"Advanced Power Controls for Hydrogen Hybrid Microgrids (HHMs) with Thermal Storage"

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ABSTRACT

The Hydrogen Hybrid Microgrid (HHM) is a resilient and scalable power generating plant comprised of a (NG) turbine, a compressor, a NG reformer, a Solid Oxide Electrolizer Cell (SOEC) and a Solid Oxide Fuel Cell (SOFC) that runs off of hydrogen, which the HHM produces on-site with carbon-based fuel stock, most frequently natural gas. The HHMs are designed for distribution utilities, military and commercial use.

The advanced power controls being worked on by the RPW and NETL team are called the ***"Precision Power Platform"*** (PPP) and they involve integrating (and monitoring) dynamic, supervisory and cybersecurity functions; these controls have multiple capabilities that will enable the national grid to become more resilient, more distributed in nature and cleaner.

Keywords: Hydrogen, Hybrid Power, Solid Oxide Fuel Cells (SOFC), Resilient, Cybersecurity

1 THE HYDROGEN HYBRID MICROGRID (HHM) CONFIGURATION & COMPONENTS

The hybrid power generation system provides clean, reliable base power; this hybrid generating configuration is powered by hydrogen, and not by burning natural gas (NG) directly in a turbine. Instead, the NG is used to produce hydrogen on-site; the SOFC utilizes thermal storage and powers the turbine with a compressor on the same shaft. This results in high-efficiency fuel conversion (<70%) with a minimal carbon footprint. The HHM is scalable and versatile.

1.2 Renewables can be added to the Hybrid Generator providing the Baseload Power

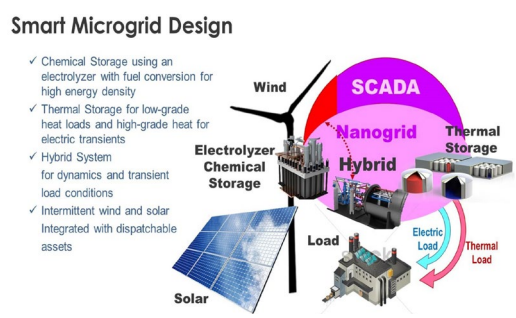


Figure 1. The Hydrogen Hybrid Microgrid

"Smart Microgrid Design incorporating Renewables with Hybrid Baseload"

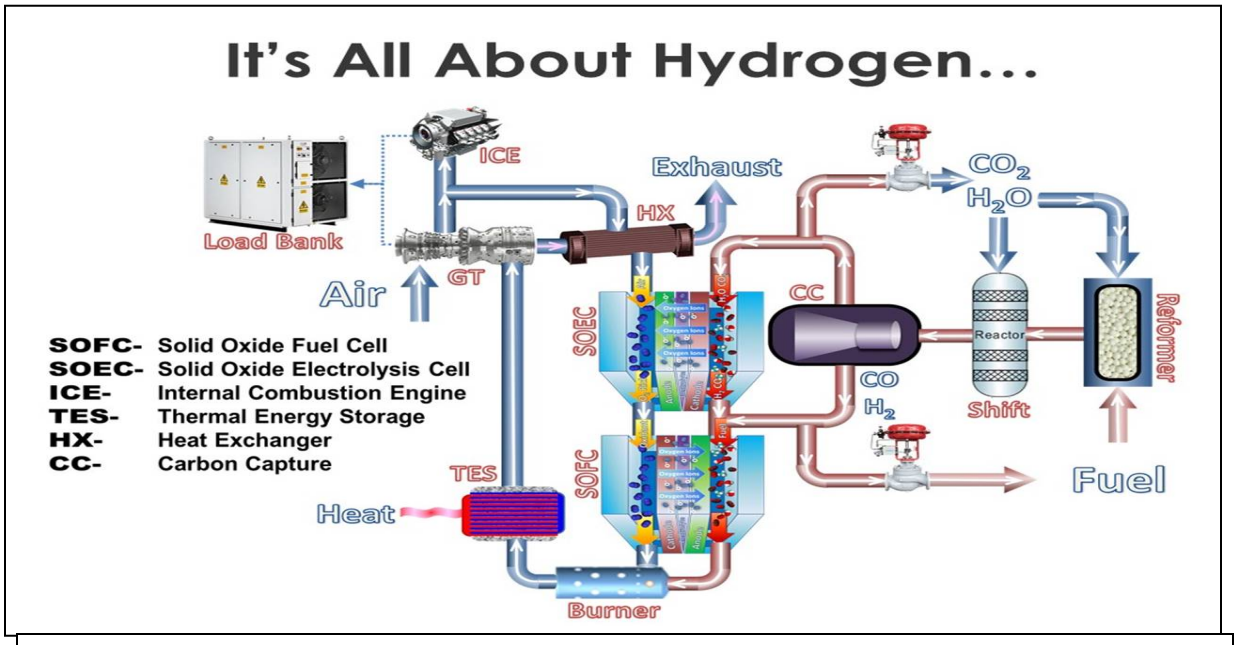
Features include (1) Chemical Storage using an electrolyzer with fuel conversion for high energy density and (2) Thermal Storage for low-grade heat loads and high-grade heat for electric transients. Intermittent energy sources integrated as needed.

1.3 Hydrogen Power provided by a Natural Gas Reformer is the "Keystone" to Success

This HHM power station can produce its own hydrogen. With the hybrid configuration that has been demonstrated and tested in the NETL HyPer Lab, using numeric and cyber-physical simulations, this dynamic system can produce other ancillary benefits, including optimizing fuel consumption within each

HHM. And a long-term goal is to produce the advanced power controls that would enable several HHM power stations to operate in a network – in synchrony or dependently – providing unsurpasssed localized low cost spinning reserves, as well as providing the distribution utility with additional black-start capacity.

(2) Remarkable ramp-up speeds for the turbine/compressor combination – making the HHM a superb power source for microgrids
(3) Low-cost Spinning Reserves for the Host Utility



It's All About Hydrogen: The Hydrogen Hybrid Microgrid Fundamentals
(#1) SOFC = Solid Oxide Fuel Cell (#2) SOEC = Solid Oxide Electrolysis Cell
(#3) ICE = Internal Combustion Engine (#4) TES = Thermal Energy Storage
(#5) HX = Heat Exchanger (#6) CC = Carbon Capture

2. The "PRECISION POWER PLATFORM" ("P3"): Value-Added Benefits to the End-User & Operator/Utility

Dynamic, supervisory and cyber-security controls integrated into one Control Package.

Advanced power controls permit/enable the HHM Unit operate either as a stand-alone (islanded) or as an enhancement to a bulk-grid feeder. Some of the many advantages of HHM to other on-site generators and microgrids include:

(1) The extension of the life of a SOFC of up to seven times the current useful life (of roughly two years to fourteen), (3) (9)
(4) Designed for load-following capability – suitable for smart grid applications
(5) Designed to incorporate "plug-and-play" add-ons, such as a block-chain based cyber-security system (under development – BLOSEM Project at NETL/DOE (7)

2.1 Extended Capabilities: Augmentation

Capacity to increase the compressor efficiencies beyond the current 80% - greater stability as the hybrid is approaches the "stall line"

Any excess energy (both heat and electricity) from the Hybrid System can be converted to fuel using the SOEC (Electrolysis Cell) and either (a) a Fischer-Tropsch process or (b) an HZSM catalyst.

3. RESOURCES BUILDING THE BUSINESS CASE FOR THE HYDROGEN HYBRID MICROGRID

Hydrogen is gaining importance as a fuel for both utilities and industry (4) and is a top priority for the US Department of Energy (DOE) as a future fundamental energy source in the quest to achieve a carbon-free electric grid (5); the first major initiative is aimed at making hydrogen more affordable and accessible, through the EarthShot program.

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