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MARITIME TRANSPORT OTHER THAN SHIPPING: ELECTRICAL ENERGY CASE

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Abstract

Large demand for energy results in necessity for its transportation in various ways. On land areas, energy media transfer consists mainly of transport in tanks by rail, road or river routs as well as pipeline systems for liquid or gasified hydrocarbons. A part of energy media in the world is electric energy flowing though metallic conductors of overhead and cable networks.

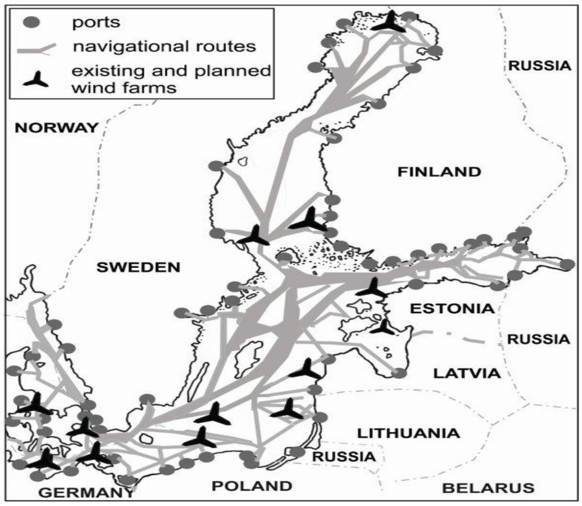
If sea areas are considered, ship navigation routs crosses with pipelines and electrical energy transfer systems. Furthermore, every transport system can interfere with other. Marine areas occupied by pipelines and submarine cables must be excluded from use of anchors and bottom fishing gear. On the other hand, pipeline systems interfere with the free development of navigation, particularly in areas near ports. Power transfer systems modify the natural force fields in the water column, surface water and even in near-water layer of atmosphere.

In this article, we show the main ways of transferring electricity in the sea and the resulting modifications of physical fields: electrical, magnetic and electromagnetic ones. We also discuss the probable impact of modifications of natural fields on ship traffic as well as corrosion of hulls of ships and marine structures. The considerations presented in the article are related primarily to the Polish Exclusive Economic Zone of the Baltic Sea.

***Keywords**: maritime transport, submarine energy transfer, marine environment, wind farms, Polish Exclusive Economic Zone*

1. Introduction

In terms of annual maritime transport, about one-third is oil, gas and coal (more than 3,000 mln ton, 15 billion of ton–miles) [8]. It is about 300,000 MJ in terms of the amount of energy (calorific value) and $8 \cdot 10^{10}$ kWh in the conventional electricity unit (without the efficiency of the any plant, which does not exceed 50%). Part of the energy transported by sea areas is transferred through submarine transmission systems. There is approximately 8,000 km of undersea cable routes around the world, with the largest concentration occurring in the Baltic Sea [1]. Furthermore, it is important that the countries surrounding the Baltic Sea participate in the construction of offshore wind farms. In the Polish Exclusive Economic Zone, they will be built in the area of Slupsk Bank, Middle Bank and the Pomeranian Bay [5]. Transmission of electricity generated by offshore wind farms to the land requires the construction of high power transmission systems (of several hundred megawatts). The High Voltage Direct Current (HVDC) submarine cables are most frequently used for transmission of electricity over long distances, including the area of Baltic Sea where there are currently over a dozen-power transmission systems of this type [6]. This is a different situation than in the case of land-based electricity transmission, where three-phase High Voltage Alternating Current (HVAC) is almost exclusively used. Each of the power transfer techniques results in the modification of existing or creation of new physical fields in the transmission area. They are mainly magnetic, electric and electromagnetic fields. Therefore, a question arises whether such interventions in the maritime space could affect the safety of vessels passing near these systems or crossing submarine cable routes. As far as the environment is concerned, it is important that the introduction of new energy into the seawater masses may have a detrimental effect on the functioning of the living organisms, especially in synergy with the fields generated by the ships. However, the available data concerning this issue is rather scanty and further studies are necessary. It is also worthwhile to disseminate among the users of the sea the essence and scale of new ways of transferring energy in connection with other aspects of marine transport activities.



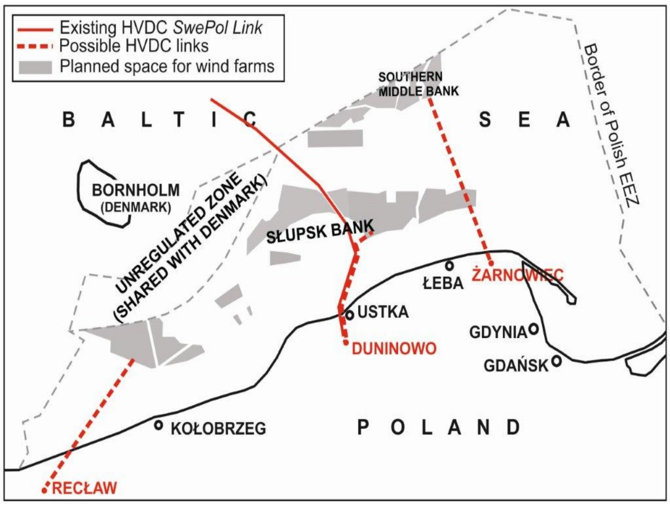


Fig. 1. Areas of potential offshore wind power stations in the Baltic Sea vs. maritime transport routes (left), and most probable scenarios of electric power transfer to the land power grid in the Polish Exclusive Economic Zone (right) [3,4]

In this article, we present a set of possible ways of transferring energy in marine areas and the resulting types of modifications of physical fields as well as their impacts on technical activities – primarily on shipping.

2. Solutions of submarine energy transfer systems

The electricity transmission system from offshore wind farms to land customers consists of an electric power station (which integrates energy flowing from wind generators), a conductive cable system and a land-based power station receiving and transferring energy from the Marine Wind Farms (MWF) to the National Power System (NPS). In some cases, the transmission system consists of electrodes that introduce electrical current to the seawater. Contemporary MWFs are equipped with power generators of up to a dozen megawatts [2]. Generators produce low voltage electricity (LV) (0.6-6.6 kV), which is increased in the transformer (inside the gondola together with the generator) to medium voltage (MV) (20 – 66 kV). From each power plant, electricity is discharged through the MV system, which integrates all power plants into the transformer station. At the transformer station, the medium voltage current is converted to high voltage (MV/HV) (up to several hundred kV), which is transferred to the land.

The way of discharging electricity (HVAC or HVDC) from offshore transformer station to the land transformer station is not explicitly established in the case of MWF in Polish Maritime Areas. This is the choice between high voltage alternating current (HVAC) and high voltage direct current (HVDC). In the case of HVDC system, this may be an electrode solution (Fig. 2) or solution with the return cable (Fig. 3). Additionally, independently to the solution (electrode or return cable), transmission lines operating in monopolar or bipolar systems may be designed. Bipolar transfer systems are used to double the transmitted power and prevent a break in power transmission in the case one of cable failure.

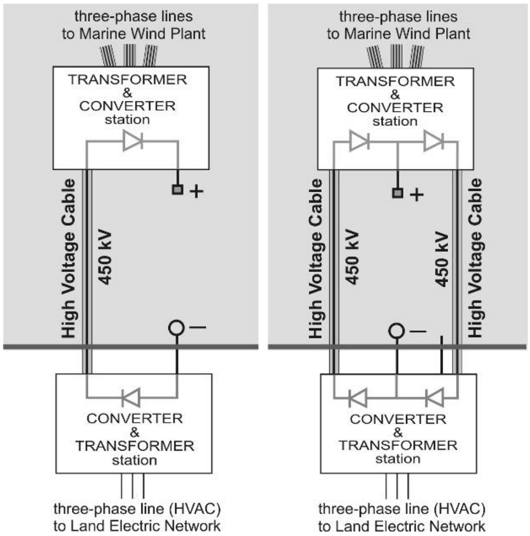


Fig. 2. HVDC electricity electrode transfer system: left – monopolar solution, right – bipolar solution

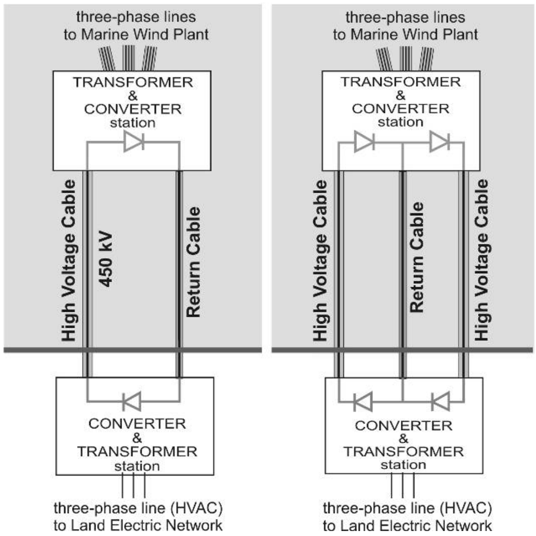


Fig. 3. HVDC electricity return cable transfer system: left – monopolar solution, right – bipolar solution

In the case of power transmission in the HVAC system, a high voltage three-wire cable may be used (Fig. 4 left). However, it should be assumed that in a case of transmitting high power, due to the possibility of overheating inside the cable, three wires might be used in separate cables (Fig. 4 right).

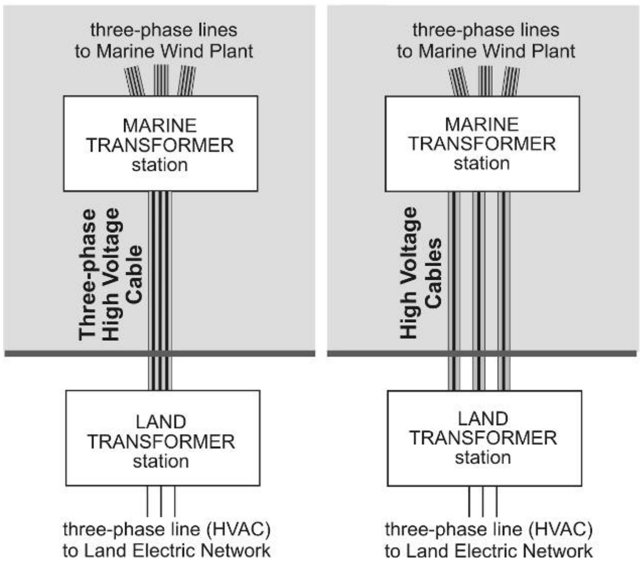


Fig. 4. HVAC three-phase electricity transfer system: left – 3-core cable solution, right – 1-core three cables solution

3. Environmental effects of different transfer systems – physical field modifications

Each way of transmitting electricity will affect the nature and intensity of changes in natural physical fields. Chapter 3 presents the mechanism of these changes and the analyses of the scale of field modifications in relation to specific transmission system engineering.

The construction of HVDC transmission systems in the electrode solution results in the existence of an electric field in the water mass, which mobilizes dissociated ions of dissolved salts – triggering the electricity flow. Providing a sufficiently large surface of the electrode ensures that even directly in a small distance from it the electric field intensity is low enough that it does not directly affect the marine organisms. Fig. 5 shows changes in electric field intensity as a function of the distance from the electrode (in the case of the southern Baltic sea) for current 1330 A (the nominal value for operating in the *Baltic Cable* electrode system).

The current flowing in the HVDC cable is the source of the magnetic field, which decreases with the inversely proportional distance. In the case of 1330 A, the magnetic induction value at 5-6 m from the cable is comparable to induction of geomagnetic field, whereas at 50 m – one rows lower, at 500 m – two rows lower. The value and direction of the resultant vector of the magnetic induction depends on the orientation of the cable route direction in relation to direction of the geomagnetic field.

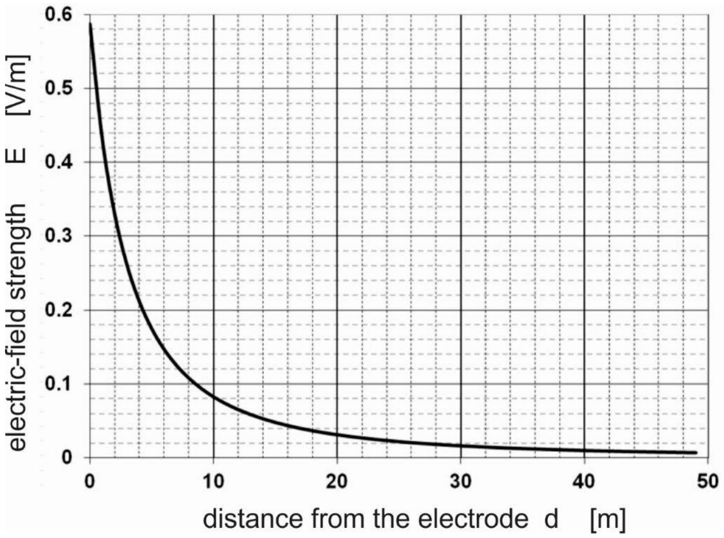


Fig. 5. Decrease of intensity of electric field with the distance from the submarine electrode of typical HVDC electricity transfer system in electrode solution (modelled for power of 600 MW at current of 1330 A)

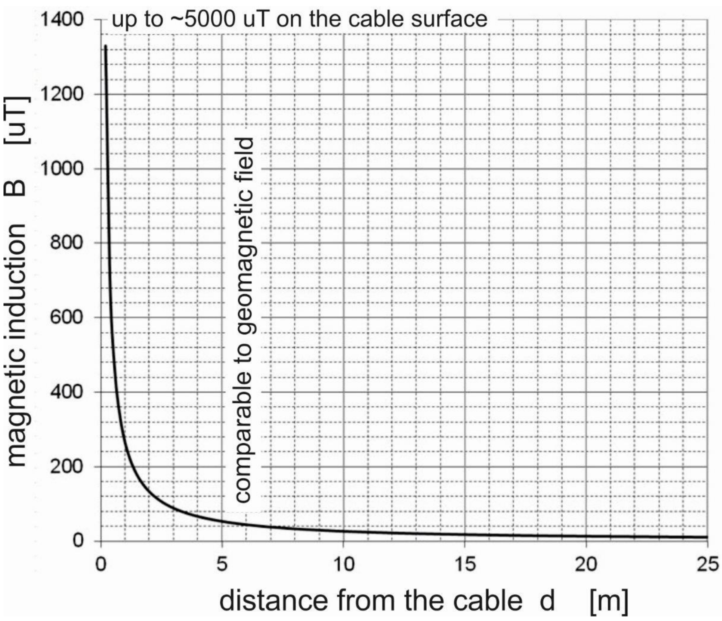


Fig. 6. Decrease of magnetic induction with the distance from the HVDC cable (modelled for HVDC system the same like at Fig. 5)

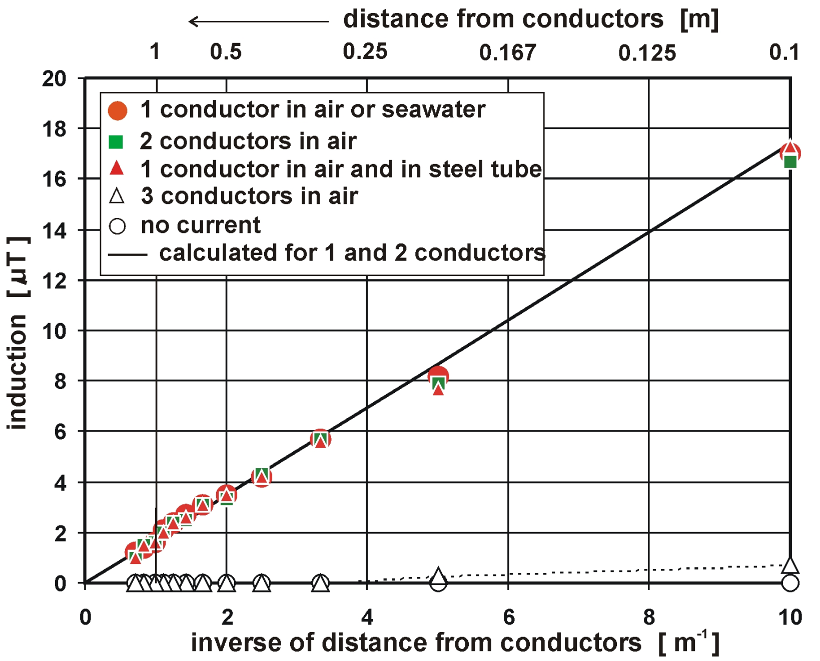


Fig. 7. Electromagnetic field (expressed by the magnetic factor) around conductors transferring alternating current of 8.6 A (laboratory measurements by Otremba and Andrulewicz [7])

4. Discussion and conclusions

In salt water, there is no electrical field if the return cable for HVDC is used. However, for HVAC an electric component, which intensity depends on the intensity of magnetic component and salinity, exists. Magnetic factor is independent on salinity (only amperage impacts magnetism). Close proximity of conductors within a tree-core HVAC cable (three-phase system) leads almost to complete electromagnetic field neutralization at the surface of cable. However, in the case when one or two phases disappeared electromagnetic field is generated in the same manner like for one-core cables.

Considering the above examples of impact of different types of electricity transfer systems, a compilation of cases of introducing changes in sea space is presented in Tab. 1.

Tab. 1. Occurrence of define type of physical field vs. technical solution of the energy transfer system

	electric	magnetic	electro-magnetic
HVDC electrode solution (Fig. 2)	yes	yes	no
HVDC return cable solution (Fig. 3)	no	yes	no
HVAC 3-phase, 3 core cable solution (Fig. 4 left)	no	no	yes (weak)
HVAC 3-phase, 3 cables of 1 core solution (Fig. 4 right)	no	no	yes

The above-described modifications of power fields in marine areas related to the development of energy transportation can be important for both, navigation and operation of technical facilities at sea. Undoubtedly, in certain situations submarine electric power transmission systems HVDC can affect the operation of the magnetic compass, which is still the most important tool in determining the position of ships, despite the existence of satellite navigation systems. In the case of electrode solution there is risk of corrosion of steel structures due to generation of stray currents. In the case of alternating current solution (HVAC), a new type of energy (electromagnetic field) is introduced into the maritime space and so far, it is difficult to determine how it could affect navigation. However, for all types of physical fields, the synergistic impact on technical activities at sea may be also revealed.

According to current knowledge there are no serious conflicts of interests between navigation and maritime systems for energy transfer, however HVDC solutions for energy transport systems may affect navigation due to modification of geomagnetic field. Also, this way of transmitting energy in the electrode solution can intensify the corrosion process of metallic objects. The development of energy transmission networks represents a particular inconvenience for navigating and fishing fleet by making the necessity to avoid MWF area and anchoring along underwater cables transferring electrical power.

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