Shore connection

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1. Preface

The government is monitoring the air quality above residential areas near harbors and has been doing this for a while. Because of the air pollutants, that vessels produce when lying at berth, the government made restrictions on the amount of produced NOx, SOx and CO₂ by vessels. This will result in a better air quality of the surrounding areas.

Beginning our research to a cleaner solution, we researched the air pollutants in cooperation with DCMR and the Port of Rotterdam.

Shore connection seems to be a good solution to improve the air quality in the harbor. Therefore we did a research about shore connection and why shipping companies aren’t using shore connection. To present our findings, opinions, conclusions and recommendations we write this report.
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3. Introduction

3.1 Problem description
Nowadays our society has to deal with the enhanced greenhouse effect, the NOx- and SOx emissions. In the maritime business adjustments must be made to tackle this problem. The focus of this project lies on the emissions produced by vessels lying at berth in the port of Rotterdam. Vessels still use auxiliary engines when lying at berth to produce the needed energy. All the vessels together produce a large amount of emissions. Governments are creating stricter regulations to tackle and control this problem. Shipping companies have been looking at different types solutions like: sulfur scrubbers, alternative fuels and shore connection.

3.2 Problem definition
Vessels produce too many air pollutants(NOx, SOx and CO\textsubscript{2}) while at berth which results in a bad air quality in the surrounding residential areas.

3.3 Objectives
The objective is to come up with a good, innovative and clean solution to reduce the NO\textsubscript{x}, SO\textsubscript{x} and CO\textsubscript{2} emissions produces by vessels, lying at berth in the port of Rotterdam.

3.4 Main question
How can fuel emission (NO\textsubscript{x}, SO\textsubscript{x} and CO\textsubscript{2}) be reduced by using shore connection at berth?

3.5 Sub questions
1. What is the amount of emission produced by vessels lying at berth in Rotterdam?
2. What are the technical aspects of the whole system?
3. What are the safety procedures when using a shore connection?
4. Which types of vessels are suited for shore connection?
5. Why has shore connection failed so far?

3.6 Project borders
What has been investigated in this project:
• The amount of emission vessels produce when the vessels are at berth in the harbour.
• Safety procedures when connecting vessels to the shore.
• What type of vessels are eligible for shore connection.
• The energy savings that will be created with this idea.

What has not been investigated in this project:
• The amount of money that it will cost to create a ship-shore connection.
• The electrical infrastructure in the Port of Rotterdam.
3.7 Research methodology

3.7.1 The DCMR research
DCMR is an organization that enforces and control the environment in the region of Rotterdam-Rijnmond. The goal of this government owned company is to get a clear view of the emissions in the harbor caused by the sea-going vessels. Students have been asked to cooperate with the research of DCMR. The research team have to board vessels lying at berth. The questionnaire is filled in while interviewing the captain and the chief engineer. The questionnaire has been made by DCMR. The questions are about general data like type of vessel, cargo and personnel but mainly about the emissions and fuel consumptions during berthing, maneuvering and the journey.

For the DCMR research quantitative research have been carried out. This means that it is a systematic research with always the same answers because a questionnaire has to be filled in. the answers can be put into figures which can be implied in computational techniques which provides useful graphs. The questionnaire is made by DCMR and the data will be processed by DCMR.

3.7.2 The shore connection research
In the research about shore connection a research has been done to investigate the problems that came up in previous researches which were not solved. The research has been done in two ways: the desk research and the field research. The desk research is research on the internet. The field research is a research where the group members go out to companies to get answers so that the group members can come up with solutions that will help solve the previous mentioned problems. To achieve this goal, it requires to take a closer look at the researches that have already been done. Now that this has been completed the group members will have a better view why the other researches have failed.

3.7.3 The field research

**ABB**
ABB is a company which stands for ‘Power and Productivity for a Better World’. They are one of the suppliers of shore connection. A meeting was held with the Representative of ABB, namely Ton Haasdijk. He gave us a lot of information about the machines for shore connection, such as the transformer and the frequency convertor. These related details which were provided by Ton Haasdijk can be read in the appendix.

**Pilot**
For further investigation the Pilot Station was visited and a meeting was held with Sjaak Sprong, a pilot. The meaning of this meeting was to find out how pilots think about shore connection. The main objective for this interview was to see if shore connection is dangerous for pilots while doing their job. The full interview can be found in the appendix.

The information that was received from Sjaak Sprong was unfortunately not new for us. For example: the shore connection system is environmental friendly. It will also help to decrease noise that is created. After interviewing Sjaak Sprong, we contacted Koen Willems, Head of Technical Services, for a few technical questions. He explained us that shore connection is not a dangerous solution as long as the system is shut down before connecting or disconnecting. With this safety manner, dangerous situations will be avoided.
4. Desk research

4.1 Introduction

Due to the increased oil usage worldwide, the air pollutants NOx, SOx and CO2 have increased as well. Therefore, the government is restricting the maximum amount of the previous mentioned air pollutants. Because of this, ship owners are forced to search for innovative and cleaner fuel solutions. One solution is shore connection. The shore connection will provide the electricity that is needed, and thus takes over the "job" of the auxiliary engines when lying at berth. This way the auxiliary engine(s) will not produce hazardous emissions. Therefore this is a clean solution for the surrounding areas.

4.2 HVSC

Shore connection is already in use nowadays and people can see these facilities around the world in Europe and on the West coast of America. With the increasingly stricter air emissions legislation implemented through mainly local air quality controls the number of vessels that use shore connection will only increase. However the HVSC (High Voltage Shore Connection) requires significant investments by the ship owners as well as for the port owners and the port state control. Adjustments must be made inside the vessels and space is needed on land for the different types of buildings that are needed.

The additional requirements that are needed to realize shore connection are the following:

1. A shore side transformer for each vessel.
2. Substation which includes a convertor for 50/60 Hz with automated earthing switch
3. Communication equipment that enables to link the ship and the shore
4. Shore connection panel on board the vessel.
5. Main HV/LV switchboards depending on type of vessel
6. Drum with cables for HV power sets.

Steps to connect shore connection:

1. Vessels arrive at port
2. Power cables and control cables are to be connected
3. The engine is synchronized with the shore power grid.
4. Shore connection circuit breaker is closed, the generator is off-loaded and engine is stopped.

Steps while being connected:

1. First engine is started and synchronized with shore power grid
2. After load is transferred to the generator the shore connections opens.
3. Power cables and control cables are disconnected and the vessel is ready for departure.
5. Emissions

Sub question 1: What is the amount of emission produced by vessels lying at berth in Rotterdam?

5.1 Energy saving

All the group members did a survey in cooperation with DCMR to investigate the amount of emissions that vessels produce lying at berth. All this data was sent to DCMR to be further investigated.

Vessels at berth with shore connections still use the same amount of energy. This energy still needs to be generated somewhere. Green energy is available for vessels. Unfortunately, the produced green energy is far from enough to use for shore connection. A power plant will supply this energy for the shore connection.

To give an estimation of the amount of NOx that a ship produces during the time at berth, a comparison is given to get an indication of these produced NOxes.

A cruise ship, lying at berth for a duration of eight hours, has the same amount of NOx as 10,000 cars driving from Zurich to London (1000Km). Source: ABB
In order to provide shore-based power supply, a technical installation is required. Both vessel and quay have to be equipped with systems for a shore-based power system. The technology to realize a shore-based power supply isn't new. Engineers can use existing technology to develop a reliable system. Below, an example is given to realize shore connection by engineers.

### 6.1 The shore-side technology

The infrastructure, needed for shore connection in a port or terminal, can be divided in several parts:

1. A powerful grid
2. A frequency converter, if the frequency needs to be changed
3. A transformer for each vessel connected
4. Switchgear equipment for each vessel’s power supply
5. An automated earthing switch for each vessel’s power supply
6. A communication system in order to safely link the vessel to the power grid
7. Protection relays to ensure the safety of the cable handlers

The power grid in port is developed for small factories and their equipment, such as cranes, belts, cooling and heating. Most ports have enough power to run all these consumers with approximately an additional 2-3 megawatts for incidental needs. The power which a vessel needs while in port, may be as high as 2 megawatts for small vessels. Big vessels can use up to 10 megawatts. In many ports, the electrical infrastructure will be insufficient to connect seagoing vessels to the shore. The infrastructure must be enlarged, which will bring extra costs.

In many countries around the world, the on-shore frequency is 50 Hz. On board of vessels 60 Hz is a very common frequency. Therefore, a static frequency converter is required for most shore-based power connections. This frequency converter is an expensive machine, which is likely to be placed in the substation. Depending on the port’s layout, a centralized solution with one converter can serve multiple ships and berths.

For each shore connection point, the port or terminal must have a special transformer. The transformer serves two purposes. First, it provides separation (a non-metallic direct connection between the onshore power supply grid and the ship’s internal system), so that an earthing fault in the ship will not endanger the land grid or vice-versa. Separation is a requirement to shore-based power connections. Secondly, the transformer steps down the voltage supply from a high voltage level optimized for distribution from the substation to the quayside. This voltage is for example 20 kilovolts, which is transferred to the quayside transformer. Here the voltage is transformed to one of the two voltage levels standardized for shore-based power connections: 11 or 6.6 kilovolts. This voltage comes from the quayside location close to the vessel and runs through the cable.
Each shore-based power connection point needs its own switchgear equipment to connect or disconnect the vessel to the shore. While the cables are being handled and connected to a vessel, the switch also ensures that there is no power in the cables between the ship and shore. The cable handling is completely safe as long as there is no power on the cable. The highest risk for injury or accidents is when people try to manipulate the cable or the safety system.

Every connection needs also an automated earthing switch to switch off the power in cases of a leaking current.

In order to ensure the safety of the shore based power connection, a communication system must be included. This system is needed on the vessel as well as onshore. It allows the crew on land to coordinate the connection of the cables. It also allows synchronizing the electrical load to the ship which is often arranged by two computers. These computers communicate with Ethernet communication through a fiber-optic line which is incorporated in the cable connection. As long as there is no communication, the communication system will not switch power on to the high voltage system.

It is important for the shore-based power connection system not to take up too much space on the quayside because there is a lot of activity going on there. The substation has a large footprint, but it can be located as far as 10 kilometers from the quayside transformer. This transformer will directly supply the vessel with electricity. On the quayside there is only a small and secure container-sized room that contains the shore-based power transformer, the switchgear with an automated earthing switch and the operator’s interface. The major benefit of a small quayside infrastructure is that it can be made mobile. This is interesting for vessels that are not always berthed at exactly the same position.
6.2 Cable handling

In order to use a shore power supply, the vessel must be connected by a cable to shore. This connection consists of a high voltage system and a communication system. Therefore the cable must be handled with care while tension on the cable must be avoided. The cable handling can be done from the shore and also from the ship.

For cable handling from the ship, most cargo vessels use a system consisting of a large drum with the cable on it, which is installed on board the vessel. When the vessel is at berth the cable is rolling off the cable and through guide wheels it is lowered to the quay where it can be connected.

Another system, that is usually found on ferries and cruise ships, is a system with the cable handling on shore. When the cables are on the shore-side and need to be connected, they have to be lifted by a crane. Then the connector is pulled through the hull to make the connection onboard the ship.

When the cable-handling system is on shore, the electrical connection is received on the ship by a shore connection panel. This panel must generally be located close to the hull and in convenient reach of the heavy shore-side cables.

Here is an example of a cable made by the company ABB. This shore connection cable is already in use by some installations. This cable has requirements according to the IEC rules. These are the specification of the cable:

- Flame-retardant type according to IEC 60332-1-1
- Outer sheath shall be oil, sea air, seawater, UV-resistant
- Outer sheath shall be non-hygroscopic
- Temperature class at least 90 degrees C
- Three power cores, earth core, pilot cores and optical fibers
- Optical fibers at least six 62,5/125 gradient
- Correction factor for ambient air temp according IEC 60092-201
- Insulation test according IEC 60811
- Bending test according IEC 60092-354
6.3 Ship side technology

On board of the ship equipment is also needed to use the shore-based power grid. This can be retrofitted in the ship. Existing ships can be retrofitted over a period of weeks while in operation, or as quickly as a week at a shore-side berth.

The power from the shore first transferred to the shore connection panel. When the cable handling is provided on shore, the shore connection panel is close to the hull in reach of the heavy shore side cables. The shore connection panel contains a circuit breaker, a protection relay, the physical electrical connection (plugs and grounding cable) and a control interface with the ship’s integrated automation system, or power management system. These system allows the incoming power from the shore to synchronizes the power with the generators on board of the ship. It is important to synchronize before switching the power over. If synchronizing fails it can damage harmful electrical machines.

Below a picture about what a system onboard of a ship can look like. The blue engines are the mechanical propulsion engines, the diesel engines directly drive the propeller. The yellow diesels are the auxiliary power systems, they provided the vessel with power. Most systems work with 400 or 690 volts, these voltage are called low voltage system. The low voltage system on board requires a transformer to receive the 11 kV or 6.6 kV power supply from shores high voltage system. The transformer needed is relative big, but it can be installed in the engine room, or any other suitable place. The shore connection panel is placed near to the hull with the cable connector mounted in front of it.

The process of connecting and disconnecting a ship to the shore-based power supply takes half an hour at the most, and five minutes at the least. Onboard, the chief engineer or some other personnel familiar with the ship's power management system handle the power synchronizing and switching.
7. Safety

Sub question 3: What are the safety procedures when using shore connection?

7.1 Safety aspects

The vessels using shore connection are often supplied with 6.6 or 11 kilovolts delivered from the shore side. The 6.6 and 11 kilovolts are very dangerous voltages. When the cable handling is in progress, the cable may not contain any energy. The different electricity wires of the power grid are positioned close to each other in the connector with a thin layer of air as isolation. When the air is moist, or the connector makes contact with a material able to conduct electricity, large sparks can appear. Cable handling can be done either by ship- or shore personnel, with adequate training to prepare for handling medium voltage equipment.

The system is created in such a way that electricity will run through the cable when the system is completely safe and locked. This will be ensured by communication between ship and shore. The shore connection panel and the shore side send signals through the cable to determine whether the connection is good and stable. If every system gives the “ok”, electricity can be switched on.

The picture below shows the safety system created by ABB. Power can only run through the cable when all the lights are green and give the “ok” signal. This systems checks all the different aspects for a secure connection with the shore.

The systems indicate that there is a problem with the emergency stop and will only give you permission to connect when this problem is solved.
8. Eligible vessels

Sub question 4: Which types of vessels are eligible for shore connection?

All types of vessels are eligible for shore connection because all vessels are using electricity onboard. Vessels that currently use shore connection are: cruise ships, RoRos, container vessels, LNG carriers, ferries and inland shipping vessels. These vessels are selected because they have multiple standard ports. In this way only two or three harbors have to create a system where shore connection is available. Merchant ship owners must be certain that a vessel will arrive in a certain port multiple times a month so that shore connection can be efficiently used. The port authorities want this certainty as well because they will have to invest a lot of money in such a system in the harbor. A growing number of vessels sails by standard routes. This way it’s more interesting for merchant ship owners as well as for port authorities to create a shore connection system. Vessels sailing around the world to remote and a lot of different harbors will have less interest in investing in shore connection. These vessels will only invest if it is mandatory by law in some harbors or worldwide.

Already existing vessels will have a more difficult time creating space that is needed for the systems. When building new vessels, space can be reserved for future installations. This is needed because equipment is necessary for transforming the high voltage to low voltage and for the main switchboard. Shore connection is more likely to be installed in future vessels then in already existing vessels.
9. ‘Pros’ and ‘Cons’

Sub question 5: Why has shore connection failed so far?

9.1 Introduction

‘Shore connection has failed so far’ is a statement easily made. Nevertheless, facts state otherwise. The company Stenaline is the living proof. Stenaline is a ferry company and the reason they use shore connection is because of the ships always use the same port. Therefore an investment like shore connection can redeem the costs. For companies with vessels that do not use the same port around the year, this investment, in these crisis times, cannot redeem the costs. This is why companies are not willing to install the shore connection for a better environment.

9.2 ‘Pros’ of shore connection

- Green image for companies
Nowadays, a green image for a company is desirable. The government is willing to give subsidy for green solutions. When a company is advertising, this image is for a lot of people very persuasive.

- Maintenance possibilities, lying at berth
When lying at berth, the auxiliary engines can be stopped because the power is supplied by the shore connection. Therefore, maintenance can be done. This saves time and even gives the opportunity to purchase machinery elements for the engine on shore that are not in stock.

- Reduction of air pollutants
The most important pro is the reduction of air pollutants. (These are the NOx, SOx and the CO2.) These pollutants cause acid rain, smog and the common known enhanced greenhouse effect.

- Reduction of vibrations and noise
When ships are lying at berth and the auxiliary engines are running to produce the needed energy for the vessel, they cause a lot of vibrations. Locals in surrounding houses feel these unwanted vibrations. Furthermore, noises are also produces by these same auxiliary engines and are unwanted. Using shore connection, these vibrations and noises are no longer produced.

9.3 ‘Cons’ shore connection

- Expensive investment
Because of the high investment costs, shore connection is not used worldwide.

- It requires a lot of space
When installing the system for the shore connection, a lot of space is required. Space that was used for cargo, must now be used for this system.

- Different types
Shore connection comes in different types. This can cause problems when another ship wants to use the shore connection of another type.
10. Conclusions

According to the findings, described and explained in this report, a conclusion can be drawn that shore connection could definitely be applied in harbors all over the world because the possibilities are most certain available. The fact that these systems are not already worldwide in use is due to the lack of interest and investing in the project. Partly due to the not yet defined laws and restrictions concerning vessels emissions, many ship owners still choose to use fossil fuels. When forced by law, shore connection is an excellent opportunity to create a greener environment. The biggest disadvantage is the big investment in such a system.
11. Recommendations

Shore-based power supply is already in use in a number of harbours. The systems nowadays are running fine, and the auxiliary engines of the vessel can be turned off when at berth. The number of installations is not growing rapidly which won’t improve the air quality in the harbour. To improve the number of installations a number of recommendations have been made.

Like most environmentally friendly solutions, people will not buy it unless the government will rebate the tax or give a subsidy. To install a shore-based power system on a vessel or quay is very expensive. The benefits are not really for the investor, but for the entire population around the harbour. This makes it less interesting to invest in this system.

If the large European harbours work together and make regulations for vessels that are in the large harbours for most of the time. These regulations can say something about the equipped needed for a shore-based power connection. For vessels that are not a visitor of an European harbour on regular base, the regulation is not applicable. The regulations will lead to a lower number of the biggest polluters in the large European harbours, and reduce the amount of emission.

Another disadvantage is the different vessels that are suited for the same job. This makes it dangerous to invest in, because when the vessel and the quay stop cooperating, the installation will not be used anymore. The investors will lose their income from the system and the investment will not be lucrative, neither for the company nor the environment.

To tackle this problem more vessels and harbours should be equipped with standard connections. This will make it easier to cooperate with different companies.

The cost are one of the main reasons why shore-based power supply is not that popular. To reduce cost expensive parts in the system need to be reduced. One of such a parts is the very expensive frequency convertor.

In most harbours the power grid is not suitable for that much extra power, so the grid needs to be changed. If chosen for installing a new power grid, the power plant can run one generator al little faster which will result in a 60Hz frequency. With the new power grid of 60Hz, there is no need for an expensive frequency convertor.
12. Explanations of relevant terms, expressions and abbreviations

DCMR: an environmental protection agency in the Rijnmond area
High voltage system: system of 6.6 or 11 Kilo Volts for transporting electricity over a long distance.
SO\textsubscript{x}: Sulfur oxide, is created when burning fossil fuels. Sulfur can be extracted from fuels
NO\textsubscript{x}: Nitrogen oxide, created when combustion takes place. It can create acid rain.
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ABB

Introduction
For our field research we had to find a company which is very familiar with the shore connection system. Therefore, we went to ABB. ABB is a company which provides shore connection to inland vessels and also to seagoing vessels nowadays. This is why ABB is a very reliable source for intelligence.

The interview
At first we hoped to do an interview with the representative of ABB: Ton Haasdijk, so we prepared a questionnaire (which can be found in the appendix). We soon found out that Mister Haasdijk prepared a presentation of his own. We hoped he would answer some questions from the questionnaire but gradually, with his presentation, he gave every piece of information we hoped for.

Discussed subjects
During the presentation we discussed a lot of subjects. The main subjects were: the technical aspects, Stenaline, costs and benefits and the most important aspects; safety.

Technical aspects
A shore connection system is a very complicated system with a lot of aspects which must be dealt with. The electricity must be transformed from 50- to 60 hertz. Large cables have to be plugged into the vessel without safety failures and so on. A full description of these technical aspects can be found in chapter 6.

Stenaline
Stenaline is a ferry company which sails between Great Britain, Ireland and The Netherlands. Also between Germany, Denmark, Norway, Sweden, Poland and Latvia. The reason Stenaline is mentioned, is that their vessels are already using shore connection. This is one of the few vessels near The Netherlands that uses this system. Stenaline can be used as an argument that shore connection is a potential good solution to the environment problems.

Costs and benefits
For Stenaline, ABB made an excel sheet to calculate the costs and benefits. In this excel sheet all the variables can be filled in to calculate what the costs will be and how long it will take to gain profit out of the shore connection system. Unfortunately, this sheet is quite data sensitive, so we were not allowed to publish this sheet.

Safety
As mentioned above, the safety of the shore connection is very important. Numerous people are denying this solution to the environment problems because they think this system is very unsafe. Nevertheless, ABB gave us very good explanations why shore connection is very safe and can be used to power up vessels, laying at berth.
Pilot Interview

1. Since 12 years ago, shore connection is used with the pilot tenders.
2. These tenders use shore connection because the vessels are unmanned and it is much better for the environment.
3. In some cases shore connection is made mandatory due to vibrations, bad smell or loud noises of the engines. This was the case at Stena Line at Hook of Holland.
4. There are many reasons why shore connection does not become a success. First we have the fact that ships, lying at harbor for loading or unloading, want to leave as soon as possible. The timeframe for connecting and disconnecting is very short. Another problem is the amount of different ships coming from all over the world and they all need the exact same connection specifications for the system on shore. On shore there is not much space for shore connection because the shore is very densely built. An example: Formerly, instead of repairing a damaged water pipe, a concerned vessel was called to use a different berthing area. That was cheaper than the repairing costs of the water pipe. Another problem is the frequency of the vessel’s power grid which on most vessels is not the same as the frequency of the shore power grid. Also, earthing the shore connection can be dangerous for the anti-corrosion system.
5. The port of Rotterdam owns all the shore sides which they rent to other companies in the harbor. Therefore, the port of Rotterdam is responsible for all the facilities. However, these companies are not obligated to make use of all the facilities. This way the port of Rotterdam does not know if their expensive facilities will be used.
6. There are no practical problems with the connection, such as synchronization, weather, cable requirements, etc. This is because the system will be connected by means of a black out.
7. A dangerous situation can occur when disconnecting the cables before the system is turned off. To avoid this, first shutting down the system, then disconnect or connect the cables is necessary.
8. Because connecting and disconnecting, wear and tear on the plugs occurs but replacement can be done when necessary.
9. The personnel does not need to be educated to perform the required actions.
10. The shore connection power units are located on shore and have to comply with the NEN-standard.
11. Rotterdam has been progressive and innovative to come up with a clean solution over the past few years. Therefore, shore connection is a good solution for the environment issues and must be considered.