High MW Power Conditioning Systems Workshop

- Fuel Cell Applications for Power Electronics
- Prospects for Increased Penetration

G. Berntsen, 5/24/12
Direct FuelCell® power plants are generating ultra-clean, efficient and reliable power at more than 50 locations worldwide:

- Over 180 megawatts of power generation capacity installed or in backlog,
- Generated more than one billion kilowatt hours of ultra-clean power.
Scale-Up and Cost Reduction

70% $/kW cost reduction achieved through:

- Value Engineering
- Power Up-Rate, Economy of Scale

Gross Margin Positive Sales
3.0 MW Plant

- (2) 1500kW Power Trains
  - Common PCU, Module = Volume Savings
- Economy of Scale Achieved Thru:
  - Common Mechanical Balance-of-Plant (MBOP)
  - Transactional Costs, Service
Scale-Up Limitations

Fuel Cell Module Size

- Road Transport Constraints

1.4 MWnet module
>100,000 lbs.
Max. Height
Max. Width
Multi-MW Sites
(4 x DFC3000)

10.4 MW
Yulchon, S.Korea

11.2 MW
Daegu, S.Korea

22.9kV Express Feeder Connection to Sub-Station
Scale-Up Limitations

Distribution System Limitations

- Feeder Capacity (7-12MVA)
  - Express Feeders needed > 1.5/3.0 MW
- Sub-Station Minimum Load
  - Voltage Regulation Limitations
  - Protection Scheme Limitations
- Smart Grid Technologies May Reduce Technical Constraints
  - Jurisdictional, Statutory Constraints.

Transmission System Interconnection

- Requires much larger plant size (50MW) to be cost effective.
Grid Connected Mode
Normal Operation

- Baseload, Full Power Production
- >90% Capacity Factor
- Current Control Mode
- Match & Follow Grid Voltage
- UL-1741 Anti-Islanding Detection
  - Abnormal Volt. & Freq.
  - Active anti-islanding algorithm
Stand-Alone Mode

Grid Outage

Upon detection of abnormal Volt./Freq.
  • Tie Breaker Opens
  • Switch to Voltage Control Mode
  • Voltage to Critical loads recovered <4 cycles
  • Load Leveler Starts to maintain constant fuel cell load for varying loads.
    ▪ PLC controlled resistive load bank

Challenge: Failed transitions
  • e.g. Instantaneous Over-current trip instead of transition on under-voltage.
  • Plan to address in LVRT development.
Micro-Grid Base Load Mode

Typical Sequence of Operation:

- **t0:** Grid Outage
- **t1:** DFC transitions to Stand-Alone Mode, Facility goes dark
- **t2:** Genset(s) starts, Service Breaker Opens, Sends micro-grid signal to DFC
- **t3:** Genset connects to bus at rated voltage and frequency.
- **t4:** DFC syncs with genset and connects to bus with wider V&F relay settings and active anti-islanding disabled.
- **t5:** DFC ramps to rated power in 5 minutes.
FCE is actively implementing micro-grid mode at several sites.

- Parallel operation with other generators when utility service unavailable
- Customer facilities, behind-the-meter applications
- Interruptible and Seamless Applications

Recent Micro grid Implementations:

Central CT State University
- Gensets & 1.4MW fuel cell

San Jose Water Treatment Plant
- Gensets & 1.4MW fuel cell

Santa Rita County Jail
- DOE Smart Grid Demonstration
- Facility Static Switch Disconnect
- 1MW early generation Fuel Cell
- Gensets, 1mw solar,
- 2MW energy storage
All plants capable of generating rated output from (-) 0.9 to (+)0.9 pf

**Case Study:**
- A 600hp compressor’s start-up pulled bus voltage down below 88% for almost 8 seconds.
- The voltage sag was below UL-1741 / IEEE1547 limits requiring the fuel cell to disconnect.

**Solution:**
- The controls that start the motor now also provide a signal to the fuel cell to add 130KVAR.
- The leading reactive power offsets the compressor start-up and voltage sag is now much less, enabling the fuel cell to stay connected.
Low Voltage Ride-Through
• Germany is a New Area of Business Development
• LVRT required for fuel cells connected to the Medium Voltage Network (i.e. Distribution System)

Challenges:
• Technical Approach
• German Certification Agency
• Testing Facility
Recent Legislation in Connecticut and California enables utilities to procure Distributed Generation
• Ensures optimal siting for enhancing Distribution System
  • Power Quality
  • Reliability
  • Load Constraints
• Reduces project uncertainty regarding Electric System upgrade feasibility and costs.

60MW Projects in process in S. Korea with Utility
QUESTIONS?