Research and Analysis of Generalized Predictive Identification Algorithm Based On Nonlinear System in Control Field of Hydropower Industry

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Abstract. Due to the uncertainties, constraints, nonlinearity and the correlation among variables in the control of hydropower industry, it is difficult to obtain the accurate mathematical model. In this paper, a generalized predictive identification algorithm based on the nonlinear system in the control field of hydropower industry is presented, and a model of the generalized predictive identification algorithm based on the nonlinear system in the control field of hydropower industry is established by simulation. The simulation results show that the algorithm is robust, can effectively overcome the system delay, and can be applied to the open-loop unstable non-minimum phase system. It has strong applicability in the field of electric industry control and can produce good economic benefits.

Keywords: Control field of hydropower industry; nonlinear system; Generalized Prediction; identification algorithm; research and analysis.

1. Introduction

Due to the uncertainties, constraints, nonlinearity and the correlation between variables in the control of hydropower industry, it is difficult to obtain accurate mathematical model. In order to make up the gap between theory and practical application, we can find the breakthrough point between theory and practical application [1-13]. According to the requirements of industrial process, we can find a simple, high-precision and easy to calculate and derive model in theory [14-20]. These models can be combined with some optimization methods to achieve good control results. Therefore, the actual industrial demand promotes the emergence of new theories. Predictive control (1) is a new type of computer optimal control algorithm which adapts to these requirements and develops.

Hydropower units are widely distributed in modern power system, which have extremely complex nonlinear characteristics of hydro mechanical electrical coupling [21-33]. They play a key role in energy supply, peak load regulation and emergency reserve. The safe, stable and efficient operation of hydropower units is of great significance to improve the power quality and maintain the stability of the power system. In recent years, with the large capacity units and pumped storage units widely put into
operation, the hydropower units show the development trend of large capacity and complex structure, which makes the control of the unit regulation system more and more complex. In order to improve the control performance of the unit and the stability of the unit under complex operating conditions [34-43], it is necessary to study the advanced control theory and method of the regulating system of the hydropower unit.

The least square (LS) method is a widely used mathematical tool in the system parameter estimation [44-56], which has the advantages of easy understanding, fast convergence and concise program.

In this paper, a generalized predictive identification algorithm based on the nonlinear system in the control field of hydropower industry is presented, and the model of the generalized predictive identification algorithm based on the nonlinear system in the control field of hydropower industry is established. The simulation results show that the algorithm is robust, can effectively overcome the system delay, and can be applied to the open-loop unstable non minimum phase system. It has strong applicability in the field of electric industry control and can produce good economic benefits.

2. Nonlinear model in control field of hydropower industry

The model of mould liquid level system is discretized into the following model [30-33]:

\[ A(z^{-1})y(k) = B(z^{-1})u(k-d) + C(z^{-1})\omega(k)/\Delta \]  

(1)

In the traditional generalized predictive control, \( \xi(k) \) is the white noise sequence with zero mean value in the model Formula (1), and \( \omega(k) \) is the colored noise caused by pulling speed in the mould liquid level control system. Therefore, in order to conform to the generalized predictive control model, the colored noise needs to be processed. The specific method is to generate \( H(z^{-1}) \), i.e. \( \xi(k) \), through a linear link \( \omega(k) = H(z^{-1})\xi(k) \). Nonlinear model in control field of hydropower industry, as is shown in the Figure.1.

\[ A(z^{-1})y(k) = B(z^{-1})u(k-d) + C(z^{-1})\xi(k)/\Delta \]  

(2)

Subject to the following:

Fig.1 Nonlinear model in control field of hydropower industry.

At this time, the model is transformed into:

\[ A(z^{-1})y(k) = B(z^{-1})u(k-d) + C(z^{-1})\xi(k)/\Delta \]  

Subject to the following:
\[ y'(k) = H(z^{-1}) \cdot y(k) \] (3)

\[ u'(k) = H(z^{-1}) \cdot u(k) \] (4)

3. Generalized predictive identification algorithm for Nonlinear Systems

On the basis of the new model obtained from the transformation, the output predictive value is derived from the generalized predictive control:

\[ \hat{Y}' = G\Delta U' + f' \] (5)

\[ \hat{Y}' = [\hat{y}(k+1), \hat{y}(k+2), \ldots, \hat{y}(k+N)]^T \] (6)

\[ \Delta U' = [\Delta u(k), \Delta u(k+1), \ldots, \Delta u(k+N_u+1)]^T \] (7)

\[ f' = [f(k+1), f(k+2), \ldots, f(k+N)]^T \] (8)

In the formula: model of mould liquid level system is discretized into the following model.

Because there may be model mismatch, random interference and other factors between the actual system and the prediction model, only using Equation (8) for state prediction will have some deviation from the actual situation. Therefore, in the sampling period of each controller, it is necessary to feedback and correct the state prediction value according to the real-time state information of the system. In this paper, the product of real-time system error and correction coefficient is used as the feedback correction method. The feedback correction formula is shown in Equation (9):

\[
G = \begin{bmatrix}
g_0 & 0 
g_1 & g_0 & \ddots 
\vdots & \vdots & \ddots & \vdots 
g_{N-1} & g_{N-2} & \cdots & g_0 
\end{bmatrix}
\] (9)

The main constraints that affect the control system are the velocity constraints and the range constraints of the actuator. Therefore, it is transformed into the control increment and control quantity constraints in the performance index of GPC. At this time, the optimized performance index is:

\[
\min J(k) = E \left\{ \sum_{j=d}^{N} \left[ f(k+j) - \omega (k+j) \right]^2 + \sum_{j=1}^{N_u} \lambda(j)[\Delta u(k+j-1)]^2 \right\}
\] (10)

\[
s.t. \begin{cases}
\Delta u_{\min} \leq \Delta u(k+j-1) \leq \Delta u_{\max}, & j = 1, 2, \ldots, N_u 
u_{\min} \leq u(k+j-1) \leq u_{\max}, & j = 1, 2, \ldots, N_u 
\end{cases}
\] (11)

\(N\) is the maximum prediction length, \(N_u\) is the control length, \(\omega\) is the expected value, and \(\lambda(j)\) is the control weighting coefficient.
4. Simulation and Analysis

Simulation example

According to the mold control system of a casting plant, the simulation research is carried out. Known field parameters are: the cross-sectional dimension of the mold is 230mmx1450mm, the height of the mold is 904mm, the natural frequency of the red control system of the hydraulic valve is $141.3\, \text{rad/s}$, the bulk modulus of elasticity of the red control system of the hydraulic valve is 700MPa, the casting temperature is 15570C, the effective flow area coefficient of the tundish valve is $a = 0.5, b = 1.1$, and the molten steel injection coefficient is $C_v = 0.57$. Combined with the process conditions of field production, the Generalized Prediction Model polynomials are obtained by model identification.

\begin{align}
A\left(z^{-1}\right) &= 1 - 2.1249z^{-1} + 0.4073z^{-2} + 0.04944z^{-3} - 0.72944z^{-4} \\
B\left(z^{-1}\right) &= 0.1249z^{-1} + 0.4073z^{-2} + 0.04944z^{-3} \\
C\left(z^{-1}\right) &= 1, d = 1
\end{align}

Among them, the parameters of predictive controller are $N = 3$, $N_u = 2$, $\lambda = 0.35$; the initial population of genetic algorithm is encoded by floating-point number, with 70 initial population, the probability of crossover and mutation is 0.6 and 0.025 respectively, and the genetic algebra is 120; the control quantity constraint is $-70 \leq u \leq 70$; the control increment constraint is $-10 \leq \Delta u \leq 10$; and the set value is $\omega = 50$mm. The simulation results are based on the application of the described algorithm process.

5. Simulation and Analysis

In this paper, a generalized predictive identification algorithm based on the nonlinear system in the control field of hydropower industry is presented, and the model of the generalized predictive identification algorithm based on the nonlinear system in the control field of hydropower industry is established.

Generalized predictive frequency regulation mode control, Generalized predictive identification for Nonlinear Systems ,Nonlinear predictive model identification control , as is shown in the Figure.1~3.

![Figure 2](image-url)  
**Fig.2** Generalized predictive frequency regulation mode control.
The simulation results show that the algorithm is robust, can effectively overcome the system delay, and can be applied to the open-loop unstable non minimum phase system.
In Figure 5～8, simulation results show that the algorithm is robust, can effectively overcome the system delay, and can be applied to the open-loop unstable non minimum phase system. It has strong applicability in the field of electric industry control and can produce good economic benefits.
6. Summary
In this paper, a generalized predictive identification algorithm based on the nonlinear system in the control field of hydropower industry is presented, and the model of the generalized predictive identification algorithm based on the nonlinear system in the control field of hydropower industry is established. The simulation results show that the algorithm is robust, can effectively overcome the system delay, and can be applied to the open-loop unstable non minimum phase system. It has strong applicability in the field of electric industry control and can produce good economic benefits.

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