STEAM-TURBINE FUZZY CONTROL

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ABSTRACT

Mathematical models of particular parts of a steam turbine control system are presented, including detailed model of the electro hydraulic system for the positioning of the control valves. On the basis of the mathematical model of the entire system, using the mathematical software Matlab the simulation models were made. Classical methods for turbine controller designing (PID) are compared with the fuzzy control system presented in the paper. Attention is also given to fault detection and isolation in the turbine control system.

Key words: Steam Turbine Dynamic Model, Steam-Turbine Control, Fuzzy Control, and Electro-Hydraulic Actuator System

1. INTRODUCTION

To move intelligent control from the academic research to the practice, it is vitally important to present the techniques of intelligent systems for specific industrial control framework. In this paper mathematical models of particular parts of a steam turbine control system are presented [1], including detailed model of the electro hydraulic system [2] for the positioning of the control valves. Classical methods for turbine controller designing (PID) are compared with the fuzzy control system presented in the paper.

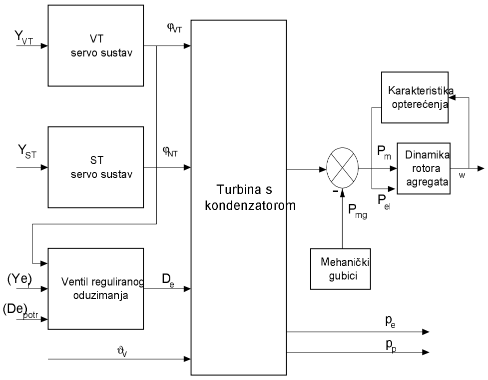

Figure 1 Configuration of the presented steam turbine

2. MATEMATICAL MODEL

The mathematical model of the electro hydraulic actuator, the steam turbine, the condenser and the generator are shown in Eq (1-22).

$$\frac{u_{ax}}{u_a} = F_{empr} = \frac{1}{T \bullet s + 1} \tag{1.}$$

$$Q_1 = k_{pr1} \bullet u_{ax} \bullet \left(s_s(u_{ax}) \bullet \sqrt{P_s - P_1} + s_s(-u_{ax}) \bullet \sqrt{P_1 - P_r} \right) \tag{2.}$$

$$Q_2 = k_{pr2} \bullet u_{ax} \bullet \left(s_s(u_{ax}) \bullet \sqrt{P_2 - P_r} + s_s(-u_{ax}) \bullet \sqrt{P_s - P_2} \right) \tag{3.}$$

$$k \bullet u_{ax} = C_q \bullet a_0 \bullet \left(\frac{\sqrt{2}}{\sqrt{\rho}} \right) \tag{4.}$$

$$s_s(u_{ax}) = \begin{cases} 1, & u_{ax} \geq 0 \\ 0, & u_{ax} < 0 \end{cases} \tag{5.}$$

$$\dot{P}_1 = \frac{\beta}{V_1 + V_h} \left(Q_1 - V_1 \dot{\varphi}_a \right) \tag{6.}$$

$$\dot{P}_2 = -\frac{\beta}{V_2 + V_h} \left(Q_2 - V_2 \dot{\varphi}_a \right) \tag{7.}$$

$$V_2 = \left(V - V_1 \right) \tag{8.}$$

$$(P_1 \bullet A_1 - P_2 \bullet A_2) \bullet r - \dot{\varphi} \bullet \mu \bullet r - M_{opt} = J \bullet \ddot{\varphi} \tag{9.}$$

$$D_{VT} = (D_{VT})_{\varphi_{VT}=1} \bullet \varphi_{VT} \tag{10.}$$

$$D_{ST} = \frac{(D_{ST})_{\varphi_{ST}=1}}{(p_e)_{nom}} \bullet \varphi_{ST} \bullet p_e \quad (11.)$$

$$T_{V1} \bullet \frac{d(D_{VT})_1}{dt} = D_{VT} - (D_{VT})_1 \quad (12.)$$

$$T_{V2} \bullet \frac{d(D_{ST})_i}{dt} = (D_{ST})_i - (D_{NT}) \quad (13.)$$

$$T_{V3} \bullet \frac{d(D_{NT})_i}{dt} = (D_{NT}) - (D_{NT})_i \quad (14.)$$

$$(P_T)_U = (P_T)_{VT} + (P_T)_{ST} + (P_T)_{NT} \quad (15.)$$

$$h_e = 1.4023 \bullet 10^6 \bullet p_e^{0.05353} \quad (16.)$$

$$h_p = 1.49988 \bullet 10^6 \bullet p_p^{0.047298} \quad (17.)$$

$$a_p \bullet V_p \bullet \frac{dp_p}{dt} = (D_{NT})_i - D_k \quad (18.)$$

$$K_{kond} = \left[\frac{D_k}{\vartheta_p - \vartheta_v} \right]_{nom} \quad (19.)$$

$$D_k = K_{kond} \bullet (\vartheta_p - \vartheta_v) \quad (20.)$$

$$a_e \bullet V_e \bullet \frac{dp_e}{dt} = (D_{VT})_i - D_{ST} - D_e \quad (21.)$$

$$J_m \bullet \dot{w} = \frac{P_B}{w} \bullet (P - P_{el}) \quad (22.)$$

Symbols and abbreviations*:*

u_a- voltage [V],

F_{empr}- servo valve electrical part transfer function

Q_1 -oil flow in chamber 1[m^3/s]

Q_2 -oil flow in camber 2 [m^3/s]

P_s –pump oil pressure[Pa]

P_1-oil pressure in chamber 1 [Pa]

P_2-oil pressure in camber 2 [Pa]

P_r -storage oil pressure [Pa]

A_1=A_2 area of cross section[m^2]

β -oil bulk modul [Pa]

V1-volume in chamber 1[m^3]

V2-volume in chamber 2[m^3]

J moment inertia [kgm^2]

D_{VT} - high pressure steam flow [kg/s]

φ_{VT} - high pressure steam valve position [p.u.]

D_{ST} - intermediate pressure steam flow [kg/s]

φ_{ST} int. pressure steam valve position [p.u.]

p_e - intermediate steam pressure [Pa]

T_{V1}, T_{V2}, T_{V3} - time constant [s]

$(P_T)_U$ - total power delivered [W]

$(P_T)_{VT}$ -power delivered by high pressure section [W]

$(P_T)_{ST}$ power delivered by int. pressure section [W]

$(P_T)_{NT}$ power delivered by low pressure section [W]

h_1 - high pressure steam specific enthalpy [J/kg]

h_p - int. pressure steam specific enthalpy [J/kg]

h_e - condensate specific enthalpy [J/kg]

a_p - pressure-density rate [kg/m^3Pa]

ϑ_p - low pressure steam temperature [K]

ϑ_v - condensate temperature [K]

K_{kond} - condensate coefficient

P- mechanical power [p.u.]

P_{el} electrical power [p.u.]

w –frequency of generator[rad/s]

J_m moment inertia of generator[kgm^2]

3. FUZZY CONTROLER

The fuzzy controller used in this example is Mamdani type [3] and structure of controller is shown in Figure 2. Inside the block Fuzzy in Figure 2 fuzzyfication of input signals, inference mechanism and defuzzyfication are included. The parameters of the fuzzy controller are shown in Figures 2 a,b membership functions and in Figures 3 a,b Output surface, for valve 1 and 2. This Mamdani fuzzy controler is used to the control non-linear MIMO plant (the steam turbine plant).

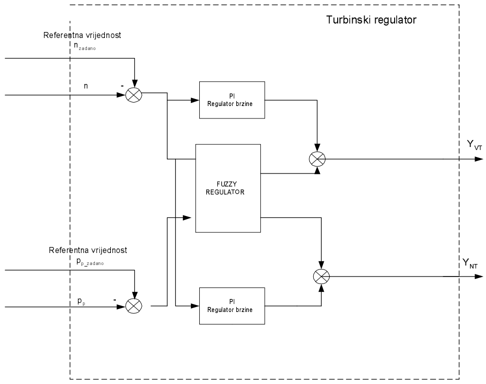

Figure 4 Fuzzy control system

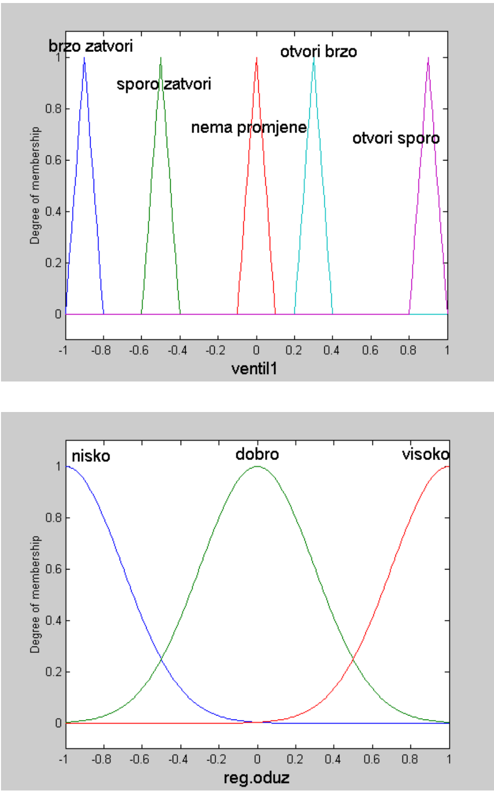

Figure 5 a,b Membership functions

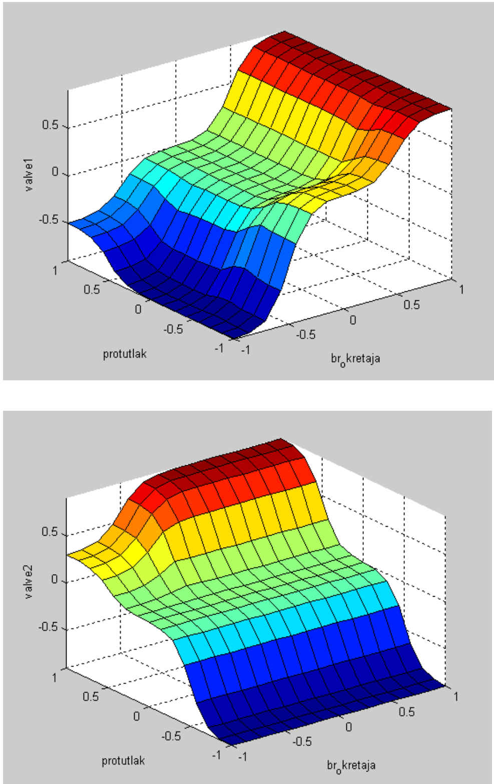

Figure 6 a,b Output surface, valve 1,2

4. SIMULATION RESULT

The step changing load/frequency control simulation result for PID and the fuzzy control algorithm are presented. The responses of the system shown in Figure 1 with given fuzzy and PID controller [1] are compared. The simulation was perfomed with parameter detailed descripted in [1]

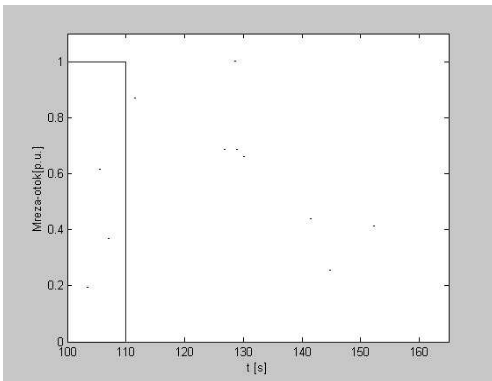

Figure 7 Step changing load/frequency

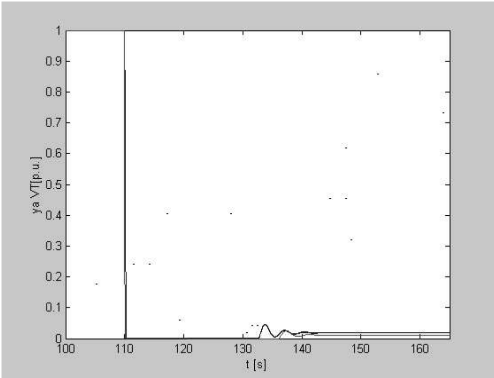

Figure 8 high-pressure steam valve positions

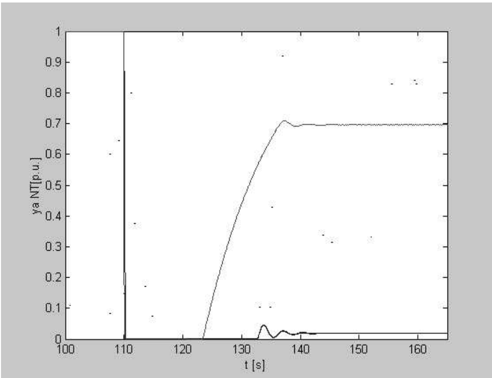

Figure 9 Int. pressure steam valve position

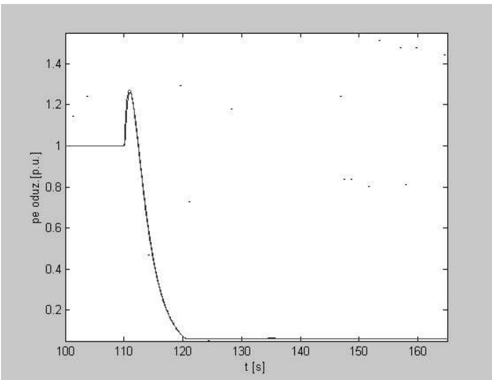

Figure 10 Intermediate steam pressure

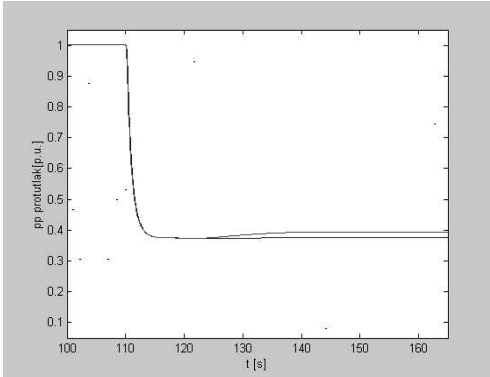

Figure 11 Condenser pressure

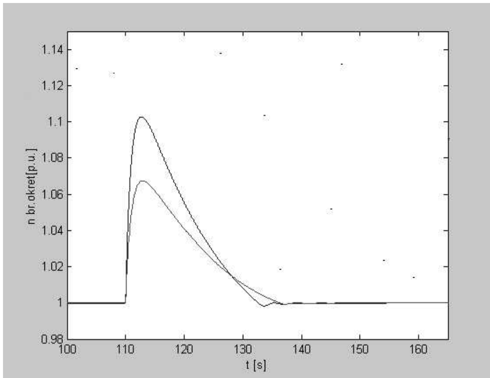

Figure 12 Speed change

5. CONCLUSION

In this paper, we considered the adaptive control of the non-linear dynamic systems where parameters occur nonlinearly. After the presentation of the simulation result for PID controller compared it with the fuzzy controller some conclusions could be given. It can be said that fuzzy controller show better control characteristics than PID controller. The main advantage is better over speed control, more than 3 percent lower over speed of generator and much simpler synthesis [1]. The further advantage is engaged with simultaneous synthesis of the fuzzy controller for the boiler control and the steam turbine controller [1].

6. REFERENCES

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