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ENERGY EFFICIENCY STRATEGIES FOR OFFSHORE VESSELS WITH DYNAMIC POSITIONING SYSTEMS

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Abstract: The maritime and offshore sectors are under increasing pressure to reduce greenhouse gas (GHG) emissions in line with European Union regulations. Starting from January 2025, the revised EU Monitoring, Reporting, and Verification (MRV) framework extends its scope to offshore vessels above 400 Gross Tonnage. In this context, energy efficiency has come increasingly into focus of operational team of offshore vessels equipped with Dynamic Positioning (DP) systems. Aiming to identify the strategies to optimise fuel consumption and to improve energy efficiency in DP operations, the authors adopted a simulation-based approach using Kongsberg K-POS simulator. This research study analyses the performance of a DP-equipped vessel under varying environmental conditions, system settings, and operational modes. The results highlight several practical pathways for reducing energy consumption: lower gain, the use of green mode, and the optimisation of vessel heading relative to external forces. The conclusions confirm that strategic adjustments to DP system parameters and vessel orientation can yield meaningful reductions in fuel consumption and emissions, thereby lowering operational costs and supporting compliance with EU MRV requirements. This research demonstrates the utility of simulator-based analysis in evaluating energy efficiency strategies and provides practical insights for offshore operators seeking to improve sustainability and compliance to EU regulations.
Key words: dynamic positioning; energy efficiency; fuel consumption; greenhouse gas emissions; offshore vessels; simulations.

1. INTRODUCTION

Industries worldwide are under regulatory, economic, and environmental pressures to promote and drive sustainability objectives. One of the most pressing challenges for maritime industry and offshore operators is the reduction of greenhouse gas (GHG) emissions. The International Maritime Organization (IMO) has introduced several initiatives, such as the Energy Efficiency Design Index (EEDI) and the Carbon Intensity Indicator (CII), aimed at improving energy performance across the global fleet [1],[2],[3]. In parallel, the European Union has strengthened its Monitoring, Reporting, and Verification (MRV) Regulation [4],[5], requiring companies to submit GHG emissions report through EMSA portal [6]. As of 1 January 2025, the revised MRV framework extends its scope to include offshore vessels and general cargo ships above 400 GT, irrespective of flag or registration state [7]. This regulation obliges vessels to monitor, report, and verify emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), in addition to collecting operational data such as transported cargo, distance travelled, and time spent at sea [8].

Against this backdrop, energy efficiency has come increasingly into focus for offshore vessels equipped with Dynamic Positioning (DP) systems. While DP technology is indispensable for operations requiring precise station-keeping - such as offshore drilling, subsea construction, or wind farm installation - it is inherently energy-intensive. Maintaining a fixed position under the influence of wind, current, and waves demands continuous use of thrusters and generators, often leading to substantial fuel consumption and associated emissions. Thus, identifying strategies to optimise DP operations has become a central theme in both academic research and industry practice [9].

The purpose of this paper is to investigate and evaluate energy efficiency strategies for offshore vessels using Dynamic Positioning systems. The study employs a simulation-based methodology using the Kongsberg K-POS simulator, one of the most advanced DP training and research platforms available [10]. This approach allows for controlled experimentation under varying environmental conditions, operational modes, and system configurations, without the costs or risks associated with full-scale sea trials.

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Beyond the technical adjustments of DP system parameters, it is equally important to recognise the role of DP operator behaviour in shaping energy efficiency outcomes. While operational strategies are designed to limit power demand, fuel consumption, and emissions, their effectiveness ultimately depends on how they are applied in practice. Encouraging sustainable decision-making must therefore begin during simulator-based training, where operators can develop awareness of energy-efficient practices, and continue through consistent application on board vessels. In this way, technological solutions and human behaviour act in synergy to achieve meaningful improvements in efficiency and compliance with regulatory requirements.

The research design focused on three primary variables: (1) adjustment of gain settings, which influence the responsiveness of thrusters; (2) use of different DP operational modes (high precision, relaxed, and green); and (3) the vessel's heading relative to external forces such as wind and current. Through systematic variation of these parameters, the study emphasizes practical measures that reduce fuel consumption, and, consequently, greenhouse gas emissions.

2. METHODOLOGY

The methodology employed a simulation-based approach to analyse the energy efficiency of offshore vessels equipped with Dynamic Positioning (DP) systems. The study was conducted using the Kongsberg K-POS simulator, which provides a realistic operational environment for testing vessel performance under controlled conditions.

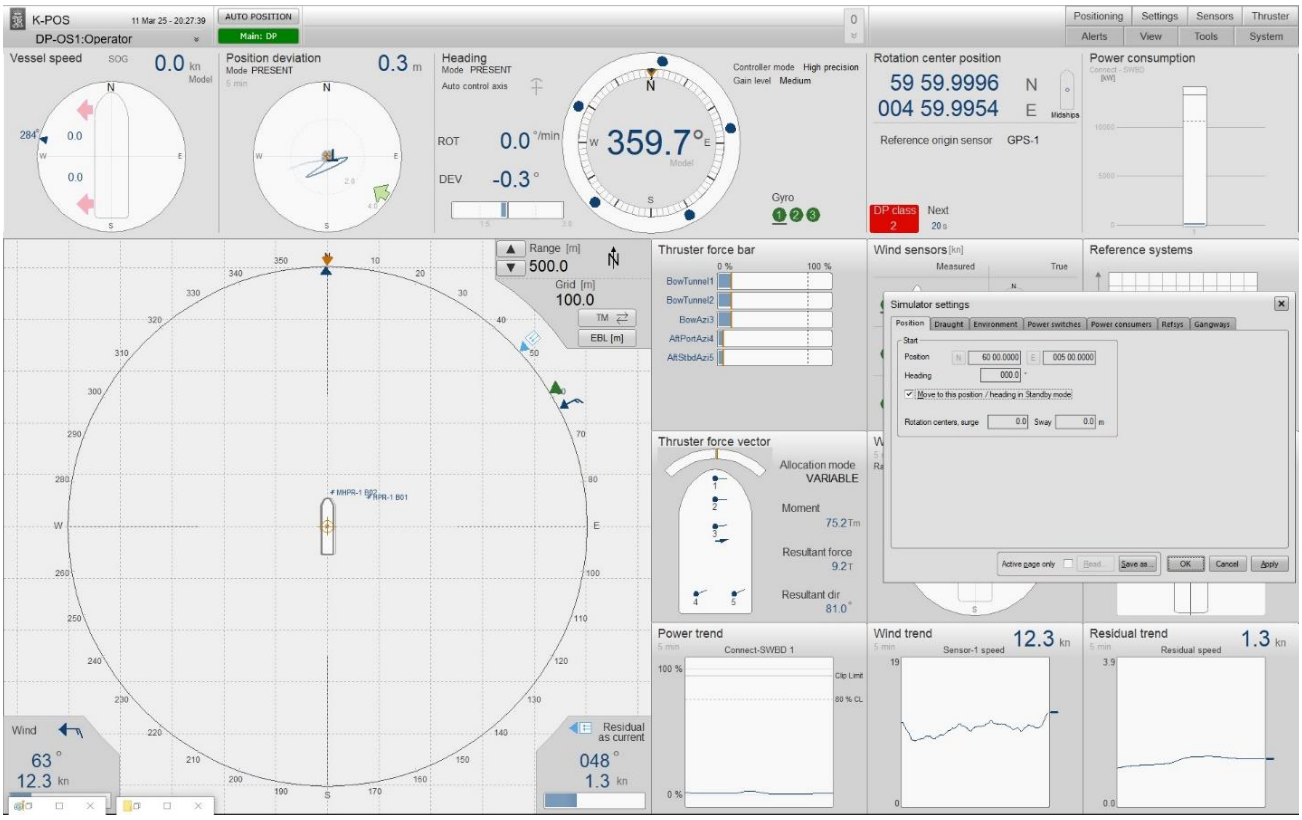

Figure 1 DP Kongsberg K-POS system interface

2.1 Simulation environment

The simulated DP vessel configuration comprises two bow tunnel thrusters, one azimuth thruster at the midship, and two azimuth thrusters at the stern. The control and monitoring display of the DP Kongsberg K-POS (Figure 1) integrates several key operational parameters, including the vessel's longitudinal and lateral speeds (ahead/astern and port/starboard), the real-time deviation from the reference position, and gyro data such as heading, rate of turn, and active gyro sensors. The interface also shows the coordinates of the vessel's centre of rotation, which can be adjusted according to the operator's preferences. The power is supplied by seven diesel-electric generators, monitored in real time through the simulator's Power Management System (PMS). The system allows tracking of energy production, distribution, and thruster load under different operational scenarios [11]. To replicate realistic offshore operations, the following baseline conditions were introduced: wind: 10 kN from 60°, current: 1 kN from 45°, wave height: 1 m from 60° with a 4 s period. These values were later varied to assess system behaviour under increasing external forces.

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2.2 Operational parameters tested

The methodology includes systematic variation of three sets of variables: gain, DP control modes, and heading, as well as the observation of the performance metrics: total power demand (kW), fuel consumption implications, positional deviation (m) relative to the set point, and capability limits of the vessel under different environmental forces.

2.3 Data analysis

Data were collected from simulator logs and visual interfaces (PostPlot, PMS, and capability plots). The analysis focused on evaluation of energy consumption trends across different configurations, with particular attention to energy savings from reduced gain and "Green" mode, the trade-off between precision and fuel efficiency, and the impact of vessel heading on thruster demand.

3. RESULTS AND ANALYSIS

The simulations conducted on the Kongsberg K-POS platform provide insights into how Dynamic Positioning (DP) operations can be optimised for improved energy efficiency. The results are structured according to the main parameters tested, with references to the simulator's graphical outputs.

3.1 Baseline DP Operation

To analyse the vessel's behaviour in Dynamic Positioning mode, the following external conditions have been introduced in the simulator: wind of 10 kN from 60°, current of 1 kN from 45°, and waves of 1 m from 60° with a period of 4 seconds. These values are variable, to make the simulation as close to reality as possible. The vessel is set in DP mode, maintaining position as shown at the top of the figure, with speed at 0 kN, deviation from the set point of 0.3 m, and the system constantly adjusting to keep deviation as close to zero as possible. The vessel's heading was set at 0°.

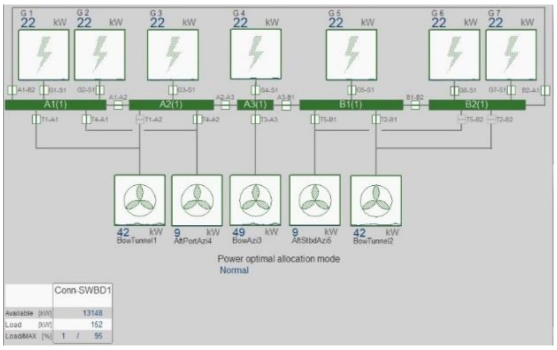

Figure 2 DP Power Management System

The Power Management System comprises seven diesel-electric generators (G1–G7) with an interface that allow real-time monitoring of the kW output of each generator. They are connected to a single distribution board (for simplicity in this simulator configuration). However, in DP2 or DP3 class operations, redundancy requires two distribution boards, reducing the risk of losing all thrusters simultaneously and enabling the vessel to maintain position in case of system failures. From the distribution board, power is supplied to the thrusters, displayed at the bottom of the figure, with their real-time kW consumption. Next to it, the additional data shows 13,148 kW as total generation capacity and 152 kW as the current load.

The DP system uses an algorithm to calculate the vessel's station-keeping limits for headings between 0°–359°, accounting for external forces. This is emphasised in the capability plot (Figure 3). At the centre, the blue contour diagram represents maximum wind forces the vessel can withstand while maintaining position for each heading. At the lower side, 56.6 kN is shown as the maximum wind speed the vessel can resist at 0° heading. The plot demonstrates that a heading near 60° is far more favourable than 0°, enabling position-keeping with lower energy consumption. Under stronger wind forces, the vessel could maintain position at winds up to approximately 130 kN when heading 60°.

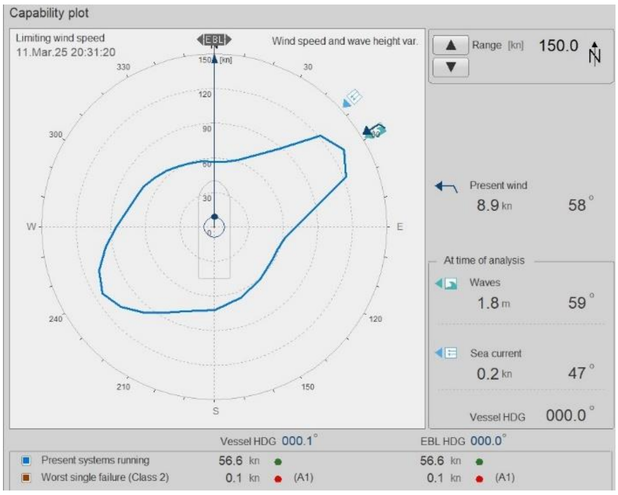

Figure 3 Capability Plot

The Capability plot also includes the "Worst single failure" condition. Although not applicable in this single-board configuration, in a dual-board setup this value would show the maximum wind under which the vessel can still maintain position after losing the most critical board and thrusters. In this case, however, the loss of the only distribution board would disable all thrusters, meaning a mere 0.1 kN wind would be enough to cause loss of position and drifting.

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As external forces intensified (wind 25 kN, current 1.3 kN), thruster demand grew substantially, raising generator load to 698 kW (Figure 4).

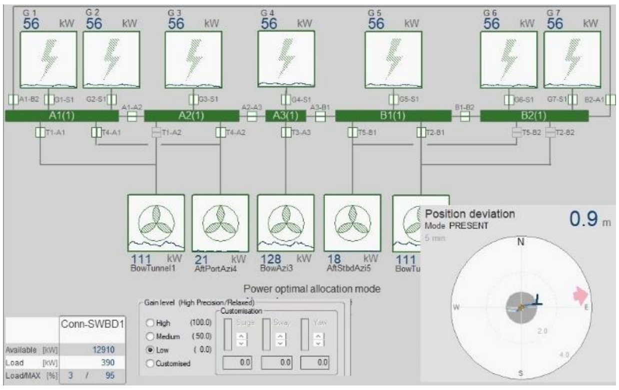

Figure 4 Increase of external forces

This directly linked fuel consumption to environmental conditions, underscoring the importance of adaptive operational strategies.

3.2 Adjust of gain settings

A parameter that directly affects fuel consumption is gain adjustment. Gain determines the "aggressiveness" of thrusters in position-keeping, with four settings: high, medium, low, and custom (user-defined percentages for surge, sway, and yaw).

- High gain provides the most precise station-keeping but at the cost of maximum fuel use.
- Medium and low settings reduce thruster workload and fuel consumption, though with larger positional deviations.

Thus, gain selection must balance required accuracy with weather conditions; high gain is not recommended in calm seas as it unnecessarily increases fuel use.

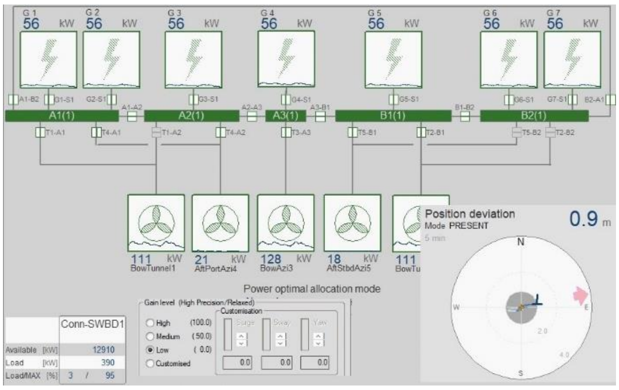

Figure 5 Low gain

Figure 5 shows energy demand under low gain, reduced to 390 kW compared with 698 kW at medium gain, but with deviation increasing to 0.9 m.

3.3 DP Control Modes: High precision, Relaxed, and Green

Although "High precision" mode is the most common DP control setting, some systems include "Relaxed" and "Green" modes designed to reduce energy consumption and equipment wear.

In "Relaxed" mode, the vessel maintains position within an operator-defined circular zone rather than a fixed point. While this reduces thruster demand, the vessel may leave the zone temporarily before DP commands higher thrust to re-enter. This mode is suited to calm conditions.

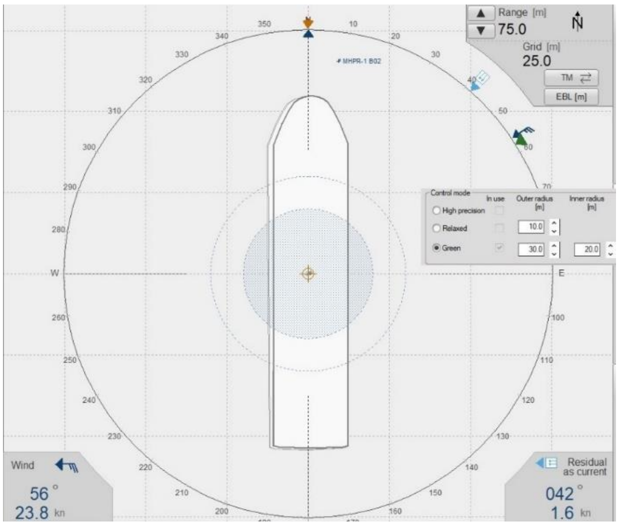

Figure 6 "Green" mode

The "Green" mode, shown in Figure 6, is more advanced. It uses predictive algorithms to minimise thruster operation while keeping the vessel inside a predefined zone between an inner and outer circle. It is more energy-efficient than "High precision" and more accurate than "Relaxed" mode. This makes it applicable in a broader range of operating conditions. Figure 7 illustrates reduced load under "Green" mode: 580 kW compared to 698 kW in High precision", both at medium gain.

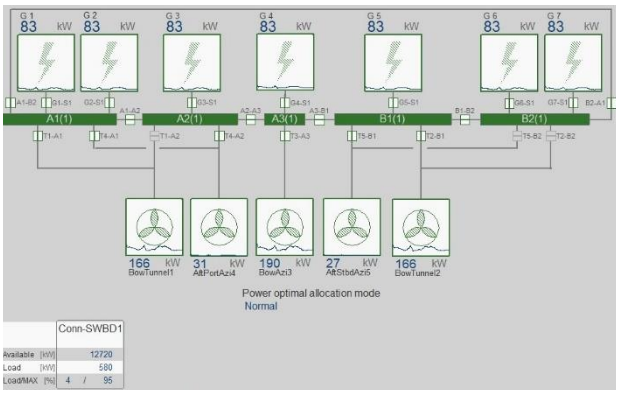

Figure 7 Energy consumption in "Green" mode

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3.4 Change of heading

Another critical factor for fuel consumption is vessel heading. As indicated in the capability plot (Figure 3), energy demand is significantly affected by orientation relative to wind and current. When positioned with the bow into prevailing forces, exposed surface areas are reduced, lowering resistance. Figure 8 shows vessel heading adjusted to 61°.

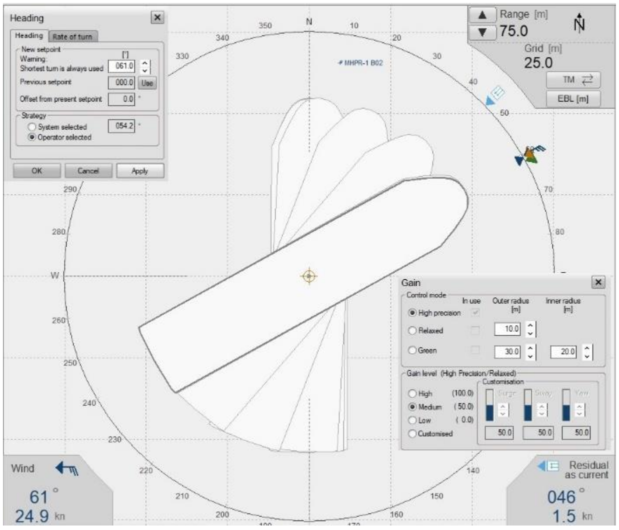

Figure 8 Change of Heading

Figure 9 confirms the efficiency gain: power demand dropped from 698 kW at 0° heading to 36 kW at 61°, both at medium gain. This demonstrates substantial fuel savings. Heading optimisation is therefore essential in DP operations, within the limits of operational safety and mission requirements.

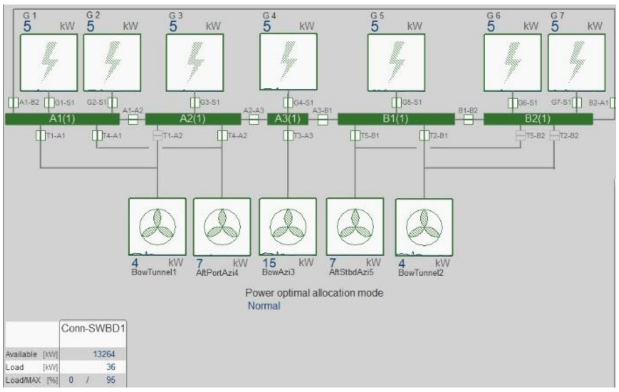

Figure 9 Energy Consumption at 61° Heading

4. DISCUSSION

The simulations clearly demonstrated that three operational strategies have the greatest impact on improving energy efficiency during DP operations:

Gain adjustment – Lowering gain settings (from medium to low) reduced overall power demand from 698 kW to 390 kW, albeit with a modest increase in positional deviation (0.9 m). This illustrates the trade-off between accuracy and efficiency: in calm environmental conditions, a less aggressive gain setting can deliver significant fuel savings without compromising operational safety.

Control mode selection – Employing alternative DP modes such as green or relaxed significantly reduced thruster activity compared to the default high precision mode. The green mode, in particular, achieved a reduction from 698 kW to 580 kW while maintaining acceptable accuracy. These findings suggest that operators can achieve meaningful fuel savings by tailoring DP mode selection to operational requirements, especially in standby or low-risk conditions where absolute positional accuracy is not mandatory.

Heading optimisation – Adjusting vessel orientation relative to wind and current produced the most substantial energy savings. For example, changing heading from 0° to 61° reduced power demand from 698 kW to only 36 kW. This highlights the critical role of navigational planning in minimising thruster workload. Heading optimisation should therefore be considered a primary strategy whenever safety and operational constraints allow, as it can reduce both fuel consumption and emissions by an order of magnitude.

Together, these strategies demonstrate the potential for operational decision-making to substantially reduce fuel consumption and associated greenhouse gas emissions in DP operations. Importantly, the study shows that such reductions do not necessarily require costly retrofits or new technologies, but can be achieved through informed adjustments to existing DP system parameters. This provides practical guidance for offshore operators seeking to comply with the extended EU MRV regulation

5. CONCLUSIONS

The analysis conducted on the Kongsberg K-POS simulator identified several methods that can significantly contribute to reducing fuel consumption in Dynamic Positioning (DP) operations. Each factor studied had a measurable impact on the vessel's energy efficiency, and the findings provide practical solutions for optimising fuel use in offshore activities.

First, gain adjustment proved essential in reducing energy demand. Using a lower gain setting, such as Low Gain, resulted in a significant decrease in thruster load, leading to lower fuel consumption. While this adjustment may increase positional deviation, under favourable weather conditions the compromise is acceptable given the benefits of reduced energy use.

Second, the activation of the "Green" mode delivered notable energy savings without substantially compromising station-keeping accuracy. In this mode,

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the DP system applies predictive algorithms to minimise thruster activity, making it far more efficient than the standard high precision mode. This is especially valuable in calm operational environments, where the vessel is not exposed to high external forces such as strong wind or current.

Another critical finding was the influence of vessel heading on fuel consumption. Adjusting the vessel's orientation relative to wind and current had a major impact on energy efficiency. This emphasises the importance of selecting an optimised heading that minimises thruster load and enables substantial energy savings.

In terms of power management, careful monitoring of each thruster and balanced distribution of load across the generators improved the efficiency of the DP system. Load on the distribution board varied according to external conditions, and by adjusting system parameters such as gain settings and control modes, total fuel consumption was significantly reduced without compromising the vessel's essential performance.

In conclusion, by implementing targeted fuel-saving strategies - adjusting DP control parameters, using more energy-efficient modes, and selecting favourable headings relative to environmental conditions - it is possible to achieve meaningful reductions in energy consumption. These measures not only lower operational costs but also support environmental protection by reducing CO_2 emissions.

Ultimately, achieving lasting improvements in fuel efficiency and emissions reduction requires not only technical optimisation but also behavioural change, with sustainability becoming an integral part of operator decision-making and maritime practice.

However, the study is limited by its reliance on simulation data, and future research should validate these findings through full-scale trials under real offshore operational conditions to further refine energy efficiency strategies.

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