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A REVIEW OF ELECTRIC POWERED BOATS

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Abstract: In recent years, numerous advancements occurred in the Electric Vehicle sector. This paper focuses on the type of Electric Powered Boats. One of the promising area where usage of solar energy has been used for electric powered boat. The rapid development in the field of power electronics and control techniques has generated an area for different types of electric motors to be used in Electric Boats. Electric boats provide a fun and fulfilling experience of cruising without having to worry about running low on fuel. They are energy-efficient, easy to control and provide a smooth ride while protecting the environment from harmful emissions. Attention is shifting towards electrifying recreational boats to reduce environmental impact as a result of greenhouse gases emissions from running of fossil-fuel powered recreational boats. In addition to solar-electric boats, conversion of a traditional recreational boat into a hybrid electric boat by replacing the hybrid drive train with a regular propulsion system is also discussed

IndexTerms **– Electric Powered Boat, Electric Propulsion, Charging Stations, Hybrid Electric Boat.**

I. INTRODUCTION

Global increase in the amount of Carbon Dioxide (CO2) is primarily a result of fossil fuel use and leads to increase in global average temperature by 0.2 degree per decade over the last 30 years. Air pollution, global warming, and the rapid depletion of the Earth's petroleum resources are now problems of paramount concern. In recent decades, the research and development activities related to transportation have emphasized the development of high efficiency, clean, and safe transportation. Electric vehicles (EV), hybrid electric vehicles (HEV), and fuel cell vehicles (FCV) have been typically proposed to replace conventional vehicles in the near future. The waterborne transport is considered to be the most energy efficient and consuming around 6.7% of the global oil consumption, but contributed it share of Greenhouse Gas Emission (GHG) to the environment due to high consumption of low quality grade fuel Heavy Fuel Oil

The electric propulsion systems have been adopted by the electric boats. From an environmental point of view, this is a solution with advantages, as for instance, less local pollution, higher efficiency, silent, etc. From the technological side, the energy storage systems, mainly the batteries are the main obstacle to spread this solution, as it is well known. In the coming years, it is expected to get new developments on the energy storage systems in order to improve the autonomy of the electric vehicles. In addition, the weight and volume of the power converters onboard should be reduced and optimized.

Designing adequately the power converter topology (semiconductors type included), the electric motor and the control system, it is expected to get technological improvements on electric boats. In recently years, the shortage of fossil fuels and environmental pollution awareness are two importance issues that affect people's daily life, and therefore many countries are actively doing research and developing renewable energy resources. Solar energy is one of the most potential options. The conservation and protection of the marine environment are values often mentioned by boaters. Even though the characteristics of electric motors agree with these values, few boaters have at the moment chosen electric propulsion mode.

Several solutions are proposed to de-carbonise the marine sector, one of the solutions is the electrification of the marine sector due to its potential to significantly reduce emissions from heavy consumption of fossil fuel, combined with the increase of solar energy sources. This has induced different actions from both private and public sectors like governments, boat manufacturers, energy companies. Electric boats are marine vessels with electric drive propulsion technology. Electric boats can be pure electric, hydrogen fuel cell electric, or hybrid electric type.

The rest of this paper is organized as follows: History of Electric Boat is discussed in Section II, and the environmental impact of conventional boat is discussed in Section III. Section IV illustrates the usefulness and advantages of Electric motors for Boat. Finally, Section V concludes the paper.

II. HISTORY OF ELECTRIC BOATS

The first electric boat was invented in 1881 by the Parisian chemist Gustave Touré. A century later, the use of the electric motor remains marginal. Its thermal neighbour has been favoured by the public and the builders. But, oil reserves are running out, the preservation of our environment has become the major issue of the last century and the price of fossil fuels is increasing. The design of new modes of propulsion is necessary. Electric propulsion is one of these areas of research and development. Electric

propulsion can use local renewable energy sources, including photovoltaic panels, fuel cells, super capacitors and batteries. Electricity from renewable sources is intermittent and dependent on weather conditions. The electric boat, taking advantage of owning an electric propulsion chain can also use infrastructures already available and contribute to relieve the nowadays traffic problems of some cities. It has been observed a growing tendency to use this kind of transportation in urban and tourism context.

Due to demanding range requirements, the most commonly Studied solutions are hybrid electric marine propulsion systems, which combine mostly diesel internal combustion engines (ICE s) and electric motors (EMs). The integrated electric propulsion concept, consisting of diesel (turbine) – EMs mechanically connected to the propeller shaft with no electric energy storage, has been used in high-level ships since 2004, Conversely, serial hybrid and parallel hybrid propulsion systems are provided with electric energy-storage capabilities. In serial hybrid, a battery bank is interposed between the ICE /generator and the power converter (PC)/EM that alone powers the propeller shaft. In the parallel hybrid system, both the ICE and EM/generator are mechanically connected to the propeller shaft, the EM/generator exchanging energy with a battery bank.

III. IMPACT OF CONVENTIONAL BOATS

The Engine powered vessels caused huge environmental impact including greenhouse gas emissions and oil pollution. The International Maritime organization (IMO) estimates that Carbon dioxide emissions from Engine powered vessels were equal to 2.2% of the global human-made emissions in 2012 and expects them to rise 50 to 250 percent by 2050 if no further action is taken. Engine powered vessels are one of the main sources for the air pollution as well as the water pollution. 3.5 to 4 percent of all climate change emissions are caused by shipping, primarily carbon dioxide. The two main pollutants from the ships' emission are Nitrogen oxides (NOx) and Sulphur oxides (SOx). These gases have adverse effects on the ozone layer in the troposphere area of the earth's atmosphere which results in the greenhouse effect and global warming.

Faulty engine system and improper repair work are two areas through which oil could leak and mix with the oceanic water. While less frequent than the pollution that occurs from daily operations, oil spills have devastating effects. While being toxic to marine life, polycyclic aromatic hydrocarbons (PAHs), the components in crude oil, are very difficult to clean up, and last for years in the sediment and marine environment. Marine species constantly exposed to PAHs can exhibit developmental problems, susceptibility to disease, and abnormal reproductive cycles. Electric powered boat helps to slowdown the global warming. Global warming threatens the survival of human society, as well as the survival of countless species.

Electric vessels run quietly, as opposed to their diesel and gasoline counterparts that produce a lot of noise when in use. Since the electric motors don't need a combustion system, the only sound they produce is from a rotating rotor, which is not noisy at all. The silent operation condition making passengers are able to enjoy their conversations as normal during trips. Compared with engine powered vessels, the machinery mechanism of electric vessels are much simpler. They do not have to undergo the complex procedures of winterization and de-winterization, making them much easier to operate and maintain. Electric vessels are much safer when compared with engine powered vessels. Using electric motor can eliminate the need to carry large amount of fuel and oil within the vessels that can easily spill and cause fire.

Plug in electric vehicle has the simplest construction of all it has components such as battery, converter, motor and gear system. Battery is used to store energy, which is converted to in to dc or ac according the drive used to drive the vehicle. The motor may be asynchronous motor i.e. induction motor, dc motor, brushless dc motor, synchronous motor and switched reluctance motor. It is also possible to place more than one motor for splitting the torque. The motors are placed in wheel hubs. But in this case, each motor needs a separate converter with speed and torque control, which guarantees necessary torque splitting in each condition. An electric vehicle is an emission free, environmental friendly vehicle. These PEVs have a disadvantage of battery getting discharged faster so it's not being used at a larger scale as they cannot travel a long distance.
Some boats come with the installation of large battery capacity to cover large distances thus, leads to higher investment with reduction in the efficiency of the boat due to the energy consumption directly related to the weight of the battery. Another solution would be easy access to public Charging Station (CS), but the availability of CS for electric boats is still a big problem. With the increase in the number of electric boats, more charging points will be needed to meet their charging demand. Optimal number of chargers (fast and slow charger) is provided to meet the demand of electric boats.

IV. LITERATURE REVIEW OF ELECTRIC BOATS

Propulsion drives have a large impact on the ship power system. This gives rise to the requirement for designers to understand in depth the effects of propulsion drives on the ship network in different operating conditions. A Delprezo et al [1] proposed the Sizing criteria of on-board sources and energy storage systems for a hybrid electric boat. Two different design criteria are proposed. A criterion to ensure the engine-generator group runs at fixed speed and power and the other to run the engine at variable power and speed. Series hybrid for providing the average power required by the load is considered. But it is not suitable for studying the electrical and electromechanical phenomena related to motor behaviour.

The fuel prices, the increasing restrictions of CO2 and nitric oxides NOx emission due to new ecological policies, and generally the need for more eco-friendly transportation were the reasons that forced the marine companies to re-examine the systematic use of PV systems on large vessels. Without changing the weight and dimensions of the diesel powered boat is converted to solar powered G Schirripa Spagnalo et al.[2]. A ferry boat powered by Lithium-Iron batteries that can be charged at any harbor visit In addition the energy for navigation is derived from a photovoltaic plant. The Power Management System (PMS) for managing the energy resources to navigate safely in the event of failure of one or more devices is also proposed. Better performances can be achieved with highly efficient solar panels and rechargeable batteries with light weight and high capacity.

Global aspects of a boat propulsion system investigated using a low scale system was developed by Tiago Freire et al. [3] which is modeled and analyzed using two different battery types (lead acid and Ni-MH) and a power converter. Using classical approaches (DC motor model), the proposed solution is analyzed by implementing a speed control system with a sliding mode controller. A ripple rejection model was implemented to reduce substantially the capacitance needed at the converter output. These solutions could reduce also the cost and dimensions of the all propulsion system. The controller for both converters can be built only with digital components, capable also of PWM control at constant frequency, with current-mode control done cycle-bicycle.

Design and analysis for the solar-powered boat development where a diesel powered boat converted into solar powered is discussed by Leung C P et al. [4]. For starting from standstill, super capacitors are used for supplement to the high startup current. Carbon dioxide emission can be dropped by 74.2% and the percentage of the cost saving is more than 87%. Better performances can be achieved with high efficient solar panels and rechargeable batteries with light weight and high capacity.

The rising transport expenses due to the fuel prices, the increasing restrictions of CO2 and nitric oxides NOx emission due to new ecological policies, and generally the need for more eco-friendly transportation were the reasons that forced the marine companies to re-examine the systematic use of PV systems on large vessels. An electric boat with Variable-speed diesel generator (DG) used as the main energy source, with the multiple energy storage system based on the super capacitors (SC) and the batteries was proposed in [5] by Kosseila Bellache et. al. The SC and the batteries are linked to dc-bus through two bidirectional dc/dc converters to control the high-frequency component independently to those of the average-frequency component. The proposed control algorithms are implemented in PIC18F4431 microcontroller assisted by the dspace control system.

Zhibin Zhou et al [6] presented a co-ordinated power management strategy for HEB based on dynamic loads. A dynamic power control strategy was proposed to share power between DGs and battery. Permanent magnet synchronous generator (PMSG) based variable speed DG sets are considered. The optimal loading on DGs and effective utilization of sources is achieved and the speeds of the DGs are also controlled for ensuring good engine performance. The speeds of the DGs are also controlled for ensuring good engine performance. At low load demand one of the DGs will be switched off to improve the diesel-fuel efficiency.

In [7] M.B. Camara et al. proposed a dc-bus configuration for onboard energy management, and various equipments in hybrid electric boat (HEB) which can be easily connected to dc-bus. Super capacitors and lithium battery are linked to DC-bus through two bidirectional converters. Load's current sharing based on frequency component distribution and the super capacitor module provides the high frequency component of load current. The lithium battery compensate average frequency component. Diesel generator provides the low frequency component. This enables to reduce current fluctuations impact for diesel, and minimizes the required energy storage devices sizes.

Design and fabricate of a boat based on solar power was proposed by Khizir Mahmud et al. [8] which can satisfy the requirements of short transportation. The boat has a navigation capacity of 25km/Day with maximum total weight of the unit of 200kg. The proposed solar boat has two batteries which can provide power in short cloudy periods as if it can be a reliable source of transportation. Both mechanical and electrical part of the boat has been designed for a particular weight carrier and particular distance. So if the number of passenger and distance changes then photovoltaic cell, emergency battery and engine specification should change according to the condition.

An energy management based on frequency distribution approach using the fluctuations of demanded energy by HEB was proposed by Bellache et. al.[9]. Super capacitors and lithium battery are linked to through two bidirectional converters. Diesel generator is connected to DC-bus using three phase controlled rectifier. DC-bus and the super capacitor module provides the high frequency component of load current. The lithium battery compensate average frequency component and Diesel generator provides the low frequency component. So this enables to reduce current fluctuations impact for diesel generator and minimizes the required energy storage devices sizes.

A solar powered boat design using distributed PV power system with maximum power point tracking technology, power optimizer and PV power controller is proposed in [10] by Ru-Min Chao et al.. The central controller communicates with the battery management system and the motor control system. The system is efficient for fast changing insulations and temperature variation condition if compared with other MPPT. Energy balance between the battery system and PV system is also provided by the above system.

The electric motors used in EV or HEV should not only satisfy specific requirements in performance and efficiency but also vibration, cost etc. Permanent magnet synchronous motors (PMSM) can be designed to operate over wide torque speed range with superior torque density and power density and the limitations are cost and availability of rare earth material used in permanent magnet. Zhi Yang et al. in [11] presented a comparative study of different types of motors used in EV or HEV. For 48/8 IPMSM, the highest efficiency is 97% and locates around 2000 rpm and between 20 and 50 Nm. For the same 12/8 topology, the SRM has severe vibration deformation than that of IPMSM, as the former operates in discontinuous current mode.

The electric chain of an electric boat is modeled using as reference a low scale system was presented by Tiago Freire et al. in [12]. A solution for controlling the boat speed is presented and discussed based on the sliding mode control method which allows controlling the boat speed with accuracy. A 6.5m long and 2m wide regular solar ferry boat has been fabricated and tested for different parameters in [13]. The boat is powered by a BLDC motor. The approximate speed of the boat is measured as 3 knots per hour, considering 70 % DOD of the battery. The payload of the boat is 1200 kg. The boat will be operated almost at uniform

speed even if the sun's insolation over a day varies because of battery backup. To reduce the number of power switches and winding leads, three-phase SRM is chosen for optimisation which has different stator and rotor pole number combinations [14].

While the initial cost of an electric boat may be higher than a traditional boat, over the long term, they can be more cost-effective due to their low maintenance requirements and lower fuel costs. Electric motors are more efficient than traditional boat engines, so they can provide more power with less energy. This can result in longer cruising ranges and lower energy consumption. They have a number of benefits, including being environmentally friendly, quiet, low maintenance, cost-effective, and efficient. However, whether an electric boat is worth it depends on individual needs and preferences, as well as budget.

V. CONCLUSIONS

Electric boats produce zero emissions and do not contribute to air or water pollution. Electric boats produce very little noise, which can make for a more enjoyable and peaceful boating experience. These boats have fewer moving parts than traditional boats, making them easier to maintain and less prone to mechanical issues After reviewing related literature, it was found that optimal number of slow chargers and fast chargers needed to meet the demand of electric boats at each station. By varying the battery capacity of the boat has a significant impact on the optimal number of chargers obtained from the model. Electric boats may be more expensive upfront, but they can offer long-term cost savings due to their low maintenance requirements and lower fuel costs. Ultimately, those who prioritize sustainability and a cleaner, quieter boating experience may find that electric boats are worth the investment.

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