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SAFETY CRITERION IN ASSESSING THE IMPORTANCE OF AN ELEMENT IN THE COMPLEX TECHNOLOGICAL SYSTEM RELIABILITY STRUCTURE

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Abstract:
The paper presents the need to develop a description of the importance of the technological systems reliability structure elements in terms of security of the system. Basic issues related to the exploration of weak links and important elements in the system as well as a proposal to develop the current approach to assessing the importance of the system components have been presented. Moreover, the differences between the unreliability of suitability and unreliability of safety have been pointed out.

Key words: *importance of an element, importance assessment, weak link, system security/safety*

INTRODUCTION

Within the reliability theory measurements for the quantitative evaluation of the importance (relevance) of a given system component for the proper execution of the object's functions have been worked out. Various measures of importance lead to different systems relevance rankings, due to their different definitions [1, 5, 9].

For the assessment of which elements are most likely to lead to failure of the system, Vessely-Fussell importance measure and Lambert criticality can be used. These measures relate to the reliability of system components and reliability structure, which the components are located in.

Among the importance measures there can be found measures not dependent upon the reliability of the analyzed element, but only on the reliability of all the other components and the system reliability structure. An example of such a measure is Birnbaum reliability importance measure. So far, apart from the above mentioned, a great deal of other importance measures based on the reliability characteristics of devices including Bergman, Natviga, Barlow-Proshan and others have been developed.

The issues of assessing the importance of elements are related to the problem of searching for "weak links", that is the most unreliable components.

"WEAK LINKS" AND IMPORTANT COMPONENTS

One way to increase system reliability is the use of reserving the most unreliable elements. Such elements are amplified by the introduction of a parallel or threshold structure. By improving the reliability of the system using the structural excess of the current "weak link", another element is the most unreliable. This phenomenon is called "wandering cell".

The criterion to determine the weak link of the n-element system can be represented in the form [1]:

$$\Omega_i^N > \Omega_{io}^N, \quad i = 1,2...n, \quad i \neq i_o \tag{1}$$

where:

Ω_i^N - A measure of reliability of the i-th element,

Ω_{io}^N - A measure of "weak link" reliability.

In this case, reliability of a multi-system always satisfies the condition:

$$\Omega_{OT}^N < min(\Omega_1^N, \Omega_2^N ... \Omega_n^N) \tag{2}$$

where:

Ω_{OT}^N - A measure of reliability of the i-th element,

If the load of all the elements changes simultaneously, after crossing the critical load one of the elements will go into unfitness. The element is the system's 'weak link' and the reliability of the system then equals the reliability of this element:

$$\Omega_{OT}^N = \Omega_{io}^N = min(\Omega_1^N, \Omega_2^N ... \Omega_n^N) \tag{3}$$

Summary of key issues related to the search for weak links is shown in Fig. 1.

Elements importance rating based only on indicators of reliability leads to the limited applicability of these relevance measures. Such measures, however, provide preliminary results for further analysis. An example of a block model of the reliability structure of a complex technological system in the form of an industrial robot manipulator is shown in Figure 2.

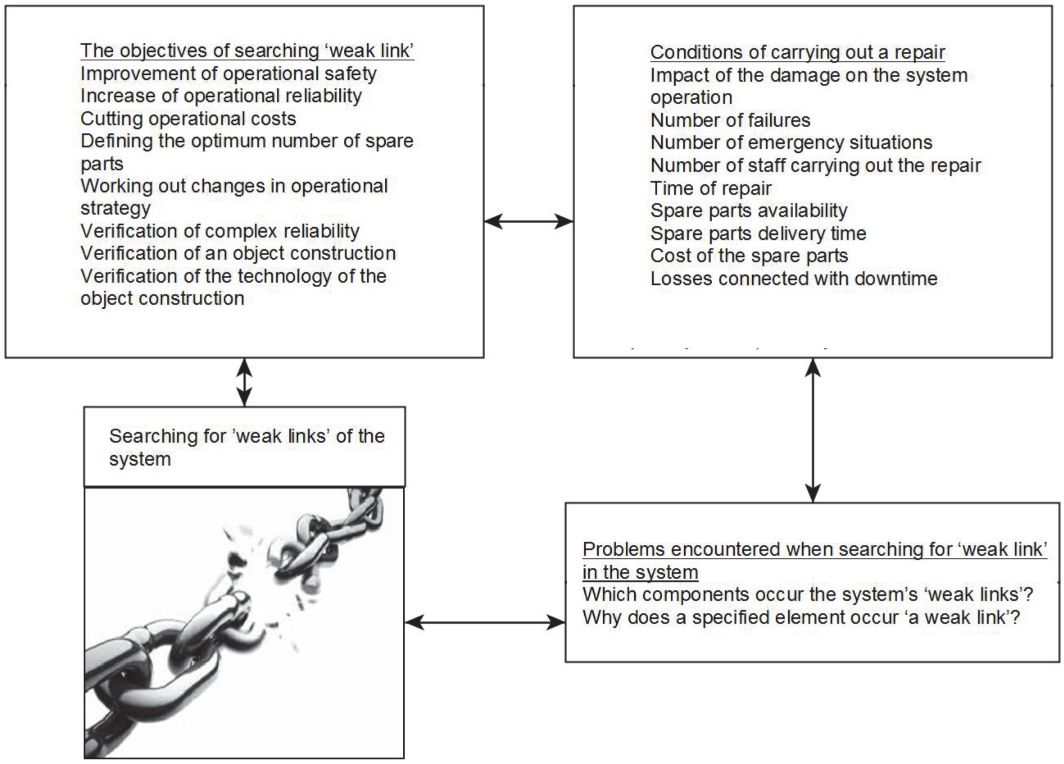

Fig. 1. Problems and objectives of seeking "weak links"

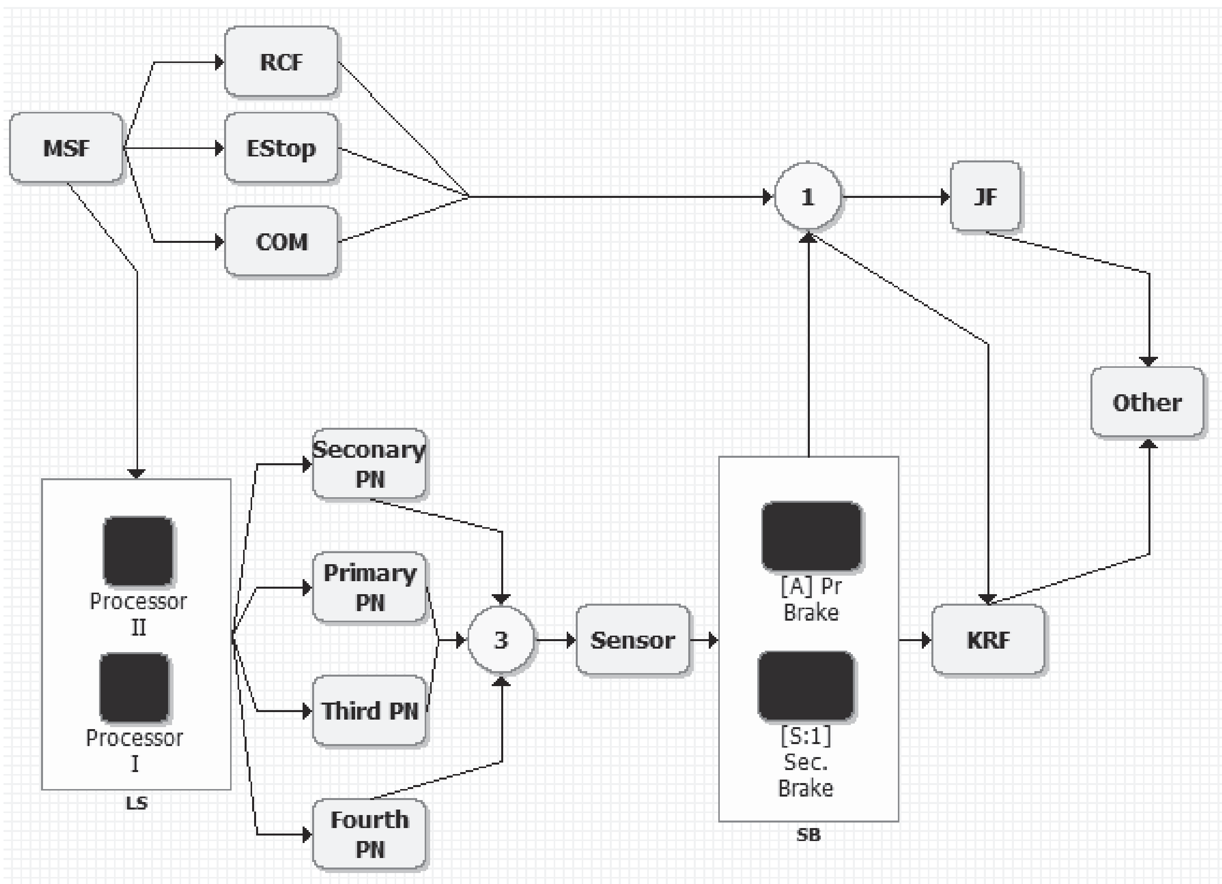

Fig. 2. Reliability structure of an industrial robot manipulator [10]

For the example in Figure 3 the waveforms of importance reliability measures of various elements of the system have been shown [10]. The presented computer code is one of the few that will promote the time course of the reliability importance values (here: A measure of Birnbaum).

Virtually, all popular packages for the analysis of reliability only allow for the construction of bar graphs (importance point), but the author is not aware of any programs to assess the importance based on additional criteria for the importance of elements.

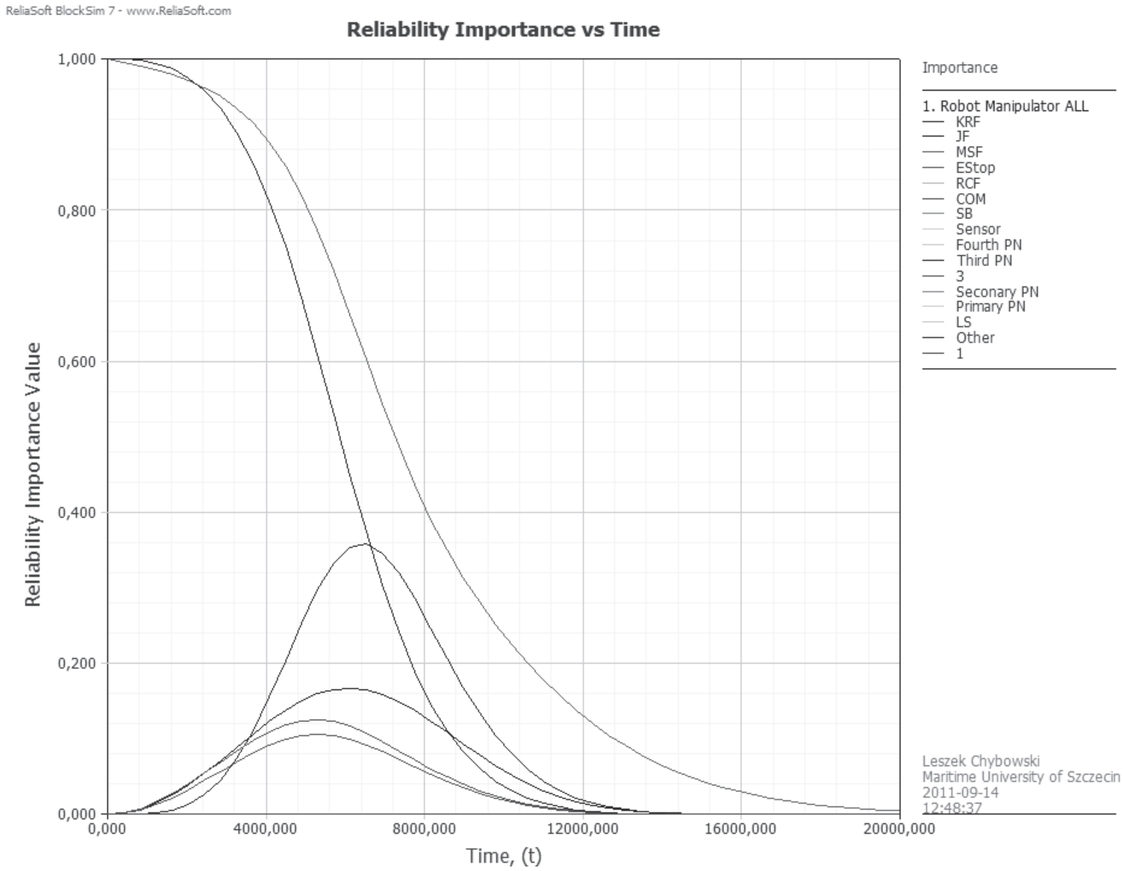

Fig. 3. A measure of Birnbaum of system elements presented in Fig. 2

There appears a necessity to introduce additional importance criteria, since, as practice shows important operational elements due to their reliability are often not the "weak links". Criteria for the selection of "weak links" may be based on [1]: reliability, maintainability, safety measures and technological efficiency.

The selection of the 'weak links' here needs to be related to the impact of the working system environment on the characteristics of the system components. According to the publication [1] there exist the following criteria to assess the impact of factors forcing the state characteristics of the elements shown on the basis of the internal combustion engine: the criterion of the thermal load, the criterion of dynamic forces, the criterion of continuity of work, the criterion of safety, traffic noise criterion, the criterion of maintainability, the criterion of difficulty of operation.

The author proposes to develop a methodology to evaluate the importance of elements in the structure of the reliability of complex technological systems by introducing a number of criteria of importance for the construction of multi - criteria importance model [4, 5, 6, 7]. The initial importance of the elements can be determined on the basis of unreliability of the component F(t) and the number of fitness tracks xi, involving the i-th element for all the x tracks of the fitness system:

The author proposes a measure describing the importance of the item, taking into account the relevant criteria,

$$I(t) = f[F_i(t), x_i, x] \qquad (4)$$

to be determined by appropriate weight factors for various criteria, such as the criterion of amount of labor time , the effort of staff participation, maintainability, spares delivery time, maintainability economics and safety of operation. Then the element importance can be defined by means of a function like the following:

$$I^{KRYT}(t) = f[F_i(t), x_i, x, c_t(t), c_p(t), c_m(t), c_s(t), c_e(t), c_b(t)] \qquad (5)$$

Importance criteria will be modified through the application of weight factors: c_b (t) - the operational safety, c_t (t) - amount of working time to carry out the element renewal, c_p (t) - the participation of personnel for the element renewal, $c_o(t)$ - operationality in the element renewal, c_s (t) - delivery time of spare parts for the implementation of recovery (repair) of an element, c_e (t) - the economics of service took the form presented in [7].

THE UNRELIABILITY OF THE SUITABILITY AND SECURITY FAILURE

The main and most important issue in the operation of the systems is security (Fig. 4). The author proposes to adopt reliability indicators in assessing the importance of elements in a reliability structure that recognize the operational safety, followed by the introduction of other indicators [8].

Fig. 4. Safety is always the most significant aspect [11]

The definition of reliability of measurement is described by the relation (3) and refers to the reliability of the system operation and can be generalized to measure R related to safety reliability. R_B Safety reliability of the system is immune to errors of action involving a threat to the system existence, cooperating systems, the environment and human life [2].

$$R=1-Q \tag{6}$$

Where:

$Q = Q_B + Q_Z$ – system unreliability,

$Q_B = 1 - R_B$ – safety unreliability,

$Q_Z = 1 - \Omega_{OT}^{N}$ – suitability unreliability (operation).

Application of the presented set of measures causes serious application difficulties because of the need to find the appropriate length of time distributions in relation to the failure and the possible state of emergency. That is why some parameters are defined as simulation methods or evaluated by experts.

FINAL CONCLUSIONS

Previous work on the importance of the elements mainly focused on elements vulnerability, and in a marginal way discussed other importance criteria [3, 4, 5]

In practice, the definition of security failure is very difficult or impossible. In addition, a user of a complex technological system must know not only a "weak link" of the system, but a set of "weakest links", i.e. "a collection of relevant links ".And often after the adoption of certain criteria such as safety it may appear that the sets of important elements and the "weak links" are not part of the joint. This follows from the fact that failure to the most deceptive element does not need to cause the state of security threat.

For utilitarian reasons it is necessary to develop much simpler measures that recognize the safe operation of the system and related indicators of the effectiveness of the operation process.

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