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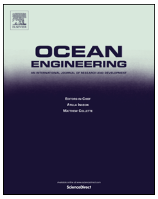

A decision making tool concerning retrofit of shaft generator frequency converter

Halvor Schøyen [*,a], Hussein Sow [b,1]

[a] Buskerud and Vestfold University College, Box 235, N-3603 Kongsberg, Norway
[b] Wagle Chartering AS, Box 230, N-1501 Moss, Norway

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ABSTRACT

This paper considers the area of fuel saving through retrofitting shaft generator frequency converter during a vessel operational phase. This retrofit enables the vessel to slow steam with the shaft generator engaged to the main switch board and still maintaining the proper voltage and frequency. An exploratory case study approach is adopted, to achieve an empirically anchored theoretical insight. By considering the trade-off between a cost-benefit analysis and risk area identification a theoretical framework for decision making of the retrofit is proposed. Data is collected from ship-owners and machinery system suppliers. This study shows: (1) In the case of the multipurpose dry bulk ship, the fuel price is demonstrated to have the strongest impact on profitability, (2) the importance of the cost of retrofitting the system appears to be more significant in the short-term, compared to the long-term perspective, (3) eight risk areas that have an impact on the retrofit profitability are identified and mapped in a risk matrix from acceptable to intolerable, and (4) it is revealed that liner operators - in opposite to ship owners – are the most common customers of the shaft generator conversion.

1. Introduction

This paper addresses the topic of vessel retrofitting with the purpose of saving fuel. Since retrofitting possibilities are numerous, the paper will zero in on one specific type, i.e. shaft generator frequency conversion (SGFC). This retrofit enables ship operators to slow steam with the shaft generator engaged to the main switch board and still maintaining the proper voltage and frequency. Because SGFC technology has existed for decades and is a common energy-saving practice (Basurko et al., 2013), it is not widely considered to be revolutionary. Nonetheless, technological advances have undoubtedly modernized it, bringing it up to standards with the latest technologies. This study investigates the extent to which fuel costs can be reduced by retrofitting with SGFC, and informs on the decision-making process to conduct such vessel upgrading. There are three research questions:

1. To answer this question, a cost benefit analysis (CBA) of a one-vessel case will be performed.
2. What are the main risks areas related to retrofitting with SGFC?
3. What is the nature of most customers of SGFC technology, and what are their common commercial attributes?

To answer these three questions, the experiences of a ship manager, an engine manufacturer and a supplier with the SGFC retrofit are collected and analysed.

Section 2 presents the theoretical framework. Section 3 describes the research method, while Section 4 illustrates the results from the cost benefit assessments, along with those from the risk identification of main threats and those pertaining to the main customers. The findings are discussed in Section 5. Finally, Section 6 presents the conclusions along with recommendations for further research.

2. Theoretical framework

2.1. Shaft generators in four-stroke engine ships with controllable pitch propellers (CPP)

Throughout the latest decades, electrical power demand for vessels has grown significantly, the reason behind this being the development of electrical facilities on board. Consequently, the fuel consumption has also grown. In pursuance of lower fuel costs, installing shaft generators became a practical solution (Xiaoyan et al., 2009). Shaft generators (S/G) are driven by the main engine

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[*] Corresponding author. Tel.: +47 31009411.
E-mail addresses: hs@hbv.no (H. Schøyen), sowhussein@hotmail.com (H. Sow).
[1] Tel.: +47 97744164.

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(Dokkum, 2011), and have the capacity to supply the ship with electricity (Prousalidis et al., 2005). However, many large actors in the field of marine propulsion manufacturing point out that diesel engines running at constant-RPM to drive shaft generators without frequency converters are operated inefficiently at part load, based upon the fact that, when slow steaming at reduced vessel speed and engine load, an above optimal engine RPM is required (Rolls-Royce, 2010; Sam-Electronics, 2010). The problem lies in the fact that ships' consumers require constant frequency, which is only possible when the S/G is run at constant RPM. The efficiencies of the CPP propeller and M/E are diminished when the load is reduced as the ship is then operated off-design (Stoye, 2011). Thus, by installing a frequency converter, the M/E will run at various RPMs instead of at constant RPM, while simultaneously adjusting the propeller pitch. As a result, fuel savings are enabled at various vessel speeds through the efficient operation of the M/E and S/G in combinator mode, which are optimal combinations of RPM and pitch (Stoye, 2011). The fuel savings deriving from combinator mode are between 7 and 10%, depending on the case (Casal and Würzburg, 2014). The deciding factor seems to be the operational speed of the vessel.

2.2. Retrofitting of SGFC for M/E fuel savings

The interest of vessel retrofitting has grown considerably in the past few years, in light of higher fuel costs and environmental restrictions. Lassesson and Andersson (2009), together with Armstrong (2013), point out both technical and operational measures, which can result in fuel savings and lower emissions to air. These include, among others, M/E performance optimization. Baldi and Gabrielii (2015) acknowledge the impact of ship operational profile on vessel power requirement, and find out that two or three operational speeds can be suitable in a techno-economic analysis for ships operating according to fixed sailing schedules. Solla et al. (2012) describe the retrofit of a new variable frequency drive technology called the Shymgen system on a fishing vessel, and compare the results post-retrofit, with the initial evaluation of the retrofit project: The Shymgen system generated a 10 % reduction in fuel consumption, which was in line with their initial forecast. In Fig. 1, the S/G generates electric energy that is transmitted to the frequency converter (FC). The FC corrects the frequency of the electricity, which is then distributed via the switchboard to electric consumers.

Lyridis et al. (2005) deal with a cost-benefit analysis of the installation of new advanced automation technology, which optimizes maritime operational safety on board the icebreaker *Frej*. The authors concluded that the investment was worthwhile, the major part of the savings coming from decreased crewing expenses instead of from reduced fuel consumption. In order to build their analysis, Lyridis et al. (2005) make use of the payback period method, a limitation of which is that it does not take into consideration the time value of money.

2.3. Cost benefit analysis of the retrofit

NPV is a measure used to determine the profitability of an investment by looking at the sum of all discounted cash flows coming from the project (Berk and Demarzo, 2013). The NPV represents the equivalent of what one would be endowed with today, if one chose to undertake the investment. Below is the standard NPV formula

$$NPV = \; - C_{0+} \sum_{i=1}^{T} \frac{CF_i}{(1+r)^i}$$

CF is a term that stands for the net cash inflow in period i, and $-C_o$ is the initial investment for the project. The investment's discount rate is denoted r, which is used to discount CF_i. CF_i represents the opportunity cost that the company could invest elsewhere. The NPV investment rule states that the firm should undertake the project if the NPV is positive (Berk and Demarzo, 2013).

2.4. The relevance of risk identification for a successful retrofit

The level of success in a retrofit project is linked to the management of risks. Risk identification is considered as one of the most important steps of risk management (Barati and Mohammadi, 2008; Rolstadås, 2008). The company should focus on answering the questions of whether the expected benefits justify the risk of failure, and how the possibilities of failing can be mitigated in a cost effective fashion. Further, Lozier (2010)

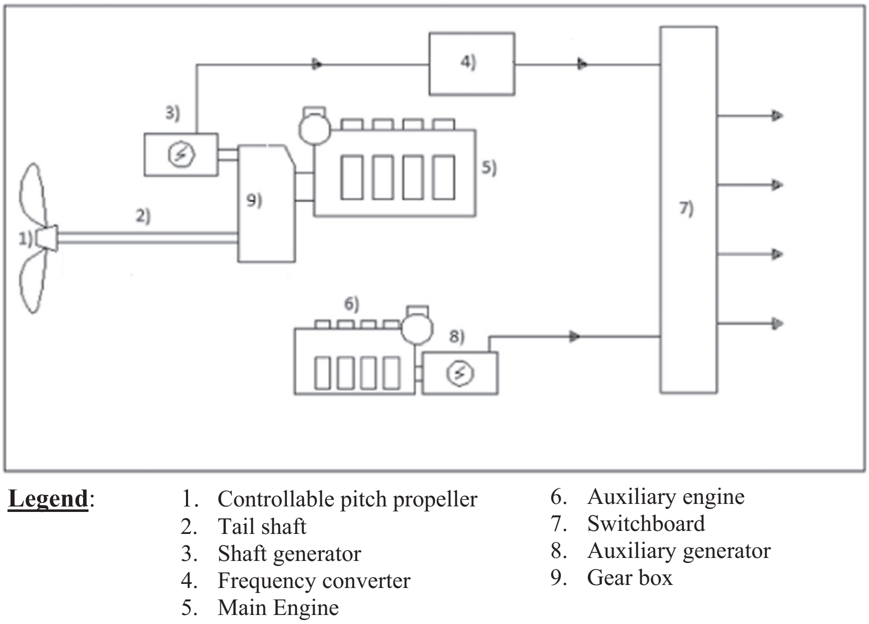

Fig. 1. Illustration of a SGFC arrangement.