

Power Electronics Topologies for Future Electric Grid

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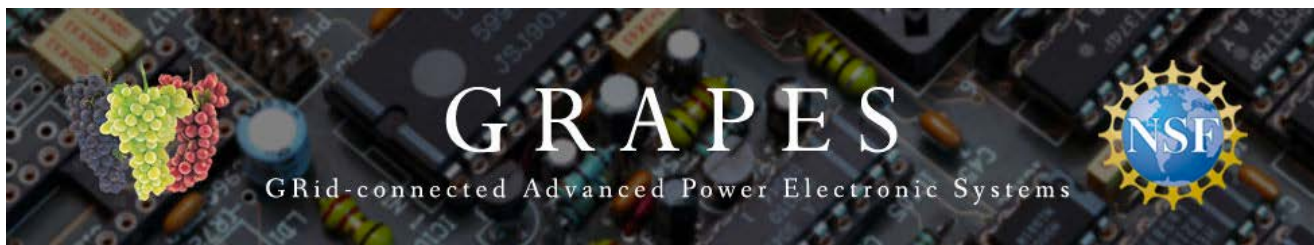
Center for Sustainable Electrical Energy Systems

NSF I/UCRC on Grid-connected Advanced Power Electronics

University of Wisconsin-Milwaukee

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

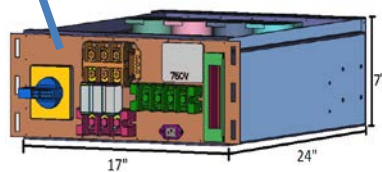
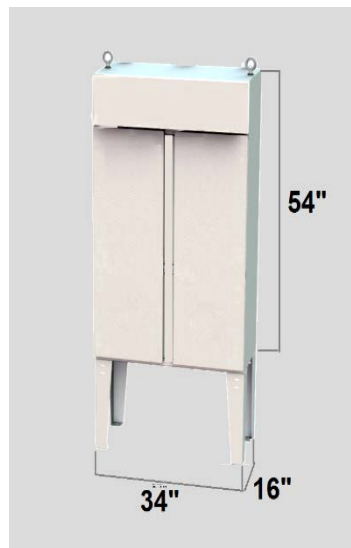
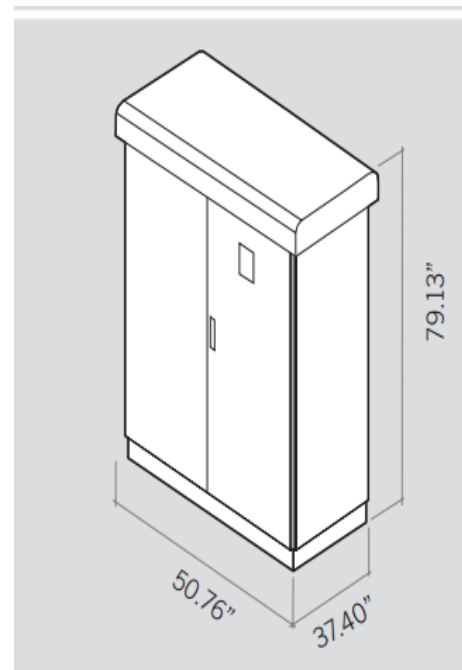


Imagen 150kW (IM-900)
 (1x)
 17.7cmx42.6cmx60.9cm
 93.9cmx127cmx200cm



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



Company B 150kW
 (50x)

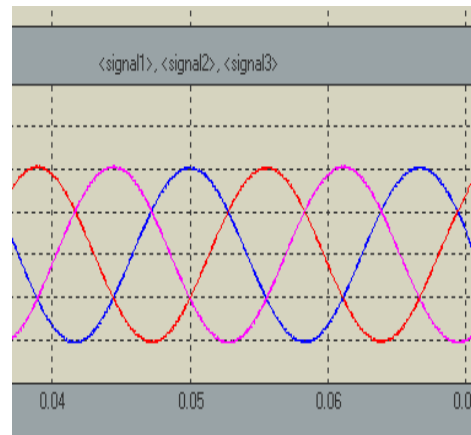
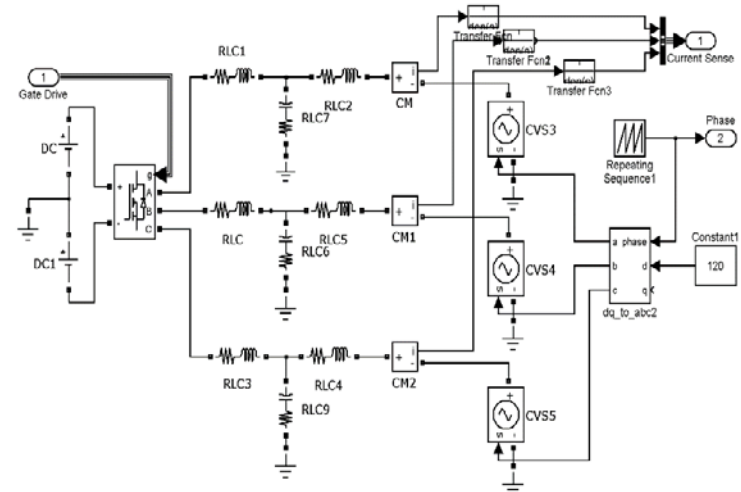
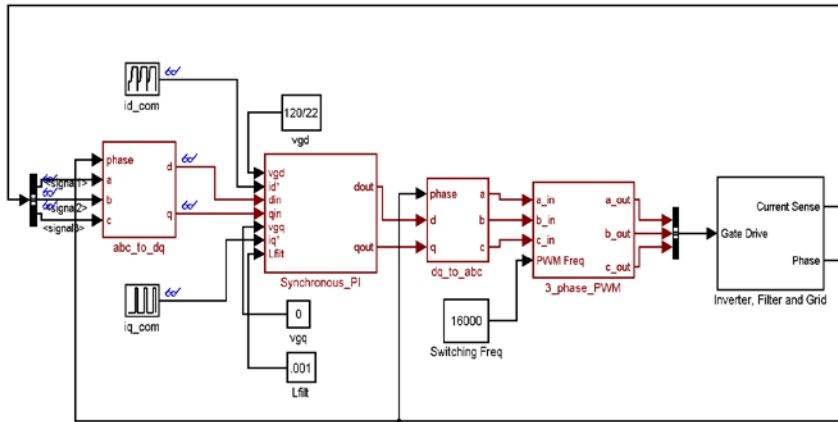
Extremely Compact Inverter Allowing Total Integration and Cost Reduction, for Solar and Energy Storage Applications with >10X Inverter Size Reduction

Advanced Technology to Improve Efficiency, Reduce, Size and Cost of Energy Storage Systems

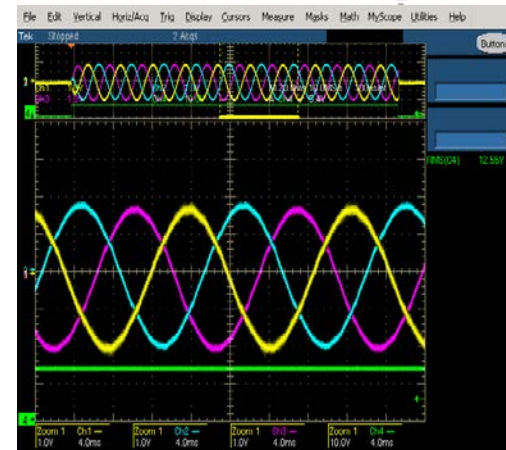
- Improved Efficiency (99% Peak efficiency, and power quality , <2.5%THD at FL
- Improved EMI Performance due to reduced di/dt and dv/dt of 3-L configuration
- Highly Integrated converter allowing easy installation
- FPGA based faster control
- Next generation with WBG SiC power semiconductor modules
- 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



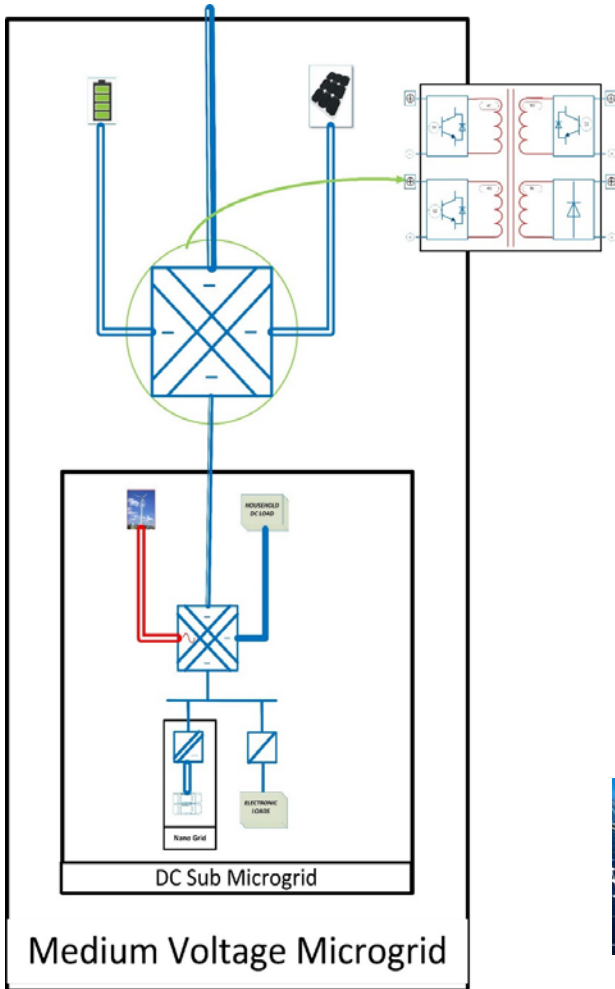
simulation



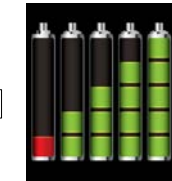
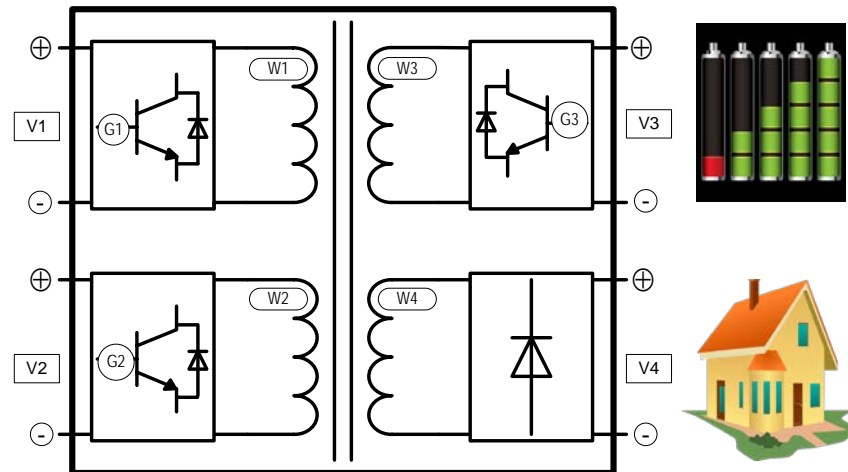
actual

Seamless Model-based Design and VHDL auto coding

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.



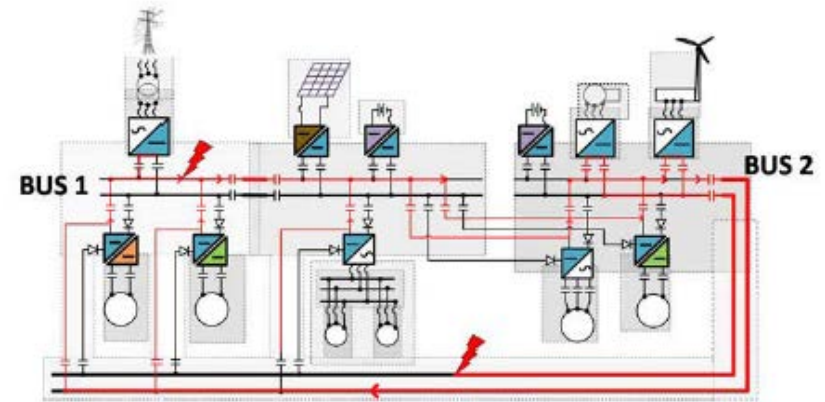
Fault Current Limiting and Isolating Multi-Port Solid State Transformer (FCLI-MPSST)

Zonal DC distribution and hybrid AC/DC microgrid problem:

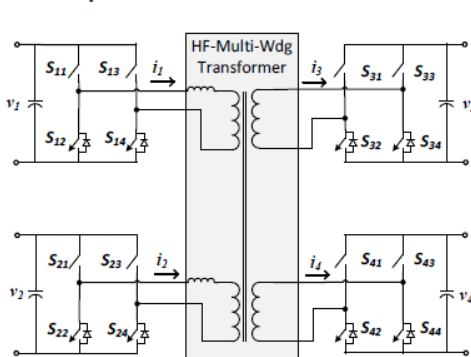
- Multiple paths for system energy delivery
 - Not galvanically isolate every possible conduction path, grounding is at a single point or the system is un-grounded
- Multiple line-to-ground faults on buses and within equipment can cause system-wide fault recoverability problems

Solution:

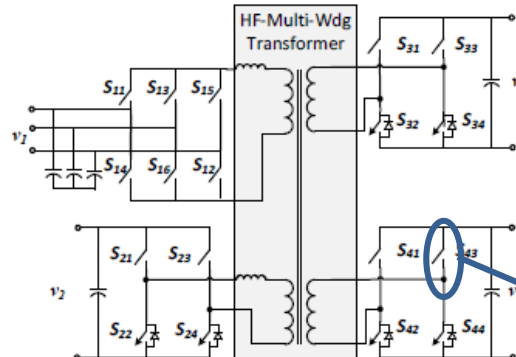
The FCLI-MPSST manages flow between multiple sources and loads capable of isolating a fault at any connecting port without affecting power flow through un-faulted ports.



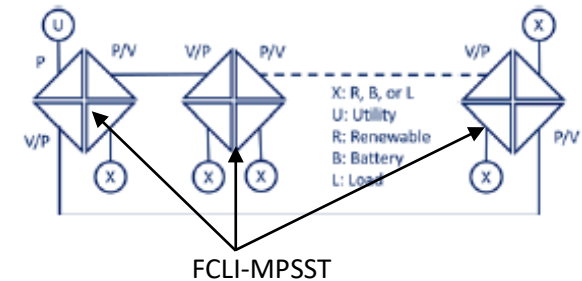
FCLI Implementations:



Four DC Ports



1 AC Port, 3 DC Ports



FCLI-MPSST