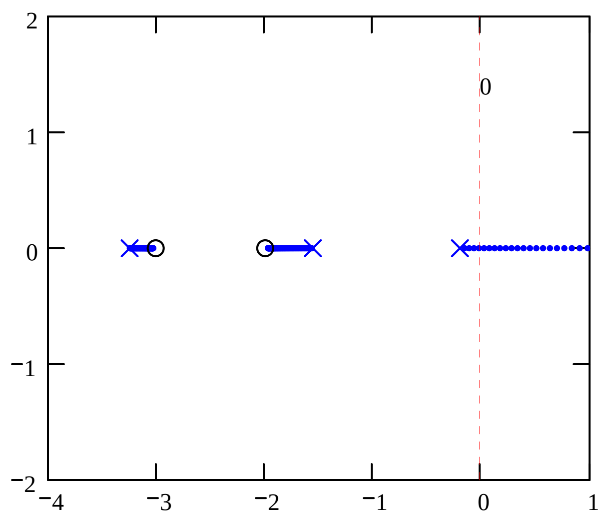
$$coeff_n(\alpha) := (6\cdot-\alpha+1 \quad 5\cdot-\alpha+6 \quad -\alpha+5 \quad 1)^T$$

$$m := 1..n \qquad i_{max} := 100 \qquad i := 1..i_{max} \qquad \beta_i := 10^{\left(\frac{i}{i_{max}}\cdot\beta_{max}\right)} - 1$$

$$R_p^{\langle i\rangle} := polyroots(coeff_p(\beta_i)) \qquad Q_p(\beta) := polyroots(coeff_p(\beta))$$

$$R_n^{\langle i\rangle} := polyroots(coeff_n(\beta_i)) \qquad Q_n(\beta) := polyroots(coeff_n(\beta))$$





Root Locus de una Función en L.D. gr(s,Δβ)

Problema Graficar el root locus de una F. de T. en L.D. arbitraria.

Parametros

$$gr(s) := 20.7\cdot\frac{s+3}{s\cdot(s+2)\cdot(s+8+\Delta\beta)} \qquad 1 + 20.7\cdot\frac{s+3}{s\cdot(s+2)\cdot(s+8+\Delta\beta)} = 0$$

$$10\cdot s^3 + (10\cdot\Delta\beta + 100)\cdot s^2 + (20\cdot\Delta\beta + 367)\cdot s + 621 = 0 \qquad \frac{1}{10}\cdot\frac{10\cdot s^3 + (10\cdot\Delta\beta+100)\cdot s^2 + (20\cdot\Delta\beta+367)\cdot s + 621}{s\cdot(s+2)\cdot(s+8+\Delta\beta)} = 0$$

$$n := 3$$

Solución A continuación se grafica el locus requerido.

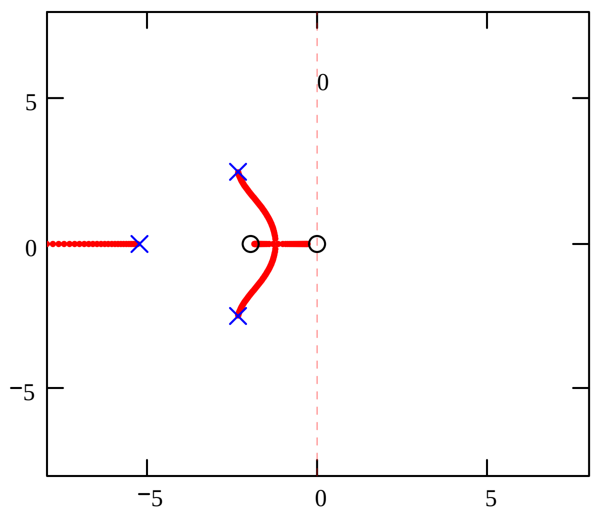
$$coeff_p(\Delta\beta) := \begin{bmatrix}621 & (20\cdot\Delta\beta + 367) & 10\cdot\Delta\beta + 100 & 10\end{bmatrix}^T \qquad \beta_{ol} := 0 \qquad \beta_{max} := 2 \qquad \beta_{cer} := 10^{1.5\cdot\beta_{max}}$$

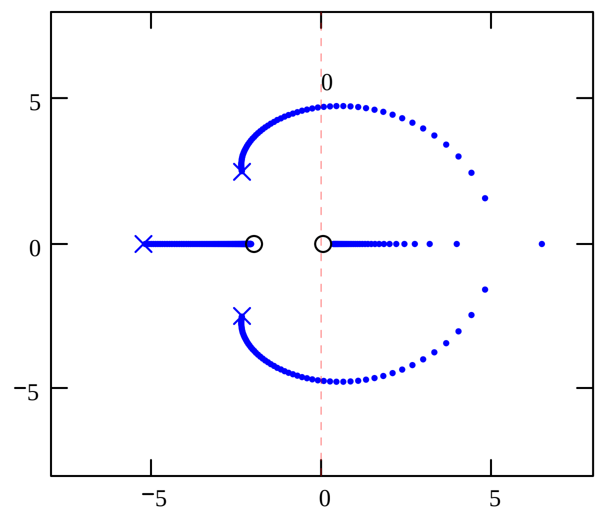
$$coeff_n(\Delta\beta) := \begin{bmatrix}621 & (20\cdot-\Delta\beta + 367) & 10\cdot-\Delta\beta + 100 & 10\end{bmatrix}^T$$

$$m := 1..n \qquad i_{max} := 100 \qquad i := 1..i_{max} \qquad \beta_i := 10^{\left(\frac{i}{i_{max}}\cdot\beta_{max}\right)} - 1$$

$$R_p^{\langle i\rangle} := polyroots(coeff_p(\beta_i)) \qquad Q_p(\beta) := polyroots(coeff_p(\beta))$$

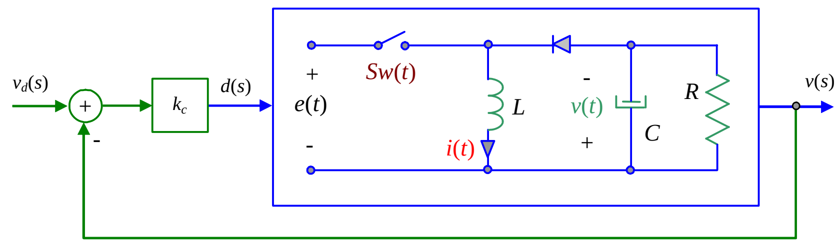
$$R_n^{\langle i\rangle} := polyroots(coeff_n(\beta_i)) \qquad Q_n(\beta) := polyroots(coeff_n(\beta))$$





L.G.R.

Problema Estudiar la aplicabilidad del LGR a sistemas en ingeniería.



Fuente DC/DC

Parámetros

$L := 12\cdot 10^{-3}$ $\quad C := 250\cdot 10^{-6}$ $\quad R := 10$

$d_o := 0.5$ $\quad e_o := 10$ $\quad \Delta e := 0.5$

Variables de Estado

$x_1 = v$ $\quad x_2 = i$

Punto de operación

$$v_o := \frac{d_o}{1-d_o}\cdot e_o \qquad v_o = 10 \qquad i_o := \frac{v_o}{R\cdot(1-d_o)} \qquad i_o = 2 \qquad u_o := d_o \qquad p_o := e_o$$

Modelo Lineal Normalizado

$$A_n := \begin{bmatrix} \frac{-1}{R\cdot C} & \frac{1}{R\cdot C} \\ \frac{-R}{L}\cdot(1-d_o)^2 & 0 \end{bmatrix} \qquad b_n := \begin{bmatrix} \frac{-d_o}{R\cdot C\cdot(1-d_o)} \\ \frac{R}{L}\cdot(1-d_o) \end{bmatrix} \qquad e_n := \begin{bmatrix} 0 \\ \frac{R}{L}\cdot(1-d_o)^2 \end{bmatrix} \qquad c_n := (1 \quad 0)$$

F. de T. en L.D.

$$l(s) := \frac{1}{1-d_o}\cdot\frac{s\cdot\frac{-1}{R\cdot C}\cdot d_o + \frac{(1-d_o)^2}{L\cdot C}}{s^2 + s\cdot\frac{1}{R\cdot C} + \frac{(1-d_o)^2}{L\cdot C}}$$

cero $\quad s\cdot\frac{-1}{R\cdot C}\cdot d_o + \frac{(1-d_o)^2}{L\cdot C} = 0$

polos $\quad s^2 + s\cdot\frac{1}{R\cdot C} + \frac{(1-d_o)^2}{L\cdot C} = 0$

$$pp := \lambda^2 + \lambda\cdot\frac{1}{R\cdot C} + \frac{(1-d_o)^2}{L\cdot C} \text{ coeffs}, \lambda \rightarrow \begin{pmatrix} 83333.333333333333333 \\ 400 \\ 1 \end{pmatrix} \qquad \text{polyroots}(pp) = \begin{pmatrix} -200 - 208.167i \\ -200 + 208.167i \end{pmatrix}$$

$$zz := \lambda\cdot\frac{-1}{R\cdot C}\cdot d_o + \frac{(1-d_o)^2}{L\cdot C} \text{ coeffs}, \lambda \rightarrow \begin{pmatrix} 83333.333333333333333 \\ -200.0 \end{pmatrix} \qquad \text{polyroots}(zz) = 416.667$$

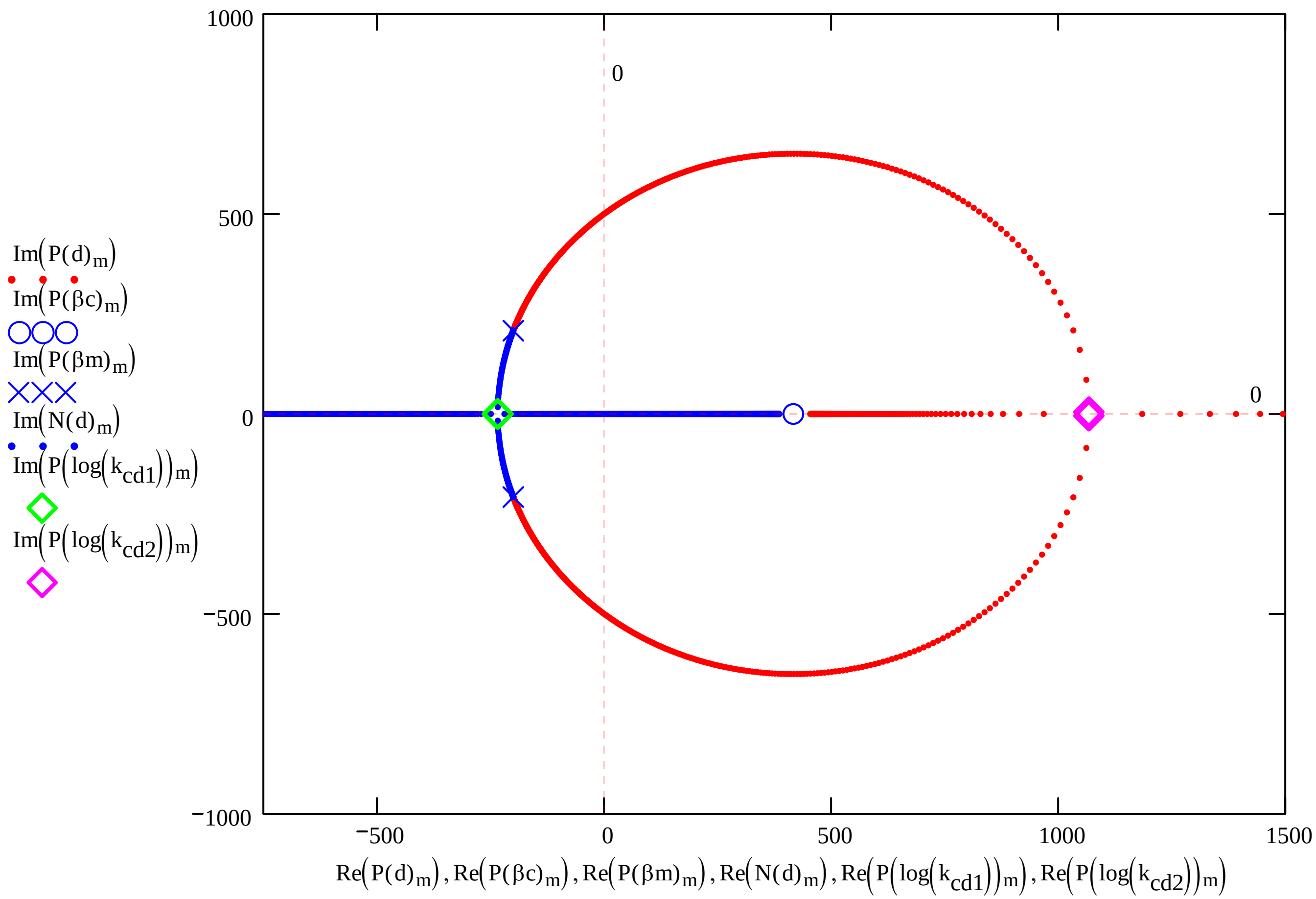
Puntos de partida y/o llegada

$$dlds(s) := d_o\cdot(1-d_o)\cdot R\cdot C\cdot \frac{s^2 - 2\cdot\frac{R}{L}\cdot\frac{(1-d_o)^2}{d_o}\cdot s - \frac{(1+d_o)}{L\cdot C}\cdot\frac{(1-d_o)^2}{d_o}}{\left[s\cdot d_o - \frac{R}{L}\cdot(1-d_o)^2\right]^2}$$

$$s_d := dlds(s) \;\Big|\; \begin{matrix}\text{solve}, s\\ \text{float}, 10\end{matrix} \rightarrow \begin{pmatrix}-234.1874730\\ 1067.520806\end{pmatrix}$$

$$k_{cd1} := \frac{-1}{l(s_{d_1})} \qquad k_{cd2} := \frac{-1}{l(s_{d_2})} \qquad k_{cd1} = -0.171 \qquad k_{cd2} = 6.338 \qquad k_{cd} := (k_{cd1} \;\; k_{cd2})^T$$

Puntos de partida y/o llegada



Valores de
k críticos

$$h_{vvd}(s) := \frac{\frac{k_c}{1-d_o}\cdot\left[s\cdot\frac{-1}{R\cdot C}\cdot d_o + \frac{(1-d_o)^2}{L\cdot C}\right]}{s^2 + s\cdot\frac{1}{R\cdot C}\cdot\left(1 - k_c\cdot\frac{d_o}{1-d_o}\right) + \frac{(1-d_o)^2}{L\cdot C}\cdot\left(1 + k_c\cdot\frac{1}{1-d_o}\right)}$$

F. de T. en L.C.

$$\frac{1}{R\cdot C}\cdot\left(1 - k_c\cdot\frac{d_o}{1-d_o}\right) = 0 \qquad k_{ci1} := \frac{1-d_o}{d_o} \qquad k_{ci1} = 1$$

$$\frac{(1-d_o)^2}{L\cdot C}\cdot\left(1 + k_c\cdot\frac{1}{1-d_o}\right) = 0 \qquad k_{ci2} := -(1-d_o) \qquad k_{ci2} = -0.5$$

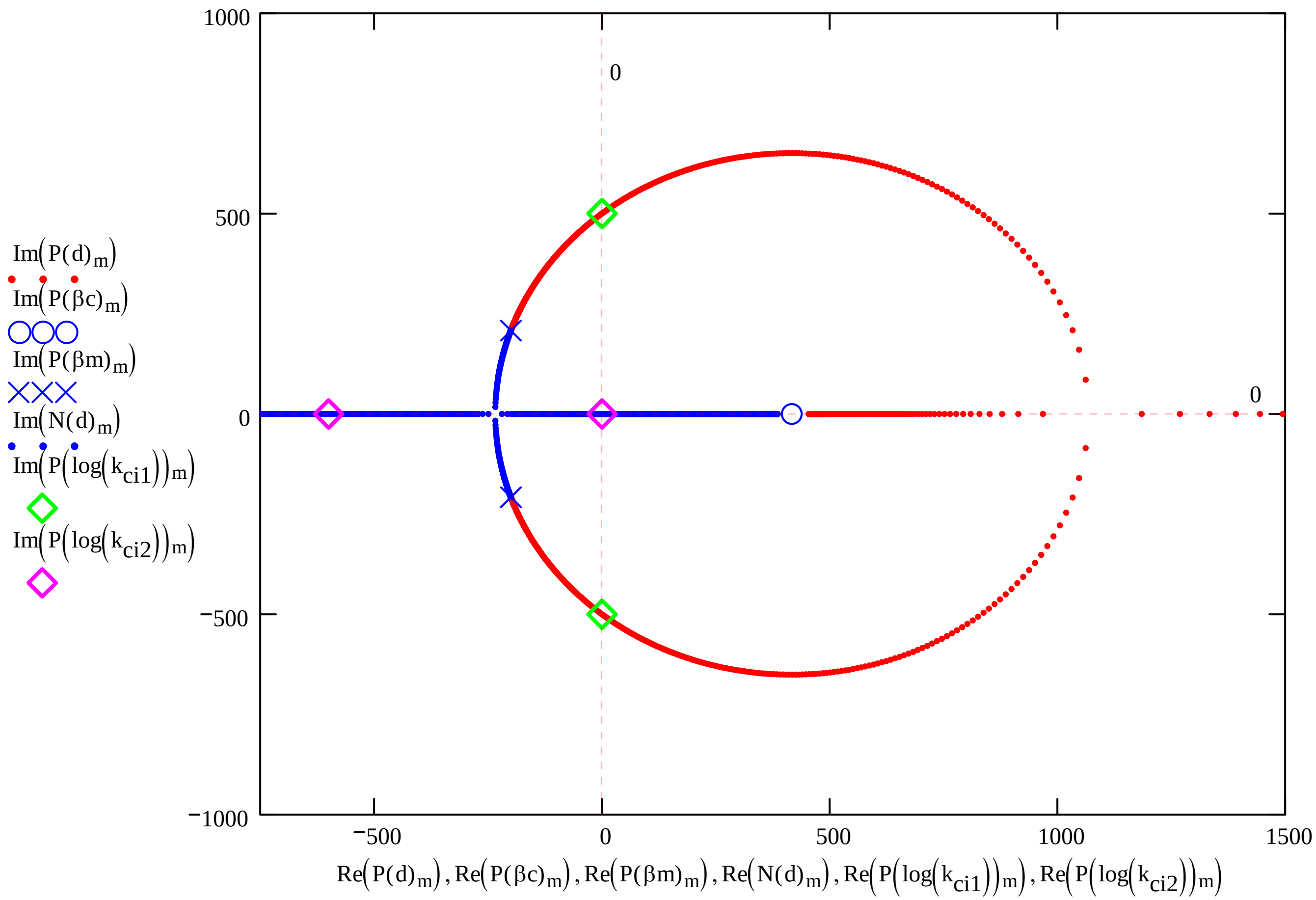
En un polinomio de segundo orden se tienen raíces en el eje imagnario cuando un coeficiente es nulo.

$$pp(k_c) := \lambda^2 + \lambda\cdot\frac{1}{R\cdot C}\cdot\left(1 - k_c\cdot\frac{d_o}{1-d_o}\right) + \frac{(1-d_o)^2}{L\cdot C}\cdot\left(1 + k_c\cdot\frac{1}{1-d_o}\right) \ \Big|\ \begin{matrix}\text{coeffs}, \lambda \\ \text{float}, 5\end{matrix} \rightarrow \begin{pmatrix} 83333. + 1.6667\cdot 10^5\cdot k_c \\ 400. - 400.00\cdot k_c \\ 1. \end{pmatrix}$$

$$\text{polyroots}(pp(k_{ci1})) = \begin{pmatrix} -500.003i \\ 500.003i \end{pmatrix}$$

$$k_{..} := (k_{ci1} \ \ k_{ci2})^T$$

Valores de
k críticos



Sistema de 1^{er} orden

Si hay valores de kc que hacen al sistema estable y de primer orden, son los cercanos a

$(\lambda + a)\cdot(\lambda + b) \left| \begin{array}{l} \text{expand} \\ \text{collect}, \lambda \end{array} \right. \rightarrow \lambda^2 + (b + a)\cdot\lambda + a\cdot b$ $\quad a := 19 \quad b := 190 \quad k_{c\_} := 10$

Given $\quad a + b = \frac{1}{R\cdot C}\cdot\left(1 - k_{c\_}\cdot\frac{d_o}{1 - d_o}\right) \quad a\cdot b = \frac{(1 - d_o)^2}{L\cdot C}\cdot\left(1 + k_{c\_}\cdot\frac{1}{1 - d_o}\right) \quad a = \frac{b}{0.1}$ $\quad k_{c1er} := \text{Find}(a, b, k_{c\_})_3 \quad \text{polyroots}(pp(k_{c1er})) = \begin{pmatrix} -492.531 \\ -49.249 \end{pmatrix}$

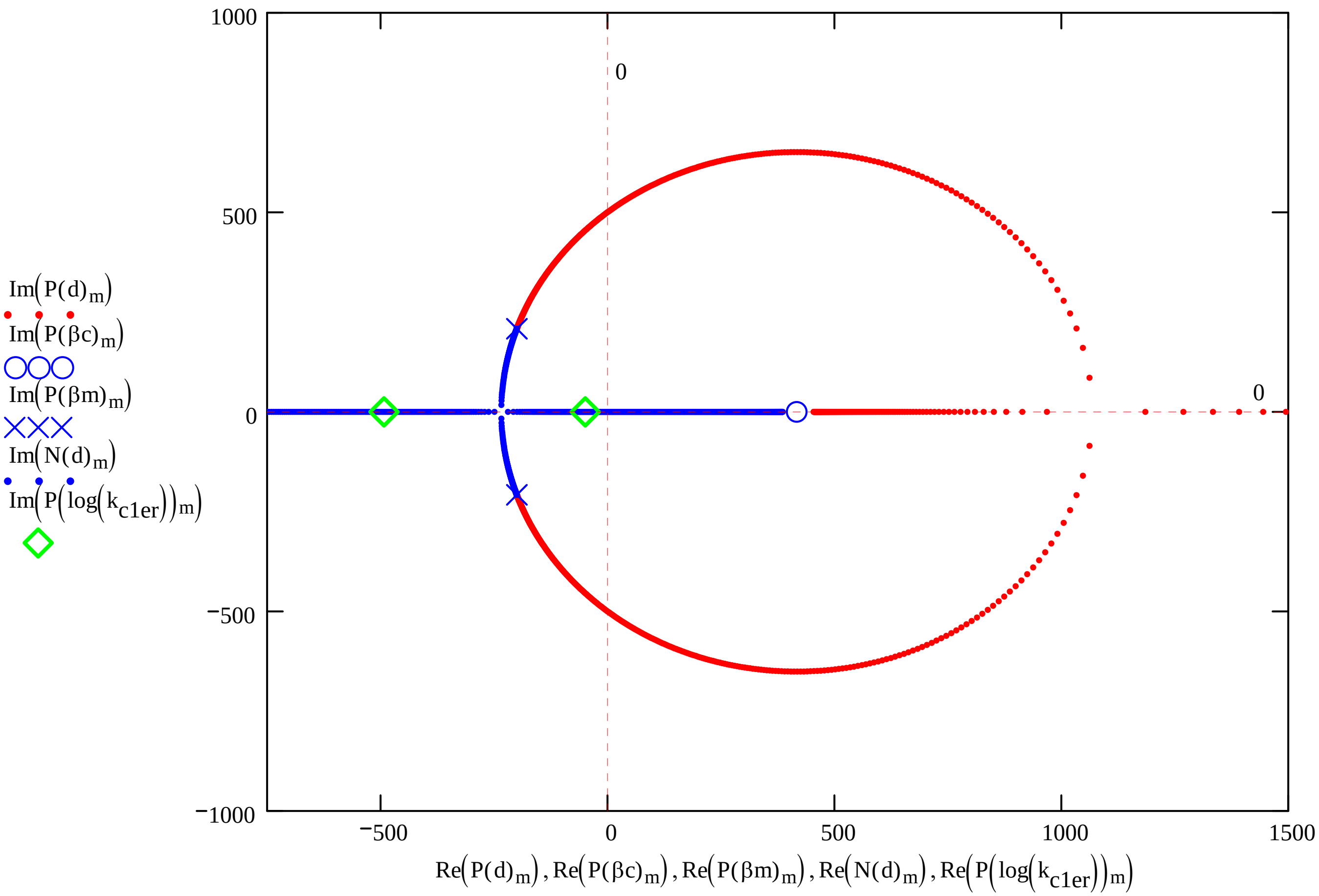
El sistema es estable y de primer orden k_c menor que $\quad k_{c1er} = -0.354$ $\quad$ y mayor que $\quad k_{ci2} = -0.5$

Se grafica el L.G.R.

$\beta m := -4 \quad \beta M := 1.5 \quad \beta c := 10\cdot\beta M \quad re_{min} := -750 \quad re_{max} := 1500$

$m := 1..2 \quad d := \beta m, \beta m + 0.005 .. \beta M \quad P(d) := \text{polyroots}(pp(10^d)) \quad N(d) := \text{polyroots}(pp(-10^d))$

Sistema de 1^{er} orden



Root Locus Multiparámetrico de gr(s,k,T)

Problema Graficar el root locus de una función gr(s,k,T) en función de k y T positivos.

Parametros

$$gr(s,k,T) := k\cdot\frac{T\cdot s+1}{s}\cdot\frac{6}{(s+1)\cdot(s+2)}$$

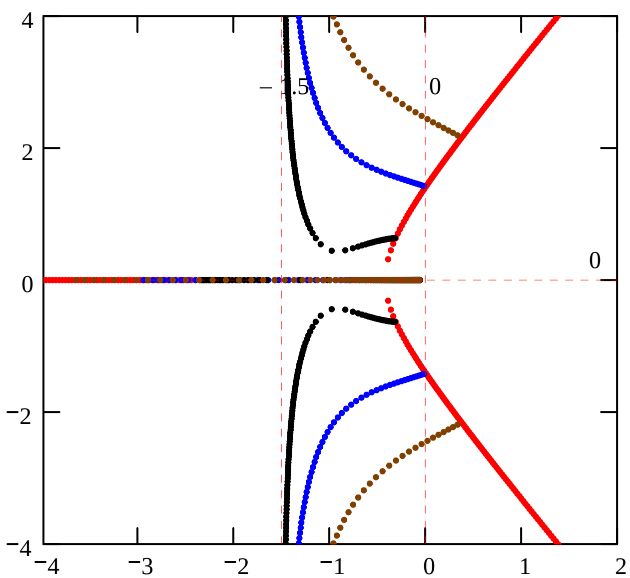
$$s^3 + 3\cdot s^2 + (2+6\cdot k\cdot T)\cdot s + 6\cdot k = 0 \qquad n := 3 \qquad k_{max} \equiv 1.3 \quad T_{max} \equiv 1.2$$

Solución A continuación se grafica el locus requerido.

$$coeff_p(k) := (6\cdot k \;\; 2 \;\; 3 \;\; 1)^T \qquad coeff_1(T) := (6\cdot 1 \;\; 2+6\cdot 1\cdot T \;\; 3 \;\; 1)^T \qquad coeff_2(T) := (6\cdot .2 \;\; 2+6\cdot T\cdot .2 \;\; 3 \;\; 1)^T \qquad coeff_3(T) := (6\cdot 3 \;\; 2+6\cdot 3\cdot T \;\; 3 \;\; 1)^T$$

$$m := 1 .. n \qquad i_{max} := 100 \qquad i := 1 .. i_{max} \qquad k_i := 10^{\left(\frac{i}{i_{max}}\cdot k_{max}\right)} - 1 \quad t_i := 10^{\left(\frac{i}{i_{max}}\cdot T_{max}\right)} - 1$$

$$R_p^{\langle i\rangle} := polyroots\left(coeff_p\left(k_i\right)\right) \qquad R_1^{\langle i\rangle} := polyroots\left(coeff_1\left(t_i\right)\right) \qquad R_2^{\langle i\rangle} := polyroots\left(coeff_2\left(t_i\right)\right) \qquad R_3^{\langle i\rangle} := polyroots\left(coeff_3\left(t_i\right)\right)$$



L.G.R. de un Sistema Híbrido

Parámetros

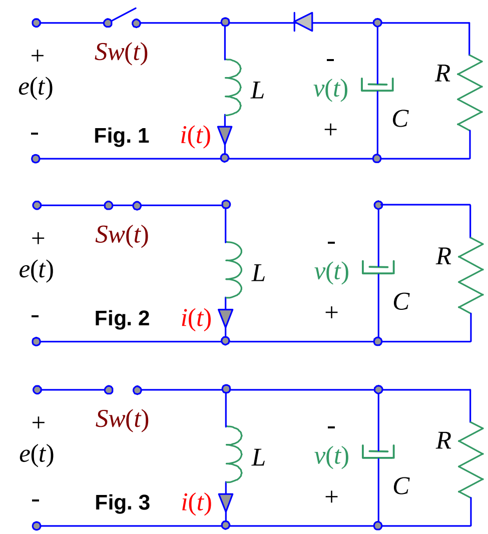
$L := 12\cdot 10^{-3}$ $\quad C := 250\cdot 10^{-6}$ $\quad R := 10$

$d_o := 0.5$ $\quad e_o := 10$ $\quad \Delta e := 0.5$

Punto de operación

$v_o := \dfrac{d_o}{1-d_o}\cdot e_o$ $\quad v_o = 10$ $\quad i_o := \dfrac{v_o}{R\cdot(1-d_o)}$

$u_o := d_o$ $\quad p_o := e_o$ $\quad i_o = 2$



Modelo Lineal Normalizado.

$$A_n := \begin{bmatrix} \dfrac{-1}{R\cdot C} & \dfrac{1}{R\cdot C} \\ \dfrac{-R}{L}\cdot(1-d_o)^2 & 0 \end{bmatrix} \qquad b_n := \begin{bmatrix} \dfrac{-d_o}{R\cdot C\cdot(1-d_o)} \\ \dfrac{R}{L}\cdot(1-d_o) \end{bmatrix} \qquad e_n := \begin{bmatrix} 0 \\ \dfrac{R}{L}\cdot(1-d_o)^2 \end{bmatrix} \qquad c_n := (1\ \ 0)$$

Ecuaciones de Estado Discretas Equivalentes.

$$\Phi_{c11}(t) := \left[(s\cdot identity(2) - A_n)^{-1}\right]_{1,1} \ \Big| \begin{matrix} invlaplace, s \\ float, 5 \end{matrix} \rightarrow -.96077\cdot\exp(-200.\cdot t)\cdot\sin(208.17\cdot t) + \exp(-200.\cdot t)\cdot\cos(208.17\cdot t)$$

$$\Phi_{c12}(t) := \left[(s\cdot identity(2) - A_n)^{-1}\right]_{1,2} \ \Big| \begin{matrix} invlaplace, s \\ float, 5 \end{matrix} \rightarrow 1.9215\cdot\exp(-200.\cdot t)\cdot\sin(208.17\cdot t)$$

$$\Phi_{c21}(t) := \left[(s\cdot identity(2) - A_n)^{-1}\right]_{2,1} \ \Big| \begin{matrix} invlaplace, s \\ float, 5 \end{matrix} \rightarrow -1.0008\cdot\exp(-200.\cdot t)\cdot\sin(208.17\cdot t)$$

$$\Phi_{c22}(t) := \left[(s\cdot identity(2) - A_n)^{-1}\right]_{2,2} \ \Big| \begin{matrix} invlaplace, s \\ float, 5 \end{matrix} \rightarrow .96077\cdot\exp(-200.\cdot t)\cdot\sin(208.17\cdot t) + \exp(-200.\cdot t)\cdot\cos(208.17\cdot t)$$

Variables de Estado

$x_1 = v \qquad x_2 = i$

$$\Phi_c(t) := \begin{pmatrix} \Phi_{c11}(t) & \Phi_{c12}(t) \\ \Phi_{c21}(t) & \Phi_{c22}(t) \end{pmatrix} \qquad T := 0.005 \qquad A_d := \Phi_c(T) \qquad A_d = \begin{pmatrix} -0.119 & 0.61 \\ -0.318 & 0.491 \end{pmatrix}$$

$$b_d := \left[\int_0^T \left(\Phi_c(T-\tau)\cdot b_n\right)_1 d\tau \quad \int_0^T \left(\Phi_c(T-\tau)\cdot b_n\right)_2 d\tau\right]^T \qquad b_d = \begin{pmatrix} 0.408 \\ 2.163 \end{pmatrix}$$

$$e_d := \left[\int_0^T \left(\Phi_c(T-\tau)\cdot e_n\right)_1 d\tau \quad \int_0^T \left(\Phi_c(T-\tau)\cdot e_n\right)_2 d\tau\right]^T \qquad e_d = \begin{pmatrix} 0.509 \\ 0.827 \end{pmatrix}$$

$$c_d := c_n \qquad c_d = (1\ \ 0)$$

Funciones de Transferencia en L.A.

$h_{vndn}(z) := c_d\cdot\left(z\cdot identity(2) - A_d\right)^{-1}\cdot b_d$ polos : $pol := eigenvals\left(A_d\right)$ $pol = \begin{pmatrix} 0.186 + 0.317i \\ 0.186 - 0.317i \end{pmatrix}$ ceros : $cer := h_{vndn}(z) \left| \begin{matrix} solve, z \\ float, 10 \end{matrix} \right. \rightarrow -2.740114990$

Error en S.S. - Sistema en L.C. de Voltaje - Controlador k_c/(z-1), con k_a = 1, y k_{st} = 1. $k_a := 1$ $k_{st} := 1$

$\Delta e_{ram\_ss} := 0.02$ $k_c := Re\left(\dfrac{T}{\Delta e_{ram\_ss}\cdot k_a\cdot h_{vndn}(1)}\right)$ $k_c = 0.125$ $l(z) := \dfrac{h_{vndn}(z)}{z\cdot(z-1)}$

$a := 0$ $A_{ck} := \begin{bmatrix} 0 & 1 \\ a & -(a-1) \end{bmatrix}$ $b_{ck} := \begin{pmatrix} 0 \\ 1 \end{pmatrix}$ $c_{ck}(k) := (k \;\; 0)$ $d_{ck} := 0$

Funciones de Transferencia en L.C.

$A_{k2}(k) := stack\left(augment\left(A_d - b_d\cdot d_{ck}\cdot c_d, b_d\cdot c_{ck}(k)\right), augment\left(-b_{ck}\cdot c_d, A_{ck}\right)\right)$ $b_{k2} := stack\left(b_d\cdot d_{ck}, b_{ck}\right)$

$c_{k2}(k) := augment\left(c_d, c_{ck}(k)\cdot 0\right)$ $e_{k2} := stack\left(e_d, b_{ck}\cdot 0\right)$

$h_{vnvnd}(z,k) := c_{k2}(k)\cdot\left(z\cdot identity(4) - A_{k2}(k)\right)^{-1}\cdot b_{k2}$ $h_{vnvnd}\left(1, k_c\right) = 1$

$h_{vnen}(z,k) := c_{k2}(k)\cdot\left(z\cdot identity(4) - A_{k2}(k)\right)^{-1}\cdot e_{k2}$ $h_{vnen}\left(1, k_c\right) = 0$

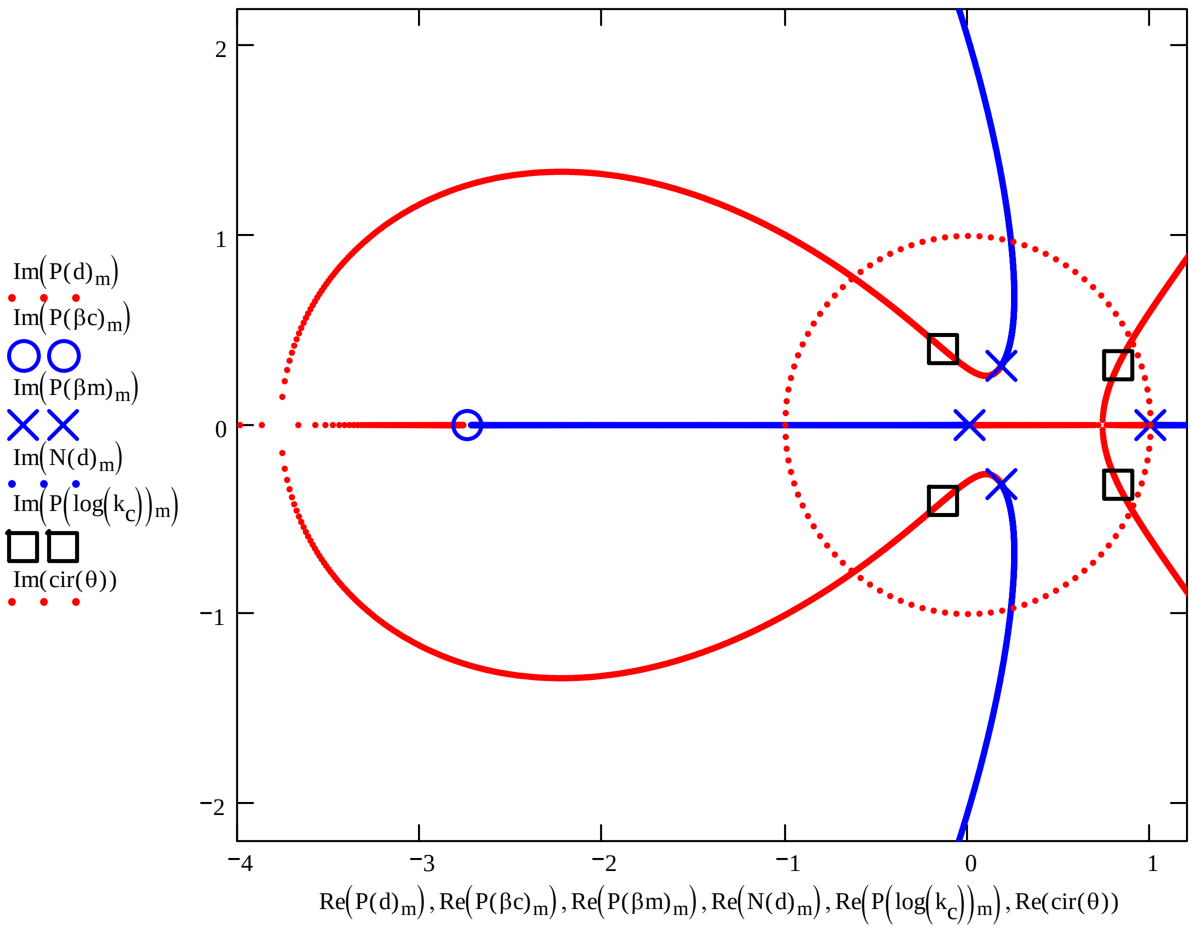
Polos y ceros en L.C. para k_c calculado.

polos : $pol := eigenvals\left(A_{k2}\left(k_c\right)\right)$ $pol = \begin{pmatrix} -0.137 + 0.402i \\ -0.137 - 0.402i \\ 0.822 + 0.316i \\ 0.822 - 0.316i \end{pmatrix}$ ceros : $cer := eigenvals\left(A_{k2}\left(10^{200}\right)\right)$ $cer = \begin{pmatrix} -3.443\times 10^{66} \\ 1.722\times 10^{66} + 2.982i\times 10^{66} \\ 1.722\times 10^{66} - 2.982i\times 10^{66} \\ -2.74 \end{pmatrix}$

Se grafican los valores propios de A_r; es decir, el L.G.R.

$\beta m := -3$ $\beta M := 4$ $\beta c := 10\cdot\beta M$ $re_{min} := -4$ $re_{max} := 1.2$ $cir(\theta) := e^{j\cdot\theta}$ $\theta := 0, \frac{\pi}{50} .. 2\cdot\pi$

$m := 1 .. 4$ $d := \beta m, \beta m + 0.005 .. \beta M$ $P(d) := eigenvals\left(A_{k2}\left(10^{d}\right)\right)$ $N(d) := eigenvals\left(A_{k2}\left(-10^{d}\right)\right)$



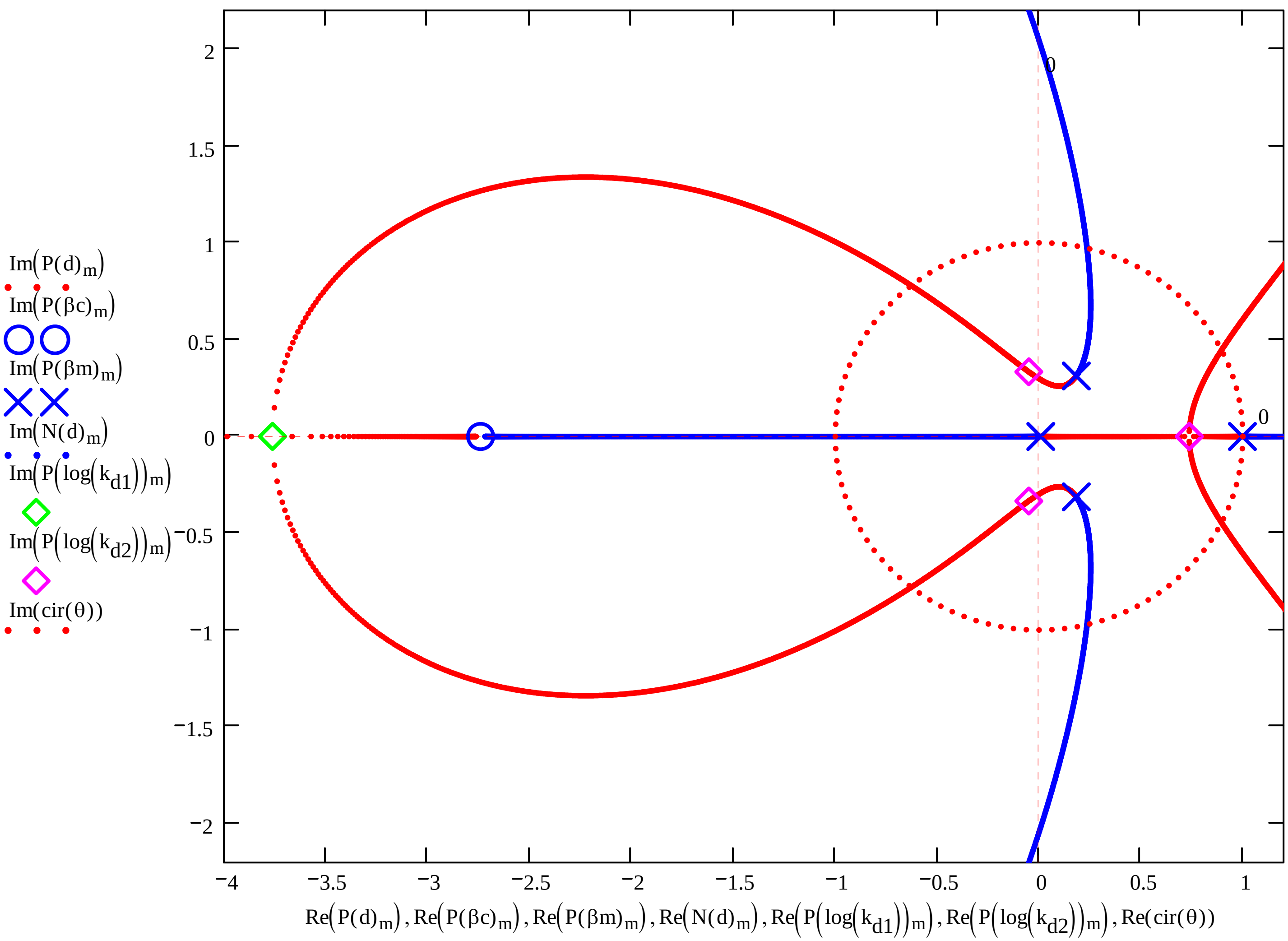
Lugares de Despegue con sus respectivas ganancias k_{d_1} y k_{d_2} y raíces en L.C. para estos casos

$$z_d := \frac{d}{dz}\left(\frac{-1}{l(z)}\right) \Big|_{\text{float},10}^{\text{solve},z} \rightarrow \begin{pmatrix} -3.761211999 \\ .1428764018 - .1555725027 \cdot i \\ .1428764018 + .1555725027 \cdot i \\ .7365835908 \end{pmatrix}$$

$$k_{d1} := \frac{-1}{l\left(z_{d_1}\right)} \qquad k_{d1} = 673.672 \qquad k_{d2} := \frac{-1}{l\left(z_{d_4}\right)} \qquad k_{d2} = 0.055$$

$$\text{eigenvals}\left(A_{k2}\left(k_{d1}\right)\right)^T = \left(4.447 + 5.787i \quad 4.447 - 5.787i \quad -3.761 + 2.601i \times 10^{-8} \quad -3.761 - 2.601i \times 10^{-8}\right)$$

$$\text{eigenvals}\left(A_{k2}\left(k_{d2}\right)\right)^T = \left(-0.051 + 0.334i \quad -0.051 - 0.334i \quad 0.737 \quad 0.737\right)$$



Ganancias Críticas k_c y raíces en L.C. para estos casos

$kj := 100 \qquad zz := 0.85 + j\cdot 0.85$

Given

$$\frac{1}{c_{k2}(kj)\cdot\left(zz\cdot \text{identity}(4) - A_{k2}(kj)\right)^{-1}\cdot b_{k2}} = 0 \qquad |zz| = 1 \qquad y := \text{Find}(kj, zz) \qquad y = \begin{pmatrix} 0.234 + 7.399i \times 10^{-3} \\ 0.891 + 0.454i \end{pmatrix}$$

$$k_{i1} := \text{Re}(y_1) \quad \text{eigenvals}\left(A_{k2}(k_{i1})\right)^T = (0.898 + 0.449i \;\; 0.898 - 0.449i \;\; -0.212 + 0.464i \;\; -0.212 - 0.46\ldots \qquad k_{i1} = 0.234$$

$kj := -100 \qquad zz := 0.2 + j\cdot 0.2$

Given

$$\frac{1}{c_{k2}(kj)\cdot\left(zz\cdot \text{identity}(4) - A_{k2}(kj)\right)^{-1}\cdot b_{k2}} = 0 \qquad |zz| = 1 \qquad y := \text{Find}(kj, zz) \qquad y = \begin{pmatrix} -0.855 - 0.525i \\ 0.083 + 0.997i \end{pmatrix}$$

$$k_{i2} := \text{Re}(y_1) \quad \text{eigenvals}\left(A_{k2}(k_{i2})\right)^T = (1.52 \;\; 0.234 + 0.983i \;\; 0.234 - 0.983i \;\; -0.616) \qquad k_{i2} = -0.855$$

$kj := 100 \qquad zz := -0.5 + j\cdot -0.5$

Given

$$\frac{1}{c_{k2}(kj)\cdot\left(zz\cdot \text{identity}(4) - A_{k2}(kj)\right)^{-1}\cdot b_{k2}} = 0 \qquad |zz| = 1 \qquad y := \text{Find}(kj, zz) \qquad y = \begin{pmatrix} 2.505 - 2.688i \times 10^{-3} \\ -0.627 - 0.779i \end{pmatrix}$$

$$k_{i3} := \text{Re}(y_1) \quad \text{eigenvals}\left(A_{k2}(k_{i3})\right)^T = (1.313 + 1.038i \;\; 1.313 - 1.038i \;\; -0.627 + 0.779i \;\; -0.627 - 0.77\ldots \qquad k_{i3} = 2.505$$

$kj := 100 \qquad zz := 1$

Given

$$\frac{1}{c_{k2}(kj)\cdot\left(zz\cdot \text{identity}(4) - A_{k2}(kj)\right)^{-1}\cdot b_{k2}} = 0 \qquad |zz| = 1 \qquad y := \text{Find}(kj, zz) \qquad y = \begin{pmatrix} 8.35 \times 10^{-9} \\ 1 \end{pmatrix}$$

$$k_{i4} := \text{Re}(y_1) \quad \text{eigenvals}\left(A_{k2}(k_{i4})\right)^T = \left(0.186 + 0.317i \;\; 0.186 - 0.317i \;\; 1 \;\; 6.902 \times 10^{-8}\right) \qquad k_{i4} = 8.35 \times 10^{-9}$$

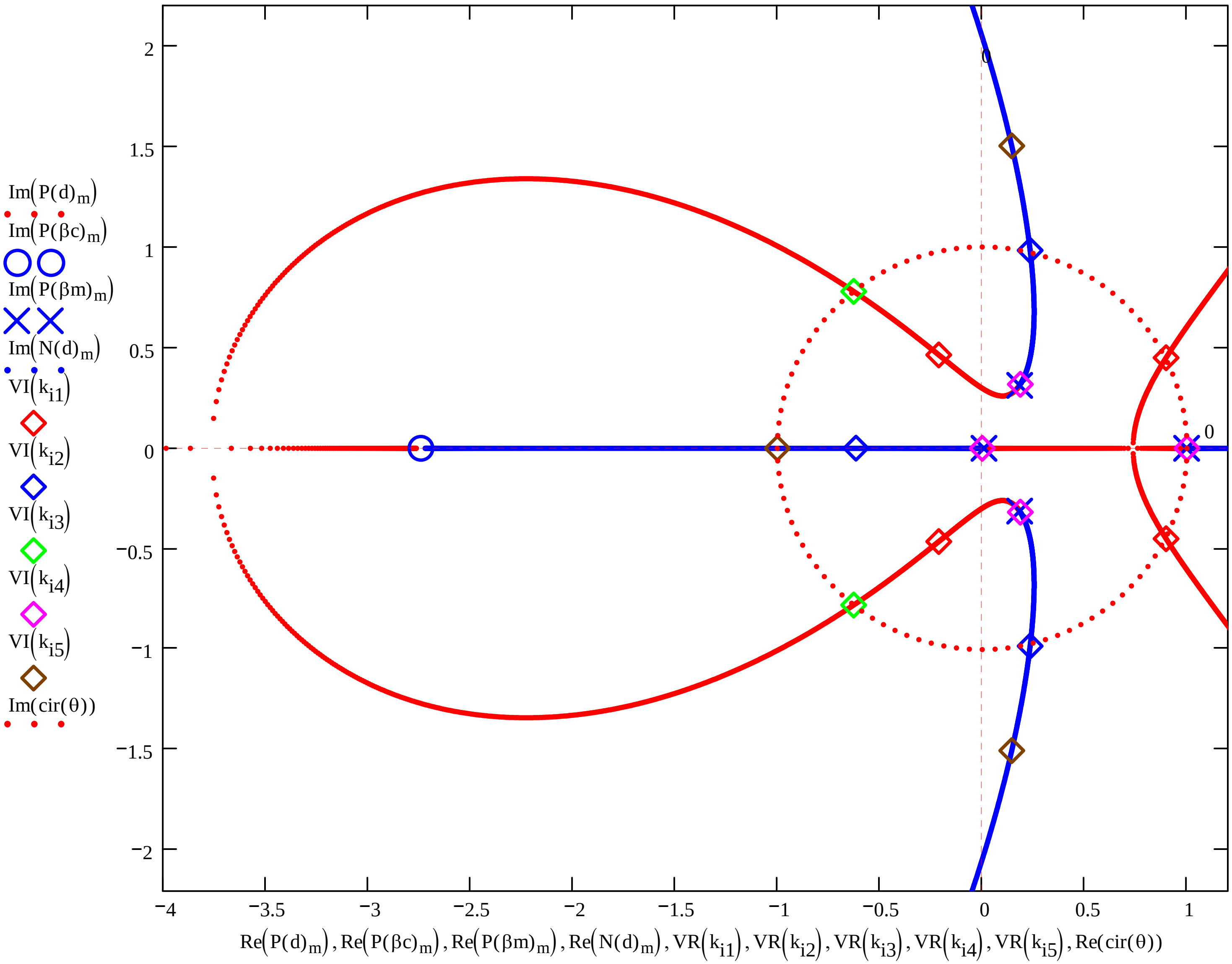
$kj := -100 \qquad zz := -1$

Given

$$\frac{1}{c_{k2}(kj)\cdot\left(zz\cdot \text{identity}(4) - A_{k2}(kj)\right)^{-1}\cdot b_{k2}} = 0 \qquad |zz| = 1 \qquad y := \text{Find}(kj, zz) \qquad y = \begin{pmatrix} -4.244 \\ -1 \end{pmatrix}$$

$$k_{i5} := \text{Re}(y_1) \quad \text{eigenvals}\left(A_{k2}(k_{i5})\right)^T = (2.084 \;\; 0.144 + 1.502i \;\; 0.144 - 1.502i \;\; -1) \qquad k_{i5} = -4.244$$

$VR(\xi) := Re(P(log(\xi)))$ $VI(\xi) := Im(P(log(\xi)))$



(i) El sistema es estable para kc mayor que 0 y menor que $k_{i1} = 0.234$

(ii) El sistema es estable y oscila para kc mayor que 0 y menor que $k_{i1} = 0.234$

(iii) No hay un valor de kc en donde el sistema es estable y no oscila

Entrada para lograr un 20% de aumento en la tensión.

$t_f := 0.20 \qquad l_f := 500 \qquad l := 0 .. l_f$

$e(t) := e_o + \Delta e \cdot \Phi(t - 0.12) \qquad p(t) := e(t) \qquad \Delta p_n(t) := \dfrac{p(t) - p_o}{p_o} \qquad t := 0, \dfrac{t_f}{l_f} .. t_f$

Sistema en L.C. de Voltaje - Controlador $k_c/(z\text{-}1)$, con $k_a = 1$, y $k_{st} = 1$.

$a := 0 \qquad A_{ck} := \begin{bmatrix} 0 & 1 \\ a & -(a-1) \end{bmatrix} \qquad b_{ck} := \begin{pmatrix} 0 \\ 1 \end{pmatrix} \qquad c_{ck} := \begin{pmatrix} k_c & 0 \end{pmatrix}$

Funciones de Transferencia en L.C.

$A_{k2} := \text{stack}\left(\text{augment}\left(A_d - b_d \cdot d_{ck} \cdot c_d, b_d \cdot c_{ck}\right), \text{augment}\left(-b_{ck} \cdot c_d, A_{ck}\right)\right) \quad b_{k2} := \text{stack}\left(b_d \cdot d_{ck}, b_{ck}\right) \quad c_{k2} := \text{augment}\left(c_d, c_{ck} \cdot 0\right) \quad e_{k2} := \text{stack}\left(e_d, b_{ck} \cdot 0\right)$

$h_{vnvnd}(z) := c_{k2} \cdot \left(z \cdot \text{identity}(4) - A_{k2}\right)^{-1} \cdot b_{k2} \qquad h_{vnvnd}(1) = 1 \qquad h_{vnen}(z) := c_{k2} \cdot \left(z \cdot \text{identity}(4) - A_{k2}\right)^{-1} \cdot e_{k2} \qquad h_{vnen}(1) = 0$

Simulación Sistema en L.C. de Posición - Controlador $k_c/(z\text{-}1)$.

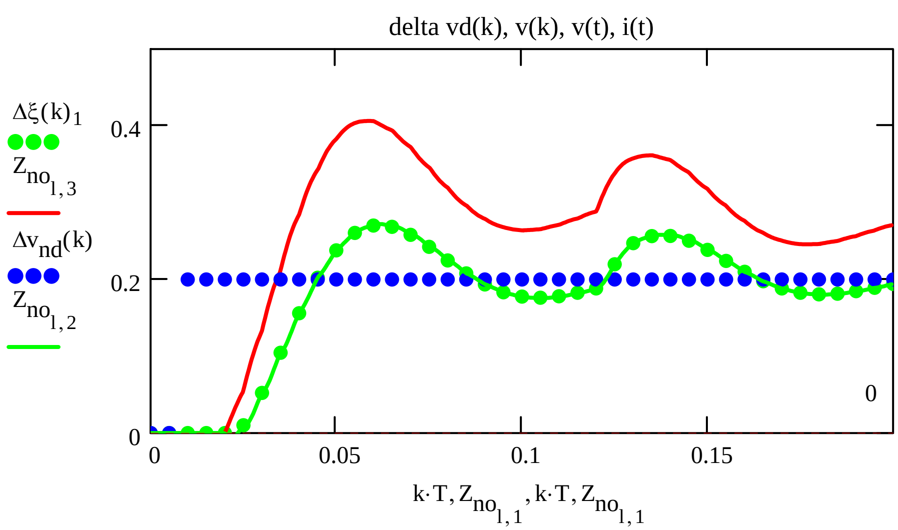
$\Delta p_n(t) := \dfrac{p(t) - p_o}{p_o} \qquad \Delta v_{nd}(t) := 0.2 \cdot \Phi(t - 0.01)$

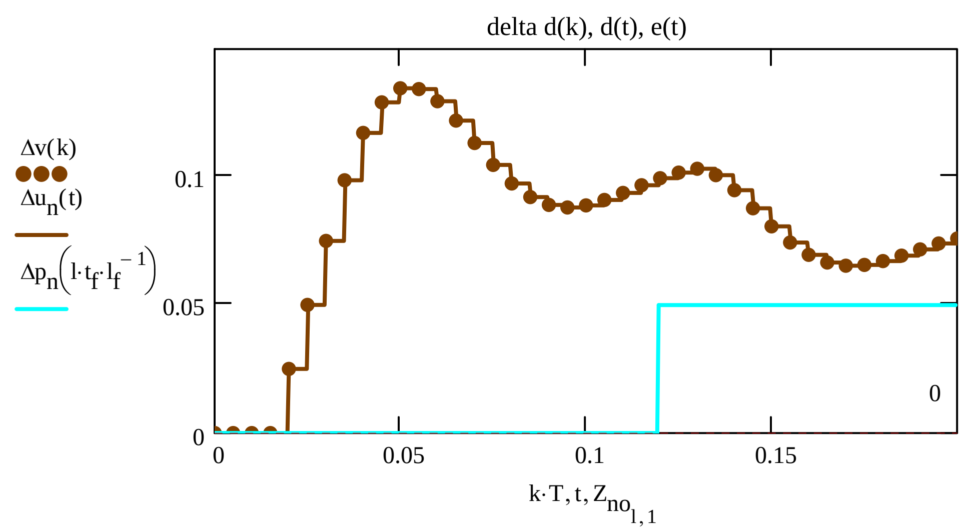
$\Delta v_{nd}(k) := \Delta v_{nd}(k \cdot T) \qquad \Delta p_n(k) := \Delta p_n(k \cdot T) \qquad \Delta\xi_o := \begin{pmatrix} 0 & 0 & 0 & 0 \end{pmatrix}^T$

$\Delta\xi(k) := \text{if}\left(k = 0, \Delta\xi_o, A_{k2}{}^k \cdot \Delta\xi_o + \sum_{j=0}^{k-1} A_{k2}{}^{k-j-1} \cdot b_{k2} \cdot \Delta v_{nd}(j) + \sum_{j=0}^{k-1} A_{k2}{}^{k-j-1} \cdot e_{k2} \cdot \Delta p_n(j)\right) \qquad k_f := \dfrac{t_f}{T} \qquad k := 0 .. k_f$

$\Delta v(k) := \left(\left(\left(c_{ck}\right)\right)^T\right)_1 \cdot \Delta\xi(k)_3 + \left(\left(\left(c_{ck}\right)\right)^T\right)_2 \cdot \Delta\xi(k)_4 \qquad \Delta u_n(t) := \text{Re}\left(\Delta v\left(\text{trunc}\left(\dfrac{t}{T}\right)\right)\right) \qquad \Delta p_n(t) := \dfrac{p(t) - p_o}{p_o}$

$D(t, x) := A_n \cdot \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + b_n \cdot \Delta u_n(t) + e_n \cdot \Delta p_n(t) \qquad CI := \begin{pmatrix} 0 \\ 0 \end{pmatrix} \qquad Z_{no} := \text{rkfixed}\left(CI, 0, t_f, l_f, D\right)$





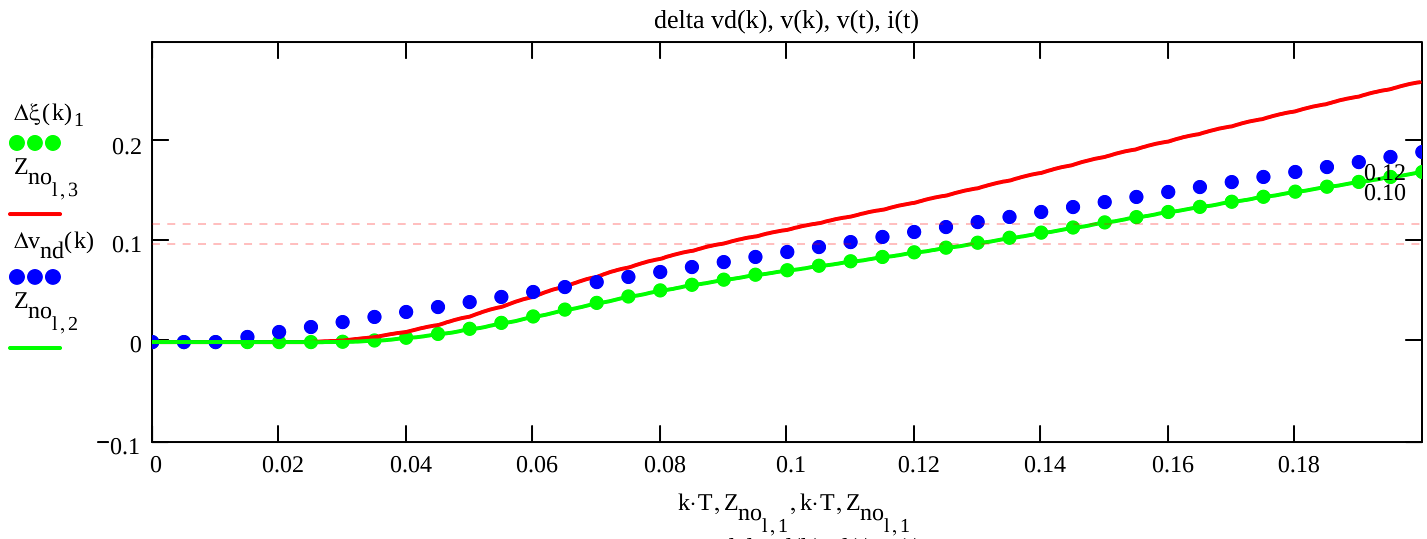
$\Delta v_{nd}(t) := (t - 0.01)\cdot\Phi(t - 0.01)$ $\qquad \Delta v_{nd}(k) := \Delta v_{nd}(k\cdot T)$ $\qquad \Delta p_n(t) := \dfrac{p(t) - p_o}{p_o}\cdot 0$ $\qquad \Delta p_n(k) := \Delta p_n(k\cdot T)$ $\qquad \Delta\xi_o := (0\ \ 0\ \ 0\ \ 0)^T$

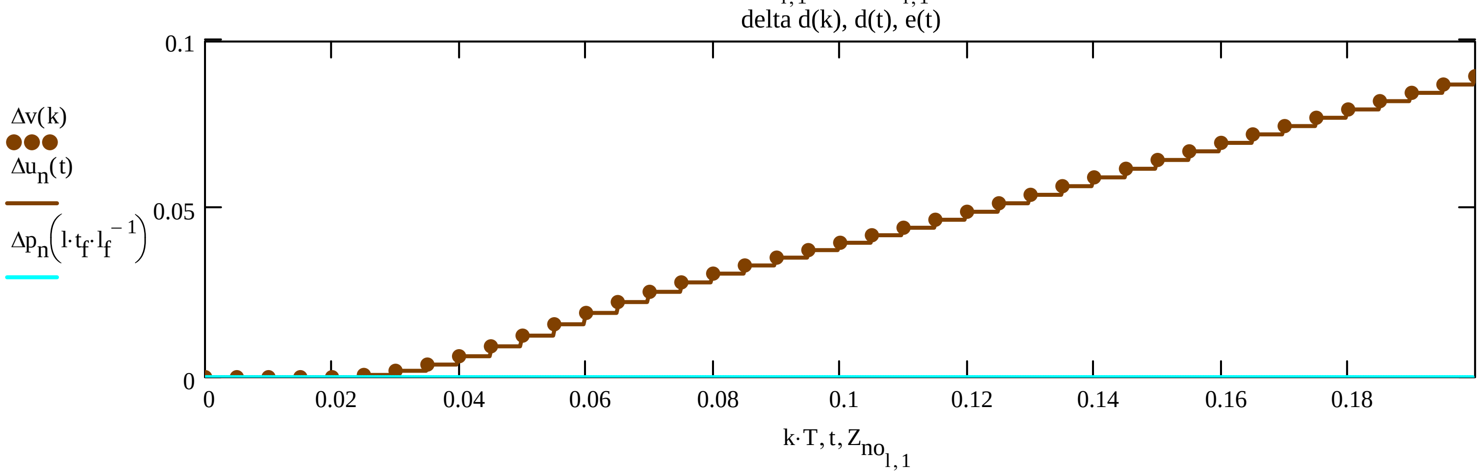
$$\Delta\xi(k) := \text{if}\left(k = 0, \Delta\xi_o, A_{k2}{}^{k}\cdot\Delta\xi_o + \sum_{j=0}^{k-1} A_{k2}{}^{k-j-1}\cdot b_{k2}\cdot\Delta v_{nd}(j) + \sum_{j=0}^{k-1} A_{k2}{}^{k-j-1}\cdot e_{k2}\cdot\Delta p_n(j)\right) \qquad k_f := \frac{t_f}{T} \qquad k := 0 .. k_f$$

$$\Delta v(k) := \left(\left(\left(c_{ck}\right)\right)^T\right)_1\cdot\Delta\xi(k)_3 + \left(\left(\left(c_{ck}\right)\right)^T\right)_2\cdot\Delta\xi(k)_4 \qquad \Delta u_n(t) := \text{Re}\left(\Delta v\left(\text{trunc}\left(\frac{t}{T}\right)\right)\right)$$

$$D(t,x) := A_n\cdot\begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + b_n\cdot\Delta u_n(t) + e_n\cdot\Delta p_n(t) \qquad CI := \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$$Z_{no} := \text{rkfixed}\left(CI, 0, t_f, l_f, D\right)$$



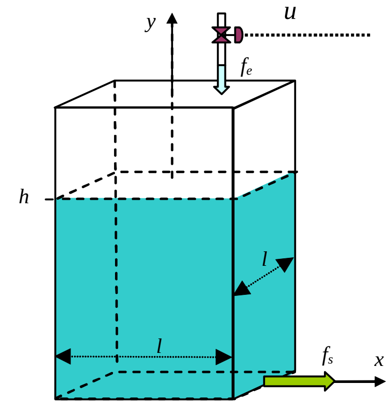


L.G.R. de un Sistema Discreto con Retardo

Problema Ilustrar la eficacia del control realimentado.

Estanque Parámetros. Variable de Estado

$f_{s0} := 0$ $h_a(s) = 1$ $A_e := 2.5$ $x_1 = h$



Modelo Continuo

$\frac{d}{dt}h(t) = \frac{1}{A_e}\cdot\left(v(t) - f_s(t)\right)$ $A_t := 0$ $b_t := \frac{1}{A_e}$ $e_t := -\frac{1}{A_e}$ $c_t := 1$

Modelo Discreto de la Planta

$T := 0.25$ $A_k := 1$ $b_k := \frac{T}{A_e}$ $c_k := 1$ $e_k := -\frac{T}{A_e}$

Controlador Discreto

$A_{ck} := 0$ $b_{ck} := 1$ $c_{ck}(k_c) := k_c$ $d_{ck} := 0$ $\theta := 0, \frac{\pi}{50} .. 2\pi$ $x(\theta) := \cos(\theta)$ $y(\theta) := \sin(\theta)$

Matriz A del Sistema Resultante

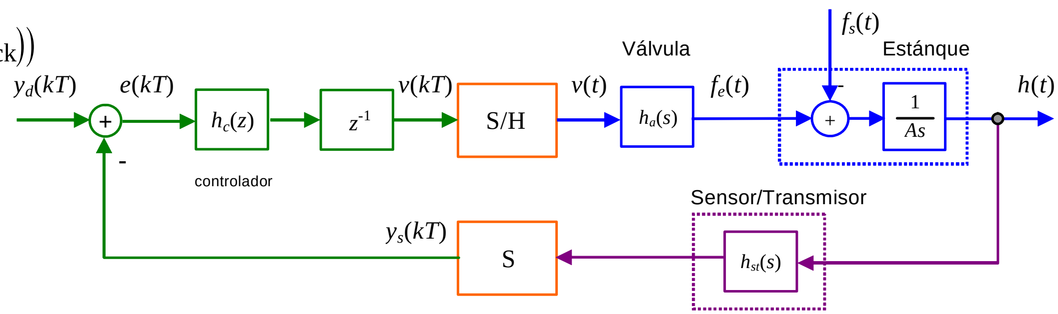
$A_{Tk}(k_c) := \text{stack}\left(\text{augment}\left(A_k, b_k\cdot c_{ck}(k_c)\right), \text{augment}\left(-b_{ck}\cdot c_k, A_{ck}\right)\right)$

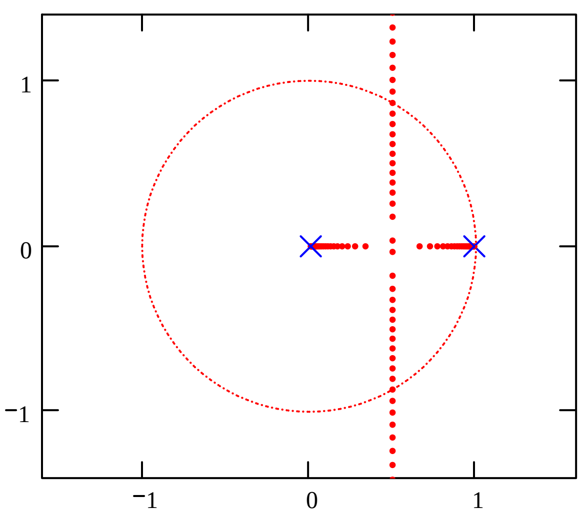
$\beta m := -1$ $\beta M := 2$ $\beta c := 10^{1.5\cdot\beta M}$

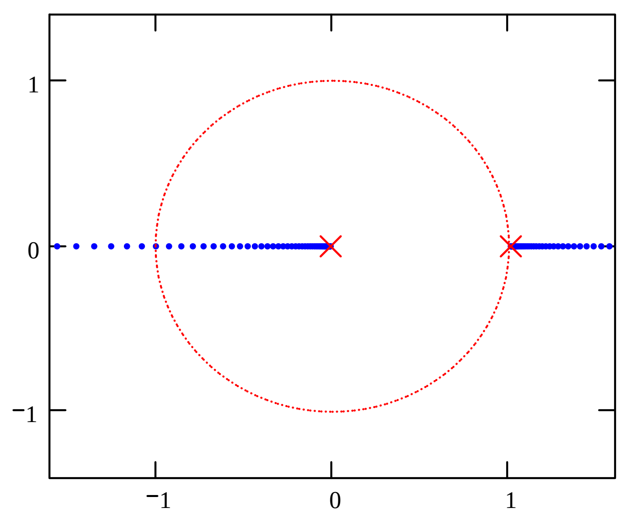
$m := 1 .. 2$ $d := \beta m, \beta m + 0.05 .. \beta M$

$P(d) := \text{eigenvals}\left(A_{Tk}\left(10^d\right)\right)$

$N(d) := \text{eigenvals}\left(A_{Tk}\left(-10^d\right)\right)$

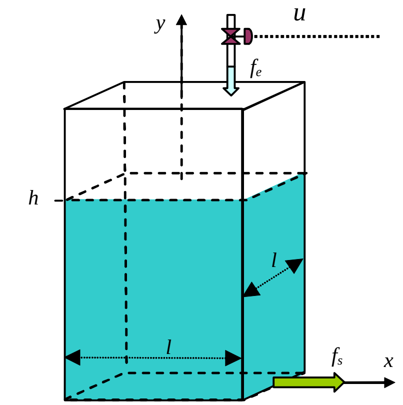






L.G.R. de un Sistema Discreto con Retardo

Problema Ilustrar la eficacia del control realimentado.



Estanque Parámetros.

$f_{s0} := 0$ $A_e := 2.5$

Variable de Estado

$x_1 = h$

Modelo Continuo

$\frac{d}{dt}h(t) = \frac{1}{A_e}\cdot\left(v(t) - f_s(t)\right)$ $h_a(s) = e^{-t_r\cdot s}$ $t_r := 0.25$ $A_t := 0$ $b_t := \frac{1}{A_e}$ $e_t := -\frac{1}{A_e}$ $c_t := 1$

Modelo Discreto de la Planta

$T := 0.25$ $A_k := \begin{pmatrix} 1 & \frac{T}{A_e} \\ 0 & 0 \end{pmatrix}$ $b_k := \begin{pmatrix} 0 \\ 1 \end{pmatrix}$ $e_k := \begin{pmatrix} 0 \\ 1 \end{pmatrix}$ $c_k := \begin{pmatrix} 1 \\ 0 \end{pmatrix}^T$

Controlador Discreto

$A_{ck} := 0$ $b_{ck} := 1$ $c_{ck}(k_c) := k_c$ $d_{ck} := 0$

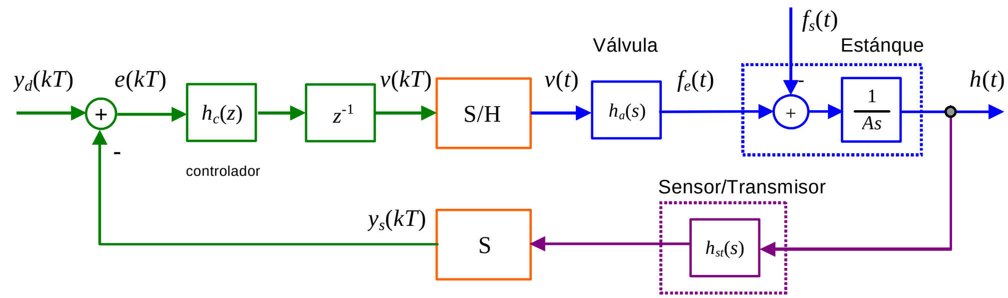
Matriz A del Sistema Resultante

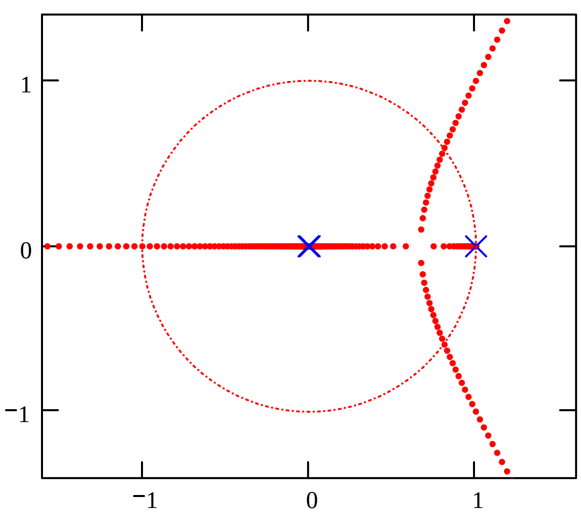
$A_{Tk}(k_c) := \text{stack}\left(\text{augment}\left(A_k, b_k\cdot c_{ck}(k_c)\right), \text{augment}\left(-b_{ck}\cdot c_k, A_{ck}\right)\right)$

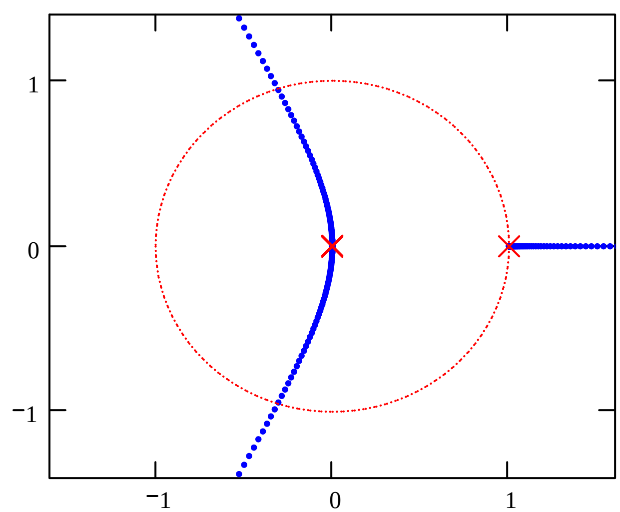
$\beta m := -4$ $\beta M := 2$ $\beta c := 10^{1.5\cdot\beta M}$

$m := 1..3$ $d := \beta m, \beta m + 0.05..\beta M$ $P(d) := \text{eigenvals}\left(A_{Tk}\left(10^d\right)\right)$

$N(d) := \text{eigenvals}\left(A_{Tk}\left(-10^d\right)\right)$

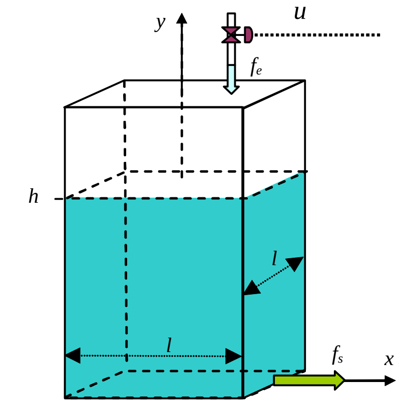






L.G.R. de un Sistema Discreto con Retardo

Problema Ilustrar la eficacia del control realimentado.



Estanque Parámetros.

$f_{s0} := 0$ $A_e := 2.5$

Variable de Estado

$x_1 = h$

Modelo Continuo

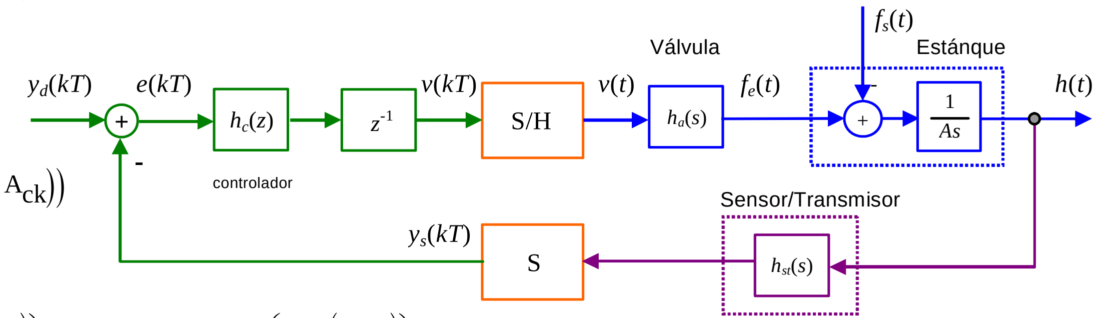
$\frac{d}{dt}h(t) = \frac{1}{A_e}\cdot(v(t) - f_s(t))$ $h_a(s) = e^{-t_r\cdot s}$ $t_r := 0.5$ $A_t := 0$ $b_t := \frac{1}{A_e}$ $e_t := -\frac{1}{A_e}$ $c_t := 1$

Modelo Discreto de la Planta

$T := 0.25$ $A_k := \begin{pmatrix} 1 & \frac{T}{A_e} & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{pmatrix}$ $b_k := \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$ $e_k := \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$ $c_k := \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}^T$

Controlador Discreto

$A_{ck} := 0$ $b_{ck} := 1$ $c_{ck}(k_c) := k_c$ $d_{ck} := 0$



Matriz A del Sistema Resultante

$A_{Tk}(k_c) := \text{stack}(\text{augment}(A_k, b_k\cdot c_{ck}(k_c)), \text{augment}(-b_{ck}\cdot c_k, A_{ck}))$

$\beta m := -7$ $\beta M := 2.6$ $\beta c := 10^{1.5\cdot\beta M}$

$m := 1..4$ $d := \beta m, \beta m + 0.05..\beta M$ $P(d) := \text{eigenvals}(A_{Tk}(10^d))$ $N(d) := \text{eigenvals}(A_{Tk}(-10^d))$