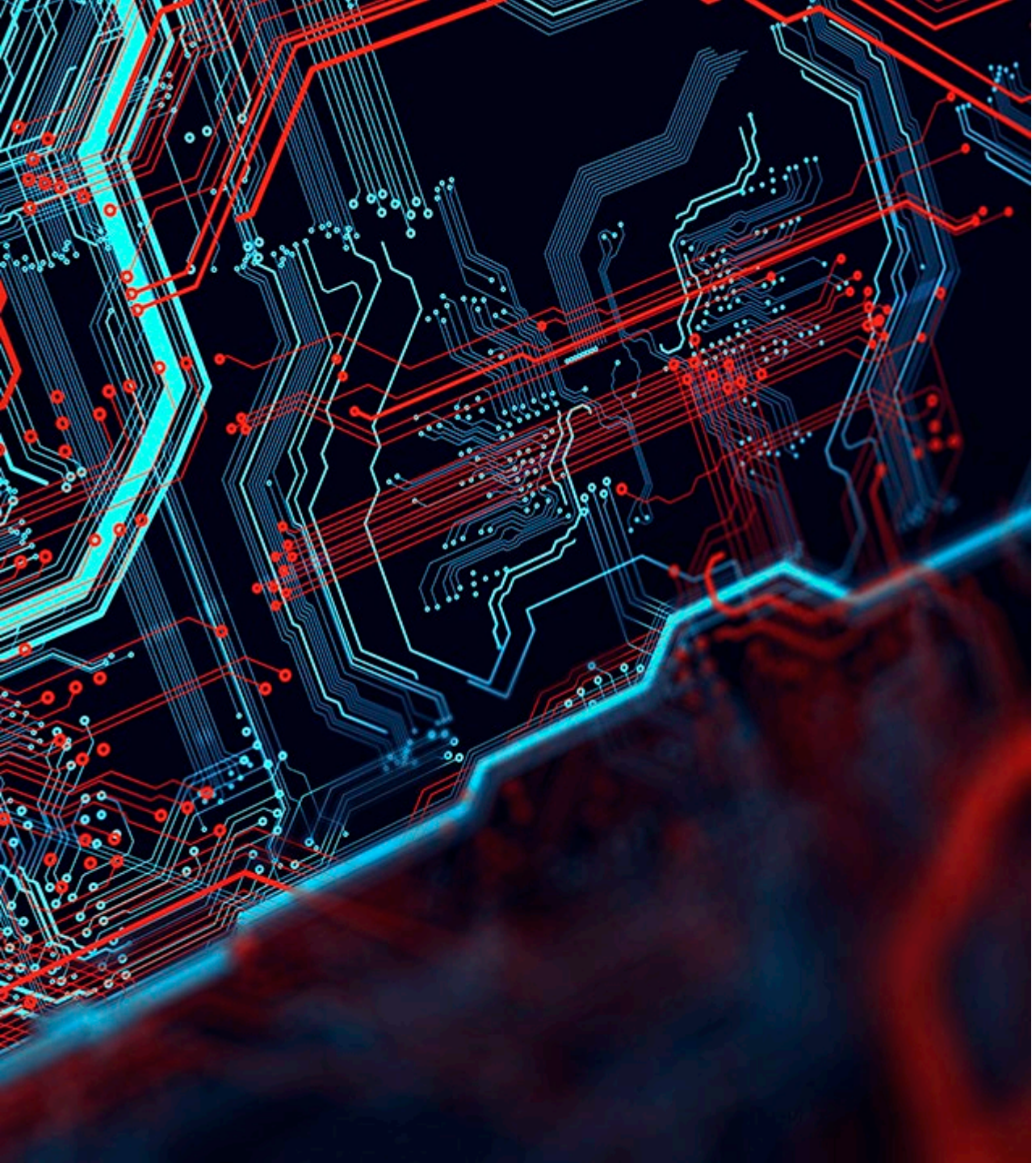


Power Electronics for SOFC in Stationary Applications

Minyu Cai
Cummins Corporate R&T
Electrification Technologies

Dec 02, 2021

About Cummins Inc.

- A global power leader that designs and manufactures diesel engines, alternative fuel engines, electrical generator sets, hybrid and electric platforms, and related technologies (batteries, fuel cells, hydrogen generators and hydrogen tanks).

Engine

Electrical generation set

Battery

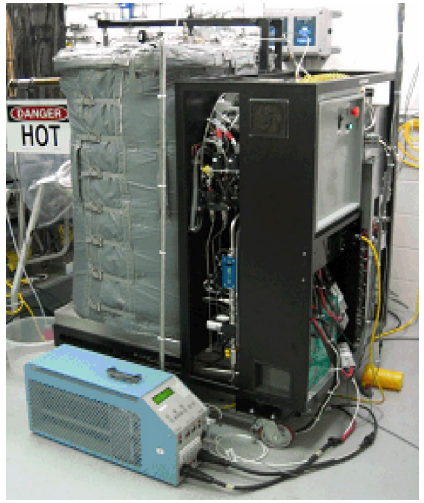
Hydrogen generator (electrolyzer)

Hydrogen storage

PEMFC	SOFC
Transportation • Truck • Transit bus	Stationary • Data center • Microgrid • Utility

Cummins SOFC History

- US Department of Energy (DOE) awards
  - 2002-2007: SECA* program, 5 kW SOFC system
  - 2004-2009: EERE** program, 1.5 kW SOFC vehicle auxiliary power unit (APU)
  - 2016-2020: $5 million project with Ceres Power to develop a Steel Cell SOFC for data center
  - Since 2020
    - $2 million to investigate a reversible solid oxide fuel cell
    - $5 million to automate solid oxide electrolyzer cell (SOEC) and stack assembly
    - **$2.6 million to build a 20kW SOFC power system**



SECA* program SOFC system

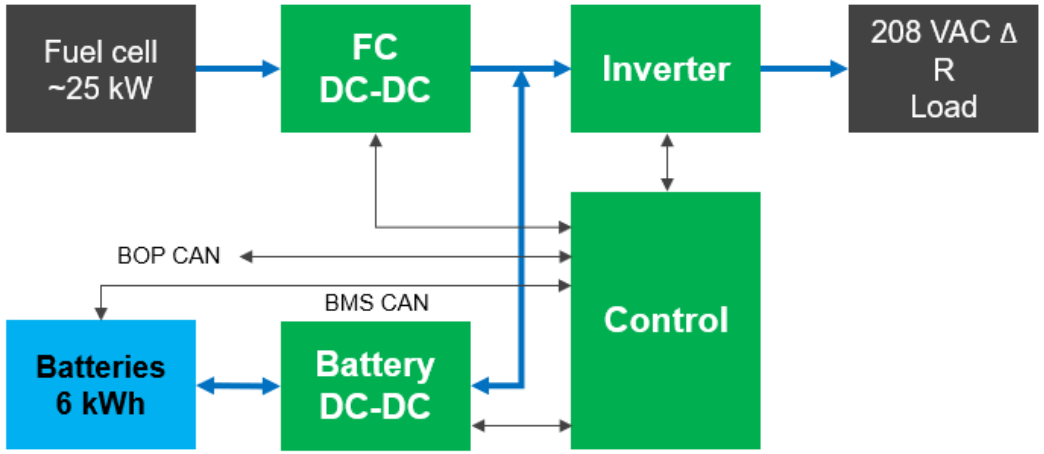
*Solid State Energy Conversion Alliance

EERE program SOFC system**

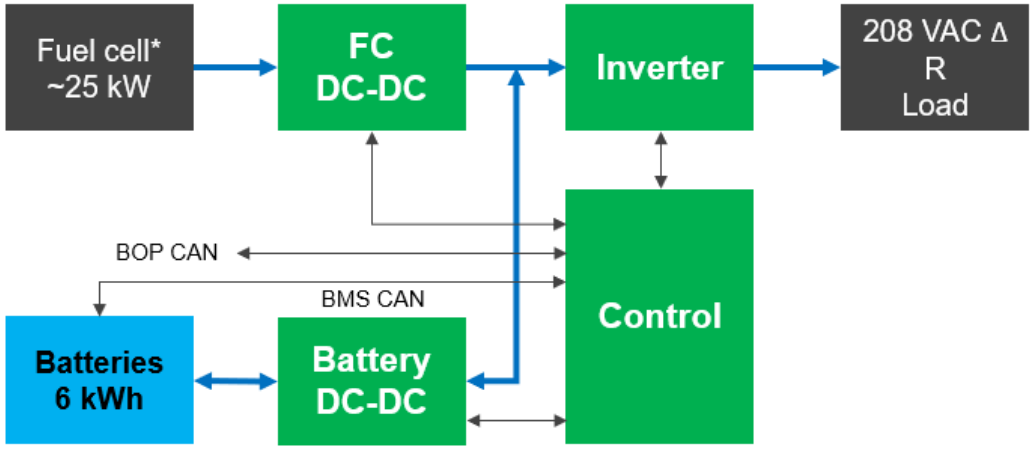
** Energy Efficiency and Renewable Energy

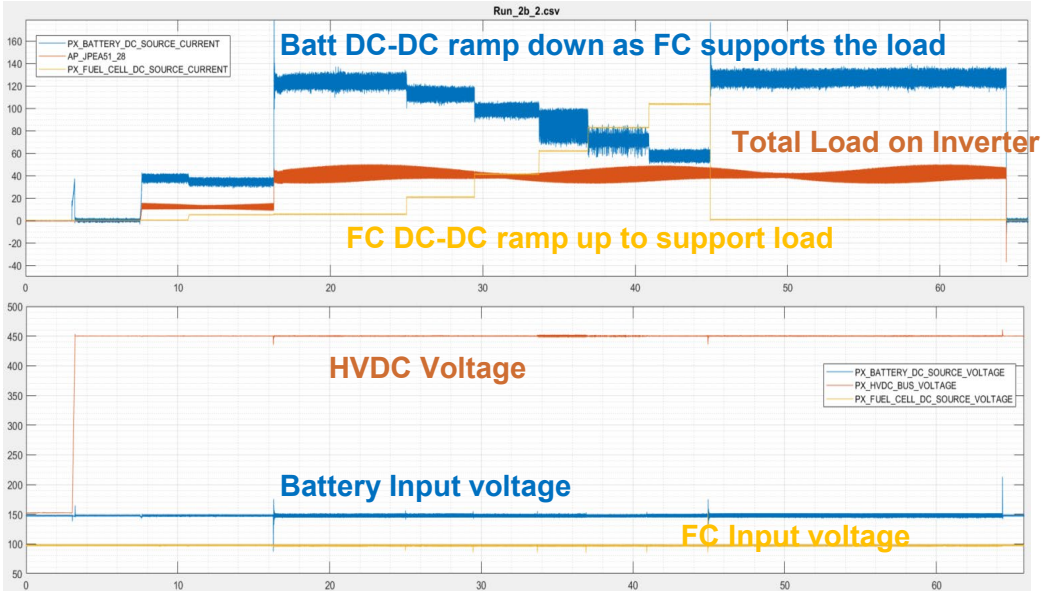
20kW SOFC Power Electronics System

- Inverter output: 3-phase, 20 kW @ 208 $V_{ll,rms}$, 60 Hz
- Fuel cell DC-DC: 20 kW boost only
- Battery DC-DC: 20 kW boost (discharging), 6 kW buck (charging)
- Common DC bus voltage: 450 V
- Cooling: air-cooled
- Data center server load
  - Continuous load 30% - 40% rated capacity
  - Transient load can be significant



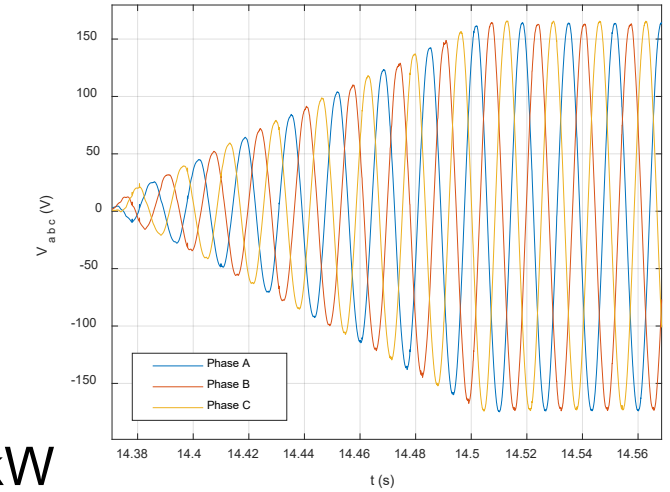
20kW SOFC System Operating Modes



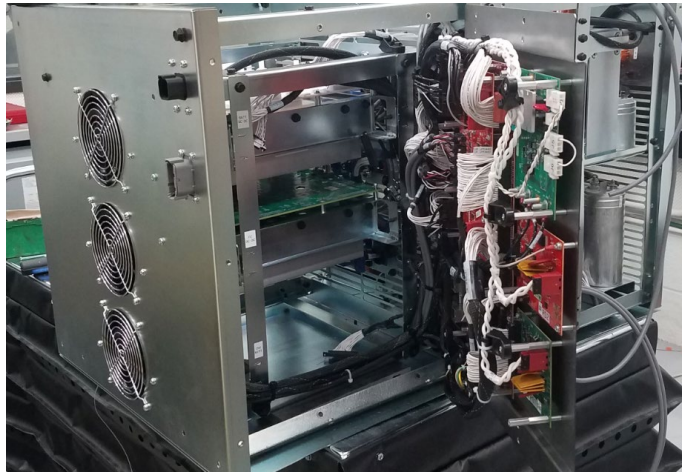


FC* and battery sharing load

- **Idle Mode**
  - FC charges battery
- **Derate Mode**
  - Only battery supports the load
  - FC can startup gradually
- **Run Mode**
  - Both FC and battery support the load based on FC power availability
  - Battery can support transient load (6 kW within 20 ms)



Inverter output voltage



Air-cooled integrated PE system

*Fuel cell is simulated by a DC power supply

Challenges for SOFC PE

- Fuel cell module
  - Fuel cells from different manufacturers have different output characteristics. Need customized DC-DC converters.
  - Grounding the negative terminal or not affects isolation requirement.
- Control
  - Communication protocol: CAN, Ethernet, …
  - Centralized vs distributed control
  - Application-related control: islanded, microgrid, grid-tied
- System architecture (take data center as an example)
  - “Fuel cell at the rack” (15-60kW) vs “fuel cell at the row” (200-300kW)
  - DC vs AC system
  - 1Φ vs 3Φ AC
  - Redundant design
- Target
  - Lifetime, Cost, Power Density, Efficiency, Reliability, Serviceability

Q+A


Cummins