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Development of Intelligent AVR for Synchronous Generator

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Abstract -***The major part of an automatic voltage regulator (AVR) is to normalise the terminal voltage of synchronous generator. The structure modelled contains of the amplifier and generator. The AVR organisms are recycled usually in exciter control system. The part of an AVR is to grip the generator terminal voltage constant below standard operating surroundings at different load levels. The AVR loop of excitation mechanism preparation works terminal voltage error for adjusting the field voltage so as to mechanism the terminal voltage. The basic mechanisms of an exciter control system arrangement comprises of four leading components, namely amplifier, sensor, exciter and generator. The generator and amortisseurs systems state matrix are included, the system equations developed in that model includes one d-axis amortisseurs and two q-axis amortisseurs. This exertion targets to improve a simulation on steady state analysis of a power system with a controller established on fuzzy logic to maintain the terminal voltage.***

Keywords - ***Small-signal stability analysis, power system dynamics, eigenvalues, power system components modeling.***

I. INTRODUCTION

While doing a literature study, there are a few things need to be understand. There are the concepts excitation systems of a single generator, automatic voltage regulator (AVR). The strategy of AVR for synchronous generator using mat lab simulation [3] of the synchronous generator is done using Matlab instructions which based on d-q axes models and the considered AVR as against wind up fuzzy controller. Describes that AVR is designed for synchronous generator utilizing fuzzy logic controller to retain the terminal voltage of the generator at the rated value . When an inductive load is useful to the generator the terminal voltage drops, the AVR is spontaneously increasing the excitation to get free of this the disturbance as fast as possible.The synchronous Generator models are identified and parameter operating datas are Estimated is illustrated as H. Bora Karayaka, and Ali Keyhani. A related learning can be originate in for a small round rotor synchronous generator.

1.1 Notations

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L_{ads}, L_{aqs} = d & q - axis stator to rotor mutual inductance saturated in p.u

L_{1d}, L_{1q} = d& q- axis equivalent leakage inductance.

R_a = Armature resistance per phase.

L_l = Stator leakage inductance.

R_{1d}, R_{1q} = d & q-axis equivalent resistance.

R_{fd} = field resistance.

v_d, v_q = Generator terminal voltage d & q-axis.

i_d, i_q = Stator current d & q – axis p.u.

I_{fd} = field and amortisseurs circuit currents.

L_{fd} = Leakage inductance of field winding .

x_e = Reactance of transmission line.

$K_1 - K_6$ = constants of the linearised model of the synchronous machine.

T_{d0} = d-axis open circuit field time constant.

M, H=Inertia coefficient, constant (M=2H)

D= Damping coefficient.

P=Electric power output.

P_m =Mechanical power input.

Q = output reactive power to machine.

δ = Torque angle.

ω = angular velocity

V_{ref} = reference input voltage

II PROBLEM DESCRIPTION

The configuration of the synchronous mechanism typical recovered in this study is iiustrated in a figure 3.1 given below, with one damper in d-axis and two damper in q-axis.

The state space demonstration of this prototypical is

$$\dot{X} = AX + BU$$
$$Y = CX + DU$$

Where A= is the state or plant matrix; B= is the control or input matrix; C= is the output matrix; D= is the feed forward matrix.

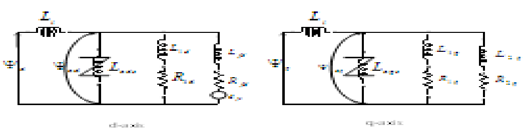

Figure 3.1 Synchronous machine equivalent circuits for d-axis and q-axis

The state space model of the synchronous generator is

state vector

$$X = [\Delta\omega_r \;\; \Delta\delta \;\; \Delta\Psi_{fd} \;\; \Delta\Psi_{1d} \;\; \Delta\Psi_{1q} \;\; \Delta\Psi_{2q}]$$

input vector

$$U = [\Delta T_m \;\; \Delta E_{fd}]$$

output vector

$$Y = [\Delta\omega_r \;\; \Delta\delta \;\; \Delta\Psi_{fd} \;\; \Delta\Psi_{1d} \;\; \Delta\Psi_{1q} \;\; \Delta\Psi_{2q}]$$

The complete state equation is given by

$$\begin{bmatrix} p\Delta\omega_r \\ p\Delta\delta \\ p\Delta\Psi_{fd} \\ p\Delta\Psi_{1d} \\ p\Delta\Psi_{1q} \\ p\Delta\Psi_{2q} \\ p\Delta V_1 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & a_{17} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} & a_{26} & a_{27} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} & a_{36} & a_{37} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} & a_{46} & a_{47} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & a_{56} & a_{57} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} & a_{67} \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & a_{77} \end{bmatrix} \begin{bmatrix} \Delta\omega_r \\ \Delta\delta \\ \Delta\Psi_{fd} \\ \Delta\Psi_{1d} \\ \Delta\Psi_{1q} \\ \Delta\Psi_{2q} \\ \Delta V_1 \end{bmatrix} + \begin{bmatrix} b_{11} & 0 \\ 0 & 0 \\ 0 & b_{32} \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \Delta T_m \\ \Delta E_{fd} \end{bmatrix}$$

Where,

$$a_{11} = -K_D / 2H; \;\; a_{12} = -K_1 / 2H; a_{13} = -K_2 / 2H;$$

$$a_{14} = -K_{21} / 2H; a_{15} = -K_{22} / 2H; a_{16} = -K_{23} / 2H$$

$$a_{21} = 2\pi f_0; \;\; a_{31} = 0; a_{32} = -w_0 R_{fd} / L_{fd} * m_1 L''_{ads};$$

$$a_{33} = -w_0 R_{fd} / L_{fd} (1 - L''_{ads} / L_{fd} + m_2 L''_{ads});$$

$$a_{34} = -w_0 R_{fd} / L_{fd} * (m_3 L''_{ads} - L''_{ads} / L_{fd});$$

$$a_{35} = -w_0 R_{fd} / L_{fd} * (m_4 L''_{ads});$$

$$a_{36} = -w_0 R_{fd} / L_{fd} * (m_5 L''_{ads});$$

$$b_{32} = w_0 R_{fd} / L_{adu}$$

$$a_{41} = 0; a_{42} = -w_0 R_{1d} / L_{1d} * m_1 L''_{ads};$$

$$a_{43} = -w_0 R_{1d} / L_{1d} * m_2 L''_{ads} - L''_{ads} / L_{fd});$$

$$a_{44} = -w_0 R_{1d} / L_{1d} * (1 - L''_{ads} / L_{fd} + m_3 L''_{ads};$$

$$a_{45} = -w_0 R_{1d} / L_{1d} * m_4 L''_{ads};$$

$$a_{46} = -w_0 R_{1d} / L_{1d} * m_5 L''_{ads};$$

$$a_{51} = 0; a_{52} = -w_0 R_{1q} / L_{1q} * n_1 L''_{aqs};$$

$$a_{53} = -w_0 R_{1q} / L_{1q} * n_2 L''_{aqs}$$

$$a_{54} = -w_0 R_{1q} / L_{1q} * n_3 L''_{aqs};$$

$$a_{55} = -w_0 R_{1q} / L_{1q} * (1 - L''_{aqs} / L_{1q} + n_4 L''_{aqs};$$

$$a_{56} = -w_0 R_{1q} / L_{1q} * n_5 L''_{aqs} - L''_{aqs} / L_{2q})$$

$$a_{61} = 0; a_{62} = -w_0 R_{2q} / L_{2q} * n_1 L''_{aqs};$$

$$a_{63} = -w_0 R_{2q} / L_{2q} * n_2 L''_{aqs}$$

$$a_{54} = -w_0 R_{2q} / L_{2q} * n_3 L''_{aqs};$$

$$a_{65} = -w_0 R_{2q} / L_{2q} * n_4 L''_{aqs} - L''_{aqs} / L_{1q})$$

$$a_{66} = -w_0 R_{2q} / L_{2q} * (1 - L''_{aqs} / L_{2q} + n_5 L''_{aqs};$$

$$a_{71} = 0; a_{72} = (K_5 / T_R); a_{73} = (K_6 / T_R); a_{74} = (K_{61} / T_R);$$

$$a_{75} = (K_{62} / T_R); a_{76} = (K_{63} / T_R);$$

III. IEEE TYPE I EXCITER

It delivers dc power to the field winding of synchronous instrument. It organizing the power stage of the excitation scheme.In progressions and supports input mechanism signals to a smooth and from proper for device of the exciter. This includes both regulating and excitation system for stabilizing functions.

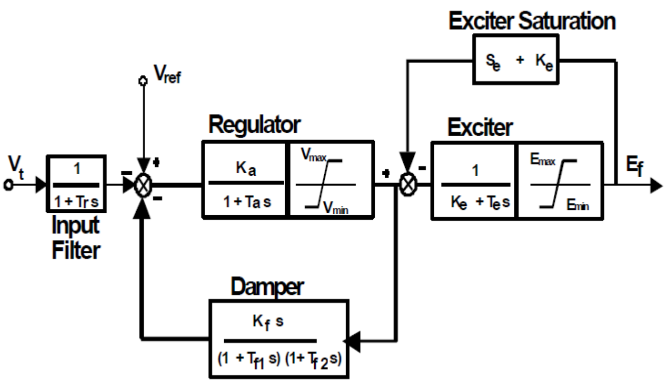

Figure 3.2 IEEE type 1 – Continuously Acting Regulator and Exciter

3.1 Fuzzy logic controller

The improvement of the control arrangement based on the fuzzy logic rules.

Fuzzy if-then rules are given below [1]

If (error is LN) then (control is LN) (1)

If (error is MN) then (control is MN) (1)

If (error is S) then (control is S) (1)

If (error is MP) then (control is MP) (1)

If (error is LP) then (control is LP) (1)

If (error is S) and (output rate is LP) then (control is LN) (1) ,

If (error is S) and (output rate is LN) then (control is LP) (1) ,

LN – Large Negative;

MN – Medium Negative,

S – Small;

LP – Large positive;

MP – Medium positive

IV. PROBLEM MODEL FORMULATION

The synchronous mechanism for which output the voltage is organized by an AVR functional to its excitation coordination is simulated in the Matlab[1]. The block diagram of synchronous machine without controller is Fig.4.1.

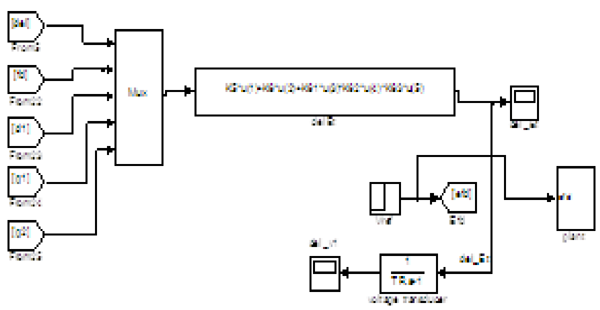

Fig 4.1 Block diagram representation of synchronous machine without controller simulated in Matlab

The succeeding step conversion without controller introduce to IEEE type 1 exciter for the for the better performance of the terminal voltage of the synchronous generator. The block diagram representation of the synchronous generator with controller is illustrated in Fig.4.2.

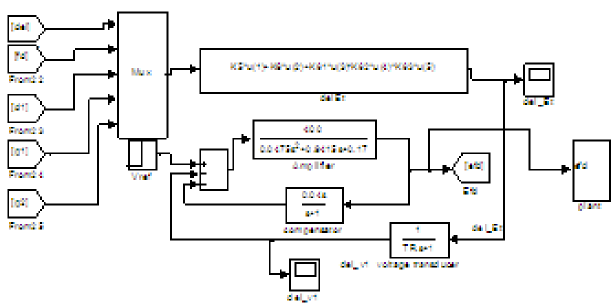

Fig 4.2 AVR controller with synchronous machine

he ensuing stage is without controller to replace by an AVR scheme in imperative to patterned its terminal voltage in the synchronous machine excitation voltage control as shown in Fig.4.3.

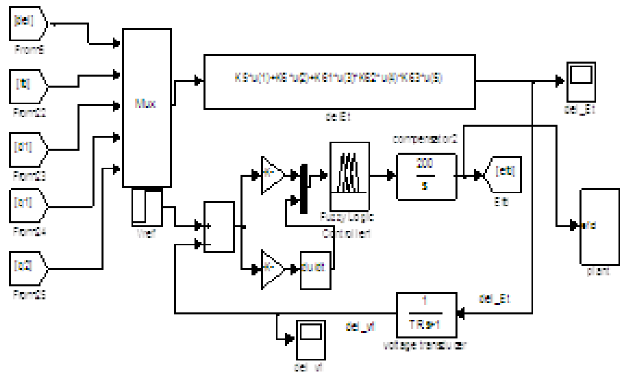

Fig 4.3 Block diagram synchronous machine with fuzzy controller simulated in Matlab

V . DISCUSSION OF THE PROPOSED WORK

Results of synchronous machine without controller

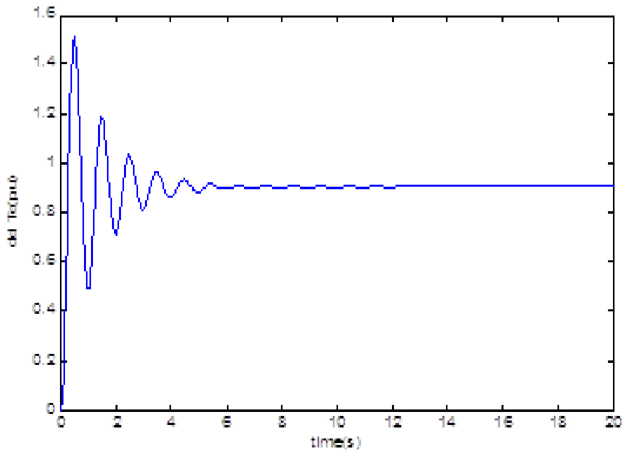

Fig 5.1 Response of Del Te without controller

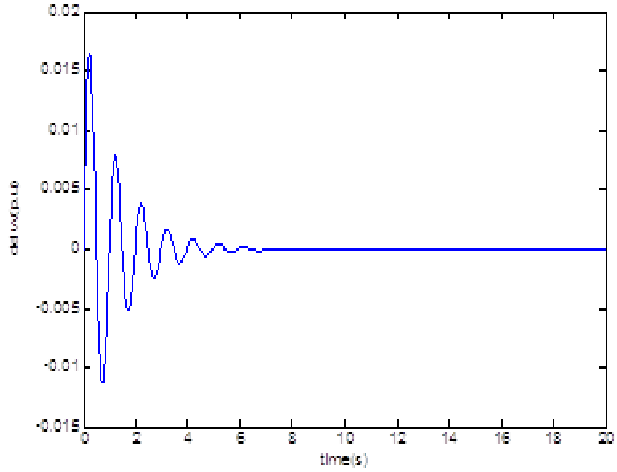

Fig 5.2 Response of Del W without controller

The next step including AVR there is better results for previous one. Results of synchronous machine with AVR simulated in Mat lab given below.

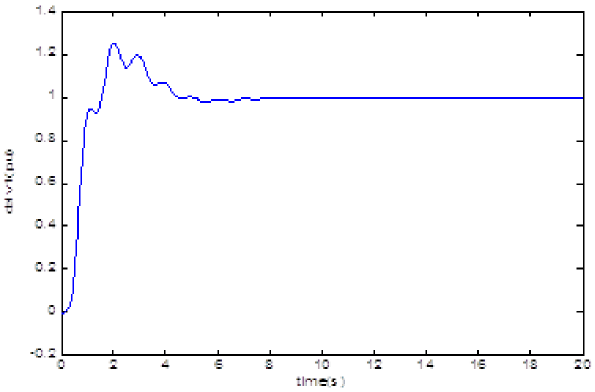

Fig5.3 Response of Del V1 with AVR

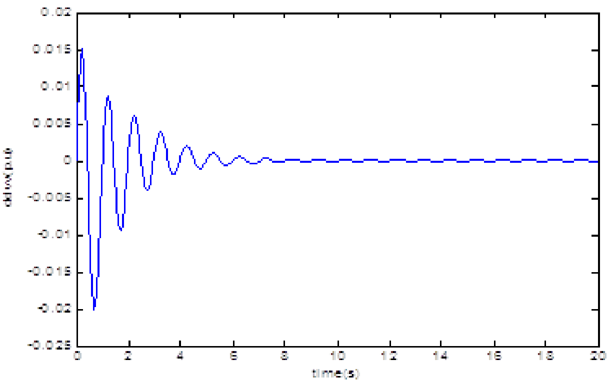

Fig 5.4 Response of Delw with AVR

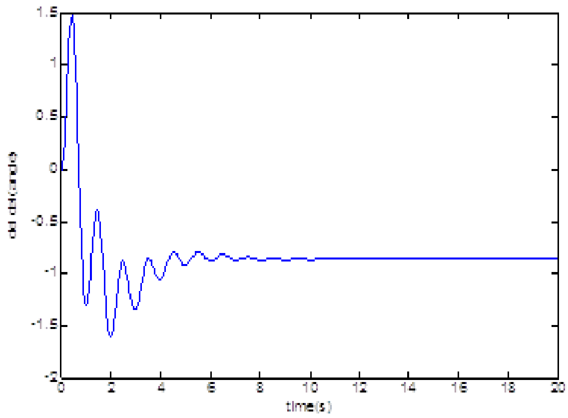

Fig 5.5 Response of Del Del with AVR

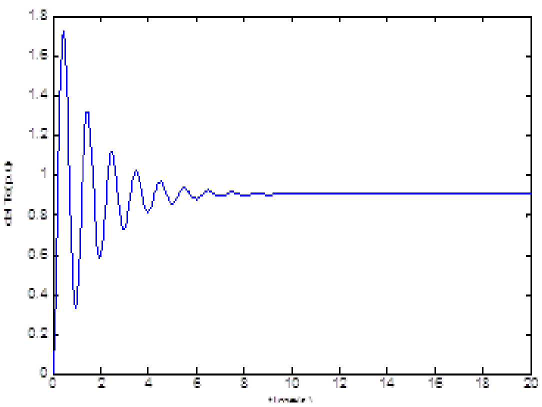

Fig 5.6 Response of Del Te with AVR

The next step including Fuzzy logic controller there is better results for previous one. Results of synchronous machine with fuzzy simulated in Mat lab given below.

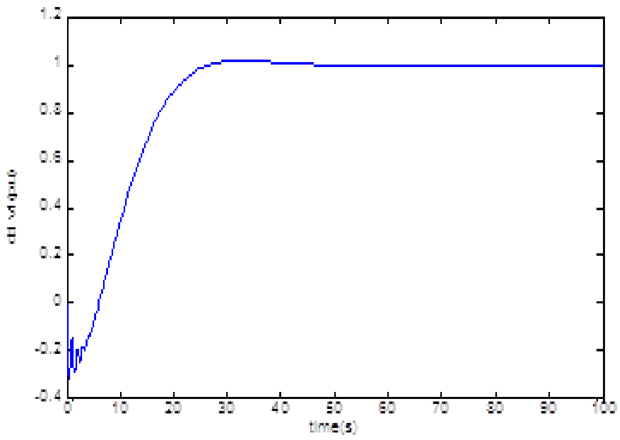

Fig 5.7 Response of Del VI with fuzzy controller

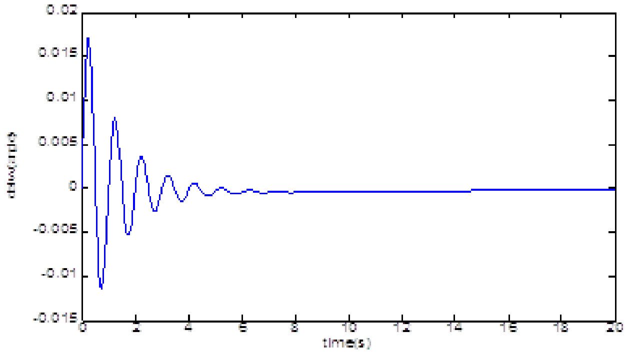

FIG 5.8 RESPONSE OF DEL W WITH FUZZY CONTROLLER

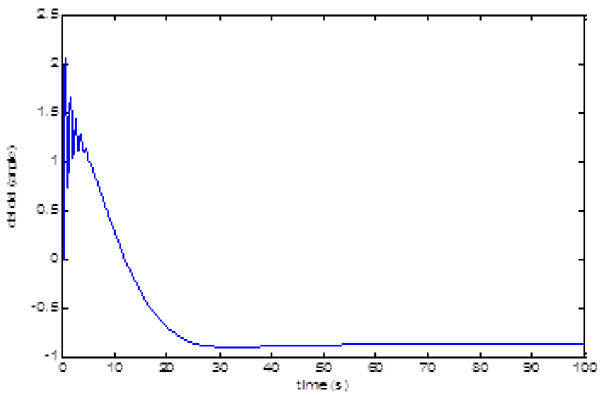

Fig 5.9 Response of Del Del with fuzzy controller

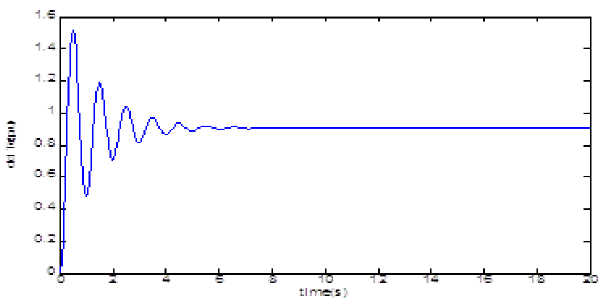

Fig 5.10 Response of Del Te with fuzzy controller

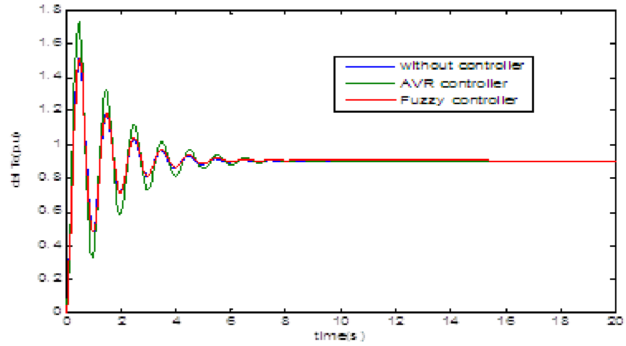

Fig 5.11 Response of Del Te characterstics for Without, AVR, Fuzzy controller

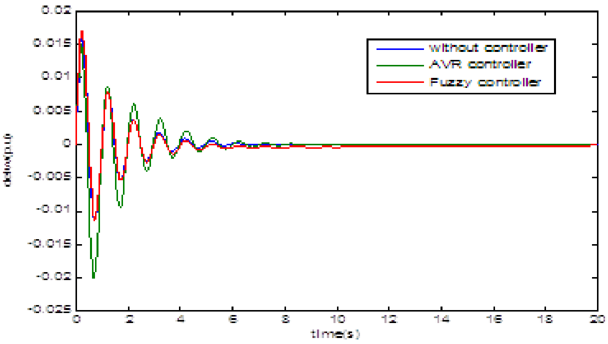

Fig 5.12 Response of Del w characterstics for Without, AVR, Fuzzy controller

VI. CONCLUSION

The synchronous generator with AVR is modeled using state space equations. The d-axis and q-axis dampers are reserved as state variables. From the results of IEEE type 1 exciter and Fuzzy logic controller it could be observed that, the performance characteristics of fuzzy logic controller are excellent.

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