

RELIABILITY ASSESSMENT FOR LIQUEFIED NATURAL GAS
SHIP'S DISTRIBUTED CONTROL SYSTEM

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To my beloved wife Munirah and my lovely daughters Alya and Bahi

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ABSTRACT

Distributed Control System (DCS) is installed onboard liquefied natural gas (LNG) ships to ensure safety and efficiency during all modes of operations. The aim of this paper is to establish reliability assessment for ship's DCS and measure the probability of failure for DCS equipment by using field failure data. DCS components failure data of four series of LNG ships was taken from the company maintenance database. Reliability of individual component was calculated by fitting the two parameter Weibull model to failure data. The shape parameter, β and scale parameter, η are deduced from linear regression and subsequently the reliability for each DCS component can be calculated. The reliability block modelling was developed and then the overall reliability of DCS system of a ship can be calculated by substituting each individual component reliability into the equation of total system reliability. There are five main components of DCS i.e. FTA, IO, NIM, CPU and HIS. The failure of IO and HIS made up 88% of total failure. Ship A and B having large number of failures with 36% and 46% each. The linear regression for all ships showing good fitting as the R^2 value is all above 0.8 even for small sample data. IO on all ships was showing short lifetime with low η value of about 10,000 hours while HIS was even lower with 3,000 to 8,000 hours. Other component η value was minimum 13,000 hours. The total reliability for Ship A, B, C and D was 53%, 0.1%, 2% and 6% respectively. Ship A reliability at this point of time is showing the highest reliability compared to all other ships. Other ships' low reliability was due to either high failure rate of one of the components or early infant failure. It can be concluded that reliability of DCS are not influenced by the number of component failures. Even though Ship A has the most number of component failures but the reliability is the highest. The DCS system total reliability depends on the failure rate, the criticality of the components whether connected serially or parallel and the date of when the last time the component was replaced.

ABSTRAK

Kebolehpercayaan peralatan boleh memberi impak pada penyelenggaraan dan keselamatan operasi kapal. Sistem Kawalan Tersebar (SKT) dipasang di atas kapal gas asli cecair untuk memastikan kelancaran operasi semasa di laut, muat naik kargo dan pemungghahan kargo. Ketika ini tidak ada kaedah untuk membantu membuat keputusan sama ada perlu memanjangkan, menggunakan semula atau menaiktaraf selepas 20 tahun SKB digunakan. Dengan menggunakan fungsi pengagihan Weibull, penilaian kebolehpercayaan untuk SKT kapal boleh dibangunkan dengan menggunakan data kegagalan komponen. Namun, data kegagalan komponen seringkali tidak lengkap sehingga model matematik dan algoritma diperlukan untuk mengira kebolehpercayaan. Model blok kebolehpercayaan dibangunkan untuk memperoleh nilai keseluruhan kebolehpercayaan SKT. Hasilnya, kaedah penilaian kebolehpercayaan telah dibangunkan dan kebolehpercayaan system SKT telah berjaya dikira. Data kegagalan komponen SKT diambil dari empat siri kapal gas asli cecair. Fungsi Weibull dua parameter digunakan dan dideduksi dengan menggunakan kaedah regresi linear. Parameter ini digunakan dalam pengiraan kebolehpercayaan. Didapati padanan data yang baik walaupun untuk sampel data yang kecil. Nilai kebolehpercayaan untuk Kapal A, B, C dan D masing-masing adalah 53%, 0.1%, 2% dan 6%. Ini adalah sangat rendah. Maka demikian, dicadangkan untuk melakukan penggantian secara menyeluruh atau menyediakan alat ganti yang cukup apabila jangka hayat komponen semakin hampir. Dalam kajian ini kebolehpercayaan sistem SKT telah dibangunkan dan hasil daripada analisis kebolehpercayaan dapat membantu operator dalam membuat keputusan mengenai penyelenggaraan.

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LIST OF ABBREVIATIONS

λ	-	Failure Rate
β	-	Shape parameter
η	-	Scale parameter (Characteristics life)
ABS	-	American Bureau of Shipping
AMOS	-	Application and Maintenance Operating System
CPU	-	Centralized processor unit
DCS	-	Distributed Control System
$f(t)$	-	Probability density function
FCS	-	Field Control Station
FTA	-	Field Terminal Adaptor
HIS	-	Human Interface Station
IO	-	Input Output
LNG	-	Liquefied Natural Gas
LNGC	-	LNG Carrier
MISC	-	Malaysia International Shipping Corporation
MTBF	-	Mean Time between Failure
NIM	-	Network Interface Module
PC	-	Personal Computer
$Q(t)$	-	Unreliability
R_s	-	System reliability
$R(t)$	-	Reliability
SCADA	-	Supervisory Control and Data Acquisition

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APPENDIX	TITLE
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CHAPTER 1

INTRODUCTION

1.1 General Introduction

Distributed control system (DCS) is a microprocessor-based control and monitoring system which is normally installed in complex chemical plant, offshore platform, drill ships etc. In commercial ship application, it is provided onboard Liquefied Natural Gas (LNG) carriers to handle the complex boiler steam, boil off gas system and miscellaneous machinery control in ensuring that the ship will operate safely and with minimum intervention by the operator. Taylor (1987) explained that it is the ultimate goal to have every possible operation controlled from centralized control room. Onboard LNG ships, DCS equipment is important in ensuring ship's smooth operation during normal sea going, loading and discharging operation.

DCS is where the entire system of controllers is connected by networks to a centralized control room where operator will monitor and control the plant through several workstation monitor. In short, DCS is the brain of a ship. The plant starts up will

be brought up manually by experienced personnel. Once the plant is stable, the control mode can be changed to automatic mode and DCS will ensure that the operation is kept steady by controlling valve in order to keep the flow, pressure or level within the desired value. Zivi (2002) stated that DCS reliability is important in ensuring safe operation and continuity of control. Currently, there is no method to measure DCS reliability.

Neubeck (2004) states that reliability engineering is a field that got its start during the NASA space program in year 1960 and continue to exist today. To name a few application, it is used in civil engineering and bridge design, product reliability testing and in asset life extension study known as RAM (Reliability, Availability and Maintainability). Reliability method can be used as an effective tool to measure current condition of a system or equipment.

1.2 Background of Problem

The first LNG carriers (LNGC) were built in late sixties and since then have increase in numbers. The increase of LNGC fleet worldwide is shown as Figure 1.1. From the graph, currently there are about 70 LNGC that is more than 20 years old.

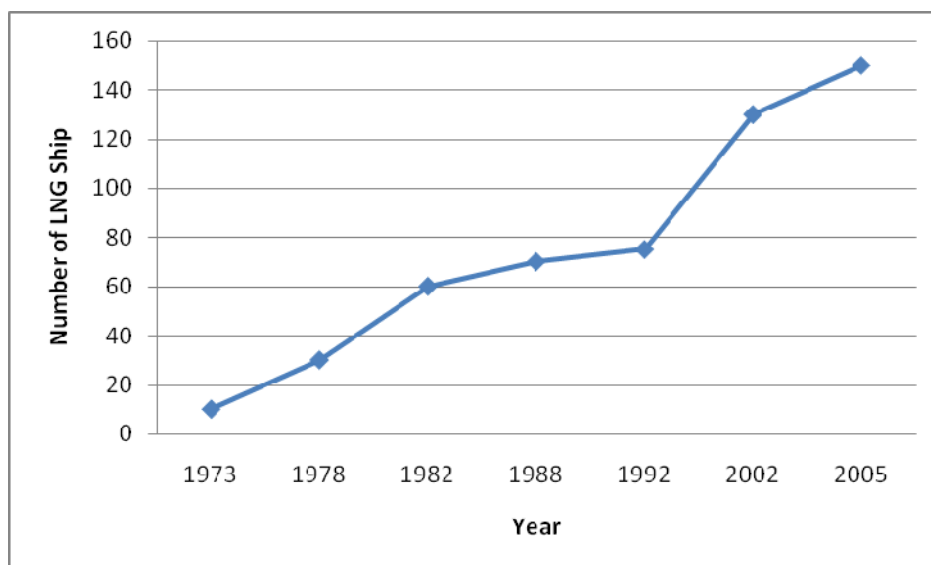


Figure 1.1: Increase of LNGC Fleet, ABS(2005)

Lifetime of machinery onboard ship, such as diesel generator, pump, turbine etc is normally up to 20 years. Unlike any other commercial vessels, most of LNG ships operate up to 40 years plus due to the high initial capital cost. To further serve for the next 20 years, the ship must go through refurbishment process. For LNG ship, this option is adopted since the price of new ship is almost 6 to 7 times the refurbishment cost. During refurbishment, major works such as cargo tank strengthening, main diesel generator replacement, boiler & main turbine assessment etc will be done to extend the ships life.

DCS is also no exception. Replacement, reuse or upgrade of DCS equipment is carried out after 20 years in service due to parts obsolescence, increase maintenance cost or unsatisfactory after sales support. On board ship, the environment is cruel to the equipment, where vibration, humidity and temperature can contribute to premature failure of the components. The cost of replacing DCS contributes up to 6% of the total cost of ships life extension program. Thus it is imperative that the decision be taken carefully.

DCS total failure so far has never been heard of. However, it is known due to discontinued production, difficulty in getting the spare parts, defective parts because of aging will relate to operation constraint and the scenario can get worse when spares are fully utilized and there is no capability to repair defective components. When this happen, it is like a time bomb if any single failure of DCS components occur.

Thus it is important to assess current DCS status to advise maintenance strategy that need to be adopted. Reliability assessment method need to be developed in order to assess the current status of DCS. Currently no failure analysis or assessments of the reliability of DCS system have been carried out. The decision to renew, reuse or upgrade relies mainly on the Maker's recommendation. This sometimes led to premature renewal or unexpected failure, causing downtime. A better way of assessing the need for renewal or replacement need to be developed. This project proposes a method based on reliability engineering. Reliability method which originate from reliability engineering using field failure data is hope to supplement the shipowner on status of DCS equipment if not accurately advise them what to do next.

The research problems can be summarized as follows;

- i) Currently there is no method to assist decision making of whether to renew, reuse or upgrade DCS system after 20 years in service. How to establish reliability assessment for ship's DCS?
- ii) How do we measure the probability of failure for DCS component?

1.3 Objectives of the Study

The objectives of this research are to;

- i) Develop a reliability assessment method of DCS system for LNG ships in operation by using field component failure data utilizing reliability engineering method
- ii) Calculate reliability of the system

1.4 Scope of Study

This study puts emphasis on using of mathematical calculation and reliability engineering to establish reliability assessment method. The data of DCS component failure was taken from four (4) series of LNG ships of a global shipping company. LNG ship's DCS components failure data is obtained from onboard maintenance and purchase software which is known as Application and Maintenance Operating System (AMOS). The software combines planned maintenance with spare parts control and integrates fully with AMOS purchase. Information is shared between ships and the office to allow on-board personnel to plan and manage maintenance and stores.

Based on the structure of DCS component, reliability block modeling is done. Failure rate, MTBF (mean time between failure) and reliability for each component shall be calculated. There are four main reliability distributions namely exponential, binomial, poisson and Weibull. Binomial and poisson are only suitable for

discrete distributions such as rocket launching failure therefore only exponential and Weibull are explained. Correct reliability distribution shall be selected. Based on this, reliability of the system is calculated.

1.5 Importance of Study

This study basically showed on how to model DCS system reliability and evaluate it based on field failure data. It is expected that there is availability of 6 to 7 years period of data.

The result from reliability analysis can be used by ship owner to enhance their decision making on whether to upgrade, purchase critical parts or revamp the whole system. This would benefit the shipowner rather than taking Maker's recommendation solely and making wrong decision.

In the end, the ultimate goal of having a more reliable DCS system onboard can be achieved.

1.6 Limitations of Study

The limitations of this study are that external factor such as ambient temperature, trading route, thermal effect and software failure is not considered. The DCS equipment reliability assessment is also limited up to the terminal connection of DCS cabinet. The

sensors, control valve and control system is not part of the study. This is primarily due to the fact that modeling all these would be too large an effort to undertake

1.7 Thesis Organization

Chapter One will consist of the problem background, research objectives, scope and importance of study and limitations. Chapter Two covers literature review, which discusses on DCS definitions, history, reliability engineering and method. Chapter Three presents the methodology in developing reliability block model and reliability calculation. Chapter Four presents the results of field failure data and reliability calculation. Chapter Five discusses on the results. Chapter Six concludes and recommends future work.

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