H2-PACE

Power And Control Electronics for Hydrogen Technologies

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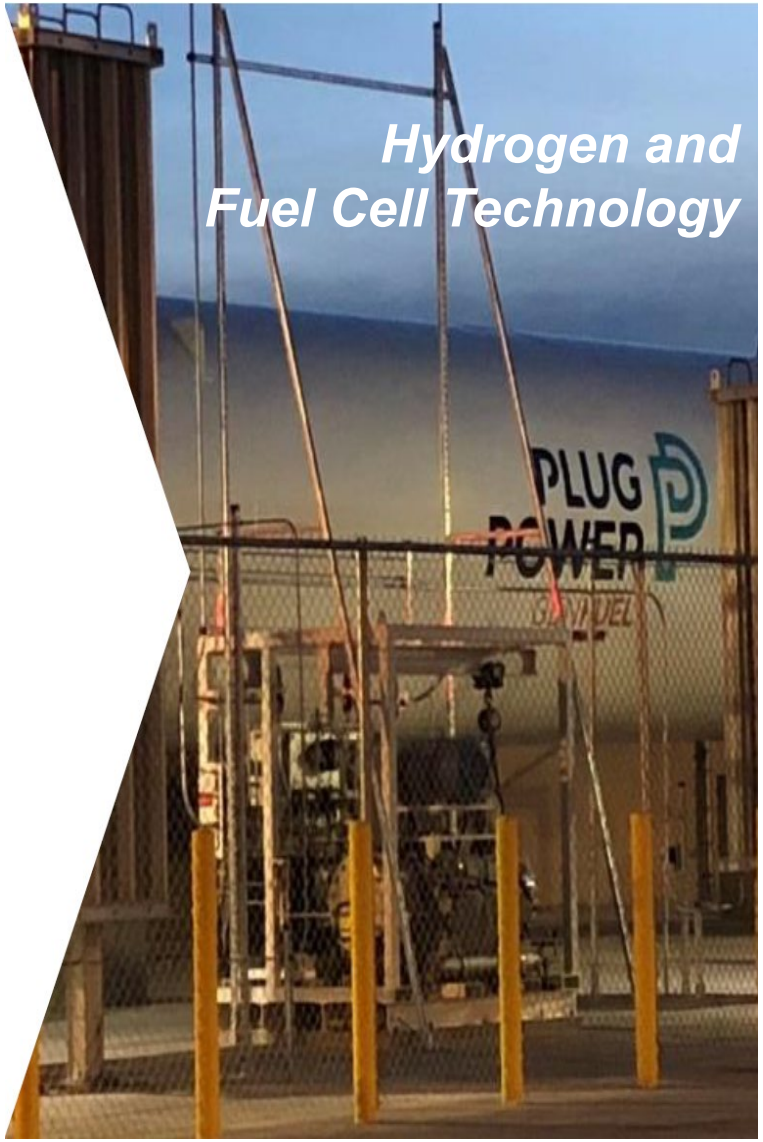
Company Overview

- Plug Power is a global leader in the design and manufacture of Hydrogen and Fuel Cell Power generation systems
  - **Electrolyzers** for Hydrogen generation
    - Electrolyzer system pipeline: 1, 5, 10, and 20MW systems, and GW by 2025
  - **Fuel cells** for Power Generation
    - Material Handling, 52,000+ fuel cell systems in the field
    - Mobile & Stationary Power Generation
      - Large-Scale Stationary Line: 250kW, 500kW, and 1MW FC Modules
  - **Hydrogen Dispensers & Refueling Stations**
    - 165+ Fueling stations built
  - **Hydrogen Liquification Plants & High-Pressure Storage Facilities**
    - 40+ tons of liquid hydrogen used daily
    - Largest consumer of liquid hydrogen in US



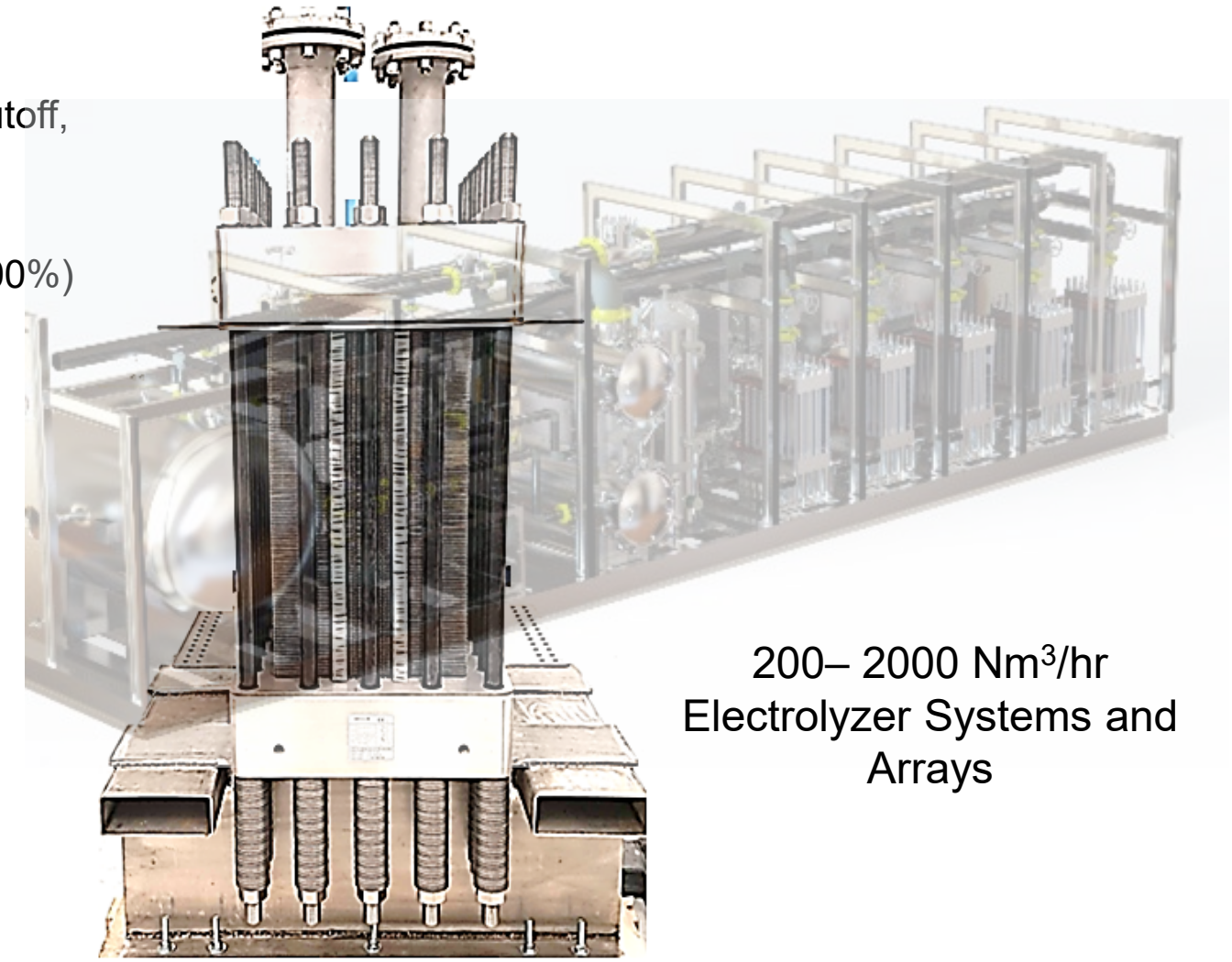
Electrolyzer Technology/End Uses/Scale

Technology Features

- PEM-Based Electrolysis Stacks and Systems
- Operating modes: Continuous, periodic turn down/shutoff, load following
- Operating Range (High Current Density Stacks)
  - Current - 3,750 to 6,000 A, Operable range (0-100%)
  - Voltage – 300 to 1500VDC depending on stack configurations
  - Operating mode: Current and Voltage Control
- Required power supply ranges: 1 to 10MW

Technology/End-uses/Scales

- Power to Gas (Biogas)
- Power to Mobility (P2M)
- Grid Load-leveling - Ongoing broad development of the solar & wind energy sector. Large reserves of stranded energy (need to store/shift)
- Hydrogen for Industrial use



200– 2000 Nm^3/hr Electrolyzer Systems and Arrays

Current Rectifier Technologies for Electrolyzers

RECTIFIER TYPES USED TODAY		
SCR Thyristors	**IGBT Chopper**	**WBG**
Silicon Controlled Rectifiers	**Insulated Gate Bipolar Transistors**	**Wide bandgap semiconductors**
PROS		
■ Good current control ■ Low cost ■ Reliability/Low Maintenance ■ Fast Response ■ Efficient: Up to 99.5% (at design load)	■ High frequency operation ■ Compact size & reduced weight compared to SCR ■ Smaller snubber circuit requirements ■ Reduce requirement for harmonic filter and power factor compensators ■ Easier to conform to IEEE 519	■ High Efficiencies ■ Higher Voltage Operation (improved performance) ■ Higher Frequency leading to more compact/ smaller footprint than IGBT or SCR ■ Higher operating temperature (lower cooling requirements)
CONS		
■ Generate current harmonics and reactive power when operated below design load ■ Typically require the use of harmonic filters to comply with IEEE 519 and a capacitor bank to clean out the reactive power (power factor correction) ■ Can not be used at high frequencies	■ Higher cost than SCR ■ Can't block high reverse voltage (Diode Requirements)	■ High cost (newer technology) ■ Requires new material designs that can withstand high temperatures

PACE (Power Electronics -Controls/Diagnostics)

Current Status & Needs

- Low harmonic feed back
  - Eliminating use of power filters & pF compensators
  - Requirements < 1% THDi for microgrids
- Reduced size & weight
- Improved efficiency at all load conditions, > 97%
- Improved thermal management
- Cost reduction
- Stack voltage monitoring
  - High common mode voltage capability

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Thank You!