Grid Scale Power Conversion at Eaton Eaton Research Labs

Dr. Sudipta Chakraborty – Global Technology Manager Dr. Bogdan Borowy – Senior Principal Engineer

August 15, 2024



Who is Eaton?

We are an **intelligent power management** company made up of approximately **85,000 employees**, doing business in more than **175 countries** with annual sales of around **\$23 billion USD**.

We make what matters work.



Eaton Research Labs Core Research Platforms



Energy systems

 Technology development for DER-EV integration, grid intelligence and onboard power integration

Parten Pavering Business Worldwide

Corporate Research Centers



- DERMS
- Grid Intelligence

• EATON RESEARCH LABS: Explore, Mature Early Technical and Manufacturing Readiness Levels

• **POWERONE HUB:** Leverage PowerOfOne Eaton Application, Domain Expertise for Speed and Scale of Launches



ERL Energy Systems

Dr. Sudipta Chakraborty

Global Technology Manager *Eaton Research Labs (Energy Systems)*



Energy Systems Technology Themes



Grid intelligence

Grid reliability, resilience and sustainability

Distributed energy resource integration & EV charging DER Integration, control and optimization DC Distribution, EVCI and V2X

Electrification

Energy storage technology, More electric vehicle, More electric aircraft

Grid automation and microgrid control

Energy management with DER and EVCI

Energy storage system modeling and battery management



EV Charging Infrastructure



Powering Business Worldwide

DC-based Integration

Challenges:

- DC control
- DC Protection DC breakers
- Coordination
- Interoperability





ERL Power Electronics

Dr. Bogdan Borowy

Senior Principal Engineer



Eaton Research Labs *Power Electronics*



Innovation Drivers: Faster, Smaller, Lighter, Lower Cost, Problem With No Solution



MV Power Conversion SST

Moving from LV to MV

(480VAC to 10/11/13.8kVAC)



- Improve efficiency
- Reduce cable/busbar size and weight

Prefabricated Solution

(Integrated the separate components physically)



- Footprint still not optimized due to MV/LV transformer
- **Transportation** is challenging due to large size and weight
- Efficiency limited due to multiple stages from MV to LV

Proposed MV SST Solution

(Cascaded topology with HF PE and magnetics)



- -40% of footprint with HF transformer
- +1% efficiency due to WBG devices
- -30% weight with less components
- An active infrastructure that can enable high distribution capacity
- Lower cost potential due to less
 material

MV SST can reduce the footprint and weight, improve efficiency, and more

Solid State Protection

NextGen Technology



IGBT/MOSFET enabling solid-state DC circuit protection



Ultra-fast vacuum switch with solid-state interruption

End-User Value Proposition



Solid state and hybrid breakers enable DC power distribution (more then 100 times faster current interruption then conventional breakers)

Leading Applications



Intelligent solid-state breakers (12kV, 2kA) Next Generation Ships – ONR



Medium voltage circuit breakers (6kV, 200A) enables MVDC distribution market – ARPA-E



High speed fault clearance required to enable DC distribution

Industrial Drives and Machines

Traction Motor Technology





Permanent Magnet Synchronous Motor

Induction Motor



Switched Reluctance Motor

Motor Controls



Advanced motor control



Power Electronics



Use of WBG Devises





Higher switching frequency and voltage decrease weight and increase power © 2024 Eaton. All rights reserved. density

System Optimization



Footprint Reduction



Reliability/Durability



Higher efficiency

Electric Vehicles

NextGen Technology

Polymer UV Curing

7

Silver In

NextGen Power Electronics:

- SiC
- Packaging
- Thermal management
- Protection
- Intelligence and Prognostics
- Vertical & Horizontal integration

Powering Business Worldwide



End-User Value Proposition

NextGen Power Electronics



PE Integration:

- Cost: 10%-30% down
- Weight: 10% -15% down
- OEM manufacturing efficiency: 2%-4% up
- Reliability: FIT 10%-20% down
- Durability: Years 10% 30% up
- Power density: 15-30% up
- Space claim: 15% 30% down

Technologies, component and system antimization for lower

Leading Applications



Traction Inverter



DC-DC Converters, OBC, PDU, Charger

Compact Electric Vehicle Charging Infrastructure (EVCI)



Compact Electric Vehicle Charging Infrastructure (EVCI)

Compactness & Integration



Thermal Management Integration

E. Floating P. Supplies



□ Medium Voltage Grid \rightarrow DC

- Grid Voltage: 12.7 13.8 kV
- DC Voltage: 750 850 V
- Power: 2.5 MVA
- PF: +/- 0.95

Rapid Deployment (Platform System)

- Utility Interconnection Time/Cost Reduction
- Pre-Installation Factory Acceptance Tests
- DC Distributed Bus (E. sources, Storage, Chargers)



Modularity



MV+HF XFR + LV Cell





Central Controller / Comm Card

HF XFR



Loop Thermosyphon Adv. Cooling



Isolated Power Supply

SST: Energy Router for Future Grids (Energy Superhighway)



Powering Business Worldwide

13.8kV AC Bus

