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THE CONCEPTION OF DECISION-MAKING SUPPORT SYSTEM FOR COMPLEX ENERGETIC SYSTEM ON EXAMPLE OF SHIP PROPULSION SYSTEM

Jacek Rudnicki

Gdansk University of Technology
ul. Narutowicza 11/12, 80-233 Gdańsk, Poland
tel.: +48 58 3472973, fax: +48 58 3471981
e-mail:jacekrud@pg.gda.pl

Abstract

In paper, the conception of decision-making support system for complex energetic system on example of ship propulsion system has been presented. Diversity of conditions, information overload and very often contradiction of decision-making criteria and time constraints result in difficulties in making right (rational) decision without using more or less expanded information processing systems (eg. database systems, expert systems, programs dedicated to particular situations, etc.)

Using that systems undoubtedly increases the probability of making a good decision and efficiently decreases the time of its development. Following analysis relates to the test program implementation of exploit decision-making support system, which was developed in Department of Ship Power Plants in Gdansk University of Technology.

Keywords: *decision making, exploitation, operation, ship power plants*

1. Introduction

During exploitation of every power plant, its functional subsystems are affected by different external and internal factors, which are reasons for irreversible degradation processes, causing changes in technical state and usually gradual deterioration of its exploit characteristics. In those subsystems, damages to their components will appear inevitably.

The intense development of marine transport, increasing number of ships, enhancing marine traffic and diversity of realized tasks creates a real danger for people and natural environment.

Taking into consideration also the fact of significant complication of functional and structural ship energetic system (mostly main propulsion system), proper analysis of decision-making situation, which results directly influence ship's safety becomes particularly important problem.

Diversity of conditions, information overload and very often contradiction of decision-making criteria and time constraints result in difficulties in making right (rational) decision without using more or less expanded information processing systems (eg. database systems, expert systems, programs dedicated to particular situations, etc.)

Using that systems undoubtedly increases the probability of making a good decision and efficiently decreases the time of its development. Following analysis relates to the test program implementation of exploit decision-making support system, which was developed in Department of Ship Power Plants in Gdansk University of Technology.

2. General description of the application

The developed application, in present version, is designed to work off-line and works in interactive mode with user, requiring from him input from keyboard data essential for analysis, including:

- operative characteristics of analysed propulsion system (main engine + hull + propeller)
- conditions of task's realization
- results of exploit tests concerning reliability characteristics
- chosen values connected with reserves state and realization of preventive inspections of analysed system elements

The application consists of 4 main parts that realize analysis in sphere shown below and presents its results and possible conclusions. Its general scheme is presented in Fig. 1.

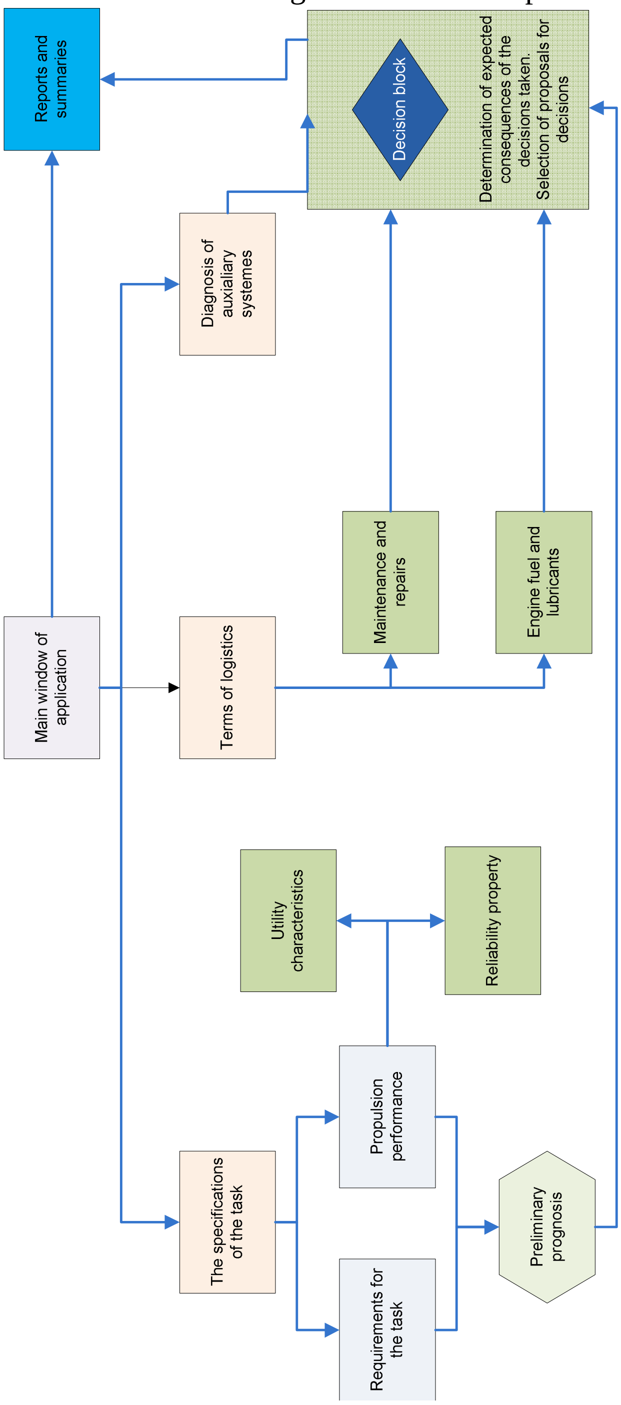


Fig.1. Block diagram of the application

First of all, the beginning of working with the application requires input the analysed system's characteristics data and specification of task realisation requirements. Realisation of those two conditions is possible by next choice of two options in programme's main window: “Entrance data input” and “Result of exploit tests”.

3. General task realisation assumptions

After choosing the “Entrance data input” option, a transition to next part of the programme approaches, in which:

- provide general transport task realisation data (distance, required realisation time),
- by choosing buttons: “Engine's characteristics”, “Propeller characteristics” and “Resistance characteristics” input the description of individual elements of propulsion system.

Example of main engine window is presented in Fig. 2.

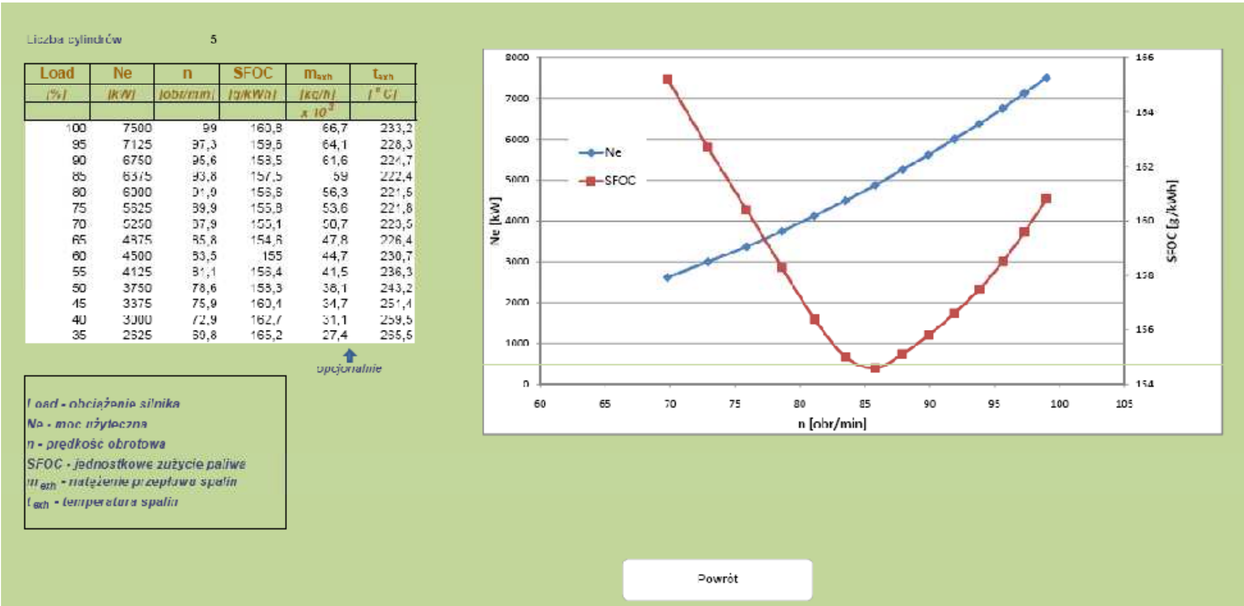


Fig.2. Description of main engine's operative characteristics.

Really expanded part of this application block is description of propeller operative characteristics. In this part were implemented algorithms of propeller hydrodynamic characteristics determination that were developed in Wageningen Institute, where pressure and moment indexes values depend on advance index value – J, jump index – H/D, surface index – S0/S, number of wings – Z and Reynolds number – Re [1]. Results of calculations are presented as it is on Fig. 3.

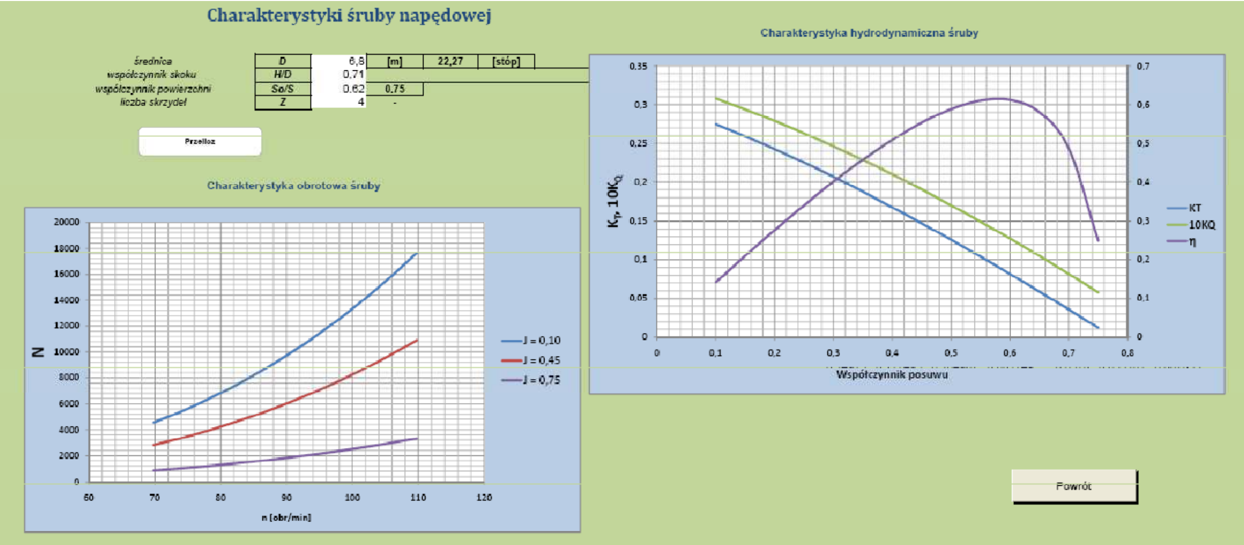


Fig. 3. Characteristics of propeller.

Input of all required data and return to data input window enables generating preliminary predictions and their explanation (Fig. 4.)

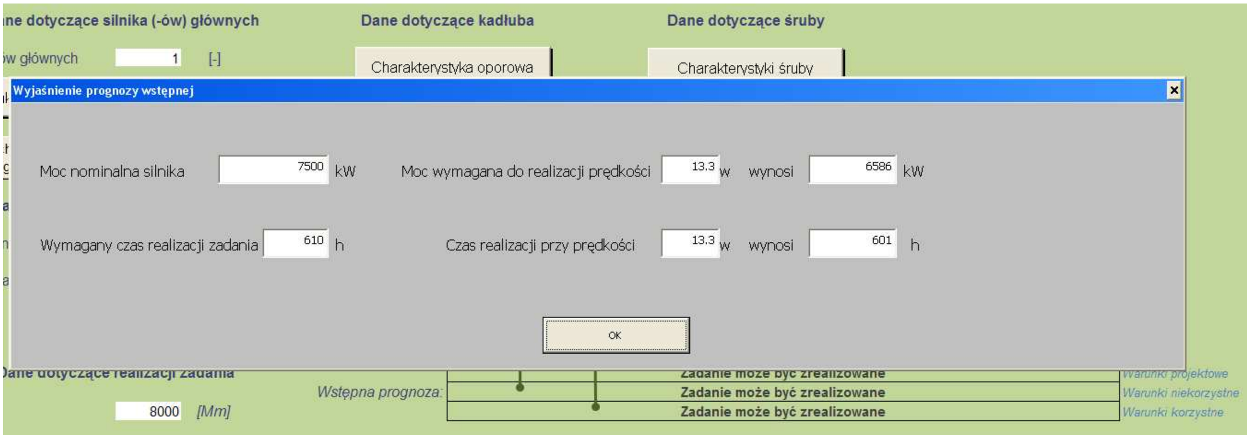


Fig. 4. Explanation of preliminary prediction

as well as presentation of optimised variants of power transmission system operation in disadvantageous, project and advantageous conditions when taking consumption of fuel during realisation of the transport task into consideration.

4. Assignation of reliability characteristics of power transmission system.

During exploitation of vessels, usage and operative for power plant devices decisions are made permanently – mainly about power transmission system. The choice of the decision, necessary for determination of right exploit strategy, is possible after taking many different information into consideration, but it will never be right choice without accounting power transmission system or its basic elements reliability data and indexes.

Amongst nowadays used reliability models of complex technical objects, we can distinguish two groups [2, 3, 5]:

- two-state models – in case of using this type of model, the process of technical state changes is binary – in particular moment the device is either serviceable or not,
- multi-state models – the process of technical state changes is constant in time and unobtrusive in states – the number of distinguished states is unrestricted.

The described application uses both groups of presented models, in order to get fuller description of analysed system reliability characteristics. The effect of that choice is window presented in Fig. 5.

Definition of reliability characteristics using classical methods of reliability theory and two-state probabilistic models.

Realisation of calculation based on conventional models is possible after choosing one of three buttons in “A” part presented in Fig. 5.

That kind of choice results is transfer to appropriate distinguished elements power transmission system sub-programmes (engine, propeller, shafting elements) considered as their serial reliability structure.

Interface managing this part of the application is presented in Fig. 6.

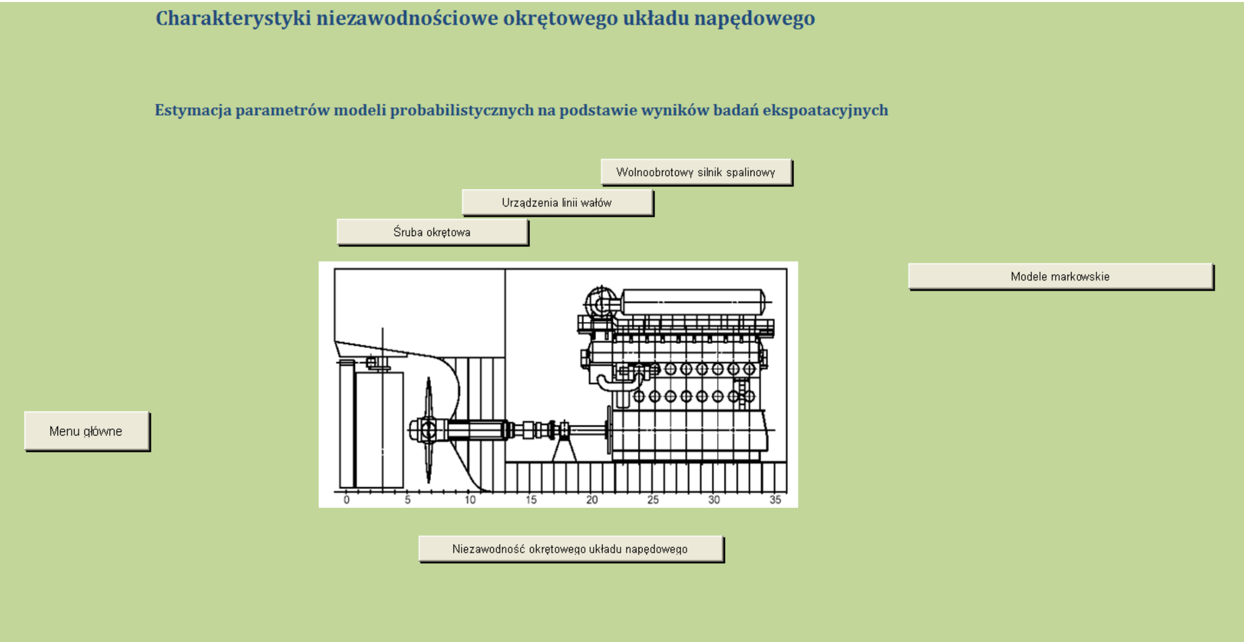


Fig.5. The choice of procedures making reliability calculations.

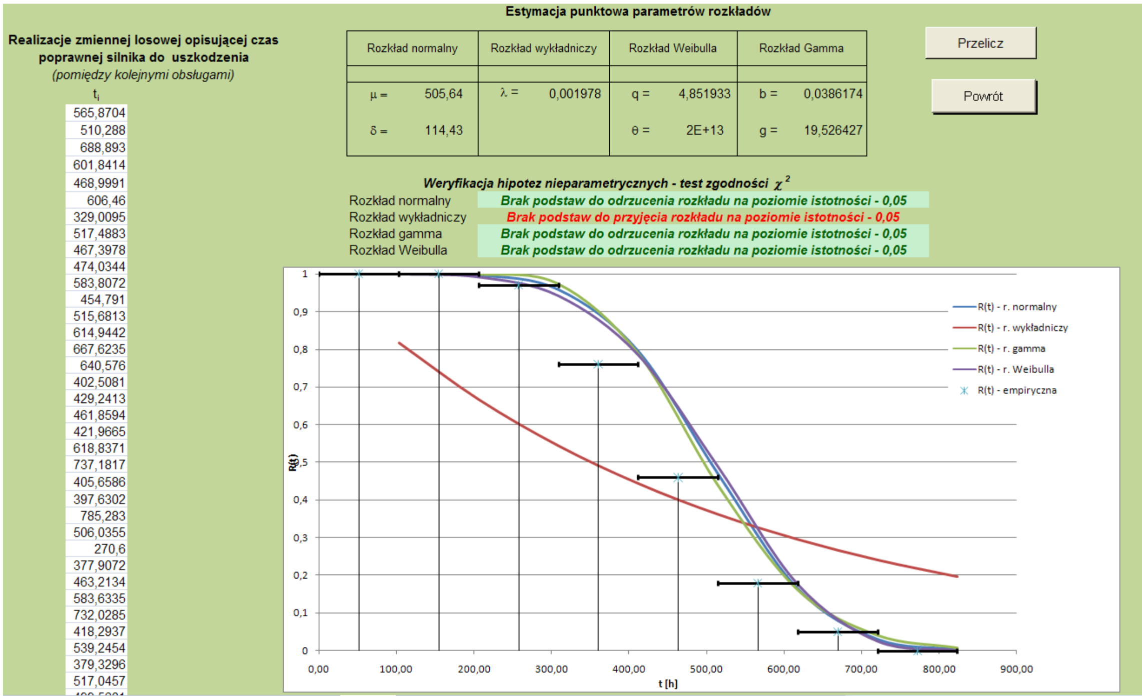


Fig.6. Interface of unit realising reliability calculations.

The algorithms implemented in this part of the programme require user to input up to 100 values of random variable realisation describing the time of main device correct functioning between subsequent main operations (in present version, it is assumed that realisation of main operation brings values of reliability functions to 1) and then the programme realises actions as follows:

- assignation of empiric reliability characteristics – presented as graphics,
- empiric distributions of particular random variables are used to check the function form of their distribution by verifying following statistical hypothesises with empiric and theoretical distributions compatibility [3].

The results of carried calculations are presented in table seen in window in that part of the application.

5. Use of Markov's processes theory in estimation of reliability indexes values

The use of stochastic processes theory in description of reliability enables giving up an bistativity assumption of technical, reliability and exploit states changes process and composing into the model a very important feature characterising mechanical machines and devices – renewal. In case of ship devices it is particularly important, because as complicated and complex technical objects they can be damaged in many ways, with different probability and consequences corresponding to their task reliability.

Reliability model are in this case stochastic processes with unobtrusive set of distinguished states and constant duration.

In researches in reliability of complicated technical objects, which power transmission systems definitely are, so far generally semi-Markov stochastic processes theory and Markov's processes have found their use.

In present version of the described application so far only Markov model has been implemented (mostly because of calculation complexity of semi-Markov model – calculation of Volterra integral equation of second type) with all its limitations [2, 3] but eventually it is planned to implement semi-Markov model as well.

In proffered functional – reliability model from the set of all possible reliability states of power transmission system, 7 classes (subsets) were distinguished, described as states s_i (i=1, 2, …, 7):

- s_1 state – the state of power transmission system's complete task ability. System in this technical state is capable of fulfilling all tasks it was designed and made for.
- s_2 state – the state of system's incomplete task ability due to partial capability of engine, which can happen eg. when:
    - it's impossible to achieve all the parameters in engine's work field;
    - all the parameters in field work are achieved, but SFOC and/or $SL_{ub}O_{il}C$ are increased.
- s_3 state – the state of system's complete inability due to complete engine's incapability, which precludes using the engine as intended.
- s_4 state – the state of system's incomplete task ability due to partial capability of shafting elements caused by eg. excessive vibration entailed by radial bearings emaciation
- s_5 state – the state of system's complete inability due to complete incapability of power transmission line.
- s_6 state – the state of system's incomplete task ability due to partial capability of propeller, eg. in case of mechanical damaging one of propeller's blades, which interferes its balance.
- s_7 state – the state of system's complete inability due to complete propeller's incapability, which precludes using the propeller as intended eg. in case of wide mechanical damage to the propeller.

The graph of states-transitions can be presented as follows:

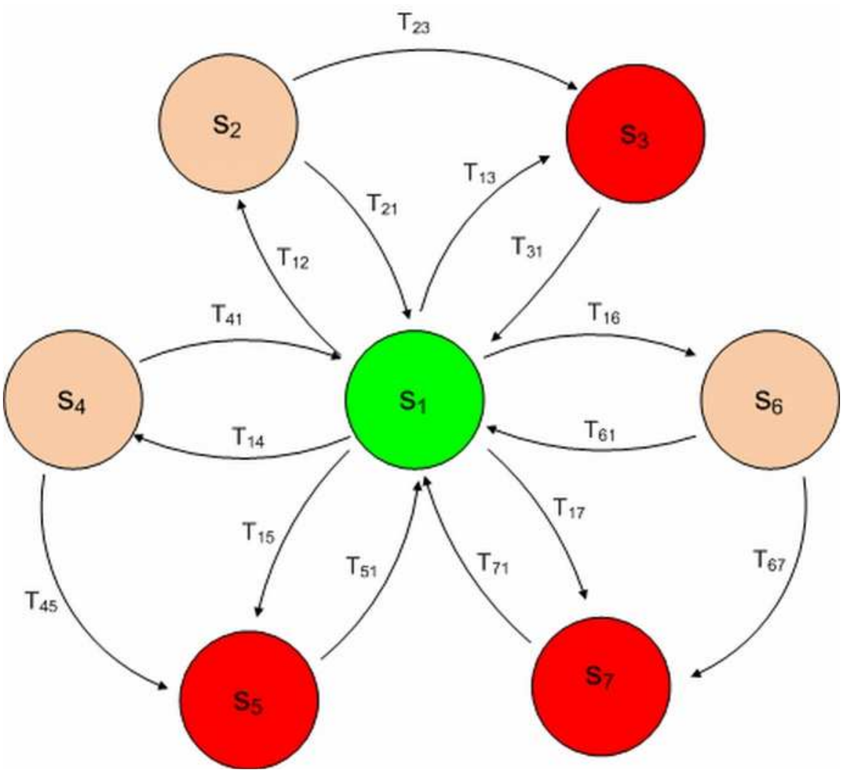
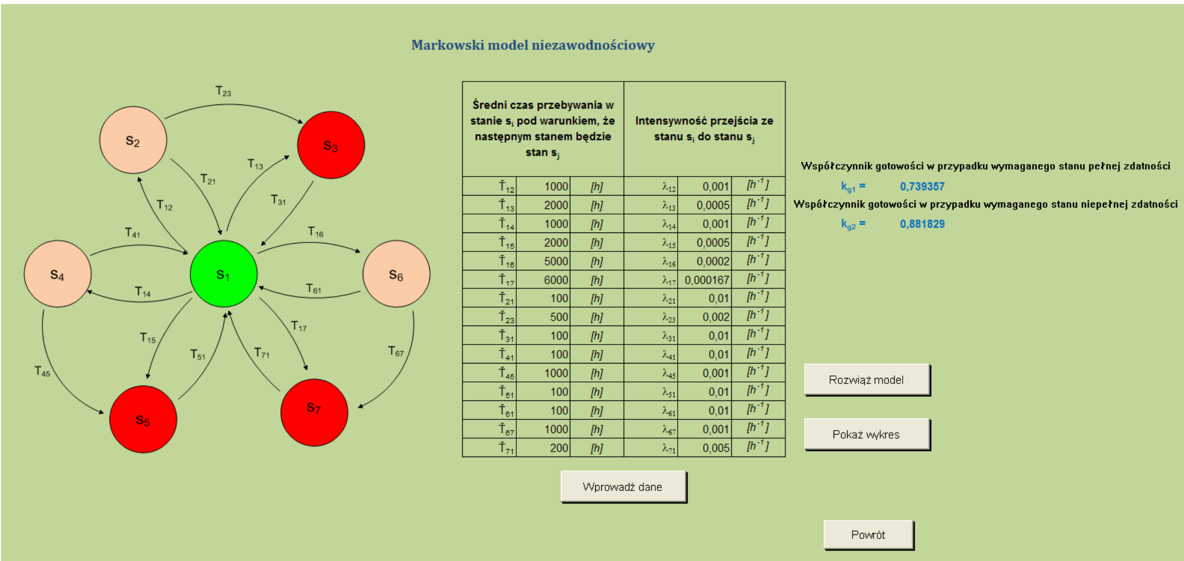


Fig.7. The graph of states-transitions of implemented Markov model.

The window of Markov model is presented in Fig.8.



Średni czas przebywania w stanie s_i pod warunkiem, że następnym stanem będzie stan s_j			Intensywność przejścia ze stanu s_i do stanu s_j		
$\check{T}_{12}$	1000	[h]	λ_{12}	0,001	$[h^{-1}]$
$\check{T}_{13}$	2000	[h]	λ_{13}	0,0005	$[h^{-1}]$
$\check{T}_{14}$	1000	[h]	λ_{14}	0,001	$[h^{-1}]$
$\check{T}_{15}$	2000	[h]	λ_{15}	0,0005	$[h^{-1}]$
$\check{T}_{16}$	5000	[h]	λ_{16}	0,0002	$[h^{-1}]$
$\check{T}_{17}$	6000	[h]	λ_{17}	0,000167	$[h^{-1}]$
$\check{T}_{21}$	100	[h]	λ_{21}	0,01	$[h^{-1}]$
$\check{T}_{23}$	500	[h]	λ_{23}	0,002	$[h^{-1}]$
$\check{T}_{31}$	100	[h]	λ_{31}	0,01	$[h^{-1}]$
$\check{T}_{41}$	100	[h]	λ_{41}	0,01	$[h^{-1}]$
$\check{T}_{45}$	1000	[h]	λ_{45}	0,001	$[h^{-1}]$
$\check{T}_{51}$	100	[h]	λ_{51}	0,01	$[h^{-1}]$
$\check{T}_{61}$	100	[h]	λ_{61}	0,01	$[h^{-1}]$
$\check{T}_{67}$	1000	[h]	λ_{67}	0,001	$[h^{-1}]$
$\check{T}_{71}$	200	[h]	λ_{71}	0,005	$[h^{-1}]$

Fig.8. Markov model's window.

The window requires input of si state average time data, provided that the next state is sj state. To enhance the clarity of input data it's done in additional form that includes proper explanations. The results of calculations are kept in the programme and presented as graphics.

6. Generation of decision-making situation solution's proffer.

Obtained in previously described parts of the application number values of particular indexes are used in exploit decision proffer generation mode. Access to this part of the application is possible from the main window level by the “Decision-making trees” reference.

The decision-making procedure is presented in one of most popular structural forms – decision-making tree.

In 1st step two decision-making tress are analysed, as shown in Fig.9.

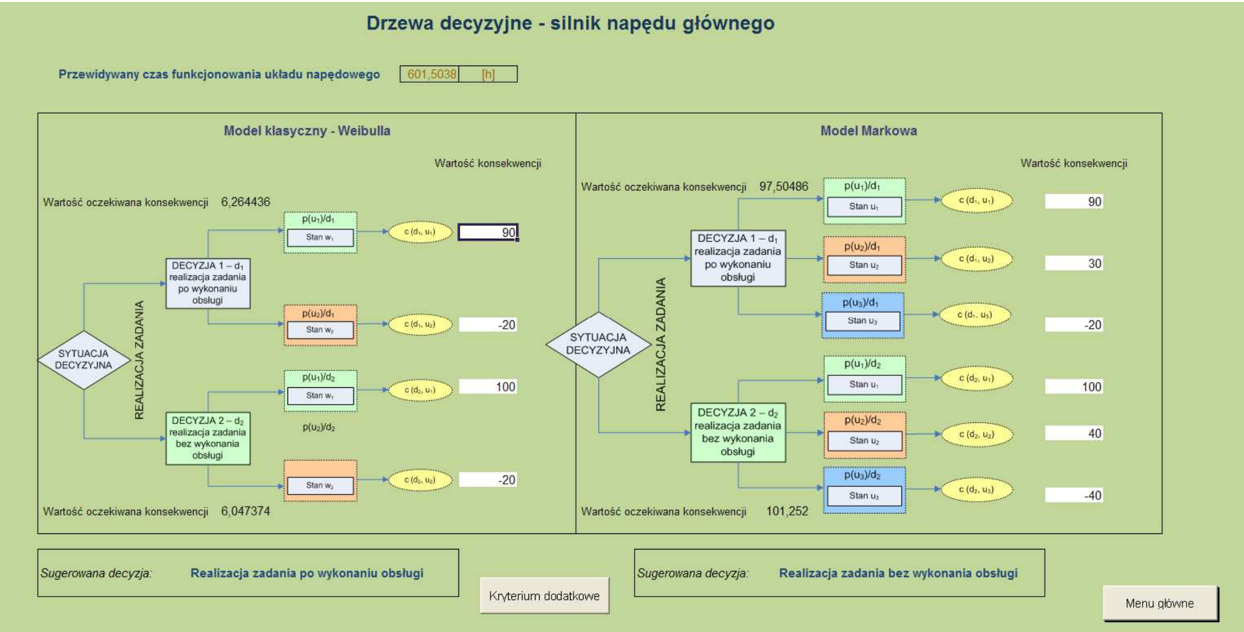


Fig.9. The window of analysed decision-making trees.

The criteria function for shown tree I maximisation of expected consequence value c (d_j, s_i) which for individual tree's nodes symbolising making particular dj decision can be described as [9]:

$$E(c/d_j)=\sum_{i=1}^{k}\left[p(s_i)/d_j\cdot c(d_j,s_i)\right]\qquad i=1,2,\ldots,k\qquad j=1,2,\ldots,n \tag{1}$$

User is obliged only to estimate the consequence of particular state to occur.

In case of contradictory decision proffers communicated by the programme, it is possible to use additional procedure using evaluative description of operation, which was described wider by the author inter alia in papers [7, 8].

This option becomes active right at the moment of described contradictory of proffered decisions ascertainment by programme and access to that is available by “Additional criteria” overlap – Fig.10.

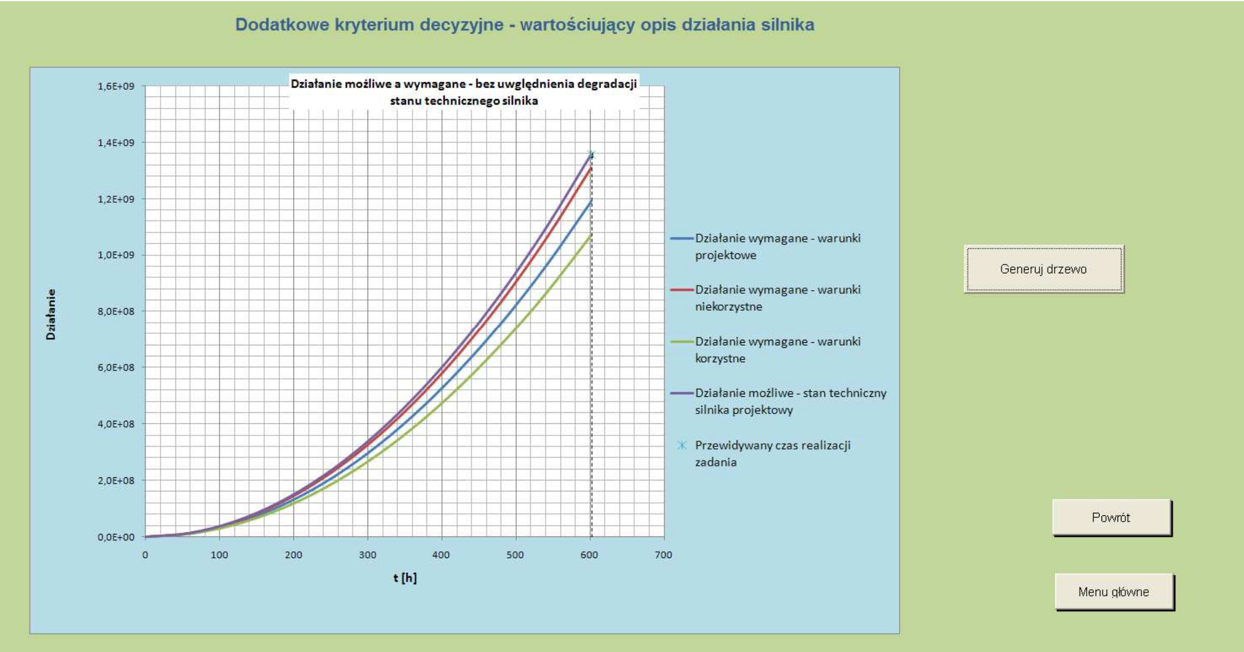


Fig.10. *The window of additional decision-making criteria.*

Model's calculation ("Tree's generation" button) results in generated decision-making tree display – Fig. 11.

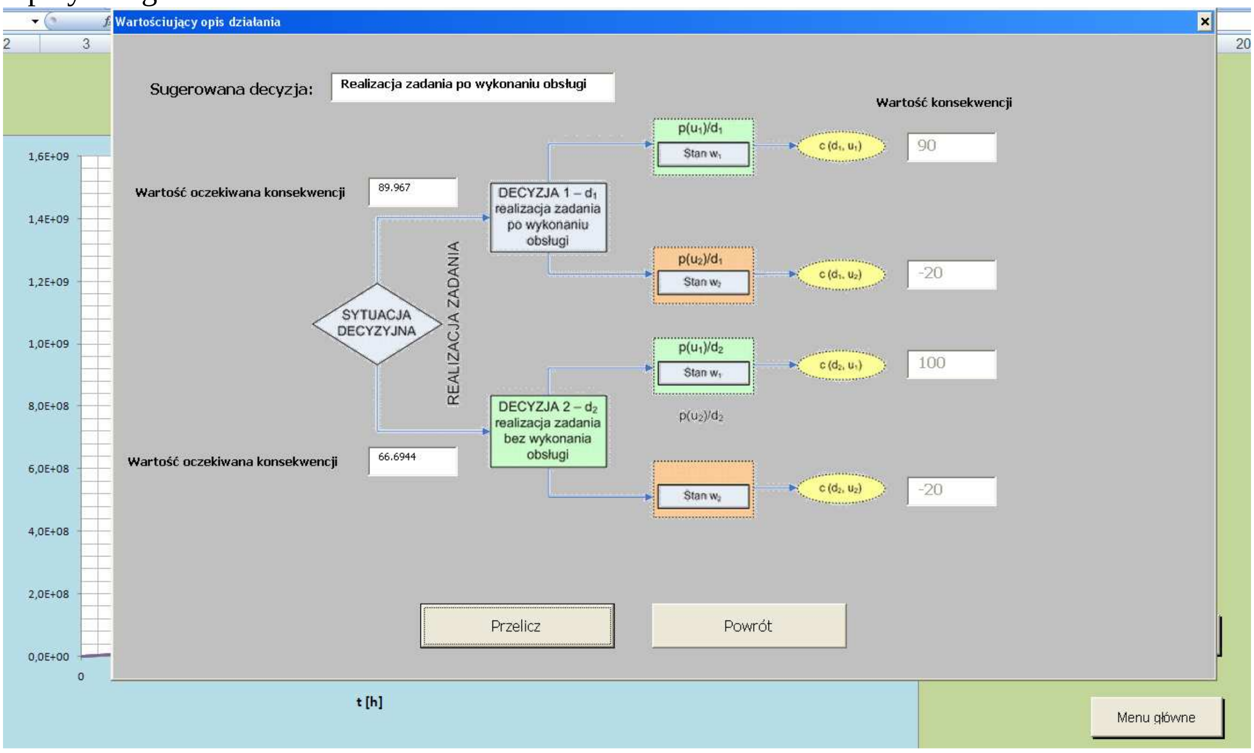


Fig.11. *Generation of decision-making tree based of evaluative operation description.*

as well as decision proffer, which possibly predominates on one of two generated in previous stage.

7. The application's extension – power plant's additional installations neuron state classifiers

The additional mode of the application is its part that is additional installations that secure main power transmission system functioning state classifier. The idea of neuron system of damages detection is described in many thesis inter alia, [4, 10] and the described solution is based on author's experience described in inter alia [6].

A choice of analysed installation accessible from the application's main window. - Fig.12.

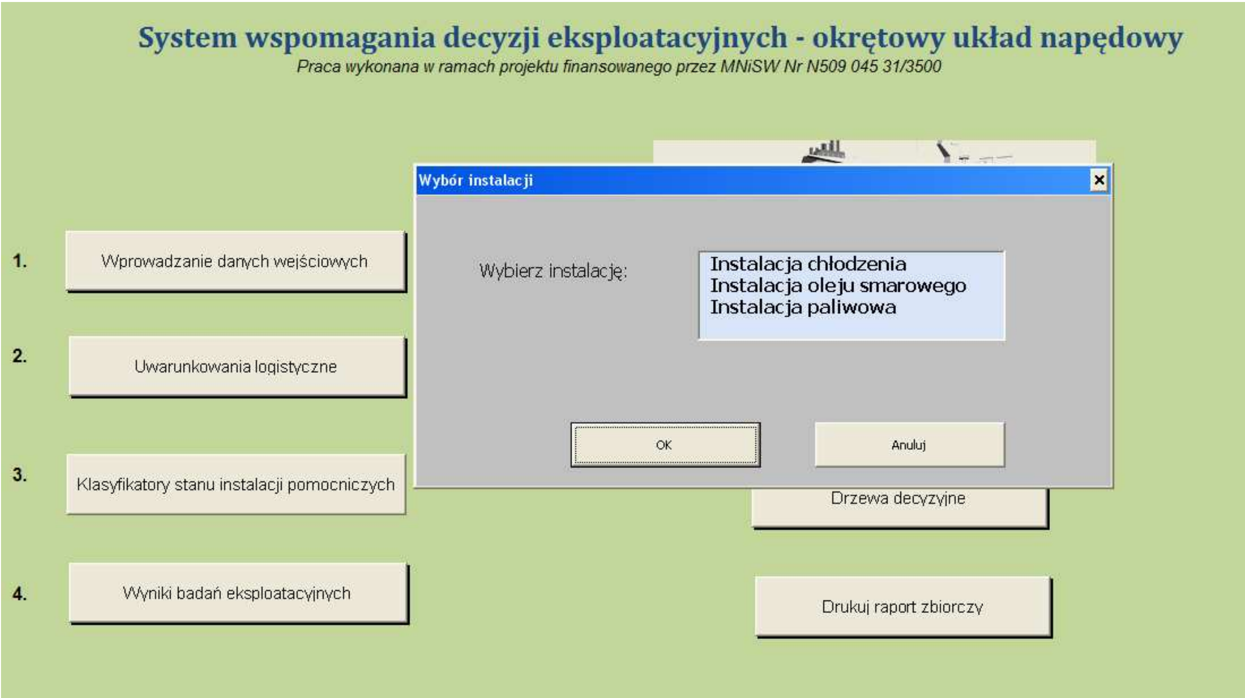


Fig.12. The form of classified additional installation choice

followed by particular classifier window's opening – Fig.13.

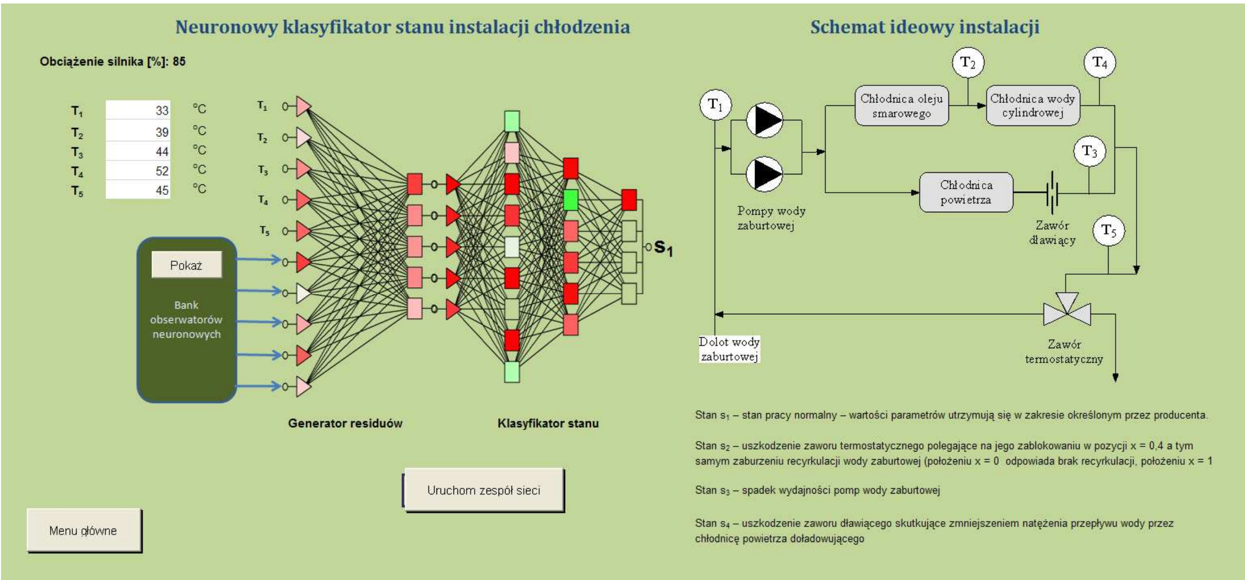


Fig.13. Cooling installation state classifier

in which user inputs basic parameters characteristic for chosen installation, and then properly trained system of neuron networks does the proper classification.

8. Summary

The process of making that kind of decision (amongst all possible) that in particular conditions will be thought to be the best, should be based on as many accessible in that conditions data as possible. But even in the (practically unparalleled) case of having all device's exploit data, the nature of decision-making process is a choice of criteria that enables appraising and comparing consequences of making different decisions. In case of complex technical systems realising particularly important tasks connected to both expected profit and creating significant danger to the environment (including the exploitation object), two main, equal criteria are:

- maximisation of profit value (minimisation of loss),
- minimisation of danger situation chance.

Therefore, besides multiplicity of conditionings in the reality, a natural contradictory between presented criteria occurs – maximisation of security level decreases profits and vice versa – and existing formal regulations in the field of security determine some minimal, required level, the realisation of the decision-making process is rather diverse, very often intuitive, even when according to the same objects, exploited in similar conditions.

The described conjuncture in specific way affects the situation of ship energetic systems (especially ship power plant and ship power transmission system) as they realise tasks that influences natural environment, as well as human health and life.

Amongst tools enhancing the probability of the right decision choice and being available for decision maker, should be tools basing on decision-making models created basing on mathematical models of exploitation process.

Modulation of exploit reality is always a simplification of existing state, which means it's impossible to create one, universal model that in full way would reflect the complexity of structure and processes going on during that part of power plant existence.

The multiplicity of information about conditions of making and verifying different types of models useful during decision-making process can be found in literature and thesis. The more does seem strange the fact of their sporadic use in exploit practice of complex technical systems, especially power plant and its elements.

This gap in ready-made tools enabling practical use of developed models section can be up to some level program tools developed and improved basing on available software, which is proved by this application, developed in this thesis and presented in test version.

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