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Environment-friendliness in Maritime Transport: Designing Smart Recharging Stations in North Adriatic Sea

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***Abstract*—Today, the electrification plays a crucial role in the challenge towards the energy sustainability. Focusing on the transportation field, the integration of carbon-free electric vehicles (cars, ships, trains and so on) and smart charging infrastructures based on renewable resources can strongly reduce the pollutants emissions of human mobility, while at the same time promoting the Smart City paradigm. In this context, the INTERREG project METRO (Maritime Environment-friendly TRanspOrt systems) is aimed at proposing innovative solutions for the improvement of the environmental sustainability in the North Adriatic maritime transport. The goal is to be reached by means of an integrated strategy, focusing on tackling both ships and ports. On one hand, by using electrical propulsion and energy storage systems onboard the ship, it is possible to decrease the vessel's environmental impact while sailing. On the other hand, a well-designed recharging infrastructure in the port can recharge the ship's energy storage system while at berth, possibly exploiting renewable carbon-free resources.**

Keywords*—*maritime transport; bidirectional ferry; energy storage system; series-hybrid; DC power system; recharging infrastructure; microgrid; Renewable Energy Sources.

I. INTRODUCTION

Since the interest in green technologies is increasing day by day, the hybrid-electric propulsion systems are becoming one of the most effective means to reduce the ship emissions during navigation and maneuvering operations. Such a trend is observable in several shipboard applications, starting from the pushboats for inland waterway navigation [1], then following-on the multipurpose crafts for coastal navigation [2]-[3] or the luxury yachts [4]-[5]. Beside these applications, also the ferries [6]-[7] are becoming an interesting test-bench for proposing energy storage systems and innovative control approaches. On one hand, the new hybrid solutions are making greener the ship's impact during navigation. On the other hand, the land infrastructure is to be rethought, to enable reducing the impact during mooring and further decrease the emissions in navigation.

Focusing on bidirectional ferries, a hybrid propulsion design is required to effectively reduce emissions. Indeed, if the propulsion is supplied by an onboard energy storage system (ESS), its emissions are entirely avoided. Moreover, if the energy is supplied at berth by means of carbon-free sources, additional savings are achieved. Thus, there is the need for an integration among shore-to-ship connections [8]-[11] and Renewable Energy Sources (RESs), in a microgrid (MG) structure [12]-[14].

By considering the potentiality of port's MG in green-refilling the onboard ESS, this work discusses the integration of a hybrid ferry with the land recharging infrastructure. The aim is to assess the results achievable by recharging the ship at berth, while at the same time reducing the onboard generators' operating time. In particular, by starting from a given series-hybrid shipboard power system and data coming from its daily route/scheduling, the present paper proposes two possible designs for the integration among the port recharging infrastructure and the vessel operation. Such a comparison will offer useful technical insight to help the designer in selecting the most suitable short-to-ship infrastructure for feeding the ferries. Moreover, it will make evident the strict relationship among the ship design, its operation, and the land infrastructure, which needs to be analyzed as a whole to maximize its environment-friendliness.

This paper wants to promote the activities achived in the INTERREG project METRO (Maritime Environment-friendly TRanspOrt systems). This research project exploits a synergic connection among Universities, companies and public bodies for delineating a more integrated, efficient and sustainable maritime passenger's transportation network between Italy and Croatia.

Conversely, a second smart idea is aimed at employing locally installed RESs for powering the SC recharge. Particularly, both photovoltaic (PV) systems and wind turbines can be suitable sources for producing carbon-free energy in Brestova and Porozina ports. Given the small area available, and the specific characteristics of RESs, it is not possible to use them to directly supply the SC. Thus, in both ports it becomes necessary to install a land ESS. This will enable to store the renewable energy during the RES operation, by means of low power generation systems, and then transferring them to the ship at berth through the SC. A dedicated design is to be fulfilled for correctly sizing the RESs generation plants, the related land ESS, the required power converters, and their management system. However, this is beyond the scope of this paper. Since a high-power interconnection to the land grind is no more necessary with this solution, it becomes possible to apply the MV SC to both ports. Thus, the fast charges to the ship can be doubled, both using carbon-free energy, further increasing the achievable environmental friendliness of the transport infrastructure.

V. Conclusion

The paper has presented a study performed in the context of the INTERREG project METRO (Maritime Environment-friendly TRanspOrt systems). Such a project is aimed at proposing new solutions for enhancing the environmental sustainability in the North Adriatic maritime transport. The green target can be achieved by implementing an integrated strategy, thus adopting electrical propulsion fed by batteries and smart recharging infrastructures. By starting from a ferry operative profile, two recharging solutions has been designed for being installed in two Croatian ports. Both solutions show good results in limiting the DG operation during the ferry route. Final considerations on port electrical infrastructures open interesting scenarios about the RES exploitation in green recharging the onboard battery pack.

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