Comparison of two Quantitative Reliability Assessments of a Class 3 DP System

Victor R. L. Souza-Franco[1], Maria V. Clavijo[2], Marcelo R. Martins[3]

Analysis, Evaluation and Risk Management Laboratory – LabRisco, Naval Architecture and Ocean Engineering Department, University of Sao Paulo, Brazil

Adriana M. Schleder[4]

Department of Industrial Engineering, Sao Paulo State University – UNESP, Brazil

ABSTRACT

Two methods with Fault Trees are used to computed the reliability of a class 3 Dynamic Positioning System, whose differs from each other about the consideration of uncertainties in failure rate data. Without consider uncertainty, one can obtain a reliability value for the system, although considering then, reliability distributions are obtained instead of single values. Some advantages of each method are briefly discussed and the reliability for 3 and 12 months campaign are presented. A reliability of 80.65% and 94.77%. are achieved for 12 and 3 months periods respectively without failure rate uncertainty. When the uncertainty is used, average values increase to 86.90% and 96.55% for 12 and 3 months operating campaign as well.

INTRODUCTION

On offshore oil and gas industry, one of the most significant issues on the challenging deepwater exploration and production' environment has been maintaining the position of the vessel to perform necessary operations, as drilling and maintenance campaigns. As securing the position by traditional means, such as mooring lines, becomes highly costly and, in some cases, unviable, the Dynamic Positioning System (DPS) was therefore introduced since early 1970s [1] to assure the positioning of deep and ultra deep water vessels, which is a critical issue due to the increased congestion of oil fields.

This paper presents a comparison between two methods for a quantitative assessment of the reliability of a class 3 Dynamic Positioning System (DPS3), analyzing the advantages and disadvantages in considering uncertainties in the failure rates of the DPS components.

DESCRIPTION

As [2-4], this paper uses Fault Trees (FT) to model the relation among DPS3' components to obtain the system' Probability of Failure (PoF). Once the PoF is the same as unreliability F(t) computed for a determined mission time t, the DPS Reliability can be derived easily from the equation:

$$R(t)=1-F(t) \qquad (1)$$

Definition of DPS' worst case failure modes and classes can be seen at [5-7]. Figure 1 shows the general configuration of a generic DPS.

1 victorlsouza@usp.br
2 valentina.clavijo@usp.br
3 mrmartins@usp.br
4 adriana.miralles@unesp.br

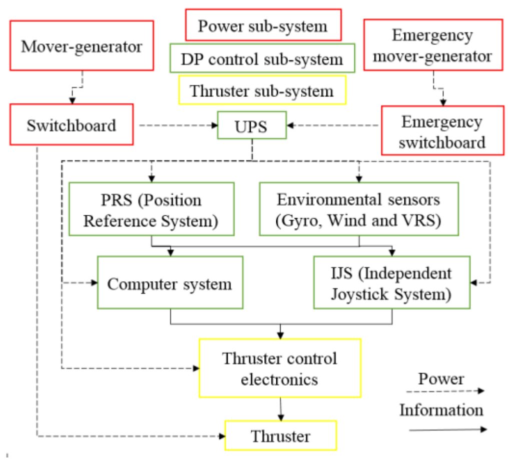

Fig. 1. General configuration of DP system, [3,4].

Figure 2 shows the main DPS subsystems related to achieve "free drift" top event. The OR logical gate indicates that the failure of either of them leads to the top event (free drift).

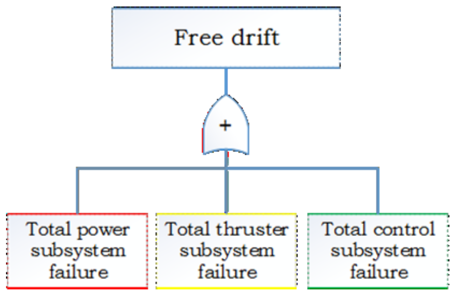

Fig. 2. Fault Tree with "Free drift" as top event, [4]

To obtain the DPS F(t) value, the designed FT was filled with component failures rates from databases such as IEEE [8], NIOT [9] and OREDA [10].
The method stated by [2,3] uses single failure rates values for each component, without considering data uncertainties. Whereas the method proposed in [4] uses probability density functions (pdf), as gamma or uniform distribution, for represent the component failure rate behavior due to it own "parameter uncertainty" [11], which are the input data for a MCS (Monte Carlo Simulation) algorithm.
Figure 3 shows a comparison between the methods considering uncertainty ("proposed method") [4] and without considering them ("former method") [2,3]:

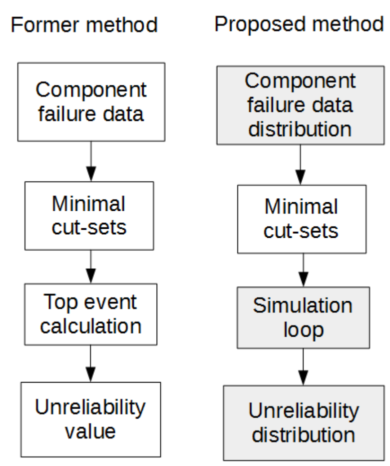

Fig. 3. Differences in proposed method [4].

DISCUSSION

For this analysis, a inhouse software named Engineering Reliability Analysis Software (ERAS) [12], developed in the Laboratory of Analysis, Evaluation and Risk Management - LabRisco of the University of Sao Paulo was used. The software validation was done using SAPHIRE [13] as benchmark.

To calculate the F(t), the mission time of one year (8760 h) was defined and four sets of simulations were performed, with 10^3, 10^4, 10^5 and 10^6 simulations respectively. Then, for each F(t) value, the corresponding reliability R(t) was computed using equation 1. The calculated reliability values were organized as distributions, whose some statistical parameters are shown in Table 1:

Table 1. Reliability values obtained from proposed MCS method, adapted from [4].

Samples	Mean	Mode	Percentile	
			5th	95th
10^3	0.8687	0.8875	0.8133	0.9000
10^4	0.8691	0.8850	0.8142	0.9000
10^5	0.8688	0.8875	0.8137	0.8998
10^6	0.8689	0.8850	0.8138	0.8998

The reliability distribution obtained for 10^6 simulations are shown in Figure 4 below:

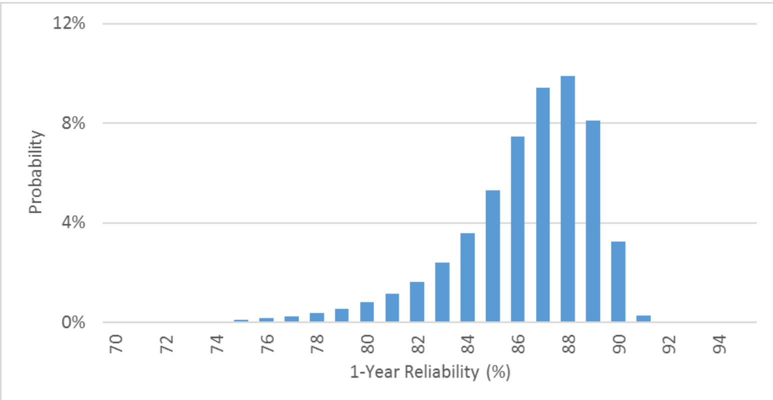

Fig.4. Reliability pdf for DPS3, one year (8760h) mission time, 10^6 simulations.

Table 2 shows the MTTF calculated for 10^6 simulations data from Table 1, which consider uncertainties in the failure rates of DPS components, compared to the value obtained with the model that does not consider uncertainties:

Table 2. MTTF values for reliabilities from 10^6 simulations, adapted from [4].

MTTF (years)				
Mean	Mode	Percentile		Single failure rate [3]
		5th	95th	
7.12	8.19	4.85	9.47	4.65

CONCLUSION

Without considering uncertainties on failure rate data, a DPS3 achieved a reliability of 80.65% for 12 month operating period, while for a 3 month period its reliability rises to 94.77%.
The analysis with uncertainty proves to be important because it allows to take into account the lack of information about the real value of the equipment failure rate. Considering the uncertainties, the second method has an average reliability of 86.90% for 12 months of operation and 96.55% for a 3-month operating campaign.
The analysis with the uncertainty present in the second method allows to know the probability distribution function of the reliability of the DPS3. From these curves several statistical parameters can be obtained, which allow a better understanding of the reliability behavior of a DPS3 vessel.

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