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Concept Development of Marine Charging Station using SMR

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1. Introduction

With the global consensus on the need to regulate carbon dioxide emissions, the International Maritime Organization (IMO) has set a goal of reducing carbon dioxide emissions from ships by more than 50% by 2050 compared to 2008 levels [1]. Consequently, there is a growing interest in battery-electric ships as they can help achieve significant reductions in carbon dioxide emissions. As of 2020, there were over 300 battery-electric ships in operation or under construction, and this number is steadily increasing.

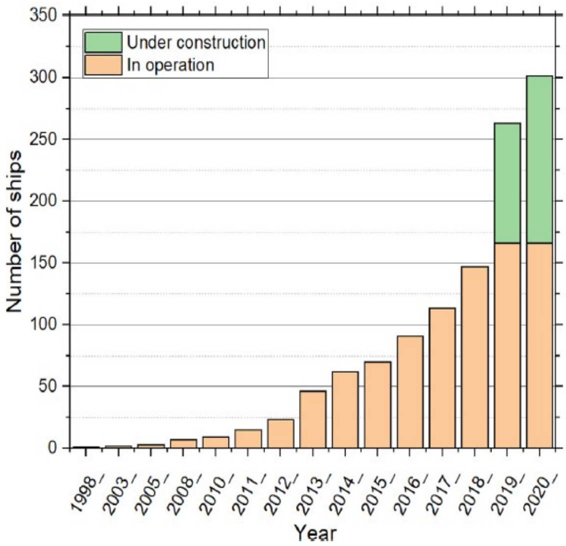

Fig 1. Growth trend in global battery-powered ships [2]

Just as there are electric charging stations on land for charging electric vehicle batteries, there will also be a need for charging stations at sea to charge battery-electric ships. Unlike land charging stations, marine charging stations cannot receive electricity from large power plants. Therefore, marine charging stations must inevitably have their own power generation function, and considering the feature of the sea where fuel for power generation is not frequently supplied, it is effective to use nuclear power with a low fuel replacement cycle. In recent years, the development of Small Modular Reactors (SMRs), which are smaller in size compared to traditional nuclear reactors, has made it feasible to have a floating power plant at sea. This paper presents the concept of marine charging station using SMR.

2. Marine charging station

2.1. Marine charging station concept

Floating nuclear reactors on water isn't all that new. Major maritime countries have been using nuclear-propulsion ships for decades, and Russia has already built SMR on floating platforms. (KLT-40S). Other countries, including South Korea and China are also considering designs for floating SMR platforms that can be built on the coastal near land. Such as floating SMR platform configuration is mostly considered as a ship configuration.

Fig 2. KLT-40S (Ship, 'Akademik Lomonosov') [3]

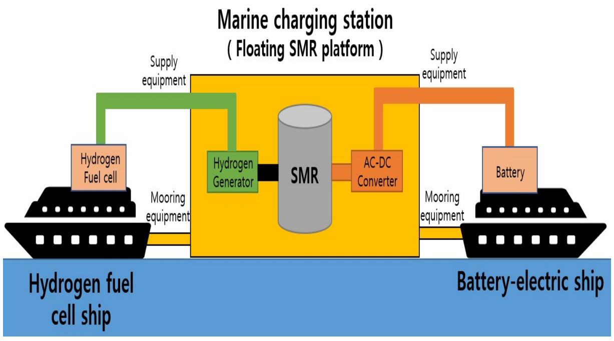

Fig 3. Marine charging station conceptual diagram

Table 1. Marine based water cooled SMR [4]

Design	Output MWe	Country	Status
KLS-40S	35 X 2	Russia	In Operation
ACPR50S	50	China	Detailed Design
ACP100S	125	China	Basic Design
BANDI-60	60	Korea	Conceptual Design
ABV-6E	6 ~ 9	Russia	Final design
RITM-200M	50	Russia	Basic Design Completed
VBER-300	325	Russia	Licensing Stage
SHELF-M	~ 10	Russia	Basic Design

In fact, If the floating SMR platform can be equipped with only the surrounding space for battery electric ships to be located and the facilities required for ship mooring and electricity supply, it can serve as marine charging stations for electric battery ships. Assuming that Russia's KLT-40S, the only floating SMR in existence, is a marine charging station, it can fully charge the world's first fully-battery electric cargo ship, 'Yara Birkeland', having a 6.8 MWh battery capacity in 349 seconds (~6 min.) if the battery allows such high charging rate.

Marine charging stations located on the coast are only suitable for charging small-capacity battery-electric ships that operate primarily near the shore. To charge ships sailing in open sea, marine charging stations located in international water are needed. Such charging stations require floating SMR platforms that can remain stable at deeper depths. Large marine structures (TLP, SPAR, FPSO etc.) that support oil drilling operations are currently the most viable options for such platform.

KAIST in Korea and MIT in the United States have individually proposed a concept of floating nuclear power plants using large marine structures [5, 6]. These floating SMR platform were intended to be usable up to 100 m deep sea, but considering the operational case of TLP and SPAR structures used, it is expected that they can be designed to be operated even at a depth of about 2 km or more will be possible. If ship mooring and electricity supply facilities are equipped in the structures, they can serve as a marine charging station in the distant sea.

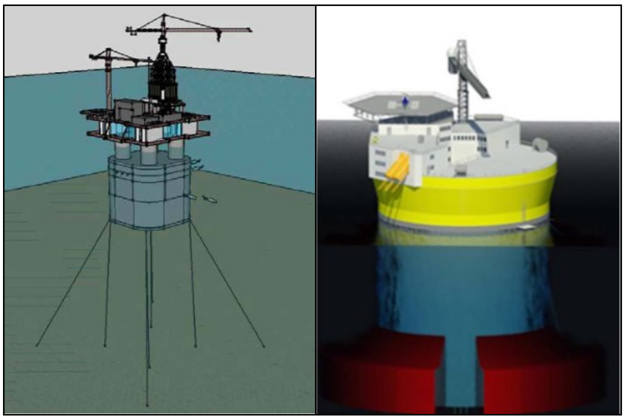

Fig 4. TLP-OFNP by KAIST (left) [5] / SPAR-OFNP by MIT (Right) [6]

Furthermore, an SMR can be mounted a ship with own propulsion capability. In this case, a DPS (dynamic positioning system) that fixes absolute location and direction of the ship by adjusting propellers must be utilized. If the sea condition is fair, the ship can stop regardless of the depth. In addition, because it can move on its own, it becomes possible to directly visit and supply electricity to battery-electric ships that lose their propulsion ability due to discharged the battery.

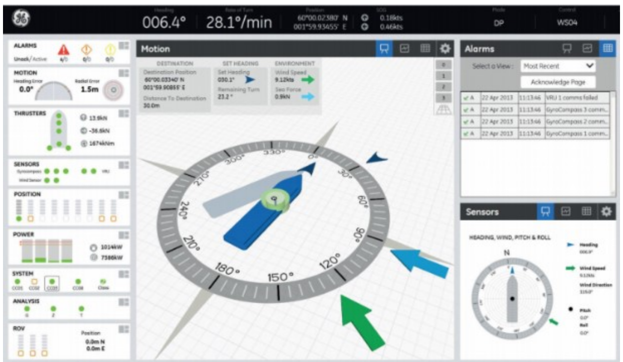

Fig 5. Ship's Dynamic Positioning System [7]

For marine charging stations on distant sea, their primary customers are battery-powered large ships. However, current battery storage technology does not allow for the creation of fully battery-powered large ships. As an interim solution, a hydrogen fuel cell powered ships could be developed. If marine charging stations are also equipped to produce and supply hydrogen through water electrolysis technology using nuclear-generated electricity and sea water to hydrogen fuel cell ship, they can be also utilized during the mid-course period when the ship's propulsion system is being changed.

2.2. Special considerations

In order to mount SMR on a marine platform and use it as a marine charging station, sufficient review is needed on the impact of the six free movements caused by the platform being above the sea. It is believed that the standards applied to the design of nuclear-powered ships will be used but, floating SMR marine charging stations should apply more conservative standards than nuclear-powered ships. If the sea weather in the area they are located in becomes challenging, nuclear-powered ships can leave the area. However, marine charging stations on floating SMR platforms do not have this option.

In the case of Russia's KLT-40S, artificial breakwaters were built around the platform to minimize the influence of waves. The floating SMR platform, which will be located in the open sea, cannot build a breakwater to block waves around it. Therefore, when designing the floating SMR platform, it should be made to withstand adverse environmental conditions by conservatively designing the structure and setting the safety evaluation criteria compared to nuclear-propulsion ships.

Utilizing a floating SMR platform as a marine charging stations depends on installing adequate ship electrical facilities. The power generation system using turbines has no choice but to generate AC power due to rotating machinery characteristics. However, most batteries are DC power. Therefore, AC-DC power conversion equipment should be considered in order to supply electricity from nuclear power generation to battery-electric ships at the marine charging station. In addition, efforts should be made to increase compatibility by establishing standards for electricity supply and demand facilities around the world in advance.

3. Conclusions

As the demand for reduced carbon emissions from maritime transportation increases, the propulsion systems will gradually shift from oil-based gas turbines and diesel engines to battery-electric propulsion. However, high-weight ships require too much battery, and their application can be limited.

The development of a marine charging station is essential to meet the growing demand for battery-electric ships. This is because concept of 'charging' can accelerate commercialization of battery-electric ships by reducing the required amount of batteries on board.

It is expected that the once proposed concept of marine charging stations using SMR, which is a small and eco-friendly generator, is developed and commercialized, the system will definitely help achieving zero carbon emission goal of shipping industry in the near future.

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