General linear parameter-varying (LPV) system with input saturation, uncertainties, and matched disturbance

$$
(\mathtt{P})\left\{\begin{array}{rcl}
\dot{\mathbf{x}}_p(t) &=& \big[\mathbf{A}_p(\boldsymbol{\rho}_t)+\boldsymbol{\Delta}\mathbf{A}_p(t)\big]\mathbf{x}_p(t)+\big[\mathbf{B}_p(\boldsymbol{\rho}_t)+\boldsymbol{\Delta}\mathbf{B}_p(t)\big]sat\big(\mathbf{u}(t-\theta(\boldsymbol{\rho}_t))\big)+\mathbf{d}_i(t)\big)+\big[\mathbf{D}_p(\boldsymbol{\rho}_t)+\boldsymbol{\Delta}\mathbf{D}_p(t)\big]\mathbf{d}(t),\\[2ex]
\mathbf{z}(t) &=& \mathbf{C}_z(\boldsymbol{\rho}_t)\mathbf{x}_p(t)+\mathbf{D}_{zu}(\boldsymbol{\rho}_t)sat\big(\mathbf{u}(t-\theta(\boldsymbol{\rho}_t))+\mathbf{d}_i(t)\big)+\mathbf{D}_{zd}(\boldsymbol{\rho}_t)\mathbf{d}(t),\\[2ex]
\mathbf{y}(t) &=& \mathbf{C}_y\mathbf{x}_p(t),\\[2ex]
\mathbf{x}_p(s) &=& \boldsymbol{\phi}(s),\quad \forall s\in[-\overline{h},0]
\end{array}\right.
$$

Uncertainties:

$$
\left[\begin{array}{c}\boldsymbol{\Delta}\mathbf{A}_p(t)\\ \boldsymbol{\Delta}\mathbf{B}_p(t)\\ \boldsymbol{\Delta}\mathbf{D}_p(t)\end{array}\right]=\mathbf{E}\mathbf{F}(t)\left[\begin{array}{c}\mathbf{G}_A\\ \mathbf{G}_B\\ \mathbf{G}_D\end{array}\right]
$$

Matched disturbance dynamics with unknown but bounded energy input, $\boldsymbol{\nu}(t)$,

$$
(\mathtt{D})\left\{\begin{array}{rcl}
\dot{\boldsymbol{\omega}}(t) &=& \mathbf{W}\boldsymbol{\omega}(t)+\mathbf{H}\boldsymbol{\nu}(t),\\
\mathbf{d}_i(t) &=& \mathbf{V}\boldsymbol{\omega}(t)+\mathbf{J}\boldsymbol{\nu}(t),
\end{array}\right.
$$

Proposed output-feedback controller

$$
(\mathtt{C})\left\{\begin{array}{rcl}
\dot{\mathbf{x}}_K(t) &=& \mathbf{A}_K(\boldsymbol{\rho}_t)\mathbf{x}_K(t)+\mathbf{A}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{x}_K(t-\theta(\boldsymbol{\rho}_t))+\mathbf{B}_K(\boldsymbol{\rho}_t)\mathbf{y}(t)+\mathbf{B}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{y}(t-\theta(\boldsymbol{\rho}_t))+\mathbf{E}_K(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\overline{\boldsymbol{\Psi}}(t)\\
&=& \mathbf{A}_K(\boldsymbol{\rho}_t)\mathbf{x}_K(t)+\mathbf{A}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{x}_K(t-\theta(\boldsymbol{\rho}_t))+\mathbf{B}_K(\boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{x}_p(t)+\mathbf{B}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{x}_p(t-\theta(\boldsymbol{\rho}_t))+\mathbf{E}_K(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\overline{\boldsymbol{\Psi}}(t)\\
&=& \left[\begin{array}{ccc}\mathbf{B}_K(\boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{A}_K(\boldsymbol{\rho}_t) & \mathbf{0}\end{array}\right]\left[\begin{array}{c}\mathbf{x}_p(t)\\ \mathbf{x}_k(t)\\ \mathbf{e}_\omega(t)\end{array}\right]+\left[\begin{array}{ccc}\mathbf{B}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{A}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \mathbf{0}\end{array}\right]\left[\begin{array}{c}\mathbf{x}_p(t-\theta(\boldsymbol{\rho}_t))\\ \mathbf{x}_k(t-\theta(\boldsymbol{\rho}_t))\\ \mathbf{e}_\omega(t-\theta(\boldsymbol{\rho}_t))\end{array}\right]+\mathbf{E}_K(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\overline{\boldsymbol{\Psi}}(t),\\
\mathbf{u}(t-\theta(\boldsymbol{\rho}_t)) &=& \mathbf{C}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{x}_K(t-\theta(\boldsymbol{\rho}_t))+\mathbf{D}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{y}(t-\theta(\boldsymbol{\rho}_t))-\widehat{\mathbf{d}}_i(t)\\
&=& \mathbf{C}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{x}_K(t-\theta(\boldsymbol{\rho}_t))+\mathbf{D}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{x}_p(t-\theta(\boldsymbol{\rho}_t))-\mathbf{V}\widehat{\boldsymbol{\omega}}(t)\\
&=& \left[\begin{array}{ccc}\mathbf{0} & \mathbf{0} & \mathbf{0}\end{array}\right]\left[\begin{array}{c}\mathbf{x}_p(t)\\ \mathbf{x}_k(t)\\ \mathbf{e}_\omega(t)\end{array}\right]+\left[\begin{array}{ccc}\mathbf{D}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{C}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \mathbf{0}\end{array}\right]\left[\begin{array}{c}\mathbf{x}_p(t-\theta(\boldsymbol{\rho}_t))\\ \mathbf{x}_k(t-\theta(\boldsymbol{\rho}_t))\\ \mathbf{e}_\omega(t-\theta(\boldsymbol{\rho}_t))\end{array}\right]-\mathbf{V}\widehat{\boldsymbol{\omega}}(t),
\end{array}\right.
$$

Proposed input disturbance observer

$$
(\mathtt{IDO})\left\{\begin{array}{rcl}
\dot{\mathbf{x}}_d(t) &=& \mathbf{W}\widehat{\boldsymbol{\omega}}(t)+\mathbf{L}_K(\boldsymbol{\rho}_t)\mathbf{x}_K(t)+\mathbf{L}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{x}_K(t-\theta(\boldsymbol{\rho}_t))+\mathbf{L}_y(\boldsymbol{\rho}_t)\mathbf{y}(t)+\mathbf{L}_{y_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{y}(t-\theta(\boldsymbol{\rho}_t))+\mathbf{F}_K(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\overline{\boldsymbol{\Psi}}(t)\\
&=& \mathbf{W}\widehat{\boldsymbol{\omega}}(t)+\mathbf{L}_K(\boldsymbol{\rho}_t)\mathbf{x}_K(t)+\mathbf{L}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{x}_K(t-\theta(\boldsymbol{\rho}_t))+\mathbf{L}_y(\boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{x}_p(t)+\mathbf{L}_{y_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{x}_p(t-\theta(\boldsymbol{\rho}_t))+\mathbf{F}_K(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\overline{\boldsymbol{\Psi}}(t)\\
&=& \mathbf{W}\widehat{\boldsymbol{\omega}}(t)+\mathbf{L}_y(\boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{x}_p(t)+\mathbf{L}_K(\boldsymbol{\rho}_t)\mathbf{x}_K(t)+\mathbf{L}_{y_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{x}_p(t-\theta(\boldsymbol{\rho}_t))+\mathbf{L}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{x}_K(t-\theta(\boldsymbol{\rho}_t))+\mathbf{F}_K(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\overline{\boldsymbol{\Psi}}(t)\\
&=& \mathbf{W}\widehat{\boldsymbol{\omega}}(t)+\left[\begin{array}{ccc}\mathbf{L}_y(\boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{L}_K(\boldsymbol{\rho}_t) & \mathbf{0}\end{array}\right]\left[\begin{array}{c}\mathbf{x}_p(t)\\ \mathbf{x}_k(t)\\ \mathbf{e}_\omega(t)\end{array}\right]+\left[\begin{array}{ccc}\mathbf{L}_{y_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{L}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \mathbf{0}\end{array}\right]\left[\begin{array}{c}\mathbf{x}_p(t-\theta(\boldsymbol{\rho}_t))\\ \mathbf{x}_k(t-\theta(\boldsymbol{\rho}_t))\\ \mathbf{e}_\omega(t-\theta(\boldsymbol{\rho}_t))\end{array}\right]+\mathbf{F}_K(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\overline{\boldsymbol{\Psi}}(t),\\[3ex]
\widehat{\boldsymbol{\omega}}(t) &=& \mathbf{x}_d(t)-\mathbf{L}_d(\boldsymbol{\rho}_t)\mathbf{y}(t),\\[2ex]
\widehat{\mathbf{d}}_i(t) &=& \mathbf{V}\widehat{\boldsymbol{\omega}}(t)
\end{array}\right.
$$

Design constraints

$$
\left[\begin{array}{ccccccccc}
\widehat{\mathbf{A}}(\boldsymbol{\rho}_t)+\widehat{\mathbf{A}}^{\mathrm{T}}(\boldsymbol{\rho}_t)+\overline{\mathbf{S}}-\overline{\mathbf{R}}+\overline{\mathbf{Q}}(\boldsymbol{\rho}_t)+\Big(\sum\limits_{i=1}^{n_s}\dot{\rho}_i(t)\dfrac{\partial\overline{\mathbf{P}}(\boldsymbol{\rho}_t)}{\partial\rho_i(t)}\Big) & \overline{\mathbf{P}}(\boldsymbol{\rho}_t)-\overline{\mathbf{P}}_1+\kappa\widehat{\mathbf{A}}^{\mathrm{T}}(\boldsymbol{\rho}_t) & \overline{\mathbf{R}}-\overline{\mathbf{S}}_1+\widehat{\mathbf{A}}_d(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \overline{\mathbf{S}}_1 & \widehat{\mathbf{B}}_\Psi(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)+\widehat{\mathbf{G}}^{\mathrm{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)-\widehat{\mathbb{K}}^{\mathrm{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)+2\overline{\mathbf{V}}^{\mathrm{T}} & \widehat{\mathbf{B}}_w(\boldsymbol{\rho}_t) & \widehat{\mathbf{C}}^{\mathrm{T}}(\boldsymbol{\rho}_t) & \widehat{\mathbf{E}}(\boldsymbol{\rho}_t) & \varepsilon\left[\begin{array}{ccc}\mathbf{G}_A\mathbf{Y} & \mathbf{G}_A & \mathbf{G}_B\mathbf{V}\\ \mathbf{0} & \mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{0} & \mathbf{0}\end{array}\right]^{\mathrm{T}}\\
* & -\kappa(\overline{\mathbf{P}}_1^{\mathrm{T}}+\overline{\mathbf{P}}_1)+\overline{h}^2\overline{\mathbf{R}} & \kappa\widehat{\mathbf{A}}_d(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \mathbf{0} & \kappa\widehat{\mathbf{B}}_\Psi(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \kappa\widehat{\mathbf{B}}_w(\boldsymbol{\rho}_t) & \mathbf{0} & \kappa\widehat{\mathbf{E}}(\boldsymbol{\rho}_t) & \mathbf{0}\\
* & * & -2\overline{\mathbf{R}}+\overline{\mathbf{S}}_1+\overline{\mathbf{S}}_1^{\mathrm{T}}-\big(1-\sum\limits_{i=1}^{n_s}\dot{\rho}_i(t)\dfrac{\partial\theta}{\partial\rho_i(t)}\big)\overline{\mathbf{Q}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)}) & \overline{\mathbf{R}}-\overline{\mathbf{S}}_1^{\mathrm{T}} & \widehat{\mathbf{G}}_1^{\mathrm{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)+\widehat{\mathbb{K}}^{\mathrm{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \mathbf{0} & \widehat{\mathbf{C}}_d^{\mathrm{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \mathbf{0} & \varepsilon\left[\begin{array}{ccc}\mathbf{G}_B\widetilde{\mathbf{C}}_\theta(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \mathbf{G}_B\mathbf{D}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{0}\\ \mathbf{0} & \mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{0} & \mathbf{0}\end{array}\right]^{\mathrm{T}}\\
* & * & * & -\overline{\mathbf{S}}-\overline{\mathbf{R}} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0}\\
* & * & * & * & -4\overline{\mathbf{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & 2\overline{\mathbf{J}} & \overline{\mathbf{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\left[\begin{array}{c}-\mathbf{D}_{zu}(\boldsymbol{\rho}_t)\\ \mathbf{0}\end{array}\right]^{\mathrm{T}} & \mathbf{0} & \varepsilon\overline{\mathbf{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\left[\begin{array}{c}-\mathbf{G}_B\\ \mathbf{0}\\ \mathbf{0}\end{array}\right]^{\mathrm{T}}\\
* & * & * & * & * & -\mathbf{I} & \left[\begin{array}{cc}\mathbf{D}_{zd}(\boldsymbol{\rho}_t) & \mathbf{D}_{zu}(\boldsymbol{\rho}_t)\mathbf{J}\\ \mathbf{0} & \mathbf{0}\end{array}\right]^{\mathrm{T}} & \mathbf{0} & \varepsilon\left[\begin{array}{cc}\mathbf{G}_D & \mathbf{G}_B\mathbf{J}\\ \mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{0}\end{array}\right]^{\mathrm{T}}\\
* & * & * & * & * & * & -\gamma^2\mathbf{I} & \mathbf{0} & \mathbf{0}\\
* & * & * & * & * & * & * & -\varepsilon\mathbf{I} & \mathbf{0}\\
* & * & * & * & * & * & * & * & -\varepsilon\mathbf{I}
\end{array}\right]\prec\mathbf{0}
$$

$$
\left[\begin{array}{cc}\overline{\mathbf{R}} & \overline{\mathbf{S}}_1\\ * & \overline{\mathbf{R}}\end{array}\right]\succeq\mathbf{0}
$$

$$
\left[\begin{array}{cc}\beta & \mathbb{K}_{(i,:)}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)-\mathbf{G}_{1(i,:)}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\\ * & \overline{u}_i^2\mathbf{P}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)})\end{array}\right]\succeq\mathbf{0},\quad i=1,\ldots,n_u
$$

$$
\left[\begin{array}{cc}\beta & \left[\begin{array}{ccc}\widetilde{\mathbf{C}}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \mathbf{D}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{0}\end{array}\right]_{(i,:)}-\widehat{G}_{1(i,:)}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\\ * & \overline{u}_i^2\overline{\mathbf{P}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)})\end{array}\right]\succeq\mathbf{0},\quad i=1,\ldots,n_u
$$

With matrices given by

$$
\widehat{\mathcal{A}}(\boldsymbol{\rho}_t)=\left[\begin{array}{ccc}
\mathbf{A}_p(\boldsymbol{\rho}_t)\mathbf{Y} & \mathbf{A}_p(\boldsymbol{\rho}_t) & \mathbf{B}_p(\boldsymbol{\rho}_t)\mathbf{V}\\
\widetilde{\mathbf{A}}_K(\boldsymbol{\rho}_t) & \mathbf{X}\mathbf{A}_p(\boldsymbol{\rho}_t)+\widetilde{\mathbf{B}}_K(\boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{X}\mathbf{B}_p(\boldsymbol{\rho}_t)\mathbf{V}\\
\widetilde{\mathbf{L}}_K(\boldsymbol{\rho}_t) & \widetilde{\mathbf{L}}_d(\boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{A}_p(\boldsymbol{\rho}_t)+\left(\dot{\widetilde{\mathbf{L}}}_d(\boldsymbol{\rho}_t)-\widetilde{\mathbf{L}}_y(\boldsymbol{\rho}_t)\right)\mathbf{C}_y & \mathbf{Z}\mathbf{W}+\widetilde{\mathbf{L}}_d(\boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{B}_p(\boldsymbol{\rho}_t)\mathbf{V}
\end{array}\right]
$$

$$
\overline{\mathbf{P}}_1=\left[\begin{array}{ccc}\mathbf{Y} & \mathbf{I} & \mathbf{0}\\ \mathbf{I} & \mathbf{X} & \mathbf{0}\\ \mathbf{0} & \mathbf{0} & \mathbf{Z}\end{array}\right]
$$

$$
\widehat{\mathcal{A}}_d(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)=\left[\begin{array}{ccc}
\mathbf{B}_p(\boldsymbol{\rho}_t)\widetilde{\mathbf{C}}_\theta(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \mathbf{B}_p(\boldsymbol{\rho}_t)\mathbf{D}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{0}\\
\widetilde{\mathbf{A}}_\theta(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \widetilde{\mathbf{B}}_\theta(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{0}\\
\widetilde{\mathbf{L}}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \widetilde{\mathbf{L}}_{y_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{0}
\end{array}\right]
$$

$$
\widehat{\mathcal{B}}_\Psi(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)=\left[\begin{array}{c}
-\mathbf{B}_p(\boldsymbol{\rho}_t)\overline{\mathbf{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\\
\widetilde{\mathbf{E}}_K(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\\
\widetilde{\mathbf{F}}_K(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)
\end{array}\right]
$$

$$
\widehat{\mathcal{K}}^{\mathrm{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)=\left[\begin{array}{ccc}\widetilde{\mathbf{C}}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t) & \mathbf{D}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)},\boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{0}\end{array}\right]^{\mathrm{T}}
$$

$$\widehat{\mathcal{B}}_w(\boldsymbol{\rho}_t) = \left[\begin{array}{cc} \mathbf{D}_p(\boldsymbol{\rho}_t) & \mathbf{B}_p(\boldsymbol{\rho}_t)\mathbf{J} \\ \mathbf{X}\mathbf{D}_p(\boldsymbol{\rho}_t) & \mathbf{X}\mathbf{B}_p(\boldsymbol{\rho}_t)\mathbf{J} \\ \widetilde{\mathbf{L}}_d(\boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{D}_p(\boldsymbol{\rho}_t) & \mathbf{Z}\mathbf{H} + \widetilde{\mathbf{L}}_d(\boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{B}_p(\boldsymbol{\rho}_t)\mathbf{J} \end{array}\right]$$

$$\widehat{C}^{\mathrm{T}}(\boldsymbol{\rho}_t) = \left[\begin{array}{ccc} \mathbf{C}_z(\boldsymbol{\rho}_t)\mathbf{Y} & \mathbf{C}_z(\boldsymbol{\rho}_t) & \mathbf{D}_{zu}(\boldsymbol{\rho}_t)\mathbf{V} \\ \mathbf{0} & \mathbf{0} & \mathbf{C}_{e_\omega}(\boldsymbol{\rho}_t) \end{array}\right]^{\mathrm{T}}$$

$$\widehat{C}_d^{\mathrm{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)}, \boldsymbol{\rho}_t) = \left[\begin{array}{ccc} \mathbf{D}_{zu}(\boldsymbol{\rho}_t)\widetilde{\mathbf{C}}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)}, \boldsymbol{\rho}_t) & \mathbf{D}_{zu}(\boldsymbol{\rho}_t)\mathbf{D}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)}, \boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \end{array}\right]^{\mathrm{T}}$$

$$\overline{\mathbf{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)}, \boldsymbol{\rho}_t)\mathbf{D}_\Psi^{\mathrm{T}}(\boldsymbol{\rho}_t) = \overline{\mathbf{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)}, \boldsymbol{\rho}_t) \left[\begin{array}{c} -\mathbf{D}_{zu}(\boldsymbol{\rho}_t) \\ \mathbf{0} \end{array}\right]^{\mathrm{T}}$$

$$\widehat{\mathcal{E}}(\boldsymbol{\rho}_t) = \mathbf{U}_1\mathbf{P}_1^{\mathrm{T}}\mathbf{E} = \mathbf{U}_2\mathbf{E} = \left[\begin{array}{ccc} \mathbf{E}_p & \mathbf{0} & \mathbf{0} \\ \mathbf{X}\mathbf{E}_p & \mathbf{0} & \mathbf{0} \\ \widetilde{\mathbf{L}}_d(\boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{E}_p & \mathbf{0} & \mathbf{0} \end{array}\right]_{(2n_p+n_\omega)\times 3n_p}$$

$$\widehat{G}_A^{\mathrm{T}}(\boldsymbol{\rho}_t) = \left(\left[\begin{array}{ccc} \mathbf{G}_{A_p}\mathbf{Y} & \mathbf{G}_{A_p} & \mathbf{G}_{B_p}\mathbf{V} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \end{array}\right]_{3n_p\times(2n_p+n_\omega)} \right)^{\mathrm{T}}$$

$$\widehat{G}_{A_d}^{\mathrm{T}}(\boldsymbol{\rho}_t) = \left(\left[\begin{array}{ccc} \mathbf{G}_{B_p}\mathbf{D}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)}, \boldsymbol{\rho}_t)\mathbf{C}_y\mathbf{Y} + \mathbf{G}_B\mathbf{C}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)}, \boldsymbol{\rho}_t)\mathbf{N} & \mathbf{G}_B\mathbf{D}_{K_\theta}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)}, \boldsymbol{\rho}_t)\mathbf{C}_y & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \end{array}\right]_{3n_p\times(2n_p+n_\omega)} \right)^{\mathrm{T}}$$

$$\widehat{G}_{B_\Psi}^{\mathrm{T}}(\boldsymbol{\rho}_t) = \overline{\mathbf{T}}(\boldsymbol{\rho}_{t-\theta(\boldsymbol{\rho}_t)}, \boldsymbol{\rho}_t) \left[\begin{array}{c} -\mathbf{G}_{B_p} \\ \mathbf{0} \\ \mathbf{0} \end{array}\right]^{\mathrm{T}}$$