The 4th generation of Siemens fuel cell modules for submarine propulsion

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Abstract — Polymer-Electrolyte-Membrane (PEM) Fuel Cells are known for reliable and efficient conversion of chemical energy into electrical energy at low temperatures. The new fuel cell module BZM evo is a further optimized system from the SINAVY Fuel Cells series and already Siemens`s 4th generation. This article describes design principles, properties and operational characteristics of submarine fuel cells as well as key system components. The evolutionary innovative approach includes the option of an integration of the BZM evo modules into various applications besides the known AIP solutions.

1 Introduction

Comparative studies with various air independent propulsion (AIP) systems such as Stirling engines, closed cycle diesel and steam turbine systems in conventional (non-nuclear) submarines have demonstrated the clear superiority of fuel cells over combustion based technologies. The PEM fuel cell was selected to provide a new generation of submarines with an AIP system enabling heretofore unattainable performance in terms of submerged endurance and acoustic performance.

The PEM fuel cell technology developed and manufactured by Siemens in close cooperation with the German Navy and HDW (today ThyssenKrupp Marine Systems – tk MS) as the AIP system owner has been highly successful since over 20 years. Continuous feedback from the crews of operating AIP submarines which use the BZM34 and BZM120 has been extremely helpful for the optimization of the fuel cell plant. More than 10 MW fuel cell power is installed on conventional submarines today.

Building on the success of the previous BZM34 (Fig. 1) and BZM120 Siemens aims to combine the advantages of both module types and further optimize power density and user-friendliness of fuel cell plants on board of air-independent underwater vehicles with its new BZM evo (Fig. 2) fuel cell module. Additional drivers for the development were to reduce costs and space.

Fig. 1. The well proven fuel cell module BZM34

2 The BZM evo

A single BZM evo provides a nominal power of 40 kW. Future plants consisting of several single units will supply a maximum power of 320 – 480 kW into the grid without exceeding the footprint of an existing BZM34 or BZM120 plant.

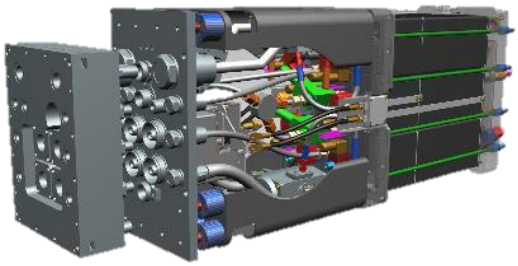

Fig. 2. The new BZM evo

In these fuel cell plants, the BZM evo modules are connected individually via DC/DC converters to the onboard power supply. This type of connection allows controlling the operation on the level of single modules.

The new concept improves the availability of the AIP plant by two facts:

- increasing the degradation rate of the entire fuel cell plant since single modules feed into the grid
- the optional integration of backup modules into the plant increases redundancy within the plant

Considering these facts, the supply of electrical energy to the onboard power grid is more reliable and flexible than with previous systems.

The new Fuel Cell module is considered an Integrated System which

- Improves power density
- Combines fuel cell modules and DC/DC converters
- Increases redundancy and provides for graceful degradation
- Reduces footprint for installation

- Allows rapid replacement by on-board stored spare modules (less than 5 hours)
- Applicable to both new construction and retro-fit installations

3 Future Applications

The evolutionary innovative concept of the BZM evo series can be integrated into various applications. In addition to the conventional operation inside AIP submarines, the compact module design also supports the integration of individual BZM evo modules into e.g. unmanned underwater vehicles (UUVs) (Fig. 3).

The power-output of a single module can be modified in a range from a view kilowatts up to 60 kW.

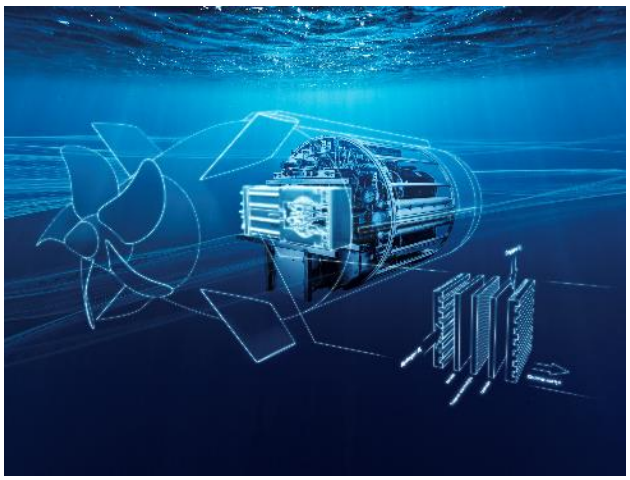

Fig. 3. Siemens' land based demonstrator inside a UUV application

Future submarine activities will be based on underwater drones which expand conventional submarine operations. Their mission profiles depend strongly on the available energy. Due to its advanced power density fuel cell systems allow longer missions than purely battery driven vehicles.
In addition to the energy aspect, a fuel cell system shows enormous advantages when it comes to low signatures compared to e.g. battery/diesel engine hybrids.

Unlike AIP systems for submarines, where most of the system components (balance of plant) are provided by tk MS, Siemens can now offer a complete UUV energy pack comprising the fuel cell module, the media storage and management, the operational control, a battery and the energy management.

The energy concept provides hybridization with batteries and can be adopted to volume and mission requirements. Process control and automation allows autonomous operation of the UUV Solution.

Initial system tests using a BZM34 from series production were completed successfully on land in 2018 in the U.S. (Fig. 4).

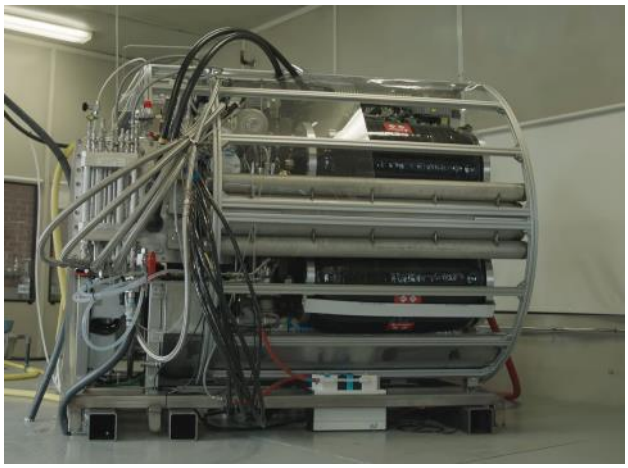

Fig. 4. Live demonstration running certain mission profiles

Another application is the air independent emergency propulsion (AIEP).
The idea is to incorporate a fuel cell system to replace conventional diesel engine driven generators in new nuclear-powered general-purpose attack submarine (SSN) designs as well as backfit on current submarines.

The advantages of the fuel cell such as lowest signatures and reliability put this technology into the focus of concept evaluations.

4 Conclusion

The BZM evo is a further optimized system from the SINAVY Fuel Cells family/series and already Siemens` 4th generation after utilizing the first 3 generations on the German submarine FGS U1, HDW class U212A, tk MS class 214, Dolphin AIP and others.

Finding its place both on conventional submarines and on future applications like UUVs or AIEPs will be Siemens' utmost concern for the naval market.

The BZM evo is designed to fulfill the requirements of new systems and retrofits of older AIP plants and should be available on the market from 2023, or a year earlier for UUV integration.