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Application of FIS Methodology to Risk Failure Estimation of LNG Transfer Loading Arms in Side-by-Side Configuration

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This paper presents a fuzzy inference system (FIS) methodology for a real-time dynamic monitoring of loading arm reactions during liquefied natural gas (LNG) side-by-side offloading operations, which may provide a practical approach to reducing the risk of loading arm failure during these operations. The methodology integrates environmental conditions in calculating the loading arm's risk of failure during these operations. Experimental data retrieved by the coupled motion response analysis of two LNG carriers were used for the tuning of the model's parameters. The outcome is a risk failure indicator that helps operators to decide whether to continue or suspend the operation.

INTRODUCTION

In 1964, the world's first commercial liquefied natural gas (LNG) plant in the Algerian port city of Arzew started delivering to the United Kingdom for a 15-year contract. Since then, the LNG trade has been shifting and changing for different reasons involving operational and trading factors, all in the context of the optimization of the distribution plan between the source and the final consumers. The number of LNG-producing countries steadily continues to grow, from 8 in 1996 to 15 in 2012, with 26 existing terminals and approximately 65 liquefaction terminal projects either proposed or under construction (Gorstenko and Tikhomolova, 2012). In the last decades, the international natural gas market has been growing at a very high rate and continues to increase (Aronsson, 2012); thus, Fig. 1 depicts the major trade movements that took place in 2012.

These developments led the LNG industry to evolve steadily into maturity and profitability; currently it accounts for 23.9% of primary energy consumption (BP, 2012). As the LNG supply chain grows rapidly, expanding into new profitable areas such as offshore and small-scale LNG projects, offloading operations (offshore to ship, shore to ship, and/or ship to ship) have become, in common practice, high-safety-levels procedures.

"Offshore-to-ship operations" refers either to fixed facilities, such as gravity-based structure (GBS) platforms, or floating facilities, such as floating LNG plants (FLNG) or floating storage and regasification units (FSRUs) (McDonald and Chiu, 2004). Shore-to-ship operations are related to the transfers from/to shore production and storage facilities such as LNG terminals to/from LNG-carrying vessels. On the other hand, the ship-to-ship (STS) LNG transfers refer to the transfer of cargo between ships positioned alongside each other or in line, which is referred to as "tandem arrangement." Figure 2 shows a floating facility, such as the gas import floating terminal (GIFT) in a side-by-side operation with an LNG carrier (LNGC).

One of the stakeholder's main concerns remains the need to maintain the enviable safety records minimizing the risk of a potential accident with adverse effects on human beings and the environment and with property loss. The stochastic nature of the offloading site-by-site operations caused by the kaleidoscopic weather conditions configures a complex marine system wherein the time for the right decisions is limited and critical.

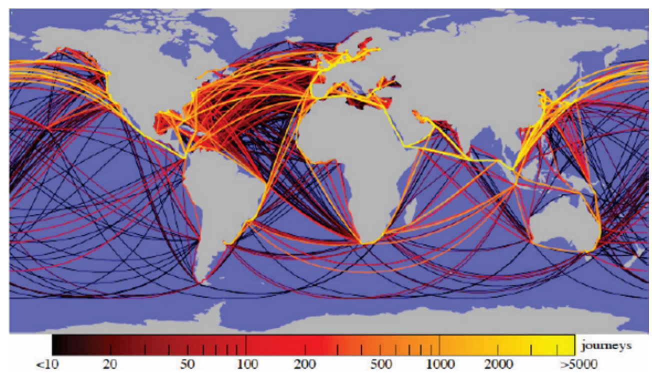

Fig. 1 Major LNG trade movements per year (Aagesen, 2012)

Now, the LNG cargo loading and offloading operations are conducted almost exclusively via fixed articulated loading arms. These arms incorporate swivel joints to accommodate the relative motion between the two vessels involved (Stone et al., 2000).

An important issue of the loading arms comes from the need to function under harsh sea conditions. Loading arms should be flexible to deal with the uncontrolled movements of the vessels

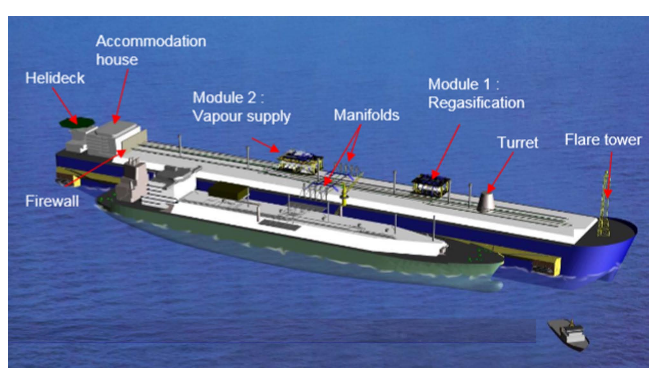

Fig. 2 General view of GIFT with a moored 138,000 m^3 LNGC

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