A Fuzzy Logic Controlled Braking Resistor Scheme For Stabilization of Synchronous Generator

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Abstract

Following a major disturbance, each synchronous generator connected to a power system experiences a net difference between its mechanical power input and electrical power output which leads to instability of the system. This paper deals with the investigations regarding the transient stability enhancement of synchronous generator making use of a fuzzy logic controlled braking resistor scheme. Following a fault, variable rotor speed of the generator is measured and the firing-angle for the thyristor switch is determined from the crispy output of the fuzzy controller. By controlling the firing-angle, braking resistor can control the accelerating power in generator and thus improves the transient stability. The effectiveness of the proposed controller has been demonstrated by considering balanced (3LG : Three-phase-to-ground) fault near the generator. Simulation results clearly indicate that the proposed fuzzy control strategy provides a simple and effective method of transient stability enhancement of synchronous generator.

Key Words: Fuzzy Logic, Braking Resistor, Thyristor Switch, Transient Stability, Balanced Faults.

1 Introduction

Amongst the various methods of improving transient stability Dynamic Braking is known to be a very powerful tool. The Braking Resistor (BR) can be viewed as a fast load injection to absorb excess transient energy of an area which arises due to severe system disturbances.

Regarding the switching of braking resistors, a number of works have been reported in the literature [1-5]. But in all these switching strategies, fuzzy logic control schemes which give robust performance under parameter variation have not been used. As a result, these strategies are inflexible and are not adaptive to the changing operating condition of the system. Therefore, to surmount such a drawback, a fuzzy logic controlled braking resistor scheme is proposed in this paper and its effectiveness is shown considering balanced fault near the generator. The simulation is implemented by using EMTP (Electro-Magnetic Transients Program). It is noteworthy that the design of the proposed fuzzy controller is very straightforward, because it has only one input variable and only three control rules in contrast to the fuzzy controller described in reference [6] where two input variables and total 49 control rules have been used. Moreover, in this work, firing-angle has been calculated using linear interpolation technique rather than the approximation method used in reference [6]. Therefore, in the present simulation, less computation is required in comparison with the simulation work of reference [6]. Simulation results clearly indicate the effectiveness of the proposed fuzzy controller.

2 Simulation Method

<2.1> Model System

Fig. 1 shows the power system model used for the simulation of transient stability. The system model consists of a synchronous generator feeding an infinite bus through a double circuit transmission line. The braking resistor is connected to the generator

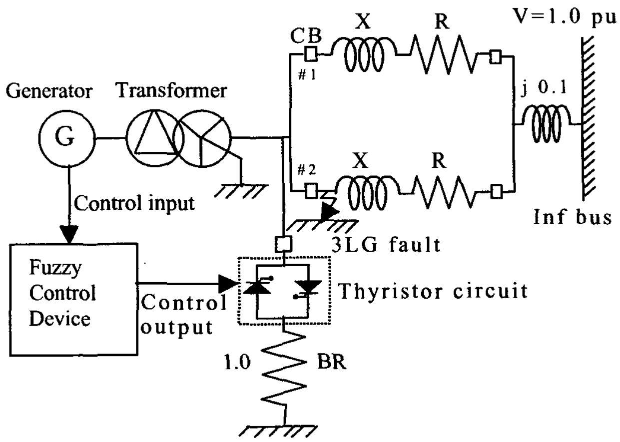

Fig. 1 Power System model

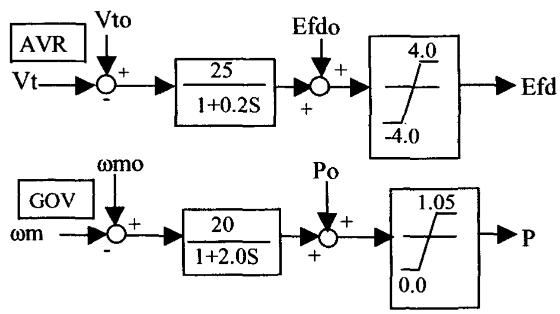

Fig. 2 AVR and GOV models

terminal bus through the thyristor switching circuit. The AVR (Automatic Voltage Regulator) and GOV (Governor) control system models shown in Fig. 2 have been included in the present simulation. In the simulation study, it has been considered that a 3LG fault occurs near the generator at line #2 at 0.1 sec, the circuit breakers (CB) of line #2 are opened at 0.2 sec and at 0.6 sec the circuit

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breakers are closed. Also, time step and simulation time have been chosen as 0.00005 sec and 5.0 sec respectively. Moreover, the BR will be switched in following a fault clearing and the switching condition of BR is such that when deviation of speed is positive, BR is switched on the generator terminal. On the other hand, when deviation of speed is negative and also in the steady state, BR is removed from the generator terminal by the thyristor switching circuit. The various parameters of the power system used for the simulation are shown in Table 1.

Table 1 Power System parameters

Generator output	(0.9+j0.11)	pu	R	0.05	pu
Generator power rating	100	MVA	X	0.5	pu
Generator voltage rating	20	KV	r_a	0.003	pu
Frequency	50	Hz	X_l	0.13	pu
Generator terminal voltage	1.0	pu	X_d	1.79	pu
Phase angle of generator terminal Voltage			X_q	1.71	pu
	19.113	deg	X'_d	0.169	pu
Generator load angle	72.019	deg	X'_q	0.228	pu
Generator neutral grounding resistance			X''_d	0.135	pu
	0.00001	pu	X''_q	0.2	pu
H(Inertia constant)	2.89	sec	X_0	0.13	pu
Transformer reactance	0.05	pu	T'_{d0}	4.3	sec
Transformer neutral grounding resistance			T'_{q0}	0.85	sec
	0.00001	pu	T''_d	0.032	sec
			T''_q	0.05	sec

3 Design of fuzzy controller

The design of the proposed FLC (Fuzzy Logic Controller) is described in the following:

<3.1> Fuzzification

To design the fuzzy controller, it has been selected speed deviation, $\Delta\omega$, of the generator as the input and conductance value, G, of the braking resistor as the output. The triangular membership functions for the fuzzy sets of $\Delta\omega$ have been shown in Fig. 3 in which the linguistic variables are represented by ZO (Zero), PS (Positive Small) and PB(Positive Big).

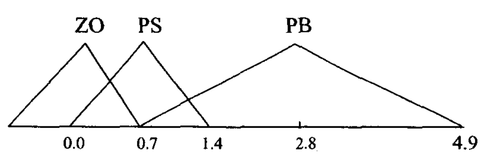


Fig. 3 Membership function of $\Delta\omega$ (rad/sec)

<3.2> Fuzzy Rule Table

The control rules for the proposed strategy are very straightforward and have been developed from the viewpoint of practical system operation and by trial and error and is shown in Table 2 where the numerical values of G represent the output of the fuzzy controller.

<3.3> Fuzzy Inference and Defuzzification

For the inference mechanism of the proposed fuzzy logic controller, Mamdani's method [7] has been utilized. The Center-of-Area method is the most well-known and rather simple defuzzification method which is implemented to determine the output crispy value (i.e. the conductance value of the braking resistor).

Table 2 Fuzzy Rule Table

$\Delta\omega$	G (Pu)
ZO	0.0
PS	0.9
PB	1.0

4 Calculation of firing-angle, α

Firing-angle, α for the thyristor switch is calculated from the output of the fuzzy controller i.e. from the conductance value of the braking resistor. Again, conductance value of BR is related to the power dissipated in BR. For any time step of simulation, the average power of SBR (System Braking Resistor), P_{SBR} and that of TCSBR (Thyristor Controlled System Braking Resistor), P_{TCSBR} are equal and hence firing-angle, α , can be calculated from the following equation .

$P_{TCSBR} = P_{SBR}$

$$\text{or, } \frac{V^2 G_{TCSBR}}{\pi}(\pi - \alpha + 0.5\text{Sin } 2\alpha) = V^2 G \quad \ldots\ldots(1)$$

Where V is the rms value of generator terminal bus voltage, G_{TCSBR} is the conductance value of BR specified to 1.0 pu for the simulation and G is the conductance value of BR which is the output of fuzzy controller.

But it is complex to calculate firing-angle, α ,directly from eq. (1) using the value of G. So, in this simulation, firstly by using eq. (1), a set of different values of G is calculated for the values of firing-angle ranging from 0^0 to 180^0 with a step of 2^0. Then by using the linear interpolation technique, firing-angle, α , is determined.

5 Simulation Results

Figures 4-8 show the simulation results of fuzzy control scheme considering balanced (3LG) fault near the generator at line #2. Fig. 4 shows the load angle responses. It is observed from these responses that because of the use of BR, the system is advancing towards a stable condition very quickly. Fig. 5 shows the speed deviation versus time curve. In this case also, it is evident that the use of BR makes the system stable quickly.

Fig. 6 depicts the firing-angle response of the thyristor switch for phase 'a'. The firing-angle varies from 0 degree to 180 degree according to the value of G .

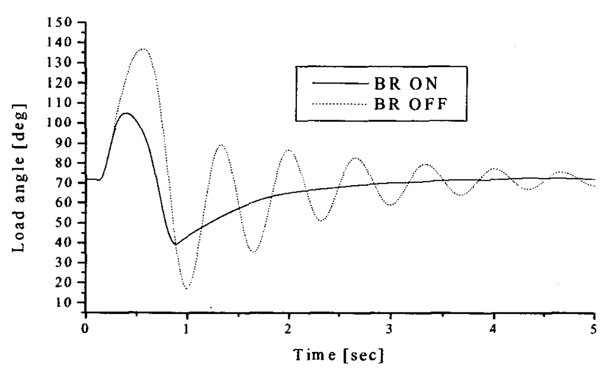


Fig. 4 Load angle responses

Generator terminal bus voltage and current responses of BR for phase 'a' have been shown in Figs. 7(a-b) for different time intervals. In Fig. 7(a), it is noticeable that current waveform has almost the same shape as voltage waveform because of the firing-angle which has values of zero degree from about 0.213 sec to 0.26 sec. Again, in Fig. 7(b), it is noticeable that current waveform differs from voltage waveform because of the firing-angle which does not have zero degree values rather it has some values from 0.35 sec to 0.40 sec.

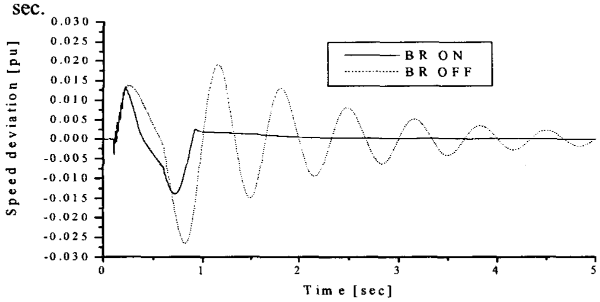


Fig. 5 Speed deviation responses

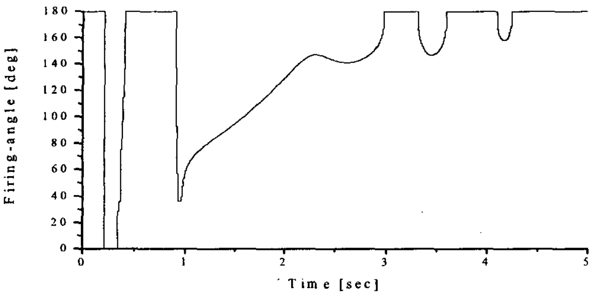
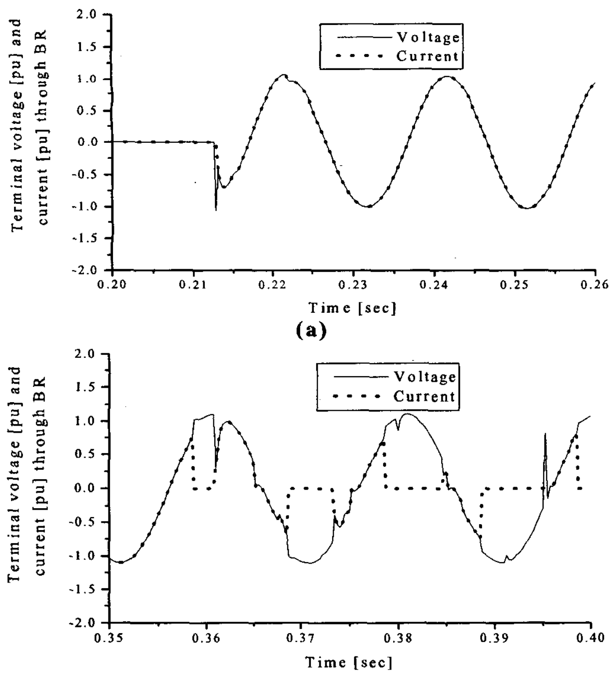


Fig. 6 Firing-angle vs time curve for phase 'a'



(a)

(b)

Fig. 7 Voltage and current responses of BR

Finally, in Fig. 8 it is shown the response of three-phase dissipated power in BR. The amount of power to be dissipated in BR depends on the value of firing-angle.

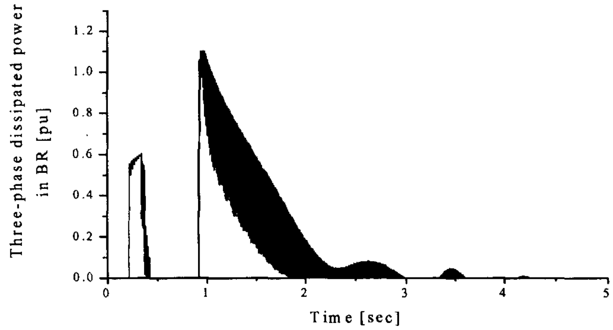


Fig. 8 Dissipated power response

Overall, from the simulation results it is observed that the performance of the proposed fuzzy control scheme is excellent and hence it can be used effectively in improving the transient stability of synchronous generator.

6 Conclusion

To augment the transient stability of electric power system, a fuzzy logic controlled braking resistor scheme is proposed in this paper. The design of the proposed fuzzy controller is simpler because it has only one input variable and only three straightforward control rules. The effectiveness of the proposed fuzzy controller is demonstrated by considering balanced fault near the generator. Simulation results clearly indicate the excellent performance of fuzzy controller. On the whole, the proposed fuzzy control strategy provides a simple and effective method of stabilization of synchronous generator under transient conditions.

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