DOI 10.15276/imms.v13.no3-4.219
UDC 004.9

Informatics and Mathematical Methods in Simulation
Vol.13 (2023), No.3-4, pp. 219-227

INTELLIGENT SYSTEM FOR SUPPORTING DECISION MAKING FOR ASSESSING THE TECHNICAL CONDITION OF COMPLEX SYSTEMS

A.V. Vychuzhanin

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

The relevance of the topic is due to the need to make decisions to ensure the reliability of elements and assemblies of complex technical systems with insufficient information about their technical condition. The problem being solved is semi-structured and interdisciplinary. The effectiveness of solving the problem lies in the use of information technologies and artificial intelligence methods, in particular expert systems. The advantages of using information technologies to automate the decision-making process to assess the current technical condition of complex systems are considered. An intelligent decision support system has been developed that allows assessing the risk of failure of elements and components of complex technical systems using elements of artificial intelligence. The proposed decision support system contains: a database; a knowledge base with methods for calculating reliability indicators (probabilities and risks of failures) and a set of decision rules for selecting appropriate decision-making methods; results of determining the probabilities and risks of failure of elements and assemblies of complex technical systems with their ranking; intellectualization model for assessing the technical condition of elements and assemblies. The proposed algorithm for the functioning of a decision support system implements the task of automating the process of assessing the technical condition of complex systems. The use of the proposed decision support system for assessing the technical condition of complex systems will improve the reliability of technical systems with insufficient information about their technical condition.

Keywords: information technology, algorithm, complex technical systems, decision support, intelligent systems, artificial intelligence, expert systems, knowledge base, database, algorithm, complex technical systems, reliability, risk of failure, ship's power plant

Introduction. One of the significant problems of ensuring the reliability of complex technical systems (CTS) with insufficient information about their technical condition (TC) is the search for ways to increase the reliability and accuracy of assessing the reliability indicators of elements and components of technical systems. During the operation of CTS systems go through the following stages of TC changes: defect; damage; destruction; refusal.

Due to the increasing complexity of technical systems and the growing requirements for their reliability, the importance of the problem of access to the volumes of diagnostic information on reliability accumulated at various stages of CTS operation is increasing [1.2,3,4].

Currently, significant information materials have been accumulated containing methods for reliability research, as well as methods and models for assessing the reliability of CTS of various types.

A feature of the field of knowledge devoted to the problem of reliability is that most of the knowledge is the personal experience of experts in the field of reliability of CTS [4]. However, experts are often forced to make management decisions to ensure the reliability of CTS in the face of insufficient information about the technical condition of such systems. When assessing reliability, it is also necessary to take into account the fact that CTS are characterized by a large number of diagnosed parameters that differ in information content and degree of accessibility. Such CTS are characterized by specific and varied operating conditions.

It is also significant that research and assessment of reliability indicators of such systems is characterized by decision-making under significant uncertainty, and often still requires significant material and time costs [5].

The growing complexity of technical systems, the variety of their parameters and insufficient information description of the state of the systems require improvement of management decisions to ensure the reliability of elements and components of systems based on the results of assessing their technical condition.

Thus, during the operation of CTS, the urgent task remains to improve methods aimed not only at assessing the technical condition of systems and the decisions made related to them, but at supporting the decisions made.

Objective and objectives of the study. To assess the reliability of CTS, various methods have been developed and used, often based on the methods of probability theory and mathematical statistics, which makes it possible to automate the process of assessing the reliability of elements and components of complex systems. However, the stages associated with supporting decisions made to ensure reliability based on the results of its assessment for CTS, in particular ship systems, are often not automated. As a result, the quality of decisions made to ensure the reliability indicators of such CTS significantly depends on the qualifications of the personnel operating the system [6,7,8].

Evolution in information processing leads to the actualization of the task of not only automating the process of assessing the reliability of elements and components of complex systems, but also to the transfer of part of the intellectual sphere of human activity to the sphere of automation of making and supporting management decisions in the field of ensuring the reliability of CTS.

The creation of intelligent decision support systems (IDSS), in the context of progress in the field of information systems and technologies, find significant application in solving complex, difficult to formalize problems, in particular, diagnosing the reliability of CTS. Distinctive features of problems that are difficult to formalize are the incomplete amount of initial data of the problem being solved, inaccuracy, heterogeneity, and significant computational complexity [9,10].

The purpose of the study is to ensure the reliability of CTS elements and components during operation based on the use of an intelligent decision support system for assessing their technical condition.

The objectives of the study are to develop a IDSS with insufficient information for assessing the technical characteristics of complex systems.

Analysis of the operating principle of the IDSS. Intelligent assessment of TC is a process that includes monitoring, diagnostics and, as a result, evaluation of the vehicle while simultaneously working with knowledge and large amounts of information.

This problem can be solved by using an expert decision support system. Decision support system is a computer system that allows the user to solve professional problems based on the use of databases, knowledge and models, by providing conclusions, recommendations, and assessments of possible alternative solutions to the problem. That is, IDSS helps the user solve a complex problem automatically [11].

In general, IDSS are information expert systems. Expert systems used to assess the reliability of CTS elements and assemblies are recommended to be built on the basis of artificial intelligence. This will make it possible to make management decisions in an automated mode, taking into account the specific tasks of monitoring and diagnosing the CTS.

The implementation of the IDSS should be based on the use of research results on the model of a specific operating CTS [5].

Previously developed mathematical models used to determine and evaluate the reliability indicators of CTS elements and assemblies, using the example of ship systems, were developed and presented in [5].

They make it possible to determine the probabilities and risks of failure of CTS elements and assemblies. Similar models can be used in the development of IDSS to assess the technical condition of complex systems.

Such systems solve problems: choosing the best solution from many possible ones - optimization; ordering possible solutions according to preferences - ranking. In both problems, the first and most fundamental point is the selection of a set of criteria on the basis of which alternative solutions are evaluated and compared.

Main part. A IDSS is proposed to evaluate the CTS TC. In such a system, in contrast to classical artificial intelligence systems, the theory of decision making is applied instead of attempts to “take into account uncertainty” using production rules of the form “IF.

For the practical implementation and operation of IDSS, it is necessary to link the developed models to an expert system containing calculated, experimental, and also data acquired by experts during the operation of the CTS. The block diagram of the developed IDSS (DSS, knowledge base) for assessing the technical condition of the CTS is shown in Fig. 1.

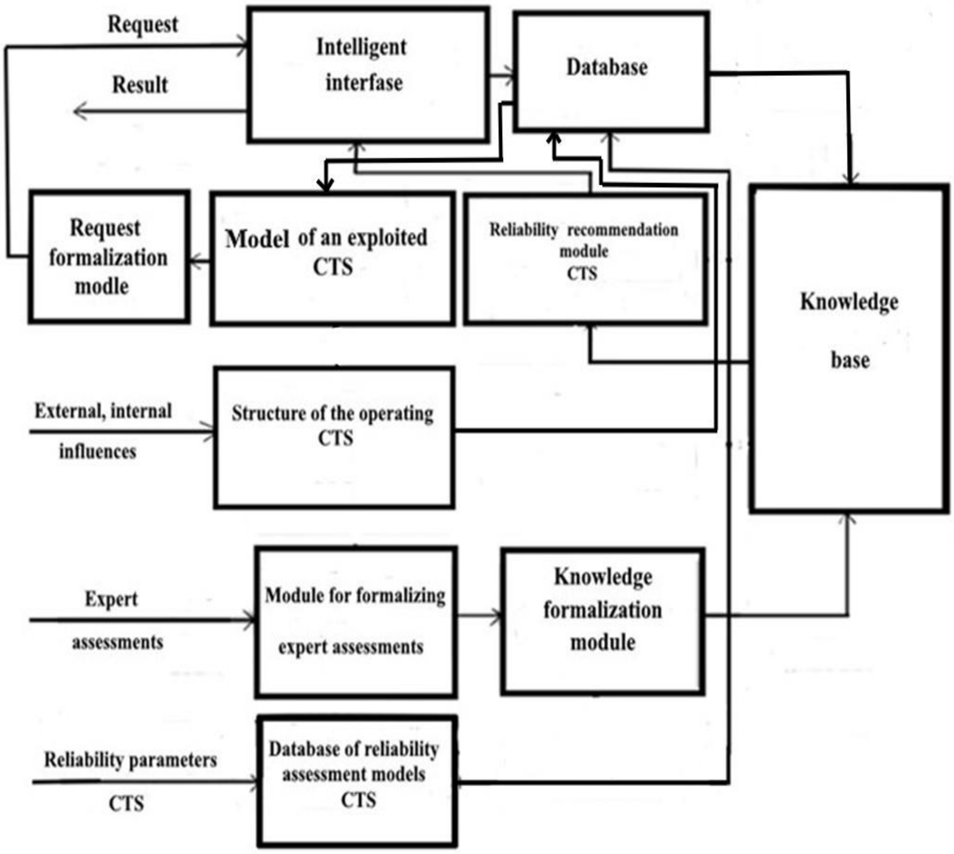

Fig.1. Block diagram of knowledge base, DSS for assessing the technical condition of CTS

When developing a IDSS, a ship's CTS, or more precisely a ship's power plant (SPP), was chosen as the object for assessing the reliability of the technical condition. Such a system is one of the main CTS out of almost hundreds of technical systems installed on the ship. Assessing the reliability of the SPP needs to take into account the fact that the CTS is characterized by a large number of diagnosed parameters that differ in information content and degree of accessibility, as well as specific and varied operating conditions. In addition, the CTS is characterized by insufficient information about its technical condition.

The functioning of the developed DSS is based on an assessment of the risk of failure of elements and components of the CTS. Those. on criteria that reflect taking into account the specifics of the interaction of various elements and components, the correlation of changes in the values of their parameters under various emergency operating conditions of a complex system.

The developed IDSS (Fig. 1) evaluates the reliability of the system using a unified system of parameters of the elements and components of the control system.

IDSS cores are: database; a knowledge base with methods for calculating reliability indicators (probabilities and risks of failures) and a set of decision rules for selecting appropriate decision-making methods; intellectualization model for assessing the technical condition of CTS elements and components.

The basis for constructing an IDSS is the formulation of the decision-making problem in general form:

$$N = f(F, G, A, FR, SG, P, C, PC, NS),$$

where F– many failures of elements and components of the CTS;

G – many set goals (to ensure the reliability of the CTS);

A – many possible alternatives;

FR - multiple failure levels of elements and components of the CTS;

SG, P, C – set of characteristics, preferences, criteria for ensuring the reliability of elements and components of the CTS;

PC - many principles for coordinating the assessment of alternatives based on individual criteria; NS– necessary solution to the problem

Preference F – assessment of the usefulness of the method of achieving the goal. The assessment is specified without highlighting the characteristics by which it is made or the characteristics SG. The characteristics include the degree of achievement of the goal. To make the final choice of how to achieve the goal, it is necessary to formulate criteria C, the number of which is determined by the number of features. If multiple criteria are used in the IDSS, then it is necessary to apply the principles of PC coordination to agree on the assessment of alternatives for each criterion.

To support decision-making on assessments of the risk of CTS failures based on a priori and a posteriori data, as well as when searching for failed elements and system components in order to increase the efficiency of their operation, a method based on dynamic Bayesian trust networks (DBTN) is used [12,13]. The use of DBTN makes it possible to determine with great accuracy the elements and components of the CTS that are closest to the critical state and their failure.

The task is solved by using a constant system of polling all elements of the system at its various levels for a specific period of time. This allows, with the help of DBTN, to study extreme situations and accurately determine the critical values of the risk of failure of elements and components of the CTS.

The construction and study of the DBTN probability of loss of performance, assessment of the risk of failure of elements and components of the CTS was carried out using the GiNIe software product [14]. The decision support strategy used when searching for failures of elements and components of ship CTS consists of a number of stages (Fig. 2).

The implementation of the strategy in the IDSS scheme for assessing the technical condition of the CTS (Fig. 1) is ensured by targeted actions in accordance with the IDSS algorithm (Fig. 3) when searching for failures of elements and components based on assessments of the risk of failure of the diagnosed CTS.

At the initial stage, the numerical values of preliminary assessments of failures of elements and components of the CTS are determined using a diagnostic model based on DBTN. The input variables for the Bayesian diagnostic model are test results.

The model of the operating CTS in the intelligent system for assessing the risk of failure of system components (Fig. 1) in the form of DBTN can be written [5]:

$$< M, S, R, L >,$$

where M - is the set of elements. components;

S - many interelement, intercomponent connections;

R - many diagnostic assessments of the risk of failure of elements, components, interelement, intercomponent connections;

L - display of connections between the sets M, S and R, based on the diagnostic model of the CTS.

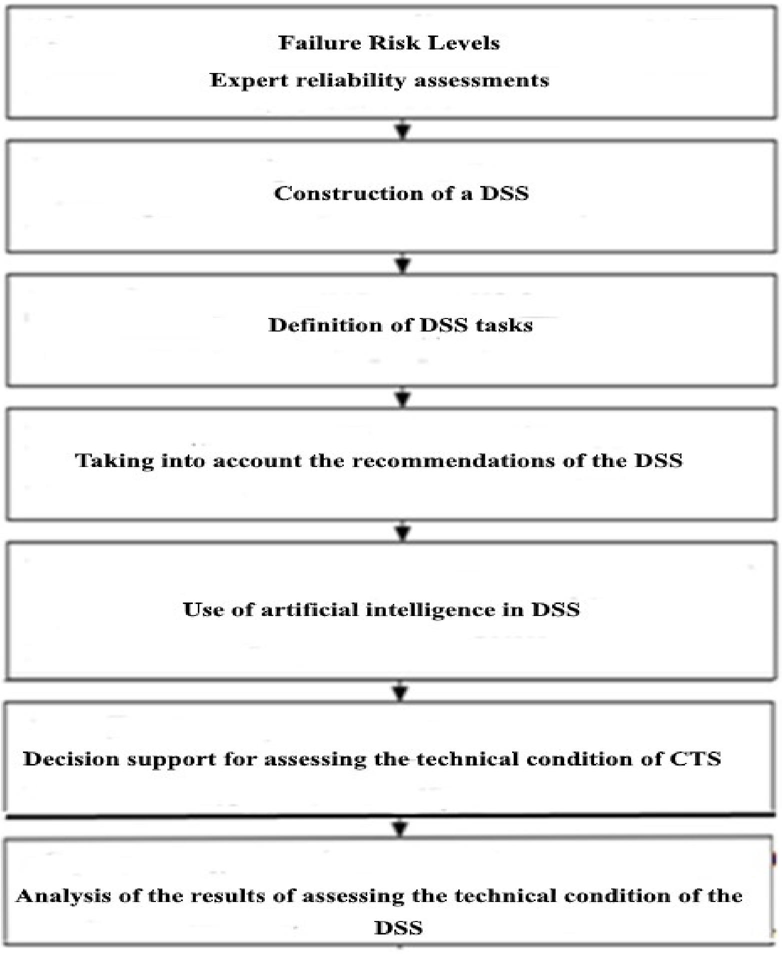

Fig. 2. Strategy for decision support when searching for failures in CTS

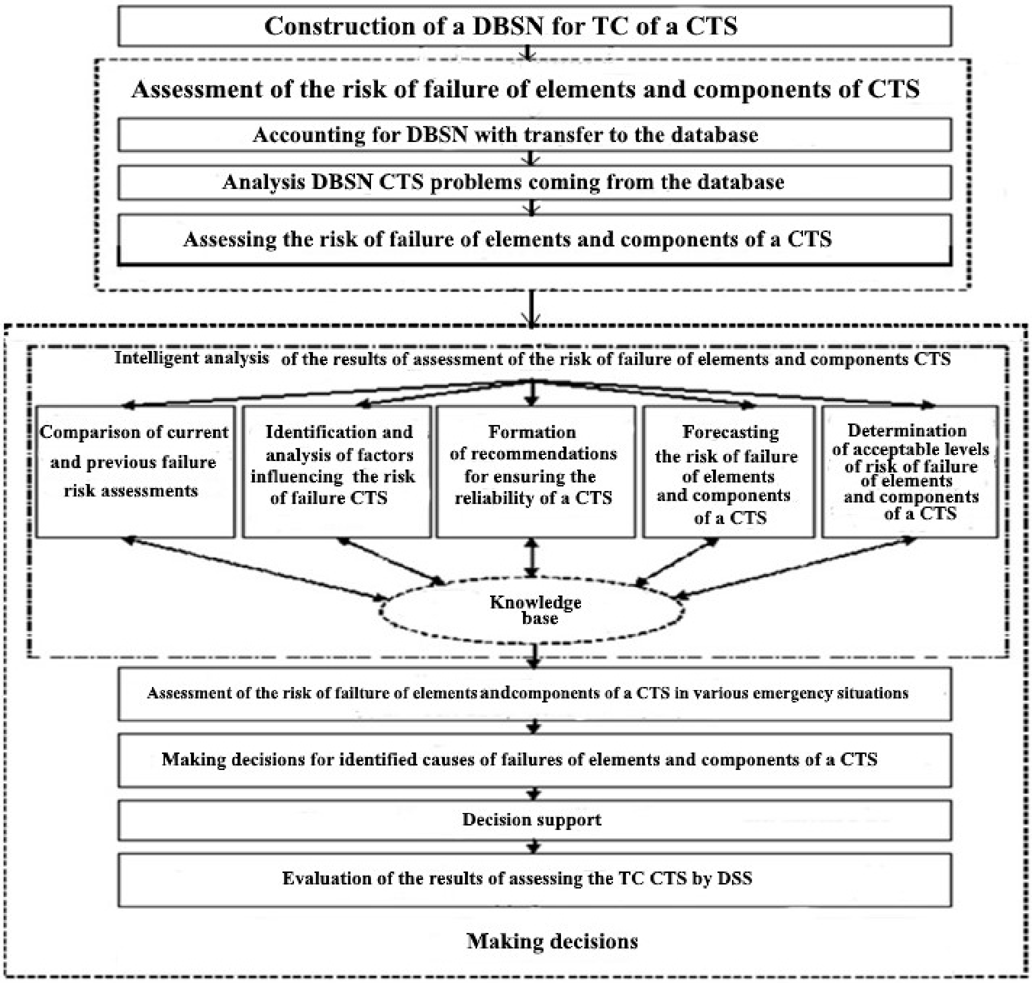

Fig. 3. IDSS algorithm when searching for failures of ship CTS

As a result of the functioning of the intelligent IDSS for vehicle assessment (using the example of a ship's CTS) in accordance with the algorithm shown in Fig. 3, using the SPP model in an intelligent system (Fig. 1) and DBTN , the dependences of the risk of failure are determined for different samples of failure probabilities of elements and components of systems serving the SPP (Fig. 4, Fig. 5)

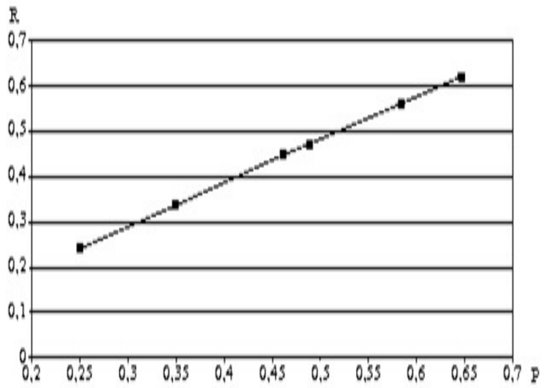

Fig. 4. Dependence of the risk of system failure on the probability of failure of elements of the SPP oil system

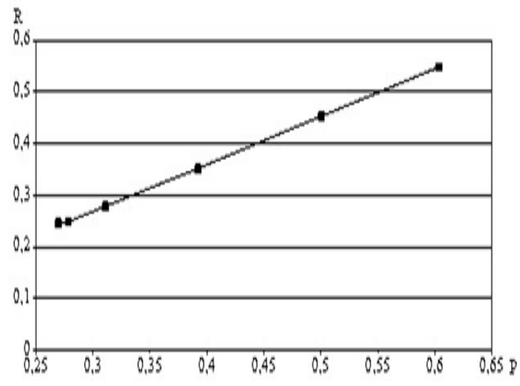

Fig. 5. Dependence of the risk of system failure on the probability of failure of elements of the SPP compressed air system

The problem-oriented knowledge base model is based on the following lists:

• elements. components affecting the trouble-free operation of the CTS;

• states in which the CTS may be in the process of failure-free operation of elements and system components;

• factors under the influence of which the current reliability of the CTS may change, systems transition to a state of failure with disruption of reliable operation;

• problem states into which the CTS can go under the influence of failures of elements and components.

The knowledge base can be presented in the form of a five-level hierarchical tree (Fig. 6).

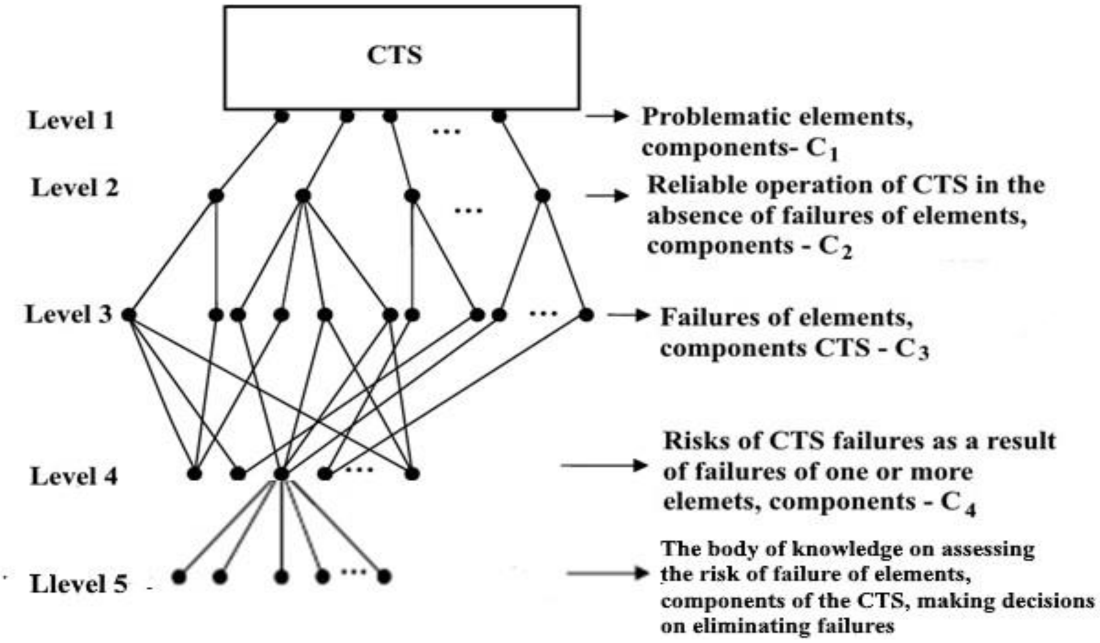

Fig. 6. Multi-level hierarchical structure of the knowledge base tree

Taking into account the hierarchical structure of the knowledge base allows you to quickly localize the cause of a defect or failure and reduce the time for diagnosing CTS.

The acquisition and addition of knowledge is carried out automatically during training and implementation of the expert system. Filling with knowledge is provided by an expert, as well as by adapting the knowledge base to changes in the subject area and the conditions of its functioning. This is implemented by replacing rules or information in the knowledge base of the IDSS.

Conclusions. The proposed decision support system contains: a knowledge base with methods for calculating reliability indicators (probabilities and risk of failures); results of determining the probabilities and risk of failures of elements and components of complex technical systems; intellectualization model for assessing the technical condition of elements and components. The proposed algorithm for the functioning of a decision support system implements the task of automating the process of assessing the technical condition of complex systems. The use of an intelligent decision support system for assessing the technical condition of complex systems makes it possible to establish the degree of risk of failure of elements and components of the CTS, which increases the efficiency of the systems. The use of the proposed decision support system for assessing the technical condition of complex systems will improve the reliability of operating systems with insufficient information about their technical condition.

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ІНТЕЛЕКТУАЛЬНА СИСТЕМА ПІДТРИМКИ ПРИЙНЯТТЯ РІШЕНЬ ДЛЯ ОЦІНКИ ТЕХНІЧНОГО СТАНУ СКЛАДНИХ СИСТЕМ

О.В. Вичужанін

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

Актуальність теми обумовлена необхідністю прийняття рішень щодо забезпечення надійності елементів і вузлів складних технічних систем при недостатній інформації про їх технічний стан. Проблема, що розв'язується, є напівструктурною та міждисциплінарною. Ефективність вирішення проблеми полягає у використанні інформаційних технологій та методів штучного інтелекту, зокрема експертних систем. Розглянуто переваги використання інформаційних технологій для автоматизації процесу прийняття рішень щодо оцінки поточного технічного стану складних систем. Розроблено інтелектуальну систему підтримки прийняття рішень, яка дозволяє оцінювати ризик відмови елементів і компонентів складних технічних систем з використанням елементів штучного інтелекту. Пропонована система підтримки прийняття рішень містить: базу даних; база знань з методами розрахунку показників надійності (ймовірності та ризиків відмов) і набір правил прийняття рішень для вибору відповідних методів прийняття рішень; результати визначення ймовірностей і ризиків відмов елементів і вузлів складних технічних систем з їх ранжуванням; модель інтелектуалізації для оцінки технічного стану елементів і вузлів. Запропонований алгоритм функціонування системи підтримки прийняття рішень реалізує завдання автоматизації процесу оцінки технічного стану складних систем. Використання запропонованої системи підтримки прийняття рішень для оцінки технічного стану складних систем дозволить підвищити надійність технічних систем з недостатньою інформацією про їх технічний стан.

Ключові слова: інформаційні технології, алгоритм, складні технічні системи, підтримка прийняття рішень, інтелектуальні системи, штучний інтелект, експертні системи, база знань, база даних, алгоритм, складні технічні системи, надійність, ризик відмови, судова енергетична установка