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Analysis of the Coupling Degree in Supervision Control Systems Based on Improved DEPSO

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Abstract. Brittleness is the basic attribute in complex systems, whose definition of brittleness is given. Through analyzing the process of collapse in complex systems, namely being motivated the process of brittleness, the definition of brittle resource, collapse; brittle recipient and brittle degree are given. The improved DEPSO algorithm is global optimization; the algorithm takes the constraint condition of fault rate into account during the course of seeking optimal solutions. Based on the above the definition of analysis, coupling degree between two subsystems is given. Finally, the process of collapse in complex systems is analyzed by the time-state method and the formula of judgment the collapse of complex systems is given. This method lays a foundation for analyzing the prediction of brittleness in complex systems.

Introduction

In general, complex systems has attribute of complexity, openness, self-organized and nonlinear. But through studying, we think brittleness is another attribute[1-2]. This will affect other apparatus whose compactly contact with these apparatus even will rise up collapse. For example, it will lead to collapse of kidney and other apparatus contacting closely. So, this will lead to death of mankind, namely system collapse. This reason is the brittleness of systems being motivated.

At first, the definition of brittleness is given. Then the process of collapse in complex systems is analyzed. Finally, analyze the change process of complex system with time-state method.

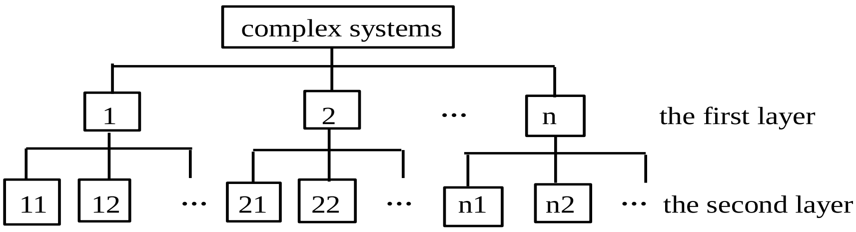

Fig. 1 Layer structure chart in complex system

Analyzing the Process of Collapse in Complex Subsystems

One important character of complex systems has layer. [3-4] The different subsystems may locate in different layers. we can think every subsystem both as a subsystem of up layer and as a mother subsystem of down layer. We call a mother subsystem and some son subsystems as a unit of complex systems. So we research the process of collapse of this complex system, we can research some unit of complex systems. We research No g subsystem and its three No. g+1 subsystems as follows (fig 2):

Math Definition of Collapse in Subsystems. Think of two conditions: ① If one or some input u_c ($c = 1,2,\cdots,r$)exceeds given threshold value because of disturb or abnormal input. It makes one or some output $y_l(l=1,2,\cdots,n)$ exceed given threshold value. ② Because of aging of the inner instrument or inner design disfigurement, makes one or some states $X_j(j=1,2,\cdots,m)$ exceed given threshold value. It makes one or some outputs $y_l(l=1,2,\cdots,n)$ also exceed given threshold value. If one of two conditions occurs, we define subsystem collapse. We define with math as follows:

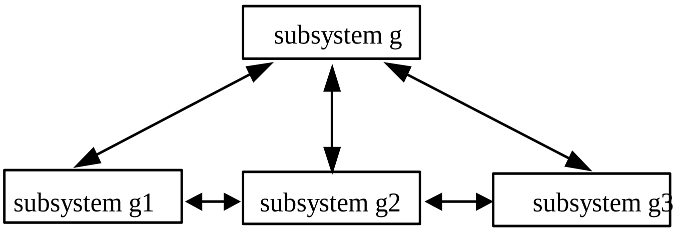

Fig. 2 Analyzing the process of collapse in four subsystems

$$\chi(i)=\begin{cases}0, \text{ all } \ y_l\in[\max E(y_l),\min E(y_l)];\\1, \text{ any } \ y_l\notin[\max E(y_l),\min E(y_l)]\end{cases}\quad (l=1,2,\cdots,n) \tag{1}$$

Definition of Brittle Resource and Brittle Receiver. From fig. 2, we define main brittle resource, non-brittle resource and hypo-brittle resource as follows:(1) Main brittle resource: the action to the brittle receiver is important to arise brittleness.(2) Non-brittle resource: the action to the brittle receiver is unimportant and not to arise brittleness.(3) Hypo-brittle resource: the action to the brittle receiver is common to arise brittleness.

Analyzing the Collapse Process and Definition the Brittle Degree. Brittle degree describes the degree of brittleness being motivated. For two subsystems, if i subsystem that has collapsed makes j subsystem collapsed, namely the brittleness is motivated, we define the brittle degree i to j is 1; if j is not collapsed, namely the brittle degree is not motivated, then we define the brittle degree i to j is 0. We use $\beta_{i,j}$ to describe the brittle degree i to j as follows:

$$\beta_{i,j}=\begin{cases}0, & \chi(j)=0 \text{ and } \chi(\mathrm{i})=1;\\1, & \chi(j)=1 \text{ and } \chi(\mathrm{i})=1\end{cases}\quad (i\neq j) \tag{2}$$

Here, $\beta_{i,j}=\beta_{j,i}$ not always exist. Because i subsystem affect j subsystem is relational to the structure of variable. The effect of output of i to j is different that of j to i.

Discuss above is the question about brittle degree of two subsystems. We define all kinds of inner factor to arise the brittleness being motivated as follows:

$$\beta_{i,i}=1 \tag{3}$$

We see from above formula, the brittle degree is a matrix. The elements on the cross is itself brittle degree of subsystem. The other elements are the brittle degree i to j. Namely

$$\beta=\begin{bmatrix}\beta_{1,1} & \beta_{1,2} & \cdots & \beta_{1,n}\\ \beta_{2,1} & \beta_{2,2} & \cdots & \beta_{2,n}\\ \vdots & \vdots & \ddots & \vdots\\ \beta_{n,1} & \beta_{n,2} & \cdots & \beta_{n,n}\end{bmatrix} \tag{4}$$

Obtain the formula definition of j subsystem with brittle degree:

$$\chi(j)=\begin{cases}0\ ,\ \sum_{i=1}^{n}\beta_{\mathrm{i,j}}=0\ ;\\1\ ,\ \sum_{i=1}^{n}\beta_{\mathrm{i,j}}\geq 1\end{cases} \tag{5}$$

We can see from analysis above: whether i subsystem collapse can lead to j collapse, we can describe with brittle degree.

Definition of Coupling Degree between Two Subsystems. In order to describe the degree of coupling, we define the conception of coupling degree.

Coupling degree describes the degree of coupling between two subsystems. We define coupling degree in [0,1]. If coupling between two subsystems is strange, the brittleness is easy to be motivation. We define coupling degree close 1 and in [0.5,1]. if coupling between two subsystems is weak, the brittleness is not easy to be motivation. We define coupling degree close 0 and in [0,0.5]. We describe the coupling degree between i and j as $\alpha_{i,j}$.

Output of i acting to output of j has two ways. One is main channels, namely change of output $Y_h\,(h=1,2,\cdots,n)$of i, ΔY_h, lead directly change of output y_k $(k=1,2,\cdots,m)$ j subsystem, Δy_k; the other is hypo-channels, namely change of output $Y_h\,(h=1,2,\cdots,n)$of i, ΔY_h, lead indirectly change of output $y_k\,(k=1,2,\cdots,m)$of j subsystem, Δy_k, through the coupling of state of subsystem.

We define the element of coupling matrix between two subsystems about first way:

$$\theta_{hk} = \left.\frac{\Delta Y_h}{\Delta y_k}\right|_{Y_g=const} \qquad (g \neq h) \tag{6}$$

Namely, we define the element of coupling matrix between two subsystems about second way:

$$\varphi_{hk} = \left.\frac{\Delta Y_h}{\Delta y_k}\right|_{y_g=c\ o\ n} \qquad (g \neq k) \tag{7}$$

Namely, the element in coupling matrix is define as follows: When we think of the coupling degree between Y_h and y_k, we suppose the change ΔY_h of output Y_h lead to the change of Δy_k of output y_k of j (note: the other y_g ($g \neq k$)is not change).

Define the element of coupling matrix between two subsystems is

$$\lambda_{hk} = \theta_{hk} \circ \varphi_{hk} \tag{8}$$

Here, denotation is Adama product. It denotes the product of corresponding location of two matrixes. Therefore, define the coupling degree between two subsystems is

$$\alpha_{i,j} = \frac{\sum_{h=1}^{n}\sum_{\substack{k=1\\ h\neq k}}^{m}\lambda_{hk}}{\sum_{h=1}^{n}\sum_{k=1}^{m}\lambda_{hk}} \tag{9}$$

We can see from above formula: coupling degree between two subsystems is between 0 and 1.

PMU Optimization Algorithm of Supervision Control

Particle Swarm Optimization. PSO algorithm assumes that the potential solution of the optimization problem as a no mass and no volume bird, called particle. PSO search mechanism: the search process of particle tracking two "extreme" to update their information, one is individual extreme that is the optimal solution found by particle itself[6-9]; another is the global extreme that the optimal solution found by the entire current population currently. Particle follow these two optimal solutions, in accordance with certain rules update their velocity and position. PSO formulas are:

$$\begin{aligned} v_{ij}(t+1) &= w(t)v_{ij}(t) + c_1 r(p_{ij}(t) - x_{ij}(t)) \\ &\quad + c_2 r(p_{gj}(t) - x_{ij}(t)) \end{aligned} \tag{10}$$

$$x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1) \tag{11}$$

$$w(t) = w_{\min} + (w_{\max} - w_{\min})\frac{T_{\max} - t}{T_{\max}} \tag{12}$$

Where p_{ij} is individual extreme, p_{gj} is global extreme, w is inertia weight factor, $w_{\max}$, $w_{\min}$ are maximum and minimum inertia weight, $T_{\max}$ is maximum evolution generation, c_1, c_2 are accelerating factors, generally $c_1 = c_2$, $r \in (0,1)$ random number.

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Improved DEPSO algorithm. Differential and particle swarm algorithms are heuristic algorithm, the local search accuracy difference algorithm is superior to PSO. PSO convergence speed is fast, establishment parameter is less, easy to implement and so on[10-12]. Optimization PSO algorithm has good performance, but because of the late evolutionary algorithms due to the reduced particle diversity easy to fall into local optimum. Differential evolution algorithm through mutation, crossover and selection operations generate new populations to achieve the optimal solution through iterative search, DE has a powerful function of the maintenance of the population diversity and search capabilities, but the convergence speed is slow in latter part. This article will combine DE algorithm and PSO algorithm, and introduced in the algorithm determines evolutionary factor H, as the ratio of previous generation iterative optimal solution and the optimal solution of the current iteration ratio, that is:

$$H = \frac{f\left(x_{ij}(t-1)\right)}{f\left(x_{ij}(t)\right)} \tag{13}$$

Where $H \geq 1$, the greater H is, the faster the speed is. With the increasing of iteration numbers, H is held on one, but did not find an optimal solution, the algorithm stagnantes or falls into local optimum.

The basic steps of DEPSO hybrid algorithm in this paper are as follows:

Initialization parameters. Set the population size N, maximum evolution algebra $T_{\max}$, and the related parameters of DE algorithm and PSO algorithm, including maximum and minimum inertia weight $w_{\max}, w_{\min}$, acceleration factors c_1, c_2, largest and smallest crossover probability $CR_{\max}, CR_{\min}$, control factor λ, evolution speed factor H, mutation probability factor F, make counter $t = 0$;

Generating a first generation population. Set the position and speed of individual populations, x_{best} is optimal particle position of initial population;

Calculate the current value of the mutation probability factor F for DE algorithm mutation operation;

Calculate the current value of the crossover probability factor CR for DE algorithm crossover operation;

Individuals on the population objective function value calculated for DE algorithm selection operation;

Calculate the speed of evolution factor H, determine whether the population into local optimum. If it is converted into local optimum step (7), if it is not fall into local optimum is transferred to step (9);

PSO to optimize the operation carried out on the population so that individuals' velocity and position update;

Select the best individual from groups;

$t = t + 1$;

Detecting whether satisfy the stop condition. If satisfied then stop, output the results, otherwise, converted to the step (3).

Analysis the Collapse Process with Time-state Method

Step 1: Number all the subsystems in The first layer. Support system number is n, we number from 1 to n.

Step 2: Compute the coupling degree of every subsystem to judge the collapse value of every subsystem at every time. If subsystem collapse, then the collapse value is 1, or not, is 0. We represent the state of subsystem as collapse value. We denote by binary system. n subsystems exist 2^n states in all the subsystems. If $n = 3$, exists 2^3 states. Namely from 000 to 111. The end location is subsystem 1, the second location is subsystem 2, and so on, the first is the subsystem n. For example, 101 denote the collapse value is 1 in The first and 3.

Step3: give the time-state chart of all the subsystems. See fig 2.

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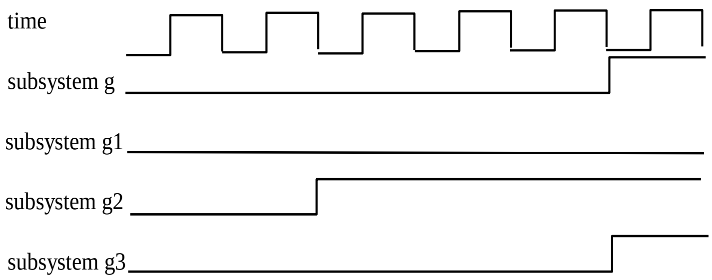

Fig. 3 the time-state chart of system

Step 4: Give the chart of state of all the subsystem. Based on fig 3, we can obtain fig 4.

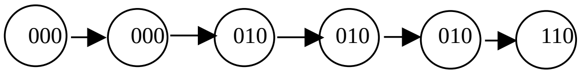

Fig. 4 the state chart of system

Step 5: One or more than one subsystems in first layer collapse. If one is 1 of brittle degree, then the complex systems collapse. So we judge the collapse with the production of brittle degree and collapse value. If it is 1, then the complex system collapses. If it is 0, then the complex system does not collapse. We chart the states as follows:

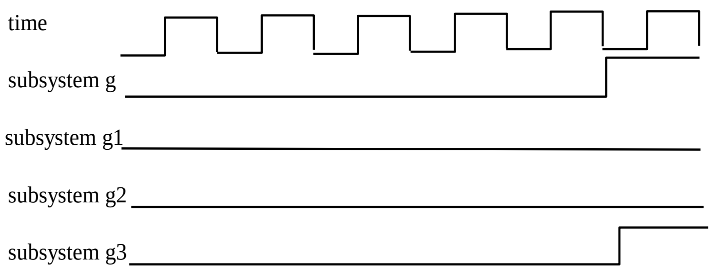

Fig.5 Judge the collapse with production of brittle degree and collapse value

We can see from analyzing with time-state method, the collapse process of complex system has some characteristic: (1) the state of 1 cannot reverse. In a moment, the state is 1. At next time, the state is still 1. Because the subsystem has collapsed in some time, namely the brittleness of this subsystem has been motivated. The subsystem may not return to the normal state at next time. (2)Judgment method of the whole system collapse: If The first layer has 1 of production of collapse value and brittle degree, namely come to 1 in chart, this denote the brittleness of system being motivated. The whole systems collapse. We can judge collapse with formula as follows:

$$\sum_{i=1}^{n} \chi(i) \cdot \beta_{i,j} \geq 1 \qquad (14)$$

Conclusion

This paper analyzed the process of collapse in complex systems. We do works as follows:

First, the definition of brittleness, collapse, brittle resource and brittle receiver were given.

Second, analyzed the process of collapse in complex systems and the definition of brittle degree and coupling degree were given.

Finally, analyzed the process of collapse with time-state method and brought forward the method of judgment formula of collapse in the complex systems.

Acknowledgments

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