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DESIGNING POWER SYSTEM STABILIZER WITH PID CONTROLLER

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Abstract- Power stabilizers are used to produce controlling signals for simulation system and to decrease the oscillation of low frequency power system. A variety of methods are proposed to overcome the faults of common power system stabilizer of which we can name fuzzy logic, genetic algorithm, neural networks, PID and PI controller. In this paper we will regard PID controller to control the system based on simulations, it is defined that the PID controller make better answers to common stabilizer.

Keywords: PID Controller, Power System Stabilizer (PSS), Synchronous Generator.

I. INTRODUCTION

Power systems have usually many disturbances. These disturbances lead to bringing low frequency oscillation in power system. The dynamic unstability is caused if the torque in the system is not sufficient. In the past two decades, the controlling signal complementing stimulate generator was used in order to improving dynamic stability.

Today, classic power system stabilizer (PSS) is widely used with stimulate system in powerhouse. The modulation of classic stabilizer coefficient is based on a linear model of system. Approximation of the plan of power system components is changed in the conditions of system construction due to the faults and operation of protection relay. The classic stabilizers would not offer high efficiency in idle range of functioning.

In recent years, different methods are proposed based on controlling techniques of nonlinear systems, adaptive controlling techniques and artificial intelligence techniques to design power system stabilizer. Recent development in design and construction of stimulation system, not only made the application of these techniques in real system possible, but also made it easy to use. The techniques based on artificial intelligence include fuzzy logic, application of artificial neural networks and intelligent searching algorithm such as genetic algorithm, tabor searching algorithm and the algorithm of developing particle swarm. In this paper PID power system stabilizer is presented [1].

II. KUNDUR TEST SYSTEM

The Kundur test system is shown in Figure 1 that consists of two fully symmetrical areas linked together by two 230 kV lines of 220 km length. Each area is equipped with two identical round rotor synchronous acts as thermal plant generators rated 20kV/900MVA connected to transformer (T1, T2, T3, and T4).

The synchronous machines (G1, G2, G3, and G4) in all area have identical parameters, except for inertia which is H=6.5s for all generators in Area 1 and H=6.175s for all generators in Area 2. Thermal generating plants having identical speed regulators and fast static exciters with a 200 gain at all locations. Each generator produces 700 MW.

The loads are assumed everywhere as constant impedance load. The Area 1 and Area 2 loads are 967 MW (L1) and 1767 MW (L2), respectively. The load voltage profile was improved by installing 187 MVAr capacitors (C1 and C2) in each area to make closer to unity. Area 1 is exporting to Area 2 through two tie-lines and a single tie-line with power transfer level 413 MW and 353 MW, respectively [2, 3].

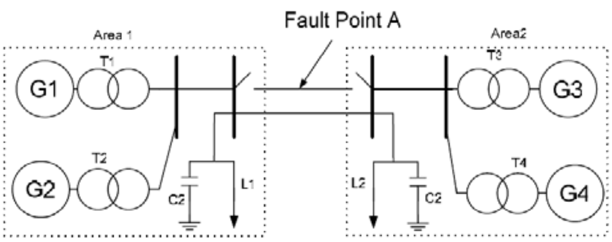

Figure.1. Kundur Test System

III. SYSTEM DYNAMIC MODELING

The system nonlinear dynamic model is derived by neglecting the resistances of all system components including generator, transformers and transmission lines and is given as the following [3].

$$\begin{aligned}
&\dot{\delta} = \omega_0(\omega - 1) \\
&\dot{\omega} = (P_m - P_e - D\Delta\omega)/M \\
&\dot{E}'_q = (-E_q + E_{fd})/T'_{do} \\
&\dot{E}_{fd} = [-E_{fd} + K_a(V_{ref} - V_t)]/T_a
\end{aligned} \quad (1)$$

After linearizing the non-linear dynamic model the system linear dynamic model is obtained. Dynamic model of the system in the state-space form is calculated as the following [3]. The model has also some constants denoted by K_i is known as Heffron-Phillips model.

$$\begin{aligned} \Delta\dot{\delta} &= \omega_0 \Delta\omega \\ \Delta\dot{\omega} &= (-\Delta P_e - D\Delta\omega)/M \\ \Delta\dot{E}'_q &= (-\Delta E_q + \Delta E_{fd})/T'_{do} \\ \Delta\dot{E}_{fd} &= -(1/T_a)\Delta E_{fd} - (K_a/T_a)\Delta V \end{aligned} \quad (2)$$

$$\begin{bmatrix} \Delta\dot{\delta} \\ \Delta\dot{\omega} \\ \Delta\dot{E}'_q \\ \Delta\dot{E}_{fd} \end{bmatrix} = \begin{bmatrix} 0 & \omega_0 & 0 & 0 \\ -\frac{K_1}{M} & 0 & -\frac{K_2}{M} & 0 \\ -\frac{K_4}{T'_{do}} & 0 & -\frac{K_3}{T'_{do}} & \frac{1}{T'_{do}} \\ -\frac{K_a K_5}{T_a} & 0 & -\frac{K_a K_6}{T_a} & -\frac{1}{T_a} \end{bmatrix} \cdot \begin{bmatrix} \Delta\delta \\ \Delta\omega \\ \Delta E'_q \\ \Delta E_{fd} \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ \frac{1}{M} & 0 \\ 0 & 0 \\ 0 & \frac{K_a}{T_a} \end{bmatrix} \cdot \begin{bmatrix} \Delta T_m \\ \Delta V_{ref} \end{bmatrix} \quad (3)$$

III. PSS STABILIZER BASED ON PID CONTROLLER

The PSS is provided to improve the power system oscillations. It provides the electrical damping torque in phase with the speed deviation to improve power system damping. The combination of pole placement and nonlinear programming techniques is considered to design the PSS with PID configuration (PSS-PID).

PID controller is used for stabilization in this system. The input of this stabilizer is the speed changing being modeling from the generator. The output of this controller is delivered to (stabilization voltage) the stimulation block to stabilizer the power system undulation. The aim is to control the angle between load and generator speed.

The nonlinear programming with the combination of pole placement is used for PSS-PID design methodology. The PSS-PID parameters are tuned from open loop transfer function to close loop based on Nichols chart, Nyquist plane and fuzzy logic [4, 5]. Therefore, the open loop transfer function and maximum peak response parameter make the objective function which used to adjust PID parameters.

The PSS-PID parameters are tuned in a nonlinear objective function with nonlinear constraints and solved by the nonlinear programming and fuzzy sets. On the other hand, the objective function $J(K_P, K_I, K_D)$ with the constraints $f(K_P, K_I, K_D)$ is solved considering the nonlinear programming to obtaining of the PID controller parameters (K_P, K_I, K_D) and forming its gain $G_{PID}(s) = K_P + K_I / s + K_D.s$.

The PID gain is applied to the power system gain $G_{PS}(s)$ in equation (3) as a closed loop system to building PSS-PID controller and making angular velocity ω . The power system without PSS is unstable and the PSS-PID structure is stable which its performance done by the defined constraints over the objective function.

IV. SIMULATION RESULT

The Kunder test system in Figure 1 is simulated in Figure 2 considering three phase short circuit between two areas. For having a complete modeling of the system, the surface internal modeling of each area, machine and turbine are shown in Figures 3, 4 and 5. The PID controllers of PSS stabilizer for Kunder test generators are given in Table 1. Each generator parameters are based on data in Table 2.

Load angles of generator before and after applying PSS are demonstrated in Figures 6 and 7. Speeds charging before and after applying PSS are shown in Figures 8 and 9. Electric torques before and after applying PSS are illustrated in Figures 10 and 11. Angular velocity and active power with and without PSS are shown in Figures 12 and 13.

Figures 14 and 15 show the active powers in buses 1 and 2 with and without PSS. Figures 16 and 17 also show the voltage of buses 1 and 2 with and without PSS.

Table 1. Parameters of PID controller

Parameter	K_P	K_I	K_D
G1	10.50	0.67	0.45
G2	9.67	0.60	0.40
G3	9.00	0.50	0.30
G4	8.33	0.67	0.53

Table 2. Parameters of the generator

Parameter	Generator
X_d	1.80
X'_d	0.30
X''_d	0.25
X_q	1.70
X'_q	0.55
X''_q	0.25
X_t	0.20
T_{do}	8
T'_{do}	0.03
T_q	0.40
T'_q	0.05

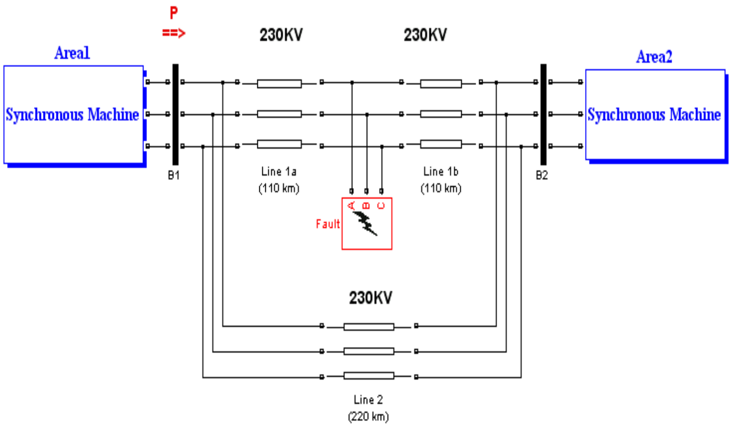

Figure 2. Simulation of Kundur test system

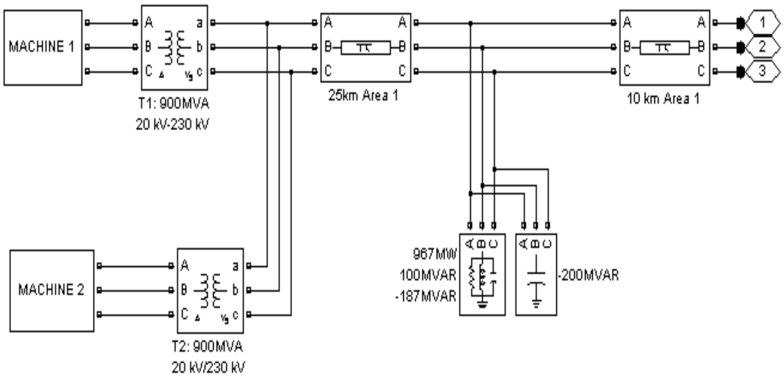

Figure 3. Surface internal area 1

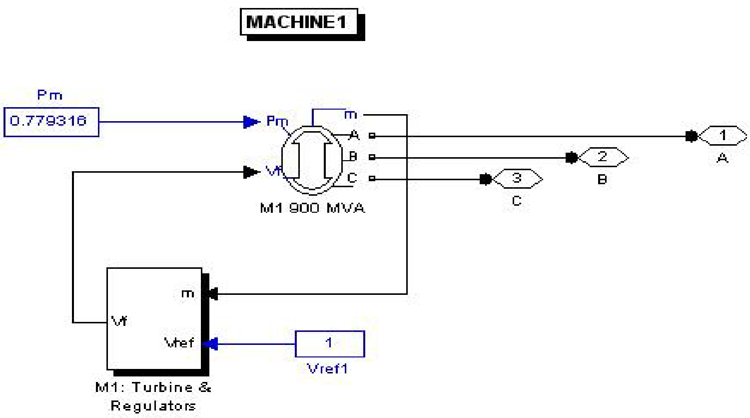

Figure 4. Surface internal machine 1

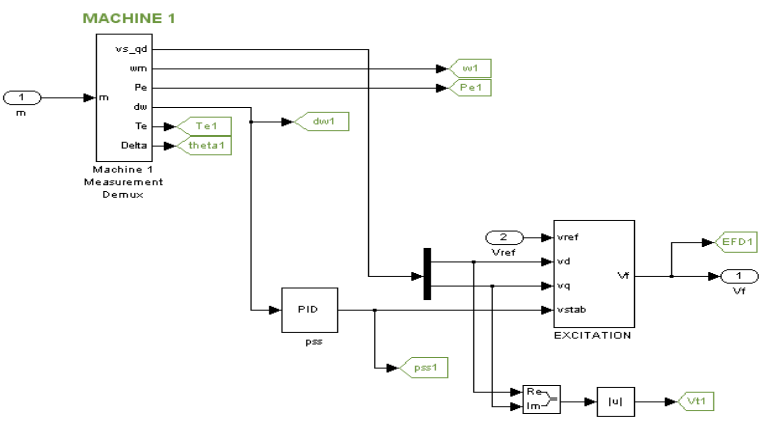

Figure 5. Surface internal turbine

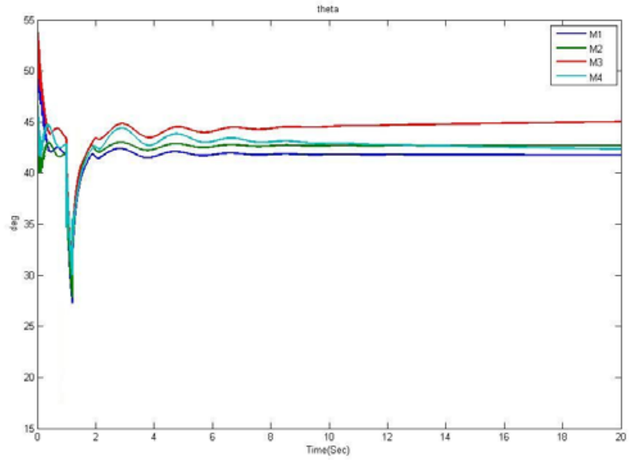

Figure 6. Load angle of generator before applying PSS

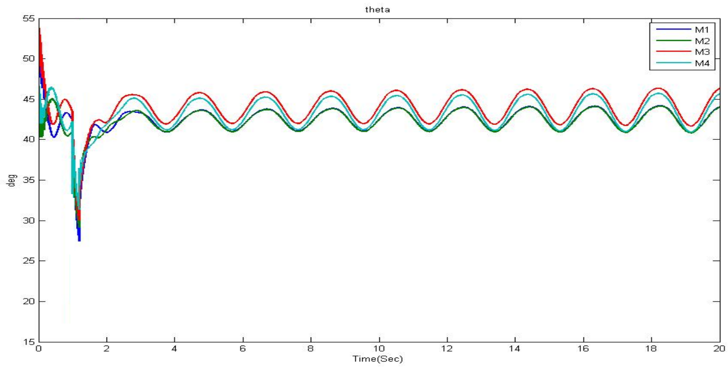

Figure 7. Load angle of generator after applying PSS

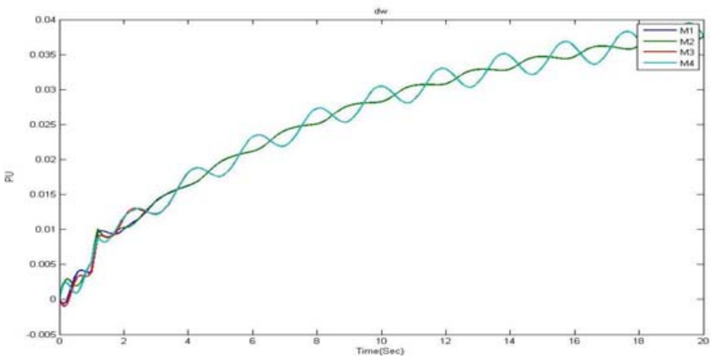

Figure 8. Speed charging before applying PSS

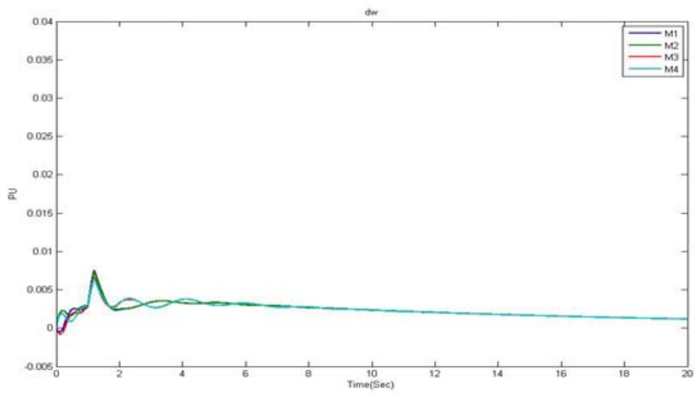

Figure 9. Speed charging after applying PSS

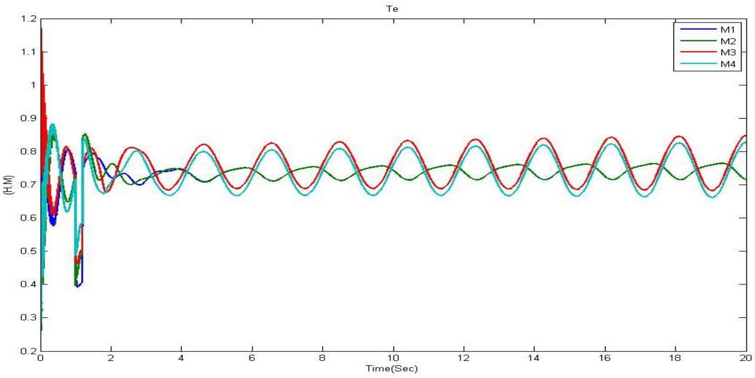

Figure 10. Electric torque before applying PSS

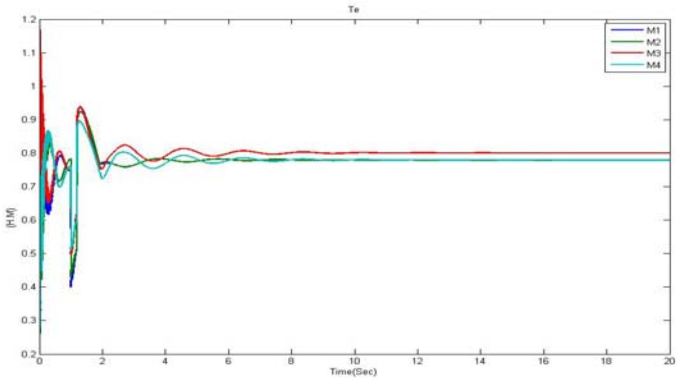

Figure 11. Electric torque before applying PSS

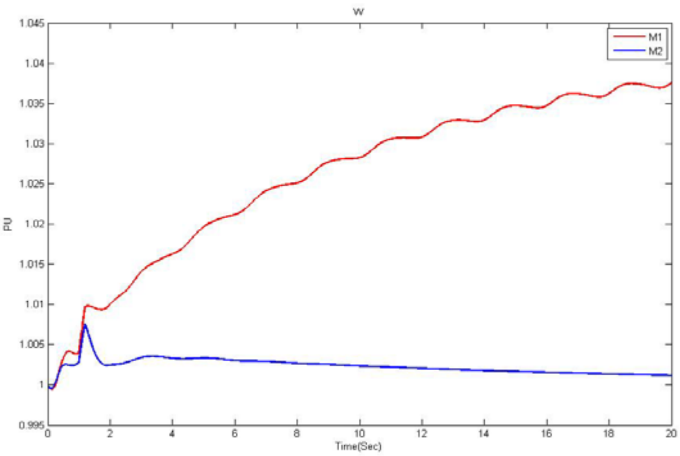

Figure 12. Angular velocity with and without PSS

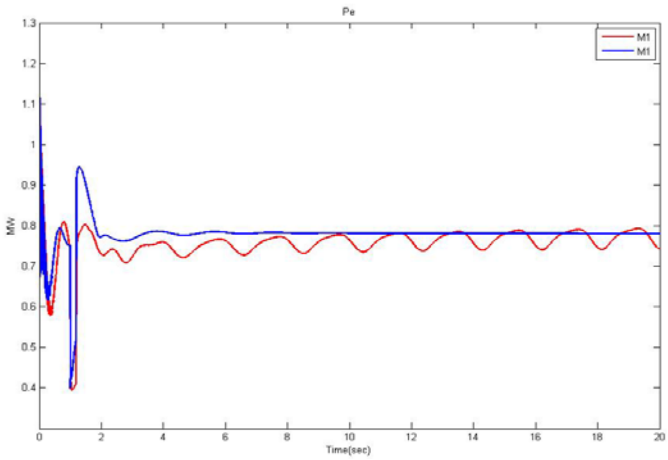

Figure 13. Active power with and without PSS

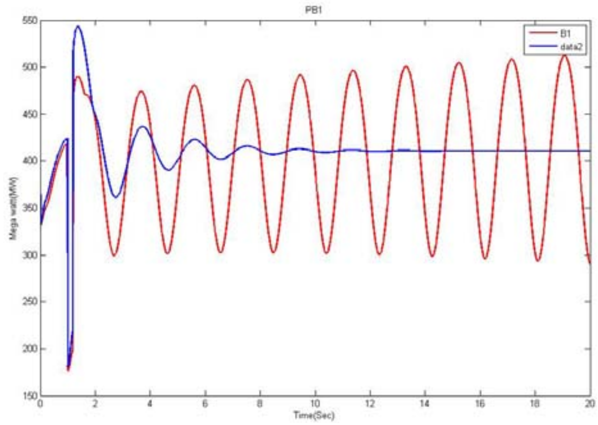

Figure 14. Active power in bus 1 with and without PSS

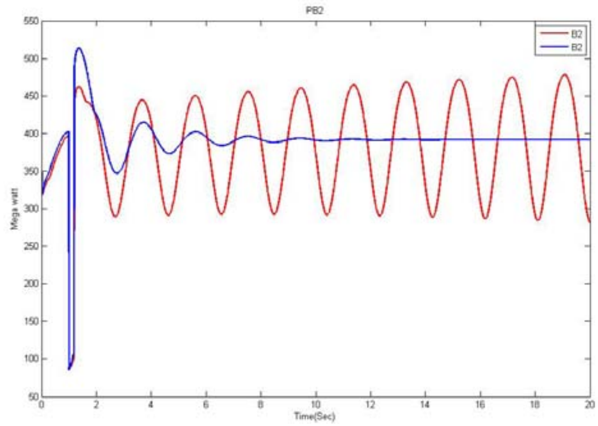

Figure 15. Active power in bus 2 with and without PSS

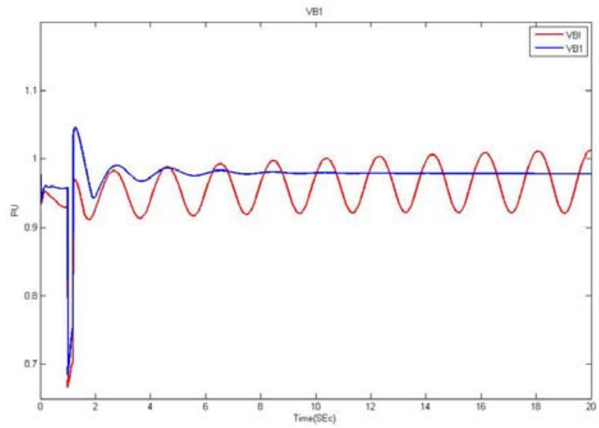

Figure 16. Voltage of bus 1 with and without PSS

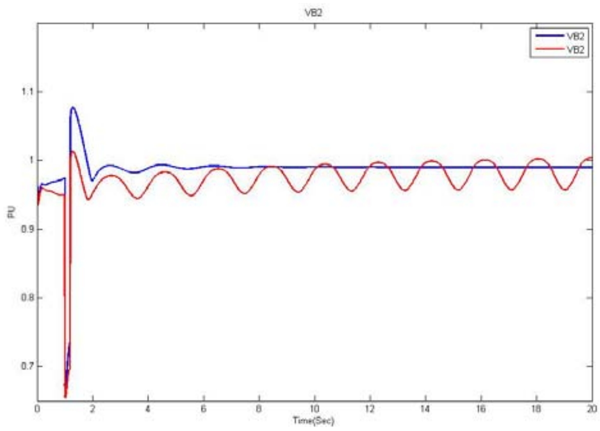

Figure 17. Voltage of bus 2 with and without PSS

V. CONCLUSIONS

Observing the result of simulation, it is obvious that the PID controller based PSS stabilizer (PSS-PID) can stabilize the mentioned synchronous generator. It is also observed that the system turned back to its stabilizer mode after disturbance, due to the three phase short circuit, to compensate the bad impact of disturbance.

NOMENCLATURES

The notation used throughout the paper is stated below.

ω	Angular velocity
P_m	Mechanical power
P_e	Electrical power
D	Damping coefficient
$M = 2H$	Inertia coefficient
δ	Torque angle
E_q	q-axis voltage behind transient reactance
E_{fd}	Equivalent excitation (field) voltage
T'_{do}	d-axis open circuit transient time constant
T'_q	q-axis transient time constant
K_a	Regular voltage gain
V_{ref}	Reference terminal voltage
V_t	Terminal voltage
T_a	Voltage regular time constant
K_i (i=1,..6)	Constants of Heffron-Phillips model

REFERENCES

[1] S.A. Mortezevi and A.M. Nasrabadi, "Design of Stabilizer of Power System with Neural Network", Shahed University, Iran, 2003.

[2] J. Persson, "SIMPOW® - Kundur's Two-Area System", STRI AB, July 1996, Revised September 2004.

[3] P. Kundur, "Power System Stability and Control", McGraw-Hill, 1993.

[4] I. Robandi, "Modern Power System Design", (Desain System Tenaga Modern, in Bahasa Indonesia), Andi Offset Publisher, 2006.

[5] I. Robandi and B. Kharisma, "Design of Interval Type-2 Fuzzy Power System Stabilizer", Proceedings of World Academy of Science Engineering and Technology, Vol. 31, ISSN 1307-688, July 2008.

BIOGRAPHIES

Naser Mahdavi Tabatabaei was born in Tehran, Iran, 1967. He received the B.Sc. and the M.Sc. degrees from University of Tabriz (Tabriz, Iran) and the Ph.D. degree from Iran University of Science and Technology (Tehran, Iran), all in Power Electrical Engineering, in 1989, 1992, and 1997, respectively. Currently, he is a Professor of Power Electrical Engineering at International Ecoenergy Academy, International Science and Education Center and International Organization on TPE (IOTPE). He is also an academic member of Power Electrical Engineering at Seraj Higher Education Institute and teaches Power System Analysis, Power System Operation, and Reactive Power Control. He is the secretary of International Conference on TPE (ICTPE) and editor-in-chief of International Journal on TPE (IJTPE). His research interests are in the area of Power Quality, Energy Management Systems, ICT in Power Engineering and Virtual Elearning Educational Systems. He is a member of the Iranian Association of Electrical and Electronic Engineers (IAEEE).

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