ABSTRACT
The paper analyzes and compares charging stations for small electric vehicles, including fast and slow boats, electric cars and their components. The analysis of charging modes of electric vehicles showed that four internationally standardized modes are used, three of which use alternating current with single-phase and three-phase switching and only one – direct current. When charging on direct current, the fastest charging is provided. There are three main options for connecting the electric vehicles to the charging station: by means of a special power cable; by means of a pantograph from bottom to top and from top to bottom; wirelesses connection. There are four standardized cases of connecting charging stations to electric vehicles. Three cases of cable connection can be used on alternating current, only the third case – on direct current, and the fourth case – when wirelessly charging an electric vehicle. A comparison of existing types of connectors for charging electric vehicles has shown that the standardized interface between the charging station and the electric vehicle remains one of the most acute problems.

Keywords: charging station, electric vehicle, charging mode, charging connector.

1. INTRODUCTION
Electricity is seen as one of the main alternative fuels. It is one of the sources of energy for use not only in road transport, but also in other transports, such as shipping. Electric vehicles (EVs) help improve air quality and reduce noise levels in urban areas. IMO (International Maritime Organization) continues to contribute to the global fight against climate change, in support of the UN Sustainable Development Goal, to take urgent action to combat climate change and its impacts on the shipping industry. IMO has adopted mandatory measures to reduce emissions of greenhouse gases from international shipping. EV is a vehicle equipped with a power plant containing an electric machine with an externally charged energy storage system as an energy converter [1]. For electric boaters, the grid infrastructure is not an issue. Virtually every marina has an electrical tower (“shore power”), which negates charging concerns for consumers. The term shore power simply refers to the electric power accessible to a dock being “shoreside”. The shore power allows one to charge their electric boat’s motor. Instead of an internal combustion engine, electric vehicles use one or more electric motors.
EVs require charging their own battery with electricity, for which special charging stations (CSs) are designed. The EV uses both direct current (DC) and alternating current (AC). Shore power is typically an AC plug, which is typically 120 volts. Existing interface technologies for EVs CSs include cable
connectors [2], but future technologies for such interfaces should also include wireless CSs [3]. For the rapid and wide distribution of EVs, it is necessary to create an extensive network of special CSs, which must have sufficient coverage.

Topical are the problems of standardization of various components necessary for the functioning of CSs for EVs at the international level. Also relevant is the issue of revising existing standards to ensure compatibility and communication between the power point and the CS for EV.

2. PROBLEM FORMULATION

In [1] there are four types of CS for EM directly from the power supply network. In [4], a mobile CS for simultaneous charging of five EVs is presented and a modular power interface between CS and EV batteries is described. The number of publications on the implementation of CS for EM is small [5]. At the same time, the development of recommendations for the standardization and implementation of CS components remains an urgent task.

3. CHARGING MODES AND CASES OF CONNECTING CS FOR ELECTRIC TRANSPORTS.

The international standard IEC 61851-1 [1] standardizes power supply equipment for charging EVs with a rated supply voltage of up to 1000 V AC or up to 1500 V DC. There are four types of EV charging. The first three modes use AC. Each EV has a AC built-in CS, which is powered by the AC, and from it the battery of the EV DC is charged.

Mode 1 provides a direct connection with a simple extension cable without additional means of controlling the CS communication between the network and the EV. In this mode, a conventional household electrical network is used (with a single-phase connection, the charging power is up to 4 kW, with a three-phase connection, up to 11 kW).

Mode 2 also uses standard household or industrial connectors, but uses a special cable according to the international standard IEC 62752 [6]. This mode is often used in private houses, individual parking spaces, etc. With a single-phase connection, the charging power in this mode is up to 8 kW, and with a three-phase connection it is up to 22 kW.

Mode 3 involves the use of a cable with special connectors on both sides and connection to special chargers. This is the most popular EV charging mode. The charging power with a single-phase connection is up to 8 kW, with a three-phase connection it is up to 44 kW.

In Mode 4, charging occurs when connected directly to the batteries of an EV through special outputs of the charging control system. Since the AC-to-DC conversion takes place in the EV CS, this makes it possible to overcome the limitations on the maximum charging current of the on-board charger. Therefore, it is the fastest EV charging mode.

The international standard IEC 61980 (three parts) [3, 7, 8] applies to EV CS using wireless methods at standard supply voltages up to 1000 V AC and up to 1500 V DC.

There are three main options for connecting the EV to the CS (Fig. 1): by means of a special power cable (Fig. 1, a); by means of a pantograph from bottom to top (Fig. 1, b) and from top to bottom (Fig. 1, c); wirelessses connection (Fig. 1, d).
There are four types of charging electric vehicles using a power cable or “hand-connected” [1]. Pantograph charging with the first type of “auto link” provides high-level wired power transfer in a very short time from the charging infrastructure to heavy-duty EVs. Wireless charging or induction charging with the second type of “automatic connection” is plug-less charging through electromagnetic fields, when the current is transferred to the EV.

Two types of charging pantographs are used for electric buses (Fig. 2): “top-down” or “inverted pantograph” (Fig. 2, a), which is an integral part of the charging infrastructure; “up” or “rooftop pantograph” (Fig. 2, b). The most common type of pantograph charger is “roof pantograph”, which use on the route or at the bus station, where charging is very fast. The type of pantograph charging has the advantage that it can also be used for slow charging at night without cables scattered around the station. Charging with a power cable is also used at bus stations and for charging boats. (Fig. 2, c).

4. TYPES OF CONNECTORS FOR CHARGING OF EV

The requirements for the 4 types of connectors with which EVs are connected to the CS are established in the international standard IEC 62196 (three parts) [9-11]. The main AC receptacles are Type 1 and 2, depending on the region in which they are used. Type 1 and 2 connectors are used to recharge the EV from CSs operating in charging Modes 2 and 3. The Type 3 connector was developed for electric vehicle manufacturers in Italy and France. It is available in single-phase and three-phase versions - type 3A and type 3C respectively [5].

Types of sockets for charging EVs from the AC mains are shown in Fig. 3.
The type of connectors for charging of EVs on DC are shown in Fig. 4.

The International Standard IEC 62196-1 [9] applies to accessories with a rated operating voltage not exceeding 1500 V DC at a rated current of not more than 400 A. The standard IEC 62196-3 [11] applies to accessories that include controls with a rated operating current voltage up to 1500 V DC and rated current up to 250 A.

5. DISCUSSION OF THE RESULTS
The analysis of charging modes of EVs showed that four internationally standardized modes are used, three of which use AC with single-phase and three-phase connections and only one – DC. When charging on DC, the fastest charging is provided. There are four standardized cases of connecting of CSs to EV. Three cases of cable connections can be used on AC, only the third case – on DC, and the fourth case – when wirelessly charging an EV. The fact is that electric boats are tackling a lot more challenges than electric cars. It’s easy to understand that extra weight means extra momentum for cars, but for boats, it’s a pure drag. That means the energy to push a car at 60 mph can only probably push a boat at 30 mph. Charging is easy with electric boats, given that the most marina’s offer shore power which can be used to charge your electric boat on a standard 16a socket.

A comparison of existing types of connectors for charging of EVs has shown that there is no single standard for them. Moreover, the types of connectors are quite different and depend on the country or region: North America, Europe, China and the United States. The standardized interface between the CS and the EV remains one of the most acute problems.

A comparison of existing types of connectors for charging of EVs has shown that there is no single standard for them. The main technical characteristics of the existing standardized types of connectors show that for both AC and DC they are used for voltages up to 750 V and currents up to 200 A. The maximum power for them on both AC and DC is up to 150 kW.
6. CONCLUSIONS

The topic of CS for EV is steadily gaining interest in recent years. Creating an infrastructure for CS for EV and ensuring accessibility for their users is an urgent task. For the successful implementation of this task, it is necessary to solve the problems of standardization of various components necessary for the functioning of CS for EV at the international levels. The issue of standardization of both the CS for EV and its components remains unresolved, so it is important to establish their main components and its technical characteristics. The main components of CS for EV include charging modes, cases of its connecting to EVs, the principles of its use, connectors for charging of EVs.

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