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MariEMS Learning Material

This is the 21th compilation by Professor Dr Reza Ziarati on the work of the EU funded Erasmus + MariEMS' partners and material extracted from the IMO TTT Course. The material is composed from Chapter 21 the learning material. Readers are also advised to refer to the papers on IdeaPort and IdealShip projects led by C4FF and published by MariFuture.

21. Onshore Power Supply (OPS)

21.1 Introduction

During the ship's port operations and at berth, auxiliary engines are run in order to generate electricity for supply to ship-board systems as well as to the cargo loading or loading/unloading machinery, where applicable. Today, this power is generally provided by auxiliary engines that emit carbon dioxide (CO_2) and air pollutants, affecting local air quality and ultimately the health of both port workers and nearby residents.

As an alternative to on-board power generation, vessels can be hooked up to an onshore power supply, i.e. connected to the local electricity grid. In this way ships' operations can proceed uninterrupted, while eliminating negative side-effects. The amount of power generated and fuel consumed is dependent on type of ships and could be anything from a few hundred kW to several MW of electric power. The operation of auxiliary engines is a major source of SOx, NOx and Particulate Matters (PM) emissions to ports. The amount of emissions is generally proportional to the amount of fuel used. The longer the ship stays at berth or at anchor, the higher the ship fuel consumption will be and thereby the more the exhaust pollutants emitted to the port.

Concern over air quality in ports has led to growing pressure on port operators to reduce exhaust emissions; in particular pollutants of SOx, NOx and PM. The supply of power from onshore (port) to ship is one system that has been advocated for this purpose. Use of this system allows ships to turn off their auxiliary engines when in port and plug into a shore-side electricity supply. As a result, not only air emissions to port are reduced but also it helps positively with other aspects of the ship and port operations. It is claimed that this system, in addition to the environmental and social benefits, could provide economical savings to all stakeholders. However, this last point has yet to be validated.

Onshore Power Supply (OPS), as defined above, has been known for a long time in particular for naval ships, where the ship normally stays at berth for a long period of time. Under such conditions, it is cost effective to run the vessel via a supply of electricity from shore. This was used by the US Navy originally and the term "cold ironing" originates from this naval application. Over the years, other terms have also been used for OPS; some of which are listed below:

- Alternative Maritime Power (AMP)
- Shore side electricity
- Shore power

In this section, the term Onshore Power Supply (OPS) will be used throughout. Figure 21.1 shows a typical OPS system.

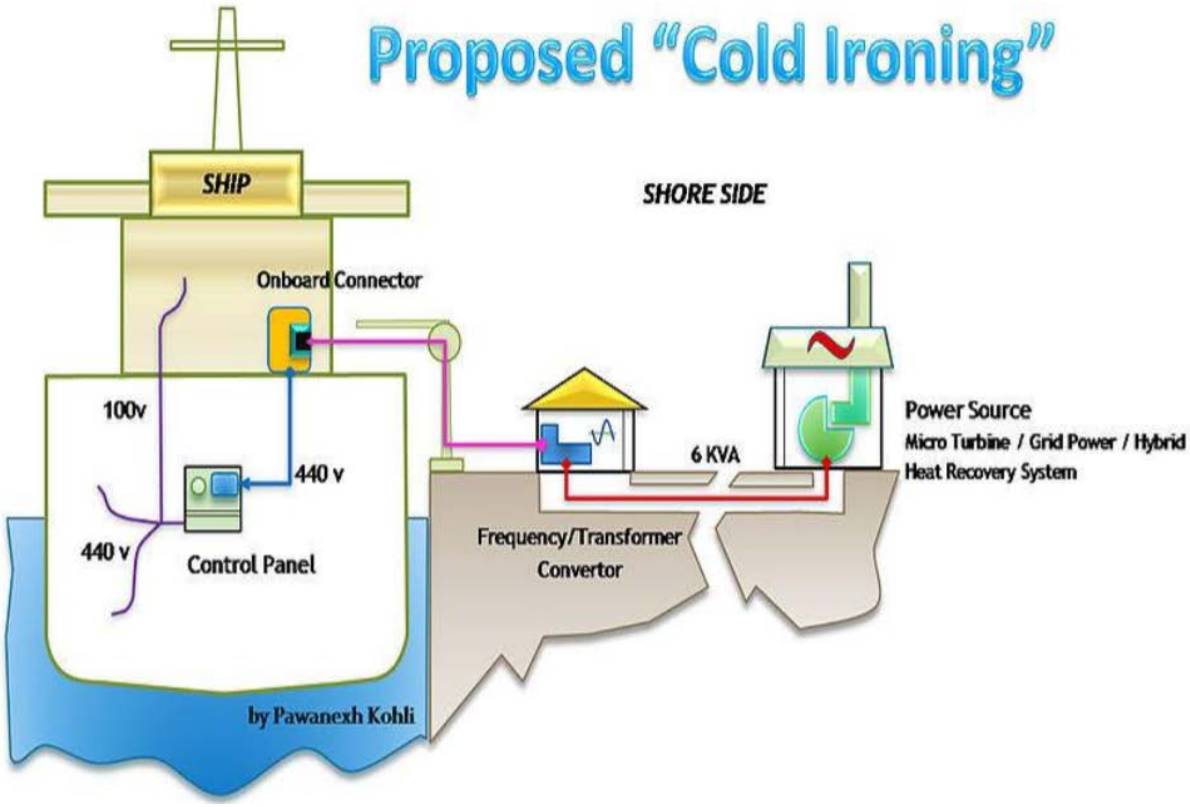

Figure 21.1 – Typical OPS arrangement [Wikipedia]

21.2 The Case for OPS

Ships normally use some base-load electricity levels for essential services all the time, including while at berth. For a case of a typical mid-size tanker, this could be about 400 kW (excluding the electricity needed for cargo operations and ballast operations). For such a tanker staying at port for 30 hours, it would require 12 MWh of electricity; the longer the vessel stays at berth, the larger this figure will be. For an average cruise ship, the electrical requirement could be about 8 MW. For such a cruise vessel, staying at berth for 12 hours will require 96 MWh of electric power. Generating this power on-board generates NOx, SOx, PM and CO_2 emissions that could be significant if the number of ships at berth, and/or their duration of stay, or number of calls increase. The environmental profile of electricity generated by power plants on land versus ships' diesel electric generators running on bunker fuels, is one of the main advantages of OPS technology. In land-based power plants, electricity can be generated at high energy efficiency in large efficient power plants with the use of either clean fuel or exhaust gas cleaning systems. Also, electricity is generally generated in remote areas beyond population centres with minimal air quality impact on population centres. On the contrary, ship-board generation is not as energy efficient as land-based plants and also any exhaust emissions from engines directly pollutes the port and surrounding areas. The reason that ship board generation is less efficient is due to smaller engines used (with an MCR of up to 2,000 kW) as well as part-load operation (engine load factors at berth barely go beyond 50% for most of the time). OPS will substantially but not completely reduce SO_X emissions as the steam generated by the on-board boiler is still needed for some ship's operation at berth. Nevertheless, OPS have been widely used as a viable way to reduce ship-based local polluting emissions. The California Air Resource Board, for example, requires a fleet operator to reduce at-berth emissions from its vessels' auxiliary engines at each California port by approximately 80 percent by 2020 either through connecting the vessel to shore power or through alternative control technique(s) that achieve equivalent emission reductions. Major ports in Europe, such as Antwerp and Gothenburg, are also engaged in provision of shore power to ships. Shore power is also being developed in some ports in China, such as Shanghai and Lianyungang. It is expected that lowered cost resulting from the economy of scale and standardization will make the OPS more attractive in the future [ICCT December 2012]. The use of OPS thus could be seen primarily as a green port initiative in order to improve the port air quality. For ports, the ability to supply power to ships at berth enables them to establish a more efficient overall electrical supply and also act as a utility; i.e. as an organisation that sells electricity to ships. For the port and ship staff closely linked to ships while at berth, there is an additional benefit of reduced noise and vibration in harbour areas. For ship staff, when the system is fully operational, more time will be available to deal with maintenance and other aspects of port-related activities. OPS are best for ships that make multiple calls at a particular terminal for multiple years. The best candidates for OPS are container ships, reefer ships, and cruise ships because they tend to operate in these types of regular services and require substantial electricity while at berth.

21.3 Infrastructure Requirements

Installing new shore power systems requires shore-side infrastructure and can be expensive, but can also result in major reductions in port emissions. The infrastructure is typically constituted of power connection to utility, power transformation, conditioning and switching equipment, and land for these facilities, cabling, synchronization equipment, and berth side infrastructure. Shipside infrastructure is also expensive, but the cost has been declining with more streamlined and standardized designs. The cost difference between the grid power, especially the high demand charges, and price of bunker are key factors in business case for OPS. Low price differential of electricity over HFO can provide a strong incentive to the use of the shore power.

To use OPS, there will be a need for extra investment both at shore-side (port) and ship side. As the responsibility for supply of electricity to ship is with port, the capital investment of ports will be more significant. Additional investments stem from construction and installation of electricity supply conditioning/safety systems at the quay and potential needs related to strengthening the port's electricity grid.

21.4 Standardisation

In order for OPS to become widespread among various ports and ship-owners, the nature and arrangement of power connections must be standardized. Neither a port owner nor a ship-owner can justify investment in expensive equipment to enable a shore connection system without assurance that such a system will be functional across many countries with alternative electrical characteristics in terms of voltage, frequency and other aspects. Work on a common standard for OPS for ships at berth began early in 2005. Major players in this effort have included technology suppliers, governments, port authorities, ship-owners (particularly cruise line, tanker and container ship companies), classification societies and others. The IEC, ISO and IEEE have joined forces and developed the international standard " ISO/IEC/IEEE 80005-1:2012 ISO/IEC/IEEE 80005-1 Utility Connections in Ports - Part 1: High Voltage Shore Connection (HVSC) Systems -- General requirements". This standard revised the "IEC/PAS 60092-510:2009 Electrical installations in ships -- Special features – High Voltage Shore Connection Systems (HVSC-Systems)" and addresses the connection between ship and shore and the procedures for safe operation.

21.5 Port Related Initiatives

The International Association of Ports and Harbours has provided information to IMO on the World Ports Climate Initiative and also established a website (http://wpci.iaphworldports.org/onshore-power-supply/environment-and-health/climate.html) to provide practical information about OPS for seagoing vessels and shore installations. The website provides information on numerous issues connected with OPS such as power generation, voltage and frequency, safety and health, costs, implementation, ports utilizing OPS, etc. The latest list of ports with some degree of OPS capability is given in Table 21.5.1.

Port	Country	High Voltage	Low voltage	Frequency
Antwerp	Belgium	6.6 kV		50 Hz/60 Hz
Goteborg	Sweden	6.6 kV/10 kV	400 V	50 Hz
Helsingborg	Sweden		400 V/440 V	50 HzV
Stockholm	Sweden		400 V/690 V	50 Hz
Piteå	Sweden	6 kV		50 Hz
Kemi	Finland	6.6 kV		50 Hz
Oulu	Finland	6.6 kV		50 Hz
Kotka	Finland	6.6 kV		50 Hz
Lübeck	Germany	6.6 kV		50 Hz
Zeebrugge	Belgium	6.6kV		50 Hz
Los Angeles	U.S.A	6.6 kV/11 kV		60 Hz
Long Beach	U.S.A	6.6 kV	480 V	60 Hz
San Francisco	U.S.A	6.6 kV/11 kV		60 Hz
San Diego	U.S.A	6.6 kV/11 kV		60 Hz
Seattle	U.S.A	6.6 kV/11 kV		60 Hz
Juneau	U.S.A	6.6 kV/11 kV		60 Hz
Pittsburgh	U.S.A		440 V	60 Hz
Vancouver	Canada			
Oslo	Norway	6.6 kV		50 Hz
Rotterdam	Netherlands	6.6 kV		50 HZ

Table 21.5.1 – Ports with OPS at 9 October 2012 [IMO MEPC.1/Circ.794]

21.6 IMO Regulations

Currently and at the time of writing this document, there is no IMO regulation on OPS. In fact, IMO has developed minimal regulations on ports development/operation other than those that may directly be required for ship operation (such as reception facilities). Thus, there have been proposals to add some new regulations to MARPOL Annex VI on introducing some ships' requirements for the future wider use of OPS. For example, it is proposed that ships should undertake an assessment of the environmental benefits as well as cost-benefit of addressing emissions from ships at berth. As

part of this, it should be taken into account how the supplied electrical power is generated, and if similar environmental benefits could be achieved by other more cost-effective means.
As part of the proposed draft regulation (http://www.sjofartsverket.se/pages/9333/55-4-13.pdf), submitted by Sweden to MEPC 55 in 2006, it is suggested:

- Ships that can document that their on-board power production has lower total emissions than the supplied shore side electricity should, if no other local circumstances dictate otherwise, be exempted from the requirement to connect to shore-side electrical power.
- No ship should be required to connect to OPS when the planned port stay at the actual berth is less than a couple of hours (e.g. 2 hours).
- The port or terminal shall provide sufficient electrical power to sustain all normal operations during the port call, including calculated peak consumption.
- The costs for the ship to connect to shore power at berth should not exceed the average comparable costs of port services in general and the cost of supplied electricity to shore based consumers within the vicinity of the port or terminal.

The apparent aim of the above proposals seems to be to protect ship owners from undue pressures by ports to force them to use OPS without good and reasonable business or environmental justifications.
Subsequently, IMO reviewed the situation in MEPC 64 meeting in 2012 and while considering various views including the above proposal concluded that:
"The majority was of the view that ports equipped with on-shore power supply are limited and mandatory requirements for the on-shore power supply should not be developed at this stage. The MEPC agreed to request the IMO Secretariat to disseminate the information relating to the on-shore power supply, e.g. lists of relevant standards and ports providing onshore power supply as MEPC.1/Circ.794" *IMO MEPC 64/23].

21.7 OPS Effectiveness
There are a number of items and issues to be considered when opting for OPS as detailed in ICCT report [ICCT June 2012] from which most of the text of this section are taken. These include infrastructure development and source of electricity and cost effectiveness. In order to provide OPS infrastructure on-berth and on-board vessels, first the necessary power needed should be estimated and ensure adaptability. It is important to consider the local power company that is providing the electrical power to the port and environmental characteristics of the supplied electricity plus transmission losses. A local power company that uses a cleaner source of energy with use of emission control technologies will optimize the overall benefits of shore power.
OPS is not universally effective for all ships and ship types. OPS works best when ships operate in liner-type services that have the same vessels calling frequently over a number of years to the same terminals. Liner-type services typically include cruise ships, containership, some bulk liquid and chemical/product tanker operations, LPG tankers, LNG tankers, and some general cargo operations.
In addition to frequency of calls by the same ships to the same terminal, another key factor is the amount of energy the ship uses while at berth. Energy is the product of ship power demand while at berth and duration at berth. Cruise ships represent one extreme as they have short times at berth, however their power demand at berth is high, as are their berthing frequencies. Other vessel classes have lower power demand at berth; however they are at berth for longer periods. In addition to

frequent calls per year, it is important to note that these same vessels need to continue to call for several years in a row to make the OPS cost effectiveness in terms of cost versus tonnes of emissions reduced.

The most expensive part of OPS infrastructure is shore-side infrastructure. Converting an existing port to OPS capabilities can be significant and the cost varies by each port. One of the most expensive container terminal retrofit projects actually built was the China Shipping berth at Port of Los Angeles which cost ~$7 million. Based on the range of feasibility studies done by ports in the US and Canada, a normal range of costs to provide shore power at a berth can be between about US $1 - $15 million. These costs vary significantly depending on the extent of terminal rebuilding, the proximity to adequate electricity supplies, and the ability to locate the shore-side infrastructure. There are also less expensive temporary approaches that use large, portable LNG generators placed on the dock near the front of the ship and connect to a ship's bow thruster electrical circuit. These systems require about $200,000 to refit each ship and approximately $1,000 per hour for the generator. The Port of Oakland, whose shore-side infrastructure for standard cold ironing was estimated at $90 million, has successfully demonstrated this system and intends to make it available to all of its customers in the near future.

The ship-side OPS retrofit capital cost can range from $400,000 to $2 million per ship due to the wide variety of ship designs. These costs have been coming down as more retrofits have led to more streamlined and standardized designs. Many new ships currently being built are including OPS systems or implementing designs that would make future retrofits less costly.

The cost of grid power is another key factor when estimating cost effectiveness. Also, the bunker price makes a significant role in cost effectiveness. The higher the bunker price and the lower the electric grid price, the more cost effective will be the shore power investments. In USA, the shore power projects in California have been awarded grants under the Carl Moyer Grant Program. The first was to the Port of San Francisco and the second was to the Port of San Diego. These awards demonstrate that OPS can be a cost effective strategy under the right conditions. Cost effectiveness estimates vary significantly by terminal, by port, and by region. A detailed cost effectiveness analysis needs to be completed on a project-by-project basis to determine what the real cost impacts would be.

Without a full-blown analysis, it is possible to estimate the potential costs and benefits of a cold ironing system using three key pieces of information:

1) Energy cost; the costs of the fuel ships use at berth and the cost of on-shore provided electricity,
2) The cost of retrofits both to ships and to port terminal facilities providing the electricity, and
3) The frequency and duration with which the system will be used. Such an analysis was performed and is documented in reference.

21.8 OPS and Energy Efficiency

There is no doubt that OPS leads to significant reduction in air pollutants in ports and areas at their vicinity. However, the case for overall energy efficiency of the OPS in terms of power used while including all the transmissions losses and overall CO emissions to atmosphere is not clear. Although both have been advocated by OPS enthusiast as justification for OPS and reduction of ship-owners' energy cost, this topic is not certain and most likely will vary case by case.

21.8.1 Energy efficiency

The energy efficiency of OPS relative to ship-board generation needs to take into account all the various forms of energy transfer and transformation losses along the transfer route. In addition, the thermal efficiency of a land-based power plant versus ship-board systems needs to be taken into account.

In general, it is estimated that transmission losses from a land-based power plant to the ship will be around 10 to 25% depending on the supply transmission network (i.e. an average value of about 17.5%). This means that from the energy efficiency and CO_2 reduction points of view, the land-based power plant needs to be generating less CO_2 by at least 10 to 25% compared to ship-board generation. As indicated above, this will vary from case to case and needs specific studies for various ports.

On the other hand, the case in favour of OPS is the operating condition of auxiliary diesel engines while at berth. This should be borne in mind while at berth, since the auxiliary engines normally work at a part load of about 40 to 50%. Under this loading condition, the engine efficiency is lower than the optimum value and the emissions are higher.

There is occasionally discussion on future low-carbon electricity that could be supplied to ports (or generated by a port itself) for supply to ships. There are a number of solutions, such as the use of greener energy in ports. As an example, there have been cases where LNG-based power plants are advocated for port-side power generation. Such cases yield a significant reduction in both CO_2 and pollutants and get rid of transmission losses over the grid. The drawback is port self-generation that is not the core expertise of shipping ports. For ports deciding on self-generation, there is a case to help the grid when they have excess electricity and thereby impose less overall load on the grid.

21.8.2 Energy cost

The issue of energy cost is important for ship-owners. There is evidence that the overall cost of OPS electricity may be higher than the on-board generation for the following reasons:

- A tax on electricity will normally be applied if it comes from OPS. The tax level may change from case to case and country to country.
- The base cost of electricity as supplied to ports may be high.
- The port charges which are intended to cover the investment and running costs will be added to electricity price.

All the above require detailed studies for each port. To reduce the cost of pollutants on society and port areas, there may be a need to transfer the burden of cost to ships as they represent the main source of pollutant. However, since this may vary from port to port, it will have an impact on port business as well.

21.9 Port Clean Air Programme

A port clean air program is a comprehensive initiative used by some ports to address air emissions from shipping and port operations. Such a program is generally established and implemented by a port authority with input from other stakeholders. Such a program normally sets specific emission reduction targets for a port and develops a roadmap to achieve those targets. To ensure success, the management would follow continuous improvement cycle and success is measured and monitored and target revised periodically based a Plan – Do – Check – Act (PDCA) process cycle [ICCT December 2012]. As any other management continuous improvement cycle, the port clean air program will be successful where the management and staff of port authorities and regulatory agencies are committed to the improvement of air quality in the region. In addition, the participation from other stakeholders and port relate organisations give the clean air team more influence and authority over the air quality improvement in the port. A successful port clean air program is dependent on the identification, evaluation, and use of appropriate technologies and operational strategies. During the "Plan" stage, it is required to determine emission mitigation measures and coordinate with different stakeholders to implement these measures. After choosing the right measures and during other parts of the cycle, the measures need to be executed and their effectiveness monitored. Finally, the overall achievements need to be reviewed and assessed against the initial targets and objectives. So far, a number of ports have been developing and implementing the "port clean air programme" as documented in ICCT reports given in the references.

21.10 References and further reading

The following list provides references for this section and additional publications that may be used for more in-depth study of topics covered in this section:

1. "IMO train the trainer course material", developed by WMU, 2013.
2. IMO MEPC.1/Circ.794, "On-Shore Power Supply", MEPC 63, 9 October, 2012 4.WPCI, "On-Shore Power Supply", http://wpci.iaphworldports.org/onshore-powersupply/environment-and-health/climate.html viewed Dec 2016.
3. WPCI, "World Port Climate Initiative website on on-shore power", http://www.ops.wpci.nl/what-is-ops-/what-is-ops--1/, viewed Dec 2016.
4. MEPC submission by Sweden "Standardization of On-Shore Power Supply", MEPC 55/4/13, August 2006, http://www.sjofartsverket.se/pages/9333/55-4-13.pdf, viewed Dec 2016.
5. ICCT December 2012, "Workshop brief: Technologies and operational strategies for best Practices in port clean air programs" A report prepared for the International Workshop on Reducing Air Emissions from Shipping, Shanghai, China, December, 2012. Viewed Dec 2016.
6. ICCT June 2012, "Developing Port Clean Air Programs: A 2012 update to the International Association of Ports and Harbor's Air Quality Toolbox", June 2012. Viewed Dec 2016.
7. IMO MEPC 64/23, "Report of the Marine Environment Protection Committee on its Sixty Fourth Session", 11 October 2012. Viewed Dec 2016.