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Dynamic And Dependent Fault Tree Analysis Of Shipping System

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The maritime sector places significant reliance on the consistent performance of propulsion systems to ensure the safety, efficiency, and reliability of shipping systems (Gaonkar et al., 2011). The propulsion failure of shipping systems can lead to critical consequences, including accidents, environmental damage, and economic losses.

Traditionally, Fault Tree Analysis (FTA) has been a primary method for assessing the reliability of such complex engineering systems (Van Ta et al., 2016). However, shipping systems, particularly with features like standby systems, exhibit numerous complex events and dependencies, posing challenges for FTA implementation.

Specifically, FTA is inherently static and often assumes the independence of events (Kabir, 2017). Nevertheless, the propulsion systems of shipping vessels involve intricate dependencies that impact their safety and reliability. These dependencies encompass control and automation, electrical systems, fuel systems, and mechanical components. Furthermore, understanding the dynamic behavior of shipping systems is crucial, as this influences their adaptability and response during various operational states, such as transitioning from normal to backup operations.

In addressing these challenges, Tolo & Andrews (2023) introduced the Dynamic and Dependent Tree Theory (D^2T^2) method, aiming to enhance FTA by overcoming its limitations related to dependencies and dynamic behavior. This methodology integrates other analysis approaches, such as Petri Net (PN), Markov models (MM), and Binary Decision Diagrams (BDD). PNs and MMs ensure the consideration of dynamic behavior in complex systems, while BDDs efficiently represent fault trees, reducing redundancy and computational burden. This integration enhances the overall efficiency of analysis and the quantification of failure probabilities.

This study presents an application of the D^2T^2 method for the reliability analysis of the propulsion of a shipping system. Figure 1 provides a graphical representation of the shipping propulsion system.

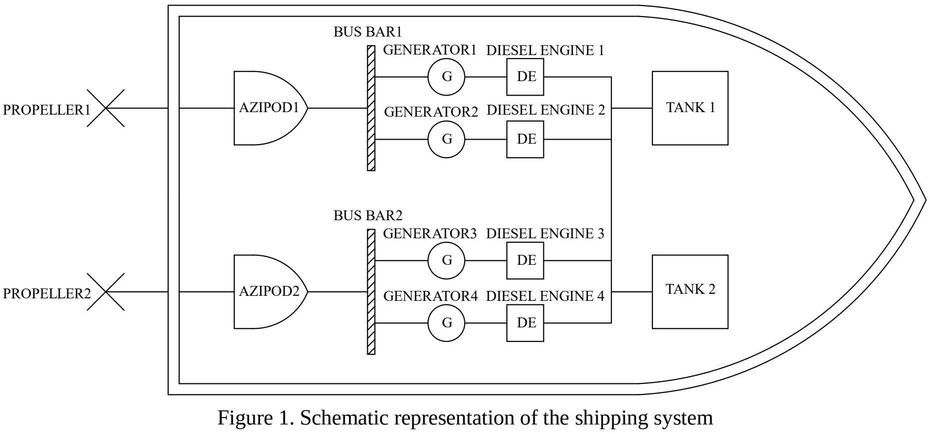

Figure 1. Schematic representation of the shipping system

The propulsion system encompasses a sophisticated array of components and machinery meticulously designed to generate the requisite thrust for propelling the ship through the water.

At its core are four diesel engines (DE), pivotal in producing the power necessary to drive the ship via four generators (G). In every generator pair, one is active, while the other stands ready as a backup. Furthermore, each generator pair serves as a standby for the other. Fuel systems, drawn from two tanks (TANK), provide the main diesel engines with the requisite fuel for combustion. In the context of electric power distribution, strategically positioned busbars, situated downstream from the generators, serve as universal electrical connection points for various components, encompassing pumping lubrication systems and electric motors. Adjacent circuit breakers (CB) manage electrical power flow, safeguard against overcurrent or short circuits, and facilitate section isolation as needed (e.g., CB1 isolates generator 1). Overseeing the entire engine operation is a controller unit (CU), orchestrating actions based on inputs from strategically deployed sensors (SEN) throughout the engine and related systems.

Critical to the power distribution network is the busbar, playing a pivotal role in channeling electrical power to the Azipods, indispensable for propelling and maneuvering the ship effectively.

Azipods, integral to this setup, incorporate two bearings supporting the rotating shaft. Given the substantial stresses they endure during operation, a meticulous lubrication system is implemented to ensure seamless functionality. This system comprises two pumps (P), one in operation and the other on standby, ensuring continuous lubrication.

Furthermore, each Azipod houses an electric motor, drawing power from the generators to propel the Azipod. To prevent overheating, a cooling pumping system is intricately connected to the electric motor through a heat exchanger. Specifically, an intake unit draws seawater, which circulates to absorb the heat generated by the electric motor, thereby maintaining optimal operational temperatures.

The propulsion fails when the Azipods are unable to deliver thrust or steering. Therefore, D^2T^2 method is adopted to perform the reliability analysis to calculate the failure probability of the propulsion system failure.

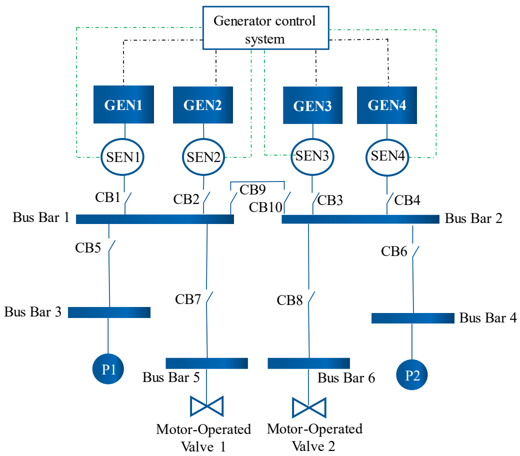

Figure 2 Schematic representation of the electric power system

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