$$\mathbf{H}(z^{-1}) \ = z^{-1}\frac{k_o(1+bz^{-1})}{(1-p_1z^{-1})(1-p_2z^{-1})}\mathbf{B} = z^{-1}\frac{k_o(1+bz^{-1})}{1-a_1z^{-1}-a_2z^{-2}}\mathbf{B} = H(z^{-1})\mathbf{B}$$

$$k_c = \frac{1-\lambda_c}{1+b},\ b_c = bk_c = \frac{1-\lambda_c}{1+1/b},\ k_u = \frac{k_c}{k_o},\ \begin{cases} \ell_1 = \lambda_c + (1+\beta) - 3\lambda_e \\ \ell_2 = ? \\ \ell_3 = ? \end{cases}$$

Estimator: Augmented state estimator, characterized by λ_e.

Initialization:

$$\mathbf{v}_f[k+1] = \frac{1}{(1-\lambda_c)(1+b)}\{b\mathbf{v}_d[k+d+1] + (1-b\lambda_c)\mathbf{v}_d[k+d] - \lambda_c\mathbf{v}_d[k+d-1]\}\ (d=2)$$

$$\delta\mathbf{v}_f[k] = \mathbf{v}_f[k+1] - (1-b_c)\mathbf{v}_f[k] - b_c\mathbf{v}_f[k-1]$$

$$\delta\mathbf{v}[k] = \mathbf{v}_f[k] - \mathbf{v}_m[k]$$

$$\delta\hat{\mathbf{v}}[k+1] = \lambda_c\delta\hat{\mathbf{v}}[k] + \delta\mathbf{v}_f[k] + \ell_1\{\delta\mathbf{v}[k] - \delta\hat{\mathbf{v}}[k]\}$$

$$\hat{\mathbf{w}}_1[k+1] = (1+\beta)\hat{\mathbf{w}}_1[k] - \beta\hat{\mathbf{w}}_2[k] + \ell_2\{\delta\mathbf{v}[k] - \delta\hat{\mathbf{v}}[k]\}$$

$$\hat{\mathbf{w}}_2[k+1] = \hat{\mathbf{w}}_1[k] + \ell_3\{\delta\mathbf{v}[k] - \delta\hat{\mathbf{v}}[k]\}$$

Uncoupled error dynamics (estimation):

$$\begin{bmatrix} e_{\delta v}[k+1] \\ e_{w1}[k+1] \\ e_{w2}[k+1] \end{bmatrix} = \begin{bmatrix} \lambda_c - \ell_1 & -k_c & -bk_c \\ -\ell_2 & 1+\beta & -\beta \\ -\ell_3 & 1 & 0 \end{bmatrix} \begin{bmatrix} e_{\delta v}[k] \\ e_{w1}[k] \\ e_{w2}[k] \end{bmatrix} \Rightarrow \begin{cases} \ell_1 = \lambda_c + (1+\beta) - 3\lambda_e \\ \ell_2 = ? \\ \ell_3 = ? \end{cases}$$

Control law:

Initialization:

$$\delta\mathbf{v}_c[k] = \delta\mathbf{v}[k] - \hat{\mathbf{w}}_1[k]$$

$$\mathbf{u}_c[k] = (1-b_c)\mathbf{u}_c[k-1] - b_c\mathbf{u}_c[k-2] + k_u\{\delta\mathbf{v}_c[k] - a_1\delta\mathbf{v}_c[k-1] - a_2\delta\mathbf{v}_c[k-2]\}$$

$$\mathbf{u}[k] = \mathbf{B}^{-1}\mathbf{u}_c[k]$$

Estimator: Augmented state estimator, characterized by λ_e.

Initialization:

$$\mathbf{v}_f[k+1] = \frac{1}{(1-\lambda_c)(1+b)}\{b\mathbf{v}_d[k+d+1] + (1-b\lambda_c)\mathbf{v}_d[k+d] - \lambda_c\mathbf{v}_d[k+d-1]\}\ (d=2)$$

$$\delta\mathbf{v}_f[k] = \mathbf{v}_f[k+1] - (1-b_c)\mathbf{v}_f[k] - b_c\mathbf{v}_f[k-1]$$

$$\delta\mathbf{v}[k] = \mathbf{v}_f[k] - \mathbf{v}_m[k]$$

$$\delta\hat{\mathbf{v}}[k+1] = \lambda_c\delta\hat{\mathbf{v}}[k] + \delta\mathbf{v}_f[k] + \ell_1\{\delta\mathbf{v}[k] - \delta\hat{\mathbf{v}}[k]\}$$

$$\hat{\mathbf{w}}_1[k+1] = \hat{\mathbf{w}}_1[k] + \delta\hat{\mathbf{w}}[k] + \ell_2\{\delta\mathbf{v}[k] - \delta\hat{\mathbf{v}}[k]\}$$

$$\delta\hat{\mathbf{w}}[k+1] = \delta\hat{\mathbf{w}}[k] + \ell_3\{\delta\mathbf{v}[k] - \delta\hat{\mathbf{v}}[k]\}$$

$$\hat{\mathbf{w}}_2[k+1] = \hat{\mathbf{w}}_1[k] + \ell_4\{\delta\mathbf{v}[k] - \delta\hat{\mathbf{v}}[k]\}$$

Uncoupled error dynamics (estimation):

$$\begin{bmatrix} e_{\delta\mathbf{v}}[k+1] \\ e_{\mathbf{w}1}[k+1] \\ e_{\delta\mathbf{w}}[k+1] \\ e_{\mathbf{w}2}[k+1] \end{bmatrix} = \begin{bmatrix} \lambda_c - \ell_1 & -k_c & 0 & -bk_c \\ -\ell_2 & 1 & 1 & 0 \\ -\ell_3 & 0 & 1 & 0 \\ -\ell_4 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} e_{\delta\mathbf{v}}[k] \\ e_{\mathbf{w}1}[k] \\ e_{\delta\mathbf{w}}[k] \\ e_{\mathbf{w}2}[k] \end{bmatrix}$$

$$\begin{cases} \ell_1 = 2 + \lambda_c - 4\lambda_e \\ \ell_2 = \dfrac{(\lambda_e - 1)^3(4b + \lambda_e + 3)}{(b+1)^2 k_c} \\ \ell_3 = \dfrac{-(\lambda_e - 1)^4}{(b+1)k_c} \\ \ell_4 = \dfrac{(\lambda_e^4 + 4b\lambda_e^3 + 6b^2\lambda_e^2 - 4b(2b+1)\lambda_e + 3b^2 + 2b)}{(b+1)^2 b k_c} \end{cases}$$

Control law:

$$\delta\mathbf{v}_c[k] = \delta\mathbf{v}[k] - \hat{\mathbf{w}}_1[k]$$

$$\mathbf{u}_c[k] = (1-b_c)\mathbf{u}_c[k-1] - b_c\mathbf{u}_c[k-2] + k_u\{\delta\mathbf{v}_c[k] - a_1\delta\mathbf{v}_c[k-1] - a_2\delta\mathbf{v}_c[k-2]\}$$

$$\mathbf{u}[k] = \mathbf{B}^{-1}\mathbf{u}_c[k]$$