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# Feasibility Study of Future Seaports

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**Abstract.** Port is a focal point especially in the trade sector, where it is represented as hub for the import and export from one destination to another. Despite the fact that it gives positive impact to country specifically in economic sector but from the health sector, this activity leaves a negative impact on the environment and human health, especially those living near the port. Now, most of developed countries have made improvements by converting conventional engines (diesel engines) to electrical engines for major vehicles in ports. The same goes for shore-side ports, most of them using cold ironing (CI). However, all the modification is still raw and faced several challenges, especially in technical aspects such as voltage difference, frequency, supply / demand. It occurs due to the difference in standard voltage and frequency between shore-side and ship. Most of the ocean ship used 60 Hz. In addition, the main constraint faced is that the power supplied on the shore-side is not enough to meet the demand from customers. Thus, to make additions to the existing substation, it will require high initial costs. After evaluating the pros and cons, the new approach is taken to integrate this system into microgrid technology. Microgrid technology is a local cluster energy source with a control capability comprising Energy Distribution Resources (DER), which cover management request, storage, and loads. One of the advantages of a microgrid is that they can be connected or disconnected from the grid to operate autonomously.

Keywords— microgrids, Shore-side, Port, cold ironing, ship.

## 1. Introduction

For the transport and maritime industry, seaports are regarded as one of the most significant components. The seaport service has also recently expanded to a logistical network. More than 90 % of the world merchandise exports today is dominated by shipping routes. Shipping has provided the most efficient means of long-distance shipping on an ongoing basis, and containerization has played a crucial role in global marine transport, as well as in improving safety and delivery times. For international trade, the organization of a port is important because the seaport is seen as the nerve of a country's foreign trade. However, the focus on environmentally sustainable port safeguards should be taken seriously by both concerned, provided that the amount of pollution from marine transport in ports is related to port operation.



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Important contributors to greenhouse gas pollution such as particulate matter ( PM), carbon dioxide ( CO<sub>2</sub>); sulfur dioxide ( SO<sub>2</sub>); nitrogen oxides ( NO<sub>x</sub>); and soot are produced from marine transport throughout the port city, based on news reports. Transport combustion engines produce soot that is normally accepted in the port area, especially from ships and cranes. Table 1 and the equation as seen in equation 1 indicate the typical shore-side behaviors during the berth [2].

Table 1. Average Time Berthing [1]

Type of ships	Average time (hrs)	berthing
Oil tanker	28	
Chemicals and other tankers	24	
Bulk carrier	52	
Container	21	
General Cargo	25	
Ferries and RoRo	24	
Cruise	28	

$$g = kW \times l \times t \times g/kWh \quad (1)$$

Where:

g = emissions (grams [g])

kW = maximum continuous rating power (kilowatts [kW])

l = load factor (percent of ship's total power)

t = activity (hours [h])

g/kwh = emission factor (grams per kilowatt-hour [g/kWh])

The emissions are proportional to the time a ship is moored, dependent on equation (1). Thus, shore-side power (also referred to as cold ironing) appears as an initial approach to reduce unnecessary environmental impacts at seaports in order to decrease ship pollution in port, but port progression must be synchronized with ship technology. The All-Electric-Ship (AES) architecture [3][4][5] is now being followed by several ships. In reducing fuel consumption and air emissions, electric propulsion grants more serviceability, and its performance is more efficient than the prime mover. Other benefits of electric propulsion are that, through automation and safety management technologies, it can minimize worker demand and reduce life-cycle costs through decreased maintenance

By using microgrids and CI architectures in traditional seaports, this thesis suggested exploring and presenting test findings, thus suggesting successful concepts for the potential port. Section II analyses traditional seaport operations and impacts in the context of EU and Asian scenarios. Microgrid innovations are introduced in Section III and their benefits are addressed, and the potential green seaport is eventually suggested and discussed in Section IV.

## 2. Port activities

### 2.1 Traditional Port

In a few viewpoints, conventional port has multiple shortcomings, such as noise, air quality, vibration and especially power demand. As seen in Figure 1, the high demand for energy in ports is due to the handling of various operations, including those related to the type of services provided to customers. As we know, port electricity is mainly generated from the utility grid that comes from mixed supply, such as coal, oil, gas, etc., which relies on a country's primary source. If more customers are

connected to electricity networks, such as an increase in the number of houses and an increase in the number of port operations, the grid is connected.

Today, owing to the alteration of shore-side and port transport, the need for power in ports is a major concern. For various types of ships, the average power required from the shore-side during the berth is shown in Table 2. Furthermore, the grid system is more complicated and difficult to manually monitor, whilst the current substation capacity needs to be extended in order to accommodate the total energy load, especially at the port, and this can require high retrofit costs. In addition, where shore-side power has limited capacity, there is another challenge that must be considered [1].

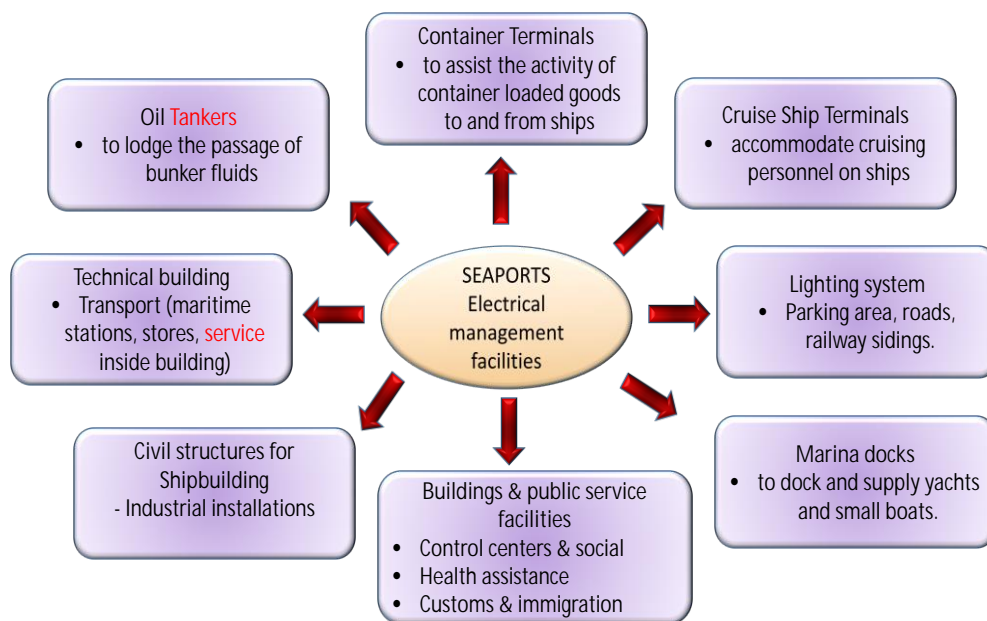


Figure 1: Flowchart of electrical management facilities in seaports

Table 2. Average power requirement during berthing [6]

Types of ships	Power MW
Container	1 – 4
Reefer	2 - 5
Roll-on /roll-off	0.7
Tanker	5 - 6
Bulk cargo	0.3 - 6

Approximately 71 percent of container port calls are in Asia [7], and over the last decade, China has dominated worldwide shipping. On the basis of global freight information, six of the world's ten largest ports with the highest number of freight transactions are located in China [8]. According to the EU Inland Water Transport (IWT) medium and long-term outlook [1] (CE Delft et al. 2011), the number of ships entering EU ports will rise by up to 125 percent by 2020, beginning from 27,000 ships in 2010. As can be shown, the number of ships in 2020 has been increased to 60,750. In order to ensure that electricity demand is adequate to support all port operations, planning and energy conservation schemes need to discover the optimal solution. The optimal approach, therefore, is to incorporate shore-side microgrid technologies. This strategy will also reduce the cost of using grid energy while increasing the usage of green electricity systems.

## 2.2 Cold Ironing (CI)

CI is one of the latest strategies to minimize the adverse effect on the atmosphere of ships at the port. It is named CI because the onboard engines and auxiliaries can shut down entirely while the ship is at the dock (cold process), but the ship operation still operates because the electricity will be moved from the shore to the ship switchboard (ironing process). The value of the CI process is that fuel consumption is saved. The comparison of the consumption of fuel before and after cold ironing is clear from the pie chart in Figure 2. Fuel consumption can be decreased by up to 45 percent, as can be seen [10].

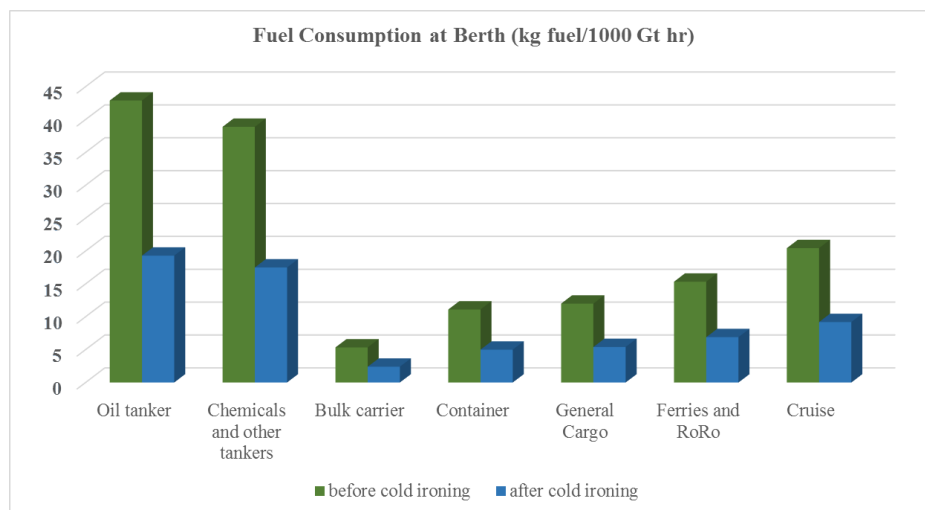


Figure 2: Fuel consumption before and after implementing the CI process [1]

Nevertheless, CI is already an inexperienced idea and is too recent for many ports. Moreover, for both inland ports and shipping, there are many challenges to enforcing this. In the case of inland shipping, adoption is constrained by the limited supply of shore-side capacity in ports due to the facilities of the energy grid (for example, in the EU). If power demand on the shore-side is raised because the problem for ocean-going ships is the fee levied on energy from shore power due to the fluctuating cost of fuel, stakeholders are also sceptical about grid reliability, further complicated by deterring tax regimes. Further investigation is therefore required at the level of the CI and the distribution system, especially in areas with flabby grids [1]. CI also faces strategic and organizational problems, (Prousalidis et al., 2014) such as:

- (a) Electricity supply / demand in such a manner that the actual overall shore-side power commitment is adequate to satisfy the demand of the ship, including the demand for visiting ships.
- (b) Varying voltage levels between ships and port sides and their effect on the maximum demand for electricity and have a direct impact on the expense of the shore-side power supply grid.
- (c) Distinct frequencies of the vessel and the shore-side. Some countries have a frequency of 50 Hz or 60 Hz depending on their region, while ocean-going ships often use a frequency of 60 Hz for the electric component [12].
- (d) Power efficiency, so that when transients occur on one vessel, they can impact the fluctuations on the other vessel and the user on the shore side.

- (e) Variance in load, meaning that safety mechanisms need to be more versatile in order to prevent defects between the ship and the shore.
- (f) Harmonics produced in one part of the system by electronic power devices could theoretically affect the harmonic resonance in another part of the system.

### 3. Microgrids technologies

A microgrid is a community within an intelligibly understood electrical partition of interrelated loads and distributed energy resources (DER) which acts as a single controllable entity relating to the grid. In order to allow it to act in both grid-connected and island-mode, a microgrid can couple and decouple from the grid. A microgrid can be seen as a small-scale model of a centralized power infrastructure capable of producing, supplying and regulating the distribution of electricity to meet the needs of residential consumers, industrial parks, commercial institutions, etc. Three attributes may be applied to microgrids, namely technological, economic, and environmental. Abu-Sharkh et al. , (2006); Palizban et al. (2014a) and Su, Li, & Duan (2009) address the benefits of microgrid technology deployment, such as:

- Qualified to foster residential and construction capacity in rural areas.
- Fend off large distribution lines that come from vast power plants situated far from the areas of consumption.
- Capable of harmonizing source capacity

In A.K Basu et al., (2011), Lasseter, (2002) and Gharavi & Ghafurian, (2011), discussed the benefit of microgrids technologies in terms of economic benefits such as:

- Ability to compete in the ancillary service sector, as the supply of grids is restricted by voltage levels and power losses, while DER can provide additional voltage support for microgrids.
- Oil expense saving
- Savings on fuel costs.
- High durability.

Morris et al., (2012) express the superiority of using microgrid technology in terms of the environment, for instance:

- Lower emissions of pollutants and greenhouse gases.
- The lower spatial footprint for the generating system
- Decreased reliance on external fuel sources
- Increased number of clean energy sources incorporated into the grid.

### 4. Future seaports

As described above, traditional seaports are not prepared to satisfy the energy demand of the customer (ships) in the future. The alteration of existing seaports would also result in higher retrofit costs. The interconnected microgrid is a single infrastructure approach that can address the carbon issue while still satisfying the load demand in the future and can reduce the electricity usage of the power grid. Figure 3 illustrates the suggested alignment of the microgrid with the CI mechanism to be introduced in future seaports. In addition, both AC and DC buses will be required to provide electricity to hybrid vehicles such as trucks and cranes. Power needs from cranes could be higher up to 700 kVA-1,650 kVA (Minglin, 2009). The AC bus is also more fitting for delivering power to the cranes.

A more sophisticated energy storage system can be used to guarantee that the tracking, regulation, and recycling of energy in buildings or client companies in the seaport is still in the best possible state.

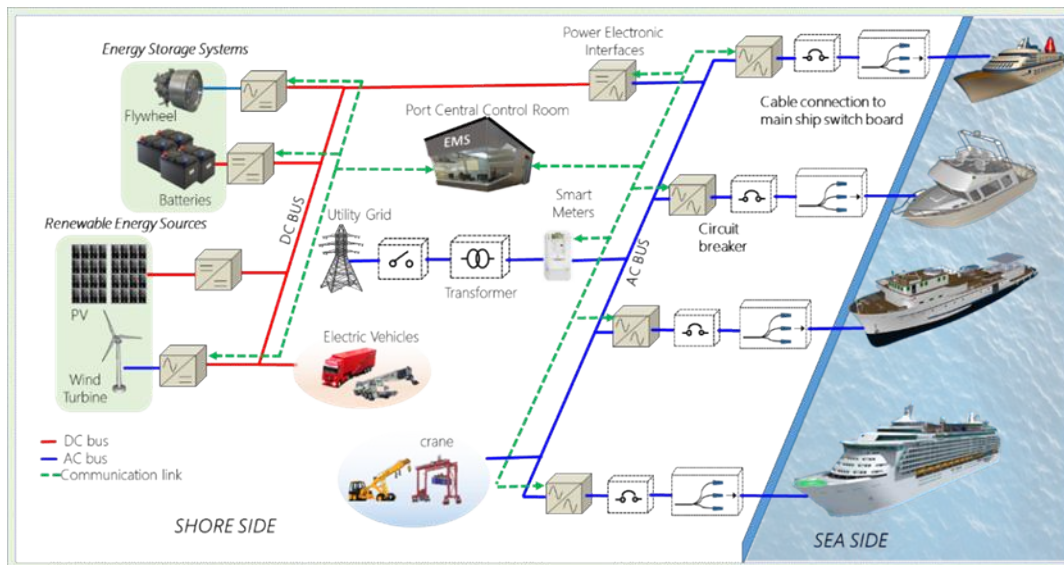


Figure 3: Integration Microgrid with CI

Seaports must also be revamped to respond to ship technology, such as AES. It is therefore important to carry out an analysis of the variety of electrical setups required for cold-ironing or Ship-to-Shore-Power (S2SP) of a berthed ship in the potential seaport. Shore-side power generation using liquefied natural gas (LNG) as an alternative fuel is often known to be ideal for CI.

Normally CI operates in medium voltage mode (1kV-100kV) [26]. The configuration of the CI is seen in Figure 4. This agreement will produce outstanding results thus meeting the demands of both stakeholders (customer and stakeholder) in terms of costs, room savings (a variety of ships can be docked at the same time), retaining inverter capacity and improving efficiency[27]. An example of such a CI distribution configuration is seen in Figure 5(a). This scheme explicitly expands the device by replicating the whole regime for each berth with frequency converters and transformers. This design provides excellent versatility and redundancy, but it is costly to create, particularly given the strength of electronic converters. It does, however, contrast with the unified CI system. This arrangement uses a single frequency converter as a central unit and a double busbar to allow a ship to use 50 Hz or 60 Hz (Sciberras et al., 2015).

The DC distribution CI topology is extended by applying the two previous configurations to the DC bus. The benefit of this configuration is that it is more usable to be combined with an energy storage system and to be used for the final terminal in a small quay area (Kanellos et al., 2015)[30].

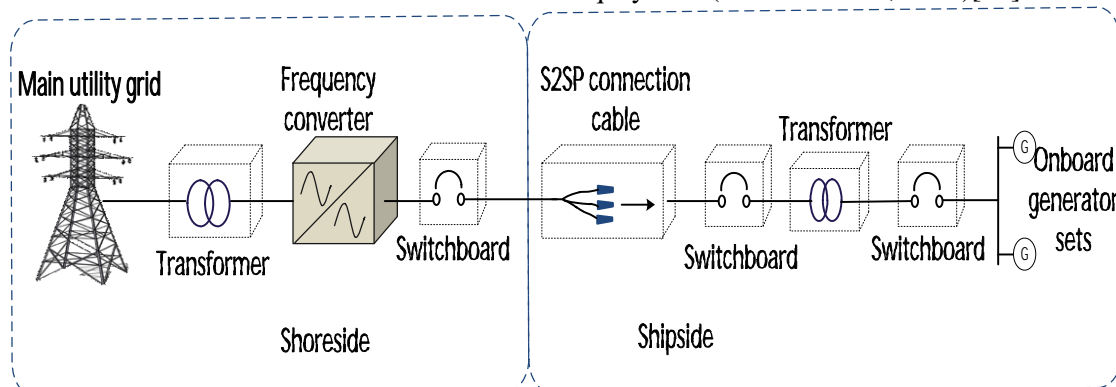
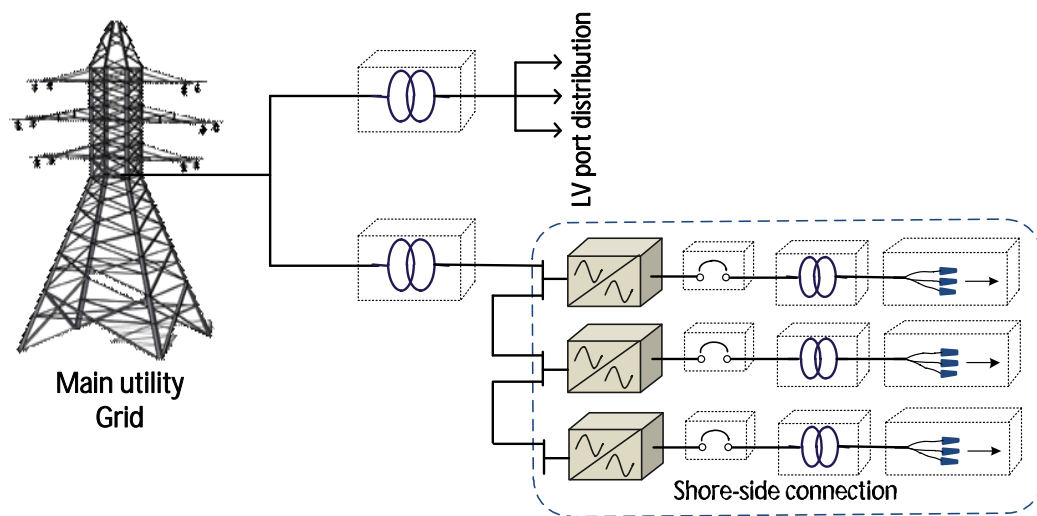


Figure 4: General diagram of CI standard requirements

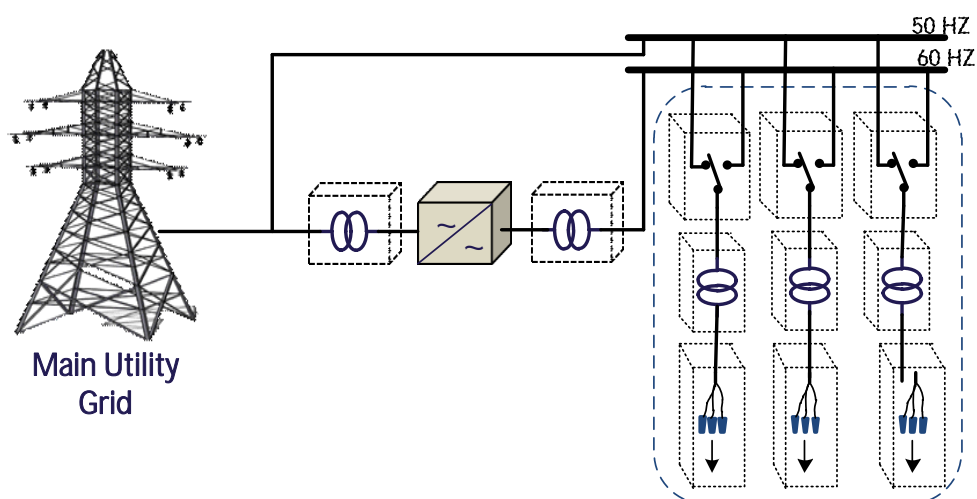


Each arrangement has its advantages and disadvantages. For example, in terms of durability during the fault conditions, the distribution type displayed in Figure 5(a) is the best option in terms of a single point of failure of the converter as compared to the centralized format and DC distribution topology. If one unit of the converter has a fault, another unit can still deliver the power to the load. However, the disadvantage is cost, which is quite high due to the expense of each inverter.

Sciberras et al., (2014), recommended that a CI delivery system be paired with LNG generation. LNG is considered an alternate source for the generator due to its lower amounts of particulate matter and sulfur emissions (Bengtsson, 2014; EC, 2016). Mobile CI was implemented in Jayasinghe & Fernando (2016) using fuel cells and batteries as the source. This setup will save time waiting for the ship to charge power from the sea. It allows a ship with low pollution to be charged easily.



(a) Distribution CI



(b) Centralized CI

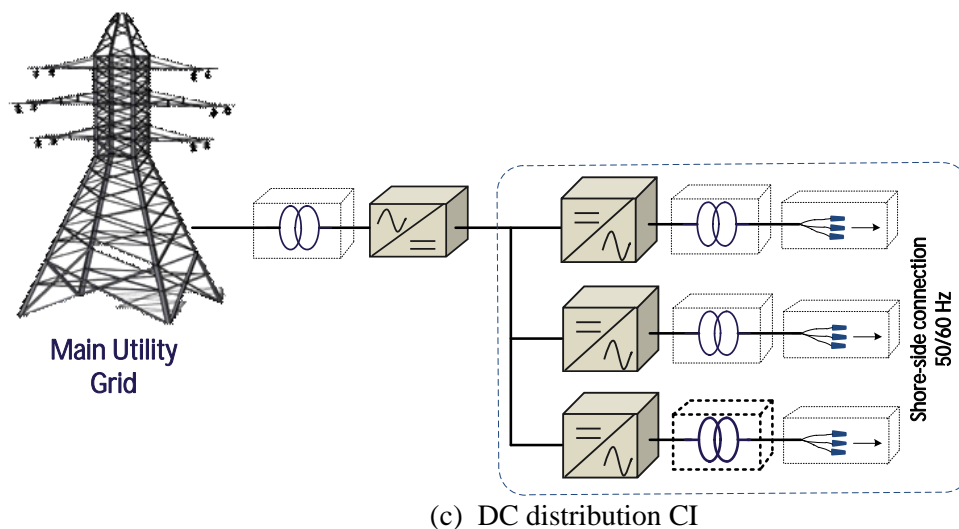


Figure 5: Configuration of CI

In order to ensure the security of assured supply between ports and ships, protection is also essential. When the cable link between the ship and the port is disconnected, it gives a strong interlocked earthing device. This helps to ensure that no electrical charge is deposited in the efficient capacitance of the cable [35]-[37].

### Discussion

The latest trends of seaports of ships relying on their own control and the impacts on air quality in port areas are illustrated in Section I. The effects and current condition of the EU and Asian ports are addressed in Section II, in particular with regard to power usage and future load demands, plus the feasibility of cold ironing and the implementation issues that need to be considered. In terms of fiscal, environmental and technology benefits, Section III explains the advantages of the microgrid. The definition of the future seaport was stressed in section IV. A mixture of solar energies, energy storage, and delivery networks is the key concept of this segment. In order to promote the use of renewable resources and to minimize energy demand from the power grid, the setup of cold ironing is illustrated.

Regarding the three cold ironing models, the better alternative to incorporate in a seaport is the delivery model that would cost more compared to the other two configurations (centralised and DC control), except in terms of costing. This test takes account of the converter 's failures, repair procedures, and so on. For eg, where three terminals have been prepared by a seaport and a failure exists with one converter, the other two terminals will also operate, while only the device drawing directly from the grid will be able to function with the consolidated structure. If the entire terminal is shut down, the worst case is for the DC delivery. Based on the reliability of the converter to still operate during the fault condition, this design is chosen as suitable, and it also provides maintenance benefits.

### Conclusion

This paper explored the techniques and technology that can be used in ports to help mitigate ship-based pollution and other practices. Present science and technology provide numerous ideas and multiple ways of meeting the desired targets. The use of a microgrid is one technology that encourages the sustainable use of renewable technologies which, at the same time, has advantageous features. In addition, renewable electricity generation, combined with an energy storage facility, will reduce the consumption of energy from the grid. With the integration of CI configuration, Microgrid technologies will realize the task of making seaports' green 'in the future, which can be used to work towards the zero emissions target.

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### References

- [1] R. Winkel et al., "Potential for Shore Side Electricity in Europe. Final Report.," 2015.
- [2] I. Tetra Tech, "Air Emissions Calculations and Methodology Air Emission," 2013.
- [3] F. H. Jan Fredrik & Wendt, "History and State of the Art in Commercial Electric Ship Propulsion, Integrated Power Systems, and Future Trends," vol. 103, no. 12, 2015.
- [4] E. & Weston and E. Thomson, "The Marine Vessel's Electrical Power System: From Its Birth To Present Day," vol. 103, no. 12, 2015.
- [5] Norbert Doerry et al., "History and the Status of Electric Ship Propulsion, Integrated Power Systems, and Future Trends in the U.S. Navy," vol. 103, no. 12, pp. 2243–2251, 2015.
- [6] Theodoros G. Papoutsoglou, "A Cold Ironing Study on Modern Ports, Implementation and Benefits Thriving for Worldwide Ports," National Technical University of Athens, 2012.
- [7] O. Merk, "Container Ship Emissions in World Ports: A Comparative Overview," Int. Forum Shipp. Ports Airports 2012, pp. 510–519, 2012.
- [8] M. Fu, H. Liu, and et al., "National- to port-level inventories of shipping emissions in China OPEN ACCESS National- to port-level inventories of shipping emissions in China," 2017.
- [9] Jan Kriz et al., "Impact of Distributed Generation On Grid Protection And Voltage Control," 2012, no. 0007, pp. 27–30.
- [10] ABB Review, "Onshore and onboard," Power and productivity for a better world ABB, 2011.
- [11] J. Prousalidis, G. Antonopoulos, C. Patsios, A. Greig, and R. Bucknall, "Green shipping in emission controlled areas: Combining smart grids and cold ironing," Proc. - 2014 Int. Conf. Electr. Mach. ICEM 2014, pp. 2299–2305, 2014.
- [12] O. Palizban and S. Mekhilef, "Power optimization and static performance investigation of an island-mode doubly-fed induction generator (DFIG)," Proc. - 2011 IEEE Int. Conf. Control Syst. Comput. Eng. ICCSCE 2011, no. November, pp. 399–403, 2011.
- [13] O. Palizban, K. Kauhaniemi, and J. M. Guerrero, "Microgrids in active network management - Part I: Hierarchical control, energy storage, virtual power plants, and market participation," Renew. Sustain. Energy Rev., vol. 36, pp. 428–439, 2014.
- [14] S. Abu-Sharkh et al., "Can microgrids make a major contribution to UK energy supply?," Renew. Sustain. Energy Rev., vol. 10, no. 2, pp. 78–127, 2006.
- [15] S. Su, Y. Li, and X. Duan, "Self-organized criticality of power system faults and its application in adaptation to extreme climate," Chinese Sci. Bull., vol. 54, no. 7, pp. 1251–1259, 2009.
- [16] S. P. A.K Basu, S.P.Chowdhury, S.Chowdhury, "Microgrids: Energy management by strategic deployment of DERs—A comprehensive survey," Renew. Sustain. Energy Rev., vol. 15, no. 9, pp. 4348–4356, Dec. 2011.
- [17] R. et al. Lasseter, "Consortium for Electric Reliability Technology Solutions," 2002.
- [18] H. Gharavi and R. Ghafurian, "Smart grid: The electric energy system of the future," Proc. IEEE, vol. 99, no. 6, pp. 917–921, 2011.
- [19] G. Y. Morris, C. Abbey, S. Wong, and G. Joos, "Evaluation of the costs and benefits of Microgrids with consideration of services beyond energy supply," IEEE Power Energy Soc. Gen. Meet., pp. 1–9, 2012.
- [20] O. Palizban, Distributed Control Strategy for Energy Storage Systems in AC Microgrids Towards a Standard Solution. 2016.
- [21] O. Palizban, K. Kauhaniemi, and J. M. Guerrero, "Microgrids in active network management -

- Part I: Hierarchical control, energy storage, virtual power plants, and market participation,” *Renew. Sustain. Energy Rev.*, vol. 36, pp. 428–439, 2014.
- [22] O. Palizban, K. Kauhaniemi, and J. M. Guerrero, “Microgrids in active network management - Part II: System operation, power quality and protection,” *Renew. Sustain. Energy Rev.*, vol. 36, pp. 440–451, 2014.
- [23] E. Planas, A. Gil-De-Muro, J. Andreu, I. Kortabarria, and I. Martínez De Alegría, “General aspects, hierarchical controls and droop methods in microgrids: A review,” *Renew. Sustain. Energy Rev.*, vol. 17, pp. 147–159, 2013.
- [24] P. Piagi and R. H. Lasseter, “Autonomous control of microgrids,” 2006 IEEE Power Eng. Soc. Gen. Meet., no. June, p. 8 pp., 2006.
- [25] J. M. Guerrero, J. C. Vasquez, J. Matas, L. G. De Vicuña, and M. Castilla, “Hierarchical control of droop-controlled AC and DC microgrids - A general approach toward standardization,” *IEEE Trans. Ind. Electron.*, vol. 58, no. 1, pp. 158–172, 2011.
- [26] K. & P. Ken Kutsmeda, “Specifying medium-voltage distribution,” *Consulting Specifying Engineer*, 2012. [Online]. Available: <http://www.csemag.com/industry-news/codes-and-standards-updates/single-article/specifying-medium-voltage-distribution>.
- [27] P. Ericsson, “A feasible study and a technical solution for an on-shore electrical infrastructure to supply vessels with electric power while in port,” Chalmers University of Technology, 2008.
- [28] E. A. Sciberras, B. Zahawi, and D. J. Atkinson, “Electrical characteristics of cold ironing energy supply for berthed ships,” *Transp. Res. Part D Transp. Environ.*, vol. 39, pp. 31–43, 2015.
- [29] F. D. Kanellos, J. Prousalidis, G. J. Tsekouras, and J. Prousalidis, “Onboard DC grid employing smart grid technology: challenges, state of the art and future prospects,” *IET Electr. Syst. Transp.*, vol. 5, no. 1, pp. 1–11, 2015.
- [30] R. Strzelecki and P. Mysiak, “In Shore-to-Ship Power Supply Systems,” pp. 454–461, 2015.
- [31] E. A. Sciberras, B. Zahawi, D. J. Atkinson, A. Juando, and A. Sarasquete, “Cold ironing and onshore generation for airborne emission reductions in ports,” *Proc. Inst. Mech. Eng. Part M J. Eng. Marit. Environ.*, vol. 230, no. 1, 2014.
- [32] S. K. Bengtsson, E. Fridell, and K. E. Andersson, “Fuels for short sea shipping: A comparative assessment with focus on environmental impact,” *Proc IMechE Part M J Eng. Marit. Environ.*, vol. 228, no. 1, pp. 44–54, 2014.
- [33] EC, “Clean Transport - Support to the Member States for the Implementation of the Directive on the Deployment of Alternative Fuels Infrastructure,” p. 136, 2016.
- [34] S. G. Jayasinghe and N. Fernando, “Floating Power Platforms for Mobile Cold-ironing,” no. 978, pp. 1–5, 2016.
- [35] D. Paul and V. Haddadian, “Transient overvoltage protection of shore-to-ship power supply system,” *IEEE Trans. Ind. Appl.*, vol. 47, no. 3, pp. 1193–1200, 2011.
- [36] P. E. Dev Paul and P. Ben Chavdarian, “A closer look at the grounding of shore-to-ship power supply system,” *Conf. Rec. - Ind. Commer. Power Syst. Tech. Conf.*, pp. 5–11, 2009.
- [37] D. Paul and P. R. Chavdarian, “System Capacitance and its Effects on Cold Ironing Power System Grounding,” *IEEE Ind. Commer. Power Syst. Tech. Conf. - Conf. Rec.*, pp. 1–11, 2006.