International Journal of Engineering and Modern Technology (IJEMT) E-ISSN 2504-8848
P-ISSN 2695-2149 Vol 10. No. 8 2024 www.iiardjournals.org Online Version

The Potentials of Direct Current Grid System Assessment in Marine Vessels Application: A Case of Mv Victoria

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DOI:10.56201/ijemt.v10.no8.2024.pg61.68

Abstract
The maritime industry's growing need for energy efficiency and reduced environmental impact has driven the exploration of alternative power distribution methods, such as Direct Current (DC) grid systems. This study examines the potential benefits of integrating a DC grid system into marine vessels, using MV Victoria as a case study. Compared to traditional diesel propulsion systems, DC grids offer advantages like enhanced energy efficiency, better integration of renewable energy sources, and minimized energy losses. Through simulations of power flow, voltage stability, and system reliability, the research identifies significant improvements in fuel efficiency and greenhouse gas emission reduction, along with challenges like initial investment costs and safety concerns. The findings suggest that adopting a DC grid system could significantly modernize marine vessels by improving energy efficiency and meeting stringent environmental standards. Further research is recommended to address technical and economic challenges to encourage broader adoption of DC grids in the maritime sector.
Keyword: *Direct Current (DC) Grid System, Marine Vessels, Energy Efficiency, MV Victoria and Power Distribution Systems.*

Introduction

In response to these challenges, there has been growing interest in exploring alternative propulsion technologies that offer greater energy efficiency, reduced environmental impact, and enhanced operational performance (Rutkowski, 2017). Direct current (DC) grid systems have emerged as a promising solution, offering several potential benefits such as improved power distribution, enhanced control capabilities, and compatibility with renewable energy sources (Fonseca et al., n.d.). Despite the potential advantages of DC grid systems, their adoption in the maritime industry, particularly in regions like MV Victoria, remains limited. Factors such as technological complexity, infrastructure constraints, and economic considerations present barriers to the widespread implementation of DC technology in maritime propulsion systems.

In particular, inland canal transportation like that offered by Tanzania's MV Victoria is essential for boosting regional economy. It makes vital connections for trade, travel, and the movement of goods, greatly advancing regional growth. The MV Victoria, a well-known ship in the area, provides dependable and effective transportation services, acting as a key lifeline for communities. However, there are a lot of difficulties associated with the existing reliance on diesel-powered conventional propulsion systems (Ghorbani et al., 2020).

Furthermore, conducting an in-depth evaluation of DC grid systems for MV Victoria would inform strategic decision-making by stakeholders in the maritime industry, 8 government agencies, and local communities. It would enable them to understand the trade-offs and benefits involved, facilitating more informed and sustainable choices (Barrett et al., 2016). Ultimately, a successful transition to DC grid systems could serve as a model for other regions looking to modernize their maritime transportation infrastructure.

Therefore, the primary problem addressed by this study is the lack of empirical evidence and analysis regarding the feasibility, benefits, and challenges of implementing DC grid systems in MV Victoria propulsion. Understanding the technical, economic, and environmental implications of adopting DC technology is essential for stakeholders in the maritime industry, policymakers, and local communities to make informed decisions regarding propulsion system upgrades and investments in sustainable transportation infrastructure.

This statement of the problem highlights the gap in knowledge and the need for research to evaluate the potential of DC grid systems in MV Victoria propulsion, setting the stage for the study's objectives and methodology.

2. Methodology

The study employs a mixed-methods research design, integrating both qualitative and quantitative approaches to assess the feasibility of implementing a Direct Current (DC) grid system for MV Victoria's propulsion. Qualitative data was gathered through semi-structured interviews with key stakeholders to capture their insights and experiences, while quantitative data was obtained from surveys and technical assessments to evaluate performance metrics. The study area focuses on technical, economic, and environmental dimensions, exploring aspects like infrastructure compatibility, cost implications, and emission reductions. Secondary data from existing literature, documents, and technical reviews formed the basis for data collection. Both thematic and statistical analyses were used to analyze qualitative and quantitative data, respectively, and were integrated to ensure a comprehensive understanding. The study also incorporates mathematical models to assess economic metrics such as Total Cost of Ownership, Net Present Value, and Return on Investment. The validity and reliability of the data were ensured through pre-testing, pilot studies, and triangulation methods, while ethical standards were strictly adhered to throughout the research process.

3. Results and Discussion

This section presents the findings of the study, including the results of surveys and documentary review then technical assessments, and data analysis. The chapter provides a detailed analysis of the potential of direct current (DC) grid systems in MV Victoria's Electric DC grid propulsion system, highlighting key insights, trends, and implications.

3. 1 Environmental Impact Analysis

The calculation of carbonic gases was conducted utilizing the carbon footprint formula, which involves the integration of daily fuel consumption data and the carbon dioxide emission factor. By applying this formula, the emissions of carbon dioxide (CO_2) were determined with precision, providing insights into the environmental impact of the activities under consideration. Specifically, the daily fuel consumption served as a crucial parameter in estimating the volume of CO_2 emissions generated over a given period. Complemented by the CO_2 emission factor, which quantifies the amount of CO_2 emitted per unit of fuel consumed

3.1.1 Calculation of carbonic gases emission

Calculating the carbonic gases (specifically carbon dioxide, CO_2) produced from burning diesel fuel involves determining the amount of CO_2 generated per unit of diesel burned. The following method was used to get the carbon dioxide emission factor:

So, the CO_2 emission can be given as;

$$CO2\ Emissions = Fuel\ Consumption(in\ liters)xCO2\ Emission\ Faxtor\ \left(in \frac{Kg}{Liter}\right) \text{........(4.1)}$$

Whereby; CO_2 emission factor is 2.63 $KgCO_{2e}$/ liter

3.1.2 Sulfur dioxide emission

Calculation of Sulfur dioxide (SO_2) emission was done by referring to the formula of carbon footprint, The calculation of sulfur dioxide (SO2) emissions was conducted using the carbon footprint formula, which relies on the daily fuel consumption data and the sulfur dioxide emission factor.

$$SO2\ Emissions = Fuel\ Consumption(in\ liters)xSO2\ Emission\ Faxtor\ \left(in \frac{Kg}{Liter}\right) \ldots\ldots\ldots\ldots(4.2)$$

Where, SO_2 emission factor is 0.0001163$KgSO_2$/Liter

This method enabled the accurate estimation of SO2 emissions resulting from the activities under scrutiny. By leveraging daily fuel consumption as a foundational parameter, the volume of SO2 emissions generated within a specific timeframe was quantified. Complemented by the SO2 emission factor, which denotes the amount of SO2 emitted per unit of fuel consumed, this approach facilitated a comprehensive assessment of the environmental impact associated with the analyzed processes or activities

3.2 Operational Energy Cost Analysis.

The fuel cost was calculated using a simple method that involved multiplying the daily diesel fuel consumption by the current diesel price. This method provided an accurate estimate of the financial expenditure related to daily fuel use. By considering both the amount of diesel consumed each day and the prevailing fuel cost, this approach allowed for a precise assessment of the daily fuel expenses. This straightforward calculation ensured that the financial impact of fuel consumption was accurately captured, providing a clear understanding of the costs associated with diesel usage. The method effectively linked daily fuel consumption with market prices, enabling a reliable estimation of the overall fuel costs.

Where by the time the diesel selling price 3,172Tshs.

The fuel cost was determined using a straightforward formula, where the total cost of diesel fuel was calculated by multiplying the daily consumption of diesel fuel by the prevailing cost of diesel. This approach ensured a precise estimation of the financial expenditure associated with daily fuel consumption.

Calculations:

- *Fuel cost calculations:*

  $$Fuel\ cost = Daily\ consumption\ \times\ diesel\ selling\ price \text{........................ (4.3)}$$

  Where; during that time, the diesel selling price was 3,172 Tsh

- *Battery Capacity for H17RL series:*

  To determine the battery capacity required to run a H17RL - 960 series Electric DC grid motor delivering 960 kW for marine propulsion, we'll use the formula:

  $$Battery\ Capacity(KWh) = \frac{Power(kW)xDuration\ of\ Operation\ (hours)}{Efficiency} \text{..(4.4)}$$

  $$Battery\ Capacity(KWh) = \frac{960\ KWh}{0.90}$$

  Battery Capacity (Kwh) = 1066.666 kWh

- *Range Archived on a Single Charge:*

$$Range(Kilometers) = \frac{Battery\ Capacity(kWh)}{Energy\ Consumption\ rate/Kilometrs} \ldots\ldots\ldots\ldots\ldots\ldots (4.6)$$

3.4 **Environmental Impact Reduction**

According to the data, the MV Victoria has a notable environmental footprint, emitting about 190398.85 kg of $CO2$ and 8.1008209 kg of $SO2$ each month. This significant emission affects both terrestrial and marine ecosystems as well as human health by causing local air pollution and contributing to global warming. Making the switch to an electric DC grid vessel may be able to completely eliminate these pollutants, particularly if the electric DC grid is powered by renewable energy.

Such a shift has advantages for the environment that go beyond the short-term decrease in greenhouse gas emissions. Since electric DC grid vessels don't emit any exhaust, NOx, SOx, or particulate matter—all of which have a negative influence on the environment and human health—are eliminated. For example, NOx and SOx are involved in eutrophication and acid rain in aquatic habitats, which can result in the extinction of marine life. Reducing these emissions can benefit marine habitats near urban shipping routes immediately in terms of biodiversity and water quality. Moreover, the adoption of Dc-Grid can enhance the acoustic environment by significantly reducing noise pollution, a factor that contributes to stress in both aquaticand human life. Quieter vessel operations allow marine species such as cetaceans and fishes, which rely on sound for navigation and communication, to thrive withoutinterference from noise pollution.
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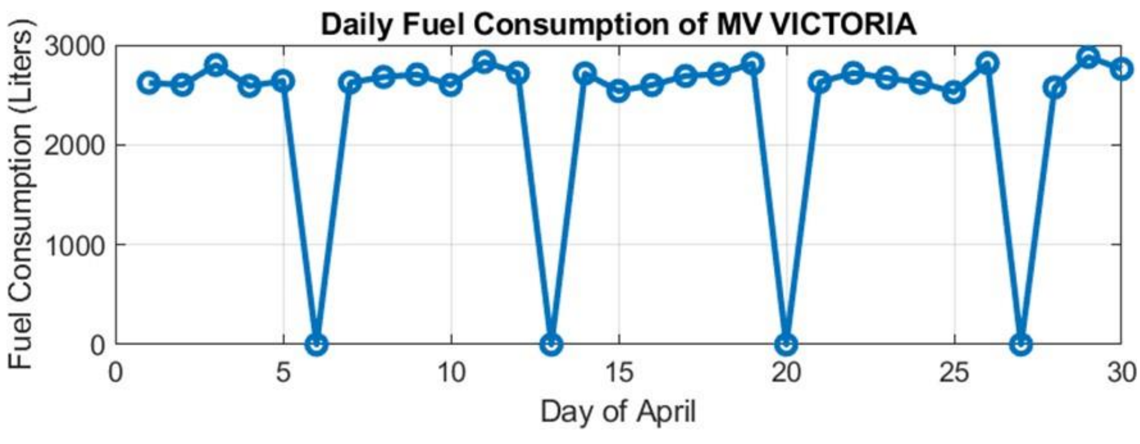

Figure 4.1: Fuel Consumption of MV Victoria

Reducing the negative effects on the environment is essential when switching from diesel to DC grid power. The transition to DC Grid vessels presents a substantial opportunity to reduce the environmental impact of maritime transportation, especiallyin urban areas and environmentally delicate zones. Large volumes of greenhouse gases(GHGs), mostly carbon dioxide ($CO2$), are released by diesel-powered vessels, contributing to climate change and global warming. According to User Data (2024), the diesel vessel MV Victoria emits roughly 190398.85 kg of

CO_2 and 8.1008209 kgof SO_2 every month. This highlights the substantial environmental impact that traditional maritime operations have on the environment. However, DC grids run on electric DC grids that may be powered by renewable energy, which means that when solar energy and other totally renewable sources are employed, GHG emissions are reduced to almost nothing. This shift is in line with international efforts to cut carbonemissions, as stated in the Paris Agreement (United Nations, 2015), which aims to keep global warming to far below 2 degrees Celsius over pre-industrial levels.

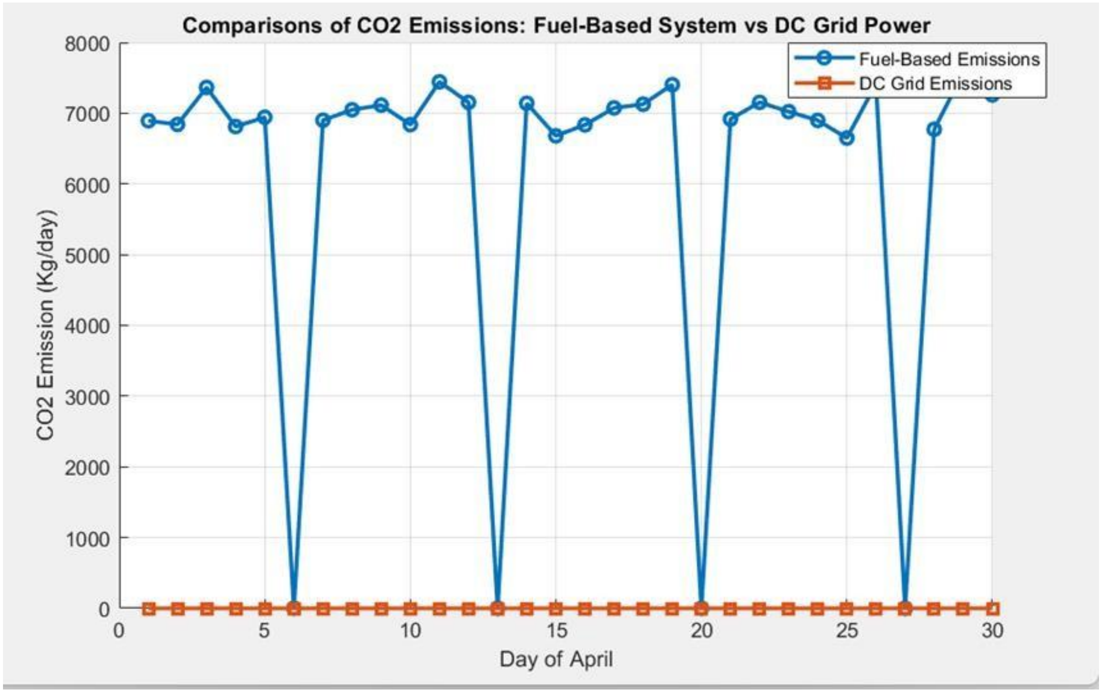

Figure 4.2**:** Comparisons of CO_2 Emissions Between diesel-based vessel and ElectricDC grid DC grid system

In addition to greenhouse gases (GHGs), diesel engines also release particulate matter,nitrogen oxides (NOx), and sulfur oxides (SOx), all of which are harmful to the public'shealth and the quality of the air. The air quality is greatly improved by DC grids, whichreduce these pollutants, especially in ports and heavily populated urban areas. Research has indicated that lowering marine vessel emissions can benefit local peopleliving near ports by improving respiratory health outcomes and lowering illnesses linked to poor air quality (Comer et al., 2020).

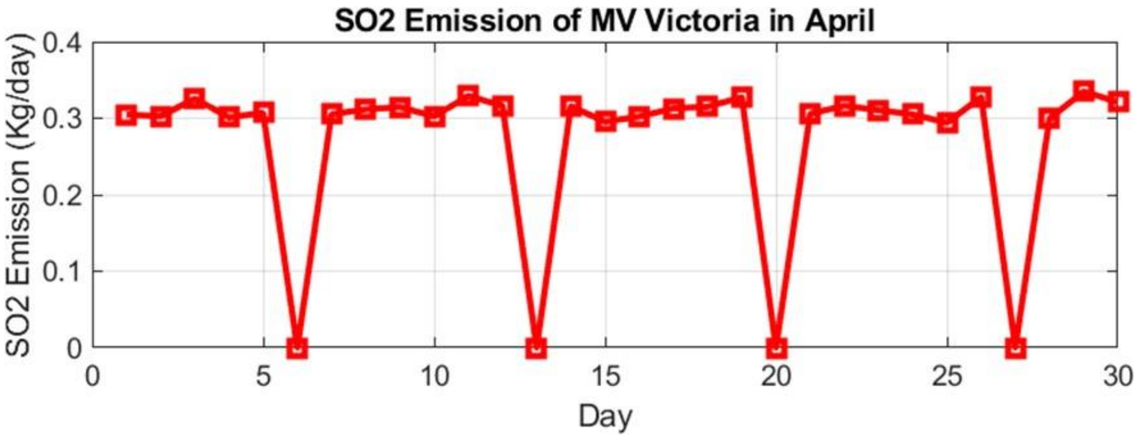

Figure 4.3**:** Rates of SO_2 Emissions

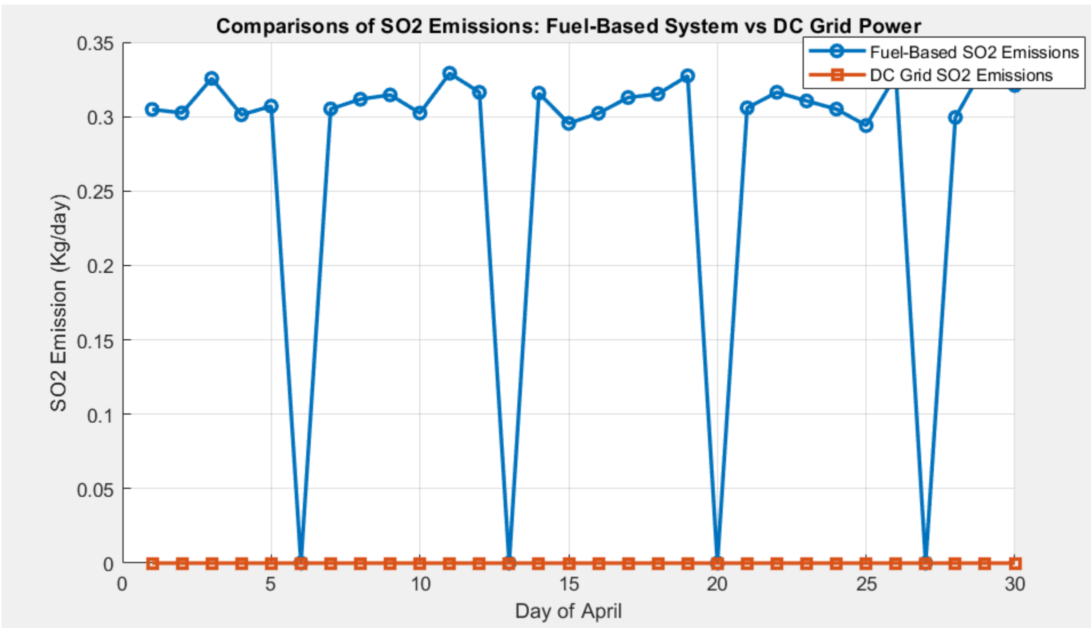

Figure 4.3**:** Comparisons of SO_2 Emissions Between diesel-based vessel and ElectricDC grid DC grid system

Vessels have an impact on the environment in many ways than only air quality; noiseand water pollution are major contributors. Significant underwater noise produced bydiesel engines can disturb marine ecosystems and have an impact on the survival behavior of marine animals, such as fish and whales (Hatch et al., 2019). Because electric DC grid motors are so much quieter, noise pollution and its effects on marinelife are lessened. Furthermore, the absence of oil spills and other pollutants from DC grid vessels contributes to the preservation of water quality, which benefits aquatic environments even more (Ocean Conservancy, 2022).

4. Conclusion

The conclusions of this study underscore the significant potential benefits of adopting DC grid systems for MV Victoria's Electric DC grid propulsion system. These benefits include enhanced energy efficiency, optimized power distribution, and improved environmental sustainability compared to traditional diesel propulsion systems. The study also identifies the technical challenges associated with implementing DC grid systems, such as infrastructure compatibility, safety concerns, and high initial investment costs, and proposes solutions to address these challenges, providing a thorough evaluation of the feasibility and impact of DC grid systems in maritime applications.

Transitioning to a DC grid system for ship propulsion presents several advantages over conventional diesel propulsion systems, particularly in terms of increased operational efficiency and reduced greenhouse gas emissions. The improved ability to integrate renewable energy sources, such as solar and wind power, further enhances the sustainability and energy optimization of vessels like MV Victoria. Given these benefits, the DC grid system emerges as a highly viable option for modernizing maritime operations and aligning with environmental regulations.

The recommendations derived from this study offer practical steps for advancing the research, policy, and technical aspects of DC grid systems in maritime applications. Future research should focus on evaluating the long-term performance and cost-effectiveness of these systems under different operational and environmental conditions. Policymakers are encouraged to develop supportive policies that incentivize the integration of sustainable DC grid propulsion technologies. Additionally, fostering stakeholder collaboration and addressing technical challenges through continued innovation in control systems and energy management strategies are critical for successful implementation. Together, these steps will facilitate the broader adoption of DC grid systems in the maritime industry, driving progress toward more sustainable and efficient propulsion solutions.

Acknowledgments

The author extends appreciation to the Department of Marine engineering, Dar es Salaam Maritime Institute (DMI) for success of this study. The author sincerely appreciates the support provided by my family on completion of this work.

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