SOEC-alkaline hybrid electrolyser promises boost for low-cost green hydrogen

By Stephen B. Harrison, sbh4 consulting


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An emerging Australian start-up is eyeing piloting partners for its new electrolysis technology that combines elements of solid oxide and alkaline systems, which it says could represent a paradigm shift in making green hydrogen more affordable.

Melbourne-based Cavendish Renewable Technology (CRT) believes its 'C-Cell' electrolyser can achieve a stack efficiency of 41.55kWh per kilogramme of hydrogen, combined with low-cost manufacturing, minimised balance of plant (BoP), and high cell durability.

Furthermore, it says the system is scalable and can precisely follow loads of variable renewable power and slashes the cost of direct connection to photovoltaic solar electricity.

"Our test results have shown that we have a winning technology which will materially reduce the LCOH. We are eager to break out of the lab and set up a pilot plant," CEO Anirudha Kulkarni, told H2 View's Editorial Advisory Board member Stephen B. Harrison. "We are scouting for piloting partners and collaborators to demonstrate our C-Cell in the real world."

CRT is no newcomer to electrolyser development. The team has designed and scaled pressurised alkaline and AEM electrolysers to industrial-sized cells and stacks, with AEM cells reaching up to 5,000cm² active area – among the largest AEM electrolysers by cell format.

The team has also played a key role in taking technologies from the lab to market. The C-Cell is CRT's third moonshot.

"We are very cautious about our public announcements," Kulkarni stated. "I stipulate that our products must endure thousands of hours of tests before we go public with our claims. We want to be creating credible solutions, not simply making noise."

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A new electrolyser classification

C-Cell represents a new class of electrolyser. It is based on a similar concept to an anode-supported solid oxide electrolyser cell (SOEC) technology, where a ceramic membrane is supported on a metal substrate, but uses an electrolyte similar to that of alkaline systems.

Conventional electrolyser innovation has been incremental, forcing compromises between capex and efficiency or between durability and operational flexibility. However, CRT claims to have "broken" that paradigm.

"There is no longer a need to trade-off capex, opex, flexibility and stack life. Our C-Cell, has broken the paradigm: we have improved all four attributes in harmony," Kulkarni stressed.

The thickness of the membrane coating is less than 100 microns – thinner than state-of-the-art alkaline diaphragms, resulting in lower ohmic resistance.

The membrane electrode has a high surface area to catalyse the oxygen evolution reaction. This is generally the rate-limiting step of classical alkaline electrolyser designs. Overcoming this hurdle has been a breakthrough that sets the C-Cell in a class of its own. The electrodes also have low kinetic resistance.

Unlike SOEC or PEM, the C-Cell uses an alkaline electrolyte, or lye. The alkalinity used in the C-Cell lye is somewhere between conventional alkaline water electrolysis and the emerging anion exchange membrane (AEM) technology.

This is so the electrolyser can operate between 100°C and 150°C. The elevated temperature results in higher electrical conductivity of the lye and improved reaction kinetics. Pure water used in PEM faces temperature limitations, while alkaline diaphragms become unstable at high temperatures.

This operating temperature is also achieved without external waste heat integration. All the heat is generated in situ, in operation, to achieve an efficiency of 41.55kWh/kg H_2 – far below the 50–55kWh/kg mark of typical PEM systems.

By going to high temperatures, CRT says it can achieve a current density of 0.6A/cm² at 1.55 volts, meaning it can produce more hydrogen from a similar-sized system than other solutions.

Moreover, CRT says cheaper membrane fabrication methods compared to traditional membrane casting processes, as well as a design which enables manufacturability and ease of assembly, will substantially reduce capex.

Kulkarni said that "with high current density and small stacks, users win twice: with compact size and reduced materials requirements. These lead to capital cost savings."

Solar-powered potential

The majority of PEM, AEM and classical alkaline electrolyser stacks are built with multiple cells in series. The voltage drops from one end of the stack to the other, limiting the maximum stack size. Another limitation is that the entire cell must be ramped up and down as a single unit. This limits the operational flexibility of the electrolyser.

In contrast, the C-Cell stack will be configured with a modular design where each module is built of several hundred C-Cells and is connected in parallel. Turndown can therefore be achieved through turning off modules within the stack, in addition to turning down the current.

"In the laboratory, we have demonstrated that each cell can turn down to only 7% of nominal load and maintain better than 99% oxygen purity," Kulkarni claimed. "Our CFD modelling indicates that at a cell level, turndown to 20% of nominal capacity will be achievable at scale.

"However, implementation of our modular design will result in an unprecedented degree of operational flexibility."

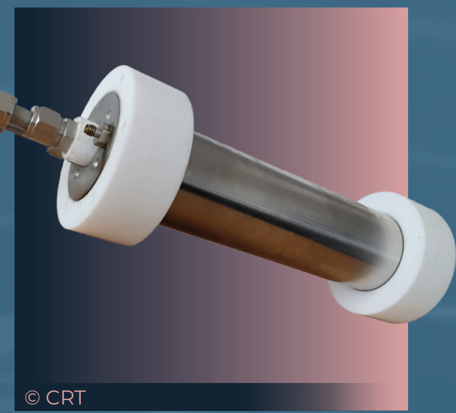
The benefits of this operational flexibility mean that the C-Cell will align with variable and intermittent renewable energy such as solar. Furthermore, it will be able to run intermittently and exploit short periods of negatively priced power to produce low-cost green hydrogen.

The modular design also simplifies direct connection to solar electricity. Solar power is produced as DC, not AC. And electrolysers want DC power, not AC. However, conventional solar-powered electrolyser schemes must use a DC to DC converter to provide power at the required voltage for the electrolyser.

C-Cell, and its preference to operate with higher voltages, enables a significant reduction in the cost of the DC to DC conversion equipment. This improves the business case for solar-powered hydrogen generation.

Pathway to commercialisation

At present, the C-Cell is operated at 5 barg in CRT's development environment. This pressure could be increased to the industry standard pressurised alkaline electrolyser operating pressure of 15 barg.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Kulkarni confirmed that there is no electrochemical limitation on the operating pressure. Instead, the limit is governed by the structural integrity of the stack and the required pressure testing to achieve safety certification."

The temperature of operation can also be increased. With an appropriate lye concentration and pressure, operation at up to 200°C may be possible. CRT has plans to validate this hypothesis through its R&D programme. The benefit would be that with waste heat input to sustain the higher temperature, the efficiency would be further improved, resulting in reduced power consumption and operating costs.

CRT is committed to focusing on what is unique about its work. Kulkarni said, "Corporations with a depth of cash and resources can support us with component production and scale up. What we do best, and will continue to focus on, is pursuing innovations that will transform green hydrogen's prospects for the better."

CRT's C-Cell IP protection strategy focuses on the unique key to the success of their C-Cell: how the membrane-electrode is manufactured to achieve the necessary performance transformation through low cost and ultra-high efficiency.

The 'secret sauce' can be leveraged to produce highly durable AEM and PEM membranes. This is more than a hypothetical wish; CRT has already proven that the base structure can be used to support Nafion, a popular PEM electrolyser membrane polymer. H2V