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INTELLECTUALIZATION OF SEARCH FOR THE CAUSES OF FAILURE OF COMPONENTS OF A COMPLEX TECHNICAL SYSTEM

V.V. Vychuzhanin

National Odesa Polytechnic University
Ave.. Shevchenko, 1, Odesa, 65044, Ukraine;
e-mail: v.v.vychuzhanin@op.edu.ua

The task set in the article is to intellectualize the search for the causes of failures of subsystems (components), intersystem (intercomponent) connections of ship complex technical systems based on the assessment of the technical condition of systems by diagnostic features and predicting the risk of failures in their composition. The purpose of the article is to ensure the reliability of complex technical systems. The novelty of the results obtained lies in the fact that in the course of the study the principles of functioning of an intelligent system for searching for the causes of failures of a complex technical system with insensitivity to incomplete technological data about it were formulated. The principle of functioning of an intelligent system for searching for the causes of failures of a complex technical system by assessing and predicting the risk of failures of subsystems (components), intersystem (intercomponent) connections, its structure, in terms of technical and technological foundations of construction, is implemented on the example of a ship power plant. The result of the research is also the developed model for searching for the causes of failures of complex technical systems, which can be considered as a conceptual model with relative insensitivity to incomplete technological data about the system. Intellectualization of the search for the causes of failures of a complex technical system, taking into account hierarchical levels, makes it possible to determine vulnerable subsystems (components) on the basis of assessing the technical condition by diagnostic features and predicting the risk of failures.

Keywords: complex technical system, subsystem, component, intersystem and interelement communications, diagnostics, forecasting, model, failure risk assessment, intelligent system, search for failure causes

Introduction. Odern complex technical systems (CTS) are diverse in equipment, consist of many interconnected and interdependent subsystems, components [1,2]. The complication of the composition and the increase in the number of CTS installed on ships lead to an increase in the failure rate of such systems, to the need to repair CTS equipment, and hence to ship downtime. The use of intelligent systems for searching for the causes of failures of subsystems (FS), components (FC), intersystem (FIC) and intercomponent links (FI) CTS based on the assessment of their technical condition (TC) by diagnostic features and predicting the risk of failures in systems can significantly extend the life cycle ship CTS [3,4,5]. This article is devoted to the solution of this problem.

Studies of ship CTS survivability models show that the defeat of any FS, FC in systems gives rise to a significant number of possible scenarios and options for the development of emergency conditions of such systems, and hence to possible marine accidents and incidents [6,7], the statistics of which are reflected in the well-known bases [8,9,10,11,12]. According to statistics, one of the main CTS - ship power plant (SPP) accounts for 60-80% of all failures of ship systems].

The operational reliability of CTS is effectively achieved by the system operation strategy as a result of searching for the causes of failures based on equipment diagnostic data [13,14,15,16,17], predicting their TS [18,19,20,21,22].

The reliability of ship CTS can be reflected in the form of an assessment of the risk of failures [23,24,25,26,27,28]. For maritime shipping, the International Maritime Organization (IMO) has developed a consolidated text formalized safety assessment should comprise the following steps: identification of hazards; risk analysis; risk control options; 4 cost assessment benefit; recommendations for decision-making [29]. To analyze the risk of failure of system components, the world-wide Reliability Centered Maintenance method [30] is also widely used.

Currently, the volume of implementation of automation tools and artificial intelligence technologies continues to grow in various industries [31]. In accordance with the requirements of the Register of Maritime Navigation, all modern ships must be equipped with automation systems for technical means using digital technologies, as well as artificial intelligence technologies [1,32,33,34,35]. Such systems should constantly monitor FS, FC of ship CTS, analyze trends in changes in the TC, search for the causes of system equipment failures. To implement such tasks, appropriate algorithmic and software tools are needed.

In artificial intelligence, knowledge representation models are actively developing - Bayesian Belief Networks (BBN) [36,37,38]. They can be used to assess the risk of failures in CTS, providing a probabilistic basis for modeling the relationships between different failure modes and their root causes.

The algorithms used to search for the causes of failures FS, FC, FIC and FI based on the diagnosis of the vehicle, as a rule, are based on the control of tolerances of individual diagnostic parameters. However, the analysis and integral assessment of the technical condition of subsystems and complexes, the development of control actions in most cases is carried out by ship operators on the basis of heuristic rules.

Thus, the problems associated with ensuring the reliable operation of ship CTS require improvement and search for appropriate new methods, models and algorithms. They should be aimed not only at the prompt detection of equipment failure conditions, at solving problems of assessing and predicting the risk of system failures, but also at finding their causes under conditions of relative insensitivity to incomplete technological data on FS, FC. Since all modern ships must be equipped with automation systems for technical means using technologies based on artificial intelligence, the introduction of approaches based on such methods, models and algorithms should ensure the reliable operation of ship CTS. That is, taking into account the specifics and existing problems in ensuring reliability during the operation of ship CTS, the intellectualization of the search for the causes of failures based on the evaluation of TC systems by diagnostic features and predicting the risk of failures in their composition is an important direction in the development of modern technologies aimed at ensuring the safety and reliability of complex systems. systems and is an urgent task.

Statement of the problem: intellectualization of the search for the causes of failures of FS, FC, FIC and FI of ship CTS based on the assessment of the TC of systems by diagnostic features and predicting the risk of failures in their composition and eliminating the consequences of their occurrence.

Purpose of the work: ensuring the reliability and safety of the work of ship CTS.

Main part. The initial data for constructing an intellectualization model for searching for the causes of failures of components of a complex technical system based on TC assessment and predicting the risk of failures of complex systems using the example of an SPP based on BBN are: scheme and principle of operation of the SPP; failure probabilities FS, FC, FIC and FI of CTS links [39]. When modeling the BBN of the SPP for various values of the risk of failure of the input element BBN, the probabilities of loss of operability FS, FC, FIC and FI of connections for 20,000 hours of operation of the SPP were determined (Fig. 1).

From the retrospective analysis of the research results in the simulation of the SPP, the components that affect the overall performance of the system are identified. In the study of emergency situations, the analysis of incidents in the CTS, the main goal is to determine the cause of the accident. It follows from the research results that the maximum non-operating state during the operation of the SPP is 20,000 hours. corresponds to the CSPSC subsystem. Since the CSPSC subsystem is dependent at the level of the hierarchical structure of the SPP, therefore, it is necessary to check the subsystem in order to find the cause of its failure. Namely, to check the subsystems and all related subsystems at other levels of the BBN scheme.

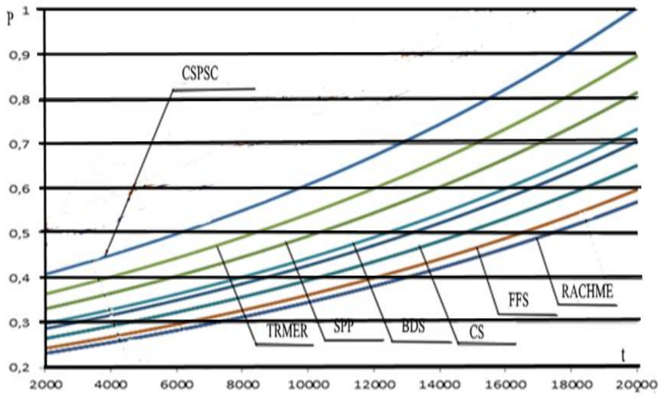

Fig.1. Probability of loss of operability of SPP subsystems

The scheme for searching for the cause of failure, for example, the CSPSC subsystem in the diagnostic model of the technical condition of the power plant using BBN is shown in Fig.2. For the BBN blocks of the SPP, we single out the blocks IE, CAS, SPP, CSPSC and intersystem communications IE-CAS, CAS - SPP, SPP - CSPSC for detailed consideration as an example to explain the principle of the model. Sets of risk of failures IE, CAS, SPP, CSPSC and interconnections IE-CAS, CAS - SPP, SPP - CSPSC at the initial moment of time and taking into account the dynamics of technical conditions in time based on a priori data on the failure rates BBN when the subsystems of the SPP IE, CAS, SPP, CSPSC and intersystem communications IE-CAS, CAS - SPP, SPP - CSPSC.

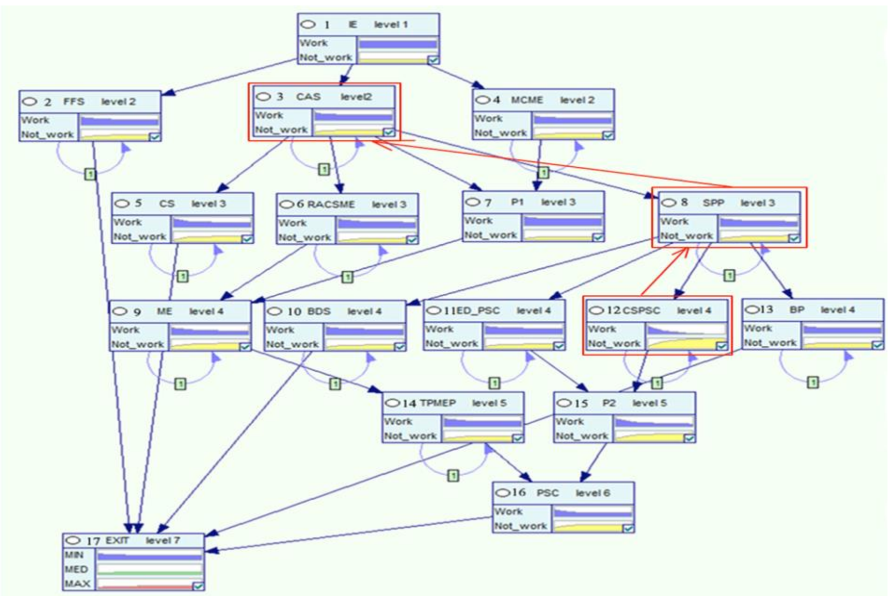

Fig.2. Scheme for searching for the cause of failure of the CSPSC subsystem in the diagnostic model of the technical condition of the SPP BBN

The search for the cause of failure of the CSPSC subsystem was performed in accordance with the algorithm shown in Fig. 3.

Symbols of subsystems, components of the SPP in BBN (Fig. 2): Input element - IE; Fire fighting system - FFS; Compressed air system - CAS; Manual control of the main engine - MCME; Control system - CS; Remote automated control system of the main engine - RACSME; Intermediate component - P1; Ship power plant - SPP; Main engine - ME; Ballast drainage system - BDS; Emergency drive propulsion and steering complex - ED PSC; Control system for propulsion and steering complex - CSPSC; Boiler plant - BP; Transfer of power from the main engine to the propeller - TPMEP; Intermediate component = P2; Propulsion and steering complex - PSC; Output component - EXIT.

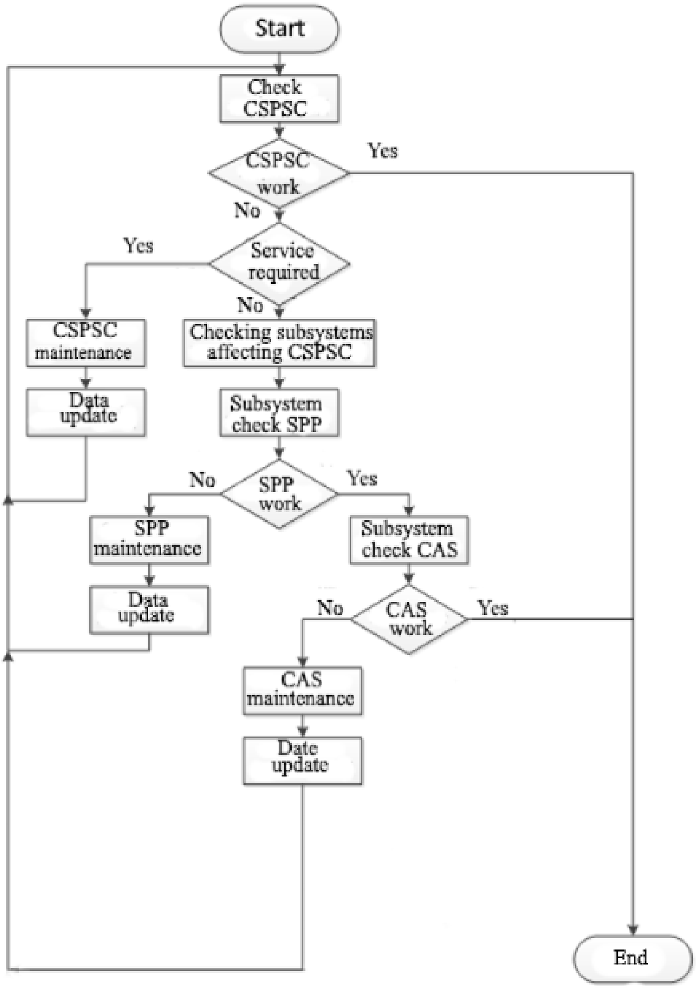

Fig. 3. Algorithm for troubleshooting the CSPSC subsystem

The technique for building a model based on BBN can be represented as follows:

1. Building BBN:

1.1. Vertices and intersystem (intercomponent) BBNs are created, denoting FS, FC, FIC and FI STS, taking into account their TC:

1.1.1. Each FS, FC may be in the following technical condition:

$Work_{n_{S(C)}}^{<m_{S(C)}>}$ - operational state $n_{S(C)}$ - th FS (FC) $m_{S(C)}$ - th level;

$Not\_work_{a(z)_{I_{S(C)}}}^{<b,q>}$ - partial (complete) failure $n_{S(C)}$ - th FS (FC) $m_{S(C)}$ - th level.

1.1.2. Each FIC and FI connection is in the following states:

$Work_{a(z)_{I_{S(C)}}}^{<b,q>}$ - operational state $a(z)_{I_{S(C)}}$ - th FIC (FI) connection $b(q)$ level;

$Not\_work_{a(z)_{I_{S(C)}}}^{<b,q>}$ - partial failure (complete) $a(z)_{I_{S(C)}}$ - th FIC (FI) communication *b(q)* level

where $S(C)$ - is the set FS (FC) CTC;

$I_S(I_C)$ - a set of FIC (FI) CTS connections;

$n_{s(c)}$ - number FS (FC) CTC;

$m_{s(c)}$ - number of the hierarchical level FS (FC) CTC;

a(z) – FIC (FI) number of CTS communication connections;

b(q) – number of the hierarchical level FIC (FI) of CTS communication links

1.2. Links between BBN vertices are indicated, denoting FS, FC, FIC and FI CTC links

2. BBN parameters are specified:

2.1. The risk of failures at the initial moment of time for FS, FC, FIC and FI of the CTS connection, assuming that before the start of the CTS operation they are all operable:

$$R(Work_{n_{S(C)}}^{<m_{S(C)}>})_{t=0} = F(P(Work_{n_{S(C)}}^{<m_{S(C)}>})_{t=0}) = 0 \quad (1)$$

$$R(Work_{a(z)_{I_{S(C)}}}^{<b,q>})_{t=0} = F(P(Work_{a(z)_{I_{S(C)}}}^{<b,q>})_{t=0}) = 0$$

The risk of failures at the initial moment of time for FS, FC, FIC and FI of the CTS connection, assuming that before the start of the CTS operation they are all inoperable:

$$R(Not\_work_{n_{S(C)}}^{<m_{S(C)}>})_{t=0} = F(P(Not\_work_{n_{S(C)}}^{<m_{S(C)}>})_{t=0}) = 1 \quad (2)$$

$$R(Not\_work_{a(z)_{I_{S(C)}}}^{<b,q>})_{t=0} = F(P(Not\_work_{a(z)_{I_{S(C)}}}^{<b,q>})_{t=0}) = 1$$

2.3. The risk of failure of FS, FC, FIC and FI of the CTS connection at the current time, provided that some subsystems (components), intersystem (intercomponent) connections failed at the previous time:

$$R((Not\_work_{n_{S(C)}}^{<m_{S(C)}>})_t/(Not\_work_{n_{S(C)}}^{<m_{S(C)}>})_{t-1}) = 1 \quad (3)$$

$$R((Not\_work_{a(z)_{I_{S(C)}}}^{<,b,q>})_t/(Not\_work_{a(z)_{I_{S(C)}}}^{<b,q>})_{t-1})) = 1$$

For the BBN blocks of the SPP (Fig. 2) IE, CAS, SPP, CSPSC and interconnections IE-CAS, CAS - SPP, SPP - CSPSC, sets of failure risk at the initial time and taking into account the dynamics of technical conditions in time based on a priori data on failure rates:

$$R(Work_{1,3,8,12}^{1,2,3,4})_{t=0} = 0;$$

$$R(Not\_work_{1,3,8,12}^{1,2,3,4})_{t=0} = 1;$$

$$R(Work_{IE-CAS,CAS-SPP,SPP=CSPSC}^{2,3,4})_{t=0} = 0 \quad (4)$$

$$R(Not\_work_{IE-CAS,CAS-SPP,SPP=CSPSC}^{2,3,4})_{t=0} = 1;$$

$$R((Work_{1,3,8,12}^{1,2,3,4})_t/(Work_{1,3,8,12}^{1,2,3,4})_{t-1}) = 0{,}1;$$

$$R((Work_{IE\_CAS,CAS\_SPP,SPP-CSPSC}^{2,3,4})_t/(Work_{IE\_CAS,CAS-SPP,SPP-CSPSC}^{2,3,4})_{t-1}) = 0{,}1$$

Sets of risk of failures at the current moment of time, taking into account the previous state of subsystems and intersystem communications, can be within:

- the level of risk of failure is assessed as minimal, the consequences of an accident are minimal when:

$$R((Not\_work_{1,3,8,12}^{1,2,3,4})_t/(Work_{1,3,8,12}^{1,2,3,4})_{t-1}) = 0{,}1-0{,}2 \quad (5)$$

$$R((Not\_work^{2,3,4}_{IE\_CAS,CAS\_SPP,SPP-CSPSC})_t/(Work^{1,3,4}_{IE\_CAS,CAS-SPP,SPP-CSPSC})_{t-1}) = 0{,}1-0{,}2$$

- the level of risk of failure is assessed as acceptable, the consequences of the accident are insignificant when:

$$R((Not\_work^{1,2,3,4}_{1,3,8,12})_t/(Work^{1,2,3,4}_{1,3,8,12})_{t-1}) = 0{,}2-0{,}37 \quad (6)$$

$$R((Not\_work^{2,3,4}_{IE\_CAS,CAS\_SPP,SPP-CSPSC})_t/(Work^{1,3,4}_{IE\_CAS,CAS-SPP,SPP-CSPSC})_{t-1}) = 0{,}2-0{,}37$$

- the level of risk of failure is estimated as maximum, the consequences of the accident are significant when:

$$R((Not\_work^{1,2,3,4}_{1,3,8,12})_t/(Work^{1,2,3,4}_{1,3,8,12})_{t-1}) = 0{,}37-0{,}63 \quad (7)$$

$$R((Not\_work^{2,3,4}_{IE\_CAS,CAS\_SPP,SPP-CSPSC})_t/(Work^{1,3,4}_{IE\_CAS,CAS-SPP,SPP-CSPSC})_{t-1}) = 0{,}37-0{,}63$$

- the failure risk level is assessed as critical when:

$$R((Not\_work^{1,2,3,4}_{1,3,8,12})_t/(Work^{1,2,3,4}_{1,3,8,12})_{t-1}) = 0{,}63-1 \quad (8)$$

$$R((Not\_work^{2,3,4}_{IE\_CAS,CAS\_SPP,SPP-CSPSC})_t/(Work^{1,3,4}_{IE\_CAS,CAS-SPP,SPP-CSPSC})_{t-1}) = 0{,}63-1$$

The risk distribution of failures of subsystems (components), intersystem (intercomponent) links in BBN, taking into account failures and restorations, has the form:

- for failure risk distributions Control system for propulsion and steering complex –CSPSC SPP in BBN:

$$R(Work^4_{12})_t = R((Work^4_{12})_t/(Work^4_{12})_{t-1})\cdot R(Work^1_1)_{t-1}\cdot R(Work^2_3)_{t-1}\cdot R(Work^3_8)_{t-1}\times$$

$$\times R(Work^4_{12})_{t-1}\cdot R(Work^2_{IE\_CAS})_{t-1}\cdot R(Work^3_{CAS-SPP})_{t-1}\cdot R(Work^4_{SPP-CSPSC})_{t-1}+$$

$$+R(Work^4_{12})_t = R((Work^4_{12})_t/(Not\_work^4_{12})_{t-1})\cdot R(Work^1_1)_{t-1}\cdot R(Work^2_3)_{t-1}\cdot R(Work^3_8)_{t-1}\times$$

$$\times R(Not\_work^4_{12})_{t-1}\cdot R(Work^2_{IE\_CAS})_{t-1}\cdot R(Work^3_{CAS-SPP})_{t-1}\cdot R(Work^4_{SPP-CSPSC})_{t-1}+$$

$$+R(Work^4_{12})_t = R((Work^4_{12})_t/(Work^4_{12})_{t-1})\cdot R(Not\_work^1_1)_{t-1}\cdot R(Work^2_3)_{t-1}\cdot R(Work^3_8)_{t-1}\times$$

$$\times R(Work^4_{12})_{t-1}\cdot R(Work^2_{IE\_CAS})_{t-1}\cdot R(Work^3_{CAS-SPP})_{t-1}\cdot R(Work^4_{SPP-CSPSC})_{t-1}+$$

$$+R(Work^4_{12})_t = R((Work^4_{12})_t/(Work^4_{12})_{t-1})\cdot R(Work^1_1)_{t-1}\cdot R(Not\_work^2_3)_{t-1}\cdot R(Work^3_8)_{t-1}\times$$

$$\times R(Work^4_{12})_{t-1}\cdot R(Work^2_{IE\_CAS})_{t-1}\cdot R(Work^3_{CAS-SPP})_{t-1}\cdot R(Work^4_{SPP-CSPSC})_{t-1}+ \quad (9)$$

$$+R(Work^4_{12})_t = R((Work^4_{12})_t/(Work^4_{12})_{t-1})\cdot R(Work^1_1)_{t-1}\cdot R(Work^2_3)_{t-1}\cdot R(Not\_work^3_8)_{t-1}\times$$

$$\times R(Work^4_{12})_{t-1}\cdot R(Work^2_{IE\_CAS})_{t-1}\cdot R(Work^3_{CAS-SPP})_{t-1}\cdot R(Work^4_{SPP-CSPSC})_{t-1}+$$

$$+R(Work^4_{12})_t = R((Work^4_{12})_t/(Work^4_{12})_{t-1})\cdot R(Work^1_1)_{t-1}\cdot R(Work^2_3)_{t-1}\cdot R(Work^3_8)_{t-1}\times$$

$$\times R(Work^4_{12})_{t-1}\cdot R(Not\_work^2_{IE\_CAS})_{t-1}\cdot R(Work^3_{CAS-SPP})_{t-1}\cdot R(Work^4_{SPP-CSPSC})_{t-1}+$$

$$+R(Work^4_{12})_t = R((Work^4_{12})_t/(Work^4_{12})_{t-1})\cdot R(Work^1_1)_{t-1}\cdot R(Work^2_3)_{t-1}\cdot R(Work^3_8)_{t-1}\times$$

$$\times R(Work^4_{12})_{t-1}\cdot R(Work^2_{IE\_CAS})_{t-1}\cdot R(Not\_work^3_{CAS-SPP})_{t-1}\cdot R(Work^4_{SPP-CSPSC})_{t-1}+$$

$$+R(Work^4_{12})_t = R((Work^4_{12})_t/(Work^4_{12})_{t-1})\cdot R(Work^1_1)_{t-1}\cdot R(Work^2_3)_{t-1}\cdot R(Work^3_8)_{t-1}\times$$

$$\times R(Work^4_{12})_{t-1}\cdot R(Work^2_{IE\_CAS})_{t-1}\cdot R(Work^3_{CAS-SPP})_{t-1}\cdot R(Not\_work^4_{SPP-CSPSC})_{t-1}$$

- for ship power plant failure risk distributions in BBN:

$$R(Work_8^3)_t = R((Work_8^3)_t/(Work_8^3)_{t-1}) \cdot R(Work_1^1)_{t-1} \cdot R(Work_3^2)_{t-1} \times$$
$$\times R(Work_8^3)_{t-1} \cdot R(Work_{IE\_CAS}^2)_{t-1} \cdot R(Work_{CAS-SPP}^3)_{t-1} +$$
$$+ R(Work_8^3)_t = R((Work_8^3)_t/(Not\_work_8^3)_{t-1}) \cdot R(Work_1^1)_{t-1} \cdot R(Work_3^2)_{t-1} \times$$
$$\times R(Not\_work_8^3)_{t-1} \cdot R(Work_{IE\_CAS}^2)_{t-1} \cdot R(Work_{CAS-SPP}^3)_{t-1} +$$
$$+ R(Work_8^3)_t = R((Work_8^3)_t/(Work_8^3)_{t-1}) \cdot R(Not-work_1^1)_{t-1} \cdot R(Work_3^2)_{t-1} \times \quad (10)$$
$$\times R(Work_8^3)_{t-1} \cdot R(Work_{IE\_CAS}^2)_{t-1} \cdot R(Work_{CAS-SPP}^3)_{t-1} +$$
$$+ R(Work_8^3)_t = R((Work_8^3)_t/(Work_8^3)_{t-1}) \cdot R(Work_1^1)_{t-1} \cdot R(Not\_work_3^2)_{t-1} \times$$
$$\times R(Work_8^3)_{t-1} \cdot R(Work_{IE\_CAS}^2)_{t-1} \cdot R(Work_{CAS-SPP}^3)_{t-1} +$$
$$+ R(Work_8^3)_t = R((Work_8^3)_t/(Work_8^3)_{t-1}) \cdot R(Work_1^1)_{t-1} \cdot R(Work_3^2)_{t-1} \times$$
$$\times R(Work_8^3)_{t-1} \cdot R(Not\_work_{IE\_CAS}^2)_{t-1} \cdot R(Work_{CAS-SPP}^3)_{t-1} +$$
$$+ R(Work_8^3)_t = R((Work_8^3)_t/(Work_8^3)_{t-1}) \cdot R(Work_1^1)_{t-1} \cdot R(Work_3^2)_{t-1} \times$$
$$\times R(Work_8^3)_{t-1} \cdot R(Work_{IE\_CAS}^2)_{t-1} \cdot R(Not\_work_{CAS-SPP}^3)_{t-1}$$

- for distributions of the risk of failure of the compressed air system of the power plant in BBN:

$$R(Work_3^2)_t = R((Work_3^2)_t/(Work_3^2)_{t-1}) \cdot R(Work_1^1)_{t-1} \cdot R(Work_3^2)_{t-1} \cdot R(Work_{IE\_CAS}^2)_{t-1} +$$
$$+ R((Work_3^2)_t/(Not\_work_3^2)_{t-1}) \cdot R(Work_1^1)_{t-1} \cdot R(Not\_work_3^2)_{t-1} \cdot R(Work_{IE\_CAS}^2)_{t-1} +$$
$$+ R((Work_3^2)_t/(Work_3^2)_{t-1}) \cdot R(Not\_work_1^1)_{t-1} \cdot R(Work_3^2)_{t-1} \cdot R(Work_{IE\_CAS}^2)_{t-1} +$$
$$+ R((Work_3^2)_t/(Work_3^2)_{t-1}) \cdot R(Work_1^1)_{t-1} \cdot R(Work_3^2)_{t-1} \cdot R(Not\_work_{IE\_CAS}^2)_{t-1} \quad (11)$$
$$R(Work_1^1)_t = R((Work_1^1)_t/(Work_1^1)_{t-1}) \cdot R(Work_1^1)_{t-1} + \quad (12)$$

- for the distributions of the risk of failure of the input component of the EMS in BBN:

$$+ R((Work_1^1)/(Not\_work_1^1)_{t-1}) \cdot R(Not\_work_1^1)_{t-1}$$

If after 20000 hours. operation, the CSPSC subsystem is in a working state, then a study is carried out on the operability of the CAS, SPP subsystems that affect the operability of the CSPSC, the failure of which can lead to the failure of the entire SPP.

After maintenance of the CSPSC subsystem, the assessments of the risk of failures of the SPP subsystems are recalculated. Because The SPP directly affects the CSPSC, so this subsystem needs to be tested. The failure of the SPP will be the probabilistic cause of the failure of the CSPSC subsystem. After the maintenance of the SPP, the data on the technical condition of the SPP subsystem is updated, and the assessments of the risk of failures of the SPP subsystems will be recalculated. If after maintenance of the CSPSC and SPP subsystems, as well as recalculation of the failure risk assessment for these subsystems, then it is necessary to check the CAS subsystem. The failure of the CAS will be the probabilistic cause of the failure of the CSPSC subsystem. After the CAS maintenance, the data on the technical condition of the CAS subsystem are updated, and the assessments of the risk of failures of the SPP subsystems will be recalculated.

Thus, based on the intellectualization of the estimation of the TS FS, FC, FIC and FI of the CTS links by diagnostic features, it is possible to search for the causes of failures of the ship's CTS components.

Conclusions. Based on the evaluation of the TC systems by diagnostic features and predicting the risk of failures in their composition, the search for the causes of failures of FS, FC, FIC and FI of ship CTS communications was intellectualized. In the course of the study, the principles of functioning of an intelligent system for searching for the causes of CTS failures with insensitivity to incomplete technological data about it were formulated. The principle of functioning of the intelligent system for searching for the causes of CTS failures by assessing and predicting the risk of failures of FS, FC, FIC and FI links, its structure, in terms of technical and technological foundations of construction, is implemented using the example of a ship power plant. A model for searching for the causes of CTS failures has been developed, which can be considered as a conceptual model with relative insensitivity to incomplete technological data about the system. Intellectualization of the search for the causes of CTS failures, taking into account hierarchical levels, makes it possible to determine vulnerable subsystems (components) on the basis of assessing the technical condition by diagnostic features and predicting the risk of failures.

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V.V. Vychuzhanin

ІНТЕЛЕКТУАЛІЗАЦІЯ ПОШУКУ ПРИЧИН ВІДМОВ КОМПОНЕНТІВ СКЛАДНОЇ ТЕХНІЧНОЇ СИСТЕМИ

В.В. Вичужанін

Національний університет «Одеська політехніка»
просп. Шевченка, 1, Одеса, 65044, Україна
e-mail: v.v.vychuzhanin@op.edu.ua

Поставлене у статті завдання полягає в інтелектуалізації пошуку причин відмов підсистем (компонентів), міжсистемних (міжкомпонентних) зв'язків суднових складних технічних систем на основі оцінювання технічного стану систем за діагностичними ознаками та прогнозування ризику відмов у їхньому складі. Метою статті є забезпечення надійності роботи складних технічних систем. Новизна одержаних результатів полягає в тому, що в ході дослідження сформульовано принципи функціонування інтелектуальної системи пошуку причин відмов складної технічної системи з нечутливістю до неповних технологічних даних про неї. Принцип функціонування інтелектуальної системи пошуку причин відмов складної технічної системи за оцінками та прогнозування ризику відмов підсистем (компонентів), міжсистемних (міжкомпонентних) зв'язків, її структура, у термінах технічних та технологічних основ побудови реалізовано на прикладі суднової енергетичної установки. Результатом досліджень також є розроблена модель пошуку причин відмов складних технічних систем, яка може розглядатися як концептуальна модель, що володіє відносною нечутливістю до неповних технологічних даних про систему. Інтелектуалізація пошуку причин відмов складної технічної системи з урахуванням ієрархічних рівнів дозволяє на основі оцінювання технічного стану за діагностичними ознаками та прогнозування ризику відмов визначати вразливі підсистеми (компоненти).
Ключові слова: складна технічна система, підсистема, компонент, міжсистемні та міжелементні зв'язки, діагностика, прогнозування, модель, оцінка ризику відмови, інтелектуальна система, пошук причин відмов