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HVDC Intelligent Controller

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Abstract

The Purposes of this paper describes Gezhouba to Nanqiao rectifier direct current transmission project PI controller, through the intelligent control theory and the combination of the traditional PI controller are intelligent controller—HVDC fuzzy-PI controller, using the improved genetic algorithm domain Fuzzy- PI controller's language of control theory. The result of improved intelligent controller has a simple structure, fast response characteristics. Using MATLAB / SIULIKMN the fuzzy toolbox and genetic algorithm toolbox for system simulation, simulation results show that the Conclusions of the intelligent controller has better adaptability and dynamic features to improve the robustness of the system and transient stability for the intelligent control of high voltage DC reference.

Keywords: HVDC; intelligence theory; fuzzy PI controller; genetic algorithm

1. Introduction

High Voltage Direct Current (HVDC) transmission is a typical non-linear, time-varying, dynamic system. The basic control for the rectifier is constant current control, constant voltage control of inverter side. Rectifier and inverter control performance is good and stable operation of HVDC system security guarantee, so the control of a HVDC system, the core issue of concern. The control strategy for the traditional PI control, but the adaptive control, robustness is poor. Intelligent control has become a focus of research in which the method of fuzzy control theory with the traditional PI controller to improve the study has become a trend, this paper as a theoretical basis for the step response curve of the fuzzy control strategy to achieve intelligent control. Fuzzy control of the domain is divided by all means uniform. In the actual control process, in order to achieve more precise control effect, the more close to zero when the variables should be taken when high-resolution fuzzy on the field. Using improved genetic algorithm to optimize the fuzzy language of the resolution and shape of the domain in order to achieve better control.

2. Traditional Pi Controller

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The Gezhouba to Nanqiao project as an example of a DC transmission PI controller parameters optimization described the specific steps. Gezhouba to Nanqiao bipolar of HVDC project in 1989, voted to run, the ratings for the ± 500kV/1200A/1200MW. Gezhouba side of the converter transformer capacity of 732MVA, variable ratio 525kV/208kV Nanqiao side converter transformer capacity of 672MVA, variable ratio 230kV/198kV; both sides of the short circuit impedance are 15%. DC overhead line length of 1046km, wire model LGJQ-300. Provide 402Mvar Gezhouba side with the exchange of reactive power filter; Nanqiao provides 696Mvar side with the exchange of reactive power and 87Mvar capacitor filter. System shown in Figure 1:

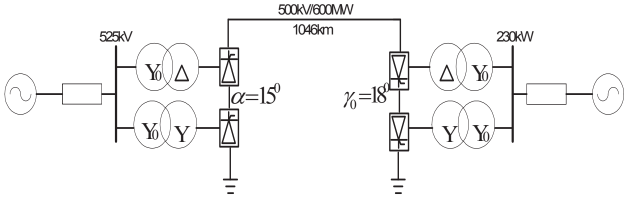

Figure 1. The diagram of Gezhouba to Nanqiao DC transmission project system

Rectifier constant current control, when the disturbance occurred in the system, by changing the rectifier α angle of the line to keep the DC current setting value. PI Controller shows in Figure 2, the control process is: The error e between the current reference value I_{ref} and the DC line current I_d as the deviation of the PI controller's input received through the traditional PI controller output, the α adjustment command as a trigger.

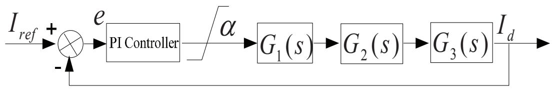

Figure 2. PI controller schematic

Where: $G_1(s)$ Link inverter; $G_2(s)$ DC line links; $G_3(s)$ Measurement link.

2.1 Link inverter

When the load time constant is greater than the inverter delay time, the inverter can be expressed as first-order inertia, the transfer function:

$$G_1(s) = \frac{G}{1+sT} \tag{2-1}$$

When the control system operating in frequency 50HZ, 6 pulse converter under the bridge, the part of the time constant T = 3.33ms. The output of inverter no-load power $U_{d(0)} = U_{d0}\cos\alpha$, $U_{d(0)}$ is no phase control is the ideal no-load DC voltage, Proportional gain $G = \frac{\Delta U_{d(0)}}{\Delta\alpha} = -U_{d0}\sin\alpha$ $\Delta U_{d(0)}$ is the phase control for the rectifier side of the ideal no-load DC voltage variation. In a stable operating point α_0 obtained after linearization $G \approx -U_{d0}\sin\alpha_0 = -\frac{3\sqrt{2}}{\pi}U_1\sin\alpha_0$, U_1 for the inverter AC side line voltage RMS. When the stability of the system, the rectifier side of the stable operation when $\alpha_0 = 15^0$, the bridge converter AC side line voltage $U_1 = 209kV$, then (2-1) is:

$$G_1(s) = -\frac{1.35\times 209\sin 15^o}{1+0.0033s} \tag{2-2}$$

2.2 DC line links

Assuming inverter side, a constant angle of γ_0 off control or constant voltage control to maintain constant voltage, direct current lines expressed equivalent T type network, the DC system equivalent circuit shown in Figure 3, ΔI_d for the rectifier DC current changes in export volume; R and L respectively, the midpoint of the DC line to the converter circuit between the outlet resistance and inductance, C is the parallel capacitance of DC line.

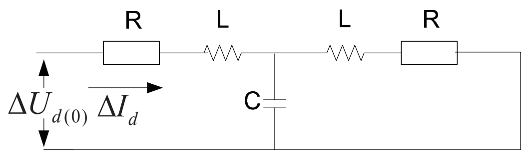

Figure 3. T-type equivalent circuit line

DC circuit transfer function is:

$$G_2(s) = \frac{\Delta I_d}{\Delta U_{d(0)}} = \frac{1}{R+sL+\frac{1}{1/(R+sL)+sC}} = \tag{2-3}$$

$$\frac{s^2LC+sRC+1}{s^3L^2C+2s^2RLC+s(R^2C+2L)+2R}$$

Parameters selection is as follows: R=13 Ω 、L=0.46H、C=13.73 μF

$$G_2(s) = \frac{6.32\times10^{-6}s^2+1.78\times10^{-4}s+1}{2.91\times10^{-6}s^3+1.64\times10^{-4}s^2+0.922s+26} \tag{2-4}$$

2.3 Measurement link

Measured DC link current measurement used to simulate the process of inertia can be used to simulate the first order, the transfer function

$$G_3(s) = \frac{K}{1+s\tau} \tag{2-5}$$

Inertia time constant τ, reflecting the response speed measuring equipment, for the current measurement is usually taken to be 0.0012s; gain K is used to transform the actual current value of the standard dimensionless What value, so taking the inverse of the current reference value. DC current rating 1.2kA, measuring the ratio of link gain of 0.833, the time constant T = 0.0012s, can be seen:

$$G_3(s) = \frac{0.833}{1 + 0.0012s} \tag{2-6}$$

MATLAB can only handle the order the following system 5, so the two first-order links $G_1(s)$ and $G_3(s)$ combined simplified,

$$G_1(s)G_3(s) \approx -\frac{1.35\times 209\times 0.833\sin 15^o}{1+(0.0033+0.0012)s} \tag{2-7}$$

The traditional K_p, K_i tuning, the results show that when $K_p = 2$, $K_i = 80$ best control parameters.

3. Fuzzy PI controller

The step response curves, the error curve e and the integral of the error e curve ec in Figure 4, the response curve as an example Figure 5 curve is divided into a number of regional, the principle is: the response curve intersects with the given time, the response curve volatility process to achieve peak and trough times, the corresponding error curve e and integral of the error e curve ec also points to these moments as a zoning point.

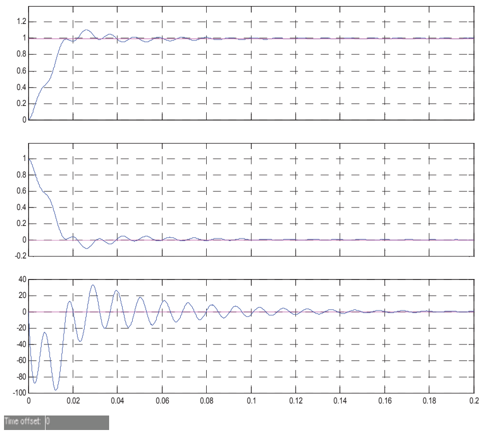

Figure 4. Response curves、e curves、ec curves

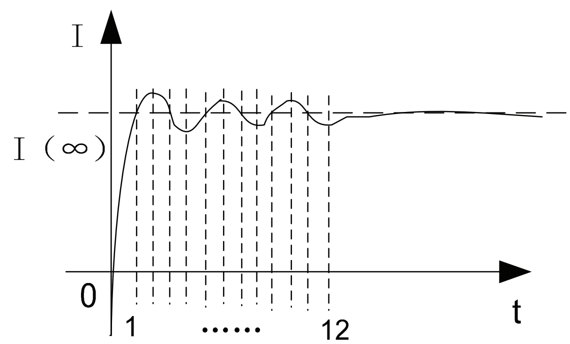

Figure 5. Response curves

To the first area, for example, when e> 0, ec <0 and e × ec <0, the setting value tend to the reference value. I come to the discussion of each case the tuning trend in Table 1:

Table I. I set trends in the entire

e	>0	<0	<0	>0
ec	<0	<0	>0	>0
e×ec	<0	>0	<0	>0
I trends	Tend to the reference value	Deviate from the given value	Tend to the reference value	Deviate from the given value

According to the principle of fuzzy control to improve the traditional PI controller, select the two-input dual-output fuzzy controller, e and ec as input into the fuzzy control rules have come out $K_p^{'}$ 、 $K_i^{'}$ the control diagram shown in Figure 6:

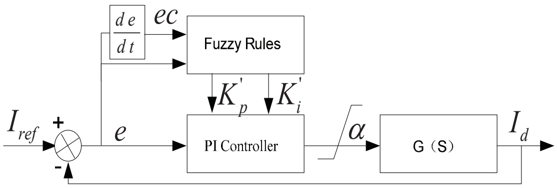

Figure 6. Fuzzy - PI controller schematic

Figure of $K_p^{'}$ 、 $K_i^{'}$ is not a fixed quantity, but rather a traditional PI control parameters on-line correction of the correction. According to e and ec .PI controller parameters for the adjustment of K_p , K_i principles:

- When $|e|$ is large, should take a larger K_p (Improve the system response speed), and to $K_i = 0$ (To avoid a large overshoot).
- When $|e|$ is medium, should take the smaller K_p (the response overshoot is smaller), K_i the appropriate selection.
- When $|e|$ is small, should take the larger K_p and K_i (to enable the system to have a good steady state performance).

Based on the above principles and Table 1, the error e and error change ec fuzzy processing, fuzzy set of input variables e, ec and fuzzy output, and the language value of the fuzzy set is {negative big, negative middle, negative small , zero, positive small, positive middle, positive big}, denoted as {NB, NM, NS, Z, PS, PM, PB}, receive $K_p^{'}$, $K_i^{'}$ control rules in Table 2.

Table II. $K_p^{'}$, $K_i^{'}$ control rules

$K_p^{'}$		the integral of the error ec						
		NB	NM	NS	Z	PS	PM	PB
the error e	NB	PB	PB	PM	PM	PS	Z	Z
	NM	PB	PB	PM	PS	PS	Z	NS
	NS	PM	PM	PM	PS	Z	NS	NS
	Z	PM	PM	PS	Z	NS	NM	NM
	PS	PS	PS	Z	NS	NS	NM	NM
	PM	PS	Z	NS	NM	NM	NM	NB
	PB	Z	Z	NM	NM	NM	NB	NB

K_i'		the integral of the error ec						
		NB	NM	NS	Z	PS	PM	PB
the error e	NB	NB	NB	NM	NM	NS	Z	Z
	NM	NB	NB	NM	NS	NS	Z	Z
	NS	NB	NM	NS	NS	Z	PS	PS
	Z	NM	NM	NS	Z	PS	PM	PM
	PS	NM	NS	Z	PS	PS	PM	PB
	PM	Z	Z	PS	PS	PM	PB	PB
	PB	Z	Z	PS	PM	PM	PB	PB

According to Figure 4 and Table 1 to determine the input variable e, the domain is [-0.5,0.5], input variable ec, the domain is[-20,20]，Output variables K_p', the domain is[-0.8,0.8]，Output variables K_i', the domain is[-10,10]，In MATLAB7.5 environment, the use of the software itself carried by Fuzzy toolbox, the control rule according to the fuzzy controller. Initialization of the membership function of triangular membership functions are selected using a two-input and two-output control Fuzzy controller, respectively K_p'， K_i'.

4. **Optimization of fuzzy PI controller**

Fuzzy control of the domain is divided by all means uniform. In the actual control process, in order to achieve more precise control effect, the more close to zero when the variables should be taken when high-resolution fuzzy on the field. So it uses the improved genetic algorithm to optimize the fuzzy control theory domain. To overcome the lack of genetic algorithm approach using the n atavistic an excellent parent to replace the n-grandson of vulnerable groups, the language of the e domain, for example, the central symmetry of the domain with an isosceles triangle membership function to fixed distance as the triangle code population. Fitness function:

$$J(ITAE) = \int_0^\infty t\left|e(t)\right|dt = \min \tag{4-1}$$

The objective function is used to optimize the control parameters, the effect well. Maximum problem, so the objective function to be mapped to find the maximum value of the form, as usually is the pursuit of maximum genetic algorithm, fitness function will be taken here

$$f = f_{\max} - J \tag{4-2}$$

Where: $f_{\max}$ is the maximum fitness of each generation; t order to achieve stability in time; $\left|e(t)\right|$ the absolute value of the error. Chosen as the initial population size of 50, chosen as the largest evolutionary generation 100, selected as the crossover probability p_c is 0.8, in order to maintain the diversity of the population mutation rate chosen as p_m is 0.5. By some algebra reproduction, crossover, mutation, replacement cycle of operations on behalf of grandson, the last uniform convergence for the same binary strings, binary strings by parsing can be obtained of the fuzzy language of the domain.

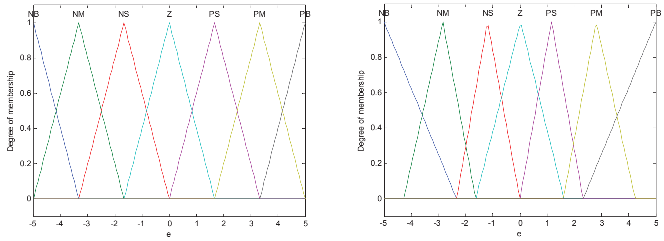

Figure 7. The language of the optimized field

The simulation time in the 0-0.25s the rectifier unit step response of ， in the 0.25s-0.35s, so that the current setting value decreased by 10%, mimicking the normal operation of the disturbance occurs, take K_p=2， K_i=50 for the PI controller initial value. The simulation results shown in Figure 8:

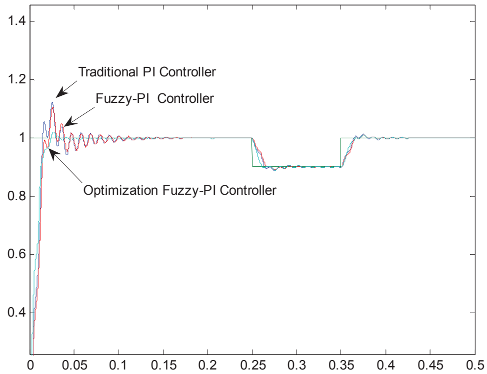

Figure 8. Simulation results

Figure 8 shows the simulation results show that, in the rectifier side of the step response curve can be seen. After the improvement of genetic algorithm to optimize the Fuzzy-PI controller than the conventional PI controller and Fuzzy-PI controller has better control. 0.25s-0.35s in the disturbance occurs, optimized Fuzzy-PI controller can better inhibit the current oscillations and fast response, making the system more quickly to restore stability and improve transient stability of the HVDC system performance.

5. Conclusion

In this paper, Gezhouba to Nanqiao rectifier direct current transmission project PI controller, for example, through the fuzzy theory and the conventional PI controller combined with improved genetic algorithm to optimize the use of the Fuzzy-PI controller. The controller is simple, fast response, showing a good robustness and adaptability, to improve the stability of the system. 0.25s-0.35s of the simulation results show that the controller has better adaptability and dynamic features to improve the transient stability of the system for intelligent control of high voltage DC reference.

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