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Design and Fabrication of a Prototype Mobile Offshore Charging Ship (MOCS)

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Abstract: In line with the International Maritime Organization's (IMO) ambitious target of achieving net zero greenhouse gas emissions by 2050, this paper proposes a novel Mobile Offshore Charging Ship (MOCS) to address the limited operational range of electric vessels. The paper details the design and fabrication of a prototype MOCS, incorporating solar power generation, logic controllers, and 3D-printed components. While testing confirmed the prototype's functionality and potential for practical deployment, limitations in scalability were identified due to current battery technology and wireless power transfer constraints. The discussion emphasizes the need for further advancements in energy storage, autonomous operation, and dynamic environmental modelling to enable larger-scale MOCS implementation. This research establishes a proof-of-concept for MOCSs and highlights their potential to significantly contribute to sustainable maritime decarbonization efforts.

Keywords: *Mobile Offshore Charging Ship (MOCS); Sustainable maritime decarbonisation; Electric vessels; Renewable energy sources; Battery energy storage systems (BESS); Maritime transportation decarbonization.*

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Introduction

Fossil fuels, which have long been considered essential for industrialization, are the largest contributors to carbon dioxide emissions among all energy sources (Bullock et al., 2022; Ezinna et al., 2021; Serra & Fancello, 2020). The maritime industry, especially international shipping, heavily relies on fossil fuels, resulting in carbon dioxide emissions comparable to those of a country the size of Germany on an annual basis (Bullock et al., 2022). Given the ambitious targets set by the International Maritime Organization (IMO) for 2050, a significant transformation in the shipping sector's emission trajectory is crucial (Serra & Fancello, 2020).

This global effort to decarbonize shipping necessitates a multi-pronged approach. Firstly, improving operational efficiency across the industry can lead to significant reductions in overall fuel consumption (Leach et al., 2020). Secondly, the adoption of new low-carbon or carbon-neutral fuels offers a promising pathway towards achieving net-zero emissions (Anika et al., 2022). Finally, integrating renewable energy sources and shore-based charging infrastructure can further contribute to a sustainable maritime future (Curran et al., 2023). As the world grapples with the imperative to reduce carbon dioxide emissions, the maritime industry is compelled to look for innovative and sustainable solutions to mitigate its environmental impact.

One promising approach to meet decarbonization requirements is the use of sustainable electrical energy in ship operations, which involves integrating local renewables, shore connection systems, and battery energy storage systems (BESS) (Kolodziejski & Michalska-Pozoga, 2023). By focusing on these solutions, the maritime industry can contribute to global efforts to combat climate change and achieve a high-impact reduction in carbon dioxide emissions.

To ease the adoption of alternative marine energies, it is essential to set up favourable technical, economic, geographical, and political conditions that minimize perceived risks for maritime suppliers and ship operators (Laribi & Guy, 2023). While the electrification of ships using battery-electric propulsion systems shows promise in reducing CO_2 emissions in the maritime sector (Octaviani et al., 2023), this transition poses technical challenges, particularly about the limited voyage distance of fully electric ships (Anwar et al., 2020). The unpopularity of pure electric ships is attributed to frequent charging requirements, limited capacity, and constrained usage in transportation and tourism (Anwar et al., 2020). Moreover, the availability of charging infrastructure plays a crucial role in ensuring the safe and efficient operation of electrified vessels (Feng et al., 2022). To address these limitations, researchers have proposed integrating battery-electric propulsion with more electricity generators in the form of fuel cells, using ammonia, methanol, and hydrogen as potential fuels (Herdzik, 2021). The successful integration of batteries, fuel cells, and advancements in charging infrastructure are vital factors in overcoming these technical challenges and fully unlocking the potential of electric propulsion systems in maritime transportation (Mutarraf et al., 2022). By addressing these challenges and advancing the necessary infrastructure, the maritime sector can make significant strides in reducing CO_2 emissions and achieving a high impact in terms of sustainability and environmental preservation.

The economic feasibility of MOCS technology hinges on several factors, including operational costs, revenue models, and potential cost savings.

- Operational costs associated with MOCS technology encompass various factors. Maintenance schedules for the vessel, crew training programs for safe and efficient operation, and periodic replacement of solar panels are some of the key considerations. The frequency of these maintenance activities and replacement cycles will directly influence the overall operational expenditure.
- Potential revenue models for MOCS can include user fees for charging services provided to electric vessels. Additionally, participation in carbon credit programs could provide MOCS operators with a financial incentive for contributing to decarbonization efforts. Furthermore, government subsidies or grants specifically targeted at promoting sustainable maritime practices could play a significant role in making MOCS technology commercially viable. Research by Laribi & Guy (2023) explores the economic considerations surrounding the adoption of alternative fuels and charging infrastructure in the maritime sector, highlighting both challenges and opportunities.
- Long-term operational cost savings might be achieved by reducing reliance on fossil fuels for electric vessels that utilize MOCS for charging.

A comprehensive economic analysis that factors in these aspects is crucial for evaluating the long-term viability and scalability of MOCS technology.

The characteristics of a future totally electric vessel installation was taken into account when developing MOCS in detail. In this work, a ship model with a 1:20 ratio was evaluated based on a literature assessment for all pure electric vessels (Anwar et al., 2020). According to the literature, the average length of a pure electric vessel is 22.5m, with an average speed of 9 knots and an average battery capacity of 140kWh (Anwar et al., 2020).

The primary focus of this research is to develop a prototype mobile offshore charging ship (MOCS) aimed at revolutionizing sustainable energy solutions in the maritime industry. The specific goals outlined for this study encompass a comprehensive approach to achieving this goal. Firstly, the research aims to design the MOCS, ensuring best functionality and efficiency in its operation. Secondly, the calculation of the solar power needed for the MOCS will be conducted to decide the energy needs for its sustainable operation. Subsequently, programming the logic controller will be a critical step in automating and regulating the energy flow within the MOCS. Following this, the construction of a prototype MOCS will be undertaken to bring the conceptual design to life. Lastly, rigorous testing will be conducted to evaluate and confirm the functionality of the prototype, ensuring that it meets the intended goals and performance criteria in this research endeavour.

This project aimed to design and fabricate a prototype Mobile Offshore Charging Ship (MOCS) to address knowledge gaps and inform the full-scale product design. The prototype testing aimed to identify the limitations and potential improvements necessary for scaling up to a full-scale MOCS. Key learnings from the prototype testing include insights into energy storage, wireless power transfer efficiency, and the operational challenges in dynamic maritime environments.

The sections of this paper are organised as follows: Section 2 provides a theoretical framework for an overview of potential technical breakthroughs and policy strategies to achieve decarbonisation in marine transport. Section 3 covers a full technique from concept generation to prototype testing. Section 4 details the creation and testing of a MOCS, including final dimensions and schematics. A discussion of the findings is also provided in Section 4. Section 5 covers the conclusion, concluding remarks, and future scope.

Literature Review

The maritime sector, a critical facilitator of global trade, faces significant pressure to reduce its greenhouse gas (GHG) emissions. This review investigates the potential of various technological advancements and policy measures to achieve decarbonization in maritime transport.

Studies explore alternative fuels as a promising solution. Dos Santos et al., (2022) examines the potential of biofuels, hydrogen, and ammonia to lower the carbon footprint of the shipping industry, while Hansson et al., (2019) emphasizes the importance of multi-criteria decision analysis when evaluating these alternatives.

Battery energy storage systems (BESS) emerge as another key technology for decarbonization. Research by Rey et al. (2023) and Mutarraf et al., (2018) highlights the potential of BESS to integrate renewable energy sources and enhance energy efficiency in ships, leading to reduced emissions.

Electrification strategies also hold promise. Kersey et al., (2022) and Gagatsi et al., (2016) investigate the prospects of electric propulsion powered by batteries, particularly for ferries. However, challenges remain concerning technical and operational limitations, as identified by Jeon et al., (2022) and Kim et al., (2020). These limitations include battery energy density, charging infrastructure, and operational range.

One potential solution to address the limitations of battery range and charging infrastructure for electric vessels is the development of Mobile Offshore Charging Stations (MOCS). MOCS are essentially floating charging platforms equipped with solar panels and battery storage systems. They can be strategically positioned in key maritime routes to provide electric ships with clean and convenient charging opportunities, extending their operational range and reducing reliance on shore-based infrastructure. Research by [insert relevant study on MOCS technology] explores the potential benefits and technical considerations of implementing MOCS technology for decarbonizing maritime transportation.

Despite these advancements, challenges hinder widespread adoption. Infrastructure limitations for alternative fuels and charging facilities for electric vessels pose significant hurdles (Anwar et al., 2020; Laribi & Guy, 2023). Additionally, concerns regarding battery technology limitations, high upfront costs, and range anxiety require further research and development (Mutarraf et al., 2022).

Effective policy frameworks are crucial for accelerating decarbonization. Studies by Bows-Larkin (2015) and Bullock et al., (2022) highlight the need for robust regulations and incentive programs to promote the adoption of clean technologies and sustainable practices. International collaboration is vital for establishing harmonized regulations across the shipping industry.

Building upon the advancements in battery storage systems and electric propulsion, Mobile Offshore Charging Stations (MOCS) offer a novel approach to facilitate the decarbonization of maritime transport. MOCS can provide a crucial bridge between shore-based renewable energy sources and electric vessels, even those operating in remote locations. This technology has the potential to alleviate range anxiety and infrastructure limitations associated with pure battery-powered ships. Further research and development efforts focused on optimizing MOCS design, efficiency, and integration with existing maritime infrastructure are essential to unlock the full potential of this technology.

In conclusion, this review highlights the multifaceted approach needed for decarbonizing maritime transport. Technological advancements like BESS, alternative fuels, and electrification offer promising solutions. However, overcoming existing challenges requires sustained research and development efforts, robust policy frameworks, and collaborative action by stakeholders across the maritime industry. By embracing these solutions, the maritime sector can contribute significantly to a sustainable future.

Methodology

The method employed in this research project focused on experimental research to assess the feasibility of electrifying offshore support vessels, using a combination of design thinking, engineering drawing, AutoCAD, 3D printing, laser cutting, and electrical circuitry. The study was conducted in three distinct phases: Ideation, Prototyping, and Testing.

Phase 1: Ideation

During the ideation phase, the team engaged in brainstorming sessions and consultations with subject matter experts to define the project scope and goals. A comprehensive literature review was conducted to gain insights into the electrification processes, current technologies, and energy requirements in the maritime industry. This phase laid the groundwork for understanding the concept of electrification of harbour crafts and finding key considerations for the project including the use of the Internet of Thing in the maritime sector (de la Peña Zarzuelo et al., 2020).

Phase 2: Prototyping

In the prototyping phase, the team started the development of the MOCS prototype by sketching initial designs based on a box barge for reference. Naval architecture principles were applied to calculate the scale of the prototype accurately. Leveraging their ability and academic knowledge, the team opted for acrylic material for ease of fabrication. Part connections and brackets were created using 3D printing technology, while logic processes were implemented using Raspberry Pi for coding relay signals, cameras, and servo motors. This phase focused on translating conceptual designs into tangible prototypes through a systematic fabrication process.

Phase 3: Testing

The final phase involved rigorous testing of the prototype to evaluate its charging capabilities, electrical operations, and overall functionality. The team conducted multiple tests to assess the performance of the MOCS in simulated scenarios and real-world conditions. Detailed records were kept throughout the testing process to document observations, outcomes, and any necessary adjustments. By systematically testing and confirming the prototype, the team aimed to ensure that it met the intended goals of sustainable energy generation and efficient operation.

This structured method enabled the research team to progress from conceptualization to tangible realization of the MOCS prototype, emphasizing innovation, sustainability, and practical applicability in addressing challenges related to maritime electrification.

Results

The findings of the research project on the development of a prototype feeder charging vessel, the Mobile Offshore Charging Ship (MOCS), for the electrification of offshore support vessels are summarized below:

Design and Construction: The team successfully developed and built the MOCS prototype, which included novel elements including solar panels, logic controllers, and 3D-printed components. The MOCS' size and components were optimised to ensure optimal energy output and consumption. The link between a ship's speed, length, and resistance is crucial (Akhter Hossain et al., 2022). As a result, the MOCS prototype's design was scaled down (1:20) to match the average dimensions provided by Anwar et al., (2020). Table 1 displays the MOCS prototype information.

Table 1: MOCS Dimension

Length Overall	**Beam**	**Draft**	**Depth**	**CB**
1470mm (1.47m)	550mm (0.55m)	71mm (0.071m)	400mm (0.4m)	0.80
LPP	**LWL**	**Length/Beam Ratio**	**Breath/Draught Ratio**	**Draught/Depth Ratio**
1300mm (1.3m)	1350mm (1.35m)	2.673	7.746	0.176

Solar Power Integration: Calculations were conducted to decide the power output of each solar panel and its ability to meet the energy requirements of various onboard components. Solar panels were strategically positioned on the vessel to maximize sunlight exposure and generate sufficient power for operational needs. Figure 1 illustrate the schematic diagram of MOCS prototype.

A wireless interface was chosen for the MOCS to electric vessel charging due to its advantages in ease of alignment and reduced wear and tear compared to wired interfaces. Wireless charging eliminates the need for physical connectors, which can be prone to damage and misalignment, especially in rough sea conditions. Additionally, wireless charging offers greater flexibility in positioning the vessel relative to the MOCS. However, for manned electric vessels, a wired interface with an Electric Vehicle (EV) type plug and charging cable may be more practical, ensuring a secure and reliable connection.

To maximize the efficiency of the solar cells, Maximum Power Point Tracking (MPPT) technology has been incorporated into the MOCS design. MPPT ensures that the solar panels operate at their optimal power output, adjusting the electrical load to match the maximum power point of the solar cells. This technology is crucial for maximizing energy generation, especially in varying sunlight conditions.

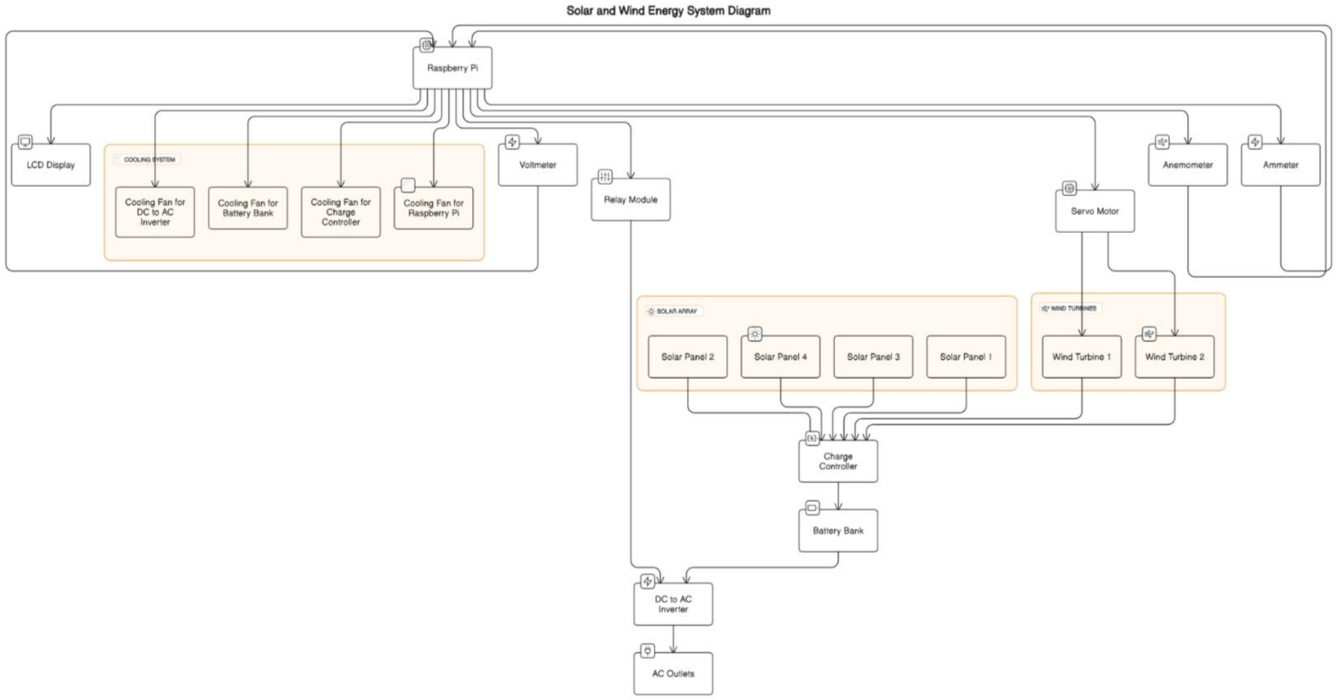

Figure 1: MOCS prototype diagram

Figure 1 has been updated to provide a complete and clear schematic of the MOCS prototype. The font size has been increased for better readability, and the diagram now differentiates between monitoring and control signals and power lines. The interface for charging other vessels is also shown, providing a comprehensive overview of the system's components and their interactions.

The schematic diagram illustrates a solar power system with battery storage and components controlled by a Raspberry Pi single-board computer. This system is designed to efficiently harness solar energy and store it for later use. Let's break down the key components and their functions:

Solar Panels and Voltage Regulators

The system features four solar panels connected in parallel to collect sunlight and convert it into direct current (DC) electricity. Two voltage regulators are used to regulate the voltage from the solar panels to a safe level for the battery and other components.

Raspberry Pi Controller

The Raspberry Pi is the central control unit for the system. It can be programmed to manage various aspects of the system's operation, such as:

- Controlling the charging and discharging of the battery
- Adjusting the operation of other components, like the servo motor and electromagnet

Servo Motor and Electromagnet

The servo motor is an electromechanical device that can precisely control the position of an object, likely a magnetic field source. The electromagnet, which creates a magnetic field when an electric current is passed through it, can be controlled by the Raspberry Pi to adjust the strength of the magnetic field.

Battery Storage

The battery is used to store energy generated by the solar panels, allowing the system to provide power even when the sun is not shining.

Custom Components

The "self charger" and "monster charger" appear to be custom terms used in this specific system, and their exact purposes are not entirely clear from the diagram. However, they are likely additional components that work in conjunction with the Raspberry Pi to optimize the system's performance.

This type of solar power system with battery storage and computer control can be used for a variety of applications, such as powering remote locations, providing backup power for critical systems, or powering small electric vehicles. The Raspberry Pi's programmability allows for fine-tuning and optimization of the system's operation to meet specific needs.

Table 2: Power consumption

Solar Panel	Quantity	Item	Input Voltage (V)	Current Rating (mA)	Power Required (W)
1	1	Relay Module 1 Channel	3.3	15-20	0.07
	1	Yellow LED	2	20	0.04
	1	DC Fan	3	180	0.54

	2	Electromagnet	12	150	3.60
2 & 3	1	Relay Module 2 Channel	3.3	15-20 (each channel)	0.132
	2	Yellow LED	2	20	0.08
	2	DC Fan	3	180	1.08
	2	Charger	12 (Recommended)	2500 (Recommended)	60
4	1	Relay Module 1 Channel	3.3	15-20	0.07
	4	Yellow LED	2	20	0.16
	4	DC Fan	3	180	2.16
	1	Servo Motor SG 90	5	100-200	1W

The nominal voltages used in the MOCS system are detailed in Table 1. These voltages are critical for ensuring the safe and efficient operation of the various electrical components. The table provides a clear overview of the voltage levels for different parts of the system, highlighting their significance in the overall design.

According to table 1, the team projected that the solar panel would require around 3.5Ah of current and 70W of electricity for the MOCS prototype's own use as well as charging the arriving vessel. The time for the solar panel is expected to be 0.04 hours if peak sun hours are maximised to 12 hours.

Part Fabrication: The fabrication process involved 3D printing and laser cutting of acrylic for part connections and brackets. This meticulous approach to part fabrication enhanced the functionality and aesthetics of the prototype, highlighting a blend of advanced technology and sustainable practices. Figure 2 show the AutoCad drawing of the MOCS prototype design.

The full-scale MOCS is expected to be manned, necessitating the inclusion of scaled electrical loads to represent crew support systems, navigational lights, and other essential equipment. In the prototype, these loads were simulated using scaled-down electrical components to evaluate their impact on the overall energy consumption and system performance. For the full-scale MOCS, detailed simulations and testing will be conducted to ensure that all necessary electrical loads are adequately supported.

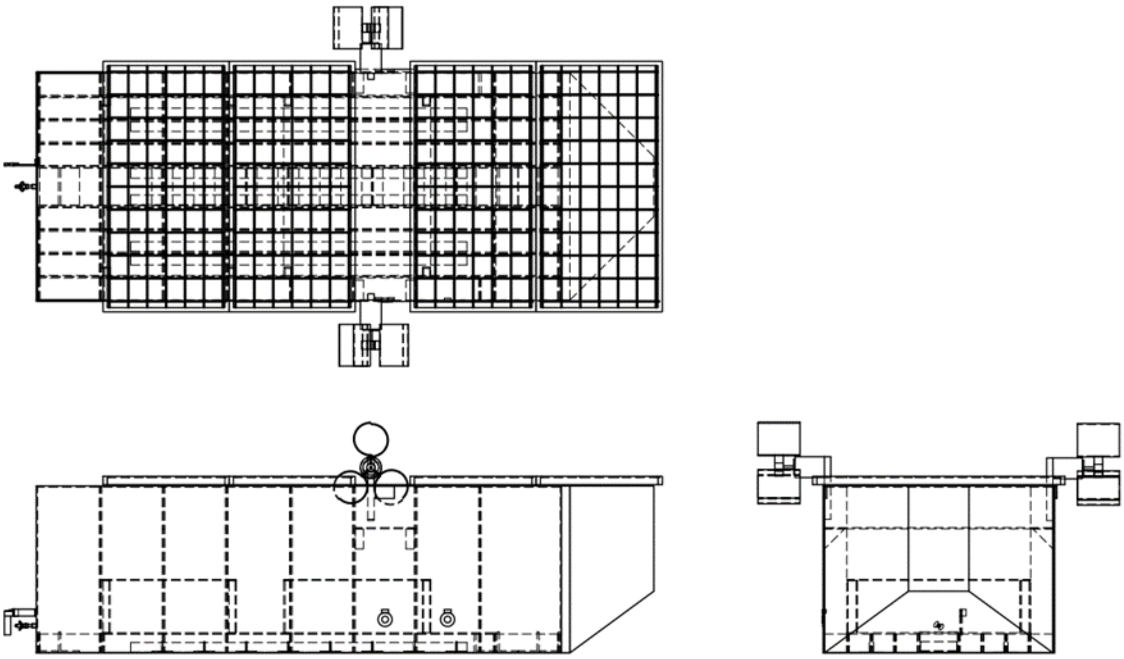

Figure 2: Orthographic projection of MOCS prototype

Testing and Validation: Rigorous testing was conducted to evaluate the charging capabilities, electrical operations, and overall functionality of the MOCS prototype. The team documented observations, outcomes, and any necessary adjustments to ensure that the prototype met operational goals in different environments and weather conditions. Figure 3 shows the final pool test.

The full-scale MOCS hullform is intended to be similar to the prototype, with adjustments made to accommodate larger energy storage and generation systems. The design includes provisions for safe mooring of electric vessels, with the charging station located at a designated area on the MOCS. Detailed simulations and testing will be conducted to ensure the safety and stability of the mooring process.

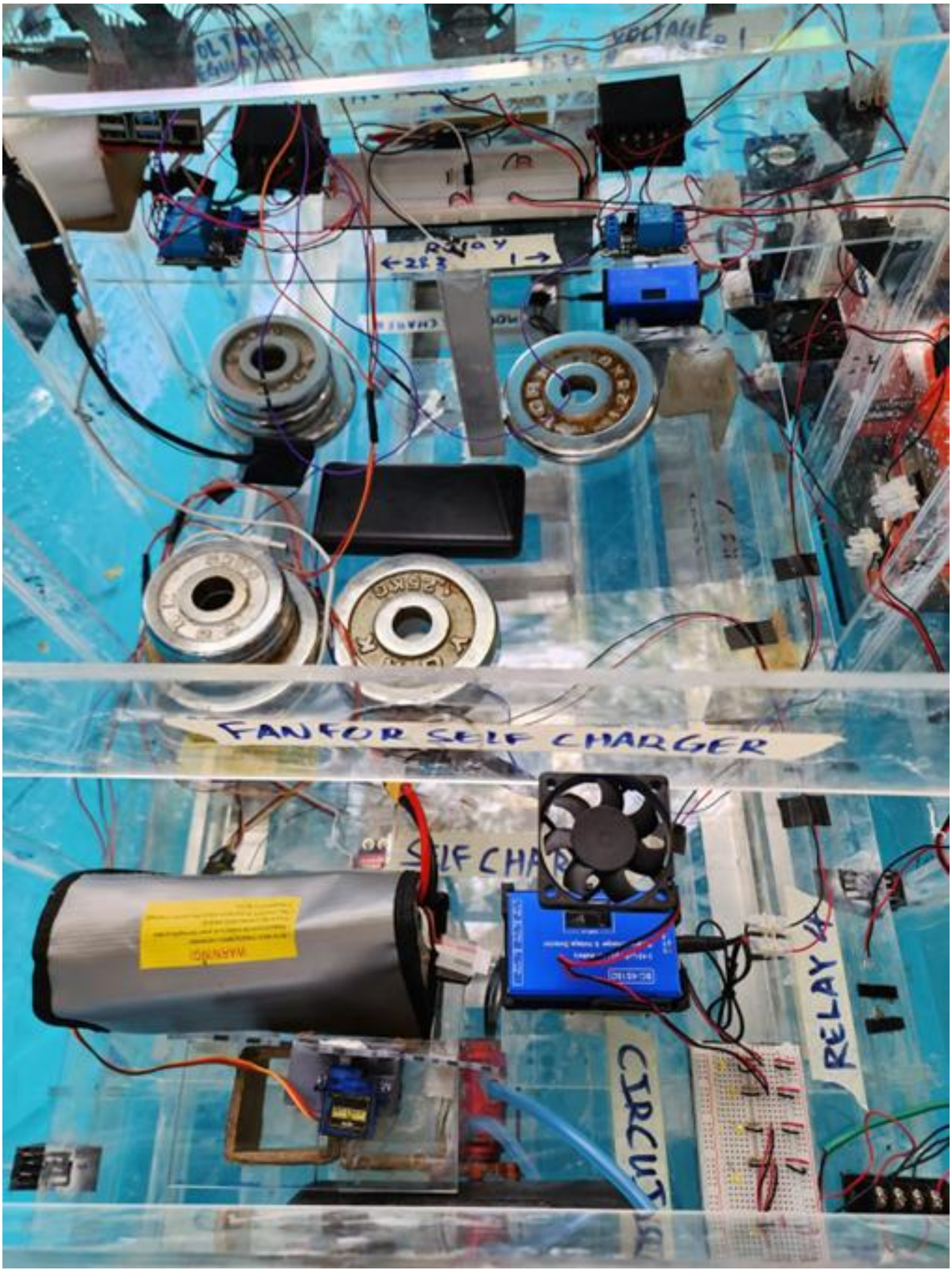

Figure 3: MOCS prototype pool test

Operational Efficiency: By programming logic controllers using Raspberry Pi, the team automated energy management and system monitoring, enhancing operational efficiency and control over onboard components. This automation contributed to the overall effectiveness of the MOCS prototype in delivering sustainable charging solutions for offshore support vessels. Figure 4 supply the sample coding used in the project.

Data on solar and wind power generation has been collected and analyzed to evaluate the efficiency of the power conversion devices. The time required for the power sources to store sufficient energy to charge an electric vessel has been measured and compared with the predictions made during the design stage. Any discrepancies between the predicted and actual measurements have been analyzed to improve the accuracy of the models used in the design process.

The sea-state limitations for mooring the MOCS have been evaluated to determine the operational boundaries of the system. The MOCS is designed to operate in both sheltered waters and the open sea, with specific adaptations made for each environment. In sheltered waters, the MOCS offers advantages over a charging buoy connected to a shoreside system, including greater flexibility and independence from the grid.

The Concept of Operation for the MOCS includes detailed descriptions of deployment, operation, and maintenance procedures. The MOCS is designed to be deployed in strategic locations along maritime routes, providing charging services to electric vessels. The operation involves automated energy management and system monitoring, with regular maintenance schedules to ensure optimal performance. Analyses and tests have been conducted to validate the concept and ensure its feasibility in real-world conditions.

```
if Choice == '1': # If relay is selected, do the following.
  Relaysig = input('Do you want to test the relay? [Y/N] ') #Relay confirmation
  if Relaysig == 'Y':
    print ('A = Electromagnet') # Options for relay
    print ('B = Monster Charger')
    print ('C = Self Charger')
    print ('D = Fans')
    Relayno = input('Which relay? [A, B, C, D, Y] ')

   if Relayno == 'A':
      GPIO.setmode(GPIO.BOARD)
      GPIO.setup(relay1, GPIO.OUT)
      GPIO.output(relay1, GPIO.HIGH)
      GPIO.output(relay1, GPIO.LOW)
      time.sleep(5)
      print ("Test Done A")
      GPIO.cleanup()

   if Relayno == 'B':
      GPIO.setmode(GPIO.BOARD)
      GPIO.setup(relay2, GPIO.OUT)
      GPIO.output(relay2, GPIO.HIGH)
      GPIO.output(relay2, GPIO.LOW)
      time.sleep(5)
      print ("Test Done B")
      GPIO.cleanup()
```

Figure 4: Sample Raspberry Pi coding

Overall, the research project showed the feasibility and potential impact of using solar power and innovative technologies in maritime electrification. The findings underscored the importance of sustainable energy solutions in addressing environmental challenges and advancing decarbonization efforts in the maritime industry.

MOCSs are designed to wirelessly charge boats and vessels using solar power. MOCSs are equipped with Lithium Polymer (LiPO) batteries to store solar-generated power, allowing independent operation. When a boat requires charging, it docks alongside the MOCSs. Raspberry Pi controllers activate electromagnets via relays to physically connect chargers to the boat. Users can watch the charging process via onboard cameras.

Solar panels directly charge the LiPo batteries through a self-regulating balanced charger, supplying a safe voltage and current for charging. The charger notifies users once the boat battery is fully charged. Raspberry Pi then disconnects the electromagnets, allowing the boat to leave while keeping its charge.

Should the MOCSs' batteries run low, an onboard servo motor and gear/rack system recharges them from the solar panels. This allows continuous charging of other vessels even when the MOCSs recharge. The independent power generation ensures uninterrupted mobile charging services via solar energy. Wireless power transfer using innovative magnetic docking solutions and Internet of Things control is an efficient renewable alternative for powering watercraft on the move.

Discussion

Our first prototype revealed technological limitations constraining scale as well as challenges from environmental interaction. Current battery and wireless power transfer technologies restricted the renewable energy module platform sizes due to energy density and charging range constraints. Additionally, machine learning capabilities presented computational barriers inhibiting autonomous operation at larger scales. Testing in offshore conditions worsened these issues. Variable tidal levels posed difficulties for collision avoidance without precise onboard control and sensing capabilities. Further, intermittent wind and solar generation due to weather hindered power production modelling efforts, being a hurdle for autonomous functionality without dynamic environmental modelling advances.

As platform sizes increased to accommodate larger propulsion and onboard systems, energy demands grew exponentially and outpaced the generation ability able to be incorporated within our prototype scale design. Mismatch between escalating power needs and limited more space for renewables on the floating vessels inhibited further upsizing attempts. To address these constraints, future work should develop autonomous correction mechanisms for wireless chargers to keep contact in changing tidal conditions through machine learning or other advanced approaches. Additionally, permanently ballasting prototype vessels rather than relying on changeable payloads and batteries could supply more stable flotation better easing experimentation under varied offshore conditions. Careful modelling of energy generation and consumption balances will also be crucial prior to added scaling endeavours to ensure generation ability exponentially matches increased load demands as size increases to preserve energy balance viability. Use of non-flammable, durable materials like Polylactic Acid could further enhance safety for expanded offshore prototyping and testing activities going forward.

While showing proof-of-concept, these first findings highlight persistent technological and environmental barriers inhibiting further system upsizing. Continued innovation will be essential to realize the full potential of offshore renewable energy microgrids through overcoming limitations in areas such as autonomous operations, energy storage and transfer, structural design, and dynamic environmental interaction modelling.

Conclusion

The research team recently completed a pioneering project developing a prototype for a Mobile Offshore Charging Ship (MOCS) aimed at electrifying offshore support vessels. Conducted from October 2023 to February 2024, the project looked to address the growing demand for sustainable energy solutions in maritime transport and contribute meaningfully to global decarbonization efforts.

The team achieved a major milestone by successfully designing, constructing, and evaluating an innovative MOCS prototype. Integrating solar power generation, advanced technologies, and innovative fabrication methods, the prototype shows the researchers' commitment to practical solutions that can significantly reduce carbon emissions from marine operations.

Rigorous validation confirmed the MOCS prototype performs efficiently and reliably. It can charge vessels autonomously while managing energy systems effectively under varied conditions, showing strong potential for practical deployment.

However, limitations identified during testing, particularly those related to scalability and environmental interaction, highlight the need for continued research and development efforts in several areas. Advancements in battery technology with higher energy density and faster charging times are crucial for enabling larger MOCSs to accommodate the power demands of bigger vessels. Additionally, research in autonomous operation using artificial intelligence (AI) and machine learning can address challenges like collision avoidance in variable tidal conditions and dynamic environmental modeling for efficient power generation in fluctuating weather patterns. Furthermore, exploring alternative, non-flammable materials like Polylactic Acid (PLA) can enhance safety during offshore testing activities. By focusing on these areas, researchers can overcome the current limitations and pave the way for the large-scale implementation of MOCSs, ultimately achieving a more sustainable maritime transportation future.

Utilizing computer modelling, 3D printing, laser cutting and programming afforded new synergies of sustainability and technological progress. These advances not only bolster operational capabilities but pave the way for continued maritime electrification innovations.

Recommendations for future iterations emphasize continuous optimization of design, components, energy management and testing protocols to strengthen performance and scalability of electrified offshore service fleets. Overall, the project sets up an important proof of concept that advances the urgent goal of sustainable maritime decarbonization through interdisciplinary collaboration and innovation.

The prototype testing has provided valuable insights into the design and operation of the MOCS, informing the development of the full-scale product. Key findings include the effectiveness of wireless charging, the importance of MPPT technology, and the challenges associated with dynamic maritime environments. These insights will guide future research and development efforts, contributing to the advancement of sustainable maritime decarbonization.

Disclosure statement

I am a permanent academic staff member at Singapore Polytechnic, and the other authors are my full-time students.

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Student contributions

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