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Environmental and operative impact of the electrification of a double-ended ferry

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Abstract— **The increasing sensibility to the environment protection and emission reduction in the atmosphere is also influencing the maritime shipping. The more restrictive regulations on pollutants suggest the adoption of alternative onboard propulsion and energy generation systems. To this end, electrification is a promising solution for pollution reduction, giving some flexibility on the strategy to use for the onboard system. Moreover, a hybrid-electric system can be combined with the exploitation of green fuel, increasing the potential reduction of total emissions. However, the final efficiency, both in term of emission reduction and expected operative expenditure, is strongly influenced by the operative profile of the vessel. This is of utmost importance both in case of a newly designed vessel and in the retrofitting of an existing one. In the present work, the impact of electrification on a double-ended ferry is presented, taking into consideration the operative profile of the vessel derived from real navigation data.**

Keywords— Hybrid ship propulsion, energy storage system, shore connection, ferry, integrated power systems, CO_2 emissions.

I. INTRODUCTION

Maritime shipping is currently the most environment-sustainable mean of transporting cargo and passengers worldwide [1]. Still, one of the main concerns in marine sector is the reduction in the ships' pollutant emissions. At present, the focus is mainly given to the reduction of pollutants inside harbor and coastal areas, where vessels manoeuver and sail at slow speed [2]. Such operative conditions make the engines operating far from their optimal working point, leading to an increase in pollutant emissions in respect to the open sea sailing. Being the ports usually built near, or even into, urban areas, and given the presence of several urban areas on the coast, it is evident why the reduction of emissions in these areas is mandatory in the new Smart Cities paradigm [3]. In a world more and more aware about environmental issues, and recognizing the impact of pollution on people health, also regulatory bodies in marine sector enforce restrictive international regulations on marine pollutions [4]. These new rules are forcing the shipping industry to adopt "green" solutions for the new vessels, or to refit the propulsion system of the existing ones to improve their sustainability and reduce their environmental impact [5]. To achieve such goals, at present three strategies are technically feasible [6]. The first option is to use an ecological fuel for supplying the main and/or auxiliary engines [7,8]. The second option is to install onboard equipment dedicated to the exhaust gas treatment. The third option is to rely on the vessel's electrification [9-12]. In this context, the INTERREG project METRO (Maritime Environment-friendly TRanspOrt systems) analyzes innovative solutions to improve the North Adriatic maritime transport environmental sustainability. Specifically, a team composed by Universities, companies, and public bodies work towards defining a more efficient, sustainable and integrated transportation network between Italy and Croatia.

In this paper, part of the project results are depicted. In particular, a study is proposed, referring to the electrification of a double-ended ferry. Three configurations for the refitting of its propulsion system are investigated, comparing them with the conventional one in terms of pollutant emissions, consumables needs, and costs. In section II the methodology applied for assessing the environmental and operative impact of the vessel is presented. Section III presents the specific vessel in study, its route, as well as the new ship configurations. Finally, Section IV discusses the results, followed by the Conclusions.

II. METHODOLOGY FOR THE ANALYSIS

In order to evaluate the performance of the different machinery configurations the so-called Data Driven Design approach has been applied. The optimal sizing of

onboard batteries. Obviously, a suitable shore infrastructure is needed, to provide the required power to the ship during berthing, which is approximately 20% of the total energy consumption for the analyzed case (Fig. 6). Since the CO_2 emissions are directly proportional to the fuel consumption, in Fig. 7 a trend similar to the Fig. 6 one can be seen. In this sense, LNG fuel in combination with batteries assures up to 10% savings in respect to SH configuration. Moreover, all the hybrid solutions enable a significant reduction of engines running hours (Fig. 8), thus lowering the engines' maintenance cost. Remarkable performances can be underlined for both the SH solutions, thanks to their high flexibility. In conclusion, Fig. 9 shows a significant reduction of the OpEx, thanks to the additional electrical subsystems. In fact, while the OpEx for DM and PH configurations depends only on the consumables cost (since maintenance costs have been neglected in this study), the shore electricity costs have a significant impact in the other two configurations. The latter is often the key factor to make such solutions feasible from an economic point of view.

V. Conclusion

In this paper, the redesign and the analysis of a ferry has been proposed, by using a methodology able to take into account several different aspects of the ship design. In particular, the applied method relies on statistical analysis of existing ships and routes, to obtain a usable mean operating profile for the ship to be designed. Then, by means of proprietary algorithms, it has been possible to analyze the results obtainable by different vessel's configurations. In particular, a comparison in terms of consumables, annual energy consumption, annual CO_2 emissions, engines running hours, and OpEx have been made, and presented. It is evident that some of the results, and consequently the appeal given by one solution in respect to another, depends also on parameters that have been ignored in this study. As an example, the CO_2 emissions related to the electrical energy supplied by the shore to the ship has not been evaluated. This has been done because such a parameter strongly depends on the port electricity contracts (which can include different quota of renewable energy sources) and on the possible presence of renewable energy sources in the port (like photovoltaic or wind generators). Actually, this is proving to be an issue in the marine sector just like in the automotive sector, where the real impact of electric cars cannot be assessed without analyzing the specific energy mix of the electricity grid on which the recharge stations are connected. In this regard, the research here presented is part of a wider research program, which is aimed at analyzing and proposing solutions for the green maritime transportation in the Adriatic area. The focus of such a project is wide, including not only the ships, but also the ports power systems, the specific routes and passenger/goods flows. By means of such an integrated approach, it will be possible to have a clearer vision about these topics, as well as to propose a solution including all the elements, specifically tailored for the needs of the single route.

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