Power Conditioning Systems for High-Megawatt Fuel Cell Plants

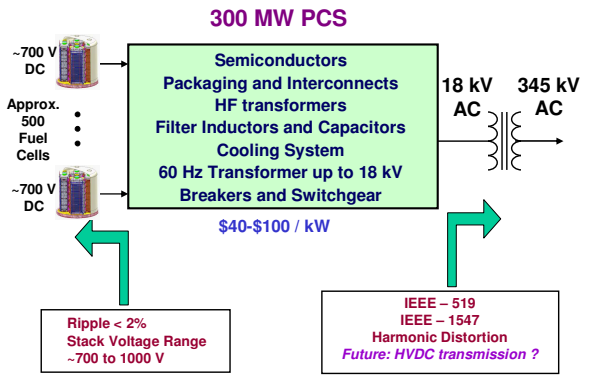
Allen Hefner

Abstract

High-megawatt PCSs are required to convert the low voltage power produced by fuel cell modules in central station scale plants to the very much higher voltage levels required for delivery to the grid. The SECA power plant PCS cost goal of $40 - $100/kW is generally recognized as a difficult stretch goal that cannot be met with today's technology. To address this challenge, DOE and NIST have entered into an Interagency Agreement to have NIST lead an effort to evaluate various advanced technology options for the PCS and to identify technologies requiring development to meet the cost and efficiency goals of SECA central station fuel cell power plants.

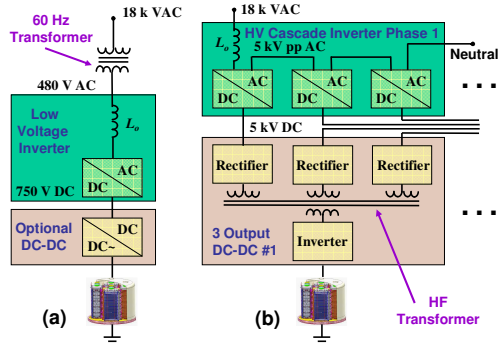
Objectives

- Identify advanced technologies that may significantly reduce the cost of the power conditioning systems (PCS) required for future high-megawatt fuel cell power plants.
- Determine fuel cell power plant PCS performance requirements, including requirements for interfacing fuel cell modules and for Smart Grid connectivity.
- Develop simulation models for advanced PCS architectures, circuit topologies, and component technologies and perform simulations required to determine overall cost and performance benefits of advanced technologies.
- Coordinate with related industry and federal government programs to enable the development of advanced high-megawatt PCS technologies necessary to meet the Solid State Energy Conversion Alliance (SECA) high-megawatt fuel cell power plant PCS goals.



Fuel cell power plant requirements for High-megawatt Power Conditioning System (PCS) indicating the component technologies included in PCS cost

HF Transformer versus 60 Hz Transformer

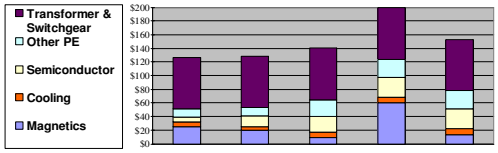


(a) 480 V AC inverter and a 60 Hz transformer to raise the output voltage to 18 kV AC for plant distribution and **(b)** multiple fuel cells each having a three output DC-DC converter that steps the voltage up to 5 kV, followed by a high voltage three phase cascade inverter connected directly to the 18 kV AC power plant distribution.

High-Voltage Semiconductors

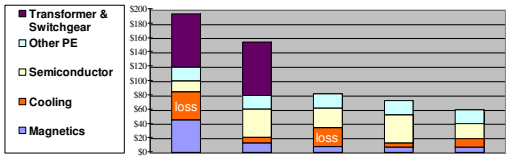
- **Baseline: High-Voltage (HV) Silicon devices (IGBT, IGCT)**
  - Typically ~6.5 kV blocking voltage maximum
  - Requires multi-level inverter for 4160 V AC
  - Low switching frequency (< 500 Hz) requires larger filter
- **High-Voltage, High-Frequency SiC Switch and Diodes**
  - ➢12 kV, 20 kHz SiC MOSFET switch and SiC Schottky diode:
  - Less inverter levels due to higher voltage
  - Less loss, lower heat removal cost
  - Less filter inductance required due to higher frequency
  - ➢15 kV, 5 kHz SiC IGBT switch and SiC PiN diode:
  - Higher current per die than SiC MOSFET, therefore lower cost
- **Advanced Technology Goals and Cost Break Points**
  - 1.2 kV Schottky diodes: $0.2/A
  - 12 kV Schottky diodes: $1/A
  - 12 kV Half-bridge SiC-MOSFET/SiC-Schottky: $10/A
  - 15 kV SiC-PiN: $0.4/A
  - 15 kV SiC-IGBT/SiC-PiN Module: $3.3/A
  - High-Frequency transformer: $2/kW
  - Power Electronics DC-DC, DC-AC: 150 % overhead
  - 60Hz Transformer and Switchgear: 50 % overhead

Estimated $/kW: LV Inverter



Inverter Voltage	Low	Low	Low	Low	Low
Converter Stages	One	One	Two	Two	Two
LV-SiC Schottky		yes	yes	yes	yes
HF Transformer				Ferrite	Nano
60 Hz Transformer	yes	yes	yes	yes	yes
Risk Level:	Low	Moderate	Considerable	High	

Estimated $/kW: MV & HV Inverter



Inverter Voltage	Medium	Medium	High	High	High
HV-SiC Diode		Schottky	Schottky	Schottky	PiN
HV-SiC Switch		MOSFET		MOSFET	IGBT
HF Transformer	Nano	Nano	Nano	Nano	Nano
60 Hz Transformer	yes	yes			
Risk Level:	Low	Moderate	Considerable	High	