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AUXILIARY INSTALLATIONS' FAULT TREE MODEL FOR OPERATION ANALYSIS OF VESSEL'S POWER PLANT UNIT

Summary

The paper contains presentation of auxiliary installations' fault tree analysis model, which can be useful in operation analysis evaluation. Example fault tree for marine diesel engine's operation analysis, which can be connected to this model, were presented.

1. Introduction

Fault tree analysis (*FTA*) method has been widely used for safety, reliability and diagnostic analysis since 1961. This method is based on graphical representation of interaction of a number of basic system elements as boolean function [9, 11]. The fundamental concept in this method of analysis is translation physical system like marine power generation and distribution unit into a structured logic diagram, called fault tree, in which certain specified causes lead to one (or more) specified *top event* of interest.

Major industries and technologies utilizing FTA include: aircrafts, nuclear systems, transit systems, space projects, robotic systems, missile systems, torpedoes, etc. In marine and offshore industries method were used to oil platforms [1] and ships safety (ro-ro, tankers) [3, 4]. This method can by also evaluated to marine power plants operation analysis [2, 7, 8]. In this case is possible to create universal model of auxiliary installations (*MAI)* for marine engines.

2. Auxiliary installations FTA model

Every marine auxiliary installation *XX* can be presented as series-parallel configuration of *r* steps. In every serial block are located s parallel paths with *t* serial connected elements. We can calculate:

$$TE(XX) = \bigcup_{i=1}^{r}[\bigcap_{j=1}^{s(r)}(\bigcup_{k=1}^{t[r,s(r)]} E_{ijk}) \tag{2.1}$$

This equation gives us logical representation of fault tree model for one marine auxiliary installation with non-exclusive and independent primary events (component failures).

Ayyub [2] presented similar model for marine diesel (fig. 1). In this case, top event as *Diesel Generator Failure* is generated in logical sum of minimal cut set associated with basic subsystems: *Fuel Oil* (*FO*), *Intake and Exhaust* (*IE*), *Jacked Water* (*JW*), *Lubrication Oil* (*LO*), *Safety Control Air* (*SC*) and *Starting Air* (*SA*). This model can be extended for other specified subsystems [6], for example in application to marine main engine's fault tree. If $\Omega(XX)$ is representation of minimal cut sets of *XX* system, we have global cut sets equation for one diesel generator *DG*:

$$\Omega(DG) = \{\Omega(FS), \Omega(IE), \Omega(JW), \Omega(LO), \Omega(SC), \Omega(SA)\} \tag{2.2}$$

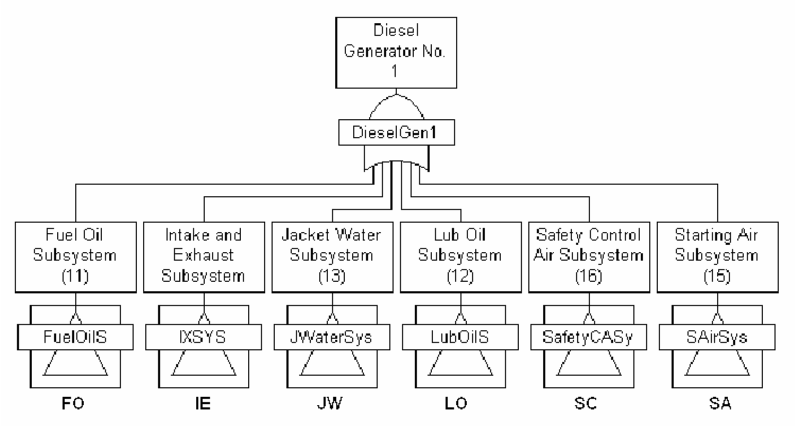

Figure 1. Fault tree model for diesel generator

Logical representation of fault tree generic MAI model for one diesel generator is presented below:

$$TE(DG) = \bigcup_{XX \subset DG} TE(XX) \qquad (2.3)$$

Where: $TE(XX)$ – logical representation of top event for XX subsystem.

3. Final conclusions

Presented model can be applied to develop complex fault tree. In figure 2 is presented fault tree model for diesel standby generator [10]. MAI model can be applied in this fault tree to develop of events: ELSSOEE106 – *Diesel generator fails to start*, and for extension of analyse ELSSOGE110 – *Failure whilst running*.

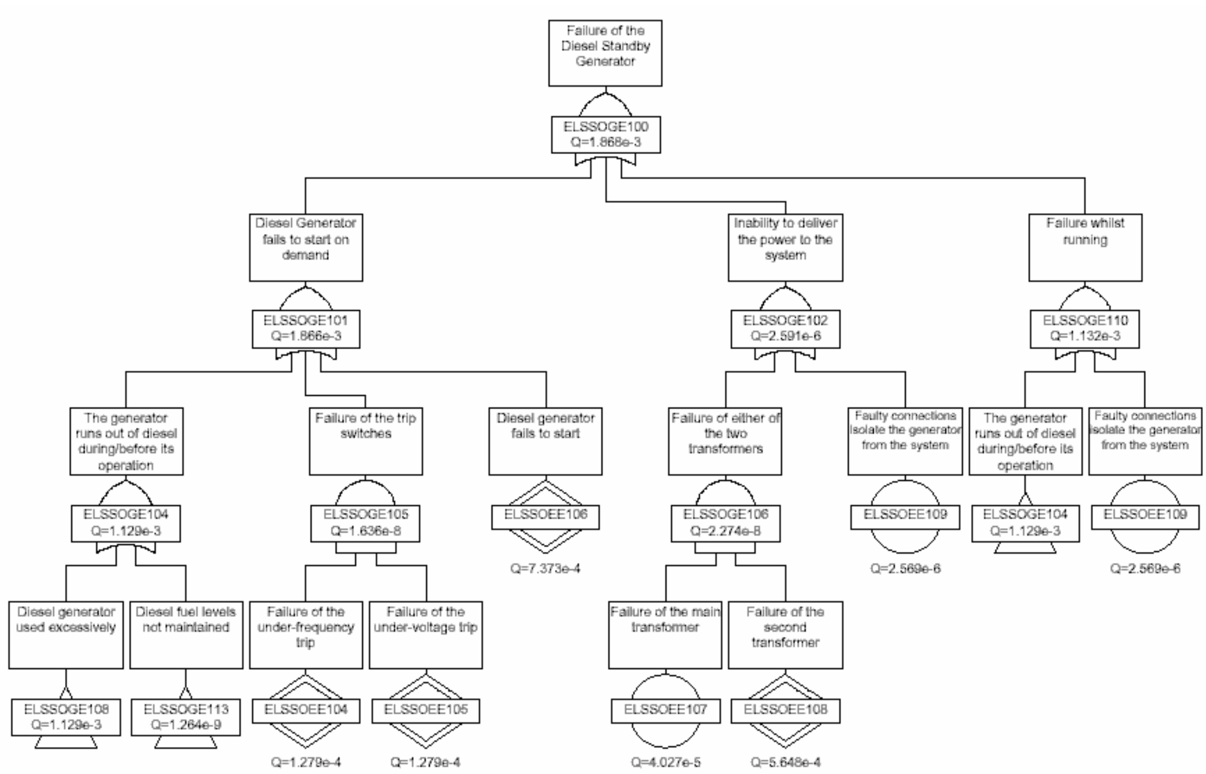

Figure 2. Example fault tree for application MAI model

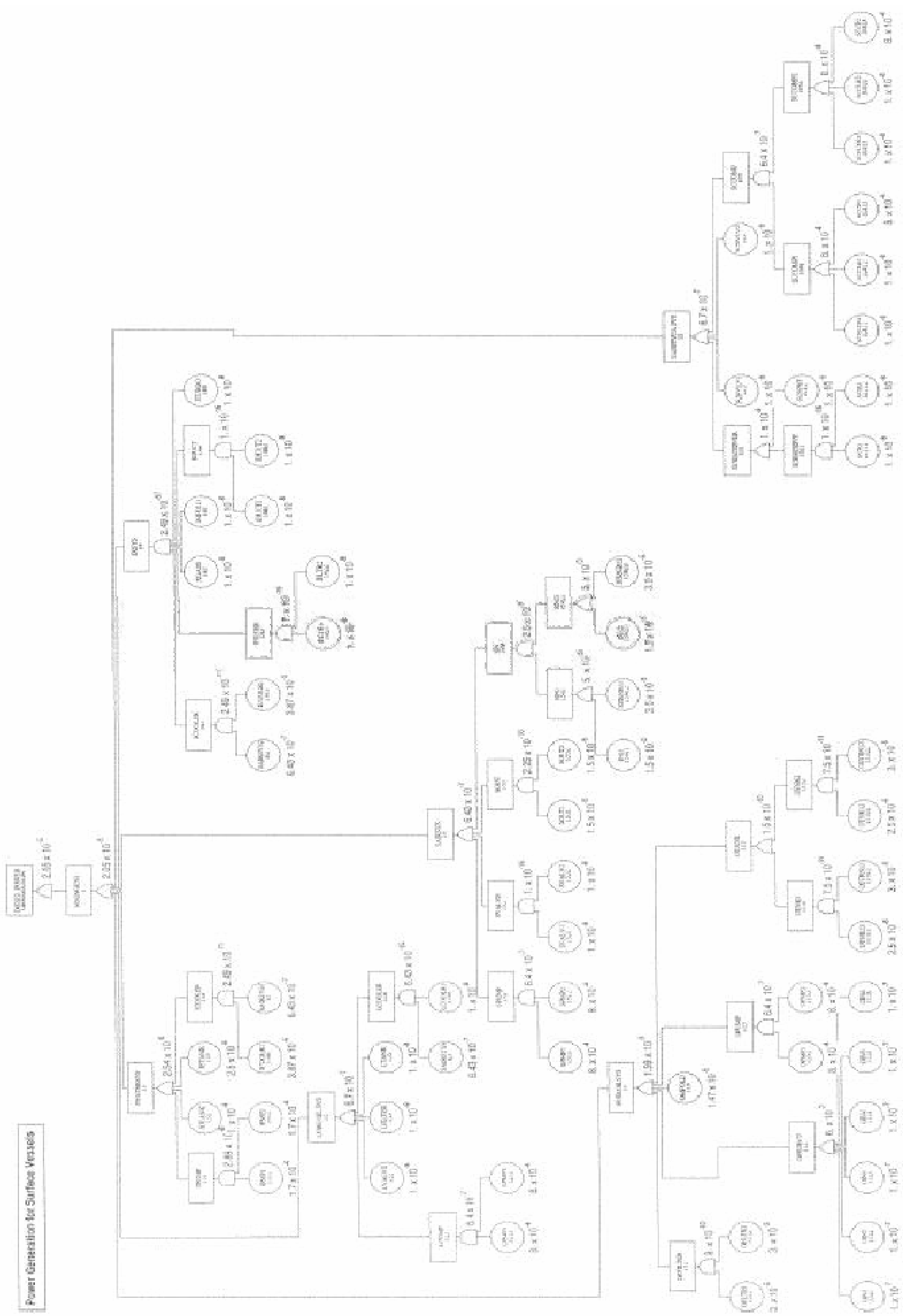

Figure 3. Example system breakdown for diesel generator

MAI model can be difficult in computing for many combinations of events, that is necessary to reducing it. Every marine installation contains many elements in serial structure and series-parallel blocks (in given decomposition level). It is constructed (according to formula 2.1) generally from $r<11$, $s<5$ and $t<6$ elements (usually less). Example fault tree (fig. 3) for diesel generator breakdown [2] has 41 minimal cut sets. That is necessary to use computer code for finding of minimal cut sets for presented model. With more generic decomposition level (for example pump with associated valves can be treat as one element) solution of model will be much easier. Presented MAI model can be use for operation analysis of marine power plant systems as part of project [8] and in connection to other methods [5].

Literature

1. American Bureau of Shipping, *Risk assessment applications for marine and offshore oil and gas industries*. ABS, Houston, June 2000.
2. Ayyub B. M., *Guidelines for Probabilistic Risk Analysis of Marine Systems*. Report CBST-97-101. University of Maryland, College Park, May 1997.
3. Brandowski A., *Ogólny model bezpieczeństwa statku morskiego oraz zasady jego budowy i badania*. Praca badawcza nr 46 / 2000 /PB. WOiO Politechnika Gdańska, Gdańsk 2000.
4. Brandowski A., Liberacki R., Nowak P., *Badania bezpieczeństwa napędowego statku serii B-488*. Praca badawcza nr 48 / 2000 / PB. WOiO Politechnika Gdańska, Gdańsk 2000.
5. Chybowski L., *Próba zastosowania wybranych testów diagnostycznych do oceny stanu technicznego systemu siłowni okrętowej*. Materiały 22 MSN, Zielona Góra, Maj 2001. Tom Mechanika, p230-237.
6. Chybowski L., *Wykorzystanie przekrojów minimalnych do analizy pracy instalacji okrętowej*. Вопросы Повышения Эффективности Судовых и Стационарных Энергетических Установок. Международный Сборник Научных Трудов. KGTU, Kaliningrad 2001, p172-177.
7. Chybowski L., *Zastosowanie drzewa uszkodzeń do wybranego systemu siłowni okrętowej*. Вопросы Повышения Эффективности Судовых и Стационарных Энергетических Установок. Международный Сборник Научных Трудов. KGTU, Kaliningrad 2001, p178-183.
8. Chybowski L., *Analiza pracy systemu energetyczno-napędowego statku typu offshore z wykorzystaniem metody drzew uszkodzeń*. Materiały XXII Sympozjum Siłowni Okrętowych SymSO 2001. WTM Politechnika Szczecińska, Szczecin 2001, p83-88.
9. IEC 61025, *Fault Tree Analysis* (*FTA*). International Electrotechnical Commission Standard.
10. Proctor P., *Infrastructure risk modelling diesel standby generators*. Railtrack PLC, EE&CS Report RT/S&S/IRM_FTA/31, Issue 1, Railtrack, November 1997.
11. Vesely W. E., Goldberg F. F., Roberts N. H., Haasl D. F., *Fault Tree Handbook*. NUREG-0492. U. S. Nuclear Regulatory Commission, Government Printing Office, Washington, January 1981.

MODEL INSTALACJI POMOCNICZYCH (W METODZIE DRZEW USZKODZEŃ) DLA ANALIZY PRACY OKRĘTOWEGO SYSTEMU ENERGETYCZNO-NAPĘDOWEGO

Streszczenie

Materiał prezentuje model instalacji pomocniczych(w metodzie drzew uszkodzeń), który może być zastosowany podczas prowadzenia analizy pracy. Zaprezentowano przykładowe drzewo uszkodzeń odpowiadające pracy okrętowych silników wysokoprężnych. Przykład ten może zostać rozwinięty w oparciu o prezentowany model.