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USING MODEL-ORIENTED DECISION-MAKING SUPPORT SYSTEM FOR THE IMPROVEMENT OF SAFE OPERATION OF A SHIP ELECTRIC POWER INSTALLATION

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Abstract: A model-based decision support system is proposed to increase the reliability of the ship electric power installation. This system consists of a simulation unit and an evaluation unit for modeling results using a fuzzy inference system. The developed system can be implemented as a part of control systems, either on the basis of programmable logic controllers, or on the basis of a separate programmable logic controller. The criteria used to evaluate the results of modeling and possible consequences are considered. A computer program for the implementation of this system is presented. The results of modeling various emergency situations are given. The possibility of using this system for training is considered.

Key words: decision support system, reliability, ship electric power installation.

1. Introduction

Modern electric power plants become complex multi-dimensional objects under the modern economical and technical conditions, when requirements for economic efficiency and environmental protection are growing. The number of maintenance staff is reduced. The concept of a virtual watch engineer is being actively developed and partially implemented. It is assumed that the vessel will operate as remotely controlled with a gradual transition to full autonomy.

It is planned to provide two sets of algorithms - for fully independent functioning and for working under the control of a dispatcher [1].

The difficulty of providing the vessel with high-quality electricity is also explained by the presence of a large number of energy sources whose simultaneous work should be carefully coordinated.

As it is known, a multi-generator system consisting of diesel generating sets is a poorly stable system, and large amplitudes and slowly damping fluctuations of voltage and frequency occur in it [2].

Due to the limited capacity of the generating units, when switching in the mains between powerful ship consumers, generators lose synchronisation and it can cause the blackout of the vessel.

2. Stating the Research Problem

The phenomenon of unstable operation and power exchange fluctuations of parallel-running synchronous generators have been investigated in many scientific publications and noted by fleet operation services [2, 3].

The problem of a long parallel operation of a shaft generator with diesel generators in marine power installation remains partially solved.

The «Siemens» company built a consistent digital ideology which includes a description of the fundamental stages of the introduction of digital technologies and contains appropriate tools for the digitization of power plants. They include, for example:

– digital model of the power system created on the basis of a software package "PSS®SINCAL";

– cloud platform "MindSphere", designed for processing large amounts of data on the states of a power facility, which allows solving complex analytical tasks and predicting system behavior taking into account various factors;

– creating and maintaining a unified information structure describing the whole variety of power equipment based on the classifier in accordance with the standard CIM to simplify the exchange of data between different processes, applications and tasks of the digital complex.

Also, computer programs are introduced to predict possible emergencies.

3. Main Part

To increase the reliability of the marine electric power installation, the authors have developed a program "SGE" that allows the assessment of the operator's current actions and the state of the power installation using a fuzzy logic decision support system. The program also contains a modelling unit that allows the prediction of the possible modes of operation and then evaluate the results using a fuzzy output block.

Simplified functional scheme of model-oriented decision making system in composition with electric power plant control system is presented in Fig. 1.

The computer program "SGE", developed by the authors, allows the simulation of the following operation modes of the marine electric power installation:

1. work of a synchronous diesel generator without load;

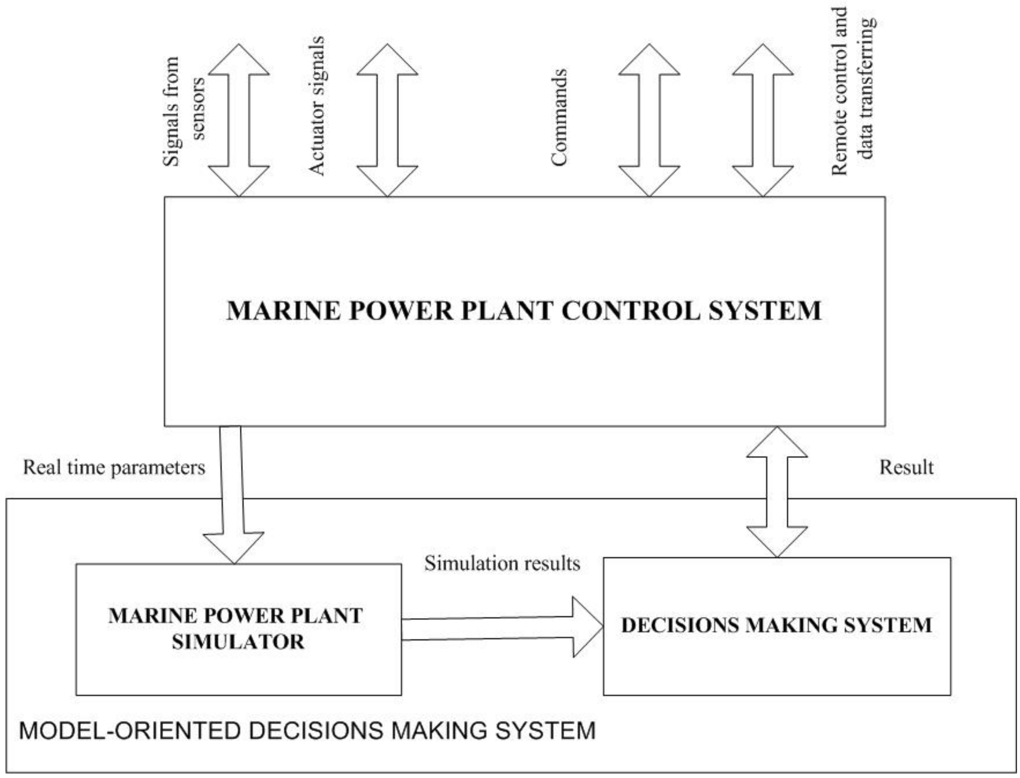

Fig. 1. Simplified functional diagram of a model-oriented decision-making system.

The main window of SGE program is presented in Fig. 2.

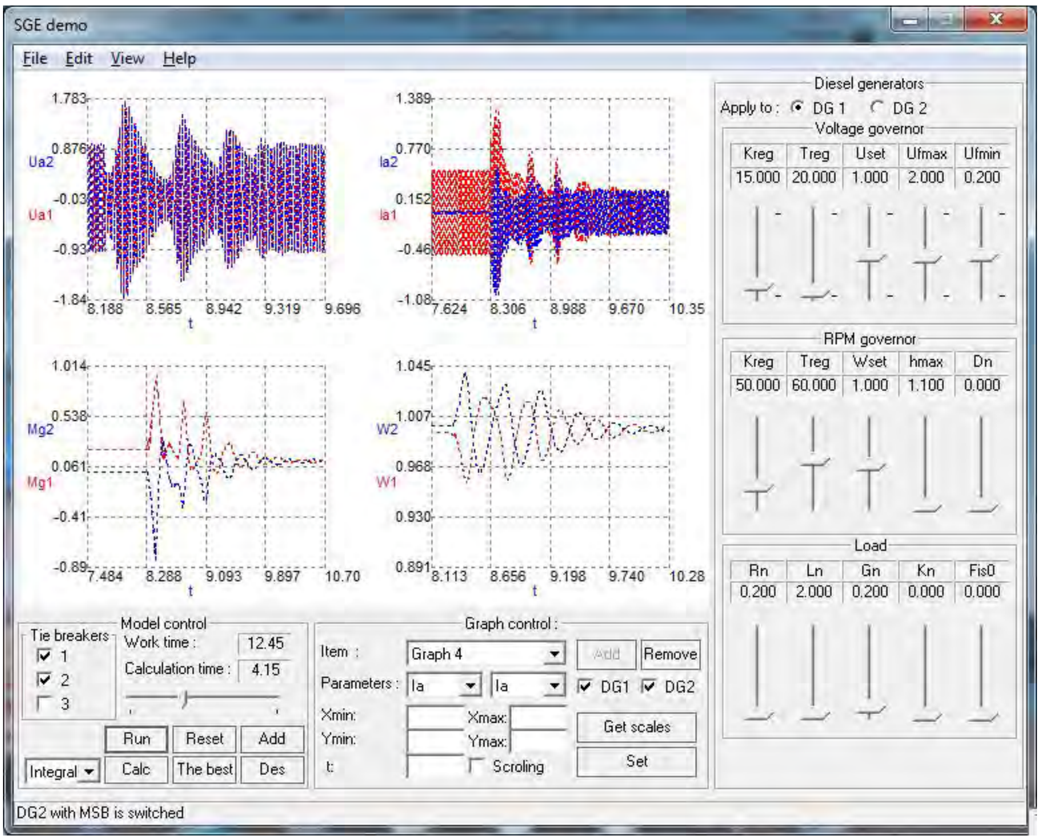

Fig. 2. Model-oriented decision-making system: main window.

2. work of a synchronous diesel generator with active or active-inductive load;

3. work of a synchronous diesel generator with coastal network;

4. parallel operation of two synchronous diesel generators with active or active-inductive load;

5. parallel operation of two synchronous diesel generators with the coastal network.

This program is an improved version of the program presented in the previous article [6].

The mathematical model of the synchronous generator based on equations from literary sources is applied in the program [2, 4, 5, 7].

Mathematical models of elements that have passed the adequacy test were chosen from the works [4, 5] of famous scientists and implemented in a computer program.

Having been based on the requirements for protection systems and emergency alarm systems, a fuzzy logic decision-making block was made [9].

As linguistic variables, phase current, phase voltage, regulation time and integral quality criterion were chosen [8].

Decision making surfaces for phase voltage, phase current and regulation time are presented in Fig. 3 and Fig. 4.

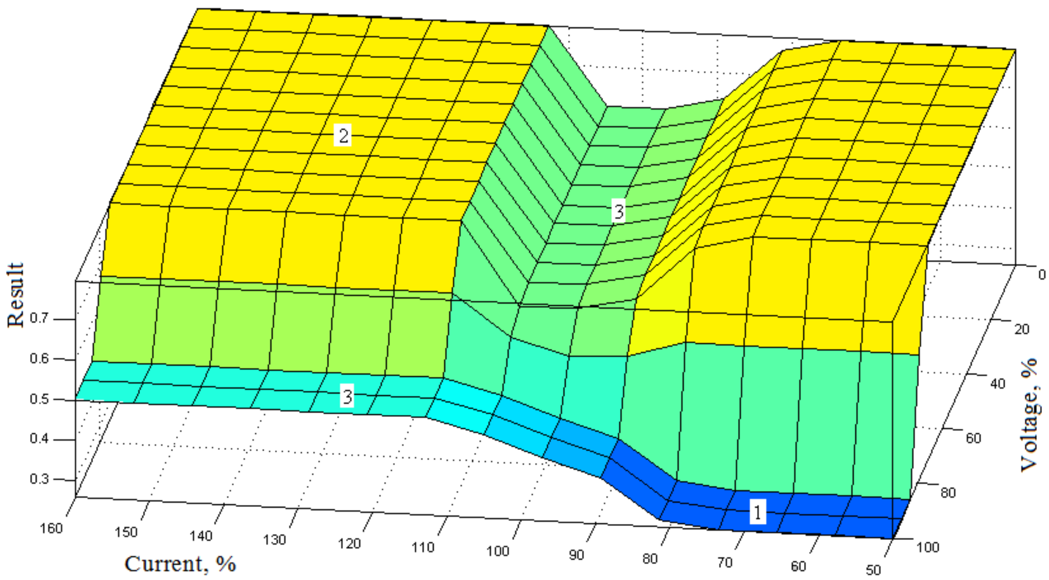

Fig. 3. Decision-making surface for phase voltage and phase current.

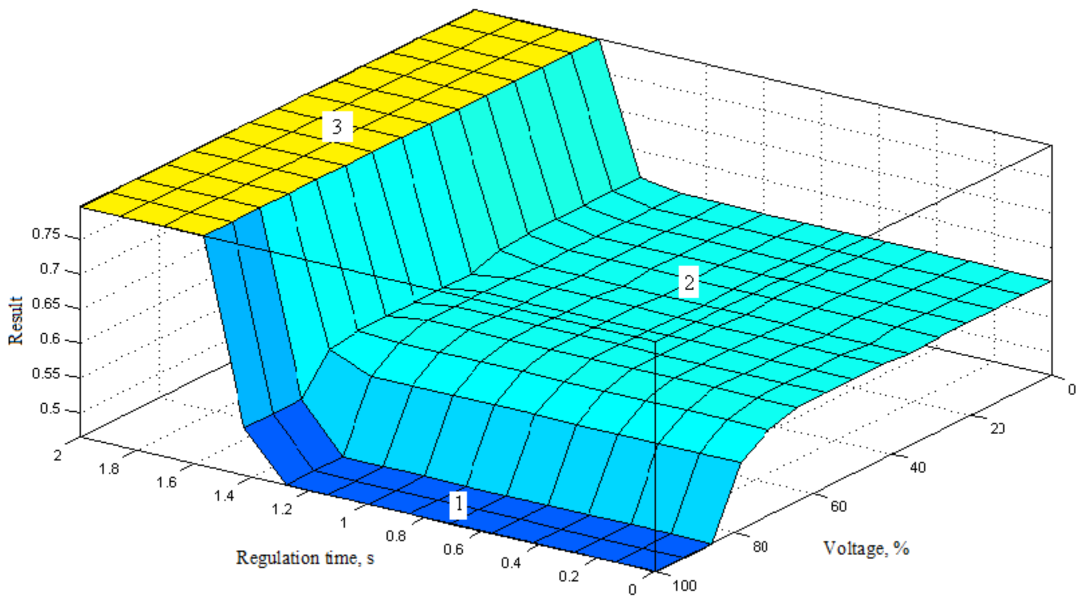

Fig. 4. Decision-making surface for phase voltage and regulation time.

In Fig. 3, the part of the surface marked with 1 (voltage from 85 to 100 % of nominal, transient time from 0 to 1.5 s) corresponds to the failure-free operation of the generators, the part marked with 2 corresponds to the emergency voltage mode (voltage protection is on), the part marked with 3 corresponds to emergency mode by two parameters at the same time.

In Fig. 4, the part of the surface marked with 1 (voltage from 85 to 100 % of nominal, current to 80 % of nominal) corresponds to failure-free operation of generators, a part marked with 3 corresponds to the emergency mode by voltage and current (voltage or current protection operates), a part marked with 2 corresponds to emergency mode by two parameters at the same time.

This system uses Mamdani decision-making algorithm.

For the demonstration of the work of the developed system, various modes of operation will be considered.

If diesel generators normally work in parallel, values of phase current, voltage and regulation time do not correspond to the values of protection settings, as it can be seen from Fig. 5.

Graphs of transients on the generator for phase current, excitation voltage, rotation frequency and generator phase voltage are shown in Fig. 5. The generator works according to the "star-star" scheme with an isolated neutral. Load is symmetrical.

The value of the output linguistic variable after defuzzification is 0.2 (the actual insensitivity of the regulator was not taken into account when the time of the transition process was estimating).

When diesel generators are turned on in parallel operation with an increase in the insensitivity of one of the speed regulators, as it is shown in Fig.6, the values of the phase current and voltage do not correspond to the values of the protection settings, but the time of the transient process is not determined, and the values of the result of the evaluation of the transient process are unsatisfactory. The value of the output linguistic variable after defuzzification is 0.85.

Next we investigate the mode of the system in case of equipment malfunction due to insulation breakdowns and short circuits.

To study this mode, we simulated the connection of the generator to the main switchboard buses and, after the end of the transition process, modeled a sudden change in load due to a short circuit or a sharp decrease in the resistance of the consumer.

A similar effect of a sharp increase in the current of the consumer can occur after insulation breakdown.

As it is shown in Fig. 6, overcurrent corresponds to the setting of the residual current device.

The value of the output linguistic variable after defuzzification is 0.75.

Next, the mode of the system in the short circuit of the excitation winding is investigated.

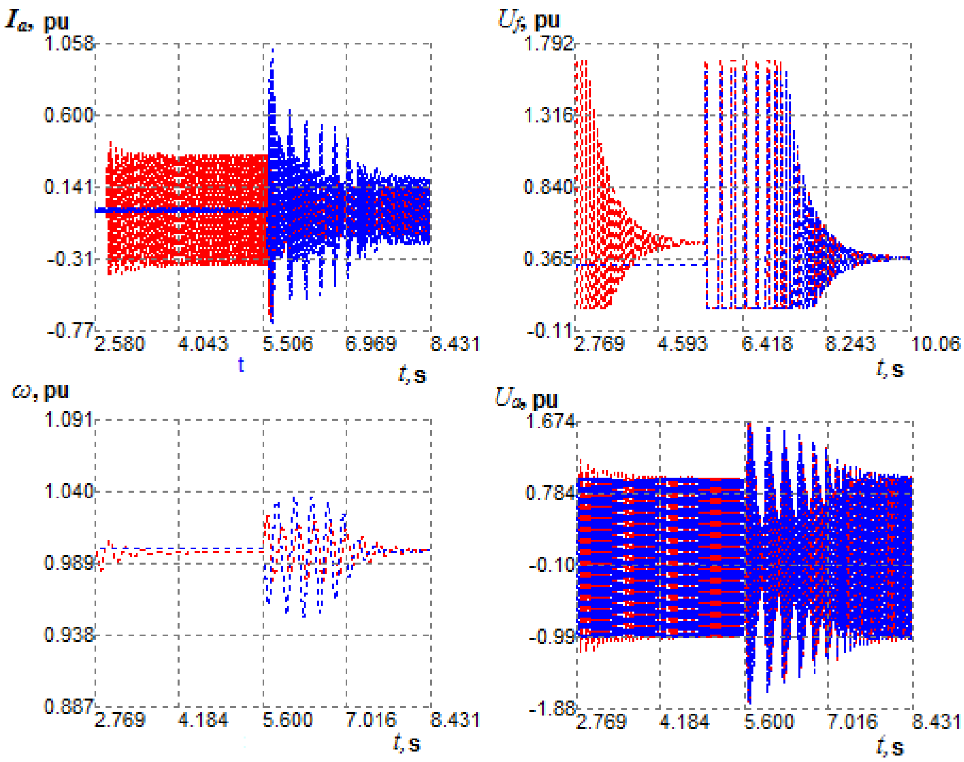

Fig. 5. Normal switching to parallel work.

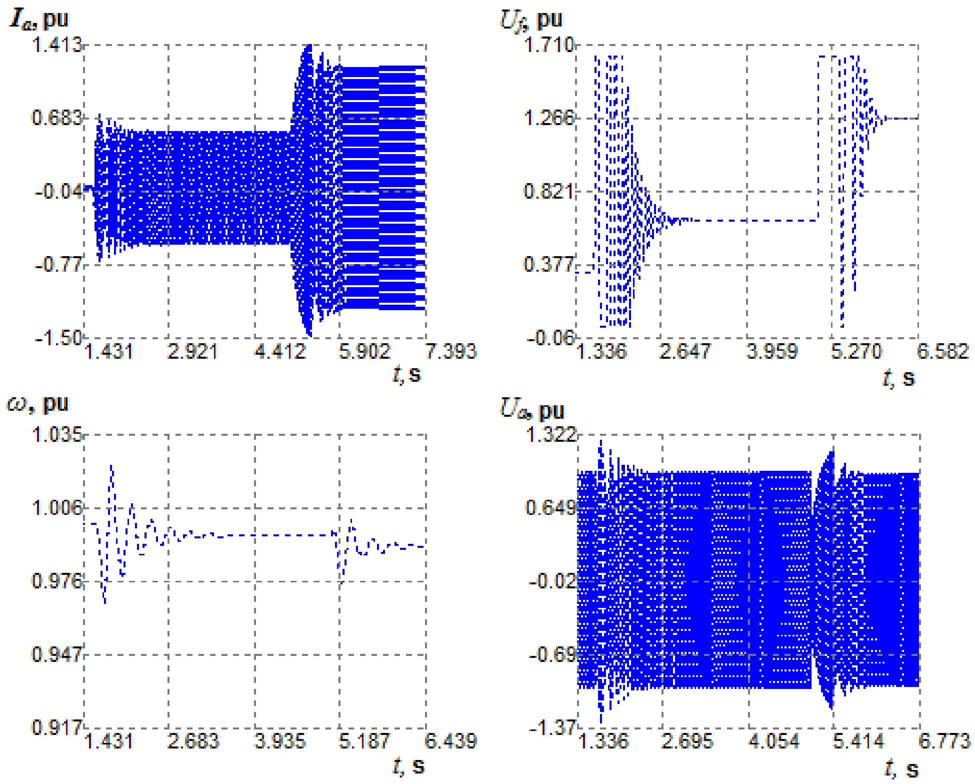

Fig. 6. Diesel generators working in parallel with an increase in the insensitivity of one of the speed regulators.

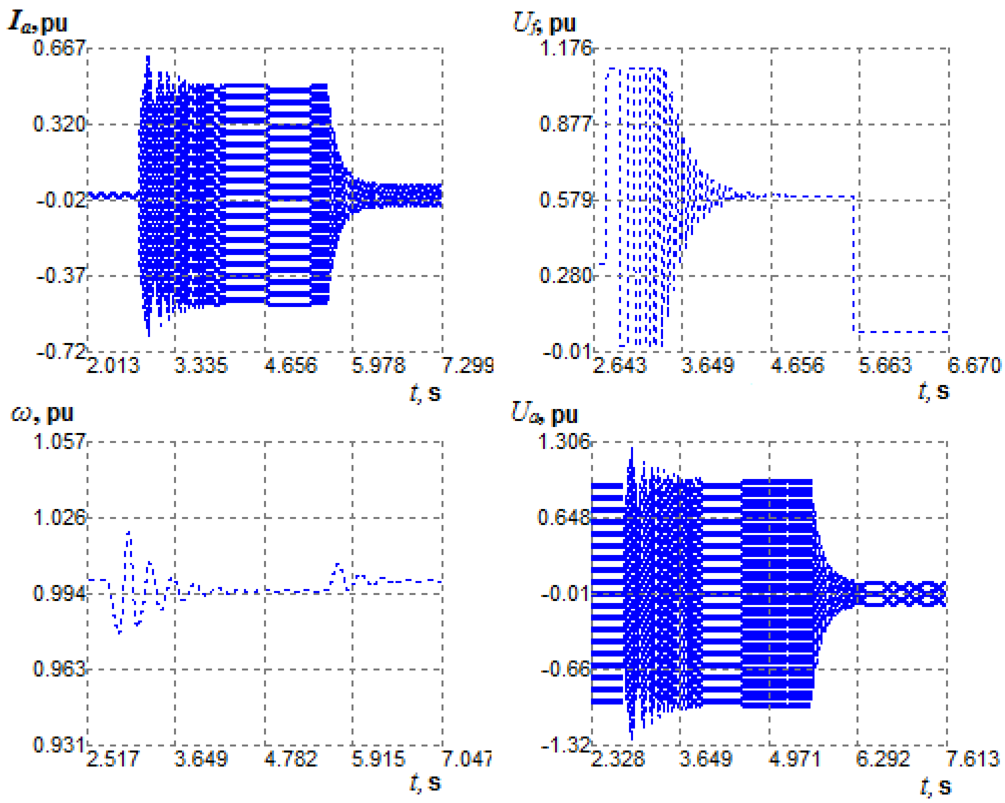

Fig. 7. Simulation of the connection of the generator to the main switchboard buses was made, and after the end of the transition process.

To study this mode, a simulation of the connection of the generator to the main switchboard buses was made, and after the end of the transition process, a malfunction was simulated after a short period of time.

During a short circuit of the excitation winding, a sudden drop in the excitation occurs, and as a result, the voltage drop across the stator windings.

If this malfunction occurs in the case of parallel operation of diesel generator sets, blackouts and other serious consequences for driving diesel engines are possible.

To protect the ship electrical installation against emergency conditions associated with the voltage drop of one of the generating sets, protection devices against reverse power are provided. When using reverse power protection, the generating unit is disconnected from the main busbars, which protects it from the racing mode of the drive engine.

The value of the output linguistic variable after defuzzification is 0.72.

By modeling various operating modes of the electric power plant, changing the settings of the regulators and exploring transients, the user improves his skills as he improves the understanding of the processes occurring in the electric power installation and can predict possible emergency operating conditions and modes that are not desirable for the operation of equipment included in the electric power installation.

Thus, the program allows trainees to simulate processes and explore transients of the electric power installation. It can be used for training and professional development of service personnel, taking into account the peculiarities of the electric power installations. The quality assessment unit allows the determination of the simulation result and the possibility of an emergency.

4. Conclusions

In modern control systems of electric power installations, the prediction of system behaviour using mathematical models is getting to be actively used.

This approach allows the prevention of unexpected emergencies before they appear in a real electric power installation.

Large manufacturers of equipment for control systems and control systems partially implement this approach.

This article describes a computer program developed by the authors, which contains a mathematical model of the marine electric power installation and a fuzzy logic-based decision-making system unit.

The results of the simulation of various operation modes of the ship electric power installation are presented.

An assessment was made of the simulation results based on the requirements of regulatory documents.

The possibility of using the developed program for staff training was considered.

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ВИКОРИСТАННЯ МОДЕЛЬНО-ОРІЄНТОВАНОЇ СИСТЕМИ ПРИЙНЯТТЯ РІШЕНЬ ДЛЯ ПІДВИЩЕННЯ БЕЗАВАРІЙНОСТІ СУДНОВОЇ ЕЛЕКТРОЕНЕРГЕТИЧНОЇ УСТАНОВКИ

Леонід Вишневський, Ігор Войтецький, Таїсія Войтецька

Запропоновано модельно-орієнтовану систему підтримки прийняття рішень для підвищення безаварійності суднової електроенергетичної установки. Ця система складається з моделюючого блока та блока оцінки результатів моделювання за допомогою системи нечіткого висновку. Розроблена система може бути реалізована в складі систем управління, і на базі програмованих логічних контролерів, і на базі

окремого програмованого логічного контролера. Розглянуто використовувані критерії оцінки результатів моделювання і можливі наслідки. Розроблено комп'ютерну програму для реалізації цієї системи. Наведені результати моделювання різних аварійних ситуацій. Розглянуто можливості використання цієї системи для навчання.

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