Power Electronics Topologies for Future Electric Grid

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GRAPES Center

- Center for GRid-connected Advanced Power Electronics Systems (GRAPES), an NSF I/UCRC
- **GRAPES Mission** is to accelerate the adoption and insertion of power electronics into the grid in order to improve system stability, flexibility, robustness, and economy.
- University members: U of Arkansas, U of South Carolina, UWM, RTWH Aachen (Germany), and Yonsei Univ (South Korea)
- Industry members: 19 energy, power, and energy conversion companies.
Main Grid-Tie Applications and Functions

- Interface for distributed energy resources (energy storage, renewable sources, and variable speed generators).

- Demand-side resource management
  - Smart inverters (peak power control, demand response)
  - Integrated inverters (load, storage, and DER)

- Power Flow Control
  - Reactive power compensation
  - Active power control
  - Phase current balancing
  - Fault diagnostics

- Fault detection and management
  - DC, AC, and Hybrid
Trend for Power Electronics Topologies

• Higher switching frequency
• High power converters
• Medium voltage converters
• Compact and integrated topologies
• High frequency isolation
• Fault tolerant
High Voltage Modules

- HV Module development
- HV packaging toward 10 kV, 20 kV and 30 kV modules.
  - 10 kV enables simpler, 2-level 4160
  - 20 kV modules enable 3-level 13.8 kV direct grid-tie converters.
  - 30 kV modules enable 2-level 13.8 kV
- They also optimize modular multilevel converter (MMC) cell voltage levels for HVDC applications.
Compact Energy Storage System

Imagen 150KW (IM-900) (1x)
17.7cmx42.6cmx60.9cm
93.9cmx127cmx200cm

Company A 125kW (10x)
40.6cmx86.3cmx137.1cm

Company B 150kW (50x)

Extremely Compact Inverter Allowing Total Integration and Cost Reduction, for Solar and Energy Storage Applications with >10X Inverter Size Reduction
Advanced Technology to Improve Efficiency, Reduce, Size and Cost of Energy Storage Systems

- Improved Efficiency (99% Peak efficiency, and power quality, <2.5%THD at FL)
- Improved EMI Performance due to reduced di/dt and dv/dt of 3-L configuration
- Highly Integrated converter allowing easy installation
- FPGA based faster control
- Next generation with WBG SiC power semiconductor modules
- Extremely Compact Inverter for Solar and Energy Storage
- >10X size and 6X weight reduction (inverter)
- Next generation with SiC: >12x size reduction And >8X weight reduction
Model Based Development

Seamless Model-based Design and VHDL auto coding

Simulation vs Actual
Multi-Port SST in for Distribution Systems

- MPSST uses multi-winding HF Transformer.
- The converters on the ports could be active or passive.
- Ports are isolated from each other using multi winding HF Transformer.

![Diagram of Multi-Port SST in for Distribution Systems]
Zonal DC distribution and hybrid AC/DC microgrid problem:
- Multiple paths for system energy delivery
- Not galvanically isolate every possible conduction path, grounding is at a single point or the system is un-grounded
→ Multiple line-to-ground faults on buses and within equipment can cause system-wide fault recoverability problems

Solution:
The FCLI-MPSST manages flow between multiple sources and loads capable of isolating a fault at any connecting port without affecting power flow through un-faulted ports.

FCLI Implementations: