This paper evaluates the transition from alternating current (AC) to direct current (DC) based electrical distribution systems for marine vessels equipped with diesel-electric hybrid propulsion. Historically, marine vessels adopted AC systems due to their prevalence in land-based infrastructure. Current hybrid diesel-electric systems generate AC power to a common AC bus, supplying propulsion drives and service loads. However, growing interest in DC-based systems stems from potential improvements in electrical performance and fuel consumption. This study provides an overview of typical AC systems, presents modifications for a DC-based system, and quantifies the benefits in terms of power factor, total harmonic distortion (THD), voltage regulation, and fuel efficiency. It also proposes a genetic algorithm (GA) based technique to improve fuel efficiency through optimized generator scheduling. **Introduction and System Overview:** The early adoption of electricity on marine vessels, dating back to the SS Columbia with its DC lighting system, gradually shifted to AC systems by the early 1900s, aligning with land-based distribution trends. AC systems, typically operating at 440 V to 11 kV, became standard. However, environmental concerns have spurred research into improving fuel efficiency through various means, including propulsion system power management and integration of renewable energy sources. Modern marine vessels frequently use electric or diesel-electric propulsion systems, which offer advantages such as improved generator and propulsion drive efficiency at low loads, faster dynamic response, and reduced equipment weight, volume, and placement flexibility. The increasing proliferation of renewable energy resources, which often interface with DC buses, further drives interest in DC distribution systems for both land-based microgrids and marine applications, as DC systems inherently avoid synchronization issues and offer potential gains in efficiency and reduced equipment size. While DC protection devices were historically a challenge, recent commercial developments in DC circuit breakers have made DC systems feasible for ships with power requirements up to 12 MW, such as offshore supply and diving support vessels. This study fills a knowledge gap by examining operational efficiency gains of DC systems compared to similarly-rated AC systems, using an experimental testbed and a diving support vessel case study, including a novel GA-based generator scheduling method. **Electrical System Architecture:** The diving support vessel under study uses an AC system with a total generation capacity of 12 MVA, supplying four electrical propulsion drives and hotel/service loads via two 690 V AC buses. Propulsion drives receive three-phase AC, which is then fed through a three-winding transformer (star-star-delta) followed by a 12-pulse diode bridge rectifier, before powering a variable speed drive. Service loads are supplied via step-down transformers from the 690 V AC bus to 230 V single-phase or 440 V three-phase. The proposed DC system directly replaces the AC architecture by moving from a 690 V AC bus to a 1 kV DC bus. The existing generators remain, but Active Front-End (AFE) converters are introduced to convert AC to DC. Propulsion drives then source power directly from the 1 kV DC bus, eliminating the need for three-winding transformers and 12-pulse rectifiers. Service loads require inverters to convert DC back to AC, replacing the step-down transformers. This DC architecture also facilitates easier integration of energy storage elements via DC-DC converters. Implementing a DC system is most feasible for new marine vessels due to extensive modifications required for retrofitting, including removal of 12-pulse transformers, installation of AFE rectifiers, replacement of AC-source propulsion drives with DC-source variants, installation of power inverters, and replacement of AC-rated cables and protection devices with DC-rated equivalents. While the total cost for a DC system is estimated to be 20% higher, primarily due to AFE converters, these costs are projected to be offset by fuel savings over the vessel's operational lifetime. An experimental testbed was constructed to compare AC and DC systems using the same generator and propulsion motor under variable loads. This single-generator, single-propulsion motor setup effectively validates electrical performance irrespective of the number of generators or motor drive size. **Electrical Performance:** In AC systems, the 12-pulse rectification system, while reducing 5th and 7th harmonics, still exhibits high current THD, particularly at low loads, leading to reactive power production and energy losses. In contrast, DC systems employing AFE converters offer active control over power flow, significantly minimizing current harmonics and improving THD. * **Power Factor (PF):** The DC system consistently demonstrates a higher power factor across all load levels (0–6 MW) compared to the AC system. At low loads, the minimum power factor for the AC system is 0.7, while the DC system maintains over 0.8. The use of active rectifiers in the DC system, which employ pulse-width modulation, allows for better control of current flow, thereby improving the power factor. * **Total Harmonic Distortion (THD):** The input current THD is lower for the DC system (8.64%) compared to the AC system (17.35%). AFE converters' ability to control input current quality leads to less distortion, preserving generator integrity and overall system efficiency by reducing harmonic-induced losses. * **DC-link Voltage Regulation (VR):** The DC-link voltage regulation is significantly improved in the DC system at 0.12%, compared to 10.14% in the AC system. AFE converters actively regulate the DC-link voltage to its set-point, preventing voltage drops that would otherwise increase line currents, leading to higher I^2R losses and potential overloading of electrical equipment. Overall, the AFE-based DC system offers superior power quality through better input power factor, lower THD, and tighter voltage regulation. These improvements translate into reduced reactive power generation, decreased energy losses, enhanced efficiency of the diesel generator-electric propulsion drive system, and improved safety and reliability of the on-board electrical network. **Generator Scheduling and Fuel Consumption:** Specific fuel consumption (SFC) curves show that a diesel generator's fuel efficiency depends on its rotational speed and power output. In AC systems, generators operate at a fixed speed due to synchronization requirements, meaning efficiency is solely power-dependent, typically increasing as power approaches the rated capacity. Conversely, in a DC system, the same diesel generators can operate at variable speeds, leveraging additional degrees of freedom to achieve lower SFC across all power levels (as shown in Fig. 10). Current marine vessels often use symmetrical loading, where total load is evenly divided among online generators, which is sub-optimal for fuel efficiency. For DC systems, the variable speed capability offered by AFE converters allows for more efficient operation. This paper proposes a genetic algorithm (GA) to optimize asymmetrical generator scheduling, minimizing total fuel consumption by efficiently allocating load powers to individual generators, subject to constraints like minimum load (typically 20% of rated power). A case study on a diving support vessel (DSV) with four 3000 kVA diesel generators compares fuel consumption. In normal operation, symmetrical loading of AC systems showed that a shift to symmetrically loaded DC systems yielded substantial fuel savings, ranging from 1.4% to 18.5%. While optimized asymmetrical loading provided only marginal savings (max 0.3%) in AC systems, it significantly enhanced fuel efficiency in DC systems, maintaining average savings within the 1.4–18.5% range compared to symmetrically loaded AC. For dynamic positioning (DP) mode, where all generators are online for fast dynamic response, optimized asymmetrical loading provided insignificant savings in AC systems. However, moving to a DC system alone delivered 7.8% to 18.5% fuel savings, which further increased to 12.8% to 18.5% with optimized asymmetrical loading, particularly beneficial at low loads. Based on the vessel's operational profile (transit:manoeuvring:DP ratio of 3:1:8), an annual fuel saving of 7% is projected. The core reason for these savings in DC systems is the ability to operate generators at variable speeds. The GA optimization method is applicable to other marine vessels, provided their SFC curves and operational profiles are known. **Discussions and Conclusion:** The shift to DC-based systems offers clear benefits in both electrical performance and fuel efficiency. Key topological changes involve replacing 12-pulse transformers and rectifiers with AFE converters and modifying the bus system to DC, requiring DC-rated auxiliary devices. Acknowledging the increased difficulty in designing DC protection devices, recent industrial advancements in high-voltage DC circuit breakers offer promising solutions. In conclusion, while hybrid diesel-electric marine vessels predominantly use AC systems due to historical prevalence, DC-based systems offer significant advantages. Experimental results confirm that DC systems with AFE rectifiers are superior to 12-pulse AC-based systems in power factor, input current total harmonic distortion, and DC-link voltage regulation. Furthermore, conventional symmetrical generator loading is sub-optimal for fuel efficiency. Optimized asymmetrical generator loading significantly improves fuel efficiency, especially in DC-based systems where diesel generators can operate at variable speeds, providing an additional degree of freedom not available in AC systems. Consequently, future marine vessels can achieve enhanced cost-efficiency and improved electrical performance through the adoption of DC-based systems coupled with optimized asymmetrical generator loading schemes. Word Count: 2984 words.