

Adaptive Tracking and Disturbance Rejection에 의한 전력계통안정화장치

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Adaptive Tracking, Disturbance Rejection and Power System Stabilizer

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Abstract - Adaptive tracking, disturbance rejection and power system stabilizer

First, this paper deals with power system stabilization problem using asymptotic tracking of arbitrary smooth bounded reference output signals, with simultaneous rejection of disturbances generated by an unknown linear exosystem. Second, this paper presents a power system stabilizer(PSS) using nonlinear adaptive observer backstepping controller.

1. Introduction

The class of observable uncertain nonlinear system has been widely studied when external disturbances w are not present. In this paper, the topic deals with power system stabilization problem using asymptotic tracking of arbitrary smooth bounded reference output signals, with simultaneous rejection of disturbances[1], and using nonlinear adaptive observer backstepping controller[2].

2. Adaptive Tracking and Disturbance Rejection Controller

The class of uncertain nonlinear system is

$$\dot{x} = A_c x + \phi(y)\theta + \frac{1}{\gamma}bu + \psi(y) + Gw, \quad x \in \mathbb{R}^n \quad (1)$$

$$y = C_c x, \quad u, y \in \mathbb{R} \quad (2)$$

$$\dot{w} = Sw, \quad w \in \mathbb{R}^r \quad (3)$$

$$\dot{\zeta} = A_c \zeta + T_1 \phi(y)\theta + T_1 \psi(y) + \frac{1}{\gamma}T_1 bu \quad (4)$$

$$y = C_c \zeta, \quad \zeta = [T_1 \ T_2] \begin{bmatrix} x \\ w \end{bmatrix} \equiv T \begin{bmatrix} x \\ w \end{bmatrix}, \quad \zeta \in \mathbb{R}^{n+r} \quad (5)$$

$$T_1 \phi(y)\theta + T_1 \psi(y) \equiv \sum_{i=1}^q \beta_i \alpha_i(y) \quad (6)$$

$$\dot{\zeta} = A_c \zeta + \sum_{i=1}^q \beta_i \alpha_i(y) + \frac{1}{\gamma} T_1 bu \quad (7)$$

$$y = C_c \zeta \quad (8)$$

$$\bar{\zeta} = \zeta - \sum_{i=2}^{n+r} \delta_i \sum_{j=2}^i d[j] \mu_{j-1}[i-1] \quad (9)$$

$$\mu[i] = \begin{bmatrix} -\lambda_1 & 1 & \dots & 0 \\ \vdots & \vdots & \dots & \vdots \\ 0 & 0 & \dots & 1 \\ 0 & 0 & \dots & -\lambda_1 \end{bmatrix} \mu[i] + \begin{bmatrix} 0 \\ \vdots \\ 0 \\ 1 \end{bmatrix} u, \quad \mu[i] \in \mathbb{R}^1 \quad (10)$$

$$y[i] = [1 \ 0 \ \dots \ 0] \mu[i], \quad 1 \leq i \leq n+r-1 \quad (11)$$

$$d[n+r] = [0 \ \dots \ 0 \ 1]^T \quad (12)$$

$$d[j-1] = A_c d[j] + \lambda_{j-1} d[j], \quad 2 \leq j \leq n+r \quad (13)$$

$$d = d[1] \quad (14)$$

$$z_1 = \bar{\zeta}_1 \quad (15)$$

$$z_j = \bar{\zeta}_j - \sum_{i=1}^{n+r} \xi_{j-1}[i] \beta_i, \quad 2 \leq j \leq n+r \quad (16)$$

$$\dot{\xi}[i] = \begin{bmatrix} -d_2 & 1 & \dots & 0 \\ \vdots & \vdots & \dots & \vdots \\ -d_{n+r+1} & 0 & \dots & 1 \\ -d_{n+r} & 0 & \dots & 0 \end{bmatrix} \xi[i] + \begin{bmatrix} -d_2 \\ \vdots \\ -d_{n+r} \end{bmatrix} I \alpha_i(y), \quad 1 \leq i \leq q \quad (17)$$

$$\dot{z} = A_c z + d \left(\frac{1}{\gamma} u + \sum_{i=2}^{n+r} \delta_i y[i-1] + \sum_{i=1}^q \beta_i (\xi_i[i] + \alpha_{ii}(y)) \right) \quad (18)$$

$$y = C_c z \quad (19)$$

$$y_1 = z_1 \quad (20)$$

$$\eta_i = z_{i+1} - d_{i+1} z_1, \quad 1 \leq i \leq n+r-1 \quad (21)$$

$$\dot{y} = \eta_1 + d_2 y + \sum_{i=2}^{n+r} \delta_i y[i-1] + \sum_{i=1}^q \beta_i (\alpha_{ii}(y) + \xi_1[i] + \frac{1}{\gamma} u) \quad (12)$$

$$\dot{\eta} = I \hat{\eta} + \bar{d} y \quad (13)$$

$$\Gamma = \begin{bmatrix} -d_2 & 1 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ -d_{n+r-1} & 0 & \dots & 1 \\ -d_{n+r} & 0 & \dots & 0 \end{bmatrix} \quad \bar{d} = \begin{bmatrix} d_3 - d_2^2 \\ \vdots \\ d_{n+r} - d_2 d_{n+r-1} \\ -d_{n+r} d_2 \end{bmatrix} \quad (14)$$

$$u = \hat{\gamma} \left[-k\bar{y} + \dot{y}_r - \hat{\eta}_1 - d_2 y - \sum_{i=2}^{n+r} \delta_i y[i-1] - \sum_{i=1}^q \beta_i (\alpha_{ii}(y) + \xi_1[i]) \right] \quad (16)$$

$$\dot{\hat{\eta}} = I \hat{\eta} + \bar{d} y \quad (17)$$

$$\dot{\hat{\gamma}} = -c_0 \bar{y} \left[-k\bar{y} + \dot{y}_r - \hat{\eta}_1 - d_2 y - \sum_{i=2}^{n+r} \delta_i y[i-1] - \sum_{i=1}^q \beta_i (\alpha_{ii}(y) + \xi_1[i]) \right] \quad (18)$$

$$\hat{\beta}_i = c_i (\alpha_{ii}(y) + \xi_1[i]) \bar{y}, \quad 1 \leq i \leq q \quad (19)$$

$$\hat{\delta}_i = c_{q+i-1} y[i-1] \tilde{y}, \quad 2 \leq i \leq n+r \quad (20)$$

3. Nonlinear Adaptive Observer Backstepping Controller

The differential equation with the unknown variable constant can be represented

$$\dot{x}_1 = x_2 + \varphi_1(x_1) \tau \theta$$

$$\dot{x}_2 = x_3 + \varphi_2(x_1, x_2) \tau \theta$$

.....

$$\dot{x}_{n-1} = x_n + \varphi_{n-1}(x_1, \dots, x_2) \tau \theta$$

$$\dot{x}_n = \beta(x)u + \varphi_n(x) \tau \theta \quad (21)$$

where θ is unknown variable constant.

(A) Step 1

$$\begin{aligned} z_1 &= x_1 - y, \\ z_2 &= x_2 - \alpha_1 \\ \dot{z}_1 &= z_2 + \alpha_1 + w_1(x_1) \tau \theta \end{aligned}$$

$$V_1 = \frac{1}{2} z_1^2 + \frac{1}{2} \bar{\theta}^T \Gamma^{-1} \bar{\theta}$$

$$V_1 = z_1(z_2 + \alpha_1 + w_1^T \theta) - \bar{\theta}^T \Gamma^{-1} (\bar{\theta} - \Gamma w_1 z_1)$$

$$\tau_1(x_1) = w_1(x_1) z_1$$

$$\alpha_1(x_1, \bar{\theta}) = -c_1 z_1 - w_1(x_1) \tau \theta$$

$$V_1 = -c_1 z_1^2 + z_1 z_2 + \bar{\theta}^T (\Gamma^{-1} \bar{\theta} - \tau_1)$$

$$\dot{z}_1 = -c_1 z_1 + z_2 + w_1(x_1) \tau \theta$$

(B) Step 2

$$z_3 = x_3 - \alpha_2$$

$$\dot{z}_2 = z_3 + \alpha_2 - \frac{\partial \alpha_1}{\partial x_1} x_2 + w_2(x_1, x_2, \bar{\theta}) \tau \theta - \frac{\partial \alpha_1}{\partial \theta} \bar{\theta}$$

$$w_2(x_1, x_2, \bar{\theta}) = \varphi_2 - \frac{\partial \alpha_1}{\partial x_1} \varphi_1$$

$$V_2 = V_1 + \frac{1}{2} z_2^2$$

$$V_2 = -c_1 z_1^2 + z_2 [z_1 + z_3 + \alpha_2 - \frac{\partial \alpha_1}{\partial x_1} x_2 + w_2^T \theta - \frac{\partial \alpha_1}{\partial \theta} \bar{\theta}] + \bar{\theta}^T (\tau_1 + w_2 z_2 - \Gamma^{-1} \bar{\theta})$$

$$\tau_2(x_1, x_2, \bar{\theta}) = \tau_1 + w_2 z_2 = [w_1, w_2] \begin{bmatrix} z_1 \\ z_2 \end{bmatrix}$$

$$\alpha_2(x_1, x_2, \bar{\theta}) = -z_1 - c_2 z_2 + \frac{\partial \alpha_1}{\partial x_1} x_2 - w_2^T \theta + \frac{\partial \alpha_1}{\partial \theta} \Gamma \tau_2$$

$$V_2 = -c_1 z_1^2 - c_2 z_2^2 + z_2 z_3 z_2 \frac{\partial \alpha_1}{\partial \theta} (\Gamma \tau_2 - \bar{\theta}) + \bar{\theta}^T (\tau_2 - \Gamma^{-1} \bar{\theta})$$

$$\begin{bmatrix} \dot{z}_1 \\ \dot{z}_2 \\ \dot{z}_3 \end{bmatrix} = \begin{bmatrix} -c_1 & 1 \\ -1 & -c_2 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} z_1 \\ z_2 \\ z_3 \end{bmatrix} + \begin{bmatrix} w_1^T \\ w_2^T \\ w_3^T \end{bmatrix} \theta + \begin{bmatrix} 0 \\ 0 \\ \frac{\partial \alpha_1}{\partial \theta} (\Gamma \tau_2 - \bar{\theta}) \end{bmatrix}$$

(C) Step 3

$$z_4 = x_4 - \alpha_3$$

$$\begin{aligned} \dot{z}_3 &= z_4 + \alpha_3 - \frac{\partial \alpha_2}{\partial x_1} x_2 - \frac{\partial \alpha_2}{\partial x_2} x_3 \\ &\quad + w_3(x_1, x_2, x_3, \bar{\theta}) \tau \theta - \frac{\partial \alpha_2}{\partial \theta} \bar{\theta} \end{aligned}$$

$$w_2(x_1, x_2, x_3, \bar{\theta}) = \varphi_3 - \frac{\partial \alpha_2}{\partial x_1} \varphi_1 - \frac{\partial \alpha_2}{\partial x_2} \varphi_2$$

$$V_3 = V_2 + \frac{1}{2} z_3^2$$

$$\begin{aligned} V_3 &= -c_1 z_1^2 - c_2 z_2^2 + z_2 \frac{\partial \alpha_1}{\partial \theta} (\Gamma \tau_2 - \bar{\theta}) \\ &\quad + z_3 [z_2 + z_4 + \alpha_3 - \frac{\partial \alpha_1}{\partial x_1} x_2 - \frac{\partial \alpha_1}{\partial x_2} x_3 + w_3^T \theta - \frac{\partial \alpha_2}{\partial \theta} \bar{\theta}] \\ &\quad + \bar{\theta}^T (\tau_2 + w_3 z_3 - \Gamma^{-1} \bar{\theta}) \end{aligned}$$

$$\tau_3(x_1, x_2, x_3, \bar{\theta}) = \tau_2 + w_3 z_3 = [w_1, w_2, w_3] \begin{bmatrix} z_1 \\ z_2 \\ z_3 \end{bmatrix}$$

$$\begin{aligned} \alpha_3(x_1, x_2, x_3, \bar{\theta}) &= -z_2 - c_3 z_3 + \frac{\partial \alpha_2}{\partial x_1} x_2 - w_3^T \theta + \frac{\partial \alpha_2}{\partial x_2} x_3 \\ &\quad + \frac{\partial \alpha_2}{\partial \theta} \Gamma \tau_3 + v_3 \end{aligned}$$

$$\bar{\theta} - \Gamma \tau_2 = \bar{\theta} - \Gamma \tau_3 + \Gamma \tau_3 - \Gamma \tau_2$$

$$= \bar{\theta} - \Gamma \tau_3 + \Gamma w_3 z_3$$

$$\begin{aligned} V_3 &= -c_1 z_1^2 - c_2 z_2^2 + z_3 (v_3 - \frac{\partial \alpha_1}{\partial \theta} \Gamma w_3 z_2) \\ &\quad + z_3 z_4 + (z_2 \frac{\partial \alpha_1}{\partial \theta} + z_3 \frac{\partial \alpha_2}{\partial \theta}) (\Gamma \tau_3 - \bar{\theta}) + \bar{\theta}^T (\tau_3 - \Gamma^{-1} \bar{\theta}) \end{aligned}$$

$$\begin{bmatrix} \dot{z}_1 \\ \dot{z}_2 \\ \dot{z}_3 \\ \dot{z}_4 \end{bmatrix} = \begin{bmatrix} -c_1 & 1 & 0 \\ -1 & -c_2 & 1 \\ 0 & 1 & -c_3 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \end{bmatrix} + \begin{bmatrix} w_1^T \\ w_2^T \\ w_3^T \\ w_4^T \end{bmatrix} \theta + \begin{bmatrix} 0 \\ \frac{\partial \alpha_1}{\partial \theta} (\Gamma \tau_3 - \bar{\theta}) \\ z_1 + \frac{\partial \alpha_2}{\partial \theta} (\Gamma \tau_3 - \bar{\theta}) \\ v_3 \end{bmatrix}$$

$$v_3(x_1, x_2, x_3, \bar{\theta}) = \frac{\partial \alpha_1}{\partial \theta} \Gamma w_3 z_3$$

$$V_3 = -c_1 z_1^2 - c_2 z_2^2 + c_3 z_3^2 + z_3 z_4$$

(22)

(23)

(24)

(25)

(26)

(27)

(28)

(29)

(30)

$$+ (z_2 \frac{\partial \alpha_1}{\partial \theta} + z_3 \frac{\partial \alpha_2}{\partial \theta}) (\Gamma \tau_3 - \bar{\theta}) + \bar{\theta}^T (\tau_3 - \Gamma^{-1} \bar{\theta})$$

(51)

$$\begin{bmatrix} \dot{z}_1 \\ \dot{z}_2 \\ \dot{z}_3 \\ \dot{z}_4 \end{bmatrix} = \begin{bmatrix} -c_1 & 1 & 0 \\ -1 & -c_2 & 1 \\ 0 & 1 & -c_3 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \end{bmatrix} + \begin{bmatrix} w_1^T \\ w_2^T \\ w_3^T \\ w_4^T \end{bmatrix} \theta$$

$$+ \begin{bmatrix} 0 \\ \frac{\partial \alpha_1}{\partial \theta} \Gamma w_3 z_3 \\ -1 + \frac{\partial \alpha_1}{\partial \theta} \Gamma w_3 \\ \frac{\partial \alpha_1}{\partial \theta} \Gamma w_3 \end{bmatrix} + \begin{bmatrix} \frac{\partial \alpha_1}{\partial \theta} \\ \frac{\partial \alpha_2}{\partial \theta} \\ \frac{\partial \alpha_2}{\partial \theta} \end{bmatrix} (\Gamma \tau_3 - \bar{\theta})$$

(52)

(D) Step 4

$$z_{i+1} = x_{i+1} - \alpha_i$$

(53)

$$\dot{z}_i = z_{i+1} + \alpha_i - \sum_{k=1}^{i-1} \frac{\partial \alpha_{i-1}}{\partial x_k} x_{k+1}$$

$$+ w_i(x_1, \dots, x_i, \bar{\theta}) \tau \theta - \frac{\partial \alpha_{i-1}}{\partial \theta} \bar{\theta}$$

(54)

$$w_i(x_1, \dots, x_i, \bar{\theta}) = \varphi_i - \sum_{k=1}^{i-1} \frac{\partial \alpha_{i-1}}{\partial x_k} \varphi_k$$

(55)

$$V_i = V_{i-1} + \frac{1}{2} z_i^2$$

(56)

$$\nabla_n = \sum_{k=1}^{i-1} c_k z_k^2 + \left(\sum_{k=1}^{i-2} z_{k+1} \frac{\partial \alpha_k}{\partial \theta} \right) (\Gamma \tau_{i-1} - \bar{\theta})$$

$$+ z_i [z_{i-1} + z_{i+1} + \alpha_i - \sum_{k=1}^{i-1} \frac{\partial \alpha_{i-1}}{\partial x_k} x_{k+1}$$

$$+ w_i^T \theta - \frac{\partial \alpha_{i-1}}{\partial \theta} \bar{\theta}] + \bar{\theta}^T (\tau_{i-1} + w_i z_i - \Gamma^{-1} \bar{\theta})$$

$$= [w_1, \dots, w_i] \begin{bmatrix} z_1 \\ \vdots \\ z_i \end{bmatrix}$$

(57)

$$\tau_i(x_1, \dots, x_i, \bar{\theta}) = \tau_{i-1} + w_i z_i$$

(58)

$$\alpha_i(x_1, \dots, \bar{\theta}) = -z_{i-1} - c_i z_i + \sum_{k=1}^{i-1} \frac{\partial \alpha_{i-1}}{\partial x_k} x_{k+1} - w_i^T \theta$$

$$+ \frac{\partial \alpha_{i-1}}{\partial \theta} \Gamma \tau_i + v_i$$

(59)

$$\bar{\theta} - \Gamma \tau_{i-1} = \bar{\theta} - \Gamma \tau_i + \Gamma \tau_i - \Gamma \tau_{i-1}$$

$$V_i = -\sum_{k=1}^{i-1} c_k z_k^2 + z_i [z_{i+1} + v_i - \sum_{k=1}^{i-2} z_{k+1} \frac{\partial \alpha_k}{\partial \theta} \Gamma w_i]$$

$$+ \left(\sum_{k=1}^{i-2} z_{k+1} \frac{\partial \alpha_k}{\partial \theta} \right) (\Gamma \tau_i - \bar{\theta}) + \bar{\theta}^T (\tau_i - \Gamma^{-1} \bar{\theta})$$

= $\bar{\theta} - \Gamma \tau_i + \Gamma w_i z_i$

$$= -\sum_{k=1}^{i-1} c_k z_k^2 + z_i [z_{i+1} + v_i - \sum_{k=1}^{i-2} z_{k+1} \frac{\partial \alpha_k}{\partial \theta} \Gamma w_i]$$

$$+ \left(\sum_{k=1}^{i-1} z_{k+1} \frac{\partial \alpha_k}{\partial \theta} \right) (\Gamma \tau_i - \bar{\theta}) - \bar{\theta}^T (\tau_i - \Gamma^{-1} \bar{\theta})$$

$$\begin{bmatrix} \dot{z}_1 \\ \dot{z}_2 \\ \dot{z}_3 \\ \dot{z}_4 \end{bmatrix} = \begin{bmatrix} -c_1 & 1 & 0 & \cdots & 0 \\ -1 & -c_2 & 1 & \cdots & \sigma_{23} \\ 0 & -1 - \sigma_{23} & 1 + \sigma_{23} & \cdots & \vdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & -\sigma_{2n} & \cdots & -1 - \sigma_{1,n-1} & -c_n \end{bmatrix} \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \\ z_{i+1} \end{bmatrix} + \begin{bmatrix} w_1^T \\ w_2^T \\ w_3^T \\ w_4^T \\ z_i \end{bmatrix} \theta + \begin{bmatrix} 0 \\ \frac{\partial \alpha_1}{\partial \theta} \\ \frac{\partial \alpha_2}{\partial \theta} \\ \frac{\partial \alpha_2}{\partial \theta} \\ \frac{\partial \alpha_{i-1}}{\partial \theta} \end{bmatrix} (\Gamma \tau_i - \bar{\theta})$$

(62)

(E) Step N

In the final step,

$$z_n = x_n - \alpha_{n-1}$$

(63)

$$\dot{z}_n = \beta u + \varphi_n \theta - \sum_{k=1}^{n-1} \frac{\partial \alpha_{n-1}}{\partial x_k} (x_{k+1} + \varphi_k \theta) - \frac{\partial \alpha_{n-1}}{\partial \theta} \bar{\theta}$$

(64)

$$w_n(x, \bar{\theta}) = \varphi_n - \sum_{k=1}^{n-1} \frac{\partial \alpha_{n-1}}{\partial x_k} \varphi_k$$

(65)

$$V_n = V_{n-1} + \frac{1}{2} z_n^2$$

$$= \frac{1}{2} z_n^2 + \frac{1}{2} \bar{\theta}^T \Gamma^{-1} \bar{\theta}$$

$$V_n = -\sum_{k=1}^{n-1} c_k z_k^2 + \left(\sum_{k=1}^{n-2} z_{k+1} \frac{\partial \alpha_k}{\partial \theta} \right) (\Gamma \tau_{n-1} - \bar{\theta})$$

$$+ z_n [z_{n-1} + \beta u + \sum_{k=1}^{n-1} \frac{\partial \alpha_{n-1}}{\partial x_k} x_{k+1} + w_n^T \theta - \frac{\partial \alpha_{n-1}}{\partial \theta} \bar{\theta}] + \bar{\theta}^T (\tau_{n-1} + w_n z_n - \Gamma^{-1} \bar{\theta})$$

(66)

$$\bar{\theta} = \Gamma \tau_n (z, \bar{\theta}) = \Gamma \tau_{n-1} + \Gamma w_n z_n = \Gamma W z, \bar{\theta} z$$

(67)

$$\bar{\theta} = \Gamma \tau_n (z, \bar{\theta}) = \Gamma \tau_{n-1} + \Gamma w_n z_n = \Gamma W z, \bar{\theta} z$$

(68)

$$W(z, \theta) = [w_1, \dots, w_n] \quad (69)$$

$$u = \frac{1}{\beta} (-z_{n-1} - c_n z_n + \sum_{k=1}^{n-1} \frac{\partial a_{k+1}}{\partial x_k} x_{k+1} - w_n^T z_n + \frac{\partial a_{n-1}}{\partial \theta} \Gamma r_n + v_n) \quad (70)$$

$$V_n = - \sum_{k=1}^{n-1} c_k z_k^2 + (\sum_{k=1}^{n-2} z_{k+1} \frac{\partial a_k}{\partial \theta}) (\Gamma r_{n-1} - \theta) + z_n v_n \quad (71)$$

$$\theta - \Gamma r_{n-1} = \Gamma r_n - \Gamma r_{n-1} = \Gamma w_n z_n \quad (72)$$

$$V_n = - \sum_{k=1}^{n-1} c_k z_k^2 + z_n (v_n - \sum_{k=1}^{n-2} z_{k+1} \frac{\partial a_k}{\partial \theta} \Gamma w_n) \quad (73)$$

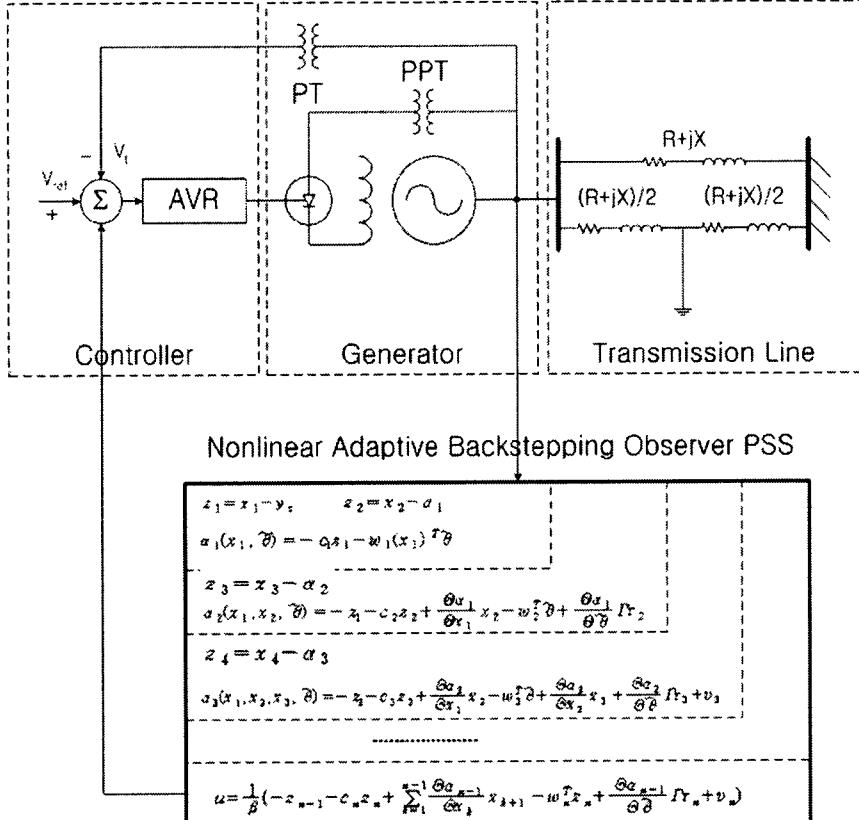
$$v_n(x, \theta) = \sum_{k=1}^{n-2} z_{k+1} \frac{\partial a_k}{\partial \theta} \Gamma w_n = - \sum_{k=2}^{n-1} \sigma_{k,n} z_k \quad (74)$$

$$V_n = - \sum_{k=1}^n c_k z_k^2 \quad (75)$$

$$\dot{z} = A_z(z, \theta)z + W(z, \theta)^T \theta \quad (76)$$

$$\dot{\theta} = \Gamma W(z, \theta)z \quad (77)$$

$$A_z(z, \theta) = \begin{bmatrix} -c_1 & 1 & 0 & \dots & 0 \\ -1 & -1 - \sigma_{21} & 1 + \sigma_{22} & \dots & \vdots \\ 0 & \vdots & \ddots & \ddots & 1 + \sigma_{n-1,n} \\ 0 & -\sigma_{21} & \dots & -1 - \sigma_{n-1,n} & -c_n \end{bmatrix} \quad (78)$$



4. Conclusion

In this paper, the block diagram for power system stabilization problem was used asymptotic tracking of arbitrary smooth bounded reference output signals, with simultaneous rejection of disturbances generated by an unknown linear exosystem and presents a power system stabilizer(PSS) using nonlinear adaptive observer backstepping controller.

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