$$\dot{G} = f(G,t) + \begin{bmatrix}1 & 2\\ 2 & -1\end{bmatrix}(u+\varphi)$$

$$\varphi = \begin{bmatrix}20\sin 4t\\ 2\cos 5t\end{bmatrix}, \quad f(G,t) = \begin{bmatrix}2\cos 4t - 10G_2\\ 3\sin 2t + 2G_1\end{bmatrix}, \quad G_1 = 0, \; G_2 = 9$$

$$D + D^T = \begin{bmatrix}1 & 2\\ 2 & -1\end{bmatrix} + \begin{bmatrix}1 & 2\\ 2 & -1\end{bmatrix} = \begin{bmatrix}2 & 4\\ 4 & -2\end{bmatrix}$$

$$\det(\lambda E - (D+D^T)) = \begin{vmatrix}\lambda - 2 & -4\\ -4 & \lambda + 2\end{vmatrix} = (\lambda-2)(\lambda+2) - 16 = 0$$

$$\lambda^2 - 20 = 0 \Rightarrow \lambda = \pm\sqrt{20}$$

$$\Downarrow$$

$$D + D^T \not> 0$$

$$\hat{G} = TG, \quad T = D^T$$

$$\dot{\hat{G}} = T\dot{G} = T\left(f + D(u+\varphi)\right) =$$

$$= TD\left(D^{-1}f + u + \varphi\right)$$

with compensation:

$$u = -\operatorname{diag}(\rho)\operatorname{Sign}(\hat{G}) - D^{-1}f$$

$$TD + (TD)^T = D^T D + DD^T = \begin{bmatrix}1 & 2\\ 2 & -1\end{bmatrix}\begin{bmatrix}1 & 2\\ 2 & -1\end{bmatrix} \cdot 2 = \begin{bmatrix}5 & 0\\ 0 & 5\end{bmatrix} > 0$$

$$\dot{\hat{G}} = TD\left(D^{-1}f - \operatorname{diag}(\rho)\operatorname{Sign}(\hat{G}) - D^{-1}f + \varphi\right) =$$

$$= +TD\left(-\operatorname{diag}(\rho)\operatorname{Sign}(\hat{G}) + \varphi\right).$$

$$\rho > \|\varphi\|$$

$$\operatorname{diag}\rho = \operatorname{diag}(24) = \begin{bmatrix}24 & 0\\ 0 & 24\end{bmatrix}$$

without compensation:

$u = -\mathrm{diag}(\rho)\,\mathrm{Sign}(\hat{G})$

$\dot{\hat{G}} = TD\left(u + \varphi + D^{-1}f\right) = TD\left(-\mathrm{diag}_\rho\,\mathrm{Sign}(\hat{G}) + \varphi + D^{-1}f\right)$

$\rho > \|D^{-1}f + \varphi\|$

Unit control:

$T = D^{-1}$

$TD + (TD)^T = D^{-1}D + DD^{-1} = 2E > 0$

$u = -\rho\frac{\hat{G}}{\|G\|} - D^{-1}f$

$\hat{G} = TG \Rightarrow \dot{\hat{G}} = T\dot{G} = TD\left(u + \varphi + D^{-1}f\right) = TD\left(-\rho\frac{\hat{G}}{\|\hat{G}\|} - D^{-1}f + \varphi + D^{-1}f\right) =$

$= TD\left(-\rho\frac{\hat{G}}{\|\hat{G}\|} + \varphi\right)$

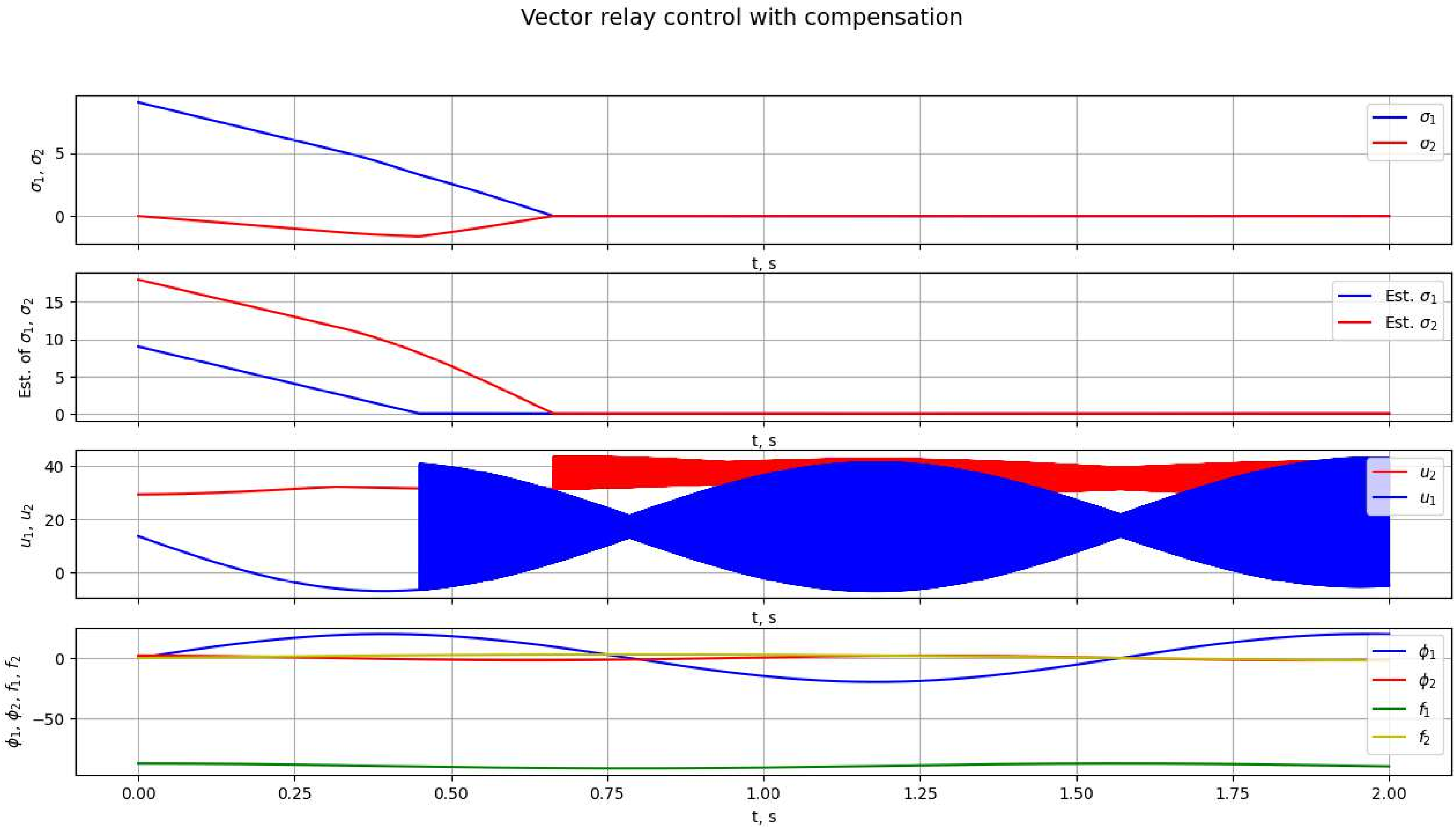
$\rho > \|\varphi\|_2$

without compensation:

$u = -\rho\frac{\hat{G}}{\|\hat{G}\|}$

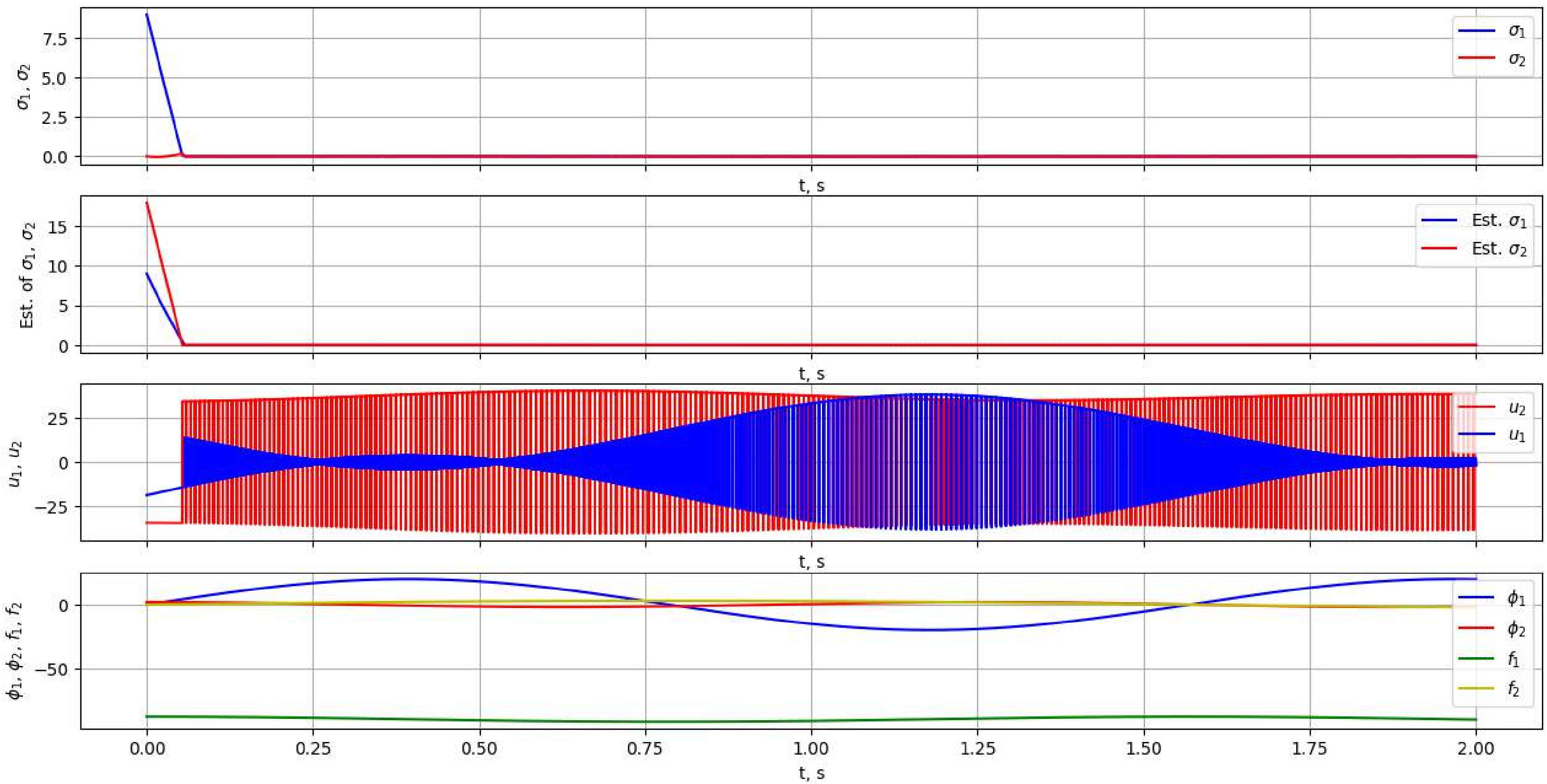
$\dot{\hat{G}} = TD\left(-\rho\frac{\hat{G}}{\|\hat{G}\|} + \varphi + D^{-1}f\right)$

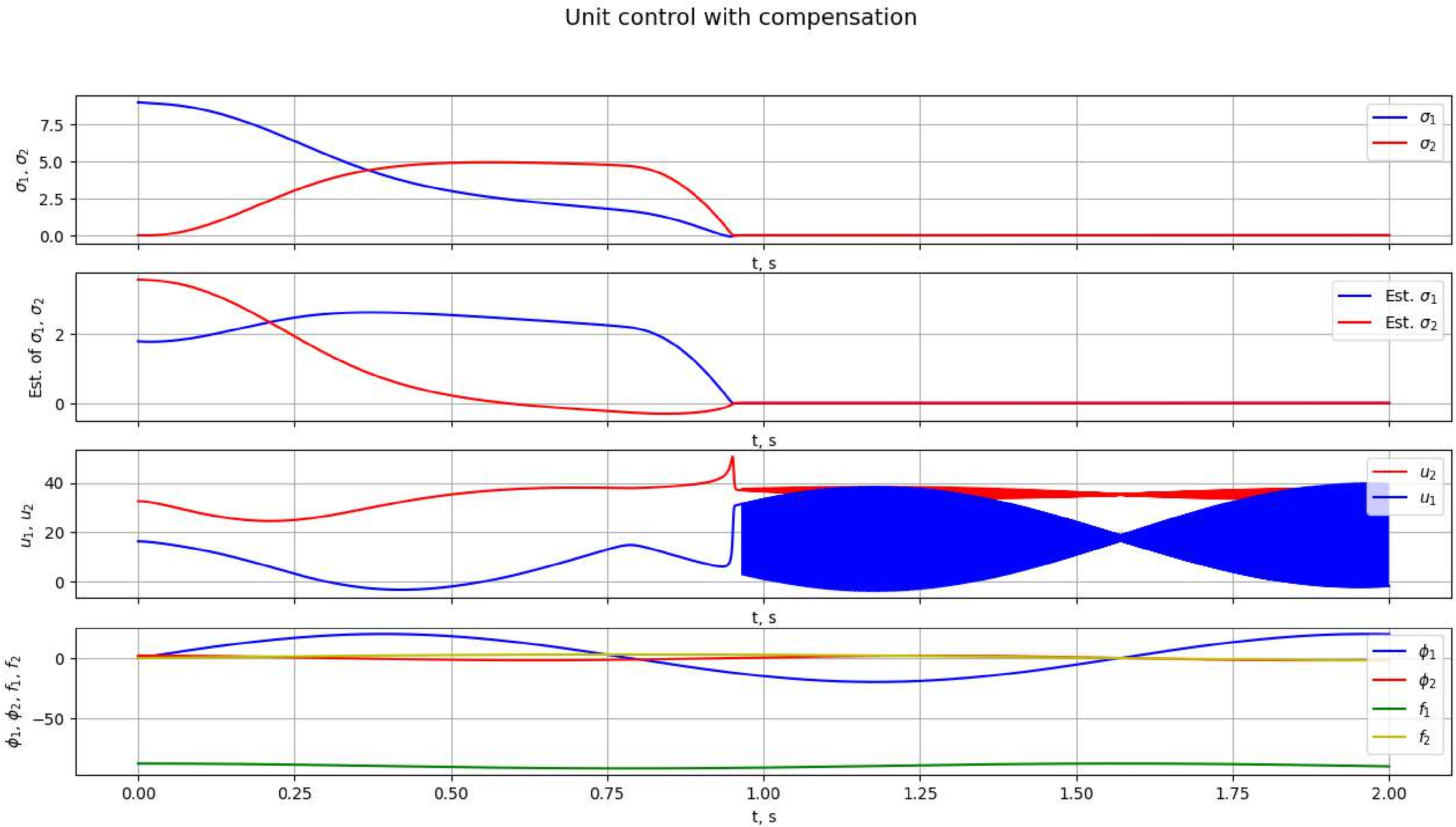
$\rho > \|\varphi + D^{-1}f\|_2$



Vector relay control with compensation
σ_1, σ_2
Est. of σ_1, σ_2
Est. σ_1
Est. σ_2
u_1, u_2
ϕ_1, ϕ_2, f_1, f_2
t, s
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00

Vector relay control without compensation




Unit control with compensation
σ_1, σ_2
σ_1
σ_2
Est. of σ_1, σ_2
Est. σ_1
Est. σ_2
u_1, u_2
u_2
u_1
ϕ_1, ϕ_2, f_1, f_2
ϕ_1
ϕ_2
f_1
f_2
t, s

Unit control without compensation