



Research Article

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Modeling and simulation in water turbine generator set systems

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ABSTRACT

Water turbine generators are a nonlinear and time-varying complexity system, the electric power voltage and frequency should maintain the stable value to ensure safety power supply. The traditional PID control algorithm is difficult for accurate controlling, which causes along stabilizing time for the system. To solve the above problems and research on water turbine generator optimal control problem .the paper proposes a water turbine generator control method based on CMAC and PID. PID is used to realize feedback control and ensure that the system is stable and the system disturbances are reduced. Using CMAC feed forward control the control method speeds up the system response speed and reduces the overshoots, thus enhances the control accuracy modeling and Simulation results show that the compound CMAC and PID controller, compared with the conventional PID controller, improves the real-time performance, enhances the stability of the system, which ensures better control effects becomes more smooth and faster in adjusting.

Key words: Water turbine generator set; CMAC neural network; Nonlinear; PID compound controller

INTRODUCTION

The hydroelectric generating set transfer the energy of moving water into electrical energy to provide to the user, not only for safe and reliable power supply, but also requires power to maintain the voltage and frequency of electric energy near the rating of a certain range, otherwise it will directly affect the quality of power supply products [1, 2].Characteristics of the turbine regulating system with the generator frequency change and adjust accordingly, PID controller has the advantages of simple structure, high reliability, so the turbine regulating system parameters adopt the PID control method [3].the basic control idea of PID is to integrate the three parameters of bias the proportion coefficient, integral and differential time in order to get a relatively ideal control effect, so the PID parameter adjustment is a key problem in PID control [4].

Hydroelectric generating set is a kind of time-varying and nonlinear multivariable high order system, the traditional linear PID control method is difficult to make an accurate and effective regulation of turbine performance. In order to effectively control of hydro-generator units, we need adaptive PID parameters adjustment on-line, commonly used methods are as follows: the gradient method and genetic algorithm, the algorithm to adjust PID parameters when there are different degrees of defects [5].Gradient method for the objective function is continuous differentiable; Genetic algorithm (ga) requirements for reproduction, crossover and mutation operation, slow evolution, are prone to premature convergence [6].With fuzzy control, expert system and neural network intelligent control theory becoming mature, a variety of combination of PID control strategies and intelligent control of intelligent PID was formed .Small (CMAC) neural network model is a new type of neural network model, with local generalization ability, has a simple nonlinear optimization, study the advantages of quick convergence, powerful generalization ability, and there is no local minima problem, in general, the CMAC neural network is better than other neural network which has the nonlinear approximation capability, more suitable for nonlinear real-time control under complex environment[7].

Traditional PID turbine regulating system

Speed is still widely used at present, the hydroelectric generating set is a PID control regulation, and its structure is shown in figure 1

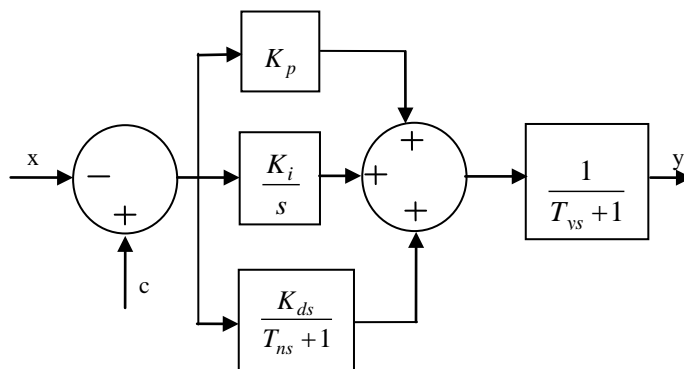


Fig 1 PID control regulatory system

The Figure 1, where X is a symbol for the relative value of turbine units speed deviation; C represents the machine control speed instructions; Y is noted as relative value in guide vane relay trip changes; Ty is the time constant the relay device response t; Kp, Ki, Kd, respectively are the three PID Parameters: the proportion, integral and differential gain; Tn is actual differential gain, and S the Laplace operator. The structure of the turbine regulating system is shown in figure 2.

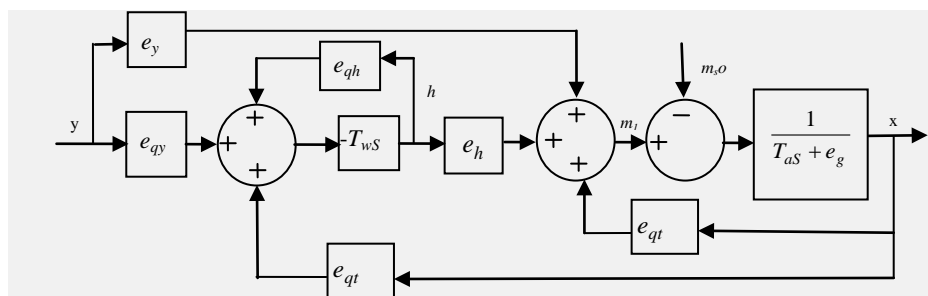


Figure 2 water turbine regulating system

In Figure 2, the e_x , e_h , e_y , e_{qx} , e_{qh} and e_{qy} represent turbine transmission coefficient respectively; T_w , T respectively are water inertial time constant in pressure water system, and the set inertial time constant. M_gO is noted as load disturbance. The turbine speed deviation and the main relay schedule Transfer function can be expressed in a form:

$$G(s) = -(K_p + \frac{K_i}{s} + \frac{K_d S}{1 + T_n S}) \frac{1}{1 + T_y S} \tag{1}$$

The transfer function of type pressure diversion system by using the rigid water hammer model can be expressed in a form:

$$G_t(s) = -T_w s \tag{2}$$

The turbine data model with minor fluctuation is as follows:

$$\begin{cases} m_t = e_x x + e_y y + e_h h \\ q = e_{qx} x + e_{qy} y + e_{qh} h \end{cases} \tag{3}$$

The mathematical model of first-order generator can be expressed as follows:

$$G_s(s) = \frac{1}{T_s s + e_g} \tag{4}$$

The traditional PID controller constants as K_p , T_i , T_d are fixed, but hydro-generator mechanical control System has the characteristics of nonlinear, time varying, unsteady, so traditional PID has low control precision. CMAC neural network can adjust dynamically by algorithm learning has the ability of information classification storage, suitable for the operation of real-time nonlinear system [8].

CMAC - PID control system design of hydroelectric generating set

The working principle of CMAC neural network

CMAC neural network is the cerebellum model joint controller which has the associative memory and the ability to multidimensional nonlinear function mapping nonlinear approximation[9], and the principle structure is shown in figure 3.

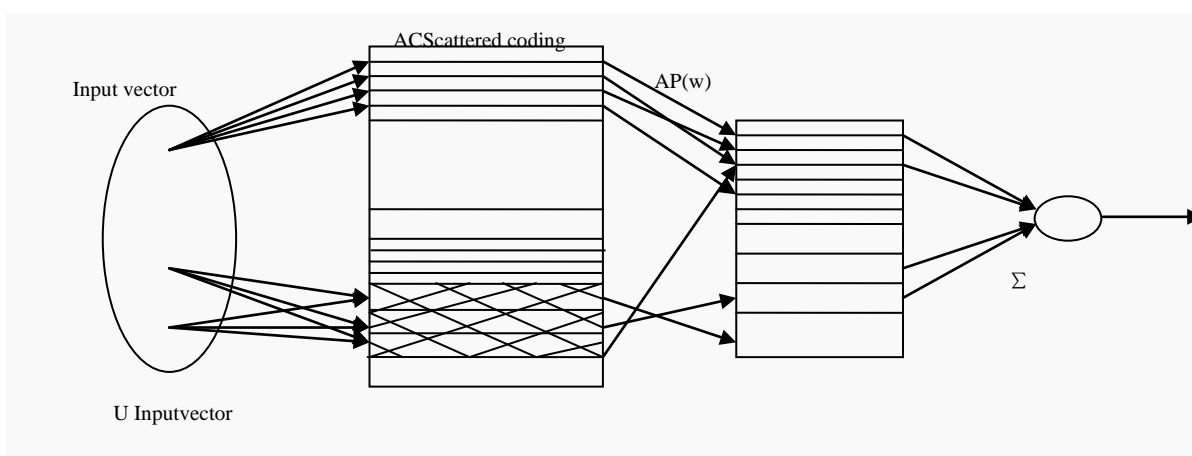


Fig. 3 principle structure of CMAC

Due to CMAC is a kind of neural network based on local learning which has fast learning speed and is suitable for real-time control [10]. CMAC neural network is put forward in this paper Combined with PID compound control strategy and control system for hydroelectric generating set System. The method of designing the CMAC model is divided into the following three steps:

1. Quantification: the concept mapping. delimiting the N input space in the input layer to make the network's input landing to N grid base in a hypercube sheet .Network interface layer is composed of several interval, for anyone to lose In only a few range of output for a non-zero value, the interval number is called parameter C . Its influence on grid internal network output decides the size of the region.
2. Address mapping: the actual mapping. The algorithm is the remainder method, namely mapping the input samples to the address of the memory, dividing the number of the sample by a Number, using the remainder as actual memory address values [11].
3. CMAC function calculation: namely the CMAC output. The corresponding weights of input mapping are saved to the actual storage as C , The actual storage unit weighted sum as C is the output of CMAC.

3. 2 CMAC and PID compound control structure

CMAC and PID compound control structure diagram is shown in figure 4, the system is accomplished by parallel control of CMAC and PID to realize feed forward and feedback control, especially the use of CMAC feed forward control realize the inverse dynamic model of hydroelectric generating set; Using nonlinear PID feedback control ensure convergence of the system.

CMAC and PID compound control

CMAC neural network adopts a mentor learning algorithm, when at the end of each control cycle, the CMAC output $U_N(k)$ and total control input $u(k)$ are compared, and the weights of the corresponding correction, and then to the learning process. Learning aim is to make total minimum error between the control input $u(k)$ and CMAC output $U_N(k)$ [12]. After CMAC neural network learning, making the compound control system of the total output produced by CMAC control. CMAC composite system with PID control algorithm is as follows:

$$u(k) = u_n(k) + u_p(k) \quad (5)$$

$$u_n(k) = \sum_{j=1}^c w_j a_j \quad (6)$$

Where w_j is the weight vector; A_j is binary choice vector; C is CMAC neural network generalization of parameters; The $U_n(k)$ is the output of the CMAC neural network; the $u_p(k)$ said the PID output generated.

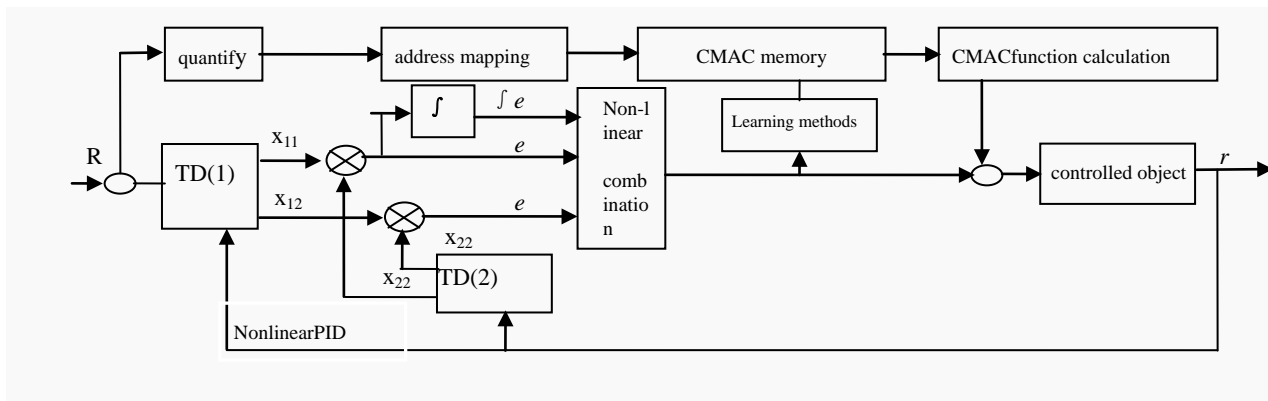


Fig. 4 CMAC and PID compound control structure

CMAC neural network mapping process is the concept that the input space S in the interval $[V_{\min}, V_{\max}]$ is divided into $N+2c$ quantization interval:

$$\begin{cases} v_1, v_2, \dots, v_c \geq S_{\min} \\ v_j = v_{j-1} + \Delta v_j, j = c+1, \dots, c+N \\ v_{N+c+1}, v_{N+c+2}, \dots, v_{N+2c} \leq S_{\max} \end{cases} \quad (7)$$

The actual mapping method in CMAC neural network is deduced as follows:

$$a_j = \begin{cases} 1, S_j \in [v_i, v_{i+c}], i = c+1, \dots, c+N \\ 0 \end{cases} \quad (8)$$

The adjustment of the CMAC neural network can be written as:

$$E(k) = \frac{1}{2} (u_n(k) - u(k))^2 \times \frac{1}{c} \quad (9)$$

$$\Delta w(k) = \eta \frac{\partial E(k)}{\partial w} = \eta \frac{u(k) - u_n(k)}{c} a_j = \eta \frac{u_p(k)}{c} a_j \quad (10)$$

$$w(k) = w(k-1) + \Delta w(k) + \beta (w(k) - w(k-1)) \quad (11)$$

where η (0, 1) is the network learning rate; β [0, 1] is the amount of inertia

When the system is running, $W = 0$, the $U_n = 0$, the $U_p = 0$, system is controlled by the conventional controller. Through the study of CMAC, the output of the PID $U_p(k)$ gradually decline to zero, CMAC control output of the $U_n(k)$ controller increasingly impend total output $u(k)$.

CONCLUSION

Due to the complexity of the turbine generator set adjustment object, the traditional effect on PID control is not optimal [13]. This paper puts forward a new kind of hydroelectric generating set intelligent CMAC-PID compound controller, give full play to the advantages of both the hydro-generator intelligent control and PID control, control the reasoning process to simulate human thinking process, and form expert knowledge which can modify the PID

parameters online. The simulation results show that CMAC-PID compound control compared with conventional PID control, adjust more smoothly, and adjust the speed faster. When the operation condition of the system parameter change or disturb, CMAC-PID control effect is much higher than the traditional PID control, the hydro-generator frequency can be stabilized faster, the CMAC-PID compound controller improves the adaptability and robustness of hydroelectric generating set, open up a new way of application online control for hydro-generator units.

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