LUČKA UPRAVA DUBROVNIK
DUBROVNIK PORT AUTHORITY

High Voltage Shore Connection (HVSC)
Pre-Feasibility Study

PROJEKTNI BIRO SPLIT d.o.o.
projektiranje i inženjering

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Table of Contents

Table of Figures

Index of Tables

1. INTRODUCTION

Dubrovnik is located in the far south of the Republic of Croatia and Dubrovnik-Neretva County. The port of Dubrovnik - Gruž is located on the north coast of the gulf and the east coast of the gulf of Rijeka, and has 1629 m of built coast and 829 m of undeveloped coast.

Port of Dubrovnik - Gruž is an important transport hub for local, regional and international maritime passenger traffic of the southern Adriatic. The most significant number of arrivals is the traffic of liner passenger vessels, while the total number of passengers is dominated by the segment of cruise passengers.

Inland, the Dubrovnik - Gruž port is connected to the hinterland of the DC-8 road to the north and the Neum corridor and south to Montenegro. It is connected to neighboring BiH by the 4.3 km road DC-223 in the direction of the Ivanica border crossing.

The main purpose of the Pre-Feasibility Study is to analyze the possibility of constructing a high-voltage shore connection at the Dubrovnik - Gruž port so that the Port of Dubrovnik Authority receives sufficient detailed information to make a decision on further project development activities. The pre-feasibility study must set out the technical and energy characteristics of the project, as well as the financial analysis and recommendations on which the further development of the project will be based.

2. THE ELECTRICITY MARKET

In Croatia, regulated and market energy activities are separated. Regulated electricity activities are transmission and distribution of electricity, the organization of the electricity market, and the supply of tariff customers with electricity. The Croatian Transmission System Operator (HOPS) is responsible for the transmission of electricity and the maintenance and development of the transmission system. The HEP Distribution System Operator (HEP ODS) is responsible for distribution of electricity and maintenance and development of the distribution system. The Croatian Energy Market Operator (HROTE) is responsible for organizing the electricity market. The supply of tariff customers to electricity is organized as a public service by the HEP Group as a public service obligation carrier.

Participants in the electricity market are producers, traders, suppliers and eligible customers (end customers). It is a bilateral market model based on electricity trading through bilateral agreements. Bilateral electricity supply agreements are concluded between customers and suppliers, and bilateral electricity purchase agreements between a supplier, a trader or a producer. All end customers are free to choose the supplier with whom they enter into a supply contract. Manufacturers, suppliers and traders wishing to participate in electricity market activities must enter into an agreement with HROTE. This agreement regulates the rights and obligations of market participants. Buyers and manufacturers must also enter into an agreement to use the network with the Croatian Transmission System Operator or the HEP Distribution System Operator, depending on the voltage level to which they are connected.

To cover deviations from the contractual schedule, HOPS sells or buys balancing energy to market participants every hour. Manufacturers, suppliers and traders must enter into a contract with HOPS for balancing energy.

Market participants must be licensed to carry out an energy activity issued by the Croatian Energy Regulatory Agency (HERA). According to Croatian Energy Regulatory Agency, 30 entities have a license for electricity production, 22 for supply, and 16 for electricity trade.

The accession of the Republic of Croatia to the European Union in 2013 had a significant impact on the organization of the national electricity market. With the adoption of the Energy Act (Official Gazette 120/12), the Law on Regulation of Energy Activities (Official Gazette 120/12) and the Electricity Market Act (Official Gazette 22/13), the harmonization of the legislative framework related to the electricity market began with the Third Energy Package of the European Union. The main objective of the provisions of the Third Energy Package of Regulations is to integrate the national electricity market into the single internal market of the European Union. The new Electricity Market Act provides a framework for the future model of the electricity market in the Republic of Croatia and prescribes the adoption of by-laws that will regulate certain parts of the market. Based on this law, some significant changes have been made in the organization of the electricity sector and energy activities, including the separation of the transmission system operator according to the model of the Independent Transmission Operator (ITO) in 2013. The ITO model for restructuring vertically integrated utilities is one of the three existing models and at the same time the most complex because it requires a lot of supervision and administration. After being separated from the vertically integrated company (HEP d.d.), the former HEP Transmission System Operator operates under the name Croatian Transmission System Operator d.o.o. (HOPS). HOPS must be fully independent, but HEP as a group remains integral, that is, HOPS assets remain in HEP's balance sheet.

In 2013, significant changes occurred in the retail electricity market. In a market where HEP Supply has a monopoly, new suppliers with cheaper electricity prices for consumers in the household sector have emerged. In view of this, the rate of change of supplier among consumers increased, after which HEP also offered households lower prices and new services.

With the adoption of new energy laws and their adaptation to EU requirements, the electricity market in Croatia is in a transitional period. It relies on secondary legislation that was developed in previous laws, with constant changes and adjustments to changes in supply conditions and market growth.

The installed capacity for electricity production in the Republic of Croatia includes hydroelectric power plants and thermal power plants within the HEP Group, industrial thermal power plants and renewable energy sources, mostly privately owned.

3. STRATEGIES, LAWS AND REGULATIONS

3.1. Spatial Planning Strategy and Program of the Republic of Croatia

The Spatial Planning Strategy of the Republic of Croatia (1997, 76/2013) respects the goals and guidelines of energy development, promotes keeping of the existing locations as a basis for expansion and development of the energy system, modernization and expansion of existing energy and transmission systems, keeping of the explored and potential locations for new energy facilities that require detailed research and apply the most relevant environmental criteria for the construction of energy and transmission systems.

The strategy announces the need for an additional 2100 MW of installed capacity by 2020 by modernizing, reconstructing and expanding existing facilities by bringing in new technology and combining energy sources. At the same time, the possibilities and needs and the economic justification for the construction of new energy facilities need to be identified in order to balance the consumption, production and transmission of energy in all parts of the Republic of Croatia. Although the Strategy envisages the construction of new capacity of approximately 120-200 MW hydro-power plants on the Sava and Drava river, it simultaneously emphasizes the limited and medium-term questionable hydro potential due to the necessary harmonization and agreements at the international level.

3.2. Croatian Energy Strategy

The Energy Development Strategy of the Republic of Croatia defines the development of the energy sector of the Republic of Croatia for the period up to 2020. The main objective of the Strategy is the balanced development of security of energy supply, competitiveness and environmental protection, which will enable quality, secure, accessible and sufficient energy supply.

Furthermore, the Energy Development Strategy of the Republic of Croatia foresees that the newly built capacities in large hydro-power plants will amount to around 300 MW by 2020, and will start operating from 2015. This amount also includes the Lešće HPP with an installed capacity of 42.3 MW (in operation since 2010). New hydroelectric power plants are assumed to have a slightly lower utilization factor than the average for existing hydroelectric plants, as it is planned to use hydroelectric plants to cover peak loads. The construction of pumped hydro power plants is expected to continue in the envisaged energy structure. This significantly increases the competitiveness of the electricity system in the electricity market in the region.

4. CURRENT CONDITION OF THE TRANSMISSION NETWORK IN DUBROVNIK AREA

The current power supply to consumers of the entire Dubrovnik area is based on transformer station TS 110/35 kV Komolac, 2x63 MVA, transformer station TS 110/20 (10) kV Srđ, 2x40 MVA, and from transformer station TS 220/110/35/20 (10) kV Plat.

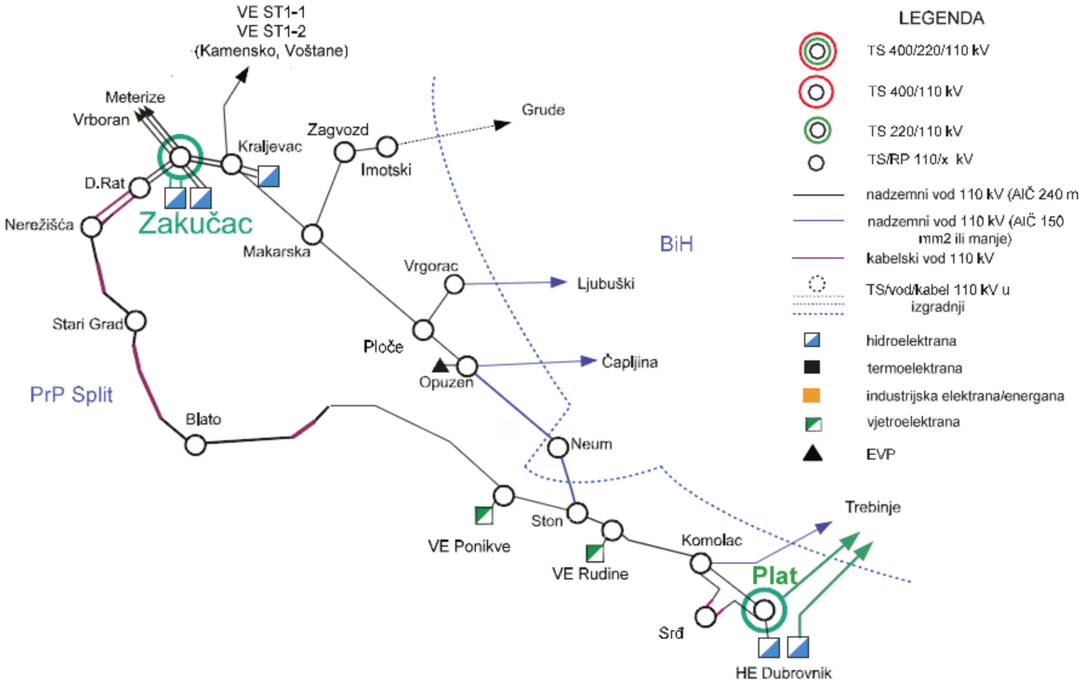

Figure 1. Local transmission lines situation in southern Croatia

The current state of the 110 kV electricity transmission network in southern Croatia is shown in Figure 1. It is noticeable that the far south of Croatia is connected to the rest of Croatia through the territory of the Republic of Croatia by only one electric power line, that is connection Komolac - TS Rudine - TS Ston - TS Ponikve - TS Blato, transmission capacity thermally limited to 110 MVA on the line between TS Komolac and TS Ston (Rudine). The second 110 kV connection is between TS Opuzen and TS Ston and goes through the territory of BiH and is introduced into TS Neum (BiH). It is obvious at first glance that the safe operation of this part of the EES is largely based on interconnected links with BiH.

The power systems of Croatia and Bosnia and Herzegovina are extremely well connected to a total of 21 interconnections at 400 kV, 220 kV and 110 kV voltage levels, which significantly contributes to the safety of both countries. However, given the specific shape of the territory and the electricity grid of Croatia, the southernmost part of the Croatian electricity system depends on interconnections to BiH.

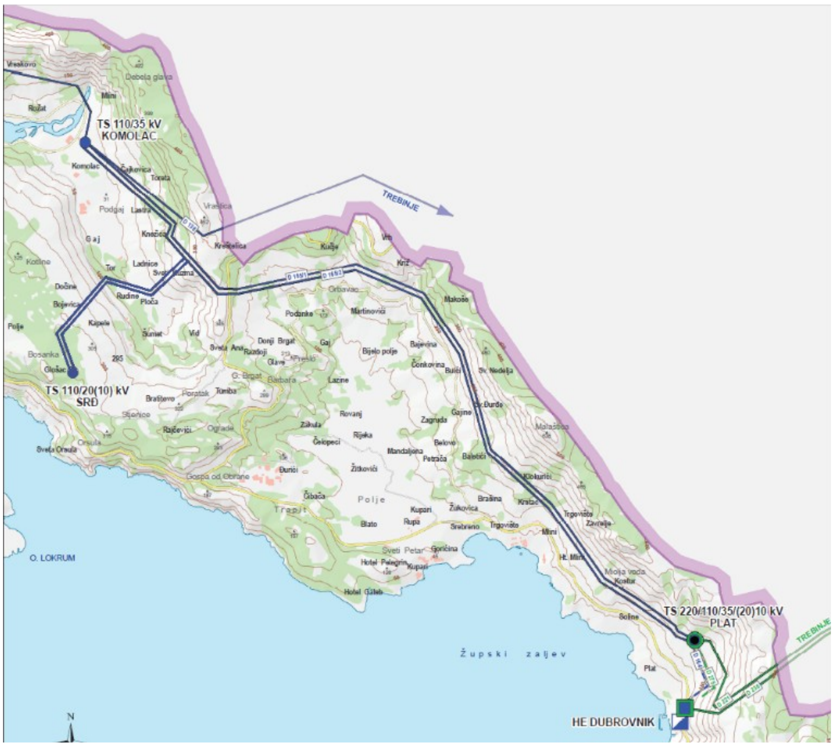

Figure 2. Local transmission lines situation in Dubrovnik surroundings

With the exception of Ponikve (34 MW) and Rudine (35 MW), the only major and reliable source in the entire southern arm is the Dubrovnik HPP. Currently, the Dubrovnik HPP is connected to the 110 kV HOPS power system by one unit of 126 MW installed power, while the other installed power unit is also 126 MW directly connected to the Trebinje substation in Bosnia and Herzegovina by air 220 kV transmission line.

It also shows the planned 120 MW Konavle Hills power plant, which is planned to be connected to a 220 kV plant in the TS Plat.

It is noted that now, after the construction of TS Plat and TS Srđ, the existing consumption of the Dubrovnik area is satisfied.

However, in the case of power supply to unconventional consumers (HVSC) in the port of Gruž with power of 3x15 MVA = 45 MVA, the current state of the transmission and distribution power grid is not satisfactory, and so much power with sufficient reliability can only be supplied by upgrading the transmission network to bring the power closer to that consumer and then through the transformation from high voltage to medium voltage and upgrading the medium voltage (distribution) network, that power would be brought to the port of Gruž.

The application for transformation of 110/20 kV in the planned TS Lapad is equal to 4x40 MVA, where 2x20 MVA would be for the needs of the Port Authority of Dubrovnik (port of Gruž), and 2x20 MVA for the needs of HEP-ODS. The metering point for the Dubrovnik Port Authority would be within TS 110/20 (10) kV Lapad itself and the 20 kV junction for the Dubrovnik Port Authority and cable lines to the port of Gruž would be owned by the Dubrovnik Port Authority.

It is envisaged that for reliable supply of TS 110/20 kV Lapad it would be necessary to build at least two cable 110 kV lines which would have a transmission power of 160 MVA each to satisfy the (n-1) condition and that the power supply of the existing TS 110 kV should be increased along with the transmission power of the existing 110 kV Komolac - Rudine (Ston) TL.

Increasing the power supply of 110 kV TS Komolac would be achieved in the case of upgrading the transmission network on the move from the location of the planned TS 400/110 kV Imotski / Zagvozd to the existing TS 220/110/35 kV Plat by constructing the following facilities:

1. TS 400/110 kV Imotski / Zagvozd,
2. TS 400/220/110 kV Nova Sela,
3. DV 2x400 kV Nova Sela - Imotski / Zagvozd,
4. DV (220 + 110) kV Nova Sela - Plat including submarine KB (220 + 110 kV) mainland – Peljesac.

4.1. Existing spatial and energy planning documents for Dubrovnik area

The relevant existing planning documents for Dubrovnik ares are:

- Spatial plan of Dubrovnik-Neretva County,
- General Urban Plan of the City of Dubovnik,
- Urban plan for Gruž area

In the following chapters there is an overview of the planned 110 kV transmission network upgrades in the City of Dubrovnik, which are presented in the existing previously mentioned planning documents.

4.1.1. Spatial plan of Dubrovnik-Neretva County

Current Spatial Plan of the Dubrovnik-Neretva County ("Official Gazette of the County of Dubrovnik-Neretva", No. 6/03, 3/05/05, 3/6 *, 7/10, 4/12/12, 9 / 13th, 2 / 15th-conjunction and 7/16); * - Judgment of the High Administrative Court of the Republic of Croatia Number: Usoz-96 / 2012-8 of 28 November 2014, Official Gazette 10/15. from 1/28/2015)

The Spatial Plan of the Dubrovnik-Neretva County (DNŽ) has planned the 110/20 (10) kV Lapad TS in the area of interest, which would be located at the location next to the existing 35/10 kV Lapad TS.

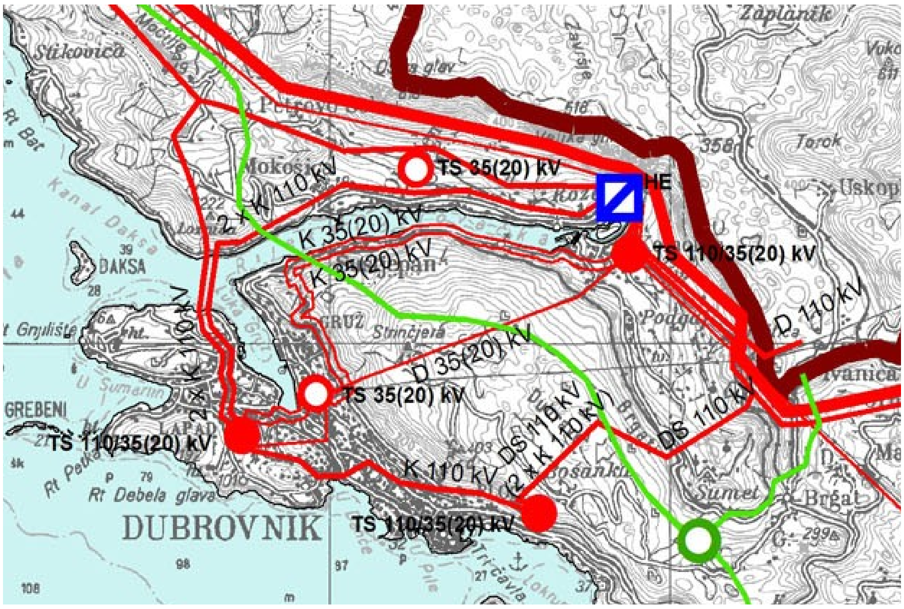

Figure 3. Excerpt from the part of the cartographic representation of the Regional Spatial Plan representation 2.3. - infrastructure systems - energy systems

In accordance with the graphical representation from Figure 3 and the textual part of the Spatial Plan of the Dubrovnik-Neretva County, the planned 110/20 (10) kV Lapad TS is foreseen in the area of interest, which would be located at the location next tothe existing 35/10 kV Lapad TS.

In addition to the construction of the TS 110/20 (10) kV Lapad, which is planned as a planned extension of the existing TS 35 kV "Lapad", the following 100kV lines are foreseen as the possible significance for this subject:

- 110 kV underground cable Srđ - Lapad,
- underground cable 110 kV Komolac - Lapad,
- underground cable 2x110 kV introduction DV Komolac - Ston in TS Lapad.

4.1.2. General Urban Plan of the City of Dubrovnik

City of Dubrovnik Master Plan (Official Gazette of the City of Dubrovnik, No: 10/05, 10/07, 8/12, 3/14, 9/14-consolidated text and 4/16-decision, 5/18, 7 / 18, 14/18, 25/18).

The GUP of Dubrovnik envisaged as buildings of importance for the County (Art. 31):

- TS 110/20 (10) kV " Lapad " (planned)
- 110 kV underground cable Srđ - Lapad (planned),
- underground cable 110 kV Komolac - Lapad (planned),
- underground cable 2x110 kV, introduction DV Komolac - Ston in TS Lapad (planned).

Construction of the 110/20 / (10) kV TS Lapad is envisaged at the location immediately adjacent to the existing 35 / 10kV TS Lapad.

Article 68 (Electricity System) provides for the following buildings:

- construction of 110/20 / (10) kV TS Lapad at the location immediately adjacent to the existing 35 / 10kV Lapad TS,
- construction of 110 kV cable line at Srđ Lapad TS 110/20 (10) kV - Solitudo - Lozica - TS Komolac 110/35/10 (20) kV,
- construction of KB / DV 110 kV line Lapad 110/20 (10) kV - Komolac 110/35/10 (20) kV (via Srđ).

Therefore, from this aspect, the City of Dubrovnik GUP is not fully aligned with the spatial plan of the National Railways.

In addition to the Spatial Plan od the County, it enables the route of overhead / cable 110 kV lines from TS Komolac to TS Šipčine via Srđ, probably along the route parallel to the route of the existing 35 kV Komolac-Šipčine line.

In the graphic part of the diagram, the GUP does not show the route of the 2x110 kV underground cable for the introduction of the Komolac - Ston DV into the Lapad TS, although this is mentioned in the textual part of the plan.

4.1.3. Urban plan for Gruž area

Urban Plan for the Gruž area (Official Gazette of the City of Dubrovnik, No. 7/11).

This plan, although beyond its scope, mentions the construction of the planned TS 110/20 (10) kV Lapad. Also, within the scope of this Plan, the route of the planned 110 kV cable on the section of the planned TS 110/20 (10) kV Lapad - Solitudo - Lozica is indicated, which means the submarine crossing from Solitudo to Lozica. In this way the display is harmonized with the Regional Plan of Dubrovnik-Neretva County and the Plans of City of Dubrovnik. Figure 4 is a graphical excerpt from the Gruž area Spatial Plan, which shows the route of the previously mentioned planned 110 kV cable.

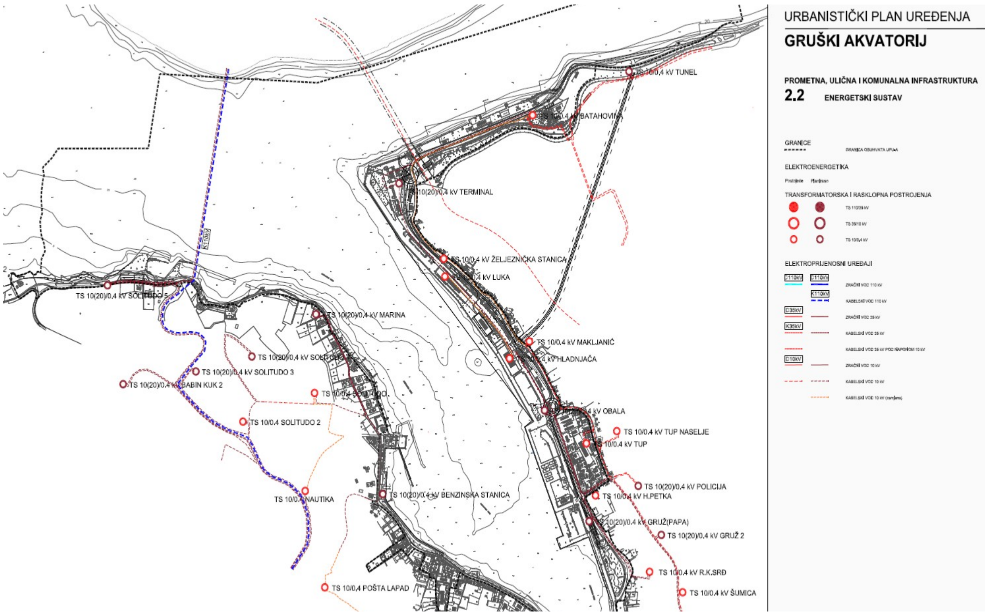

Figure 4. Excerpt from the map section of the Spatila Plan for Gruž area

Also, Article 126 stipulates in detail Article 126 requirements for the construction and reconstruction of power facilities, from which the following extract is relevant for 110 kV voltage and cable lines:

"The following conditions must be observed when constructing or reconstructing power plants:

a) Protective belts for underground power lines are: for 110 kV, 10 m; for 35 kV, 5m; for 10 (20) kV, 5m.
b) The use and arrangement of the premises within the cable security corridors shall be in accordance with the special regulations and conditions of the competent authorities and legal persons with public authority.
c) For submarine existing and planned 110 kV power cables, it is necessary to provide protective belts 4 (four) times the maximum depth of the sea on the route.
d) Deviations are possible with respect to the solutions of the power lines and the location of the power structures determined by this Plan, for the purpose of harmonization with the projects and more precise geodetic surveys, technological innovations and achievements, and will not be kept by amendments to this plan.
e) The planned 110 kV cables should be made with XLPE 3x (1x1000) mm² Al cables.
f) The width of the cable ducts depends on the number and voltage level of the parallel cables.
g) When laying cables along the entire length of the cable route, a grounding cable of Cu 50mm² is mandatory.

Power cables shall be laid wherever possible on the sidewalk of the road. In the streets where power lines are laid, it is necessary to ensure the planned layout of the installations, as a rule, one side of the road for energy, the other side for telecommunications and water supply, and the middle of the road for sewage and storm water.

We believe that the provision of Article f) (110 kV cable cross-section) may be defined differently when designing a suitable cable line, ie the selected 110 kV cable cross-section may be different from 1000 mm². This is a provision that should not be affected by the Urban Plan and also that the cable route width is independent of the cable cross section selected.

4.1.4. Croatian Transmission System Operator Plans

The current "Ten-Year Transmission Network Development Plan 2018-2027, detailing the initial three-year and one-year periods" of December 2017 does not envisage any upgrading or reconstruction of the transmission network in the Dubrovnik area until 2027.

4.1.5. HEP Distribution System Operator Plans

The current HEP-ODS 10-Year Plan (2018-2027) for the development of the HEP-ODS distribution network with detailed elaboration for the initial three-year and one-year periods of December 2017 does not foresee any upgrading or reconstruction of the distribution network in the Dubrovnik area. Until 2027.

4.2. Transmission network upgrading possibilities

Analyzing the current state of the 110 kV electricity transmission network as well as the current spatial planning documents in the observed area, the following conclusions are reached.

The construction of TS 110/20 (10) kV Lapad at the location adjacent to the existing TS 110/35 kV Lapad is considered to be in accordance with the physical planning documents.

Area required for the construction of the 110/20 kV Lapad TS, which would be GIS 110 kV plant with 2 water, 4 transformer, one measuring and 2 spare fields, and with four transformers of 40 MVA, including a plateau, roads, fence and all necessary appliances and equipment is estimated at 50x50 meters.

The location of the planned 110/20 kV Lapad TS is planned to be located in the northwest corner of the 1956 cadastral plot in k.o. Dubrovnik, while access would be from Liechtenstein's path. This site is just south of the existing 35/10 kV Lapad TS.

For the construction of cable connections 110 kV up to the planned TS 110/20 (10) kV Lapad, the above mentioned spatial planning documents were left with several of the following options, and the indicative lengths of the routes are indicated:

NAME OF THE PLANNED 110 kV LINE	Lenght
Underground line 110 kV Srđ – Lapad	4,5 km
Underground line 110 kV Komolac – Lapad	Underground line: 7,8 km Underground line: 0,7 km
Underground line 2x110 kV, input TL Komolac - Ston to TS Lapad	overground 2×110 kV line: 1,8 km underwater 2×110 kV line: 0,7 km

	underground 2×110 kV line: 2,4 km
KB/DV 110 kV line TS Lapad 110/20(10)Kv -TS Komolac 110/35/10(20) kV (over Srđa)	6,0 km overground via Srđ

With regard to the feasibility of these 110 kV lines, the 2x110 kV underground cable route is considered to be the easiest feasibility of the DV Komolac-Ston DV to TS Lapad. The first part of the route from the existing 110 kV Komolac-Rudine transmission line to above the highway (state road D8) could be constructed above ground as a double 110 kV transmission line, and the rest of the route to the Komolac TS as a double underground cable line, or partly underwater from Lozica to Solitud .

All remaining 110 kV cable lines from the zoning documents must pass through the urban area with a bottleneck from the planned TS 110/20 kV Lapad towards the city, where the city streets are already filled with existing municipal infrastructure, and it is considered very problematic to find a free corridor. Also, the execution of works on the construction of 110 kV cable lines in the conditions of maintaining the normal functioning of the city is very questionable in the said area. It is mandatory to consider that at least two 110 kV lines, or one double 110 kV line, must be brought to the planned TS 110/20 (10) kV Lapad in order to maintain the (n-1) electricity supply security criteria. From this point of view, a double 110 kV line is much easier to build and cheaper to build than two separate single line cables.

The routes of all above-mentioned 110 kV overhead / cable lines from the spatial planning documents, as well as the location of the planned TS 110 (20 (10) kV Lapad, are on the situation plan.

5. CRUISE SHIP ELECTRICAL INSTALLATIONS

5.1. Overview

All devices and elements used in the ship's electrical system can be found in land systems, but it should be noted that due to the conditions of the ship, their exploitation is much more demanding. For this reason, all equipment and all elements of the ship's electrical system must satisfy the much stricter requirements detailed in the rules and regulations of the respective classification societies. Such national classification societies are colloquially called Registers. They prescribe rules for the supervision and construction of ships in accordance with the minimum requirements for the safety of the ship, crew and cargo.

All relevant Registers issue rules based on the SOLAS Convention and those of the International Electrotechnical Committee and the IEEE Institute of Electrical and Electronics Engineers. Some of the world's most famous ship registers in the world are the Lloyd Register of Shipping, Bureau Veritas, American Bureau of Shipping, Det Norske Veritas, Germanisher Lloyd, Registro Navale Italiano, etc., and in Croatia the Croatian Register of Shipping HRB.

Power sources on board can be: generators, rechargeable batteries, solar cells, electrical converters and shore connection.

The main source of electricity on board is electrical generators, which convert the mechanical energy of the propulsion machine into electricity. Depending on the type of propulsion of the ship's electric generator, diesel, axle and turbine generators are distinguished, and all onboard power generation is carried out in one place at the ship's power plant or by means of individual generators.

Diesel generators are the most common sources of electricity for vessels. They consist of a diesel engine, an electric generator, and all associated control and auxiliary systems. They convert the energy of liquid fuel, usually light oil, into mechanical energy, which drives a synchronous generator through the shaft, which converts the mechanical energy of the propulsion machine into electrical power and supplies electrical power to the ship via electrical installation.

Nowadays, high-speed diesel generators with a higher speed orientation are mainly used - 1000, 1200, 1500, 1800 rpm. This orientation is justified in the same durability of slow-speed and high-speed diesel engines due to today's increasingly high-quality materials, but also in far smaller dimensions of high-speed aggregates, and thus occupying less volume in the ship, and certainly in the lower cost of the propulsion machine.

5.2. CRUISE SHIP INTERNAL POWER SUPPLY

Electricity sources on board may be:

- Generators,
- rechargeable batteries,
- solar cells,
- electrical converters,
- land connection.

The main sources of electricity on board are generators. Each ship must have two main generators (mainly diesel generators, less frequently steam turbines or gas turbines) and an importance generator.

Synchronous self-excited contactless generators are used almost exclusively on today's ships. According to the type of propulsion machine we divide them into: diesel generators, turbo generators and axle generators. The power of marine generators ranges from several hundred kVA to 18000 kVA on large passenger ships equipped with diesel electric propulsion. The choice of generator type and number of pole pairs is determined by the type and speed of the drive machine.

Diesel-powered synchronous generator is the most represented source of energy on board ships. Marine generators are always connected directly to the auxiliary engines (without the use of gear units), so they are powered by high-speed or mid-range diesel engines.

The most significant advantages of a diesel engine as a generator drive are the instant readiness for operation, the ability to regulate speed quickly and the high degree of utility. The disadvantages are the oscillation of energy and the appearance of torsional vibration as a result of the elasticity of the shaft, and the uneven torque, which is even greater, the smaller the number of engine cylinders.

The electromechanical oscillations caused by the aforementioned defects are mitigated by the use of a generator with a damping coil (damping cage). The required engine speed is determined by the frequency f (60Hz) and the number of pole pairs p of the synchronous generator used according to the synchronous speed formula:

$$n_S = \frac{60 \cdot f}{p}$$

In order to safely and efficiently transfer electricity from the source to the final supply, distribution boxes, cable lines and transformers are installed. As a rule, ships use an airy (radial) distribution scheme, which radiates airily from the ship's power plant directly to the loads or to the manifolds from which the individual ship systems are further fed, as shown in the following figure.

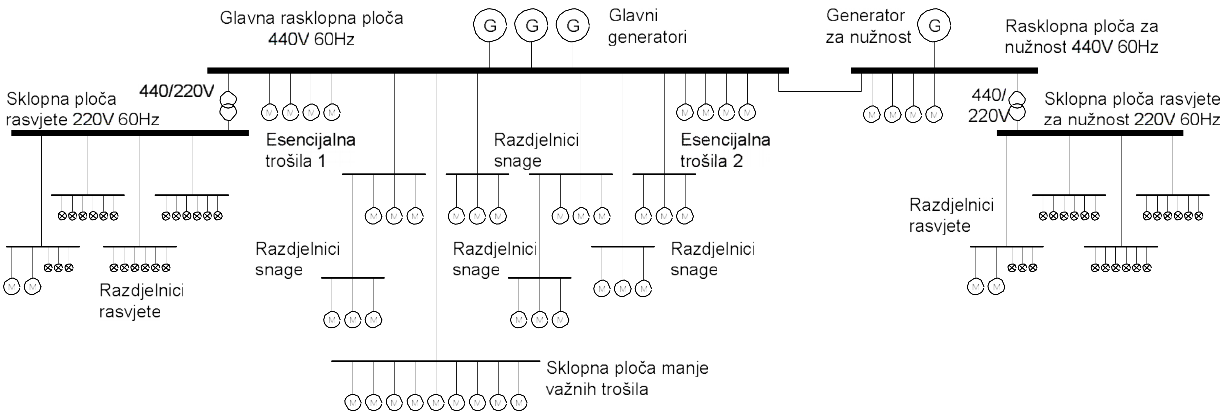

Figure 5. A typical radiant (radial) scheme for the distribution of AC voltage on board

Medium-sized merchant ships account for about 80% of the electricity consumption of electric motor drives of auxiliary machines and of commercial appliances. Such auxiliary machines are clamping and anchoring winches, cranes, pumps, compressors and the like. About 15% is spent on heating and cooling, or on heat consumers, and 3-4% of electricity consumption is spent on all lighting (general, auxiliary and emergency lighting). Powering navigation and communication devices accounts for about 1-2% of total electricity consumption.

The situation on cruise ships is similar. 75% of electricity is used to power electric motor drives, and about 12% is used for thermal energy. The biggest difference is in lighting, which accounts for about 11% of electricity consumption, while for all other consumables it is 2%.

5.3. Electricity consumption of cruise ships on a berth

According to the data from the report, the table below shows the values of the average docking power and peak power of the cruiser according to their length.

Table 1. The average and peak electrical power of the cruiser at the dock

Boat length	Average power (MW)	Peak power (MW)	Peak power for 95% of cruisers (MW)
Cruiser (< 200 m)	4,1	7,3	6,7
Cruiser (> 200 m)	7,5	11	9,5
Cruiser (> 300 m)	10	20	12,5

6. FUEL CONSUMPTION OF SHIPS ON BERTH

6.1. Diesel generator

Modern diesel engines use about 40% of the energy contained in the fuel, which is very useful compared to other heat engines. The efficiency of a diesel engine depends on the load and declines very quickly when it falls below 50% of rated power.

At low load, the combustion of the mixture is not complete and soot, sulfur (SOx) and nitrogen (NOx) compounds are formed, resulting in increased emissions and more frequent maintenance. Therefore, it is extremely important to optimize the power generation system in such a way that the generators, either individually or in parallel, at all stages of ship exploitation, operate as much as possible in the area of optimal utilization, ie with 60-90% load.

6.2. Fuel consumption of ships in navigation

For information on fuel consumption of passenger ships - cruisers we will take as an example a cruiser of length L = 340 m, gross tonnage of 140,000 registration tons (GT), which can accommodate approximately 4370 passengers, with the care of 1300 crew members.

The cruiser of these dimensions in the engine room has six diesel generators, each with a capacity of 12.5 MW. One diesel generator engine consumes 200 g / kWh of fuel / oil in operation, which in practice means about 1.5 to 2 t / h of fuel / oil (depending on external conditions, temperature, season due to humidity, tropics or north, etc.).) with an output of approximately 10 MW.

The diesel engine is always avoided at maximum load in the plant, because under such operating conditions the efficiency of the diesel engine is not maximum, ie the diesel engine consumes more fuel than when it is at 80% load. Therefore, the performance of the diesel engine is optimized to be approximately loaded with 80% MCR (maximum continuous rating) power, because it is then the most efficient and consumes fuel.

Diesel engines have two fuel options:

- Heavy fuel containing maximum 2% SO2, current price around US $ 350 / t,
- Light fuel (ordinary diesel), which often contains even below 0.1% SO2, which is the maximum prescribed amount of SO2, with a current price of about $ 600 / t.

Consumption data for the above mentioned cruiser for different speeds of navigation are:

- for 18 knots, 3 engines should run, which then consumes 2 t/h and this is the usual speed of navigation,
- for a speed of 20 knots, 4 engines operate and with the same consumption per engine.

Usually, 5 engines are used in the ride (1 engine always in reserve), with a power distribution of approximately 30 MW for propulsion and 20 MW for powering the hotel.

6.3. Ship fuel consumption on berth

During the stay of the aforementioned cruiser in the port, as a rule, 1 diesel engine operates at 80% MCR, ie at the output it gives 10 MW of power to power the load. Depending on the situation, it is assessed whether it is necessary to start the second diesel engine or whether it is sufficient to increase the operation of the first diesel engine.

Consumption during the stay of the cruiser on the berth in the port also ranges from 1.5 to 2 t / h, which also depends on the external conditions (Caribbean or eg Northern Europe, outdoor temperature, percentage of humidity, etc.).

7. ENVIRONMENTAL IMPACT

7.1. Introduction

Ports, as a significant source of pollution in coastal cities, along with road transport and industry, create a cumulative negative impact on the environment. Marine pollutant emissions contribute to a concentration of nitrogen oxides in the range between 0.5-5%, while in the case of sulfur dioxide the situation is similar with a slightly higher percentage. It is expected that by 2020. the share of maritime-related pollutant emissions reaches an even higher figure than the total amount of land-based pollutant emissions, as shown in the following figure.

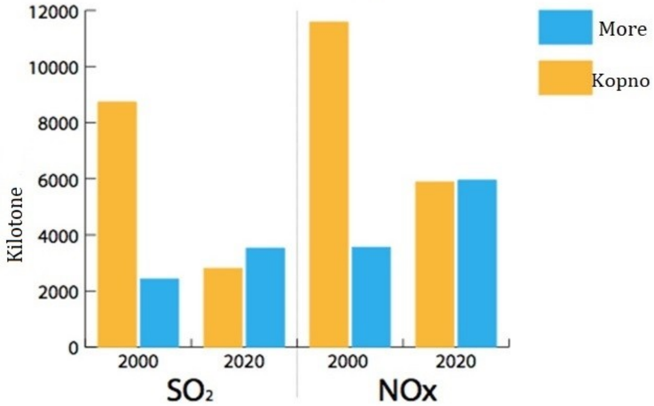

Figure 6: Comparison of emissions and estimates of emissions of sulfur dioxide and nitrogen oxides in kilo-tonnes worldwide for terrestrial and marine sources

The effect of such substances and particles on humans is well known and causes reversible consequences such as acute and chronic respiratory symptoms, followed by asthma attacks, decreased respiratory function, irritation of the eye and nose, headaches, diseases of the heart and blood vessels. The irreversible consequences are changes in the pulmonary parenchyma, the onset of malignancy and shortening of life span.

Also, the negative effects of elevated concentrations of nitrogen and sulfur oxides on the environment causing pollution of forests, agricultural land and water are known.

Emissions of ships sailing in Europe (Baltic, Black and North Sea, Mediterranean, Northeast Atlantic) are estimated at 2.3 million tonnes of sulfur dioxide, 3.3 million tonnes of nitrogen oxides, and 250 thousand tonnes of particulate matter (PM) per year, according to 2000 survey. Already for 2020, an increase of 40-50% is estimated compared to 2000.

2007 data say that such emissions of harmful substances and particulates, due to respiratory damage and the onset of malignancies, have directly led to 60,000 deaths a year, mainly in areas off the coast of Europe, eastern and southern Asia. Of course, the number of people whose health is compromised by the show is much higher.

The main cause of this problem is, of course, the composition and quality of the fuel used to power the ships. This fuel is one of the most purified products of the crude oil refining process. All of the above reasons somehow made the International Maritime Organization (IMO) 2008. revises and tightens rules on ship emissions control. Control of ship emissions is defined in Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL). Annex VI, as amended, entered into force in 2010. in July, and was accepted by 53 countries that make up approximately 82% of the world's total tonnage.

The following table shows the emission limit values for nitrogen oxides depending on the rated rpm of diesel engines. These standards are known as Tier I-III and apply only to Emission Control Areas (ECAs).

Table 2. Tier standards for nitrogen oxide emissions

NOx granica g/kWh ovisno o brzini motora				
	Godina	n < 130 º /min	130 º/min ≤ n <2000 º/min	n ≥ 2000 º/min
Tier I	2000.	17	$45 \cdot n^{-0.2}$	9,8
Tier II	2011.	14,4	$44 \cdot n^{-0.23}$	7,7
Tier III	2016.	3,4	$9 \cdot n^{-0.2}$	1,96

The following figure shows coastal areas with special Emission Control Area (ECA) emissions. We can see that the Adriatic Sea, together with the Mediterranean Sea, could in the near future also become an area with special emission control, so in our largest ports in Rijeka, Dubrovnik and Split, the installation of HVSC equipment should be planned.

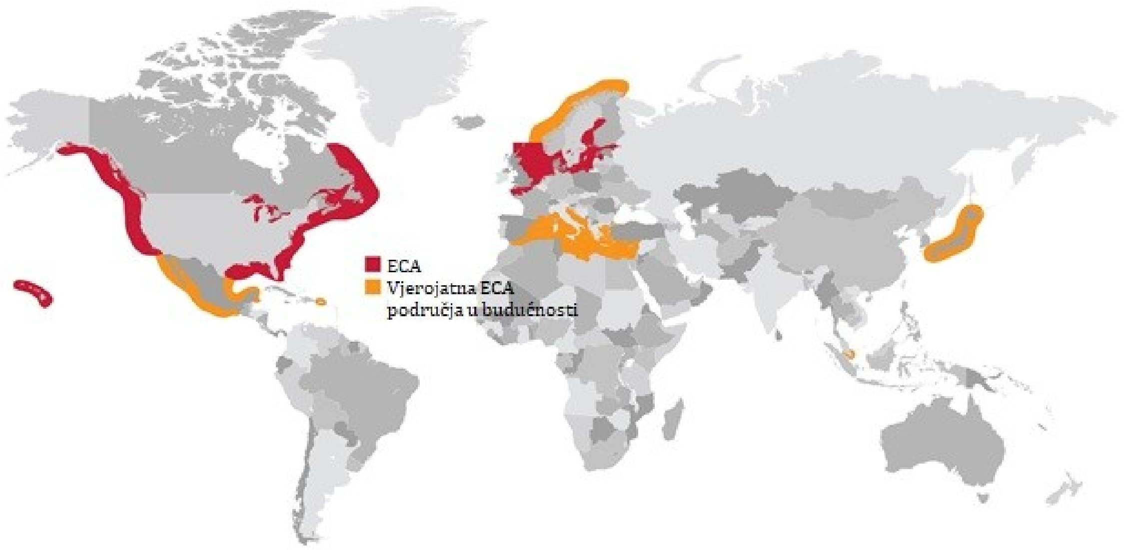

Figure 7. ECA areas worldwide

The following table shows the prescribed levels of sulfur dioxide content in diesel used in shipping. The restriction must be implemented in three stages as shown, with the result that according to the IMO's 2018 results. allows application delay until 2025. These restrictions are in line with EU Directive 2005/33 / EC, which until 2010 all ships calling at EU ports must use fuel with a sulfur content of less than 0.1%. An alternative offered by the same directive is a high voltage shore connection (HVSC).

Table 3. Limitation of sulfur content in marine fuel

IMO global limit		IMO limit for ECA		European Comission	
Active from	Limit	Active from	Limit	Active from	Limit
2000.	4.5%	July 2010.	1%	January 2010.	0.1%
January 2010.	3.5%	January 2015.	0.1%		
January 2020.	0.5%				

Recognizing the beneficial environmental effects of the study on high-voltage land-based docking, the European Commission issued a recommendation for the use of the HVSC by Directive 2006/339 / EC. This Directive encourages Member States to opt for the construction of such an installation of HVSC ports in their ports, and in particular in ports located in the immediate vicinity of densely populated urban areas.

7.2. Installation of "scrubber" on ships

According to the regulation defining coastal areas with special emission control ECA (Emission Control Area) adopted by most countries, it is valid to use LF (light fuel) as well as in ports when navigating at a distance of less than 12 NM from the coast.

The seafarers do this by diverting exhaust from the diesel engine through the so-called prescribed distance. A scrubber that drives exhaust gases through seawater and thus cools them, and as a result, for example, soot particles remain in the system and do not go into the air, seawater binds some of the sulfur, etc. In short, this achieves the prescribed limits for exhaust gas. Tanks with such saturated seawater are then emptied on the high seas. Their capacity is usually about three days.

Certainly, in the ports themselves, as a rule, on all ships, except in exceptional cases, they burn LF (light fuel), while on the run they burn HF (heavy fuel), with or without scrubber.

The installation of a scrubber system on board costs about $ 1 million per motor with a capacity of approximately 10 to 15 MW. For this reason, some companies design and install a full capacity scrubber system, that is, for all engines, and some for one or two engines, which they then work with in ECA waters or in port. The difference between a scrubber system for full capacity or for one to two diesel engines is the required pump power, tank capacity, number and capacity of filters, number of sprinklers, etc.

The installation of the scrubber system does not reduce noise and vibration, which is particularly important for the environmental impact of ports located in urbanized areas, as is the case with the Port of Dubrovnik.

7.3. Cruise ships docked at the port of Dubrovnik Gruž

he Port of Dubrovnik Authority has provided us with information / lists of arrivals of cruise ships - cruisers in 2018 to the port of Dubrovnik Gruž. The lists provide the following information:

- name of the ship, owner / company and country under whose flag the ship is sailing,
- date and time of arrival and departure,
- length and gross tonnage of the ship,
- order number of the dock / berth at which the ship resided.

According to the data from the list of cruise ships for cruise ships at the Dubrovnik Gruž port, in 2018 there were 423 cruise ship entries at the Dubrovnik Gruž port. Cruise ships - cruisers that landed at the port of Gruž in 2018 are shown in the following table:

Table 4: List of cruisers on berth at the port of Dubrovnik - Gruž in 2018

Company	Ships name	HVSC	Times on berth	Length (m)
AIDA CRUISES	AIDAaura	NE	2	202
	AIDAblu	NE	31	253
V Ships	ARTANIA	NE	1	231
P&O Cruises	ARCADIA	NE	2	285
	AURORA	NE	2	272
	OCEANA	NE	10	261
	ORIANA	NE	4	260
GCCL (Cayman)	ARTEMIS	NE	4	58
	ATHENA	NE	20	58
Celebrity Cruises	AZAMARA QUEST	NE	3	180
	CELEBRITY CONSTELLATION	NE	7	294
	CELEBRITY ECLIPSE	NE	1	317
FRED OLSEN	BRAEMAR	NE	1	195
Carnival Cruise Lines	CARNIVAL HORIZON	NE	2	321
Costa Crociere SpA	COSTA DELIZIOSA	DA	36	294
	COSTA neoRIVIERA	NE	1	216
Princess Cruises	CROWN PRINCESS	DA	3	290
	SEA PRINCESS	DA	1	261

Company	Ships name	HVSC	Times on berth	Length (m)
Crystal Cruises	CRYSTAL ESPRIT	NE	13	86
	CRYSTAL SERENITY	NE	1	250
MANO	GOLDEN IRIS	NE	1	164
Pullmantur	HORIZON	NE	9	207
Holland America	KONINGSDAM	DA	3	299
	OOSTERDAM	DA	12	285
CROISIMER FINANCE S.A.	LA BELLE DE L'ADRIATIQUE	NE	22	110
PRESTIGE	MARINA	NE	1	239
	RIVIERA	NE	6	239
	SIRENA	NE	1	180
TUI Cruises	MEIN SCHIFF 2	NE	12	262
MSC Cruises	MSC Lirica	NE	28	274
	MSC Poesia	DA	24	293
	MSC Sinfonia	NE	19	274
Oceania cruises	NAUTICA	NE	1	180
Norwegian Cruise Line	NORWEGIAN SPIRIT	NE	10	268
	NORWEGIAN STAR	DA	22	294
NYK Cruises,Co	OCEAN DREAM	NE	1	204
VARIETY	PAN ORAMA II	NE	2	49
	TO CALLISTO	NE	20	49
Cunard Line	QUEEN ELIZABETH	NE	2	294
	QUEEN VICTORIA	NE	3	294
Royal Carribean Cruises	RHAPSODY OF THE SEAS	NE	11	279
RUNNING ON WAVES LTD.	RUNNING ON WAVES	NE	3	63
SEA CLOUD Sea Dream	SEA CLOUD	NE	3	109
	SEA DREAM I	NE	1	104
	SEA DREAM II	NE	2	104
Seabourn cruise line	SEABOURN OVATION	NE	1	211
PRESTIGE CRUISE HOLDIN	SEVEN SEAS EXPLORER	NE	1	223
	SEVEN SEAS VOYAGER	NE	4	207
TUI UK Ltd.	TBC 2	NE	13	264
	THOMSON CELEBRATION	NE	26	214
VIKING OCEAN	VIKING ORION	NE	1	228
	VIKING SKY	NE	2	228

Company	Ships name	HVSC	Times on berth	Length (m)
	VIKING STAR	NE	7	228
	VIKING SUN	NE	4	228

According to the data in the table above, in 2018 there were 423 berths for cruise ships - cruisers in the port of Dubrovnik-Gruž. Of all the cruise lines that were connected to the port of Dubrovnik - Gruž in 2018, according to the available information, the following cruisers were able to receive electricity from the mainland:

Table 5: List of cruisers at the port of Dubrovnik - Gruž in 2018 prepared for HVSC

Company	Ships name	HVSC	Times on berth	Length (m)
Costa Crociere SpA	COSTA DELIZIOSA	DA	36	294
Princess Cruises	CROWN PRINCESS	DA	3	290
	SEA PRINCESS	DA	1	261
Holland America	KONINGSDAM	DA	3	299
	OOSTERDAM	DA	12	285
MSC Cruises	MSC Poesia	DA	24	293
Norwegian Cruise Line	NORWEGIAN STAR	DA	22	294

Out of 423 cruise ship docks, assuming that a high-voltage land-based (HVSC or so-called "cold ironing") system was installed in Dubrovnik-Gruž in 2018, 98 berths were able to supply cruisers with electric power energy from land, accounting for approximately 25% of total landings.

If the time spent on connecting these seven cruisers equipped to receive power cables from the mainland is taken into account, and if that time is deducted from the time required to dock the ship on arrival and off the ship when leaving the port (30 minutes for each manipulation), time the cruise ships in the table above could be powered by electricity from the mainland at 697 hours.

Taking into account the power required to power these cruisers, the electricity consumed is approximately 6,603 MWh.

It should also be noted that the docking schedule at the port of Gruž for these seven ships from the table above, which can receive power cables from the mainland, during 2018 was such that:

- seventeen times in the same day at the port of Gruž landed two ships at the same time,
- only once and 20.10.2018. at the port of Gruž, three ships were staying at the same time, with one of the three ships at anchor and not at berth.

At the same time, these ships would be powered by a VN land port to spend a maximum of 15 hours a day during their berth at the port of Dubrovnik - Gruž.

7.4. Emissions of Cruise Control Hazardous Substances in Dubrovnik

To try to show the amount of pollutant emissions into the atmosphere, we can compare 1 cruiser and 10,000 cars. One cruiser, powered by a 12.5 MW diesel engine, emits the same amount of nitrogen oxides as 10,000 cars over an eight-hour period, traveling approximately 1000 km from Dubrovnik to Athens.

Cruiser	1 cruiser x 10 kg/MWh x 8h x 12,5 MW = 1,0 t NOx
Car:	10.000 cars x 0,1 g/km x 1000 km = 1,0 t NOx

The following table provides information from the Tier I-III standard that sets the emission limit values for emissions of LFOs with a sulfur content of up to 0.1%.

Table 6. Permitted emission limit values for marine diesel

Pollutant	2012. year (g/kWh)	2020. year (g/kWh)
SO_2	0,4	0,4
NOx	8,6	2,2
CO_2	600	600

According to the permissible limit values for the emission of harmful gases during the combustion of marine diesel for 2012, and the data on cruise ships that landed at the port of Dubrovnik - Gruž in 2018 [1] and the time of their retention at the port, the quantities of pollutants discharged into the ambient air during the stay of the berths at the port and the operation of diesel engines were calculated:

Amounts of gas emitted in tonnes for the period March to November 2018.	SO_2 (T)	NOx (T)	CO_2 (T)
	20,4	439	30.603

At the same time, these same passenger ships - cruisers for propulsion of their own diesel engines during their stay at the dock / berth in the port of Dubrovnik - Gruž consumed diesel fuel in the period from March to November 2018:

Quantities of diesel consumed in tonnes for the period March - November 2018. 10,201 T

In the second case, we assumed that seven cruise ships - cruisers prepared to receive electricity from the mainland (Table 5), were connected to a possible overland mainland at each berth in the period from March to November 2018 at the port of Dubrovnik - Gruž. connection. At that time, the quantities of harmful gases not released into the surrounding air at the port of Dubrovnik - Gruž are:

Amounts of gas emitted in tonnes for the period March	SO_2 (T)	NOx (T)	CO_2 (T)

to November 2018	2,6	56,8	3.962

At the same time, these same seven passenger ships - cruisers for propulsion of their own diesel engines during their stay at the dock / berth in the port of Dubrovnik - Gruž did not consume a quantity of diesel fuel in the period from March to November 2018 equal to:

Quantities of unused diesel in tonnes for the period March - November 2018 Fuel (T) 1321

In the assumed case, we deducted from the total stay time of these seven passenger ships - cruisers in the port of Dubrovnik - Gruž - the manipulation required when connecting to the HVSC land port and disconnecting from the HVSC land port. Thus, upon arrival at the port, the manipulation of connecting the HVSC cable from land to the switching block in the ship and finally manipulating the separation of the HVSC cable from the HVSC switching block in the ship, before leaving the ship, take at most half an hour each time from the total stay of the ship on berth.

8. DESCRIPTION OF HIGH VOLTAGE SHORE CONNECTION (HVSC)

8.1. Introduction

The installation of equipment for the implementation of high-voltage land connection in ports is attracting increasing attention from port authorities, shipowners, industrial suppliers and regulatory agencies. High Voltage Shore Connection (HVSC) enables ships while connected to the port on a high voltage (HV) land network.

During the berth at the berth, one to two diesel generators are left on board cruise ships that produce the electricity needed to operate the ship's systems. When the ship is connected to the HVSC system and synchronized to the network, it can switch off its diesel generators, resulting in noise reduction and stopping the emission of harmful gases and particulates while the ship is in port.

Land-based HVSC technology in passenger ships certainly effectively reduces the amount of greenhouse gas emissions in the port area, especially if it is supplied with electricity produced from hydro or other renewable energy sources.

8.2. Technical characteristics of HVSC connector

The technical characteristics of the HVSC or the high voltage land port of ships are defined by the standard EC / ISO / IEEE 80005-1, which was ratified, accepted and confirmed by the most important maritime countries in August 2012.

Each HVSC contains primary energy equipment that transfers electricity from land to ship and secondary management, protection and control equipment, and its components are:

- coastal high voltage power supply equipment,
- an energy transformer that converts a 10 (20) kV distribution network voltage to a ground high voltage of 6.6 or 11 kV,
- frequency converter, because in most world cruisers the frequency of the low-voltage network is 60 Hz (64 world cruisers <200 m and 100% of world cruisers> 200 m)
- HV cables and cable manipulation equipment including HV plugs and sockets,
- HV switchgear on board for receiving HN cable from land,
- marine power transformer, for converting on-shore voltage of 6,6 or 11 kV to 0,4 / 0,69 kV of low-voltage ship network,
- equipment for control, signaling, protection, measurement and communication on land and ship side.

The following figure shows the components of an HVSC system.

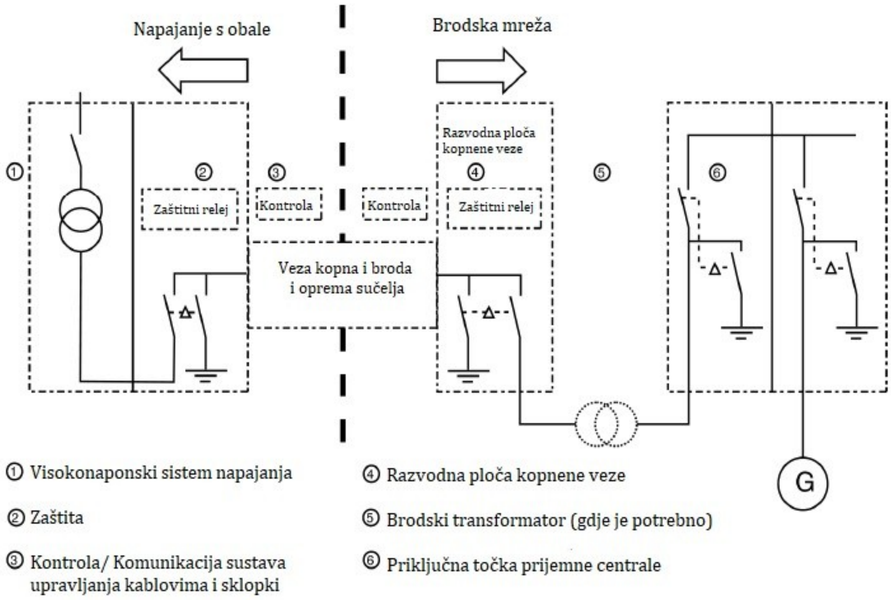

Figure 8. Schematic diagram of HVSC

In our country, the frequency converter is obligatory for normal HVSC operation, especially for the connection of cruisers, since all the world's largest cruisers operate at 60 Hz (the North American standard is generally accepted on cruisers), while the European power system operates at 50 Hz.

The following figure shows the distribution of two standard rated frequencies used by the world's electrical networks. Thus, it is evident that electricity networks in North America, then northern South America, Japan and Saudi Arabia operate at 60 Hz, while throughout Europe, Africa, Australia and most of Asia, electricity networks operate at 50 Hz.

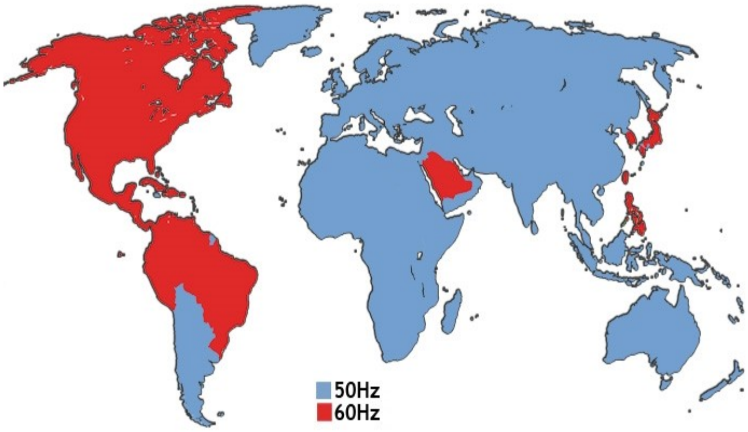

Figure 9. Frequency of electrical networks in the world

Most cruisers, on the other hand, operate at a frequency of 60 Hz, as indicated in the following table.

Table 7. Frequencies of power grids on all world cruisers

SHIP TYPE (LENGTH)	FREQUENCY ON THE SHIP 50 Hz	FREQUENCY ON THE SHIP 60 Hz
Cruiser (< 200 m)	36%	64%
Cruiser (> 200 m)	-	100%

8.3. Description of the ship part of the HVSC

In order to be able to connect to the high voltage shore connection, ie HVSC (high voltage shore connection), ships must either be equipped during the construction process or retrofitted with equipment to enable such a connection.

Electricity to power the onboard power supplies is always transmitted by high voltage cables. In some cases, such as Roll-On / Roll-Off container ships or Ro-Ro ships, VN cables are installed on board and then connected to the mainland onshore, or lowered via a spool or drum to the shore where the HV switchgear is located to accommodate the HN cable connectors. On cruise ships, HV cables are always on the shore side and must be lifted by crane and retracted into the ship where they attach to the HV switchgear.

The HV cables are lifted by crane to the opening in the hull of the ship, retracted into the ship and connected to the HV socket on the switch block / panel using standard HV plugs. It consists of a supply circuit breaker, a safety relay, a physical electrical connection (plugs and earthing) and a control interface with an integrated onboard automatic or power management system.

Also, since the ship's power system is 400-690 V, 60 Hz, in addition to the HV switchgear block for receiving cables from the mainland, it is necessary to install an 11 (6,6) / 0,4 kV transmission transformer to supply the AC main board. which may also be located in the engine room or any convenient location on board.

The process of plugging and unplugging a ship from the mainland usually takes about half an hour for each operation. The Chief Engineer or other personnel familiar with the ship's energy system shall operate the transmission. Medium-voltage cable management can be performed by ship or port personnel, implying that they have passed adequate training to handle high-voltage equipment.

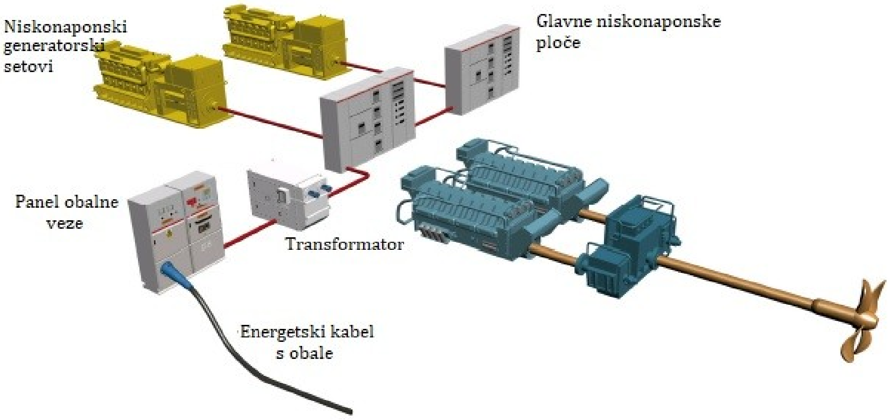

Figure 10. HVSC ship side display with HV switchgear

The HVSC assembly block (panel of the coastal link in the figure above) must be located on the ship in a dry area as close as possible to the ship shell to receive medium voltage cables from the shore, which are connected to the specified switch block by means of standard cable terminations.

8.4. List of constructed HVSC's worldwide

The following table provides information on currently made high-voltage land ports of points in world ports with information on port power, frequency and type of ships docked.

Table 8. List of HVSC's installed worldwide

Year	Harbor	Country	Power capacity (MW)	Frequency (Hz)	Voltage (kV)	Ship type
2000-10	Gothenburg	Sweden	1,25-2,5	50 and 60	6,6 and 11	RoRo, RoPax
2000	Zeebrugge	Belgium	1,25	50	6,6	RoRo
2001	Juneau	SAD	7-9	60	6,6 and 11	Cruiser
2004	Los Angeles	SAD	7,5-60	60	6,6	Container, Cruiser
2005-06	Seattle	SAD	12,8	60	6,6 and 11	Cruiser
2006	Kemi	Finland	NA	50	6,6	RoPax
2006	Kotka	Finland	NA	50	6,6	RoPax
2006	Oulu	Finland	NA	50	6,6	RoPax
2008	Antwerp	Belgium	0,8	50 and 60	6,6	Container
2008	Lübeck	Germany	2,2	50	6	RoPax
2009	Vancouver	Canada	16	60	6,6 and 11	Cruiser
2010	San Diego	SAD	16	60	6,6 and 11	Cruiser
2010	San Francisco	SAD	16	60	6,6 and 11	Cruiser
2010	Karlskrona	Sweden	2,5	50	11	Cruiser
2011	Long Beach	SAD	16	60	6,6 and 11	Cruiser

Year	Harbor	Country	Power capacity (MW)	Frequency (Hz)	Voltage (kV)	Ship type
2011	Oakland	SAD	7,5	60	6,6	Container
2011	Oslo	Norway	4,5	50	11	Cruiser
2011	Prince Rupert	Canada	7,5	60	6,6	NA
2012	Rotterdam	Netherlands	2,8	60	11	RoPax
2012	Ystad	Sweden	6,25	50 and 60	11	Cruiser
2013	Trelleborg	Sweden	3,5-4,6	50	11	NA

9. TECHNICAL FEASIBILITY AND SUSTAINABILITY OF THE ENVIRONMENT

9.1. Current state of the Gruž area distribution network

The current switching state of the distribution network in the Gruž area certainly does not have the capacity to connect a power supply of this magnitude.

Therefore, as described above in Chapter 2.10, it is necessary to ensure the conditions in the surrounding transmission and distribution network for connecting unconventional consumers to the electricity network in the port of Dubrovnik - Gruž.

This also means the construction of the TS 110/20 (10) kV Lapad at the location adjacent to the existing TS 110/35 kV Lapad from which two 10 (20) kV water fields would be provided to supply two cruise ports for the cruise ship in the port of Gruž, with total power 2x15 MVA = 30 MVA.

9.2. Proposed technical solution

9.2.1. Landline technology

The implementation of the power supply system for cruise ships onshore is achievable using existing technology. Also, the capacity of the distribution / transmission network to which the equipment of the high-voltage land port of passenger ships will be connected must be kept in mind.

The infrastructure of the high-voltage land port for passenger ships contains the following units:

- Distribution plant composed of medium voltage switchgear blocks equipped with switches, disconnectors,
- An energy transformer that converts a 10 (20) kV distribution network voltage to a ground high voltage of 6.6 or 11 kV,
- Frequency converter that converts frequency from 50 to 60 Hz, because on most world cruisers, the frequency of the low-voltage network is 60 Hz (64 world cruisers <200 m and 100% of world cruisers> 200 m)
- Earth Connector,
- Control, signaling, protection, measurement and communication equipment,
- Medium voltage power cables as well as equipment for manipulating power cables including SN plugs.

The Port of Dubrovnik Authority is considering implementing a system for powering cruise ships from the mainland. Phase design of a system that would include powering three connections of 3 x 15 MVA installed capacity is being considered.

In most cases, the technical solutions put on the market by reputable companies suggest the installation of two frequency inverters for each port, which can operate either in parallel or individually to optimize the frequency conversion losses. Frequency conversion alone should be performed in technology that enables temporary energy flow in both directions (Active Front End) so that transient occurrences at the moment of connection of the ship to the mains network will not cause unwanted outages of the ship's generators or unacceptable levels of interference in the ship's power grid. It is also recommended to install frequency inverters whose nominal power would be slightly higher than the rated power of the connection itself (eg 2x9 MVA), which ensures stable operation during transient events at loads close to the rated power.

The technical solution should provide central computerized monitoring as well as fully automatic procedure of switching the power supply of the ship to the land network (in terms of checking and achievement of electrical conditions and switching conditions before and after the physical connection of the land and ship network, which should be coordinated by the staff of the port service provider and the crew of the ship). In order to simplify maintenance, the evaluation of the selection of the technical solution as well as the implementation of such projects should pay attention to the operating characteristics of the drive of the derived system and to the adequate guarantees that should be requested from the contractor. It should be borne in mind that the functioning of such systems, with proper maintenance, should be planned for a period of 20 g.

The cruise ship dock electricity would be supplied with an 11 kV 60 Hz frequency and other technical specifications according to IEC / ISO / IEEE 80005-1 "High Voltage Shore Connection". The proposed technical solution is based on the installation of independent systems for each of the selected ports in the port of Dubrovnik - Gruž separately. In this case, each system would consist of a frequency converter with associated energy equipment that would be housed in a separate facility, as well as connection and supporting equipment located at the electrical connection point of the ship at the berth itself.

This method of project realization has the following advantages:

- the investment can be financially divided into equal parts,
- flexibility is provided when selecting a location to accommodate frequency conversion plant equipment.

The prerequisite for the implementation of the solution is to provide the network connection with adequate power at a voltage level of 10 (20) kV. (ie for each system it is necessary to provide a supply of rated current of 1000 A at a rated voltage of 10 kV or a supply of rated current of 630 A at a rated voltage of 20 kV).

9.2.2. Components of a single HVSC land port

The components of a high-voltage land connection at a single cruise ship / power dock are shown in the following figure.

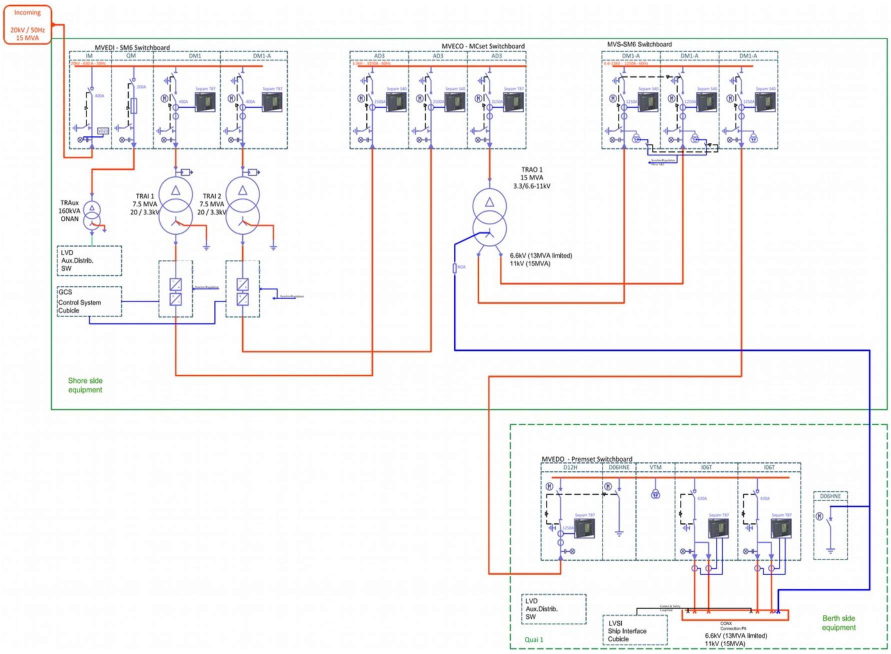

Figure 11. Preliminary design of HVSC land connection for15 MVA rated capacity

The equipment of the future HVSC land port of 15 MVA, for the power supply of one cruiser at the port of Dubrovnik Gruž, would be housed in two separate structures located on the plateau of the port of Gruž.

The first ground floor building, measuring approximately 19x17 m, would incorporate most of the energy, control, signaling, protection and metering (USZM) and telecommunications (TC) equipment consisting of:

- 10 (20) kV rated installation, constructed from prefabricated stand-alone air-insulated switchgear units.
- two power transformers TRAI 1 and TRAI 2, each with 7.5 MVA power,
- 160 kVA domestic TRAux transformer for self-supply,
- 6 kV rated installation of pre-fabricated, self-contained air-insulated switchgear,
- power transformer TRAO 1 rated at 15 MVA,
- 6,6-11 kV plant, constructed from pre-fabricated stand-alone air insulated switchgear.
- control, signaling, protection and measurement (USZM) and telecommunications (TC) equipment.

The housing of the 10 (20) kV rated block is made of a metal structure with partitioned compartments, which provide the necessary degree of electromechanical protection of the equipment, especially the protection against electric arc. The installations were tested for resistance to electric arc for one second. This means that in the event of an electric arc within the switchgear, there is no danger of personnel being found in front of the switchgear when locally operated.
The size and components of the plant are designed according to customer requirements and the essential requirements of electromechanical safety, use safety and fire and explosion protection.

A 10 (20) kV rated plant consists of four fields that have the following function:

- Field for connection of 10 (20) kV feeder cable laid from the reconstructed 110/35 kV Lapad transformer station,
- Field for connection of the transformer for own consumption,
- The first transformer field for the connection of the power transformer TRAI 1 with a transmission ratio of 10 (20) / 3.3 kV, rated at 7.5 MVA
- Second transformer field for connection of the power transformer TRAI 2 with a transmission ratio of 10 (20) / 3.3 kV, rated at 7.5 MVA

The two power transformers TRAI 1 and TRAI 2 serve to transform the 10 (20) kV voltage of the distribution network to the voltage of 3.3 kV required to power the two sets of frequency converters.

From the output of each set of frequency converters, a cable connection is made to the following in a series of 3.3 kV rated installations consisting of:

- Supply field for connection of the first set of frequency converter 50/60 Hz, rated power 9 MVA,
- Supply field for connection of the second set of frequency converter 50/60 Hz, rated power 9 MVA,
- Transformer field for connection of energy transformer TRAO 1 with a transmission ratio of 3.3 / 6.6-11 kV, rated at 15 MVA.

From the secondary transformer TRAO 1, with a transmission ratio of 3.3 / 6.6-11 kV, a cable connection is then laid to the next in a series of plants with a rated voltage of 6.6 (11) kV consisting of:

- The first transformer field for connection of the energy transformer TRAO 1 with a transmission ratio of 3.3 / 6.6-11 kV, rated at 15 MVA,
- Second transformer field for connection of the energy transformer TRAO 1 with a transmission ratio of 3.3 / 6.6-11 kV, rated at 15 MVA,
- Water field to power the next switching block to be installed in a separate object - the container to the link.

The container connection is approximately 10 x 2.5 m in size and has a 6,6 (11) kV installation consisting of:

- The water field for the connection of the supply cable laid from the installation located in the facility of the coastal part of the VN port for power supply to the cruiser
- Grounding Fields,
- Measuring field 6,6 (11) kV,
- The first water field for connecting a type cable end that switches to a cruiser and plugs into a ship's switchgear,

- A second water field for connecting a type cable end that switches to a cruiser and plugs into a ship's switch block.

The location of energy, USZM and telecommunication equipment in a ground floor building measuring approximately 19 x 17 m is shown in the following figure.

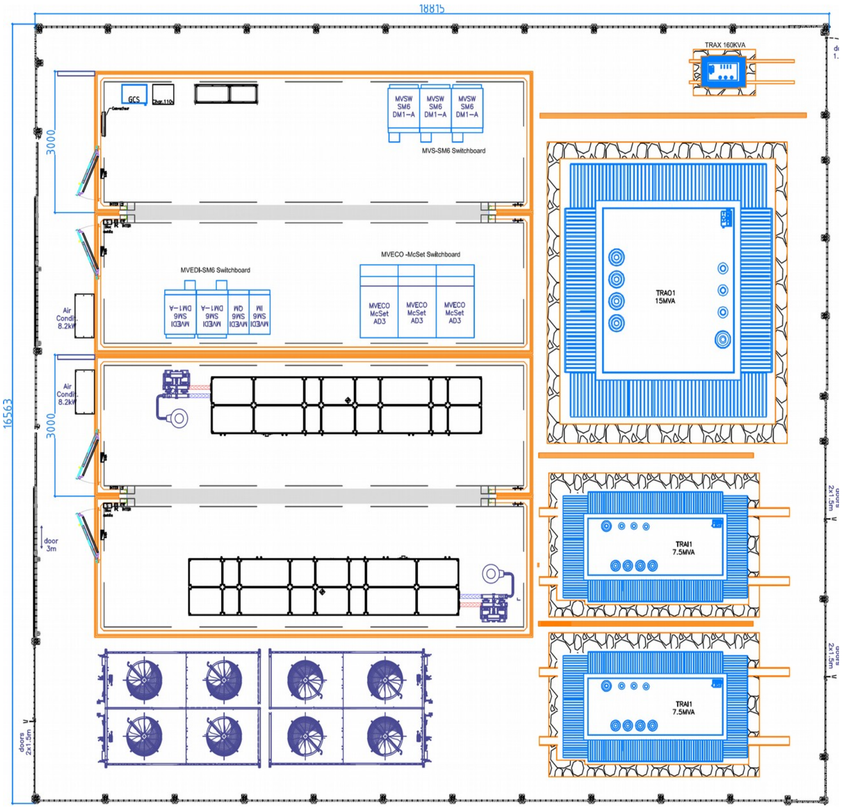

Figure 12. Facility for the accommodation of the HVSC

The following illustration shows a container at the berth / dock that houses a 6.6 (11) kV rated plant. From the 6.6 (11) kV installation, a power cable is routed in the container to the opening on the side of the moored boat, where the cable is drawn through the opening and connected to the ship's switch block (shore panel) using standard cable terminations. This has created a galvanic connection between the land and the ship's electrical network, and after synchronization of the two electrical networks, it is possible to power the ship at the dock from the land and shut off its diesel generators during the stay of the ship.

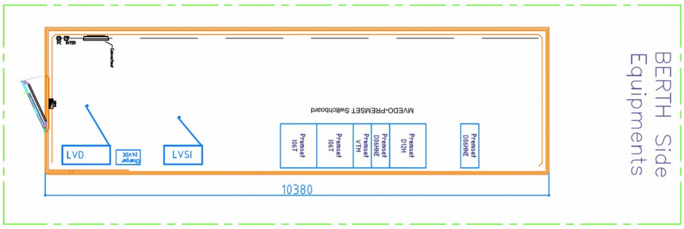

Figure 13. Container for HV land connection of 15 MVA rated power

9.2.3. HVSC port on board

Cruise ships - land cruisers must be equipped with the following equipment:

- Shore panel with sockets for receiving power cables from land,
- A room with power transformers to transform the voltage from the mainland of 11kV to the nominal voltage of the ship's network,
- Control, signaling, measuring and protection equipment for safely switching the power supply of the ship's power network from the engine to the HVSC land port.

Figure 14. Ship connection panel with HVSC power cables attached

The picture above shows the power cables from the mainland connected to the ship's shore panel, or 11 kV switchgear. The process of connecting and disconnecting a ship from the mainland takes about half an hour for each manipulation, and at least 5 minutes. The Chief Engineer or other personnel familiar with the ship's energy system shall operate the transmission. Power cable management can be performed by ship or port personnel, implying that they have undergone adequate training to handle medium voltage equipment.

Most of today's ships equipped with HVSC infrastructure are container ships, and many ship designers resort to including HVSCs in infrastructure or at least leaving room for them. Operational vessels using the HVSC system today were generally retrofitted (equipment installed on an already built ship) rather than pre-destined for the HVSC system.

9.3. HVSC connecting options

In accordance with the requirements set out in point 5.2. The terms of reference within the study identified two variants for further elaboration, namely:

- Variant 1, ie variant with installation of a mobile cable crane
- Variant 2, ie variant with installation of fixed cable crane

9.3.1. Option 1 - Mobile cable crane

Variant 1 with the installation of a mobile cable crane at the dock in the port of Dubrovnik - Gruž would look approximately as shown below.

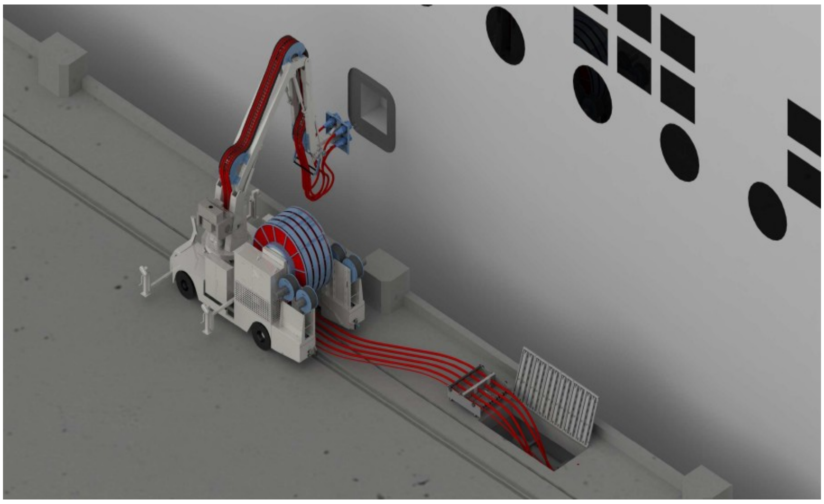

Figure 15. Variant 1 - Mobile cable crane

From the 11 kV switchgear located in the container to the link, a cable channel to the cable pane shown in the figure above would be constructed for the HVSC land cruiser terminal on the Gruž harbor. The cable pane would house the junction box shown in the following figure.

The terminal box contained in the cable box has sockets that connect one end of the power cable wound on the vehicle drum or mobile cable crane by means of standard plugs, and then extend the cable through the dock to the port position of the cruiser hull for connection. and lifts the telescopic arm up to the height of the opening and pulls it into the ship, where the crew takes the cable and plugs it into the ship's switchboard - the shore connection panel.

At the same time, when the power cable is stretched across the plateau of the port of the port of Gruž, a psychological barrier is placed immediately along the extended cable along its entire length to prevent people and vehicles from approaching.

The position of each of the three cable shafts for the three HVSC land ports would correspond to the middle of the dock / berth at which the HVSC land port for powering cruise ships would be realized. Thus, for different cruisers with berths and with different positions of openings on the hull for receiving cable from the mainland, the movable cable crane would have approximately equal reach in the direction of the bow and stern of the ship to the berth from the port in the cable shaft, which should be sufficient to reaches the point of cable transmission from land to ship.

Likewise, the cable box with the terminal box need not be placed along the edge of the dock, but may also be slightly offset from the edge of the dock towards the interior of the harbor plateau, so that when the moving cable crane pulls the cable along the dock, access to the delivery and service vehicles is not impeded. to the link

This variant of the HVSC landing berth of passenger ships - cruisers was carried out at the passenger dock at Wusongkou port in Shanghai.

There, a technical solution from Fiaveley Stemmann-Technik was selected there for the design of the HVSC land connection, the main component of which was a vehicle or a mobile power cable extension crane, equipped with a telescopic arm and powered by a battery. The movable cable crane on the drum has a winding power cable of 70 meters in length and standard cable terminals / plugs built into the cable ends. The characteristics of the onshore HVSC landline equipment at Wusongkou port in Shanghai are:

- The mobile power cable extension cable is operated by only one person,
- The drive for moving the vehicle and moving the telescopic arm is made possible by the built-in battery,
- Tidal range compensation is 6m,
- The installed power is 16 MVA, rated voltage 11 kV or 6.6 kV and frequency 50/60 Hz.

For the cable deployment solution described above in the Gruž harbor, a cable duct with a chain cable tray should not be operated for each berth, as shown in the figure below.

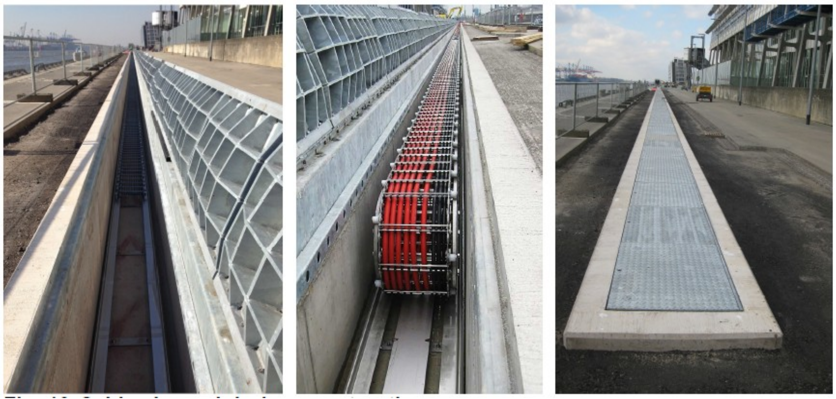

Figure 16. Cable trunk with protective covers and with power cables laid on the cable trays

9.3.2. Option 2 - Fixed cable crane

Variant 2 with the installation of a fixed cable crane at the dock in the port of Dubrovnik - Gruž would look approximately as shown below.

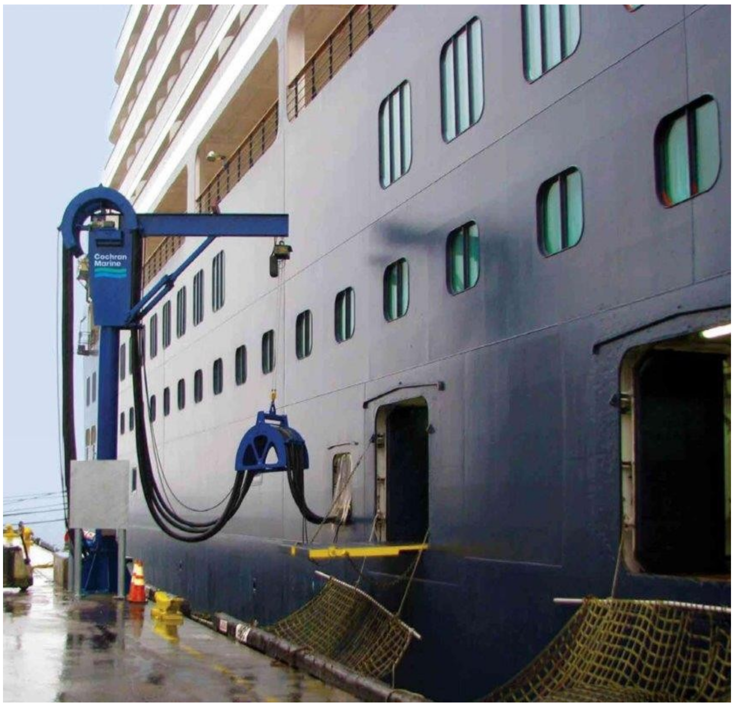

Figure 17. Variant 2 - Fixed cable crane

From the 11 kV switchgear housed in the container to the link, a cable duct would be constructed on the plateau in the port of Gruž for the HVSC land cruiser terminal to the cable pane, which would be located adjacent to the fixed cable crane. From the cable pane, the power cable is pulled up and lifted up by the pole of the fixed cable crane and transferred through the console to the opening on board where the crew accepts it and plugs it into the shore connection panel.

This variant is cheaper compared to the mobile cable crane version, but is less elastic with regard to the position of the HVSC land port at the dock, ie the position of cable acceptance from the land is already established for the cruiser. Therefore, in this variant, the position of the fixed cable crane needs to be properly determined so that different cruisers that are able to receive electricity from the mainland when aligning the openings on the hull for cable entry with the fixed cable crane do not take up the adjacent berth.

9.4. Cost estimates

9.4.1. Option 1 - Mobile cable crane

Estimation of the cost of construction of a land-based electricity system for a connection at the port of Dubrovnik - Gruž in the design of cable untangling with a mobile cable crane for one berth, is:

ELECTRICAL ENGINEERING	43,125,000.00 HRK
CONSTRUCTION PART	4,125,000.00 HRK
IN TOTAL	47,250,000.00 HRK

9.4.2. Option 2 - Fixed cable crane

The cost of building a land-based electricity system for a connection at the port of Dubrovnik - Gruž in the design of a cable untangle with a fixed cable crane for one berth is:

ELECTRICAL ENGINEERING	37,500,000.00 HRK
CONSTRUCTION PART	4,125,000.00 HRK
IN TOTAL	41,625,000.00 HRK

9.4.3. Cost of connecting HVSC to the electricity grid

The minimum connection price of the land-based electricity system at the port of Dubrovnik - Gruž in the customer category is enterprise, for medium voltage connection, for the performance with two connections, each with a rated power of 15,000 kW, is equal to:

30,000 x 1,350.00 = 40,500,000.00 + VAT = 50,625,000.00 kn

(pricing does not include the creation of terms on an EOTRP processed network).

The price of energy consumed at medium voltage is, according to the tariff model, equal to:

VT	(Kn / kWh)	0.83
NT	(Kn / kWh)	0.47

The amount of peak power equal to 29.5 kn / kW, then the amount for excess reactive energy 0.15 kn / kVArh and the amount of monthly fee for the calculated measuring point equal 66 kn should be included in the connection price.

10. ANALYSIS OF ALTERNATIVES

10.1. Options 1 and 2

10.1.1. Overview

Considering the solutions of cable separation from the land-based switching equipment in the port to the point where the ship is connected to the land-based electrical grid, these two variants are generally generally applied worldwide:

- Option 1, ie variant with installation of a mobile cable crane
- Option 2, ie variant with installation of fixed cable crane

10.1.2. Option 1

Variant 1 with the use of a mobile cable crane is more expensive than a variant with a fixed cable crane due to the price of a mobile cable crane, but in comparison with the installation with a fixed cable crane, it has one important advantage, namely the flexibility of the VN land port position, regardless of the opening position to introduce cables when the ship is connected using a mobile cable crane, we pull the power cables and pull the cable ends to the cable delivery position on the ship.

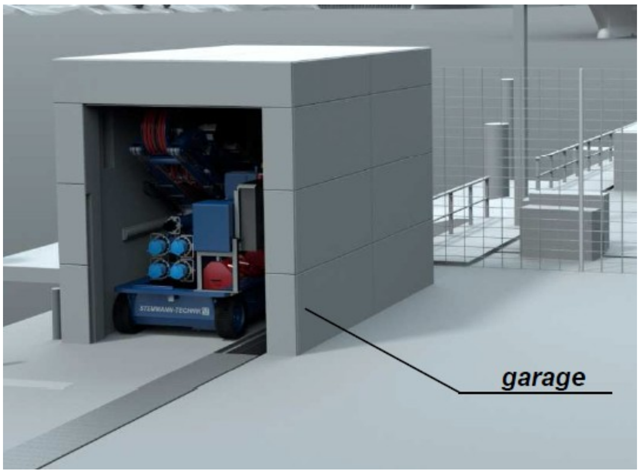

Figure 18: An example garage for a mobile cable crane

Likewise, parking a mobile cable crane in a garage that may be located somewhere at the end of the dock area of the harbor plateau along the dock edge remains walkable.

10.1.3. Option 2

Fixed cable crane variant 2 is cheaper than the mobile cable crane variant and is also used in worldwide ports. The limitation of this variant is certainly the fixed position of the cable transfer point from land to ship to berth, in which case the ship receiving power from land to berth must be positioned to position the cable entry opening opposite the fixed cable crane. When the largest ships are around 300 m in length then this can be a problem, due to the possible occupation of the adjacent berth.

10.1.4. Construction time

Considering all the necessary activities, it is estimated that for the preparation of the construction, which includes:

- entry into spatial plans,
- conducting investigative works,
- preparation of project documentation,
- obtaining the necessary permits,
- invitation to tender for contractors and suppliers of equipment.

it will take 48 months.

The estimated construction time for both variants is 24 months.

11. FINANCIAL AND ECONOMIC ANALYSIS

The purpose of financial and economic analysis is to gain insight into the financial or economic justification of the venture, and it is carried out according to the Guidelines for Cost and Benefit Analysis of Investment Projects. Financial and economic performance indicators must be calculated using a net benefit increment procedure that considers differences in costs and benefits between the two options: project implementation and project failure.

11.1. Financial analysis

Financial analysis uses the project's projected cash flow to calculate appropriate indicators: payback time, internal rate of return and net present value. Particular emphasis is placed on two financial indicators: financial net present value (FNPV) and financial internal rate of return (FRR), that is, FNPV (C) and FRR (C) when it comes to return on investment costs, and FNPV (K) and FRR (K) when it comes to the return of state capital. The methodology used to determine financial return is discounted cash flow (DCF), which is based on the following assumptions:

- only cash inflows and outflows are considered (depreciation, reserves and other accounting items that do not match actual cash flows are not considered),
- the project's cash flows should be determined by increment, that is, based on the cost / benefit difference between the realized and non-realized scenarios,
- the aggregation of cash flows over different years requires the adoption of an appropriate financial discount rate to calculate the present value of future cash flows.

The financial analysis is performed in the following steps:

1. total investment cost,
2. total operating expenses and revenues,
3. equipment replacement costs and residual value income
4. financial return on investment cost: FNPV (C) and FRR (C),
5. sources of financing,
6. financial sustainability,
7. financial return on national capital: FNPV (K) and FRR (K).

The model for calculating financial indicators enables the analysis of investments, their impact on the financial sustainability of the project. The worksheets in the model are interconnected and the model has the ability to simulate different financial and economic scenarios in order to identify and analyze the most sensitive components. All entries are on an annual basis.

11.1.1. Basic assumptions

The basic assumptions of financial analysis are:

- project evaluation is carried out through cost-benefit analysis,
- cost-benefit analysis is based on the “Guide to the Benefit-Cost Analysis of Investment Projects” (European Commission, 2014)
- the financial discount rate used to calculate the present value of the project is 4%, as recommended by the European Commission
- the total economic period of the project is 25 years, of which 2 years are construction and 23 years of using the system

11.1.2. Real financial discount rate

The discount rate used in the financial analysis should reflect the opportunity cost of capital and investors.

For the 2014-2020 programming period, the European Commission recommends that the real rate considered as a parameter reference for the long-term opportunity cost of capital be 4%.

11.1.3. Costs

Table 9. Investment costs

Expense	Price (1000×HRK)
Project documentation, supervision, etc.	9,500
Construction labor	8,250
Construction equipment	86,250
Grid connection	40,500
Total	**144,500**

Operating and maintenance costs

System operation and maintenance costs are 1.5% of investment (without network connection), ie HRK 1,417,500 / year

Employee costs

It is estimated that around 15 employees will be permanently employed on the system, with an average net salary of HRK 7000.

Electricity

Purchase price according to Chapter 4.4.3. is 870 kn / MWh (with fees included). The model predicts a 2% increase in the purchase price.

Equipment replacement costs

The cost of replacing the equipment includes the cost of replacing mechanical and electrical equipment, the duration of which is shorter than the project review period. In similar projects, replacement of electrical equipment is foreseen after 25-30 years and is not included in the analyzes, since the system has been operating for 23 years.

Concession and other fees

Concession and other fees at this project phase are estimated at HRK 500,000 / year.

11.1.4. Benefits

Electricity

Selling Price. is 1450 kn / MWh (with fees included). The model predicts a 2% increase in the purchase price. It also envisages a 5% increase in electricity demand, which would double the number of ships connecting to the VN port in 15 years.
An increase in the number of ship arrivals in this model is not foreseen.

11.1.5. Financial analysis

Conducting the financial analysis the following indicators were obtained:

- the financial net present value of the project (FNPV) and
- financial rate of return (FRR)

Financial net present value is defined as the amount that is obtained after deducting the expected investment and operating costs of the project (discounted appropriately) from the discounted value of the expected revenue.

The financial internal rate of return is defined as the discount rate that produces zero FNPV. The calculation of the financial profitability of an investment is a measure of the possibility of offsetting investment costs from net income.

The financial net present value of the FNPV (C) and the financial profitability of the FRR (C) of the total investment cost are measures of the investment results regardless of the sources or methods of financing. The financial rate of return on investment is calculated based on the total investment and operating costs as outflows and income as inflows. It measures the capacity of operating income to cover investment costs.

This budget indicates whether the project is financially viable or requires EU financial support. When the FRR (C) is lower than the discount rate applied (ie when the FNPV (C) is negative), then the revenue does not cover the costs and the project needs to be analyzed with EU co-financing.

According to the financial analysis, the main parameters are shown below:

Table 10. Financial analysis

No.	Analysis parameters	Undiscounted values	Discounted values
1.	Financial Analysis Time [Year]	25	
2.	Financial discount rate [%]	4.0	
3.	Total construction cost [million kn]	144.50	135.45
4.	Net revenue (revenues - operating and maintenance costs) [mil. kn]		65.13
5.	Financial discrepancy rate ((total construction cost - net income) / total construction cost) [%]	51.9 %	

According to the financial analysis, the following results were obtained.

Financial Internal Rate of Return	FIRR (C) = 0.2%
Financial net present value	FNPV (C) = –69.33 M €

From the above it follows that the financial model is not profitable, that is, the net present value of such a project is € 69.33 million, and EU co-financing is needed.

11.1.6. EU contribution calculation

1.	Construction costs (undiscounted) [mil. HRK]	144.50
2.	Financial gap [%]	51.9 %
3.	Amount co-financed by the EU [mil. kn] (1.) × (2.)	75.02
4.	Amount of co-financing rate [%]	85%
5.	EU co-financing amount [mil. €] (3.)×(4.)	63.77

According to the conducted financial analysis and EU guidelines on co-financing through funds, the total amount co-financed by the EU amounts to HRK 63.77 million, which is 44.13% of the total investment costs.

11.1.7. Sources of financing

Within the project the possible sources of financing are:

- Cohesion Fund
- national public contribution
- other resources (loans).

According to the financial analysis, the sources of financing are:

- Cohesion Fund 44.13% (HRK 63.77 million)
- national public contribution 35.87% (HRK 51.83 million)
- other resources (loans). 20.00% (HRK 28.90 million)

11.1.8. Financial sustainability

Once the co-financing has been determined, it is necessary to determine the financial viability of the project. Financial sustainability is achieved if the net cumulative cash flow generated is positive in all years considered.

It is important to ensure that, even if co-financed by the EU, there is no risk of lack of funding.

After determining the investment costs, operating revenues and costs and sources of financing, it is possible and useful to determine the financial viability of the project. A project is financially viable when there is no risk that it will run out of money in the future. During the construction phase, state co-financing of HRK 51.83 million should be ensured, but once the system is operational, project revenues in each year are higher than operating and maintenance costs, which ensures positive operations in all years of project consideration, ie financial sustainability.

11.1.9. Financial return on equity

The final step is to estimate the financial return on equity (FRR (K)). The purpose of this calculation is to see what the results of the project are from the perspective of both public and possibly private entities that have received assistance. For a given investment cost, the borrower needs to inject less capital into it as the EU taxpayer covers part of the project cost. The rationale for the EU grant itself under Cohesion Policy is to increase investment opportunities by shifting (changing) capital needs.

The best approach when considering this impact is simply to focus on the funds provided by the borrower, including funds that should be available as national public equity, private equity (if any), and the need to repay loans and interest to third party financiers. The outflows of funds are:

- operational costs,
- shares of national (public and private) capital,
- third party financial resources when reimbursed to those parties and
- interest on loans.

The inflows are:

- operating income
- the rest of the value.

Financial Net Present Value of Equity FNPV (K) is the sum of net discounted cash flows that arise for a borrower during the implementation of an investment project. Financial return on equity determines the return for national loan beneficiaries (private and public jointly).

When calculating FNPV (K) and FRR (K), all sources of funding other than EU funds are taken into account. These funds are considered outflows (in financial sustainability, these are inflows) and not investment costs. Even when FRR (C) is expected to be very low or even negative for public investment, FRR (K) will often be positive.

The results of the financial analysis for financial return are.

Financial internal rate of return on equity	FIRR (K) = 5.9%
Financial net present value of equity	FNPV (K) = HRK 17.53 million

11.2. Economic analysis

Economic analysis serves to prove the positive net contribution that the project has to society and is therefore worth co-financing from EU funds. In the case of the option chosen, the discounted economic benefits generated by the project must exceed the discounted economic costs.

The analysis was made using fixed prices and values adopted for discounted factors of 5.0% for economic cost-benefit analysis, as recommended by the European Commission for 2014-2020.

11.2.1. Conversion of market prices to economic prices

Observed prices or public tariffs should be converted into shadow prices that more appropriately reflect the social opportunity cost of the goods.

However, as Croatia has not yet developed its own guidelines for cost benefit analysis aimed at assessing a set of national parameters, including key shadow prices or conversion factors, the standard conversion factor 1 was used in the present analysis and no price correction was made.

According to the Cost-Benefit Analysis Guide (2014), if the planning authority does not provide its own estimates, an automatic rule should be applied according to which the standard conversion factor is 1.

This is also in line with the conservative approach to analysis, since the analysis takes into account the full value of social costs.

Applied conversion factors

As stated in the previous section, the correction factor used is 1.00 for the analysis.

Fiscal corrections

The key fiscal benefits relate to taxes paid directly to the state budget or the budget of local self-government units that flow directly from the project. The methodology used for cost-benefit analysis stipulates that all input and output data of the analysis must be free of VAT and other taxes.

11.2.2. Quantification of social benefits

Reduction of greenhouse gas (GHG) emissions

After the HVSC connection is built, the GHG emission will be reduced. The reduction of GHG emissions is reflected through MWh of electricity sold, as a replacement for the commissioning of marine generators according.

Table 11. Reduction of GHG emissions in the first year

SO2 (T)	NOx (T)	CO2 (T)
2.6	56.8	3962

Emissions were quantified by calculating total CO2 equivalents (CO2e). Greenhouse yields other than CO2 are converted to CO2e by multiplying the amount of a given GHG by a factor equivalent to its global warming potential. For NOx it stands at 298.

Accordingly, the estimated CO2e reduction for the first year of connection is 20,888 tCO2e.

Monetization of CO2e emission reductions was carried out for three CO2e price developments.

For the purposes of monetization, CO2e emission reductions were made using the mid-scenario values, following the guidance given in the benefit-cost analysis guide.

Other social benefits

The forms of project demand, in the form of realizing direct and indirect benefits, are the following:

- Croatian Electricity Company and Gruž Port:
  - revenue from the sale of "products", new opportunities for development
- Local government:
  - rent, other indirect tax revenues, new forms of organization,
- Companies in the field of construction and electrical industry:
  - capacity recruitment, profit
- Local community (population):
  - Increase in revenue, short and long term
  - reduction of noise and pollution in the port area

These benefits will not be valorized in the model, but merely noted as an additional contribution to the project.

11.2.3. Results of economic analysis

The project indicators calculated for the above economic analysis using the 5% discount rate are:

Economic internal rate of return:	EIRR = 8.7%
Economic net present value:	ENPV = HRK 77.77 million
Value for money:	K / T = 1.25

12. SENSITIVITY AND RISK ANALYSIS

The purpose of sensitivity and risk analysis is to evaluate the strength of a project's profitability indicators. To this end, the first part of the analysis (sensitivity analysis) aims to identify key variables and their potential impact in terms of changes in profitability indicators, while the second part (risk analysis) aims to assess the likelihood that these changes will actually occur, at to which the results are expressed as the estimated mean and standard deviation from these indicators.

12.1. Sensitivity analysis

12.1.1. Testing variables at 1% value

The aim of the project sensitivity analysis is to assess its acceptability if the values of the critical project parameters behave differently than planned during the analysis to date. Key parameter oscillations can be negative or positive in relation to the project cost-effectiveness assessment.

Although a number of variables appear in the model, it is possible to carry out a calculation to test the magnitude of their impact. In this way, it is possible to quickly obtain the information that is the variables of greatest influence, without having to test each of the variables in detail.

The CBA guidelines suggest identifying critical variables as those whose change of ± 1% leads to a change in net present value (financial and / or socio-economic viability) of more than 1%.

Table 12. Sensitivity analysis

Variable	FNPV change due to variation ± 1%	Criticality rating for FNPV	Change in ENPV due to variation ± 1%	Criticality Rating for ENPV
Investment costs	1.95%	Critical	1.71%	Critical
Maintenance	0.28%	Not critical	0.22%	Not critical
EE price (purchase)	2.38%	Critical	1.84%	Critical
EE Price (Sales)	3.97%	Critical	3.07%	Critical
CO2 price			1.40%	Critical

The sensitivity analysis of the variables used in the financial analysis showed that the investment cost and the cost of electricity represent critical variables in financial results, while in economic analyzes the maintenance cost is excluded from the critical variables.

12.1.2. Substitute values

A special component of sensitivity analysis is the calculation of the so-called. switching value, that is, the value that the analyzed variable should realize in order to make the net present value (financial and / or sociology-economic viability) equal to zero.

Table 13. Substitute values

Variable	FNPV=0	ENPV=0
Investment cost	Already negative	58.33%
Electricity price (buy)	Already negative	54.34%
Electricity price (sell)	Already negative	-32.60%
CO2 price	Already negative	-71.52%

Analysis of the commutation value of the variables shows that there is no single variable whose reduction in some smaller percentage could reduce the economic analysis to a neutral net present value.

12.2. Risk analysis

Estimating the effect of a percentage change in a project's performance indicator variable says nothing about the likelihood with which that change can occur. The methodology chosen is implemented based on key parameters selected through sensitivity analysis. A risk analysis was made for the key variables of the impact of the change on the economic NPV.

In order to gain insight into the impact of the above ranges of values on the results of the analysis, a risk account was conducted. For most input quantities, a normal probability distribution was assumed with 10% standard deviation and retained mean values, while electricity prices were assumed to have a log-normal distribution with the expected values given above and with a standard deviation of 10%.

The Monte Carlo method was used. This method consists of assigning randomly selected values to all key variables at the same time with a sufficient number of repetitions, to obtain a probability distribution for each of the profitability indicators. In doing so, each profitability indicator will be shown as the mean and standard deviation of the values obtained after all repetitions. In the Monte Carlo model, we considered 10,000 interactions for 1 scenario.

12.2.1. Results of Monte Carlo Risk Analysis

On the basis of the budget results, probability curves have been drawn up to show with what confidence the magnitudes of particular economic indicators can be taken. The probability curve for the economic net present value - ENSV was calculated (Figure 7 .24).

The results shown show that the net present value (ENPV) with 90% certainty will be in the range of HRK 43.40 million to HRK 135.34 million. The probability of a net present value (ENPV) being above zero is 100%.

12.3. Managing and reducing risk

In addition to the risk of variation in external costs and benefits, we can identify other risks in the project that accompany the project.

Predicting objective risks, which cannot be influenced at the time of project preparation, can prevent the occurrence of risks. In the following, we identify both objective risks and preventive / ongoing measures to prevent the occurrence of risks or consequences.

Description of risk / consequences	**Probability**	**Strength**	**Level of risk**	**Risk mitigation activity**	**Level of risk after prevention measures**
PLANIRANJE					
Not all relevant information was collected from relevant stakeholders • failure to achieve the objectives of the Project • dissatisfaction of relevant stakeholders with the results of the Project	B	III	🟨	All relevant stakeholders will be identified and a data collection plan will be developed, including tools and methods for gathering information	🟩
Disagreement among key stakeholders • slowing down implementation • change in scope of activities • delays	C	II	🟨	Meetings will be held on a regular basis with all relevant stakeholders to keep everyone informed of the implementation progress and expected results of the Project. Prior to implementation, roles and ultimate decision-making powers among stakeholders will be clearly defined	🟩
The organization of work is not efficient • increase in project costs • delays	C	III	🟨	A project management team will be formed consisting of experts who will be involved in organizing the work. Work meetings will be held regularly with stakeholders involved in the implementation of the project, where a new work organization will be agreed upon during the implementation of the Project.	🟩

Description of risk / consequences	**Probability**	**Strength**	**Level of risk**	**Risk mitigation activity**	**Level of risk after prevention measures**
Serious risks have not been identified • failure to achieve the objectives of the Project • delays • reduced quality of implementation	C	IV	🟥	Discussion meetings will be held and a team will be formed to identify the risks and conduct the risk analysis and define mitigation measures.	🟩
Lack of capacity of the Port of Gruž in planning all activities foreseen by the Project • poor project preparation • failure to achieve the objectives of the Project • delays	D	III	🟥	The possibility of supporting Luka Gruž with the additional professional capacities of external contractors is foreseen	🟩
Incorrect cost estimate • delays • increase in project costs and lack of sources to finance excessive costs • inability to complete the project	C	IV	🟥	An investment plan will be defined with all items and costs presented in total and by years of implementation The sources of funding and the proportions of funding expected from each of the identified sources will be identified. The project promoters have been directly involved in the preparation of the project since the design of the study documentation and part of the cost estimates was made based on business experience	🟩
Inadequate determination of project implementation dynamics • delays • incomplete absorption of EU funds earmarked for the project	B	IV	🟨	When defining a timetable, the logical sequence of activities, inter-activity relationships (end-to-start, start-tostart, start-to-end, end-to-end) will be taken into account, possible external influences that may slow down implementation, availability of resources for implementation, deadlines.	🟩
Change in Project Carrier Strategy • loss of management structure support	A	V	🟨	Implementation of strategy alignment with the management structure where the concept of the Project will be one of the priorities of the society development.	🟩
ADMINISTRATIVE IMPLEMENTATION					

Description of risk / consequences	**Probability**	**Strength**	**Level of risk**	**Risk mitigation activity**	**Level of risk after prevention measures**
Difficulties in conducting public procurement (repeated procedures, cancellation of tenders) • Delays in implementation • inability to complete the project	D	IV	🟥	A detailed procurement plan will be drawn up with clearly defined deadlines for the implementation of individual procedures. The timing of the implementation of the Project will take into account the duration of the procurement procedures and possible delays. In the bidding documents, the criteria and deadlines for the provision of services / works / delivery of goods will be clear but not too narrowly defined to allow the selection of a suitable bidder. External assistance will be used as needed to prepare and review the tender documentation	🟩
Difficulty in obtaining the necessary permits • delays • inability to complete the project	C	V	🟥	When planning a project, as part of the project management activities, sufficient time should be allowed to obtain permits	🟩
Risk of inability to secure the necessary EU funds for the implementation of the Project • insufficient funds in the national budget to co-finance the project	A	IV	🟩	Enhance the cooperation of the competent authorities and the Project promoter, as well as discussion on the topic of financing. Constantly monitor funding and keep in touch with major funders, secure funds in annual plans.	🟩
Property Legal Problems • Delays in implementation • inability to complete the project	D	III	🟥	It is very early to approach the landscaping of all the parcels that are part of the project.	🟩
CONSTRUCTION AND EQUIPMENT INSTALLATION					
Weather conditions slow down construction work • delays	C	I	🟩	The activity plan will be redefined in accordance with the calendar start of the project if the project starts so that the start of construction works falls in the winter months. The budget foresees a contingency reserve in case of delays in the works, etc. The construction deadlines include days unfavorable for construction.	🟩
The contractor does not have adequate resources to perform the tasks in a quality manner • delays • reducing the quality of implementation	B	IV	🟨	Contractor selection criteria must include quality assurances, not just the lowest price.	🟩
Contractor delay in the implementation of the works	C	IV	🟥	Initially setting up all activity monitoring procedures should minimize this risk as they create a tool for the technical coordinator's timely response to the Contractor. Alert all relevant services and space users to the project and the works. Prepare normal functioning with the help of competent institutions.	🟩

Description of risk / consequences	**Probability**	**Strength**	**Level of risk**	**Risk mitigation activity**	**Level of risk after prevention measures**
The contractor cannot fulfill the financial obligations • delays • Inability to fulfill part of the contract	B	III	🟨	The contractor must demonstrate financial standing when choosing. Close monitoring of the financial position of the contractor	🟩
OPERATION AND MAINTENANCE					
Improper maintenance of the new system • shortening the life span of the system • Increasing maintenance costs • diminishing project results	B	III	🟨	To avoid frequent malfunctions and malfunctions, expert technical supervision and maintenance will be ensured	🟩

13. CONCLUSION AND RECOMMENDATIONS

13.1. Overview

Based on the analysis, it can be concluded that the construction of a high-voltage land connection in the port of Dubrovnik - Gruž is a financially unprofitable project, and it requires EU co-financing but a largely socially profitable project.
The economic and financial assessment of the project in question is based on an analysis period of 25 years. In terms of investment, buildings with regular maintenance have a life expectancy of more than 100 years. The only thing that needs to be done in the case of electric power structures is the worn out equipment, which is an investment outlay after 25-30 years.
It should be borne in mind that the current way of evaluating investment projects does not sufficiently appreciate the long-term costs and benefits for the short-term benefits and costs. High discount rates on economic analysis discourage investment with long-term benefits. This disadvantage is especially pronounced in such electric power plants where initial investment is high, costs of operation and maintenance are low, profit is certain, but it is realized through many years.
Given that Dubrovnik is one of the world's major tourist destinations, and for the last two years it is also the best cruise destination in the Eastern Mediterranean category in front of Kotor, Venice, Santorini and Rhodes, except for exceptional circumstances, the number of tourist arrivals by cruise ships in the future will certainly not reduce.

In technical terms, high-voltage land connections will ensure a secure and reliable supply of cruise ships - cruisers with electricity from their land during their berth at the port of Dubrovnik - Gruž, while at the same time having a favorable environmental impact, as a consequence of which we will reduce ship emissions of harmful substances into the surrounding air.

We believe that such a project would, first of all, have the greatest environmental impact for the city of Dubrovnik, since it would certainly improve the quality of the surrounding air and reduce pollution of the surrounding soil and water. Reducing marine exhaust emissions would reduce the amount of particulate matter in ambient air that has been confirmed to cause cardiovascular, respiratory and nervous system diseases.

In addition, this type of power to the ship also reduces the noise and vibration of the port.

In addition to all of the above, it is important to emphasize that the investment project in question is fully aligned with national and European energy goals. These objectives seek to mitigate the impact on climate change and ensure energy sustainability by reducing greenhouse gas emissions, using renewable energy sources and increasing energy efficiency.

The following are the steps (projects and permits) that are required before the start of construction:

- spatial planning
- studies and tests for preliminary design (geodesy, recording and assessment of the condition of structures, connection to the network)
- conceptual design
- environmental impact analysis
- obtaining a location permit

- elaborations and backgrounds for the main project
- industry studies and backgrounds for the main project
- main project
- obtaining the main design approval and building permit
- bidding documentation
- detailed design

13.2. Economic and financial features of the project

Based on the fact that the investment decision-making process is a set of risky capital investment decisions that are expected to contribute to the future development and economic success of the economy, an economic financial analysis and an assessment of the profitability of the investment have been carried out.
The basic financial discount rate applied to calculate the present value of the project is 4%. The discount rate is defined in accordance with the Guide to Cost Benefit Analysis of Investment Projects. The project life is 25 years.

According to the financial analysis, the following results were obtained:

Financial Internal Rate of Return: FIRR (C) = 0.2%

Financial net present value: FNPV (C) = –69.33 M €

From the above it follows that the financial model is not profitable, that is, the net present value of such a project is € 69.33 million, and EU co-financing is needed.

According to the conducted financial analysis and EU guidelines on co-financing through funds, the total amount co-financed by the EU amounts to HRK 63.77 million, which is 44.13% of the total investment costs.

The social criteria for the project's cost-effectiveness in current economic and economic opportunities are: increased electricity production, reduced CO2 emissions, increased employment, reduced noise and pollution.

The project indicators calculated for the above economic analysis using the 5% discount rate are:

Economic internal rate of return: EIRR = 8.7%

Economic net present value: ENPV = HRK 77.77 million

Value for money: K / T = 1.25