Power System Fuzzy Bang-Bang Stabilizer Design VIA Critical Path Method

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Abstract

This paper addresses a new approach , Optimal Path Estimation Method (OPEM) , to implement the time optimal bang-bang control. The method is based on feedback information obtained by estimating the distance from the present state to the switching surface along the optimal trajectory. A fuzzy algorithm is used for the implementation of the control logic. The advantages of proposed method over traditional Bang-Bang control method are illustrated by numerical simulations of a multimachine infinite-bus power system.

1 Introduction

In the two-order system, the time optimal bang-bang control has the merit of fast moving, and can be applied to the control of power system .We use Optimal Reduced Order Models [7],[8] to reduce power system model into two-dimension matrix and implement the time optimal bang-bang control of the power system. However, owing to too fast states switching of the time optimal bang-bang control, the chattering occurs when near the target in an actual system. Therefore, it is usually necessary to design a separate tracking controller for the power system to accomplish large movements. Traditional design approach user a two-stage control. During the fist stage, when the actuator is undergoing large accessing motion, the control algorithm may be designed by using the classical time optimal control with the control effort constrained. As the actuator comes close to target position, the controller is switched to a regulation stage and conventional feedback control algorithms may be employed to obtain a high performance closed loop response [2],[6],[9]. This approach seems feasible theoretically; however, the transition between the accessing stage and regulation stage can be rather rough, and make the power system hard to settle.

In this paper a new class of nonlinear saturated control methodology is proposed. The proposed method is based on the classical time optimal bang-bang control. (Suitable nonlinear control action can be superior to the linear control action [1],[4],[5]). While preserving the original time optimal characteristics of the classical bang-bang control, the new method does not inherit the chattering and steady state offset problem [3],[5] often encountered in the traditional suboptimal switching control approach. A fuzzy logic is used for the controller implementation. The methods are applied to design the PSS and seem inherently robust.

2 The Structure Of FLC

The implementation of the proposed control algorithm used a fuzzy controller for making judgement on whether the state is close to the switching surface.

A fuzzy logic controller comprises five principle components (as show in fig. 1):

1. a fuzzifier, which transforms real numbers into fuzzy set (fuzzy vectors) according to membership function provided by the data base,
2. a data base, which provides the membership function of fuzzy set to used in fuzzifier and defuzzifier,
3. a real base, which provides the control rules to be used in the inference engine,
4. an inference engine, which performs the fuzzy reasoning upon the fuzzy vectors provided by the fuzzifier and the rules provided by the rule base,
5. a defuzzifier, which transforms the outcome of the inference engine into real numbers to provide single-value signals. The weighted average method is computational simple and efficient. We will use this method as the defuzzification method in this paper.

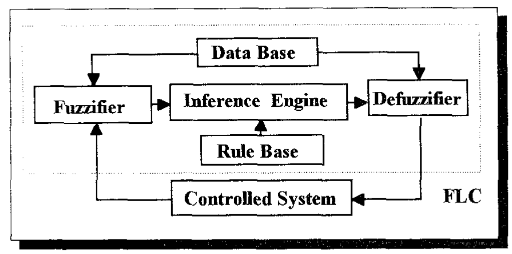

Fig. 1 The structure of FLC

3 FLC design for servo system

An example of the time optimal position control of a multimachine infinite-bus system is used to illustrate the implementation and to evaluate the performance of the "OPEM" Algorithm.

3.1 The model of multimachine system

The mathematical model of multimachine system is as follows:

$$\dot{X} = AX + BU \tag{3-1}$$

where

$$X^T = \begin{bmatrix} \Delta\omega_1 & \Delta\delta_1 & \Delta e'_{q1} & \Delta V_{FD1} & \Delta\omega_2 & \Delta\delta_2 & \Delta e'_{q2} & \Delta V_{FD2} \end{bmatrix}$$

$$A = \begin{bmatrix} -.244 & -.0747 & -.1431 & 0 & 0 & .0747 & .0041 & 0 \\ 377 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -.046 & -.455 & .244 & 0 & .046 & .13 & 0 \\ 0 & -398.56 & -19498.8 & -50 & 0 & 398.58 & -3967 & 0 \\ 0 & .178 & -.0433 & 0 & -.2473 & -.178 & -.146 & 0 \\ 0 & 0 & 0 & 0 & 376.99 & 0 & 0 & 0 \\ 0 & .056 & .1234 & 0 & 0 & -.0565 & -.3061 & .149 \\ 0 & -677.39 & -10234.22 & 0 & 0 & 677.78 & -13364.16 & -50 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 2500 & 0 \\ 0 & 2500 \end{bmatrix}$$

the eigenvalues of the system are as follows:

-25.1741+67.8187i
-25.1741-67.8187i
-0.0904+9.843i
-0.0904-9.843i

0-7803-2646-6

-0.0006

-0.2443

the retained variables: machine 1 are $\{\Delta\omega_1, \Delta\delta_1\}$,machine 2 are $\{\Delta\omega 1, \Delta\delta_1\}$ and the retained main-pole point are (-0.0006, -0.2443). Hence, the two-dimension matrix of the system matrix A, B which is using optimal reduced order models are:

machine 1:

$$A = \begin{bmatrix} -.2449 & -4.03e-7 \\ 377 & 0 \end{bmatrix} \quad B = \begin{bmatrix} -.0129 & -.0033 \\ -.0252 & -.038 \end{bmatrix}$$

machine 2:

$$A = \begin{bmatrix} -.2449 & -4.03e-7 \\ 377 & 0 \end{bmatrix} \quad B = \begin{bmatrix} -.0128 & -.0034 \\ -.086 & .0322 \end{bmatrix}$$

3.1.1 Determine the switching curve of the phase plane

From matrix A, B when the control signal U=1, the intial value are $x_1(0)$, $x_2(0)$, $y_1(0)$, $y_2(0)$, we obtain:

machine 1:

$$\begin{aligned} X_1(t) &= (1.002462x_1(0) + .0000016x_2(0) + .0529339)\exp(-0.2443t) \\ &\quad +(-.002462x_1(0) - .0000016x_2(0) - .0530033)\exp(-.0006t) \\ &\quad +.00000694 \\ X_2(t) &= (-1546.984x_1(0) - .002462x_2(0) - 81.679)\exp(-.2443t) \\ &\quad +(1546.9984x_1(0) + 1.002462x_2(0) + 33299.035)\exp(-.0006t) \\ &\quad -33217.356 \end{aligned} \tag{3-2}$$

$$\begin{aligned} Y_1(t) &= (1.002462y_1(0) + .0000016y_2(0) + .0138628)\exp(-.2443t) \\ &\quad +(-.002462y_1(0) - .0000016y_2(0) - .0138628)\exp(-.0006t) \\ &\quad -.0000884 \\ Y_2(t) &= (-1546.984y_1(0) - .002462y_2(0) - 21.528964)\exp(-.2443t) \\ &\quad +(1546.9984y_1(0) + 1.002462y_2(0) + 8712.2098)\exp(-.0006t) \\ &\quad -8690.6809 \end{aligned} \tag{3-3}$$

(3-2),(3-3) are the switching curve eq. of the meachine 1 and meachine 2, which are on the right -half of the phase plane, its figure as shown Fig. 2.

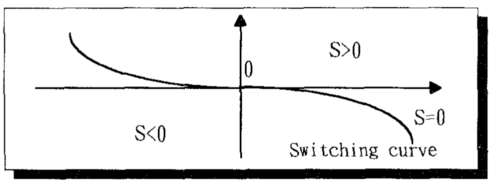

Fig. 2 switching curve on the rigt-half of the phase plane

3.1.2 Determine the optimal trajectory

when the initial state of the system lies above the switching curve (s>0), we can get the cross-point X_B of the optimal trajectory and the switching curve; and then the trajectory from the initial position of the system to the cross-point X_B is S_1 , the trajectory along the switching curve to original of the phase-plane is S_2 , as shown in Fig.3.

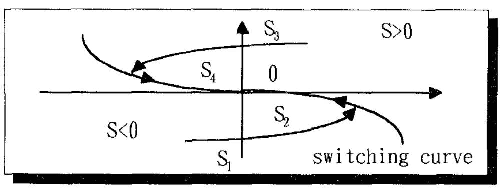

Fig.3 optimal trajectory S_1 and S_2

When the control signal U=-1, by the same way, we can get S_3 , S_4 .

3.2 Data Base

The membership function of fuzzy sets S_1 and S_2 is depicted in Fig.3. Specified on domains of S_1 and S_2 are five fuzzy sets: PL, PS, ZR, NS and, NL, where P, N, ZR, S, and L correspond to positive, negative, zero small, and large respectively. Thus, for instance, NL stand for "negative large" and PS stand for "positive small," etc. In the same manner, we also define five sets on the domain of input u. Fig.4. illustrates the membership function of these fuzzy sets

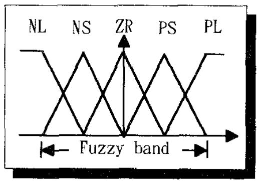

Fig.4 MSF of S_1 and S_2

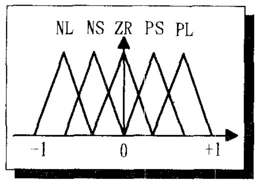

Fig.5 MSF of u

3.4 Rule Base

The control rules for OPEM are derived based on human's driving behavior. For example, a typical rule might be:

IF S_1 is Positive Small AND S_2 is Negative Large

THEN the effort is Negative Large

Which means, when the state lies near and below the switching curve while still far away from the origin, a large negative effort is applied in order to attain the Bang-Bang type strategy. Another typical rule may be:

IF S_1 is Positive Small AND S_2 is Negative Small

THEN the effort is Negative Small

Which means, when the state lies near the target and below the switching curve, a small negative effort is used to drive the state to the origin in order to avoid chattering.

Based on the authors' engineering judgment, seventeen control rules are formed. The rule base is shown in Table 1.

S_2, S_4 \ S_1, S_3	NL	NS	ZR	PS	PL
PL	NL	NL	PL		
PS	NL	PS	PS		
ZR	NL	ZR	ZR	ZR	PL
NS			NS	NS	PL
NL			NL	NL	PL

Table 1 Rule Base

3.5 Result And Discussions

1. The angle frequency response based on OPEM method of machine 1 and machine 2 expressed in Fig.5 and Fig. 7, the chattering disappear when system move into the controlled range of fuzzy controller.
2. Comparing the simulating result of machine1 in Fig.5 and Fig.6 we find the transient response of OPEM control method whose settling time is about 2 seconds is better than that of optimal reduced-order method whose time is over 4 seconds.
3. Comparing the simulating result of machine 2. in Fig. 7 and Fig. 8, we find the amplitude of transient response obtained from fuzzy bang-bang control method is larger than that obtained from optimal reduced-order, settling time is about 2 seconds is better than that of optimal reduced-order method whose time is over 4 seconds.

4 Conclusions

The main purpose of this paper is to design the PPS by the OPEM method. By using the optimal reduced order method to simplify the model of the system, we use the variable structure controller (VSS) which combine the time optimal bang-bang controller and fuzzy logic controller to replace the traditional method of feedback control. By means of the Optimal Path Estimation Method (OPEM), we schedule the optimal trajectory and switching curve of power system in two dimensions plane simplified by optimal reduced- order method, and enable the system suffered the some disturbance input .It is shown the OPEM applied to design the PPS will be inherently robust.

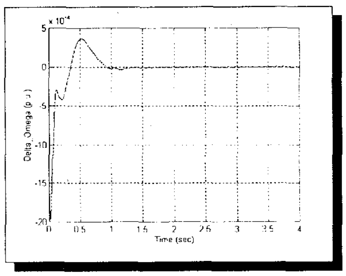

Fig.5 The angle frequency response of machine 1. base on the OPEM control

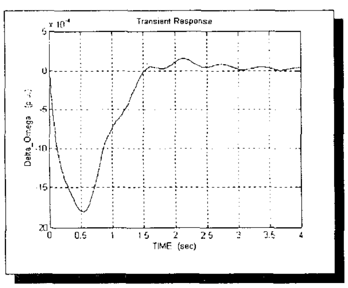

Fig.6 The angle frequency response of machine 1.bsaed on the optimal reduced order method

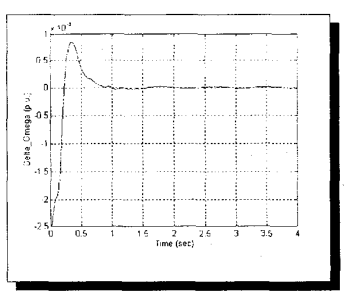

Fig.7 The angle frequency response of machine 2. base on the OPEM control

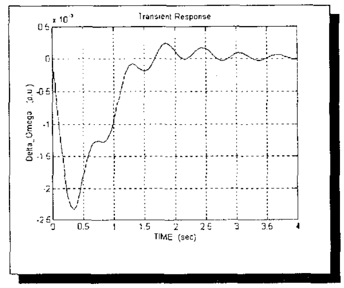

Fig.8 The angle frequency response of machine 2.bsaed on the optimal reduced order method

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