Project Title

Solid Oxide Electrolysis System Demonstration

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Program: Advanced Reactor Development Projects Pathway

ABSTRACT:

FuelCell Energy Inc. (FCE) is teaming with Idaho National Laboratory (INL) on a solid oxide electrolysis cell (SOEC) system demonstration, verification and validation (V&V) project, in response to Funding Opportunity Number: DE-FOA-0001817, *U.S. Industry Opportunities for Advanced Nuclear Technology Development*, within Pathway 2 - Advanced Reactor Development Projects. The project deliverable is a 250 kW SOEC turn-key sub-scale system with ultra-high efficiency and low cost. It will be critically verified and validated (V&V) through collaboration with INL, to the nuclear industry, that the FCE-SOEC is ready to integrate into the nuclear environment. FCE's proprietary ***C***ompact ***S***olid Oxide ***A***rchitecture (CSA) stack and system technology serve as *the enabler* for cost-competitive hydrogen production. Successful achievement of the project objective will provide a direct line of sight to advances in the innovation and particularly *economic* competitiveness of hybrid, nuclear-hydrogen production operations that will help present Light Water Reactor (LWR) and future advanced nuclear reactor plants diversify and increase their profitability by switching between electricity production and hydrogen generation. This result will serve as an enabling technology to reverse the current trend of nuclear plant curtailment or closure due to the historically low cost of natural gas and the build-up of renewable energy in some regions of the country.

Importantly, after verification testing at INL, this system will be available to support future hydrogen production demonstrations at nuclear plants to allow those demonstrations to focus on the thermal and electrical integration, rather than repeatedly spending project resources on electrolysis cell manufacturing. This system will be equipped with an electric steam generator, so that it can be used in nuclear demonstrations that only feature an electrical connection in applications where thermal energy is not available for integration. In this way, this multi-use demonstration system will be able to bridge the gap between (i) low temperature and (ii) high efficiency, high temperature electrolysis demonstrations to allow convenient and rigorous comparison between the merits of both systems. As such, a parallel objective of the project is to provide the physical test data that is needed to establish the business case for producing hydrogen using both electricity and steam from nuclear power to maximize system efficiency and flexibility

To meet accelerating market demands, the proposed project has been structured by FCE as a *subset* of a larger, multi-phased, public-private strategy to commercialize high efficiency SOEC technology. This approach represents an economical, near-term solution to meet the nation's energy, environmental, and national security needs by simultaneously supporting the markets for advanced nuclear reactor designs, the present LWR fleet, as well as carbon-free, clean hydrogen demand for non-nuclear applications, including power, chemicals and fuels. These define parallel, complementary and additive applications that will critically grow the demand base for solid oxide stacks/systems, to quickly *drive SOEC system costs down for the nuclear integration applications*, ensuring successful, sustained *commercialization* of SOEC technology *at a pace aligned with the nuclear industry's needs.*

The multi-phase, aggressive plan is consistent with the INL/EERE-FCTO nuclear-hydrogen timeline. The project will result in delivery of a 250kW SOEC System for the nuclear environment within two years. Following successful completion of the project, the FCE-INL team will be well positioned to rapidly scale up for delivery of up to 200MW SOEC utility scale systems before 2026 (including an FCE design that enables 1 GW of electrolysis to fit on a 1 acre site).

To achieve these objectives, Phase 1 project execution is structured within six tasks, including:

- Task 1. Project management and planning: reporting and deliverables
- Task 2. Electrolysis stacks: stack manufacturing and factory verification/quality assurance tests
- Task 3. System design: electrolysis module design, process, mechanical and electrical design, and INL facility design/modifications, including preliminary development of a high level controller for the SOEC system
- Task 4. System component fabrication: electrolysis module fabrication, and balance of plat (BOP) component fabrication
- Task 5. System assembly and controls: system controls development and programming, SOEC stack delivery and support, system assembly and checkout
- Task 6. Operation at INL: 250 kW SOEC facility preparation, system installation and commissioning, verification and validation (V&V) demonstration in which the FCE-developed controls will be connected to a custom high level controller that will be developed and implemented by the Project to simulate grid conditions with the FCE SOEC System acting as power hardware-in-the loop.

Aligned with DOE and industry goals and objectives, the V&V demonstration will show technical feasibility of dispatching electricity between the grid and the electrolysis units, to help establish the potential value of load, volt-ampere reactive (var) power, and frequency regulation by light water reactor (LWR)-hydrogen hybrid plants. This will provide utility commissions, regional grid reliability organizations, and balancing authorities with the data necessary to valorize LWR/advanced hybrid plants in both regulated and deregulated electricity markets.

The proposed work is supported by recent techno-economic analyses and 20 years of SOFC/EC and reversible SOFC (RSOFC) energy storage development, from fundamental R&D through systems development. This solid technological base has shown that FCE's SOEC technology is uniquely positioned to supply hydrogen at unsubsidized, economic prices that are competitive with fossil fuel-based steam methane reforming. Importantly, and in contrast to alternate electrolysis technologies (such as PEM), the critical cost targets can be achieved in the near term without major materials and manufacturing research programs to enable breakthrough efficiency and cost reductions. Instead, combined with FCE's 50 years of high temperature fuel cell system commercialization experience, this program is de-risked, and SOEC holds the promise of achieving accelerated mass-market penetration and jobs-growth via maturity-development in manufacturing/quality scale-up and a staged sequence of system demonstrations.

Finally, this project will not only verify and validate FCE's modular SOEC System for commercial readiness; it will also provide the Front End Engineering basis for determining how full-scale LWR hybrid systems can be operated without adversely impacting the safety and reliability of the nuclear plant. This will therefore provide a basis for licensing many types of integrated energy systems that can expand commercial market opportunities for LWRs and for future advanced reactor designs. Furthermore, because this technology can soon be price competitive with current carbon emitting hydrogen production methods, it can enable a new paradigm of economic US de-carbonization via SOEC-hydrogen to transform the electricity, industrial and transportation sectors -- starting with hybrid, nuclear-hydrogen production with increased profitability.