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Decision Making In Process Safety

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The paper describes solving problem of constructing knowledge database of a decision making in process safety. It is provided an analyses of the requirements and as well the analyses of the system incidents caused by specification, design and the implementation of the project. Main focus of this scientific paper is highlighted on practical stability problem and conditions for optimal performance of safe fault-tolerant controllers, I/O, engineering and pressure transmitterss. Algorithm of decision making in process safety is developed and the system has been realized taking into account C# approach in Windows environment.

Keywords: decision making, safety, process

1. Introduction

One of the most important tasks in the safety engineering lays in construction a knowledge database of decision support for the chemical plants, and on that way to ensure optimal conditions, improve quality and boost efficiency. Methods of analyze of control systems and simulation methods, which are used for observing dynamic behavior of linear dynamic systems with time delay, and distributed parameter systems, based on linear algebra, operation calculus, functional analyse, integral differential equations and linear matrix non-equations has shown long ago that modern electronic components can be used to achieve more consistent quality at lower cost in safety engineering. The main idea to do so is that the quality service is maintained and controlled. Applying the Fuzzy theory in decision making has given very good results, and it provided a flexible framework and over the years numerous mathematical models have been developed.

There are two basic problems to solve in decision making situations: obtaining alternative, and achieving consensus about solution from group of experts. First problem takes into account individual information which existed in collective information units. The later usually means an agreement of all individual opinions. Usually it is considered two approaches for developing a choice process in solving of decision making problems. It existed a direct approach where solution is derived on the basis of the individual relations and as well indirect approach where solution is based on a collective preference relation. In safe engineering technical and economic benefits over hard-wired, discrete components has shown PLC. Main problem in process

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engineering is practical stability of the system. Chosen system should be stable in required period of time, and this important task is obtained by using practical stability theory for distributed parameter systems. Most systems in chemical engineering as chemical plants for instance, are described by partial diferent equations and they belong to group of distributed parameter systems.

2. Practical Stability Issue

During process of analysing and synthesis of control systems fundamental problem is stability. It is well-known fact, that we can share stability definitions to Ljapunov and non-Ljapunov concept that are arisen from various engineering needs. The most often case for consideration of control systems is Ljapunov approach, where the system behaving is considering on infinite interval, which in real cases has only academic importance. From strictly engineering point of view it is very important to know the boundaries where system trajectory comes during there's motion in state space. These practical technical needs are responsible for non-Ljapunov definitions, and among them is extremely important behaving on finite time interval- practical stability. Taking into account that system can be stable in classic way but also can posses not appropriate quality of dynamic behavior, and because that it is not applicable, it is important to take system in consideration in relation with sets of permitted states in phase space which are defined for such a problem. In theory of control systems there are demands for stability on finite time interval that for strictly engineering view of point has tremendous importance. The basic difference between Ljapunov and practical stability is set of initial states of system (S_α) [2], and set of permitted disturbance (S_ε) in state space, for every opened set S_β permitted states and it is supplied that equilibrium point of that system will be totally stable, instead the principle of practical stability where are sets (S_α, S_ε) and set S_β which is closed, determined and known in advance.
Taking into account principle of practical stability, the following conditions must be satisfied:

- determine set S_β- find the borders for system motion
- determine set S_ε- find maximum amplitudes of possible disturbance
- determine set S_α of all initial state values.

In case that this conditions are regularly determined it is possible to analyse system stability from practical stability view of point.

3. Definitions And Conditions Of Practical Stability

Let us consider first order hyperbolic distributed parameter system, which is decribed by the following state- space equation:

$$\frac{\partial \underline{x}(t,z)}{\partial t} = A_0 \cdot \underline{x}(t,z) + A_1 \frac{\partial \underline{x}}{\partial z} \qquad (1)$$

with appropriate function of initial state

$$\underline{x}_0(t,z)=\underline{\psi}_x(t,z)$$
$$0\le t\le\tau,\ 0\le z\le\zeta \tag{2}$$

where $\underline{x}(t,z)$ is n- component real vector of system state, A is matrix appropriate dimension, t is time and z is space coordinate.

Definition 1: Distributed parameter system described by equation (1) that stisfied initial condition (2) is stable on finite time interval in relation to [ξ(t,z), β, T, Z] if and only if:

$$\underline{\psi}_x^T(t,z)\cdot\underline{\psi}_x(t,z)<\xi(t,z) \tag{3}$$

$$\forall t\in[0,\tau],\forall z\in[0,\varsigma]$$

then it follows

$$\underline{x}^T(t,z))\cdot\underline{x}(t,z)<\beta,$$
$$\forall t\in[0,T]\forall z\in[0,Z] \tag{4}$$

where ξ(t,z) is scalar function with feature $0<\xi(t,z)\le\alpha,\ 0\le t\le\tau,\ 0\le z\le\zeta$ where α is real number, β Є R and β > α.

Let calculate the fundamental matrix for this class of system:

$$\frac{d\Phi(s,\sigma)}{d\sigma}=A_1\cdot(sI-A)\cdot\Phi(s,\sigma) \tag{5}$$

where after double Laplace transformation, and necessary approximation finally it is obtained:

$$\Phi(t,z)=\exp(A\cdot t\cdot z) \tag{6}$$

where $A=\dfrac{I-A_0\cdot A_1}{A_1}$

Theorem1: Distributed parameter system described by equation by equation (1) that satisfied internal condition (2) is stable on finite time interval in relation to [ξ(t,z), β, T, Z] if it is satisfied following condition:

$$e^{2\mu(A)t\cdot z}<\frac{\beta}{\alpha} \tag{7}$$

Proof: Solution of equation (1) with initial condition (2) is possible to describe as:

$$\underline{x}(t,z)=\Phi(t,z)\cdot\underline{\psi}(0,0) \tag{8}$$

By using upper equation it follows:

where $\underline{x}(t,z)$ is n- component real vector of system state, A is matrix appropriate dimension, t is time and z is space coordinate.

Definition 1: Distributed parameter system described by equation (1) that stisfied initial condition (2) is stable on finite time interval in relation to [ξ(t,z), β, T, Z] if and only if:

$$\underline{x}^T(t,z)\cdot\underline{x}^T(t,z)=\left[\underline{\psi}_x^{\;T}(0,0)\cdot\Phi(t,z)\right]\cdot \left[\underline{\psi}_x^{\;T}(0,0)\cdot\Phi(t,z)\right] \quad (9)$$

By using well-known ineuality

$$\left\|\Phi(t,z)\right\|=\left\|\exp[A\cdot t\cdot z]\right\|\le\exp\{\mu(A)\cdot t\cdot z\} \quad (10)$$

and taking into account that

$$\underline{\psi}_x^T(0,0)\cdot\underline{\psi}_x(0,0)<\alpha \quad (11)$$

$$\left(\left\|\underline{\psi}_x^T(0,0)\right\|=\left\|\underline{\psi}_x^T(0,0)\right\|<\alpha\right)$$

then follows:

$$\underline{x}^T(t,z)\cdot\underline{x}(t,z)\le e^{2\mu(A\cdot t\cdot z)}\cdot\alpha \quad (12)$$

Applying the basic condition of theorem 1 by using equation (7) to further inequality it is obtained:

$$\underline{x}^T(t,z)\cdot\underline{x}(t,z)<\left(\frac{\beta}{\alpha}\right)\cdot\alpha<\beta \quad (13)$$

Theorem2: Distributed parameter system described by equation (1) that satisfied initial condition (2) is stable on finite time interval in relation to [ξ(t,z), β, T, Z] if it is satisfied following condition:

$$e^{\mu(A)t\cdot z}<\frac{\sqrt{\beta/\alpha}}{1+\tau\cdot\zeta\left\|A\right\|}, \quad (14)$$

$$\forall t\in[0,\tau]\forall z\in[0,\varsigma]$$

4. Architecture Of Process Safety Systems

There are few well known stages in developing computer decision support systems based on knowledge which include choosing suitable mathematical tools, formalization of the subject area [4], and development of the corresponding software. In the first phase the problem lays in making right diagnosis and in analyses of the requirements and as well the analyses of the system incidents caused by specification, design and the implementation of the project. The problem of diagnostics may be stated such as finite number of subsets, or it should be applied classical investigation methods.

System architecture consists of the following modules:

- Stability checking module. This module is designed as program for checking the practical stability of the system. If the system passes this check it goes further to other modules.

- Anlyse module of safe fault-tolerant controllers, I/O, engineering and pressure transmitters.
- Diagnostics module
- Knowledge Module of all possible situations and impacts to chemical plants
- Optimal solution- decision making module
- Presentation module

For system realization it is used object oriented approach, and the program support is presented in C# language. Each module has a supportive library, and the logical structure is based on the classes.

Main classes are:

Analyses group which has a primary task of collecting necessary facts about system.

Practical stability group which determines if the system is stable or not. If the system is unstable in view of practical stability, then it is automaticly rejected.

Diagnosis group describes all possible casualities for not required results, or potencial casualities for not optimal costs.

Performance group is used for the optimal performance.

Cost group is used for the optimal cost effect.

Decision making algorithm for optimal performance and cost consists of two phases:

Phase 1 is used for input Analyses class, Practical stability class and diagnosis class.

Phase 2 is used for output Performance and Cost group.

5. Conclusion

By analysing process systems from safety and optimal cost perspective, it is important to recognize which systems are not stable in real conditions. From engineering state of view we are interested in such a systems which are stable in finite periods of time, so our first concern should be to maintain stable and safe systems. Our knowledge database is created in DB2, and it involved all possible reasons for non adequate performanse. Key modules for obtaining best performance, safety and the low cost are a good base for the programm support in C# programming language and the UML representation.

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