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A Review of Seaport Microgrids for Green Maritime Transportation: The Shore and the Seaside

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Abstract—**Emerging from the field of microgrids is an efficient and persuasive transitional technology with great promise for easing energy crises, environmental worries, and economic limitations in seaports. When it comes to high-performance ports, this technology becomes even more important. One example is smart ports, which use state-of-the-art ICT applications to completely revamp container and vessel management. Strengthening national economic sustainability and global competitiveness are both impacted by this invention. Reducing the environmental impact of the maritime transport business is no easy feat. In this study, we take a look at how seaport microgrids are becoming more important in the quest for environmentally friendly marine transportation. We take a look at the major problems that contemporary seaports are facing, such as the ever-increasing need for energy, the contamination of both the air and water from ship emissions and the unpredictable cost of electricity. The goal is to bring together current information about smarter ports by giving examples and to encourage new ideas and research in this field. As part of our efforts to inspire new research into smart port development, we also outline certain open questions that need answering. This report could serve as a valuable resource for future research on seaport microgrids.**

Keywords*—*Smart Port Initiatives, Microgrid Technologies, Smart Ports, Energy Management, the Shore, the Seaside, and Green Maritime Transportation.

I. Introduction

The global economy has rapidly expanded in recent decades this change was brought about by an even more rapid acceleration of global trade due to its low cost and capacity to support the shipping of comedians in large quantities through cargo surface seaboards play a vital part in this economic liberalization [1]–[4]. According to the International Maritime Organization's annual report, maritime transport surfaces already handle more than 90% of global trade and are expected to triple by 2050 [5]–[7]. Seaports have evolved into complex hubs as a result of the multi-functional operations' need to adhere to many requirements, including maritime legislation, technologies, transportation, operational, and policy requirements. Significant investment is required to improve board infrastructure and facilities, as well as operations management admin maintenance [8]–[10].

The use of fossil fuels by the world's maritime transport industry has a major impact on the environment, yet it is essential to international trade. Emissions from ships contaminate both the air and water, which in turn causes acid rain, respiratory diseases, and global warming [1], [11], [12]. Green maritime transportation must be prioritized if our oceans and world are to have a sustainable future. To balance the total number of ships and vehicles used for transportation, energy consumption was required [13]–[15]. Additionally, modern ships and subsequently greater in size, reaching lengths of hundreds of meters and widths of kilotons. Due to all of these variables, a significant amount of fossil fuel must be burned to satisfy the port's following load. Energy imbalances ghost be excessive energy use make the energy system ineffective, with a history of frequent bowel disruptions and huge financial losses [4], [5], [16], [17]. Recent years have seen a surge in interest in the studies aimed at creating more effective power systems for port operations [1], [13], [18], [19].

Energy usage and environmental effects are two of the most pressing problems that modern seaports must contend with. Among them are: Energy consumption is on the rise due to the port's many operations, such as cargo handling, refrigeration, and lighting. Ships' emissions, both when docked and while navigating, are a major source of air and water pollution in cities near ports. Ports are vulnerable to price volatility and uncertainty due to their reliance on traditional energy sources, which can cause energy costs to fluctuate. A crucial bath has been seen oz integrating energy storage system ESS and renewable energy source (RES) technology into microgrid systems when properly implemented a variety of RES such as photovoltaic (PV) systems, wind turbines (WTs), biomass energy of ocean and geothermal sources hydrogen which can all be integrated in microgrids to enable power generation that is no longer limited to conventional fossil-based resources the installation of energy storage system (ESS) at seaboards wool result in more efficient energy distribution by offering emergency backup power and the capacity to store extra energy production [20], [21]. As a whole, an ESS makes seaports' energy distribution systems more adaptable and quick to react. It aids in the efficient use of renewable energy, lessens the load on the conventional grid during peak hours, and maximizes savings on energy consumption. All of this helps make the seaport's energy system better and more long-lasting. Energy efficiency, economic, environmental, and security advantages of microgrids for the marine industry can be divided into four categories [22], [23]. However, the fluctuating energy demand from large loads at the port both on land and at sea, makes it difficult to operate seaboard microgrids. Before implementing microgrid coordination and maritime applications, although wall-modified technology-based and land-based applications offer greater social benefits, which is now several problems that need to be handled. Furthermore, the body of literature in this area is far from definitive. to ensure the best advantages of incorporating the microgrids idea into seaports, many factors require additional investigations [24], [25]. The most recent and current version in smart port that thyrotoxicosis the needs of the community and its users understands the following salient features applications on surfaces for smartboards such as vessels and containers:

- Technologies including automation networking and data centers.
- Creation of communication for instructors to encourage cooperation between various ports.
- To reduce scheduling and optimization issues.

This study provides a comprehensive review of seaport microgrid principles and communication structures, scheduling optimization, and vessel delay prediction enhancement. Both shoreside applications, which investigate the possibilities for microgrids on board ships, and seaside applications, which concentrate on port operations, are taken into account in this assessment, which goes into greater detail about the particular designs of seaport microgrids. Furthermore, we will assess the outstanding obstacles and potential avenues for further research regarding this revolutionary technology. Intending to foster a future where marine transportation is more environmentally friendly, sustainable, and harmonious with our oceans, this paper delves into the possibilities of seaport microgrids.

The rest of this paper is organized as follows. Section II reviews seaport and its applications. Section III reviews the microgrid distribution system for vehicular. Section IV reviews seaport Microgrids. Section V reviews seaport Microgrid topology. Section VI provides schedule optimization issues. Section VII discusses challenges facing seaport microgrids and futuristic methods. Section VIII provides evaluation and analysis. Finally, Section IX concludes this work.

II. Review of Seaport and Applications

Seaports serve as hubs for economic activity related to shipping maintenance, freight, and the arrival of any type (tourists or commerce) [26]. Commercial/industry ports [27], ports with container terminals [28], and intermodal ports [29], [30] are the three categories under which the most typical ports fall. ports are divided into the 3 categories in [31], including municipal, national, and international ports, and is still another classification. these divisions are based on features of the port's geographic location, the annual volume of passengers, and the annual volume of ships berthing in and out of the port. Different types of ports are their characteristics are summarized in Table I.

TABLE I. Classification of Ports [1]

Board type	Characteristics
Local port	Fulfills local demands, Limited capacity, and space, Little size On handling logistical activities, Avoid assisting cruise ships, Boats yachts, and light ships with a capacity of 500 passengers
National port	Meets national requirements, Size medium large than local boards bolts ports All ship types, Medium-sized ships with a capacity of 2500 passengers and cargo-only trucks
International port	Meets needs on a global scale Greatest size, Created a sizable logistical infrastructure of more than 2500 passenger cruise ships cargo ships container ships, and RTG cranes

As illustrated in Fig. 1, a seaport serves as an important interface for both land and maritime transportation. Ports are regarded as one of the major determining factors for industrial global growth. However, due to the increased demand for logistics on a global scale, the amount of marine traffic is increasing [32], [33]. Later, this means more advancements in technology, networking, global trade, and logistics. Using cutting-edge technology, in intelligent energy management schemes position smart ports in the fifth generation.

Loads on the shore-side. The on-shore management facility and warehouse commodities are all built on the beach. lighting HVAC (heating, breathing of air, and AC) systems aren't considered the major consumer of electricity in this infrastructure [34]. The energy consumption for all the components

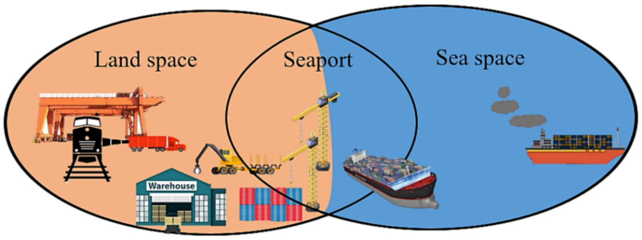

Fig. 1. Seaport intersection between land and sea space [1].

structuring this facility is mainly affected by conditions of the climate, type of materials used for the constructions, working duration, equipment, also the electrical load utilized for a few of the many variables [35]. Loads on the seaside: Any watercraft that travels across the ocean to convey people or goods is considered a marine vessel and is included in the seaside. As the global trade grew, more ships would go farther, use more fuel, and increase the amount of sea traffic. Typically, bulk ships and large boats use heavy fuel oil (HFO). Fig. 2 depicts an application for seaports.

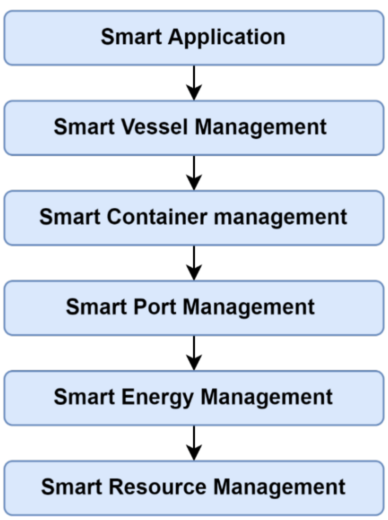

Fig. 2. Seaport Application.

The five major sea port applications are:

- Smart vessel management improves the punctuality of ships' arrival at ports by managing them, including the opinions of routes of ports, based upon volume and location of such ports. A study [26] found that 48% of container ships arrive at least 12 hours late, increasing fuel consumption and underutilizing terminal resources. Therefore, smart vessel management aids in reducing the inefficient waiting and idle time of vessels. for intense, cutting and hours' worth of docking time can result in savings of up to US$80,000 [27]. Examples are:
  - Planning the most effective and fuel-efficient routes is achieved through the use of real-time meteorological data and traffic monitoring.
  - With the use of sensors, predictive maintenance may be carried out to keep engines running smoothly and equipment in good working order, avoiding costly breakdowns.
  - Monitoring Vessels from a Distance: Information gathered on board is relayed to facilities on land so that operations can be closely watched and evaluated in real-time.
  - Automatic Collision Avoidance Systems (ACAS): These systems utilize radar, GPS, and other sensors to determine when a collision is imminent and then to make course corrections or speed adjustments automatically.
- Smart container management carries out the management of container procurement, tracking, transit, storage, and repositioning [28], also transfer shipment, that involves moving of trucks from one to another vessel. However, it lessens the amount of time a ship is in ports, which enables the logistical features and can reduce operating costs by up to 10% [27]. It enables remote detection of the events that occur in the containers during their travel as well as tracking and monitoring of the conditions (temperature) of the containers. Example of incidents and cooperation whether the operators are opened unexpectedly or not also they are adequately examined or not. Other examples include temperature changes, emergencies including vibrations and falls of delicate items, are exposure to fire or flooding. The location and timing of the occurrence, for example, may be tracked and watched, and any necessary actions, like altering stakeholders, can be done right away.
  - Containers can have their whereabouts monitored in real-time using GPS or cellular transmitters installed on them.
  - Sensors check the container's inside temperature, humidity, and other parameters to make sure the cargo is safe.
  - Paperless Customs Clearance: RFID tags and electronic seals make paperwork a thing of the past.
  - Automated solutions maximize space efficiency and speed of access by stacking containers smartly in the yard.
- Smart ports management corporates port services such as costume clearance, transport planning, the trade of applications and export permits, providing permits, customer service features, and a lot more.
  - Automated gates equipped with radio frequency identification scanners facilitate the entrance and exit of cargo from the port.
  - Optimize the flow of trucks through the port to lessen wait times and congestion using terminal traffic

management systems (TTMS).
  - Effective berth allocation for ships arriving and departing can be achieved with the use of berth management systems that make use of real-time data.
  - Integration with Smart Grids: To lessen the burden on fossil fuels and energy prices, ports are incorporating microgrids and renewable energy sources.

- Smart energy management minimizes consumption of the terminal port, also the varying energy consumption which has the port activity as in equipment and for infrastructure i.e., RTGC, YT, and QC. For instance, the ports of Hamburg & Valencia have motion-activated lights that are utilized by cars passing by. This sort of lighting system will surely cut out the energy by 80% percent.

  - Financial incentives are available to ports that take part in demand response programs, which allow them to alter their energy consumption in response to changes in grid demand.
  - Infrastructure that is energy efficient: smart building technology, energy-efficient equipment, and LED lighting all work together to lower energy usage.
  - The port's operations can run more efficiently and with less pollution thanks to the integration of renewable energy sources such as solar panels and wind turbines.
  - Systems track energy consumption in real-time across different locations, allowing for more precise energy conservation efforts.

- Smart resources management schedules & it distributes resources, such as machinery and Internet infrastructure such as (cranes, forklifts, suspension bridges, and container trucks) to ease congestion and pain points it's causes to acquire and distribute resources as quickly and affordably as possible. This lessens the amount of time spent waiting and doing nothing.

  - Port operations such as cleaning and irrigation can be optimized with the use of sensor-based water management systems.
  - Management of Waste: Intelligent garbage disposal systems maximize collection routes and promote recycling to decrease garbage.
  - Sustainable Resource Procurement: To lessen their impact on the environment, ports place a premium on using environmentally friendly materials in both building and maintenance projects.
  - Inventory Optimization: Analyzing data in real-time helps with managing resources like supplies and spare parts, reducing wastage, and making sure they're available when needed.

III. Microgrid Distribution System

The main grid is a grid that connects many homes, commercial buildings, manufacturing, and other facilities to power generation sources that are typically located far from the community's load, such as appliances, electronic devices, and cooling or heating systems. However, if there is a major repair, blackout, or fault in the grid, it can affect everyone and everything that is connected to it [29]. A microgrid, shown in Fig. 3, constitutes an independent energy system made up of distributed production energy sources such as solar arrays, fuel cells, and battery storage. It is directly connected to the loads and has the capability of connecting and disconnecting from one or more common points of the main grid system. As a result, loads can operate independently or in parallel with the main grid system. For example, if the PV system produces enough power to meet load demand, the microgrid will be disconnected from the main grid. Unless there is excess generation or none at all, a microgrid can be manually or automatically connected to the main grid to obtain support. That is, a microgrid allows communities to not only use the main grid as a backup in the event of a crisis but also to be energy self-sufficient by utilizing local renewable sources. This will also ensure energy reliability, efficiency, and affordability, as well as reduce stress on the main grid. It is also environmentally friendly. "A true Microgrid, on the other hand, is much more than a backup power system, even if that is one of its core functions." It must also include real-time, on-site controls to match the Microgrid's generation and storage capacity to power consumption in real-time, as well as some form of grid interaction".

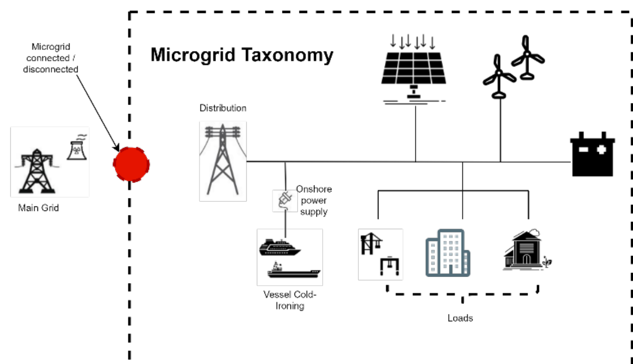

Fig. 3. Overview of possible microgrid facilities

IV. Seaport Microgrids Review

As the direction of the renewable energy sources production house gets the benefit of the installation of microgrid features. The port is the place where it happens solar panel installation, and the construction of roof flat buildings aunt acted as the storage space as well. Nevertheless, this will not be going to suitable for the solar energy board scale level. Some of the ports also utilize differences of tides, waves & geothermal power in addition to the PV and went as import of Hamburg Australia and Nova Scotia [30]. Scientist's researchers from all over the globe had to work with efficiency and energy, management also power-related fields from those of the smaller nodes. small notes are a result of low co-occurrence, which opens up more avenues of maritime power system advancement research.

In [31] author presents the seaports in Copenhagen Denmark as a case study to analyze the effectiveness of the system that was designed. utilizing software called the hybrid optimization model for electric renewables (HOMER), which contains a result from optimization and sensitivity analysis, the study is carried out. According to the simulation result, implementing microgrid technologies would be a practical way to supply electricity to the load application chipboards, and Fig. 4 seaport microgrid architecture is explained.

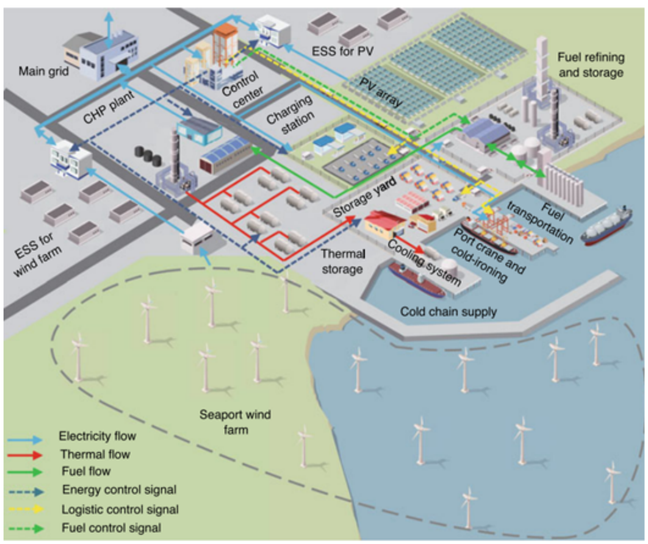

Fig. 4. Seaport microgrid architecture [34]

In [36] presented to demonstrate the current state of knowledge of the issue of greenhouse gases released by ships while docked and how to address it, a study of research developments on cold ironing is conducted. Additionally, current laws all instances of ports using technology for cold ironing are displayed. Second, the study suggests using a cold ironing system in Barcelona's port, where all of the energy generated is provided by renewable energy sources (wind turbines and photovoltaic panels). To accomplish the aim of zero emissions from berthed ships, the idea is to support the widespread use of cold ironing within smart port microgrids shown in Table II.

In [37], The port of Long Beach located in California in the case study's gone versus of 11th February 8 price that operates a single microgrid with a separate energy management system the integrated energy management approach for the pole the corner you compassing old parties is it proposed in this article and is based on a blockchain technology considerably reduces

TABLE II. Review of Seaports Microgrids

Authors	Description	Advantage	Disadvantage
[31]	Hybrid optimization model for electric renewables	High efficiency grid	Radiation efficiency is not given
[36]	Cold ironing system in the port	Reach the goal of zero emission from that of the berth crafts	It doesn't easily get navigated
[37]	Blockchain technology for the poop	High level security and efficient maintenance cost	It doesn't use any classifiers
[38]	Integrated day-ahead scheduling algorithm	Health in improvise economical concern, independence, efficiency and wide range of system	High cost

the quantity of big electricity while imposing additional costs on the board manager additionally the advantages of smart grids based on blockchain technology including their high level of security and low maintenance costs will be covered. In [38], there are two of the most demanding methods have been utilized 4 electrification techniques microgrids and onshore power supplies furthermore by utilizing the single unified layout a greater scheduling algorithm has been improved to optimize the board energy management especially for the scheduling related queries 2 stage of the model of algorithm has been proceed here the authority of the board chose the optimal birth was option for the combining crafts and the starting stage where the need of the energy volumes of the cargo and handling machineries the authority of board chose the best day ahead for scheduling with respect death of the containers also the operation assets for the stage 2 acts as the microgrid operators the formulation of the problem includes uncertainty related two forecast 4 port load and renewable energy generation the simulation based case study shown that when compared to the traditional birth allocation technique this adjust joint scheduling algorithm can improve the board microgrid energy independence system wide efficiency operational dependability and economics.

V. Seaport Microgrid Topology

A microgrid is a group of generators, loads of power converters, and some of the storage generating systems [39]. the common coupling which connected medium voltage and low voltage to the utility grid which acted and signal location which is PCC [40]. there are two main modes of operation for the microgrids island modes and connectivity of grid modes [41]–[43]. the microgrid functions acted as the extension part of the generator by applying the limited power to the utility grids. It takes the energy from the grid, here when the REC power generation is considered to be non-predictable, then there is an excess power that needs energy occasionally, which creates greater opportunity in reselling the scopes and to the revenue generation [44]. For the greater utilization of the microgrids, [45] Examined the TOU has been proposed to minimize the price of electricity. Here, the microgrid acted as the autonomous function in the island mode [46]. When the need for breakdown happens, microgrids engage in the restoration of doors and make sure to have continuous power, especially in the critical power loads. Also, the cause of utility breakdown must be a non-expecting shut down or when there is no electricity available [47], [48].

In general, there are three topologies for microgrid frameworks: (1) Alternating current AC microgrids, (2) Direct current DC microgrids & (3) hybrid AC/DC microgrids [49], [50]. The AC boss requires DC to AC inverters for the process of protecting the DCs and ESS and the AC microgrids are considered to be a common bus in the microgrids. also, the DC produces fuel cells and PV. Simultaneously, the DC loads have been adopted by AC to DC rectifiers. The common bus in DC in her considered as the DC micro, here, AC components require AC load supplies by DC to AC inverters and AC to DC rectifiers both kinds of buses can be found in a hybrid microgrids network. It eliminates any used converters and enables the flexible coupling of DC and AC components in two respective buses. A possible microgrid topology for a seaport is represented in Fig. 5.

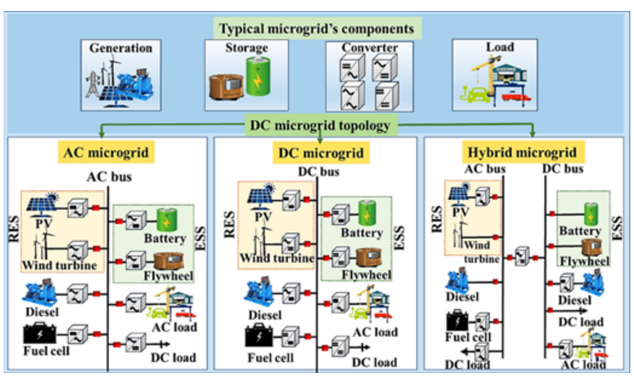

Fig. 5. Microgrid Topology Options for a Seaport [1]

Due to its ease of synchronization along with the AC's network distribution factor, its straightforward design, and its considered to be economically sustainable, the AC topology has been the most often adopted topology from the inspection of microgrids. Normally, AC microgrids are the best option when the microgrid is connected to the main utility it is suitable for induction motors and can transmit power over long distances it is also simple to modify the AC voltage to various levels for different applications though it has several merits long distance transfers are one among the obstacle which makes the process cost effective and not practically implemented Fig. 6 all straights the seaboard microgrid topology architecture.

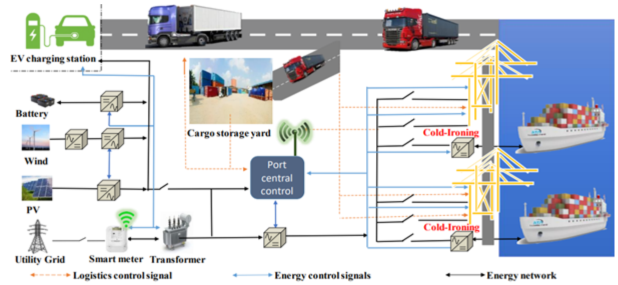

Fig. 6. Seaport Microgrid Topology Architecture [51]

In [52] have you proposed an All Electric Ship (AES) arrival time estimate technique to lower the risk of voltage violations in various ports microgrids? The optimal power flow (OPF) is then used in each microgrid to determine the day-ahead dispatch of the on-load tap changer (OLTC) and inverter-based renewable energy resources (RESs). In Step two the Dijkstra algorithm and the sea state are used to plan the best possible route. using CPLEX solvers using several alternative algorithms, the journey and generation schedule of all-electric ship AES are treated as optimization problems. In stage three, a real-time local voltage control approach is utilized to decrease quick voltage violations. Both continuous charging mode and voltage management mode are designed to control voltage while ensuring that (ESSs) have enough state-of-charge SOC levels to exit the ports. To use all the energy storage system (ESS) abroad berth-in AES, this is necessary. The simulation result demonstrated that the suggested approach is successful at reducing AES generation costs and enhancing voltage profiles and seaport microgrids shown in Table III.

TABLE III. Review of Seaports Microgrids

Authors	Description	Advantage	Disadvantage
[52]	AES	Better effectiveness and improving voltage.	It is not easy to integration.
[19]	ADMN	Economic cost to evaluate the time-cost factor.	Lower Efficiency.

In [19] presented that, to minimize the balance and violations and voltage the merits of AES and microgrids, which are considered to be the berth allotment and distributed voltage control technique have been utilized. Also, here, SOCP has been enhanced to mitigate the power loss. Furthermore, the harbor's instruction model has acted as the bridge among berthed AES on microgrids. it also values regulation or voltage and allocation of the berth the proposed model nucleus includes the time cost methods. This method brought convergence for solving the models along with discrete variables. The simulation result on the EU 16-bus microgrid embedded with a seaport confirms the efficacy of the proposed strategy and that minimizing voltage violations isn't optimizing the overall benefits of microgrids on AES.

VI. Review of Schedule Optimization Issues

In [53], have developed an automated system capable of creating the base loading/ uploading schedule in a seaport while accounting for the dynamic impact of outside influences on its effective operation. In [54] a genetic algorithm and multi-agent technology are used in the scheduling method to generate a schedule for port operations while enhancing the quality of the result. It is expected to make use of the information gathered from various agents on the adjusted throw their instructions. Genetic algorithms are used to schedule events shown in Table IV.

TABLE IV. Review of Seaport Schedule Optimization Issues

Authors	Description	Advantage	Disadvantage
[53]	Multi agent technologies and a genetic algorithm	Improving the quality	Low efficiency
[55]	Two stage adaptive genetic algorithm	ASC more efficient	It does not use any classifiers
[56]	Two basic ship port coordination	Adequate flexibility	High cost

In [56], have presented based on a graph theory model, a two-stage adaptive genetic algorithm (AGA) is suggested by altering the order of container operations, the algorithm's initial stage minimized conflicts as much as feasible. When conflicts cannot be avoided, they are handled in the second stage by turning them into obstacle diagrams. To solve the compilation time, locate the diagram's shortest path. The provided algorithm can be used to test the program's effectiveness on different scales of container numbers. The graph theory model can do variable degrees, and reduce the completion time as compared to the conventional seaside priority technique. the outcomes demonstrated that the graph theory model makes ASC automated straddle carriers more effective in terms of the method of establishing the handshake area to decrease conflicts.

In [57] have introduced both berth allocation and on-shore power supply management (cold-ironing) are basic ship-port coordination energy models are offered, in addition to scheduling model for an integrated energy system that can meet both the demand for the thermal and electric power at the same time. The simulation result demonstrated that berth allocation can provide enough flexibility to make the operation of the seaports easier, and the port of Houston was chosen as the test case to illustrate the validity of the proposed methodology.

VII. Challenges Facing Seaport Microgrids and Futuristic Methods

A. Future Direction

To achieve their full potential, seaport microgrids must overcome several obstacles and open avenues that stand in the way of more widespread adoption and environmentally friendly marine transportation. This is where we need to focus:

1) Technological Advancements:

- Innovative Energy Storage: Large-scale port applications may require batteries with more capacity and longer lifespan than what is now available. It is essential to research alternate energy storage options such as flywheels, CAES, and redox flow batteries.
- For optimal energy exchange and grid stability, smart grid integration is crucial, and microgrids must be seamlessly integrated with the broader power grid to achieve this. If grid interactions are to be optimized, then sophisticated control systems and protocols for communication are required.
- Security: Cybersecurity risks are growing in importance due to the increasing complexity and interconnection of microgrids. Cyberattacks that could halt operations necessitate the installation of stringent security measures.

2) Policy and Regulation :

- Problems with broad adoption may arise from a lack of uniform rules and technological standards. Microgrid development incentives, safety requirements, and grid connections can all be improved with the help of well-defined rules.
- Carbon Pricing Mechanisms: Ports may be encouraged to implement microgrids and other environmentally friendly technologies if a price is placed on carbon emissions. International cooperation is necessary for carbon pricing plans to be effective.
- Seaport microgrid initiatives necessitate novel approaches to funding and financing. The financial viability of microgrids can be enhanced through the use of carbon credits, public-private partnerships, and government funding.

3) Operational and Business Considerations: :

- Assessing the economic feasibility of microgrids for specific ports requires comprehensive cost-benefit assessments that take into account initial investment, operational costs, and long-term energy savings.
- The development of new business models is essential if port authorities, shipping corporations, and other interested parties are to work together and finance the expansion of microgrids.
- Training and capacity building: Increasing workers' skill sets is essential for efficient microgrid system operation and maintenance. Technicians and port employees need training programs.

4) Seaside Microgrids :

- The development of space-efficient and practically applicable solutions for ship microgrids continues to be a technological challenge. Ships that use renewable energy

sources and have energy storage systems installed need additional study and development.
- Compliance with International Regulations and Safety Standards: Microgrids installed aboard ships must comply with international regulations and safety standards.
- Efficiency and standardization in shore-to-ship power transfer would allow docked ships to connect to shoreside microgrids, lowering emissions from the ships themselves.

Seaport microgrids can transform the maritime industry for the better by tackling these unanswered questions and overcoming these obstacles. The key to making this vision a reality is ongoing research, crafting policies, and fostering collaboration among all parties involved.

B. Seaports Challenges in Developing Microgrids

This is a growing trend towards maritime microgrids, as seen by the rise in paper from scholars all around the world. However, due to several problems and obstacles that exist from different angles, there is a dearth of actual seaport metro-grade deployment in the harbor. The technological and management aspects of seaport microgrids were covered by Anthony Roy [58]. Among the crucial viewpoints are those related to security and regulation. The following addresses a few of these difficulties.

1) Technical Challenge: It is inefficient to rely only on the electric grid when there are big appliances in the harbor. cables will be highly expensive if the grid is far from the port. Thus, because of the advantages of local generation, using energy from RES is more cost-effective. However, the space available for RES installation in ports is limited [58]. unquestionably, buildings or warehouses on flat rooftops can be used to hang solar panels, but they have limited capacity and cannot be used on a bigger scale. microgrids on ship experience the same issue. For propulsion and delivering onboard load, several commercial AES use batteries and diesel generators. To provide the power needed by the shipboard microgrid the implementation of RES such solar systems is considered in [59] for the future AES generation. no mention is made of a compatible solar panel system that might be mounted on the ship though it is common knowledge that ships have extremely little space because of the hefty equipment that carries, particularly cargo ships, which often employ the available space to store their cargo additionally since ship are always in motion and alone at sea, coordination of the RES will be challenging.

2) Managerial: Additionally, since ships are always in motion and alone at sea, coordination of the RES will be challenging. The adoption of port-based microgrids is thought to be sparse in comparison to the widespread use of land-based microgrids. Although this circumstance presents a chance to introduce microgrid technology to support, it is also challenging to find references regarding the needs, design, operation, and maintenance requirements of these systems. It can be challenging to choose the optimal design for the seaport microgrid with a compatible layout and the right component size, especially early in the design process [38].

3) Security and Regulation: Due to the ultimate load behavior & features of the power electronic systems, the control and operation regulation of the microgrid seaports vary enormously with the common power system factors. Due to the frequent arrival and departure of ships, ports tend to have very fluctuating loads. Voltage/frequency stability and microgrids must be maintained by achieving a balance between supply and demand—system instability and a significant risk, especially during isolated operations. A hierarchical control approach has been suggested as a viable solution to manage these problems. Additionally, the management structure and code of behavior for shipboard and shore-based microgrids (seaside) differ [59].

4) Potential Future Research Directions: The challenges mentioned in the previous article and additional technological problems need to be addressed, and further research is required to discover the appropriate solutions. The ports will gain from having the know-how to handle all of these in a numerous technique, which incorporates efficient energy, saving of price, and circumstantial factors. The potential challenges on the seaport microgrids are listed below for future research to take into account.

5) Mobile Cold Ironing: The majority of the direct energy from the main grid is currently used for cold ironing in the harbors. there is a risk that several massive ships with demanding power requirements will show up simultaneously. As a result, relying solely on the grid supplies will not be able to maintain port operations as a whole and could lead to power shortages. Additionally, the majority of smaller seaports like cold ironing stations, which courses continual auxiliary engine pollution during birthing. A "movable shipboard microgrid" enables mobile code ironing by implementing a sharable network between the closest crafts, which is a workable solution for supplying momentary electricity to allay these worries. To put this method into practice, more studies on it can be conducted [60].

6) Optimal Board Planning: Because seaport microgrids have a variety of loads, goals, and limits, it is essential to plan effective coordination across the microgrid components. There isn't much literature on support microgrids that discusses suitable configurations and the right size/capacity for each component. Along with choosing the appropriate installation at the topology of the RES, storage component, and converter. excellent cooperation is required. This will guarantee that the microgrid implementation is adequate and not overly large, enabling efficient power distribution and avoiding superfluous expenses [1].

7) Cluster Seaport Microgrids: The bulk of articles on seaport microgrids, according to the literature that is currently available, enhance the entire outcome of the microgrid, though, the port handles a variety of big energy uses, including vessel and administrative structures of handling of ports, called irons, cargo transport, and container terminals. As a result, clustering the load into several load clusters presents a strong chance to install cluster seaport microgrids [1].

8) Optimization: This is necessary to develop an optimization algorithm that will serve the interests of the port entity and the body of the judicial which is given the current strict policy for the port operation to minimize protected harmful contamination. The analysis will assist port organizations in planning for the future so that it is consistent with port policy [1].

VIII. Evaluation and Analysis

The main objective of this research is to integrate smart ports including seaport microgrids in terms of their principles, communication infrastructure, sensors, on schedule optimization issues, the article will provide several examples. Various kinds of seaports and metrics have been introduced. The research papers which are analyzed the seaports and mostly based on common metrics such as quality, and efficiency. Efficiency: It is observed as the radiation efficiency multiplied by the impedance mismatch of the port: total port efficiency is always lesser than the think efficiency. The total number of ports using application taking according to this survey paper is pictorially shown in Fig. 7.

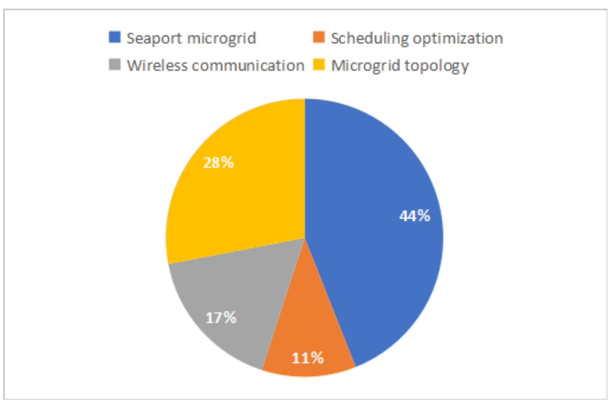

Fig. 7. Smart Application Count

The analysis explains that smart ports, including seaboard microgrids in terms of their principles, communication infrastructure, sensors, and schedule optimization issues, this article will provide several examples used and it also applied in the present research. There are around 45 research articles reviewed from the various smart ports including seaport microgrids in terms of their principles, communication infrastructure, sensors, schedule optimization issues, and ports which are taken from the years 2012-2022.

As shown in Fig. 7, a count of the number of smart applications is provided. A number of scheduling optimization, seaport microgrid, wireless communication, and microgrid topology are 11%, 44%, 17%, and 28%, receptively.

A. Dissections

There is an immediate need for the marine transport sector to lessen its negative effects on the environment. A future where our oceans and world are cleaner and more sustainably powered is within our reach, and seaport microgrids are a crucial step in that direction.

1) A Greener Energy Landscape: Just picture a port that's humming along, all thanks to a system of small, decentralized power plants called seaport microgrids. Microgrids like this combine renewable power generation resources (such as solar panels and wind turbines) with energy storage devices (such as batteries). Environmental benefits abound when we move away from energy sources that rely on fossil fuels:

- Reduced Emissions: Seaport microgrids greatly reduce air and water pollution caused by port activities by utilizing clean, renewable energy. Pollutants in the air near ports, such as sulfur oxides, nitrogen oxides, and dangerous particles, would be drastically decreased.
- The port's energy environment becomes more sustainable as a whole as its reliance on fossil fuels decreases. This is in line with the worldwide movement to protect our oceans and fight climate change.

2) Boosting Efficiency and Resilience: Seaport microgrids provide a more intelligent and effective method of managing energy within ports, in addition to their environmental advantages:

- Ports can optimize their energy usage and decrease overall energy waste thanks to microgrids, which offer sophisticated energy management. Port authorities and tenants will see substantial savings as a result of this.
- Microgrids increase grid resilience because they may continue powering essential port functions even when the main grid goes down. As a result, port operations are better able to withstand disturbances.
- Reduce Power Demand During Peak Hours: Microgrids that have energy storage can handle the high power demands that occur during peak hours. Lowering total energy costs and relieving pressure on the traditional grid are two possible outcomes of their storage and release of excess energy during off-peak periods.

3) A Brighter Future for Maritime Transportation: The possibilities of seaport microgrids go beyond just one port. In the marine industry, they have the potential to spark a larger shift:

- Greener Shipping Practices: One way to further decrease emissions when ships are in the harbor is through shore-to-ship power transfer, which involves docked ships connecting to the port microgrid.

- Sustainable Development Incentives: Cleaner maritime operations can be fostered by the establishment of onboard microgrids, which can be inspired by the success of seaport microgrids.

IX. Conclusions

Large ships use diesel to keep their engines going when docked. Trains with engines can move large loads. This paper presents the results of a comprehensive literature review and highlights the following points: the concept of seaboard microgrids, their integration into the seaboard from both shipboard and shore-based perspectives and their operational management. Microgrid topologies have the potential to support the utility grid and are a significant source of pollution. Optimal connection and three or four ports for microgrids along the coast paramount importance keys It is imperative that this issue be resolved in future board planning. Despite smart ports' ability to cut down on energy consumption and expenses related to transportation, routing remains a crucial component for the smooth operation of cooperative networks. This is especially true when it comes to predictions and other port-related operations that rely on precise location data. where ships and their machinery are situated Among the most recent advancements in smart port technology include the implementation of IoT devices for renewable energy generation and storage, the ability to recognize codes on containers for energy management and trajectory forecasting, and the utilization of data from all-electric ships' AES systems for resource management. Research into the use of blockchain and big data analytics to improve cybersecurity in autonomous seaport operations is an exciting and novel prospect. Academia now has a solid foundation upon which to build future studies on safe and effective smart port management. According to the research, seaport microgrids are a great way to make marine traffic more environmentally friendly. The main points are summarised here:

- Microgrids offer numerous advantages to seaports, including improved energy efficiency, economic growth, environmental sustainability, and safety.
- Complex energy demands from cranes, ships (including cold ironing), and buildings create challenges in port operations.
- To optimize functioning in this dynamic context, additional research is needed to determine the precise control strategies needed, as seaport microgrids have not yet seen widespread implementation.

The analysis brings attention to the potential of microgrids for sustainable maritime transport while acknowledging the need for further development to address existing challenges. The Consequences of New Technology:

- The application of artificial intelligence (AI) has several potential applications, including intelligent video surveillance for improved security, real-time traffic management, optimized freight handling, and equipment maintenance requirement prediction.
- Port operations can be simulated, new technologies may be tested, and resource allocation can be optimised with the help of digital twins, which are digital representations of actual port infrastructure.
- Secure and transparent data interchange throughout the supply chain can be achieved with blockchain technology. This technology can facilitate commerce and improve traceability.
- The Internet of Things (IoT): By installing a system of linked sensors all across the port, we can monitor environmental conditions and container locations in real-time, which will help us make better decisions and work more efficiently.

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