Journal of ELECTRICAL ENGINEERING, VOL. 55, NO. 3-4, 2004, 83–88

TWO LEVEL TURBOGENERATOR CONTROL SYSTEM

Ján Murgaš* — Andrej Dobrovič*
Eva Miklovičová* — Jozef Dúbravský**

The aim of this paper is to design a decentralized control of a non-linear turbogenerator system using the Lyapunov theory of stability. The complex non-linear model of the system to be controlled is decomposed into two subsystems — synchronous generator and turbine. The control structure is decentralized with a simplified co-ordinator. The resulting control system effectiveness is tested on a 259 MVA turbogenerator model.

K e y w o r d s: power system, turbogenerator, power system stabilizer, Lyapunov theory of stability

1 INTRODUCTION

The main aim of papers dealing with power system stabilizer (PSS) design for synchronous generator excitation systems is to assure sufficient damping of the power system transient processes under various operating conditions. The PSS design importance increases when power systems are interconnected with large units, where the complex system stability is a question of prime importance. Decomposition of a large system into isolated islands is a highly undesirable phenomenon bringing significant economical losses.

The PSS development has proceeded from systems with a relatively simple structure and fixed parameters to the adaptive ones using recursive identification of the plant model parameters [5]. During this evolution the simple PSS with lead-lag structure and one stabilizing variable (usually the rotor speed) were replaced by more efficient but also more complex systems.

The power system transient behaviour depends on the disturbance type and if the standard PSS structure is used [8] its damping depends also on the choice of the stabilizing signal (active power, excitation current, terminal voltage, rotor speed deviation). Thus the natural evolution of the standard structure is the multi-loop PSS [14], where various measurable signals or their weighted combination are used as the stabilizing signal. As an example the PSS of the Škoda control system can be mentioned [16], implemented in the 220 MW unit of the nuclear power plant. Here the two-loop structure of PSS has been used with the active power and the excitation current fed back as the stabilizing signals.

Considerable damping improvement for a wide range of disturbances can be obtained using a dynamic compensator whose structure and choice of stabilizing signals can be optimized. Such an approach is typical mainly for the Russian school (namely V.A. Venikov) [17].

Another generalization of the PSS design can be obtained using the state controllers based on the LQ or LQG approach [9], but their implementation is limited by the necessity of using all state variables which are not directly measurable. In recent papers, the PSS design based on non-linear control theory has mainly been used [1, 4, 10], taking into account the non-linear character of the synchronous generator model.

Current research aims to propose new PSS design approaches ensuring very good damping properties under various conditions in the power system. Taking into account the wide range of power system possible changes, the PSS should have the ability of adaptation, while conserving a certain measure of its simplicity. In this category the selftuning algorithms using recursive identification of the plant linear model parameters have mainly been proposed [2, 3, 6, 7, 13, 19]. The third order linear model has often been used to substitute the non-linear plant and the rotor speed deviation has been fed back as the stabilizing signal. The pole placement method with pole-shift modification has proved to be convenient for the PSS parameter synthesis. Further improvement has been obtained by introducing the variable forgetting into the identification algorithm and by the pole-shift factor adaptation [2].

The paper is organized as follows. In Section 2 the Lyapunov direct method used in turbogenerator control design is introduced. The turbogenerator model is described in Section 3, where two control variables are assumed, namely the excitation voltage and the turbine valve opening. A detailed description of turbogenerator decentralized control design methodology is in Section 4. In Section 5 the control system performances are evaluated in simulation of the turbogenerator model of the 259 MVA power.

*Department of Automatic Control Systems, **Department of Control and Automation, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Ilkovičova 3, 812 19 Bratislava, Slovakia

ISSN 1335-3632

2 THEORETICAL BACKGROUND

The direct Lyapunov method [11, 15], due to its generality, is a powerful tool for non-linear system analysis. However, it can also be used for other problems in non-linear systems. In the following we briefly introduce the concept of Lyapunov's direct method and then discuss how to apply it for designing stable control systems.

DEFINITION 1. x^* is the equilibrium point of the dynamic system described by a set of non-linear equations:

$$\dot{x} = f(x)$$

if once $x(t)$ is equal to x^*, it remains x^* for all future time.

Mathematically this means that x^* satisfies:

$$f(x^*) = 0\,. \tag{1}$$

In many practical problems we are not concerned with stability around an equilibrium point, but rather whether a system trajectory $x(t)$ will remain close to its original trajectory $x^*(t)$ if slightly perturbed away from it. This kind of stability problem can be transformed into an equivalent problem, where we study the stability of the perturbation dynamics with respect to the equilibrium point 0. The Lyapunov theorem for global stability allows concluding the stability of a system by examining the variations of a single scalar function.

THEOREM 1. *Assume that there exists a scalar function V of the state x, with continuous first order derivatives such that:*

1. $V(x)$ *is positive definite* (2)
2. $\dot{V}(x) = \dfrac{dV(x)}{dt}$ *is negative definite* (3)
3. $V(x) \to \infty$ *as* $x \to \infty$ (4)

Then the equilibrium point at the origin is globally asymptotically stable.

The time derivative $\dot{V}(x)$ along the system trajectory $x(t)$ can be calculated as follows:

$$\dot{V}(x) = \frac{\mathrm{d}V(x)}{\mathrm{d}t} = \frac{\partial V}{\partial x_1}\frac{\partial x_1}{\partial t} + \frac{\partial V}{\partial x_2}\frac{\partial x_2}{\partial t} + \cdots + \frac{\partial V}{\partial x_n}\frac{\partial x_n}{\partial t}$$

The Lyapunov's direct method can be used in control design problems, where our task is to find an appropriate control law for a given plant. The control design procedure requires hypothesizing a Lyapunov function candidate and then finding the control law to make this candidate a real Lyapunov function, namely:

1. For given dynamic system $\dot{x} = f(x)$ find an appropriate Lyapunov function $V(x)$ that is an explicit function of the control variables.
2. Select the control law that maximizes the negative value of $\dot{V}(x)$ at all points along the system trajectory $x(t)$.
3. Select locally available signals to execute the chosen control law.

3 PLANT MODEL

The turbogenerator model used in this design has been decomposed into two subsystems. The first subsystem describes the electromechanical processes in the system and is given by:

$$\begin{aligned} \frac{\mathrm{d}\delta}{\mathrm{d}t} &= \omega \\ M\frac{\mathrm{d}\omega}{\mathrm{d}t} &= P_m - P_e - D\omega \\ T_g\frac{\mathrm{d}P_m}{\mathrm{d}t} &= -P_m + U_g \end{aligned} \tag{5}$$

The second subsystem describes the turbogenerator electrodynamic processes and is of the form:

$$\begin{aligned} T'_{q0}\frac{\mathrm{d}E'_d}{\mathrm{d}t} &= -E'_d - (x_q - x'_q)I_q = E_{dd} \\ T'_{d0}\frac{\mathrm{d}E'_q}{\mathrm{d}t} &= E_f - E'_q + (x_d - x'_d)I_d = E_f - E_q \end{aligned} \tag{6}$$

The active power P_e is expressed as follows:

$$P_e = V_d I_d + V_q I_q \tag{7}$$

where

$$\begin{aligned} I_q &= \frac{V_b}{z}\sin\delta - \frac{E'_d}{z} \\ I_d &= \frac{V_b}{z}\cos\delta + \frac{E'_q}{z} \\ V_d &= E'_d - x'_q I_q \\ V_q &= E'_q + x'_d I_d \end{aligned} \tag{8}$$

Substituting (8) into equation (7) yields:

$$P_e = s_1 E'_q \sin\delta + s_2 E'_d \cos\delta + s_3 \sin 2\delta + s_4 E'_d E'_q \tag{9}$$

where s_1, s_2, s_3, s_4 are functions of $(V_b,\, x'_q,\, x'_d,\, z)$:

$$\begin{aligned} s_1 &= \frac{x'_q V_b}{z^2} + \frac{V_b}{z} - \frac{x'_d V_b}{z^2} \\ s_2 &= \frac{x'_d V_b}{z^2} + \frac{V_b}{z} - \frac{x'_q V_b}{z^2} \\ s_3 &= \frac{x'_q V_b^2}{2z^2} + \frac{x'_d V_b^2}{2z^2} \\ s_4 &= \frac{x'_q}{z^2} - \frac{x'_d}{z^2} \\ z &= x'_d + x_{tr} + x_l \end{aligned} \tag{10}$$

The turbogenerator control variables are the excitation E_f and the governor input U_g. The Lyapunov theory

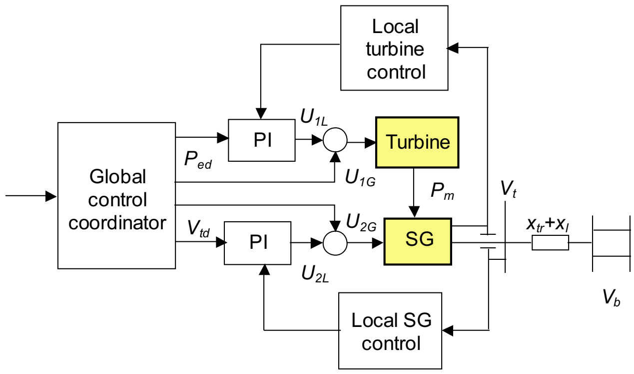

Fig. 1. The turbogenerator control structure

of stability assumes that the system under investigation has an equilibrium point at point $x = 0$. Hence the turbogenerator variables have to be transformed:

$$\begin{aligned} x_1^\top &= [\,x_{11} \quad x_{12} \quad x_{13}\,] = \big[\,\delta - \delta_0, \quad \omega, \quad \tfrac{P_m - P_e}{M}\,\big] \\ x_2^\top &= [\,x_{21} \quad x_{22}\,] = [\,E'_d - E'_{d0}, \quad E_{dd}\,] \\ U_g &= U_{1L} + U_{1G} \end{aligned} \tag{11}$$

where δ_0, E'_{d0} are the setpoint values of variables. The first subsystem equations after transformation become:

$$\begin{aligned} \frac{\mathrm{d}x_{11}}{\mathrm{d}t} &= x_{12} \\ \frac{\mathrm{d}x_{12}}{\mathrm{d}t} &= x_{13} - \frac{D}{M}x_{12} \\ \frac{\mathrm{d}x_{13}}{\mathrm{d}t} &= \frac{1}{M}\Big(\frac{\mathrm{d}P_m}{\mathrm{d}t} - \frac{\mathrm{d}P_e}{\mathrm{d}t}\Big) = \frac{1}{T_g}\Big[-x_{13} \\ &\quad + \frac{1}{M}(-P_e + U_{1L})\Big] - \frac{1}{M}\dot{P}_e + \frac{1}{T_g M}U_{1G} \end{aligned} \tag{12}$$

where $\dot{P}_e = \frac{\mathrm{d}P_e}{\mathrm{d}t}$. For the second subsystem we can write:

$$\begin{aligned} \frac{\mathrm{d}x_{21}}{\mathrm{d}t} &= x_{22} \\ \frac{\mathrm{d}x_{22}}{\mathrm{d}t} &= -\frac{1}{T'_{q0}}x_{22} + \frac{x_q - x'_q}{z}\Big[-V_b\cos(x_{11} + \delta_0)x_{12} \\ &\quad + \frac{1}{T'_{d0}}(U_{2L} - E_q)\Big] + \frac{x_q - x'_q}{zT'_{d0}}U_{2G} \end{aligned} \tag{13}$$

4 CONTROL DESIGN

The turbogenerator control design is based on the decentralized control principle [12, 18]. More specifically, for each subsystem the local (first level) stabilizing control is designed using only the isolated subsystem state variables. On the second (global) control level the reduced information from both subsystems can be used. The control structure is shown in Figure 1.

Consider the decomposed turbogenerator model in general form:

$$\begin{aligned} \dot{x}_1 &= f_1(x_1) + h_{12}(x_2) + b_1U_{1L} + b_1U_{1G} \\ \dot{x}_2 &= f_2(x_2) + h_{21}(x_1) + b_2U_{2L} + b_2U_{2G} \end{aligned} \tag{14}$$

where $f_i(x_i)$, $i = 1,2$ are non-linear functions describing the isolated subsystem dynamics; $h_{ij}(x_j)$, $i = 1,2$; $j = 1,2$; $j \neq i$ are functions describing the subsystem interactions; b_i, $i = 1,2$ are input vectors.

For the turbogenerator mathematical model stated in Section 3 the above mentioned functions and vectors are of the form:

$$\begin{aligned} f_1 &= \begin{bmatrix} x_{12} \\ x_{13} - \frac{D}{M}x_{12} \\ -\frac{1}{T_g}x_{13} \end{bmatrix}, \quad f_2 = \begin{bmatrix} x_{22} \\ -\frac{1}{T'_{q0}}x_{22} - \frac{x_q - x'_q}{T'_{d0}z}E_q \end{bmatrix}, \\ b_1 &= \begin{bmatrix} 0 \\ 0 \\ \frac{1}{T_gM} \end{bmatrix}, \qquad b_2 = \begin{bmatrix} 0 \\ \frac{x_q - x'_q}{T'_{d0}\,z} \end{bmatrix}, \\ h_{12} &= \begin{bmatrix} 0 \\ 0 \\ -\frac{1}{M}\big(\dot{P}_e + \frac{1}{T_g}P_e\big) \end{bmatrix}, \\ h_{21} &= \begin{bmatrix} 0 \\ 0 \\ -\frac{x_q - x'_q}{z}V_b\cos(x_{11} + \delta_0)x_{12} \end{bmatrix}. \end{aligned} \tag{15}$$

The control design consists of the following steps:

1. For the isolated subsystems described by:
$$\dot{x}_i = f_i(x_i) + b_iU_{iL} \quad i = 1,2 \tag{16}$$
the Lyapunov function candidates $V_i(x_i)$ are chosen in as simple form as possible.
2. The local turbogenerator control law is proposed so that the following condition is satisfied:
$$\begin{aligned} &\frac{\mathrm{d}V_i(t)}{\mathrm{d}t} \le 0 \\ ie \quad &[\operatorname{grad} V_i(x_i)]^\top\,[f_i(x_i) + b_iU^*_{iL}(x_i)] \le 0 \end{aligned} \tag{17}$$
where the control $U^*_{iL}(x_i)$ is designed using the feedback linearization principle:
$$U^*_{iL}(x_i) = \frac{1}{b_i}\,[-f_i(x_i) - k_i^\top x_i] \tag{18}$$
The $k_i^\top x_i$ term in equation (18) defines the isolated subsystem dynamics with designed control. The parameters of this term are chosen on the basis of isolated subsystem desired response.
3. The higher hierarchical level (global) control can be derived using the information from both subsystems, but in a considerably reduced form. The main design principle is to reduce the influence of subsystem interaction on the subsystem dynamics. The best solution is to design the global control in the form:
$$U^*_{iG} = \frac{1}{b_i}\,[-h_{ij}(x_j)] \quad i = 1,2 \tag{19}$$

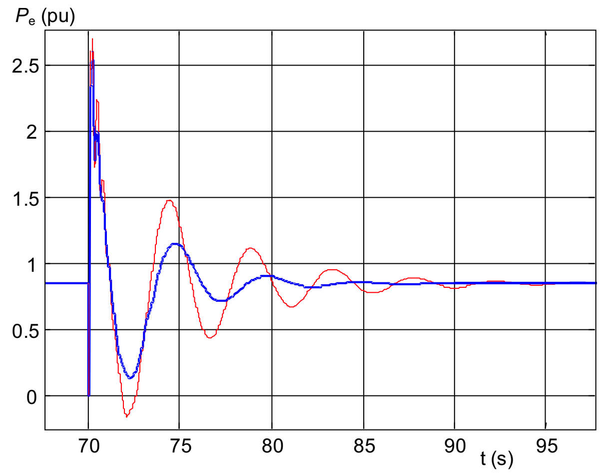

Fig. 4. Active power response to the 100 ms short circuit in the busbar with and without PSS

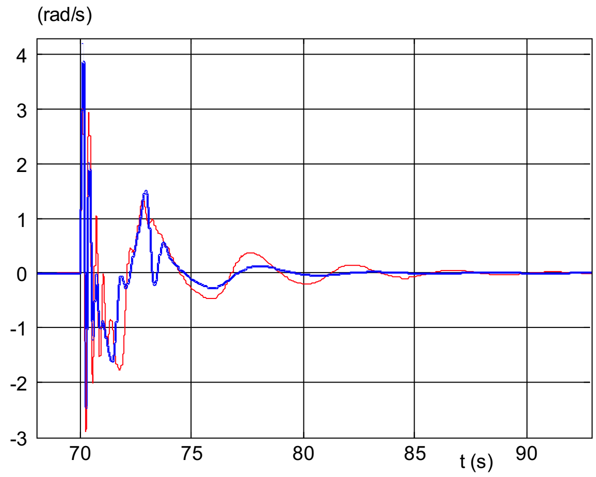

Fig. 5. Angular velocity response to the 100 ms short circuit in the busbar with and without PSS

4.1 Local Level Control Design

The turbogenerator local control design is based on the Lyapunov theory of stability and is performed separately for each isolated subsystem. Let us choose the following Lyapunov function candidates:

$$\begin{aligned} V_1(x_1) &= \frac{1}{2}x_{11}^2 + \frac{1}{2}x_{12}^2 + \frac{1}{2}x_{13}^2 \\ V_2(x_2) &= \frac{1}{2}x_{21}^2 + \frac{1}{2}x_{22}^2 \end{aligned} \tag{20}$$

satisfying:

$$\begin{aligned} V_1(0) = 0 \quad &\text{and} \quad V_1(x_1) > 0 \\ V_2(0) = 0 \quad &\text{and} \quad V_2(x_2) > 0 \end{aligned} \tag{21}$$

for all $x_{ij} \in (-\infty; \infty)$ $i = 1, 2;$ $j = 1, 2, 3$.
The Lyapunov function gradients must be continuous functions:

$$\begin{aligned} (\operatorname{grad} V_1)^\top &= [\, x_{11} \quad x_{12} \quad x_{13} \,] \\ (\operatorname{grad} V_2)^\top &= [\, x_{21} \quad x_{22} \,] \end{aligned} \tag{22}$$

Moreover the Lyapunov function candidates (20) are required to satisfy the condition (3) of Theorem 1. For the first subsystem it yields:

$$\begin{aligned} \frac{\mathrm{d}V_1}{\mathrm{d}t} &= (\operatorname{grad} V_1)^\top \frac{\mathrm{d}x_1}{\mathrm{d}t} = x_{12}x_{11} \\ &+ x_{12}\Big(x_{13} - \frac{D}{M}x_{12}\Big) - \frac{1}{T_g}x_{13}^2 + \frac{1}{MT_g}x_{13}U_{1L} \end{aligned} \tag{23}$$

Let the first subsystem control signal be in the form:

$$U_{1L} = -MT_g\left(x_{12} + \frac{x_{11}x_{12}}{x_{13}}\right) \cong -k_1\omega - k_2\delta_f \tag{24}$$

where δ_f is the filtered load angle signal $\delta_f(s) = \frac{1}{1+s\frac{M}{D}}\delta(s)$ and $k_1 = MT_g$, $k_2 = \frac{M^2}{D}T_g$

After substituting (24) into (23) we obtain:

$$\frac{\mathrm{d}V_1}{\mathrm{d}t} = -\frac{D}{M}x_{12}^2 - \frac{1}{T_g}x_{13}^2 \leq 0 \tag{25}$$

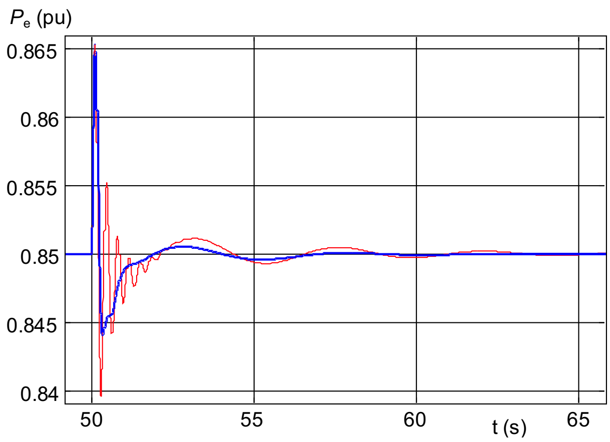

Fig. 2. Active power responses to the 2 % terminal voltage step increase with and without PSS

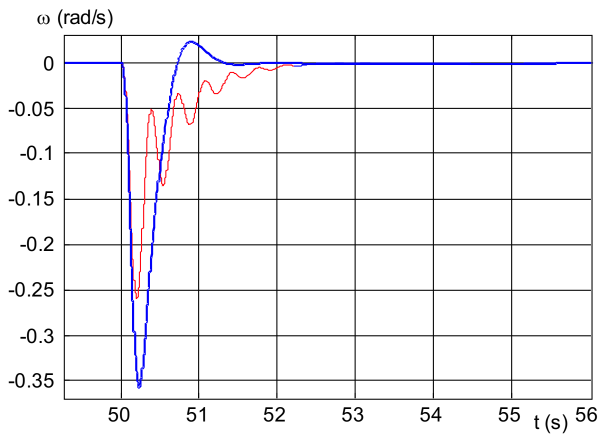

Fig. 3. Angular velocity response to the 2 % terminal voltage step increase with and without PSS

The derivative of the second subsystem Lyapunov function candidate is:

$$\frac{\mathrm{d}V_2}{\mathrm{d}t} = \left(\operatorname{grad} V_2\right)^\top \frac{\mathrm{d}x_2}{\mathrm{d}t} = x_{21}x_{22} - \frac{1}{T'_{q0}}x_{22}^2 + \frac{x_q - x'_q}{zT'_{d0}}U_{2L}x_{22} - \frac{x_q - x'_q}{zT'_{d0}}E_q x_{22} \quad (26)$$

Choosing the second subsystem control signal as

$$U_{2L} = -\frac{zT'_{d0}}{x_q - x'_q}x_{21} + E_q \cong E_q - k_e(E'_d - E'_{d0}) \quad (27)$$

with $k_e = \frac{zT'_{d0}}{x_q - x'_q}$, and substituting it into (26) we have

$$\frac{\mathrm{d}V_2}{\mathrm{d}t} = -\frac{1}{T'_{q0}}x_{22}^2 \quad (28)$$

As it can be seen from equations (25) and (28), condition (3) of Theorem 1 is satisfied for Lyapunov functions of both subsystems.

4.2 Global Level Control Design

The global level control uses the control signals from both subsystems — exciter and governor. The global control of turbine is given as:

$$U_{1G} = P_e + T_g\frac{\mathrm{d}P_e}{\mathrm{d}t} \quad (29)$$

and the global control of excitation is then:

$$U_{2G} = T'_{d0}V_b\cos(x_{11} + \delta_0) \cong k_\delta\omega\cos\delta \quad (30)$$

5 SIMULATIONS

The proposed control design procedure has been evaluated by control of the 259 MVA turbogenerator connected via a transformer to an infinite busbar system. To simulate the turbogenerator behaviour the fifth order model for the generator and the first order system of the turbine [11]has been used.

The time responses of relevant system variables to a 2 % step increase of the terminal voltage required value are shown in Figure 2 and Figure 3. The active power response is depicted in Figure 2 while the angular velocity response is shown in Figure 3. Figure 4 and Figure 5 illustrate the system response to a 100 ms short circuit in the busbar lines. The active power response can be seen in Figure 4 and the angular velocity response in Figure 5. In all figures, the bold line represents the turbogenerator response using the proposed control system while the thin line corresponds the standard PI regulator.

6 CONCLUSIONS

The paper describes an application of a MIMO PSS for the turbogenerator, which provides very effective damping of the transition processes in the power transition networks because the control of the active power and the terminal voltage is co-ordinated. Simulation results revealed excellent dynamic properties of the proposed control system.

References

[1] DOBROVIČ, A.—MURGAŠ, J.: Application of the Feedback Linearization for Synchronous Generator Excitation Control System Design, International Workshop Control and Information Technology, Ostrava, Czech Republic, 19.-20.9.2001.

[2] CHEN, G.P.—MALIK, O.P.—HOPE, G.S.—QIN, Y.H.—XU, G.Y.: An Adaptive PSS Based on the Self Optimizing Pole Shifting Control Strategy, IEEE Trans. on Energ. Conv. **EC-8** (1993), 639-646.

[3] CHOW, J.H.—SANCHES-GASCA, J.J.: Pole-Placement Designs of Power System Stabilizers, IEEE Trans. on Power Systems **4** (1989), 271-277.

[4] GAO, L.—CHEN, L.—FAN, Y.—MA, H.: A Non-linear Control Design for Power Systems, Automatica **28** (1992), 975-979.

[5] GHOSH, A.—LEDWICH, G.—MALIK, O.P.—HOPE, G.S.: Power System Stabilizer Based on Adaptive Control Techniques, IEEE Trans. on PAS **103** (1984), 1983-1989.

[6] GU, W.—BOLLINGER, K.E.: A Self-Tuning Power System Stabilizer for Wide-Range Synchronous Generator Operation, IEEE Trans. on Power Systems **4** (1989), 1191-1199.

[7] IBRAHIM, A.S.—HOGG, B.W.—SHARAF, M.M.: Self-Tuning Controllers for Turbogenerator Excitation and Governing Systems, IEE Proc. **136** Pt.D. (1989), 238-251.

[8] IEEE Working Group Report. Dynamic Models for Fossil Fuelled Steam Units in Power System Studies, IEEE Trans. on Power Systems, PWRS-6, 1991.

[9] LAHOUD, M.A.—HARLEY, R.G.—SACKER, A.: Proportional and Integral Optimal Control of a Turbogenerator, El. Power Sys. Research **7** (1984), 173-190.

[10] KENNEDY, D.—MILLER, D.—QUINTANA, V.: A Non-Linear Geometric Approach to Power System Excitation Control and Stabilization, Electric Power & Energy Systems **20** No. 8 (1998), 501-515.

[11] MACHOWSKI, J.— BIALEK, J.W.—BUMBY, J.R.: Power System Dynamics and Stability, John Wiley & Sons, Chichester, 1997.

[12] MUDRONČÍK, D.—VESELÝ, V.: Power System Stabilisation Using the Dominant Subsystem Principle, IEE Proc. Gener. Transm. Distrib. **141** (1994), 243-247.

[13] MURGAŠ, J.—RÉPÁS, Š.—HEJDA, I.: Self-Tuning Regulator for a Turbogenerator, Journal of Electrical Engineering **43** (1992), 59-64.

[14] OHTSUKA, K.—YOKOKAWA, S.—TANAKA, H.—DOI, H.: A Multivariable Optimal Control System for a Generator, IEEE Trans. on Energy Conversion **1** (1986), 88-95.

[15] SLOTINE J.E.—LI, W.: Applied Non-linear Control, Englewood Cliffs, New Jersey, 1991.

[16] ŠKODA ELEKTRICKÉ STROJE: Excitation systems, firm publication.

[17] VENIKOV, V.A.: Power System Dynamic Behaviour, Vysshaya shkola, Moscow, 1978. (In Russian)

[18] VESELÝ, V.—MURGAŠ, J.: Decentralized Adaptive Stabilization of Non-linear Systems, Int. J. Control **58** (1993), 1445-1460.

[19] WU, Q.H.—HOGG, B.W.: Laboratory Evaluation of Adaptive Controllers for Synchronous Generators, Automatica **27** (1991), 845-852.

Received 16 June 2003

APPENDIX A — list of principal symbols

E_q – steady-state emf induced in the fictitious q-axis armature coil proportional to the field winding self-flux linkages

E'_d – transient emf induced in the fictitious d-axis armature coil proportional to the flux linkages of the q-axis coil representing in the solid steel rotor body

E'_q – transient emf induced in the fictitious q-axis armature coil proportional to the field winding flux linkages

E''_d – subtransient emf induced in the fictitious d-axis armature coil proportional to the total q-axis rotor flux linkages

E''_q – subtransient emf induced in the fictitious q-axis armature coil proportional to the total d-axis rotor flux linkages

E_f – excitation voltage

V_d, V_q – voltages across the fictitious d- and q-axis armature coils

V_t – generator terminal voltage

V_b – busbar voltage

I_d, I_q – currents flowing in the fictitious d- and q-axis armature coils

ω – angular velocity of the generator (in electrical radians)

δ – power (or rotor) angle with respect to the voltage at the generator terminals

P_m – mechanical power supplied by the prime mover to a generator

P_e – electromagnetic air-gap power

T'_{d0}, T''_{d0} – short-circuit d-axis transient and subtransient time constants

T'_{q0}, T''_{q0} – short-circuit q-axis transient and subtransient time constants

x_d, x'_d, x''_d – d-axis synchronous, transient and subtransient reactance

x_q, x'_q, x''_q – q-axis synchronous, transient and subtransient reactance

x_{tr} – transformer reactance

x_l – line reactance

M – constant proportional to inertia

D – damping factor

T_g – turbine time constant

Ján Murgaš (Prof, Ing, PhD), born in 1951, graduated in control engineering in 1975 and received the PhD degree in 1980 from the Faculty of Electrical Engineering, Slovak University of Technology in Bratislava. Since 1996 he has been Full Professor for control engineering. His research interests include adaptive and non-linear control, large-scale systems. He is a member of the IEEE, of the American Mathematical Society and of the Slovak Society for Cybernetics and Informatics.

Andrej Dobrovič (Ing) graduated from the Faculty of Electrical Engineering and Information Technology, Slovak University of Technology (FEI STU) in 1999. Since 1999 he has been a PhD student in the Department of Control Systems, FEI STU. His research activities include modeling of industrial processes, adaptive control, feedback linearization and Lyapunov theory control.

Eva Miklovičová (Ing, PhD) graduated from the Faculty of Electrical Engineering and Information Technology, Slovak University of Technology (FEI STU) in 1990 and received her PhD in Automation in 1997. Since 1990 she has been with the Department of Automatic Control Systems, FEI STU. Within her research and teaching activities she focuses on modeling of industrial processes, adaptive control, predictive control and non-linear system control.

Jozef Dúbravský (Ing), born in 1952 and graduated in control engineering in 1976 from the Faculty of Electrical Engineering, Slovak University of Technology in Bratislava. He works at the Department of Control and Automation of the Faculty of Electrical Engineering of the Slovak University of Technology in Bratislava. His research activities include control systems, electronics and control of power systems.