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A BASIC STUDY OF FUZZY-LOGIC-BASED POWER SYSTEM STABILIZATION WITH DOUBLY-FED ASYNCHRONOUS MACHINE

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Abstract

This paper investigates the function of DASM (Doubly-fed Asynchronous Machine) with emphasis placed on its ability to stabilize the power system[1]. P(active power) and Q(reactive power) compensations from DASM can be determined by fuzzy logic, and regulated independently through secondary-excitation controlling[2]. Simulation results by EMTP show that such system can restore the power system to a normal operating condition rapidly even following severe transmission-line failures. Comparison studies have also been performed between a conventional controller and proposed fuzzy-logic controller.

1. Introduction

Nowadays electric power systems are becoming more and more complex, they are often subjected to various stability problems because of the unbalance between the power demand and power supply. Among the different ways being proposed to improve the dynamic performance of the system, a round rotor structure doubly-fed asynchronous machine (DASM) is investigated in the paper to control the active and reactive powers of the system[3].

On the other hand, because of the dynamic and stochastic nature of the operation of the power system, controller parameters that are suitable for one set of operating conditions may not be optimum for another set of operating conditions. Hence instead of the conventional way of calculating the desired power compensation from DASM, we applied fuzzy logic in the control strategy.

In the paper, simulation studies on a single machine infinite-bus system show that such proposed fuzzy-logic based power system stabilization way with DASM is effective even when experiencing severe transmission-line failures. Comparison studies have also been performed between a conventional controller and proposed fuzzy logic controller.

2. Model system configuration

The system under consideration is shown in Fig.1, in which SG denotes a synchronous generator and a DASM is connected to the single machine infinite-bus system with a double-circuit transmission line.

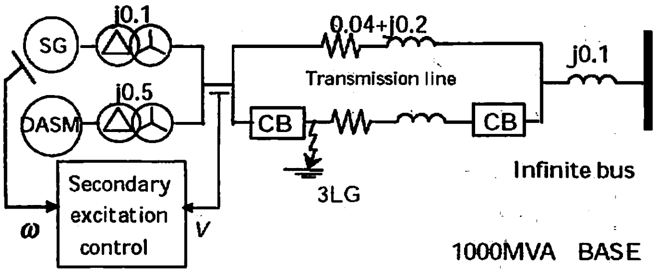

Fig.1 Power system model

The DASM used is based on a wound rotor structure, whose rotor is fed with impressed three phase currents of variable amplitude, frequency and phase so that a constant mmf could be seen from the stator side[4]. Moreover, the rotating reference frame(dq frame) to analyze the DASM is fixed on the space axis of stator voltage[5].

In the control scheme illustrated in Fig.2, when $\Delta\omega$ (synchronous generator speed deviation) and Δv(voltage deviation) are detected, the P/Q compensation required from DASM is thus determined through proportional controllers(K_W and K_V). To regulate the error between the desired and detected

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values of P/Q, a two-step controller is used, the first step of which is APR/AQR, and the second is ACR. Therefore the required field voltage is specified and applied to the rotor side of the DASM.

Controllers K_W, K_V, APR, AQR, ACR and the corresponding optimum gains selected through trial-and-error method are shown in Fig.3.

All the signals used in the control system are per unit values and are transformed to dq frame.

In the inverter side, we simulate the secondary-exciting source with an ideal DC source, and only the fundamental component of inverter output is considered.

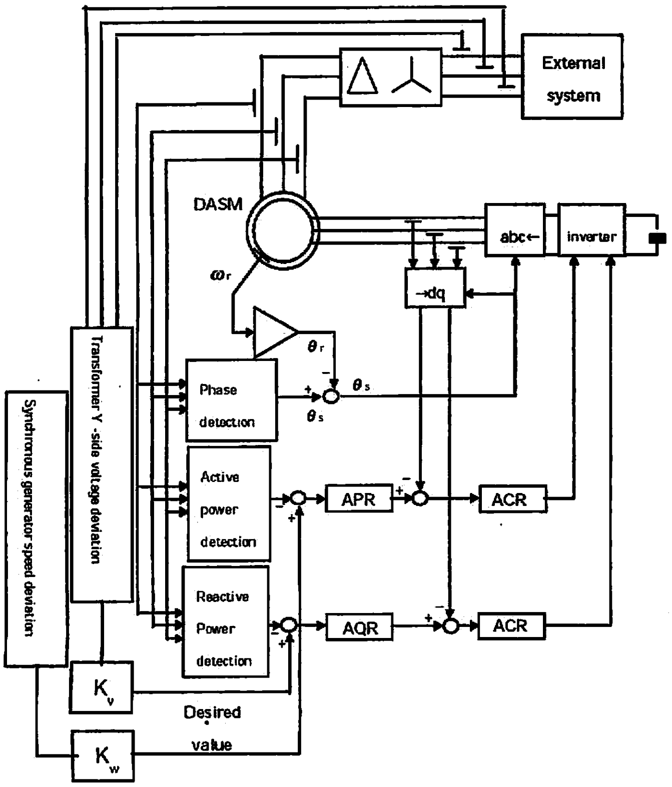


Fig.2 Studied power circuit and regulation block

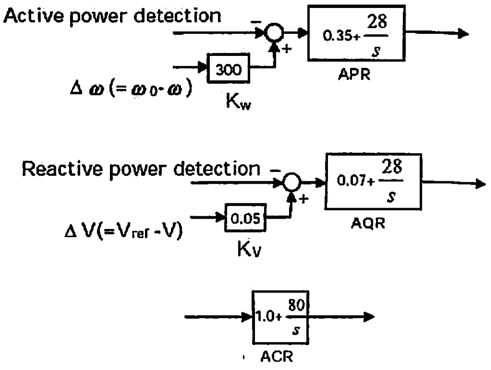


Fig.3 Control signal blocks

With the nominal values and parameters mentioned in Tables 1 and 2, simulations are carried out. In the simulation, we assume that the mechanical input to DASM is 0, that initially $\Delta\omega$ and Δv are both 0, and that before fault occurs, active and reactive power from DASM are both 0[pu], while active power and terminal voltage of synchronous machine are 0.90 [pu] and 1.0[pu], respectively.

Table.1. Synchronous machine nominal values and parameters

Rated voltage	20[kV]
Rated output	1000[MVA]
Frequency	50[HZ]
Armature resistance r_a	0.003[pu]
d-axis synchronous reactance X_d	1.790[pu]
q-axis synchronous reactance X_q	1.710[pu]
d-axis transient reactance X_d'	0.169[pu]
q-axis transient reactance X_q'	0.228[pu]
d-axis sub-transient reactance X_d''	0.135[pu]
q-axis sub-transient reactance X_q''	0.200[pu]
d-axis open-circuit transient time constant T_{do}'	4.3[sec]
q-axis open-circuit transient time constant T_{qo}'	0.85[sec]
d-axis open-circuit sub-transient time constant T_{do}''	0.032[sec]
q-axis open circuit sub-transient time constant T_{qo}''	0.05[sec]
Inertial constant (H)	2.894[sec]

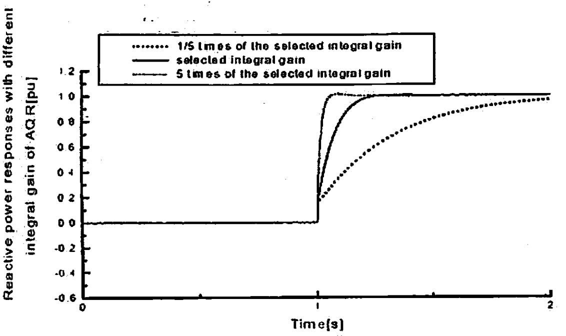
Table.2. DASM nominal values and parameters

Rated voltage	11 [kV]
Rated output	200 [MVA]
Frequency	50 [Hz]
Magnetizing reactance	2.75 [pu]
Primary leakage reactance	0.142 [pu]
Primary resistance	0.0045 [pu]
Secondary leakage reactance	0.142 [pu]
Secondary resistance	0.0045 [pu]
Inertial constant (H)	4.922[sec]

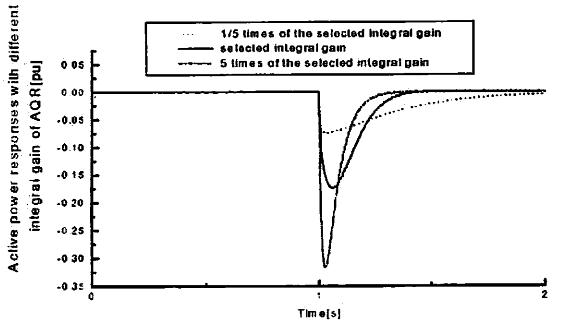
1. Tuning for appropriate PI controller (APR/AQR and ACR) gains

We first tune for the optimum controller parameters for APR/AQR and ACR without impressing three-line-to-ground fault. Soundness of the PI gains are tested through comparison of the active/reactive responses of 5 times,1 time,1/5 time of the selected gain values, which were obtained through trial and error method. Verification of the integral gain of the AQR are given in Fig.4 and 5 as an example, other corresponding simulation results are omitted here for the sake of space.

From those results, it can be concluded that the selected gain values are effective for the PI controllers.



ig.4 Reactive power responses with different integral gain of AQR[pu]



ig.5 Active power responses with different integral gain of AQR[pu]

4. Desired power compensation calculation

In the control scheme illustrated in Fig.2, when $\Delta\omega$ (synchronous generator speed deviation) and Δ v(voltage deviation) are detected, the P/Q (active power and reactive power) compensation required from DASM is thus determined. Different ways of calculating the P and Q compensations are tried in the work, and they are explained in the following.

4.1 Design a conventional P controller

When three-line-to-ground fault occurs at 0.1s and cleared at 0.2s, we applied the proportional controller to calculate the desired active/reactive power compensation from DASM. Fixing APR, AQR and ACR on the optimum values described above, soundness of the K_W,K_V gains are tested through comparison of the active/reactive responses of 5 times,1 time, and 1/5 times of the selected gain value. We note that change of the selected K_W and K_V gains will deteriorate or have no effect on the system response. It can also be concluded that selected gain values are effective for the proportional controllers.

4.2 Design a conventional fuzzy logic controller

Instead of the proportional controller shown before, we tried conventional fuzzy controllers next.

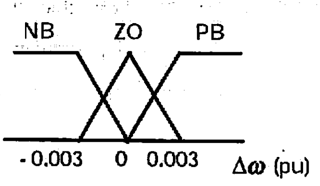
The designing of the proposed conventional fuzzy controllers is carried out in the following way.

<4.2.1>. Fuzzification

Synchronous generator speed deviation ($\Delta\omega$) and the transformer Y-side voltage deviation (Δ v) were selected respectively as inputs to the two controllers. The universe of discourse of each fuzzy variable ($\Delta\omega$ and Δ v) is quantized into three overlapping linguistic variables NB, ZO, PB, which stand for Negative Big, Zero, Positive Big, respectively. The triangular functions chosen to map the crisp value into fuzzy values are shown in Fig.6 and 7 and can be expressed as

$$A_i(x)=\frac{1}{a_i}(-|x-b_i|+a_i)\vee 0, \qquad a_i \,)\, 0 \qquad (1)$$

Where A(x) is the grade of membership values, ‘a’ is a constant that determines the spread of the i-th membership function , ‘b’ is the center of the i-th membership function.



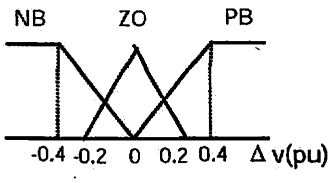


Fig.6 Membership function for $\Delta\omega$ (pu) Fig.7 Membership function for Δ v(p

<4.2.2>Rule creation and fuzzy inference

The fuzzy control rules shown in Table 3 and Table 4 have been created with previous knowledge and experience of the controlled system dynamics, and by trial-and-error method. The inference mechanism used is consequence-simplified encoding, whose rule consequence is simplified to a constant crisp value instead of a conventional fuzzy variable. In the table, P, Q represent the desired active and reactive output from DASM.

$\Delta\omega$	P
NB	1.7[pu]
ZO	0.0[pu]
PB	-1.7[pu]

Table 3 Fuzzy rule table for $\Delta\omega$

ΔV	Q
NB	-0.9[pu]
ZO	0.0 [pu]
PB	0.9 [pu]

Table 4 Fuzzy rule table for Δ v

<4.2.3> Defuzzification

The center-of-area/gravity method is used for the output(P ,Q) defuzzification.

In addition, the maximum apparent power command is limited to 1.0 times of the nominal value.

5.Comparison studies and simulation results

When a three-line-to-ground fault occurs at 0.10s, causing the opening of the CB(circuit breaker) at 0.20s, synchronous generator speed increases while transformer Y-side voltage decreases tremendously, DASM responds to these by consuming / producing adequate amount of active and reactive powers, which, in turn, ask for the corresponding field voltage change and hence the field current tuning. As a result, load angle of the synchronous generator settles down to a normal condition and CB is re-closed at 1.2s. Figs.8~9 show the various simulation results. We can see from these figures that DASM can be properly controlled to decrease the transient of the power system.

6. Conclusion

The paper proposed a fuzzy-logic-based power system stabilization with DASM. Simulation results show that the proposed fuzzy algorithm, with properly selected parameters, have better operating properties than the simple proportional controller.

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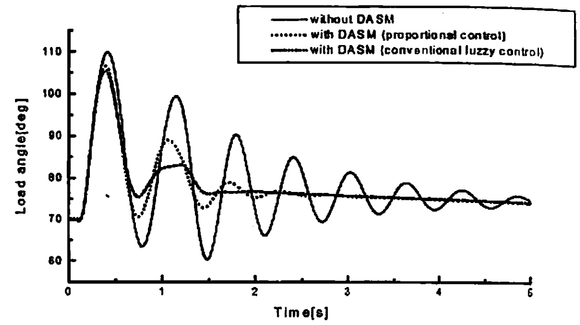

Fig.8 Synchronous generator load angle

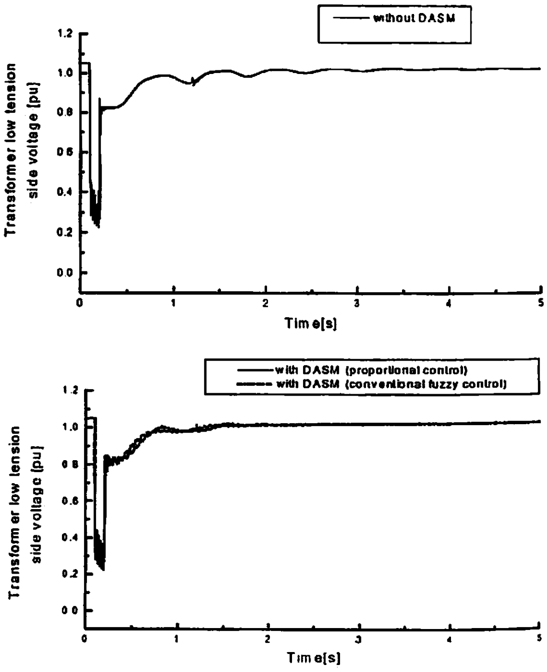

Fig.9 Transformer Δ -side voltage