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Simulation of Power System based on PID Excitation Control

Hongpeng Xu, Shehui Yin

Department of basic science, Henan Polytechnic Institute, Nanyang 473000, China
HongpengXu@126.com

With the development of power system, routine PID controller could not satisfy the requirement of systemic dynamic and static performances. In this paper, in order to overcome the shortcoming of routine PID controller, a new kind of fuzzy-PID controller is designed (Bai et al., 2010). The new fuzzy-PID controller combines the advantages of routine PID controller and fuzzy logic controller (Dou et al., 2012). The mathematical model of synchronous excitation system and the architecture, principle and function of the fuzzy-PID controller are analyzed (Fu J., et al., 2014). And the application of the routine PID controller and fuzzy-PID controller in synchronous excitation system are studied with Simulink. The results show that the fuzzy-PID controller gives a better control performance and has reference value in the further applied research (Gan et al., 2015).

1. Introduction

Synchronous generator excitation control system (SGECS) plays an important role in power system and is associated with the safety, stability and efficient operation of power system (Hao et al., 2007). The principle diagram of synchronous excitation system can be seen in Figure 1. With the continued development of China's economic construction, expanding power systems (Xu et al., 2016), large synchronous generator excitation control has become a research focus. And widespread use of fast excitation on SGECS promotes further study of excitation control system (Hao et al., 2005). The excitation control system is a time-varying, time-delaying, complex and highly nonlinear control system. When SGECS work condition changes, the dynamic characteristics of the system will significantly change (Hauser et al., 2005). In this case, the linear PID controller often cannot meet the requirements of stability, unless the use of cutting machines, brake failure and other fault treatments. Excitation controller parameter optimization methods are the key to solve the above problems. But unfortunately, the traditional methods of adjusting the controller parameters often use time domain or frequency domain manually setting under human control (Karnavas et al., 2007). Those methods do not have the ability to adjust the control parameters adaptive and lack of constraints on the sudden disturbance signal. Therefore, how to design a simple structure, and has a processing capacity of complex nonlinear excitation control system excitation controller and its parameter optimization method to be the focus of this article.

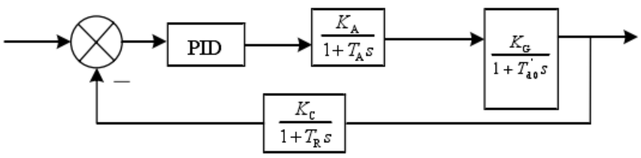

Figure 1: Principle diagram of synchronous excitation system.

2. Mathematical model of excitation system

Traditional PID controller has the characters of simple structure, robustness, easy to implement and so on and has been applied widely with a very good control effect. But, as the scale and capacity enlargement of the power system, the traditional PID excitation controller can't meet the needs, it is imperative to find better control algorithms. In order to overcome the shortcomings of traditional PID controller, Fuzzy control, that

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doesn't need the accurate model of the controlled target and has wonderful adaptability, is combined with the traditional PID controller to form many kinds of Fuzzy-PID controllers, but on the other hand the Fuzzy-PID, controller is unable to change the parameters of it once the parameters are confirmed and can't adapt to change automatically (Kim et al., 2012). So, it still needs to be further improved.

3. Design of fuzzy PID controller

3.1 Composition principle of fuzzy PID controller

The practical model for power system dynamic research is solved in this dissertation. During the research, the basic power system equations are processed by small deviation linearization and mathematical solution, then the third-order state equation mathematical model for the single-machine infinite-bus power system is obtained} the state variables of the model are local quantities which are easy to measure, and the concrete steps of model solution are given. At last, the mathematical model of Kaifeng power grid is obtained referring to practical data, which lay a foundation for the design of decentralized controllers based on mathematical model.

$$G_G(S)\frac{K_G}{1+T'_{do}S} \quad (1)$$

$$G_M(S)\frac{K_C}{1+T'_R S} \quad (2)$$

Combing the new generation intelligent control technology, the power system intelligent control based on Mamdani fuzzy inference is studied in this dissertation. Derivative (PID) excitation controller based on Mamdani fuzzy inference (MFPID} is designed according to P1D excitation control principle and the composition nipple of fuzzy PID excitation controllers. The detailed design process of fuzzy logic unit based on Mamdani model and algorithm implementation of MFPID controller is presented. Combing advantages of conventional power system stabilizer (PSS), the segmentation switch control strategy is proposed by combing PSS and MFPID further. Finally, the effectiveness of the controller designed is illustrated by simulation.

$$G_A(S)\frac{U_f(s)}{U_{pwm}(s)} = \frac{K_A}{1+T_A S} \quad (3)$$

In considering of characteristics and requirements in large SGECS, the paper establishes a synchronous generator excitation control system model of each part. Especially focus on the relationship about the synchronous generator voltage, current, torque and other energy. We analysis the basic control laws, static and dynamic characteristics of the excitation system. According to research and engineering needs, Corresponding simplification of the theoretical model of SGECS, we access to the practical excitation control system model used by this paper. Those processing provide theoretical supports for the following sections.

$$G_K(S) = K_P(1+\frac{1}{T_i S}+T_d S) \quad (4)$$

For complexity and nonlinear in excitation control system, we proposed a nonlinear system parameter optimization strategy which combined with fuzzy theory and the classical PID control law. We design a fuzzy PID excitation controller based on Mamdani fuzzy model after comparative analysis of two fuzzy models. Without considering the accurate modeling of the SGECS system, the new controller can achieve stable operation under multi-operation conditions of the excitation system. Finally, we use comparative experiments to verify the validity of the method. Particle swarm optimization methods in recent years become to be the research focus. By reading a large number of literature references on the analysis of the mechanism of particle swarm optimization and improvements, we introduce two of the most common methods of particle swarm optimization, and on this basis, propose an adaptive particle swarm optimization based on hitting the wall rebound strategy. A simulation shows the calculation precision and convergence speed of the proposed optimization method in the excitation control system by compared with other two algorithms.

3.2 Parameter PID tuning principle

The excitation control system plays an important role in power system. It can be used to maintain generator terminal voltage and improve power system stability. This paper makes a research on excitation control system and gives concerning conclusions by the type of simulation. Besides, some new control methods are proposed and a kind of simulation platform of excitation control system is established. The tuning rules of KpKtKd and the membership functions of E and EC are respectively shown in Table 1 and Figure 2.

Table 1: Tuning rules of KpKtKd

E	**EC**						
	NB	NM	NS	Z	PS	PM	PB
NB	PB/NB/PS	PB/NB/NS	PM/PM/NB	PM/NM/NB	PS/NS/NB	Z/Z/NM	Z/Z/PS
NM	PB/NB/PS	PB/NB/NS	PM/NM/NB	PS/NS/NM	PS/NS/NM	Z/Z/NS	NS/Z/Z
NS	PM/NB/Z	PM/NM/NS	PM/NS/NM	PS/NS/NM	Z/Z/NS	NS/PS/NS	NS/PS/Z
Z	PM/NM/Z	PM/NM/NS	PS/NS/NS	Z/Z/NS	NS/PS/NS	NM/PM/NS	NM/PM/Z
PS	PS/NM/Z	PS/NS/Z	Z/Z/Z	NS/PS/Z	NS/PS/Z	NM/PM/Z	NM/PB/Z
PM	PS/Z/PB	Z/Z/PS	NS/PS/PS	NM/PS/PS	NM/PM/PS	NM/PB/PS	NB/PB/PB
PB	Z/Z/PB	Z/Z/PM	NM/PS/PM	NM/PM/PM	NM/PM/PS	NB/PB/PS	NB/PB/PB

In order to study the network performance effects on NCS, the networked excitation system is studied and simulated with networked control simulation tool True time toolbox. The issues of task schedule, network schedule, node driven mode and communication network type in power system excitation system are then addressed. The results of simulation analysis validate that dynamic schedule EDF algorithm can guarantee the performance of networked excitation system in task schedule and network schedule, that event driven mode can perfectly avoid vacant sampling problem in NCS, and that the Ethernet with high band and priority mechanism can guarantee the performance of the NCS based excitation system.
Furthermore, a networked AGC model is proposed based on the time-delay dynamic system theory. The time delay dependent stability cretin and the time delay independent stability cretin are compared. As the latter is more conservative and strict in engineering application, a robust controller designed with the former cretin is proposed. The digital simulation of networked AGC demonstrates that the controller designed with the time delay dependent stability cretin has lower conservatively and better performance.

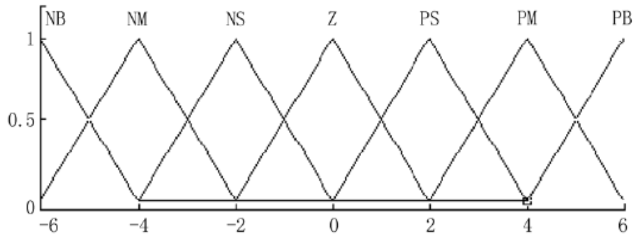

Figure 2: The membership functions of E and EC

The networked based generation unit and its realization are also dealt with in this paper. The uncertain model of time delay is built by the multiplicative perturbations model, and the robust control structure of networked dourine generating unit is thereby deduced; then a controller with both robust stability and performance robustness is designed. The simulation of frequency and load perturbation indicate that, u controller has superior control effect than controller and conventional PID controller.

$$H_j = \frac{dy}{dt} = w_0(P_m - P_e - P_D) \quad (5)$$

Next, the wide-area measuring system (WAMS) based on TCSC networked control strategy is presented. In order to transform the TCSC model with time delay to the conventional model without time delay, the augmented status is introduced. The controller design is based on the discrete sliding mode control theory so as to meet the demand of engineering application. A feasible improvement approach solution is also proposed to overcome the chattering problem. In addition, a single machine to infinite bus system is studied through digital simulations to demonstrate the comprehensive applications of the proposed strategy.

$$P_e = \frac{E_q V_s}{X_{d\Sigma}} \sin\delta + \frac{V_S^2}{2} \frac{X_{d\Sigma} - X_{q\Sigma}}{X_{d\Sigma} X_{q\Sigma}} \sin 2\delta \quad (6)$$

Finally, after analyzing the conventional IP QoS model, an integrated information transmission mode based on MPLS is proposed with the characteristics of information transmission in power system in consideration. The results of network simulation indicate that MPL S+Diff Serv network has better performance than DiffServ network alone in the power information congestion control, and that it guarantees the time delay and communication reliability of real time control information transmission.

$$T_e = \frac{dE_{fd}}{dt} = -E_{fd} + K_e U_R \quad (7)$$

3.3 The membership function of each variable is established

The membership functions of Kp and Kt and Kd.are shown in Figure 3.

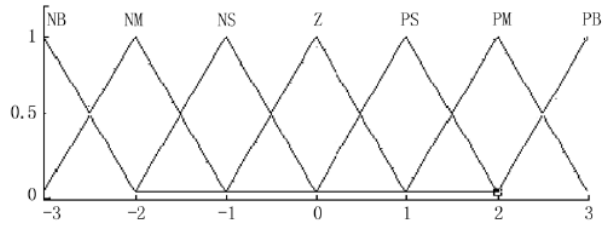

Figure 3: Membership functions of Kp and Kt and Kd.

1) The fuzzy rule table is established

The generator excitation control system is the important part of the power system. It can effectively guarantee the voltage quality and enhance the run stability of the power system. Therefore, excitation control lias the significance to the running of the entire electrical power system.

2) Simulation of Fuzzy PID Controller in Synchronous Generator Excitation Control System (see Figure 4)

In this paper analyzes the development and actuality of generator excitation control rules, and based on fuzzy control theory and particle swarm optimization(PSO) algorithm, firstly the fuzzy PID excitation controller is put forward with time-varying and nonlinear of the controlled object of synchronous generator excitation control system. The controller combines their own advantages of fuzzy control and conventional PID control, which not only maintain simplicity and the precision characteristic of PID control but also display flexibility, adaptability, quickness of fuzzy control. And then, to solve the premature problem of PSO, an improved PSO algorithm was proposed, and the improved PSO algorithm were tested through two examples. Improved PSO algorithm optimizes the parameters of fuzzy PID excitation controller, and thus a near-optimal excitation controller has been realized.

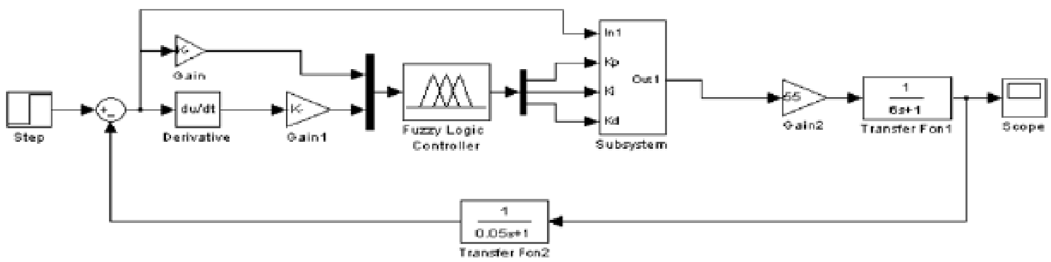

Figure 4: Block diagram of fuzzy-PID excitation controller for simulation.

Finally, Fuzzy PID excitation control system based on improved PSO algorithm simulation tests are carried on and comparisons with excitation control without PID, the conventional PID excitation control, PSO optimization of conventional PID and fuzzy PID excitation control system excitation control system are performed. The results show that fuzzy PID excitation control system based on improved PSO has excellent dynamic and static quality and control effect, stronger robustness and adaptability.

$G_G(S)\frac{K_G}{1+T'_{do}S}, K_G = 1, T'_{d0} = 6.$

Two aspects are embodied in the development of Excitation system for generator, which includes excitation way and excitation controller. Lots of data point out that it is the trend to use self and shunt excitation system on large and medium generator. This thesis sets forth the merit and flaw of excitation system and other concerned problems of main loop, magnetizing field loop and de-excitation loop in detail. On the other hand, with the development of control theory, the control ways of excitation system are constantly improved, which acquires plentiful and substantial fruits in this fields. This thesis focuses on the application of AVR+PSS excitation controller and linear optional controller. The step response of fuzzy-PID excitation controller can be seen in Figure 5.

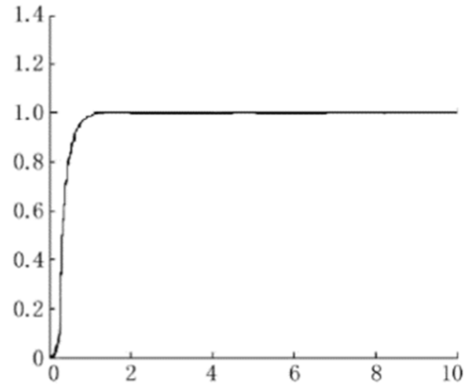

Figure 5: Step response of fuzzy-PID excitation controller.

$G_M(S)\frac{K_C}{1+T_R S}, K_C = 1, T_R = 0.05.$

Simulink toolbox provided by PID is software planet towards power system simulation, which could realize numerical simulation of power system. The Simulink toolbox is used in the fourth chapter of this thesis to construct single-machine infinite simulation model with excitation controller. Simulation tests were done on the model to test-two types of excitation controller (AVR+PSS excitation controller and liner optimized excitation controller), which have designed in the third chapter. The result indicates that liner optimal excitation controller has more preferable control performance and that AYR+PSS excitation controller has well dynamic performance, too. The step response of routine PID excitation controller can be seen in Figure 6.

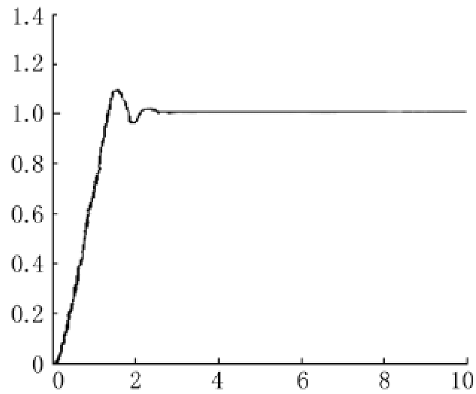

Figure 6: Step response of routine PID excitation controller.

$G_A(S) = \frac{K_A}{1+T_A S}, K_A = 55, T_A = 0.$

$K_p = 80, K_i = 10, K_d = 2.$

Finally, the design of the two controllers was compared. From the actual results of the controllers, the two can meet control accuracy and reliability requirements. In the circumstances of static small disturbance, the non-linear voltage feedback optimal controller and fuzzy controller have their advantages in control effects. In the large disturbance in the transient, Fuzzy controller is superior than the non-linear voltage feedback optimal controller In a stable time, overshoot and the limit time of stability. In overall performance, fuzzy controller is superior to the non-linear voltage feedback optimal excitation controller. The low-frequency oscillation of the system can be seen in Figure 5.

The simulation results of fuzzy PID control system in simulink are shown in Figure7. The results show that the fuzzy PID controller can be used to simulate the fuzzy PID control system. Small overshoot, steady-state error is small, fast response.

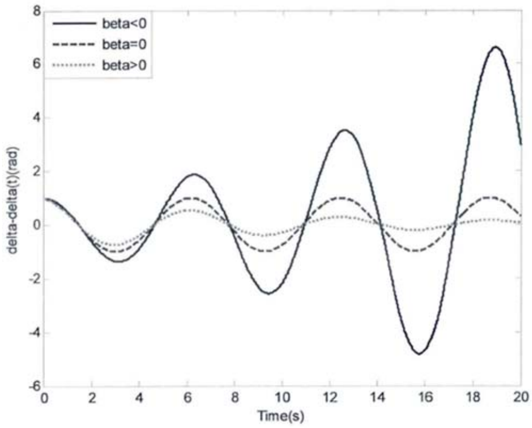

Figure 7: Low-frequency oscillation of the system.

4. Conclusion

This paper starts with the models of synchronous and excitation system, modifies the synchronous model in virtue of the need of research, and makes an introduction of measurement unit, control unit and main-loop models of excitation system. Besides, a type of Non line-PID control scheme which has better performance is put forward based on common PID control. Secondly, this paper makes simulations on PID control, Non line-PID control and Fuzzy-PID control under step-response and sudden-load change in the case of brush and brushless excitation system. Besides, concerning conclusions are given on the basis of analytic result of terminal voltage output of generators. Also, a new control type based on electric motor is put forward, the principle of which is based on excitation current closed-loop control. At the same time, control precision is considered at the basis of Noline-PID control.

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