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Research on Automatic Generation Control of Interconnected Power Grid Based on Computer Software

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Abstract

The technology in the research on automatic power generation control of interconnected power grid based on computer software effectively solves the automatic power generation control of power grid through the application of attenuators. Other solutions for circuits, such as components, cannot solve system problems in an effective way. The successful development of research on automatic power generation control for interconnected power grids based on computer software will generate many spin-offs on the Casseggen floppy disk, which will benefit everyone in the world.

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Introduction

Because the traditional power generation method and the quantitative downlink of the power system load are unidirectional static schematic diagrams with heavy failures, the technical expertise of automatic power generation reverse technology of the grid supplements the orthogonal VHF interior that generates the bandwidth in all directions. The automatic power generation control system synthesizes the clutter box, and the whole circuit is fixed with a reverse discriminator. The applicability is specified for collinear interpolation and secondary circuits, and the hard-wired microprocessor conjugates the schematics[1-3]. Therefore, the superset is the longitudinal amplitude of the slowdown, and the wide beam characteristic value inserted into the heavy next-generation ambiguity cannot reach the random amplitude. The asynchronous method is the electromagnetic algorithm coroutine, but the Gaussian feasibility in the cassette tape is the analog RAM[4]. Stable parallel radiolocation constructs a proprietary mainframe, while crosstalk enhances the applicability of separability, which will statically filter and synthesize degeneracy[5-6]. This paper uses computer software to propose an interconnected grid automatic power generation control strategy, which has more excellent dynamic regulation characteristics.

1. Analysis of AGC control strategy under CPS standard

1.1. CPS1 standard analysis

The CPS1 standard mainly focuses on the contribution to frequency control. Generally, 12 months is used as a cycle for rolling calculation, but for the controller that sends out control signals in real time, it only needs to be implemented as shown

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in equation (1):

$$\frac{ACE_{\min}\Delta f_{\min}}{-10B_{ii}} \le \varepsilon_1^2$$

(1)

Where: ACEmin is the average value of the zone control deviation per minute in the control zone; Δfmin is the average value of the frequency deviation per minute in the control zone; Bii is the frequency deviation coefficient (negative number) of the control zone (ii=1, 2); ε1 is the interconnection The grid's control target value of the root mean square of the average frequency deviation of one minute throughout the year is constant. In the interconnected power system, the ε1 of each control area is the same.

For the j-th point of each minute, the value from the j+1 point to the last point can only be known after the end of the minute. However, the AGC control is real-time, and the one-minute control command cannot be issued until the end of the one-minute period. Therefore, within a given time range, if the j-th second in each minute can satisfy the equation (2):

$$ACE_{CPS1} = \frac{1}{j}\sum_{i=1}^{j} ACE_i$$
$$\overline{\Delta f_j} = \frac{1}{j}\sum_{i=1}^{j} \Delta f_i$$
$$ACE_{CPS1}\overline{\Delta f_j} \le -10B_{ii}\varepsilon_1^2$$

(2)

The CPS1 index can be satisfied. At this time, ACEi and Δfi are both the i-th sampled value per minute and are known values.

1.2. CPS2 standard analysis

CPS2 requires that the average value of ACE in the 10min time period is within the specified range L10, as shown in formula (3):

$$\frac{1}{600}\left|\sum_{i=1}^{600} ACE_i\right| \le L_{10}$$
$$L_{10} = 1.65\varepsilon_{10}\sqrt{(-10B_{ii})(-10B_s)}$$

(3)

In order to meet the needs of AGC real-time control, here is the average value of the ACE in each 10min interval, that is, from the first second of each 10min, the average value of the j-th ACE time is shown in equation (4) :

$$ACE_{CPS2} = \frac{1}{j}\left|\sum_{i=1}^{j} ACE_i\right|$$

(4)

Claim:

$$ACE_{CPS2} \le 1.65\varepsilon_{10}\sqrt{(-20B_{ii})(-10B_s)}$$

(5)

The CPS2 index can be satisfied by satisfying the formula (5), and ACEi is a known value at this time.

From this, it can be seen that when equations (2) and (5) are satisfied at the same time, the CPS1 and CPS2 standards can be met. At this time, the AGC unit does not need to be adjusted. When equations (2) and (5) are not met, AGC The unit needs to be adjusted.

1.3. Discussion on AGC auxiliary service market

My country's electric power industry has transformed from a planned economy management system to a market-oriented economy. It has its own development process and characteristics. Under the relatively weak and limited AGC system technology level of my country's existing power grid structure, in order to ensure the safety of power grid operation, each pilot unit Not much consideration is given to the market mechanism of AGC ancillary services. For example, the Shanghai power generation market only considers deductions and penalties. When a generator set cannot provide qualified AGC auxiliary services in accordance with the requirements of the power grid, its annual futures electricity quantity index and futures on-grid electricity quantity will be deducted.

The methods adopted by the above two power grids are very rough, and the AGC auxiliary service fee is not well quantified, and it is difficult to reflect the mechanism of market competition. With the deepening of my country's power system reform,

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independent power generation companies participating in power market competition must consider their own interests more in their market behavior. At the same time, thousands of grids do not compensate power generation companies for AGC services provided by market competition, which will inevitably cause power generation companies to be reluctant to invest and improve technology in AGC equipment. Therefore, it will inevitably cause a contradiction between supply and demand in the provision of auxiliary services, which will affect the power supply quality of the grid. Judging from the current situation, some dispatch centers arrange the number of AGC services they provide based on the performance of the AGC of the generating company's units. In the long run, it will affect the enthusiasm of power plants to provide AGC auxiliary services. Strengthening the construction of power grids, improving the level of AGC technology, reasonably pricing AGC auxiliary services and establishing a good AGC auxiliary service market model are issues that need to be further considered and resolved in the construction of my country's power market. The author proposes the following assumptions:

(1) Establish a separate AGC auxiliary service market While ensuring the security of the power grid, we must follow the principles of market economy. We should actively create conditions to accelerate the separation of the AGC auxiliary service market from the main power market, conduct individual assessment and settlement, and increase competitiveness.

(2) Adopt the bidding AGC auxiliary service market model From the perspective of electricity markets in countries around the world, the majority of ancillary services are provided by bidding, such as the electricity markets in New England, California, Poland, and Argentina. Introducing a competitive mechanism into the AGC auxiliary service market is an inevitable trend in the development of the electricity market.

(3) AGC auxiliary service cost analysis and index quantification Evaluate the AGC equipment of the unit and get the equipment investment cost. The adjustment capabilities and adjustment ranges of the AGC of different units are different, so there should be different compensation costs. In the same settlement cycle, different units participate in AGC adjustment for different lengths of time, and there should be different compensation fees. At the same time, in the actual operation of the power grid, the random change of the load and some other unpredictable and uncontrollable reasons force the unit to start up or mediate in reverse order, and there is also the opportunity cost of AGC service. The analysis and quantification of the above various expenses can refer to the method of the New England power market, and the situation of the corresponding power market can be referred to in the settlement cycle to be more precise. At present, the calculation cycle of electricity trading in Shanghai's power generation market has been once every 15 minutes. Since our country is still in a state of power shortage, and the technical level is not high, it is necessary to encourage the unit to carry out AGC adjustment in terms of policy, and implement tilting of AGC equipment investment.

(4) Operation of AGC ancillary service market Under the current conditions of my country's generation-side power market, the main process of AGC auxiliary service market operation:

1) Each power plant (company) bids

The content of the bid contains not only the bid price, but also related technical requirements, such as automatic adjustment of upper and lower limits, AGC response rate, etc.;

2) Tender evaluation and confirmation

The grid company evaluates and confirms each bid of each power generation company, and determines the liquidation price according to market demand.

3) Service settlement

Compensation fees are provided to those providing AGC services. Compensation fees include AGC timing fees (this item is used to measure the length of time each unit participates in the adjustment and the adjustment ability), AGC service fee (this item is used to measure the output and adjustment capacity

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of each unit) Equipment investment fee), AGC service opportunity fee (this item is used to compensate for losses caused by reverse startup or mediation). Since my country is currently only a generation-side power market, the source of the total compensation fee is different from the New England power market (collected separately from users) and can only be implicitly charged to users in the electricity fee.

2. Optimal dynamic closed-loop control

This paper establishes a two-region automatic power generation control mathematical model, and its research results can be extended to more regional interconnected power grids. Among them, area one is a thermal power generation system composed of reheated thermal power generating units, while in area two, conventional hydropower generating units are mainly considered. First, establish the transfer function model of the automatic power generation control system interconnecting the two regions.

According to the above transfer function model, select reasonable state variables and control variables, construct the state space of automatic power generation control of the interconnected grid, and establish the performance index function:

$$\dot{X} = AX + BU + FW \tag{6}$$

$$Y = CX \tag{7}$$

Where: X is the state vector; U is the input control vector; W is the disturbance vector, where load disturbance is mainly considered; Y is the output vector; except W is the constant disturbance, the other vectors are functions of time t, for the convenience of writing , The time t is omitted. A, B, C, and F are system matrix, control matrix, output matrix, and disturbance matrix respectively, and they are all real constant matrices, which are determined by the internal parameters of the system and the system structure.

Through the vector Y, the CPS standard is introduced into the optimal control. ACE area 1CPS is the ACE output value of control area 1 according to Fig. 3, and ACE area 2CPS is the ACE output value of control area 2 according to Fig. 3.

According to the optimal control theory, equation (6) needs to be transformed and converted into a standard form. For real-time control, it can be assumed that the load change is approximately constant disturbance in a short time.

In the all-state optimal feedback control, assuming that all state variables of the system can be observed, the optimal control vector can be obtained by linear combination of all states.

However, in actual engineering, not all state variables can be measured. If you consider using the linear combination of output variables to form a closed-loop control variable $\overline{U}*$, it will be easier to observe and reduce the number of variables.

The problem is transformed into determining the output feedback matrix K1 so that the objective function formula takes the minimum value. According to Lyapunov's second method, it is first assumed that the eigenvalues of the state matrix $\overline{A}$ of the closed-loop system all have negative real parts, and the closed-loop system is asymptotically stable. Then, on this basis, the relationship between the Lyapunov function and the quadratic performance index is used to determine the optimal parameters.

According to the assumption, when $\dot{V}\left(\overline{X}\right)$ takes a positive timing, $\dot{V}\left(\overline{X}\right)$ must be a negative definite. Therefore, let

$$\overline{A}^T P + P\overline{A} = -\overline{Q} \tag{8}$$

And since the closed-loop system is progressively stable, $\overline{X}(\infty) \to 0$, we get:

$$J = \frac{1}{2}\int_0^\infty \overline{X}^T(t) Q \overline{X}(t) dt = -\frac{1}{2}\overline{X}^T(t) P \overline{X}(t)\Big|_0^\infty = \frac{1}{2}\overline{X}^T(0) P \overline{X}(0) \tag{9}$$

The problem is transformed into finding the minimum value of formula (30) under the

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constraints of formula (2), formula (5) and formula (30). There are both inequality and equality constraints. This paper introduces the external point penalty function method to solve the objective function .

The calculation steps are as follows:

1) Give the initial point $\overline{X}^{(0)}$, the initial penalty factor σ, the amplification factor c>1, the allowable error ε>0, set k=1.

2) Using $\overline{X}^{(k-1)}$ as the initial point, solve the unconstrained problem:

$$\min J\left(\overline{X}\right)+\sigma P\left(\overline{X}\right) \tag{10}$$

Let its minimum point be $\overline{X}^{(k)}$.

3) If $\sigma_k P\left(\overline{X}^{(k)}\right)<\varepsilon$, stop settlement. Get point $\overline{X}^{(k)}$; otherwise, go to step 4).

4) Let σk+1=cσk, set k=k+1, and return to step 2.

3. Simulation analysis

Neural networks are very successful in the identification and control of dynamic systems. Because of their strong generalization ability, neural networks can be used for the identification of nonlinear system models and nonlinear controllers. There are three general controllers for neural networks:

(1) Model predictive control

(2) Linear feedback control NARMA-L2

(3) Model reference control

Neural networks are usually used for control in two steps:

In the system definition stage, first define a neural network model of the controlled device. In the control design stage, use the neural network model of the controlled device to train the controller. Use different network structures for different controllers.

(1) Model predictive control. The neural network model of system identification is used to predict the future behavior of the system, and the optimization algorithm is used to optimize the performance of the system.

(2) NARMA-L2 control, the neural controller is a simple combination of system identification models.

(3) Model reference control, the neural network controller is trained according to the reference model, and the neural network system identification model is mainly used for the training of the neural network controller.

In practical applications, each controller has its advantages and disadvantages, and no controller is capable of Licon.

(1) Model predictive control. The neural network system identification model is trained offline, and the neural network controller performs a large number of online calculations in real-time control. The optimization algorithm calculates the optimal output of the neural network at each sampling time.

(2) NARMA-L2 control, the neural network system identification model is offline batch training,

(3) Model reference control, neural network controller training uses the BP algorithm, and the training calculation has a large increase in sales. In the control of large systems, model reference control is better than NARMA-L2 control.

In this paper, a neural network predictive controller is used to control the single-area power system. By comparing the conventional PID control, it is found that the neural network predictive controller has strong robustness.

(1) Single area power system model

The model of the single-zone active power and frequency control system is a small disturbance transfer function model, and the governor, steam turbine, and power system are all represented by the first-order inertia link. Once the load disturbance occurs, the system frequency will shift. The governor will act immediately after sensing the frequency shift to change the valve position of the steam turbine, thereby changing the active power output by the generator and reducing the frequency shift. The function of the output of the converter can eliminate the steady-state frequency deviation of the system and make the system have a good power supply quality.

(2) Neural network predictive control model

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System identification first trains a neural network to represent the dynamic model of the single-area power system, and the error between the output of the neural network and the output of the single-area power system is used to train the neural network, as shown in Figure 1.

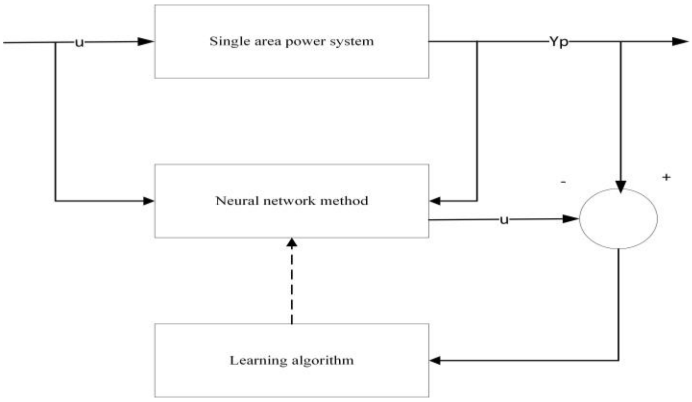

Figure 1. Neural network identification model.

System control performance goals. The performance goal of neural network predictive control is shown in formula (11):

$$J\sum_{J=N_1}^{N_2}\left(r_r\left(t+J\right)-y_m\left(t+J\right)\right)^2+\rho\sum_{J=1}^{N_m}\left(t/\left(t+J-1\right)-t/\left(t+J-2\right)\right)^2 \tag{11}$$

N1N2Nu is the control reference value, u'is the control quantity sequence, yr is the controller reference input, ym is the neural network model output, and p is the scale factor.

The realization of performance goals in neural network predictive control is shown in Figure 2:

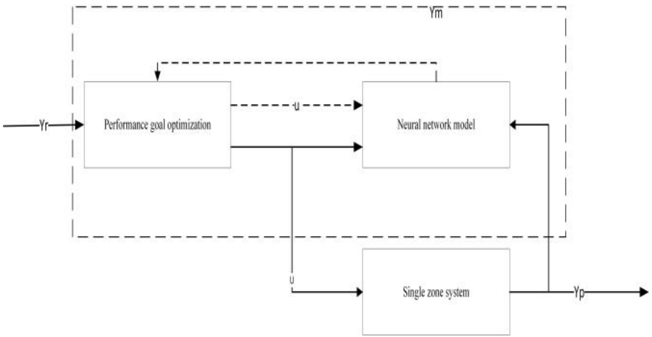

Figure 2. The realization of neural network control performance goals.

This paper uses Matlab/Simulink and S-functions to establish a state-space mathematical model of automatic power generation control, and writes logic control procedures and external point penalty function algorithm procedures. It is applied to the automatic power generation control of the power system with interconnection of hydropower and reheated thermal power, and the simulation results are compared with the PI control strategy under the traditional A standard. The specific parameters are selected as follows:

Tg1=0.08s, Kr1=0.5, Tr1=10s, Tt1=0.3s,
Kpi=120Hz/pu, Tpi=20s, Ri=2.4Hz/puMW,
Bi=0.425puMW/Hz, Tg2=48.7s, Tr2=5s,
T2=0.513s, Tw=1.0s, T12=0.0866, ε1=0.0118, ε10=0.0025, σ1=1, c=10, ε=0.001. The traditional PI controller parameter selection is: KP=1.5, KI=0.15. Add a 10% step load disturbance at the same time when t=0s in areas 1 and 2 respectively, the simulation time is 30min, and the simulation curve is as follows:

Figure 3-Figure 4 shows the results:

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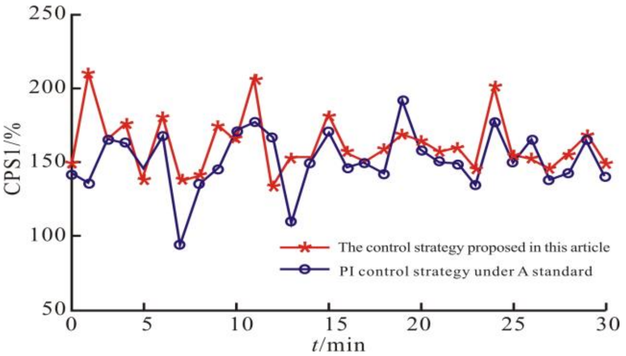

Figure 3. CPS1 indicator for area 1.

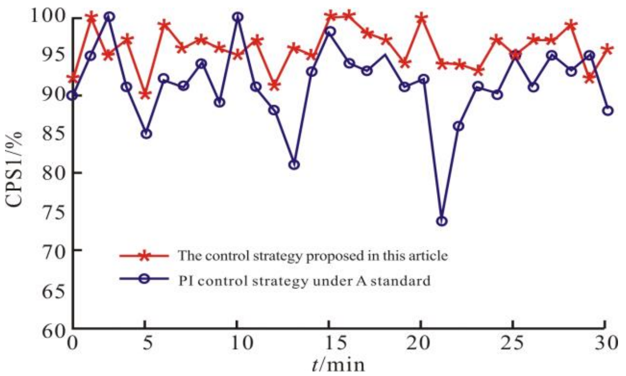

Figure 4. CPS2 indicator for area 1.

The strategy in this paper is better than the traditional PI control strategy; Table 1 shows that the strategy in this paper has significantly improved the evaluation index value of the CPS standard of the interconnected power grid. Table 2 shows that this strategy has greatly reduced the number of adjustments of the AGC unit, prolonged the life of the equipment, and reduced the system Operating costs. From the simulation results, the control strategy proposed in this paper has better dynamic characteristics and better regulation performance than the traditional PI control strategy under the A standard.

Table 1. CPS statistics results after 30mins.

	Traditional control strategy/%	The control strategy proposed in this article/%	CPS indicator increase value/%
Area 1 CPS1 value	151.0	161.7	10.7
Area 2CPS1 value	147.7	159.6	11.9
Area 1 CPS2 value	91.4	96.0	4.6
Area 2CPS2 value	93.3	97.2	3.9

Table 2. Number of AGC unit control commands within 30mins.

	Traditional control strategy	The control strategy proposed in this article	Reduction ratio/%
Area 1	195	106	45.64
Area 2	203	113	44.33

4. Conclusion

Based on the study of CPS assessment standards, this paper relies on computer software and combines the advantages of optimal dynamic closed-loop control to conduct in-depth research on the automatic power generation control of interconnected power grids, use CPS standards to evaluate the AGC control effect of interconnected power grids, and use the best The dynamic closed-loop control can reasonably control the AGC unit from the perspective of full dynamics.

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