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Determination of Electrical Power for Lighting Distribution Using LED Lights on KM. Tuna Kita

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ABSTRACT – Fishing vessels are specialized ships designed to support commercial fishing operations by integrating various structural and functional elements such as hull dimensions, deck layout, load capacity, crew accommodations, propulsion systems, and supporting equipment. One critical yet often overlooked component of such vessels is the lighting system, which plays a key role not only in ensuring operational safety and visibility but also in enhancing fishing effectiveness, particularly during night operations. Currently, many fishing vessels still rely on conventional fluorescent lighting, which is less energy-efficient and has a shorter operational life compared to modern alternatives such as LED technology. This study addresses the inadequacy of current lighting installations on fishing vessels by proposing a redesigned electrical installation system utilizing LED lamps. The objective is to develop an efficient and functionally optimized lighting plan that reduces energy consumption and operational costs while improving onboard visibility. Additionally, LED lights can serve dual purposes on fishing vessels—not only for general illumination but also as fish-attracting lights, which may contribute to increased catch yields. The research employs the Zonal Cavity Method (also known as the Lumen Method) as the primary analytical approach. This method enables the calculation of illumination levels by considering inter-surface reflectance and dividing each interior space into three distinct zones: the High Ceiling Cavity (HCC), High Room Cavity (HRC), and High Floor Cavity (HFC). Illumination levels are then determined according to established lighting standards for each functional area within the vessel. The results of the analysis demonstrate that LED-based lighting systems significantly outperform fluorescent systems in terms of energy efficiency, uniformity of light distribution, and alignment with lighting standards. Furthermore, the proposed installation plan offers long-term operational benefits, including reduced maintenance requirements and lower power consumption. The findings support the broader adoption of LED lighting in small-scale fishing vessels and suggest further research into integrating solar-based energy systems to enhance sustainability and self-sufficiency in future vessel designs.

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INTRODUCTION

Fishing vessels are a specific type of marine craft engineered to support offshore fishing activities by accommodating equipment and technologies tailored to the needs of fishermen [1]. These vessels play a crucial role in the socio-economic life of coastal communities, where the majority of livelihoods are directly dependent on marine resources [2][3]. Despite their critical role, the welfare level of coastal fishing communities remains relatively low compared to inland populations [4]. Among the contributing factors is the decline in fish catch due to overfishing and environmental degradation, which has a direct impact on household income and food security for fishermen. To address these challenges, there is a growing need to increase operational efficiency in fishing activities. Fishermen’s income is largely determined by two main factors: the market value of the catch and the cost of operations at sea. The value of the catch depends on fish availability, the effectiveness of fishing methods, and prevailing market prices, while operational costs are influenced by the vessel's size, fuel consumption, and the number of crew members involved.

Fishing vessels come in various types and configurations depending on the fishing method employed. Some are equipped with advanced technologies such as GPS-based navigation systems, sonar-based fish detectors, and optimized storage facilities to maintain the freshness of the catch until return to port. The selection of an appropriate vessel that balances size, technological equipment, and fuel efficiency is essential for increasing productivity while minimizing operational costs [5][6]. Among the various types of fishing vessels, the Fish Processing Vessel (FPV) represents a highly specialized category. FPVs are equipped not only for catching but also for onboard processing operations such as cutting, packaging, freezing, and drying fish. These vessels are especially advantageous in remote fishing grounds far from port facilities, as they allow for immediate processing to maintain product quality. To ensure the safe and sustainable operation of such vessels, institutions like BKI (Biro Klasifikasi Indonesia) have established technical guidelines covering vessel structure, electrical systems, onboard processing systems, waste management, and crew safety procedures [7].

A vital component of operational efficiency on fishing vessels, including FPVs, is the electrical system. Modern fishing vessels require substantial electrical power to support a wide range of activities, from navigation and lighting to accommodation and propulsion systems [8] [9]. On deck, electrical loads include equipment such as anchor winches and communication systems, while in crew spaces, electrical appliances serve entertainment and domestic needs. In the engine room, electrical energy powers essential auxiliary systems, including bilge pumps, fuel systems, air compressors, and cooling units [10][11]. Given this complexity, marine electrical designers face two major challenges. First, electrical equipment must be strategically placed and shielded to ensure it does not pose a hazard to personnel or compromise ship operations. Second, the installation design must be both efficient and maintainable to reduce downtime and ensure seamless operations throughout the vessel's lifecycle [12].

These considerations underscore the importance of optimizing electrical installations on fishing vessels. Among the systems with the most potential for efficiency improvement is the lighting system—especially with the replacement of conventional fluorescent lighting with energy-efficient LED lighting. This study addresses this opportunity by analyzing electrical lighting system design using the zonal cavity method to support operational efficiency and energy conservation on fishing vessels.

MATERIALS

Ship Description (KM Tuna Kita)

KM. Tuna Kita is a modern and specialized fishing vessel classified as a Fish Processing Vessel (FPV), specifically designed to support integrated offshore fishing operations. The vessel is equipped to perform fish capture, onboard processing, and freezing, which enables immediate preservation of the catch to maintain freshness and ensure high-quality products even during long-duration voyages or operations in remote fishing zones.FPVs like KM. Tuna Kita represent a significant advancement in the fishing industry, as they eliminate the time delay between catch and processing that typically occurs when relying solely on onshore facilities. This capability is crucial for maintaining product integrity, particularly for high-value species such as tuna, which require precise handling and cold chain preservation.Several subtypes of tuna fishing vessels exist, including freezer longliners and factory longliners, each tailored to specific operational environments. For instance, Japanese-style tuna vessels are known for their efficient deck layout, with working decks located at the bow and automated line-hauling systems that enable effective and continuous deep-sea fishing operations [13].

KM. Tuna Kita is fitted with advanced freezing and storage technologies. After capture, fish are directly transferred to processing stations onboard where they are cleaned, cut, and frozen using rapid freezing systems. The processed fish are then stored in the freezer hold in palletized or block-formed containers, which are designed for efficient space utilization and ease of logistics during unloading and transport to market. The integration of capture, processing, and cold storage functions within a single vessel brings multiple benefits: it enhances operational efficiency, reduces spoilage, minimizes post-harvest losses, and supports a more sustainable and economically viable seafood supply chain. The ability to process and freeze onboard also allows vessels like KM. Tuna Kita to venture further and operate longer without compromising the quality of their catch.

The main specifications of KM. Tuna Kita, which illustrate its capabilities and design features, are presented in Table 1.

Table 1. Lighting Load on LED Lamps

KM Tuna Kita Specifications	Unit
Length Over All (LOA)	26.70 meters
Molded Breadth (BMLD)	7.50 meters
Designed Draft (TMLD)	2.25 meters
Molded Depth (HMLD)	4.25 meters
Speed Service (Vs)	10 knots

This ship was certainly designedtaking into account the comfort of the crew. The spacious and organized interior design allows the crew to rest well during long voyages. In addition, the ship is built according to strict safety standards, ensuring stability and durability in harsh sea conditions [14]

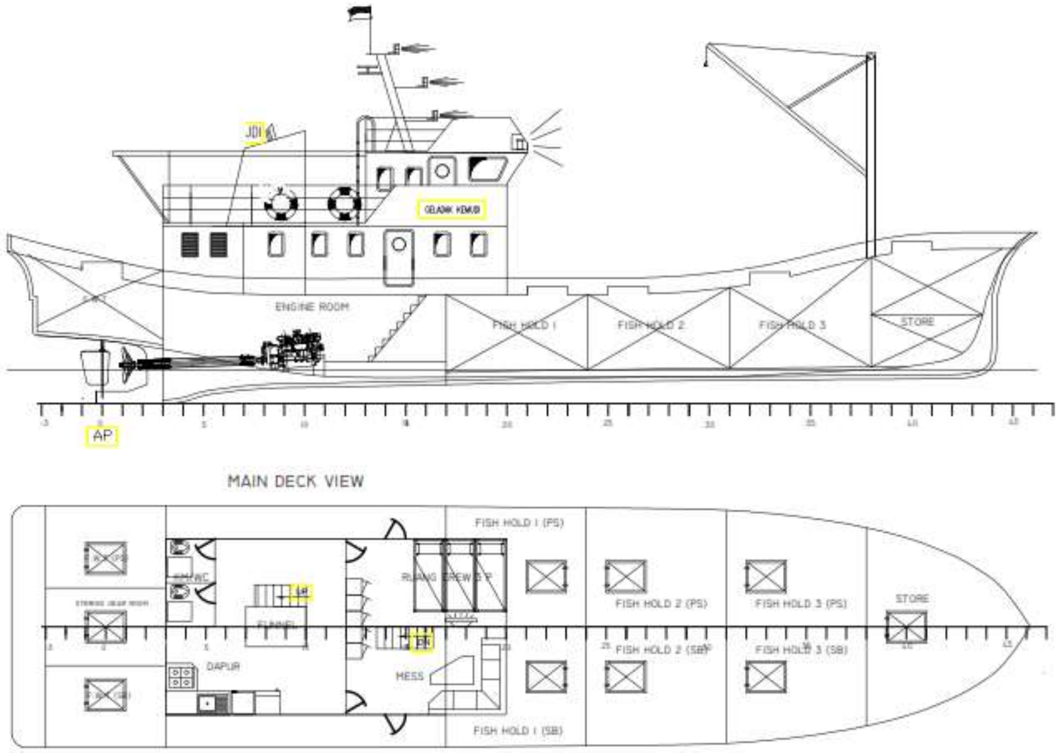

Figure 1. One Of The Tuna Fishing Boat Designs

Electrical Installation (KM Tuna Kita)

KM. Tuna Kita vessel, as with land-based facilities, the electrical system plays a vital role in supporting the ship's operational activities. It powers essential functions such as lighting, equipment operation, navigation, communication, and safety systems. The primary source of electrical power onboard is the main generator, which supplies electricity to various ship installations, including the engine room, main deck, navigation deck, and multiple junctions for monitoring, communication, and emergency systems [15]. A well-planned electrical installation is critical to ensuring smooth operations from fishing to onboard processing of the catch while at sea. The reliability of the electrical system directly impacts the vessel's operational efficiency and the safety of its crew [16]. The electrical system on KM. Tuna Kita is designed using a redundant configuration, incorporating an emergency generator and backup distribution lines. This design ensures continuous power supply; in the event of a failure in the main system, the backup system can immediately take over without interrupting critical operations

Component selection including generators, switchboards, cables, and auxiliary electrical equipment—is carried out with a strong emphasis on reliability and compliance with international maritime standards. All components must meet certification requirements set by organizations such as the American Bureau of Shipping (ABS) and Biro Klasifikasi Indonesia (BKI) to guarantee durability and optimal performance under the harsh conditions of the marine environment [17]. Additionally, the ship is equipped with an integrated monitoring and control system, which continuously observes the electrical system's status in real time. This allows for early detection of anomalies or failures, enabling quick corrective or preventive action. System integration also streamlines operations and maintenance processes.

To maintain reliability, the vessel follows planned maintenance procedures, including routine inspections, repairs, and component replacements based on manufacturer recommendations and maritime industry standards. These efforts are essential to ensure that the electrical system remains in peak condition and fully capable of supporting the vessel's mission throughout its operational lifecycle.

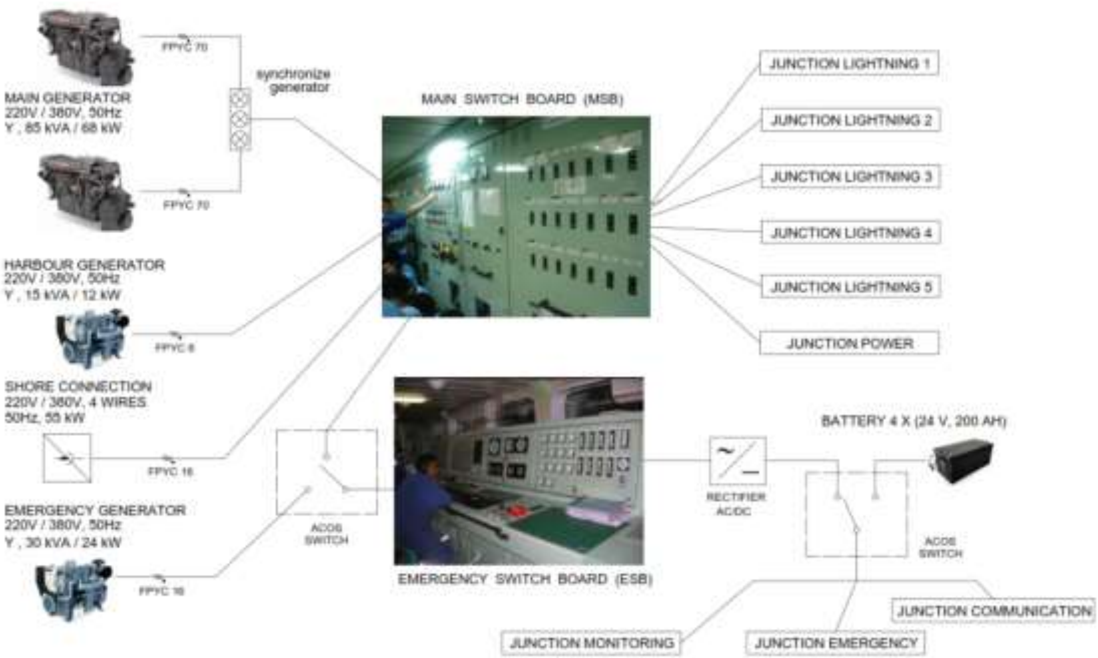

Figure 2. Example of Electric Power Distribution on the KMP Bambit 300 GT [10].

Room Illumination Standart according to zonal cavity method provisions

Illumination refers to the amount of light that falls on a specific surface area, measured in lux units [18]. This measurement is a fundamental aspect in the design of lighting systems, whether for buildings on land or maritime vessels. Proper illumination is not merely a matter of visibility—it plays a critical role in ensuring safety, comfort, and productivity across different environments. The concept of illumination is closely tied to light intensity. For instance, direct exposure to summer sunlight represents one of the highest natural levels of illumination experienced by humans [18]. While this is an extreme case, it illustrates how variations in light intensity can significantly affect human perception and activity.

In the maritime context, achieving the correct illumination level is particularly crucial due to the diverse and demanding operational conditions aboard ships. Each area onboard from crew accommodation, engine rooms, and navigation bridges, to common areas has specific lighting requirements tailored to its function and activities. These requirements are governed by standardized guidelines to ensure that tasks can be performed efficiently and safely, while also minimizing fatigue and the risk of human error. Properly designed lighting systems onboard not only enhance visual comfort but also contribute to operational reliability. By adhering to illumination standards, ship designers and engineers help foster a work environment that supports crew well-being, reduces accident risk, and enhances operational effectiveness—ultimately contributing to the overall safety and performance of the vessel.

Table 2. Standardized Lighting Criteria for Crew Habitability Areas [17]

Space	Illuminance Level	Space	Illuminance Level
		Cabins and Sanitary Spaces	
For the reading room in general	150 Lux		
Reading and Writing		Sanitary Spaces	
Desk	500 Lux	Lavatory/Toilet room	200 Lux
Bunk Light	200 Lux	Bath/shower area	150 Lux
Changing Room	200 Lux	Light During Sleep Period	<30 Lux
		Dining Room	
Mess Room and Cafeteria	300 Lux	Snack or Coffee Area	150 Lux
		Recreation Space	
Lounges	200 Lux	Gym Room	300 Lux
Library			
General Lighting	150 Lux	Bulletin Board	150 Lux
Reading Area	500 Lux		
Computer Room	300 Lux	Game Rooms	200 Lux
Movie room/Movie Theater	150 Lux	Reception Areas	300 Lux

METHOD

The Zonal Cavity Method, also known as the Lumen Method, is a widely utilized technique for estimating and designing lighting levels in enclosed indoor environments [19]. It is commonly applied in settings such as buildings, industrial complexes, and maritime vessels, primarily due to its proven accuracy and consistency in lighting calculations. One of the key advantages of this method is its ability to incorporate the reflective behavior of interior surfaces, which plays a crucial role in determining the final illumination levels within a space.

This approach divides the interior space into distinct reflective zones, or “cavities,” which include the ceiling cavity, room (or middle) cavity, and floor cavity. Each of these zones interacts differently with light—either reflecting or absorbing it—thereby influencing the overall lighting distribution in the room. As shown in Figure 3, segmenting a space in this manner enables a detailed and structured evaluation of how light travels and behaves within an interior environment. As a result, the Zonal Cavity Method supports more precise, effective, and optimized lighting design, tailored to the functional needs of each area.

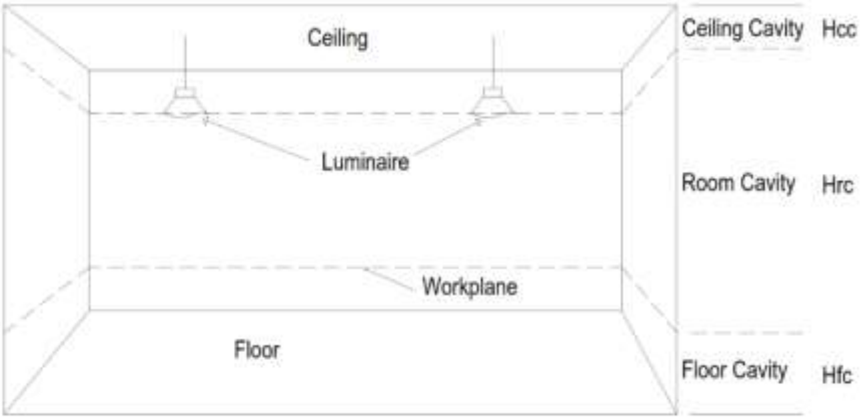

Figure 3. Cavity dimensions of the room [19]

The calculation stages in finding the lighting level are the first to determine the Cavity Ratio, then determine the reflectance factor, then determine the coefficient of utilization and finally, compute the average illuminance level.

To get the value of the Room Cavity Ratio (RCR) ratio, you can use the following formula: Room Cavity

Ratio (RCR) = 5 hrc (L + W) / (L x W) (1)

Where :

hrc = distance from lighting to work plane
L = length of room (m)
W = room width (m)

The amount of light flux required in a room is calculated using the following formula.

Φ Room = (E Room x A) / (CU x LLF) (2)

Where :

Φ Room = Luminous flux produced in a space (Lumen)
E Room = Nominal illumination required in a room (Lux)
A = Area of a room (m^2)
CU = Coefficient of Utilization/ coefficient of utilization of the luminaire
LLF = Total light loss factor

Meanwhile, to calculate the number of lights needed in a room, you can use the following formula.

N Rooms = Φ Rooms / Φ Lamps (3)

Where:

N room = Number of lights needed in a room

Φ Room = Light flux produced in a room (Lumen)

Φ Lamp = Luminous flux of the lamp to be selected (Lumen).

Zonal cavity methodis often used to obtain initial estimates of lighting in architectural design, especially in commercial and industrial spaces. However, this method has limitations, such as only providing average values and not considering variations in lighting at certain points in the room. Therefore, although this method is useful for initial planning, the results should be validated with other methods or direct measurements.

RESULTS AND DISCUSSION

Measurement Planning the power requirements for lighting on the KM Tuna Kita ship using LED lights is highly dependent on the room area and illumination standards set by ABS and other related regulations. By choosing efficient LED lights, ships can save energy and optimize generator usage, which in turn supports the sustainability of ship operations. In addition, the measurement of lighting intensity in each room on the ship is carried out by referring to room conditions such as room width, room height, room length, room area and determining the illumination value according to the standards set for each room. As previously explained, the generator on the ship supplies power for all electrical needs on the ship, including lighting power, power for pumping installations, power for telecommunications and monitoring. This analysis focuses on lighting needs with the aim of finding out how much power the LED lights on the KM Tuna Kita ship are based on the lighting regulations issued by ABS. The amount of power needed for lighting on the KM Tuna Kita using LED lights on each deck.

Table 3. Lighting load on the bottom plane electrical installation

Equipment On Bottom Plane	Power (kW)
Engine Casing	0.026
Engine Control Room	0.026
CO^2 Room, Store, and Freezer (0.011)	0.033
Accommodation Stairs & Gang Way	0.011
Processing Deck	0.026
Cargo Hold Deck	0.014
Fish Freezer Hold	0.015
800W Power Outlet	0.8
400W Power Outlet	0.4
Total	1.351

For lighting load on the main deck electrical installation can be seen in table 4

Table 4. Lighting load on the bottom plane electrical installation

Equipment On Bottom Plane	Power (kW)
Mess Room (When On and Off) (0.011)	0.022
Galley	0.026
Engineer Room	0.0065
2 LIDS	0.017
Toilet	0.0065
Accommodation Stairs & Gang way	0.014
Crew Room (When On and Off) (0.017)	0.034
Open Deck Bow	0.026
800W Power Outlet	0.8
400W Power Outlet	0.4
Total	1.352

For lighting load in navigation deckk electrical installation can be seen in table 5

Table 5. Lighting load on the bottom plane electrical installation

Equipment On The Navigation Deck	Power (kW)
Captain's Room	0.014
Captain Room (Sleeping)	0.011
General Steering Room	0.017
Accommodation Stairs & Gang way	0.014
Open Deck Bow	0.014
Total	0.07

Plan LED Light Layout

Main Deck

This plan illustrates the layout and distribution of LED lights planned for the ship's Main Deck. LED lights are placed in important areas such as the mess room, galley, toilets, accommodation, and other spaces. The distribution of LED lights is designed to meet the illumination standards set by ABS, which are 300-500 lux for public areas and 150-300 lux for corridors as recommended. Thus, adequate lighting can be obtained throughout the main deck.

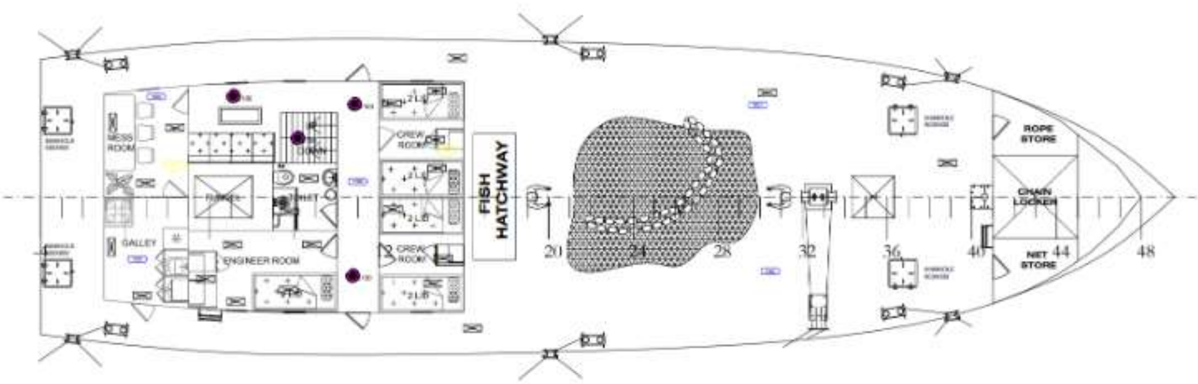

Figure 4. 2D Main Deck Plan using LED lamps

Processing Deck

This area is the center of fish processing activities on board, so sufficient lighting is required to support the safety and smooth running of the process. LED lights are evenly placed to meet the recommended illumination standard of 500-750 lux for the processing area.

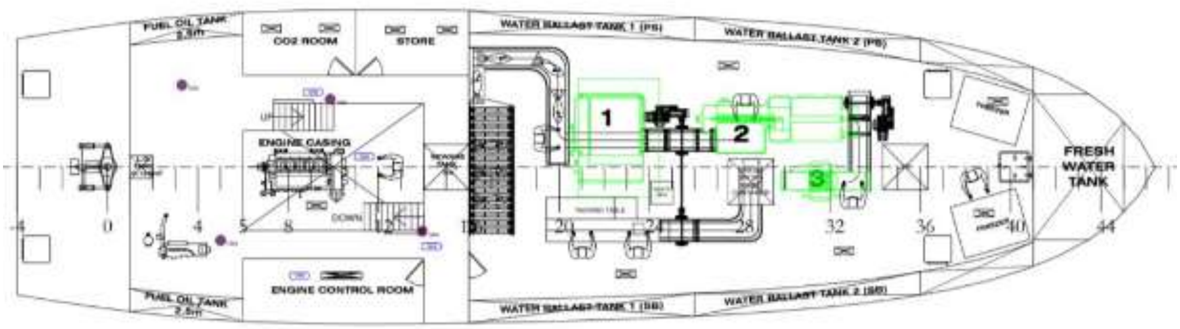

Figure 5. 2D Processing Deck Plan using LED lamps

Deck Navigation

In this area, LED lights are placed in the wheelhouse, captain's accommodation room, and along the evacuation route. Good lighting on the navigation deck is very important to support navigation activities and safe ship operations, according to the illumination standard of 300-500 lux.

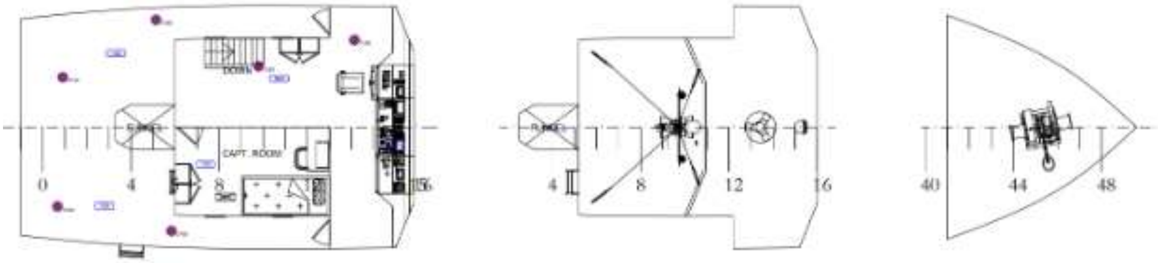

Figure 6. 2D Navigation Deck Plan using LED lamps

Cargo Hold

In this area, LED lights are placed to provide sufficient lighting during the fish loading and unloading process. Good lighting in this area will help the smoothness and safety of cargo handling activities, according to the illumination standard of 200-300 lux.

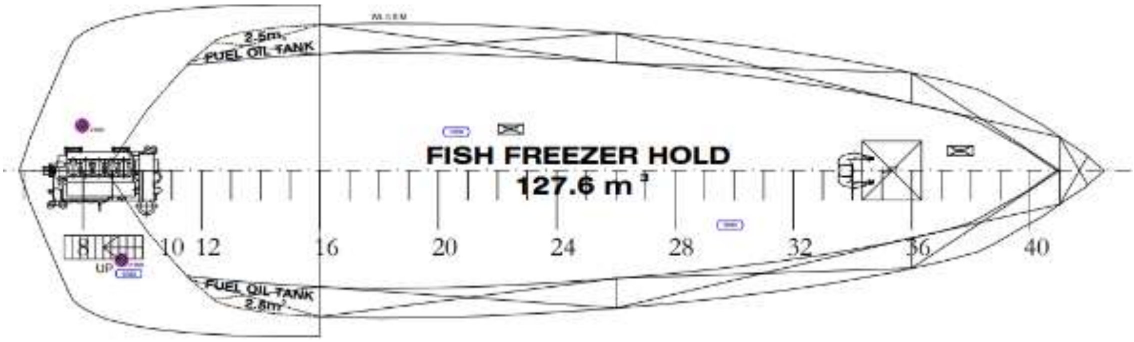

Figure 7. 2D Cargo Hold Plan using LED lamps

The implementation of LED lighting system on the KM. Tuna Kita ship like this shows a significant improvement in the overall lighting quality and energy efficiency on board. The 2D layout plan provides a clear visual representation of the placement of LED lights throughout the main deck, thus allowing for optimal lighting arrangement and compliance with the illumination standards set by ABS [17].

On the Main Deck, the even distribution of LED lights in key areas such as the mess room, galley, toilets and accommodation has ensured adequate lighting levels of 300-500 lux, as recommended. Similarly, the Processing Deck and Navigation Deck have been equipped with strategic LED lighting placements to meet specific illumination requirements of 500-750 lux and 300-500 lux respectively. The Cargo Area has also been equipped with sufficient LED lighting of 200-300 lux to support safe and efficient loading and unloading activities. Overall, the LED lighting system has proven to be a reliable and energy efficient solution, contributing to the operational efficiency of the vessel as well as the well-being of the crew.

CONCLUSION

The results of determining the electrical power from measuring each room using the ABS illumination standard obtained reflectance to determine the light flux and the placement of the number of lamps using the lamp power lumen method on the KM fishing vessel. Tuna Kita by using LED lighting type, the amount of electricity load of lighting that has been accumulated for the load during sailing conditions is a continuous load of 0.2 kw, intermittent load of 7.5 kw, so that the total available capacity is 6.54 kw from a generator load factor of 84%, the load during the conditions of entering and leaving the port is a continuous load of 0.3 kw, intermittent load of 7.6 kw, so that the total available capacity is 6.80 kw from a generator load factor of 82%, the load during anchored conditions is a continuous load of 0.6 kw, intermittent load of 7.2 kw, so that the total available capacity is 6.80 kw from a generator load factor of 83% and the load during emergency conditions is a continuous load of 0.1 kw, intermittent load of 0.1 kw, so that the total available capacity is 25 kw from a generator load factor of 0.3% so that for the selection of generators on fishing vessels KM. Tuna We obtained a large power of 4000 watts by dividing the capacity by the amount of power available on the generator.

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