$$V_3 = V_1 + \frac{\gamma}{2} z_2^2 + \frac{\gamma}{2k_0} \tilde{M}_L^2 \tag{1}$$

$$\dot{V}_3 = \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \dot{\mathbf{z}}_1 + \gamma z_2 \dot{z}_2 + \frac{\gamma}{k_0} \tilde{M}_L \dot{\tilde{M}}_L \tag{2}$$

$$= \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \left(\mathbf{f}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) x_2\right) + \gamma \left(x_2 - \alpha_1(\mathbf{x}_1)\right) \left(\dot{x}_2 - \frac{\partial \alpha_1(\mathbf{x}_1)}{\partial \mathbf{x}_1} \dot{\mathbf{x}}_1\right) + \frac{\gamma}{k_0} \tilde{M}_L \dot{\tilde{M}}_L \tag{3}$$

$$= \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \left(\mathbf{f}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) x_2\right) + \gamma \left(x_2 - \alpha_1(\mathbf{x}_1)\right) \left(u - \frac{\partial \alpha_1(\mathbf{x}_1)}{\partial \mathbf{x}_1} \left(\mathbf{f}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) x_2\right)\right) + \frac{\gamma}{k_0} \tilde{M}_L \dot{\tilde{M}}_L \tag{4}$$

$$= \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \left(\mathbf{f}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) \alpha_1(\mathbf{x}_1) - \mathbf{g}_1(\mathbf{x}_1) \alpha_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) x_2\right) + \gamma \left(x_2 - \alpha_1(\mathbf{x}_1)\right) \left(u - \frac{\partial \alpha_1(\mathbf{x}_1)}{\partial \mathbf{x}_1} \left(\mathbf{f}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) x_2\right)\right) + \frac{\gamma}{k_0} \tilde{M}_L \dot{\tilde{M}}_L \tag{5}$$

$$= \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \left(\mathbf{f}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) \alpha_1(\mathbf{x}_1)\right) + \gamma \left(x_2 - \alpha_1(\mathbf{x}_1)\right) \left(u - \frac{\partial \alpha_1(\mathbf{x}_1)}{\partial \mathbf{x}_1} \left(\mathbf{f}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) x_2\right) + \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \frac{\mathbf{g}_1(\mathbf{x}_1)}{\gamma}\right) + \frac{\gamma}{k_0} \tilde{M}_L \dot{\tilde{M}}_L \tag{6}$$

$$= \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \left(\mathbf{f}_1(\mathbf{x}_1) + \hat{\mathbf{f}}_1(\mathbf{x}_1) - \hat{\mathbf{f}}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) \alpha_1(\mathbf{x}_1)\right) + \gamma \left(x_2 - \alpha_1(\mathbf{x}_1)\right) \left(u - \frac{\partial \alpha_1(\mathbf{x}_1)}{\partial \mathbf{x}_1} \left(\mathbf{f}_1(\mathbf{x}_1) + \hat{\mathbf{f}}_1(\mathbf{x}_1) - \hat{\mathbf{f}}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) x_2\right) + \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \frac{\mathbf{g}_1(\mathbf{x}_1)}{\gamma}\right) + \frac{\gamma}{k_0} \tilde{M}_L \dot{\tilde{M}}_L \tag{7}$$

$$= \underbrace{\frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \left(\hat{\mathbf{f}}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) \alpha_1(\mathbf{x}_1)\right)}_{\leq 0} + \gamma \left(x_2 - \alpha_1(\mathbf{x}_1)\right) \underbrace{\left(u - \frac{\partial \alpha_1(\mathbf{x}_1)}{\partial \mathbf{x}_1} \left(\hat{\mathbf{f}}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) x_2\right) + \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \frac{\mathbf{g}_1(\mathbf{x}_1)}{\gamma}\right)}_{=-k_1(x_2 - \alpha_1(\mathbf{x}_1))} + \underbrace{\frac{\gamma}{k_0} \tilde{M}_L \dot{\tilde{M}}_L + \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \left(\mathbf{f}_1(\mathbf{x}_1) - \hat{\mathbf{f}}_1(\mathbf{x}_1)\right) + \gamma \left(x_2 - \alpha_1(\mathbf{x}_1)\right) \left(-\frac{\partial \alpha_1(\mathbf{x}_1)}{\partial \mathbf{x}_1}\right) \left(\mathbf{f}_1(\mathbf{x}_1) - \hat{\mathbf{f}}_1(\mathbf{x}_1)\right)}_{=0} \tag{8}$$

$$\mathbf{f}_1(\mathbf{x}_1) - \hat{\mathbf{f}}_1(\mathbf{x}_1) = \begin{bmatrix} 0 \\ \frac{M_L - \hat{M}_L}{I_a} \end{bmatrix} \tag{9}$$

$$\frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} = \frac{\partial}{\partial \mathbf{z}_1} \left(\int_0^{z_{11}} \left(M(\xi + x_{11R}) - M_L\right) \mathrm{d}\xi + \frac{I_a}{2} z_{12}^2\right) \tag{10}$$

$$= \begin{bmatrix} M(z_{11} + x_{11R}) - M_L & I_a z_{12} \end{bmatrix} \tag{11}$$

$$\dot{x}_{12,ist} = \dot{x}_{12,soll} \tag{12}$$

$$\frac{1}{I_a} \left(M_L - c_0 \left(x_{11} - \alpha_1(\mathbf{x}_1) - d_a x_{12}\right)\right) = \frac{1}{I_a} \left(M_L - M(x_1 1) - d x_{12}\right) \tag{13}$$

$$-c_0 \left(x_{11} - \alpha_1(\mathbf{x}_1)\right) - d_a x_{12} = -M(x_{11}) - d x_{12} \tag{14}$$

$$\alpha_1(\mathbf{x}_1) = x_{11} + \frac{(d_a - d) x_{12} - M(x_{11})}{c_0} \tag{15}$$

$$\frac{\partial \alpha_1(\mathbf{x}_1)}{\partial \mathbf{x}_1} = \begin{bmatrix} 1 - \frac{\partial M(x_{11})}{\partial x_{11}} \frac{1}{c_0} & \frac{d_a - d}{c_0} \end{bmatrix} \tag{16}$$

$$0 = \frac{\gamma}{k_0} \tilde{M}_L \dot{\tilde{M}}_L + \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \left(\mathbf{f}_1(\mathbf{x}_1) - \hat{\mathbf{f}}_1(\mathbf{x}_1)\right) + \gamma \left(x_2 - \alpha_1(\mathbf{x}_1)\right) \left(-\frac{\partial \alpha_1(\mathbf{x}_1)}{\partial \mathbf{x}_1}\right) \left(\mathbf{f}_1(\mathbf{x}_1) - \hat{\mathbf{f}}_1(\mathbf{x}_1)\right) \tag{17}$$

$$= \frac{\gamma}{k_0} \tilde{M}_L \dot{\tilde{M}}_L + \left(-\tilde{M}_L\right) z_{12} + \gamma \left(x_2 - \alpha_1(\mathbf{x}_1)\right) \left(-\left(-\tilde{M}_L\right)\right) \frac{d_a - d}{c_0 I_a} \tag{18}$$

$$\dot{\tilde{M}}_L = \frac{k_0}{\gamma} \left(z_{12} - \gamma \left(x_2 - \alpha_1(\mathbf{x}_1)\right) \frac{d_a - d}{c_0 I_a}\right) \tag{19}$$

$$= \frac{k_0}{\gamma} \left(z_{12} - \gamma \left(x_2 - x_{11} - \frac{(d_a - d) x_{12} - M(x_{11})}{c_0}\right) \frac{d_a - d}{c_0 I_a}\right) \tag{20}$$

$$-k_1 \left(x_2 - \alpha_1(\mathbf{x}_1)\right) = u - \frac{\partial \alpha_1(\mathbf{x}_1)}{\partial \mathbf{x}_1} \left(\hat{\mathbf{f}}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) x_2\right) + \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \frac{\mathbf{g}_1(\mathbf{x}_1)}{\gamma} \tag{21}$$

$$u = \frac{\partial \alpha_1(\mathbf{x}_1)}{\partial \mathbf{x}_1} \left(\hat{\mathbf{f}}_1(\mathbf{x}_1) + \mathbf{g}_1(\mathbf{x}_1) x_2\right) - \frac{\partial V_1(\mathbf{z}_1)}{\partial \mathbf{z}_1} \frac{\mathbf{g}_1(\mathbf{x}_1)}{\gamma} - k_1 \left(x_2 - \alpha_1(\mathbf{x}_1)\right) \tag{22}$$

$$= \begin{bmatrix} 1 - \frac{\partial M(x_{11})}{\partial x_{11}} \frac{1}{c_0} & \frac{d_a - d}{c_0} \end{bmatrix} \begin{bmatrix} x_{12} \\ \frac{1}{I_a} \left(M_L - c_0 \left(x_{11} - \alpha_1(\mathbf{x}_1) - d_a x_{12}\right)\right) \end{bmatrix} - \frac{1}{\gamma} \begin{bmatrix} M(z_{11} + x_{11R}) - M_L & I_a z_{12} \end{bmatrix} \begin{bmatrix} 0 \\ \frac{c_0}{I_a} \end{bmatrix} - k_1 \left(x_2 - x_{11} - \frac{(d_a - d) x_{12} - M(x_1 1)}{c_0}\right) \tag{23}$$

$$u = x_{12} - \frac{\partial M(x_{11})}{\partial x_{11}} \frac{x_{12}}{c_0} + \frac{d_a - d}{c_0 I_a} \left(\hat{M}_L - c_0 x_{11} - d_a x_{12} + c_0 x_2\right) - \frac{z_{12} c_0}{\gamma} - k_1 \left(x_2 - x_{11} - \frac{(d_a - d) x_{12} - M(x_{11})}{c_0}\right) \tag{24}$$