DC Hydrogen Micrograms

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The world needs to decarbonise difficult sectors like transport, energy storage, and shipping. Hydrogen has a vital role to play. Hydrogen microgrids will help to decarbonise these sectors and can assist in tackling related global challenges including energy and food security. A microgrid is an electricity-based energy system with internal control capacity and may be connected to or independent of the national grid. In a hydrogen microgrid, both electricity and hydrogen flows are managed, with conversion between them done using an electrolyser and fuel cell, for instance. DC microgrids have lower energy losses than conventional microgrids and are a natural choice for producing and managing renewable hydrogen and electricity together because photovoltaics, batteries, electrolysers and fuel cells are natively DC. Asynchronous rotary generators (e.g. wind, wave) generally include a DC stage ahead of conversion to the AC grid voltage and frequency.

While DC power transmission technology is already common in high-voltage networks, DC microgrids are still in development. The challenges include equipment compatibility and transients. Adding hydrogen adds to the challenges of energy management and energy storage control.

Overcoming the technical challenges to building DC hydrogen microgrids is important because they can help with a range of problems, including long-term energy storage, renewably produced ammonia fertilisers, and decarbonising marine vessel fuels, islands, ports, mining and food production. The Blue Economy is a particularly promising sector for applications of DC hydrogen microgrids.

This project examines the challenges to building pure-DC hydrogen microgrids and looks for possible solutions and opportunities (Figs 1 & 2). Research methods used include literature review, simulation studies and building a bench-scale DC microgrid (Figs 3 & 4) in which an electrolyser and fuel cell are emulated by a programmable load and programmable power supply respectively, each controlled by means of a Simulink model. The project is linked to the major demonstration project being carried out by the Blue Economy CRC to build a hydrogen microgrid at first onshore, with a 700-kW electrolyser, then offshore.

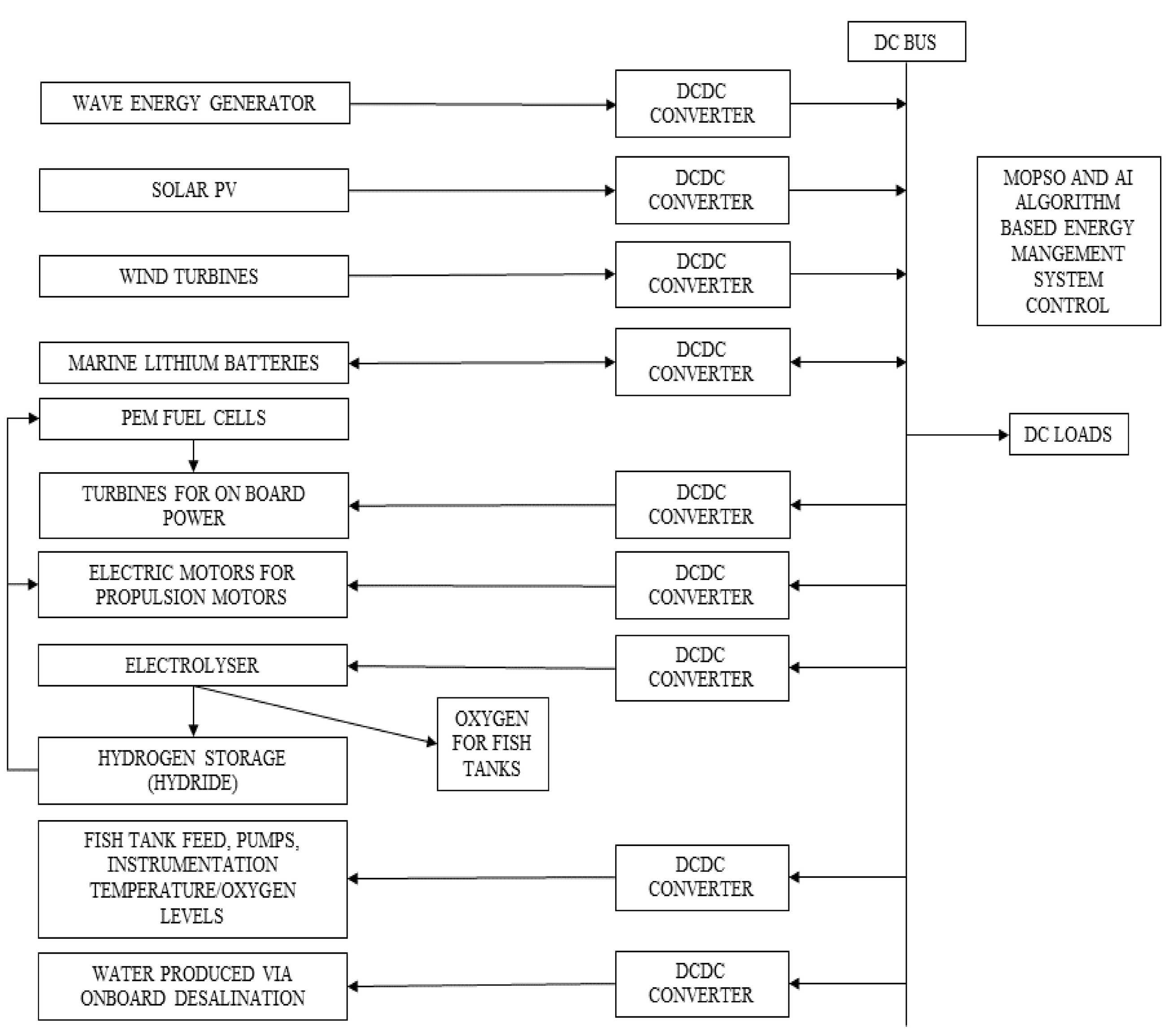

Figure 2: Proposed hydrogen-powered marine vessel for aquaculture powered by a DC hydrogen microgrid

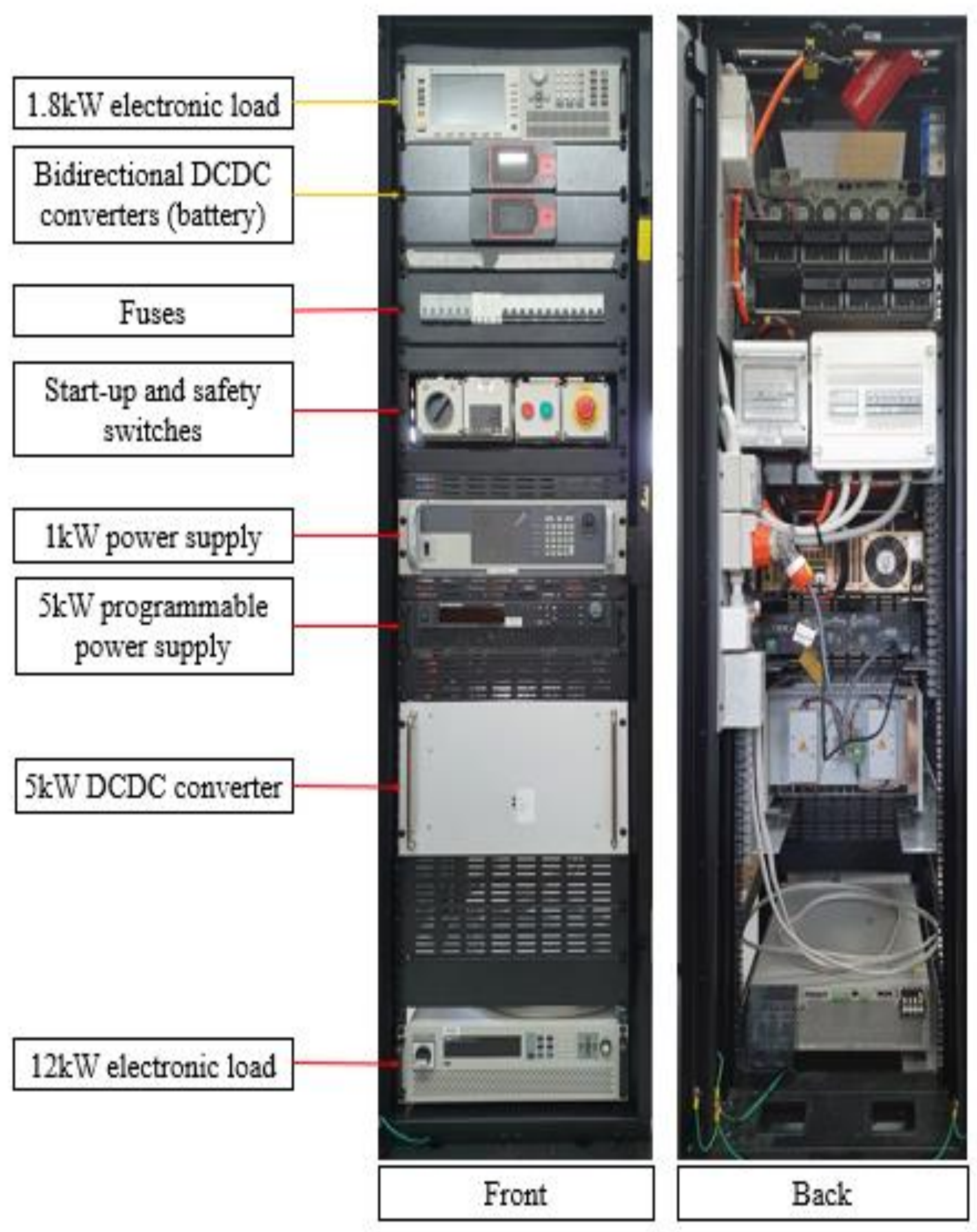

Figure 4: bench-scale DC hydrogen microgrid under construction

Bench-scale DC hydrogen microgrid

The immediate context of the project is offshore renewable energy, emphasizing integration of green hydrogen with offshore industries such as aquaculture. The research results will have much wider application.

The microgrid is built around a 38-volt DC bus with generators and loads connected via commercial DC-DC converter, exception the directly connected 12-kW programmable load that will be used to emulate the electricity end-use profile. Physical batteries (22.5 kWh) are connected via bi-directional DC-DC converters. The PV, wind and wave are emulated by programmable power supplies, as is the fuel cell. Hydrogen storage is emulated in software and the electrolyser is emulated by a programmable load.

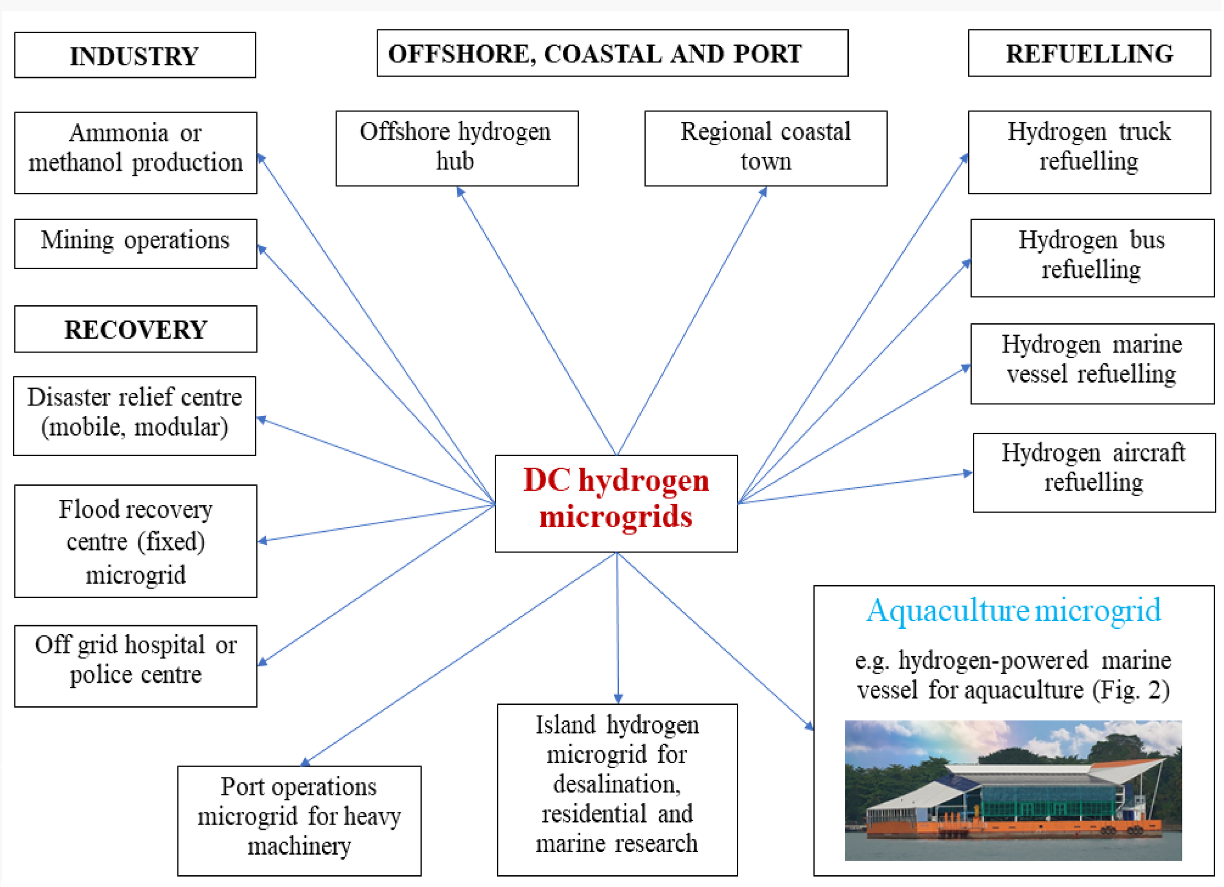

Figure 1: Radial diagram of DC hydrogen microgrid uses from literature review

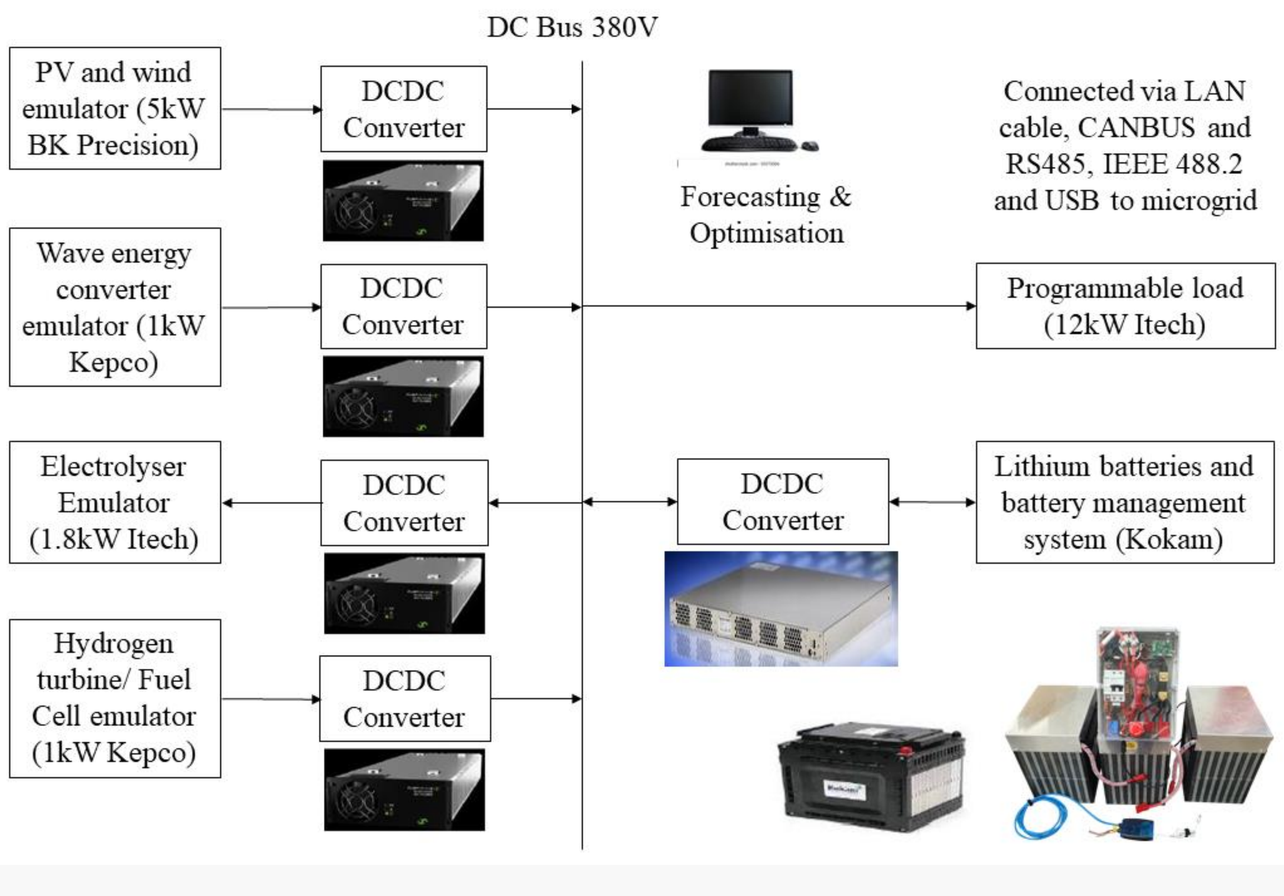

Figure 3: Bench-scale DC hydrogen microgrid architecture

Summary

As the world looks toward improving the health and further utilising the resources of the oceans, we must design new systems to sustainably produce and use energy in the ocean, environment including hydrogen.

Multiple promising applications for DC hydrogen microgrids in the blue economy are apparent, including offshore platforms for industry, vessels and ports (e.g. bunkering, cold-ironing), and food production (e.g. fish and seaweed farming). Numerous challenges need to be overcome, including the technical and engineering problems associated with building hydrogen microgrids and locating and operating them offshore, authoritative technoeconomic modelling and optimising microgrid designs to be both affordable and sustainable. The present project in development addresses some of these issues and provides an experimental platform for testing strategies for control and energy management in hydrogen microgrids.

Acknowledgement

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