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A research on the simulating control model of earthquake disaster field

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ABSTRACT: This paper presents a theory frame of the simulating control problem of earthquake disaster field. A definition of earthquake disaster field is given. And then, the paper discussed the reliability control of disaster field and the recovery process control after seismic. Based on these general model, a heuristic calculation method of simulation of earthquake disaster field were given in the paper.

1 INTRODUCTION

The ultimate aim of researching and recognizing earthquake disaster is to control it. General to say, the control methods of earthquake disaster can be divided into two types: the engineering control and system control. For engineering control, people have made a great effort. Various asseismic design codes are the results of these effort. In recent years, people have gone further into the question of active or passive seismic response control of structures. But, in another side, the problem of system control of earthquake disaster have not been paid enough attention. In fact, the developing of modern city would prove that the earthquake disaster can not be controled only by single engineering method.

In 1990, the auther presented the concept of earthquake disaster field and discussed the theory model of earthquake disaster field control (Li Jie 1990a). After that, we tried to constructe an open-loop control model of buried pipeline network (Li Jie, 1990b). In this paper, the auther will futher discuss the problem of simulating control of earthquake disaster control.

2 EARTHQUAKE DISASTER FIELD

The earthquake disaster field is defined as the district which would be endangered by potential or real earthquake. Furthermore, the object of earthquake disaster field which we discussed here is intended for urban area.

The general earthquake disaster field control should incloud all the effort to matigate or confine earthquake disaster loss. The system control of earthquake disaster field refer in particular to theory method or practice that apply mordern control theory and large scale system theory to confine the region of disaster or matigate earthquakd disaster loss.

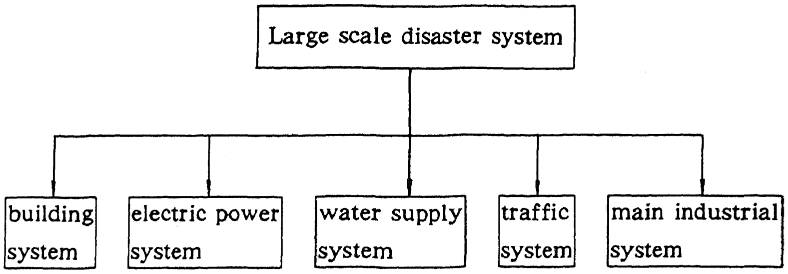

Figure 1. Large scal disaster system

The social system which might be endangered by earthquake is a complexing engineering social and economical system. The target which we could hold scientifically is only engineering system. The object of earthquake disaster field control is also these engineering system. The basic system categories of large scale disaster system were shown as Fig 1.

General to say, these basic systems are coupling each other. By using the concept of sequence coupling (Li Jie 1991b), we may consider these system separately.

Earthquake disaster field control includes three basic types: potential disaster field control, recovery process control after seismic and simulation control of earthquake disaster field.

The problem of potential disaster field control is refered to system reliability control. Basing on the post—earthquake system reliability pridiction, it is demanded that the expected reliability distribution achieved an optimum state by selecting optimum control tactics.

The question of recovery process control after seismic is defined as follow: basing on the correct judgement of post-disaster state of system, and according to principle of propotionate increasing of system output, some control tactics were seeked to satistify the requirement that the total system have a muxmum recovery speed.

Based on above two side works, the simulating control of disaster field is refered to apply system simulation to find disaster prevention defect of engineering system and to apply some control tactics to improve system disaster prevention function.

3 THE SYSTEM RELIABILITY CONTROL OF DISASTER FIELD

The system reliability is a probability for which the system has a set of function. It can be written as:

$$\psi = P(E) \qquad (1)$$

where P( ) is probability and E is a provide random event.

By earthquake disaster pridiction, we can generally obtain the system probability desity which is based on the earthquake damage index set (Li Jie, 1991a). From integration of probability density, we can obtain

$$P(E) = \int_0^{[\alpha]} f(\mathit{ind})\,d\mathit{ind} \qquad (2)$$

where f( ) is the probability density function, *ind* is earthquake damage index, α prescribes a special system function.

By system indentification method we can written subsystem state equation as follows:

$$x_{l+1} = x_l + B_l(k)u_l(k)$$

$$x = x(k) \qquad x_L = x(k+1) \qquad (3)$$

$$(1 = 1, 2, \cdots L)$$

where *l* is the damage rank and k is time parameter, u is the control investment and $x = \ln\psi$.

Notice recurrence relationship in formula (3), the following equation may be obtain:

$$x_l(k+1) = x(k) + B_l^T(k)u_l(k) \qquad (4)$$

where

$$B_l(k) = (B_1(k), B_2(k), \cdots B_L(k))^T$$

$$u_l(k) = (u_1(k), u_2(k), \cdots u_L(k))^T$$

Considering further the decrease of system reliability which cause by circumstances action, the sub-system state equation can be written as:

$$x_l(k+1) = x_l(k) + B_l^T(k)u_l(k) - D_l(k) \qquad (5)$$

where D is a constant about reliability and i is the subsystem ordiral.

For provided system investment confine c(k), the problem of the system reliability of disaster field may be described as follows:

find u(k)

$$\min \quad J = \frac{1}{2}x^T(M)P(M)x(M) + \frac{1}{2}\sum_{k=0}^{M-1}$$

$$[x^T(k)Q(k)x(k) + u^T(k)R(k)u(k)] \qquad (6)$$

s. t

$$x(k+1) = x(k) + B^T(k)u(k) - D(k) \qquad (7)$$

$$x(0) = x_0 \qquad (8)$$

$$c(k) = \sum_{i=1}^{N} u_i(k) \qquad (9)$$

$$u_i(k) = 1 - \sum_{j=1}^{k-1} u_i(j) \qquad (10)$$

$$(i = 1, 2, \cdots N)$$

where P, Q, R are weight matrix, M is the time end and

$$B(k) = (B_1^T(k), B_2^T(k), \cdots B_N^T(k))^T$$

$$D(k) = (D_1(k), D_2(k), \cdots, D_N(k)^T$$

Because the confine relationship (9) and (10), the solution of the control problem may not derectly obtain from general control theory. We have developed a type of calculation method which is based on the resolution of time index (Li Jie 1992). For simple system, the solution process can be described as Fig 2.

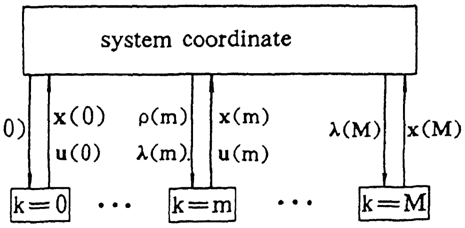

Figure 2. Simple system reliability control

4 THE RECOVERY PROCCESS CONTROL AFTER SEISMIC

For post-disaster system, the state equation of recovery process can be written as (Li Jie 1991b):

$$x_i(k+1)=x_i(k)+b_iu_i(k)$$

$$(i=1,2,\cdots N) \qquad (11)$$

where x is the system allowrance output, u is control invest, and b is constant.

In other side, applying system invest and output analysis method, we may give the system output equilibrium equation as follows:

$$x_i(k) = a_{11}x_1(k) + a_{12}x_2(k) + \cdots +$$

$$a_{1N}x_{1N}(k) + y_i(k)$$

$$(i = 1,2,\cdots N;\ k = 2,1,\cdots M) \quad (12)$$

where k is the time imdex, i is sub-system ordial, y is total system out-puts and a_{ij} is constant.

Adopting vector expression, the formula (12) can be rewritten as:

$$x(k) = (I - A)^{-1}y(k) \qquad (13)$$

where I is unite matrix, and

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1N} \\ a_{21} & a_{22} & \cdots & a_{2N} \\ \cdots & \cdots & & \cdots \\ a_{N1} & a_{N2} & \cdots & a_{NN} \end{bmatrix} \qquad (14)$$

combining formula (13) with equation (11), the system output state equation can be written as:

$$y(k + 1) = y(k) + Du(k) \qquad (15)$$

where

$$D = (I - A)B \qquad (16)$$

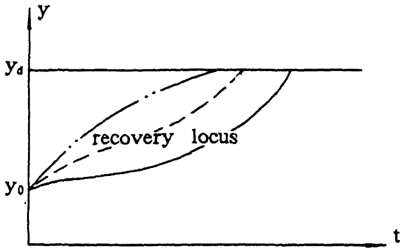

Figure 3. Subsystem recpvery locus

For special subsystem, its recovery process may be various locus (Fig 3), the aim of system recovery pocess control is to seek a set of special locus which could ensure optimum total system function in every time point of recovery process. These problem may be described as follows:

find $u_i(k)$

$$\min J = \sum_{i=1}^{NS}\{\frac{1}{2}(y_i(M) - y_{di})^TP(M)(y_i(M) - y_{di})$$

$$+ \frac{1}{2}\sum_{k=0}^{M-1}[(y_i(k) - y_{di})^TQ_i(k)(y_i(k) - y_{di})$$

$$+ u_i^T(k)R(k)u_i(k) + z_i^T(k)S_i(k)z_i(k)]\} \qquad (17)$$

s • t

$$y_i(k+1)=y_i(k)+D_iu_i(k)+G_iz_i(k) \qquad (18)$$

$$y_i(0)=y_{i0} \qquad (19)$$

$$z_i(k)=\sum_{j=1}^{NS}L_{ij}y_j(k) \qquad (20)$$

$$c(k)=\sum_{i=1}^{NS}E_iu_i(k) \qquad (21)$$

where Z is the coupling vector of subsystem, G is the coupling matrix, L_{ij} is the transform matrix between state vecter and coupling vector, N_i is the number of input、output or coupling vectors, and NS is the number of subsystems.

This problem can be solved by hierarchical control model (Li Jie 1991b). Fig 4 shows the general solution process. In the figure λ , h and ρ is Lagrange multiplier.

Following formulas are the solutions of every stage:

(1) the third grade

$k=0$:

$$\lambda_i(1)=-Q_i(0)(y_{io}-y_{di})+\sum_{j=1}^{NS}h_j^T(0)L_{ji} \quad (22)$$

$$u_i(0)=R_i^{-1}(0)[E_i^T\rho_i(0)-D_i^T\lambda_i(1)] \quad (23)$$

$$z_i(0)=-S_i^{-1}(0)[h_i(0)+G_i^T\lambda_i(1)] \quad (24)$$

$k=1,2,\cdots M-1$:

$$y_i(k)=y_{di}+Q_i^{-1}(k)[\lambda_i(k)-\lambda_i(k+1)+\sum_{j=1}^{NS}h_j^T(k)L_{ji}] \quad (25)$$

$$u_i(k)=R_i^{-1}(k)[E_i^T\rho_i(k)-D_i^T\lambda_i(k+1)] \quad (26)$$

$$z_i(k)=-S_i^{-1}(0)[h_i(k)+G_i^T\lambda_i(k+1)] \quad (27)$$

$k=M$:

$$y_i(M)=y_{di}+P_i^{-1}(M)\lambda_i(M) \quad (28)$$

(2) the second grade

$$\lambda_i^{(l+1)}(k+1)=\lambda_i^{(l)}(k+1)+\alpha_1\left(\frac{\partial J_{ai}}{\partial\lambda_i(k+1)}\right)^{(l)} \quad (29)$$

$$\rho_i^{(l+1)}(k)=\rho_i^{(l)}+\beta_l\left(\frac{\partial J_{ai}}{\partial\rho_i(k)}\right)^{(l)} \quad (30)$$

where l is iteration number, α,β is iterative step length, and J_{ai} is the Lagrange function about J_i.

(3) the first grade

$$h_i^{l+1}(k)=h_i^{(l)}(k)+\gamma_l\left(\frac{\partial J_a}{\partial h_i(k)}\right)^{(l)} \quad (31)$$

$$c_i^{(l+1)}(k)=c_i^{(l)}(k)-\zeta_l\left(\frac{\partial J_a}{\partial c_i(k)}\right)^{(l)} \quad (32)$$

where γ,ζ is iterative step length.

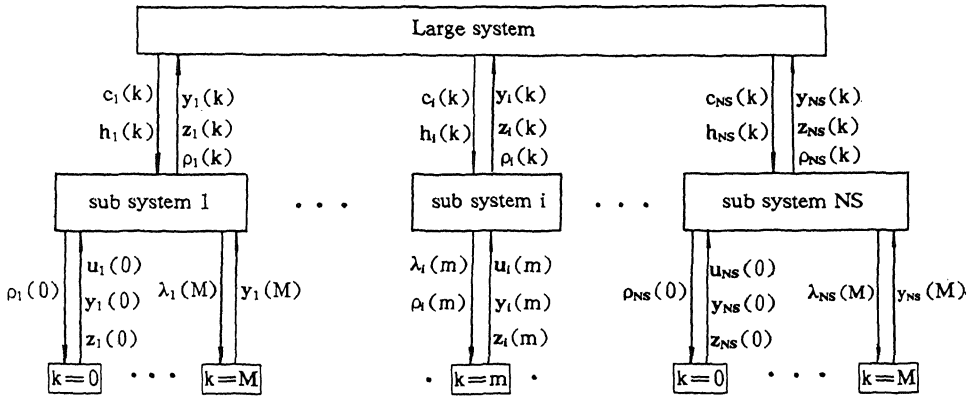

Figure 4. Hierarchical control model

5 SIMULATION CONTROL OF EARTHQUAKE DISASTER FIELD

The simulation control of earthquake disaster field may be divided into two categories: to consider system model and to consider control model. This paper discussed the simulation control to consider control model only.

Taking the post-disaster recovery process as an example, we can give a heuristic calculation method as follows:

(1) Applying earthquake disaster prediction method to obtain the failure probability of considering system;

(2) Based on system failure probability, the post-disaster state sample may be gained by Monte carlo method;

(3) Providing system investe curve and carring out system recovery. process control calculation;

(4) Analysing the recovery process curve of subsystem, and finding the defect of important subsystem recovery function;

(5) Inproving system reliability or taking other control tactics, and carring out simulating repeatly until that the main subsystem function sytisfy the specified output function of post-disaster.

The total process may be shown by Fig 5. In the figure, n is the simu-lating number and P is the probability of satisfying with the expected function of main subsystem.

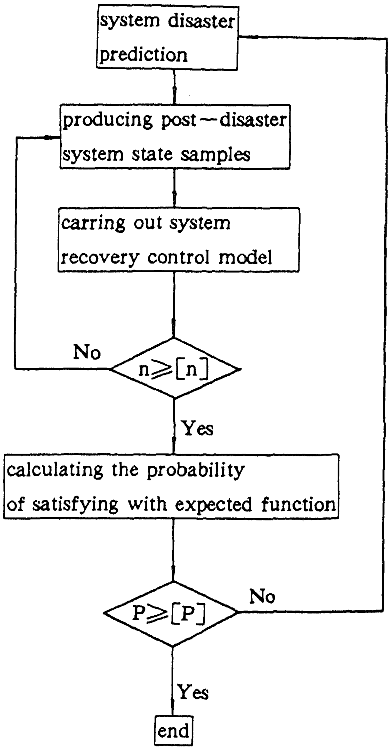

Figure 5. Simulating control calculation

The other simulating control calculation method is similiar to here.

6 CONCLUSIONS

This paper presents only a theory frame of the simulating control of earthquake disaster field. The frame is theoretical basis of a series of disaster field control research which have been developed by author in recent years. It may be predicted that the simulating control technique disaster field will be an importent means of urban seismic risk mitigation.

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REFERENCES

Li Jie, 1990 a. A reasearch on the theory model of earthquake disaster field. *Report of IEEDC of China Chemical Industry Ministry.*

Li Jie, 1990 b. A reasearch on the seismic secondery fire disaster prediction model and control model. *Report of IEEDC of Chemical Industry Ministry.*

Li Jie, 1991 a. Research on the simulation system of earthquake disaster prediction. *Journal of Zheng Zhou Institute of Technology.*

Li Jie, 1991 b. Research on the system control theory of earthquake disaster field. *Report of IEEDC of China Chemical Industry Ministry.*

Li Jie, 1992. A research on the potential earthquake disaster field reliability process control model. *Proc. of ICCE* (to appear).