

Development of Novel Power Electronic Topologies for the Integration of Battery Energy Storage in FACTS Devices

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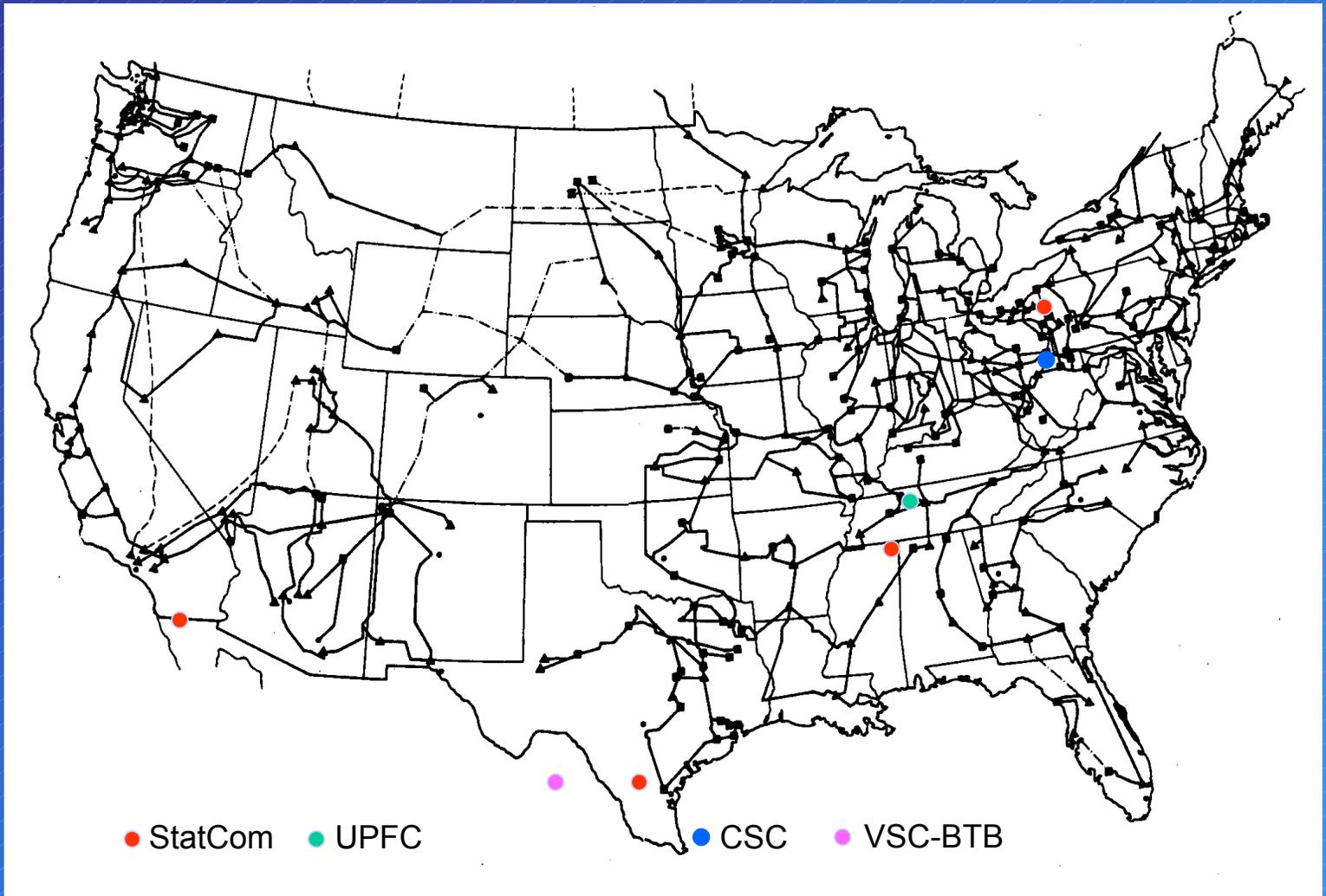
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Motivation

- Deregulation has led to the increased need for embedded controllers in the transmission system
- FACTS is an emerging technology that is being implemented in a number of facilities nation-wide and internationally
- The integration of FACTS and energy storage provides increased control flexibility for a wide range of power system dynamics

US FACTS Installations

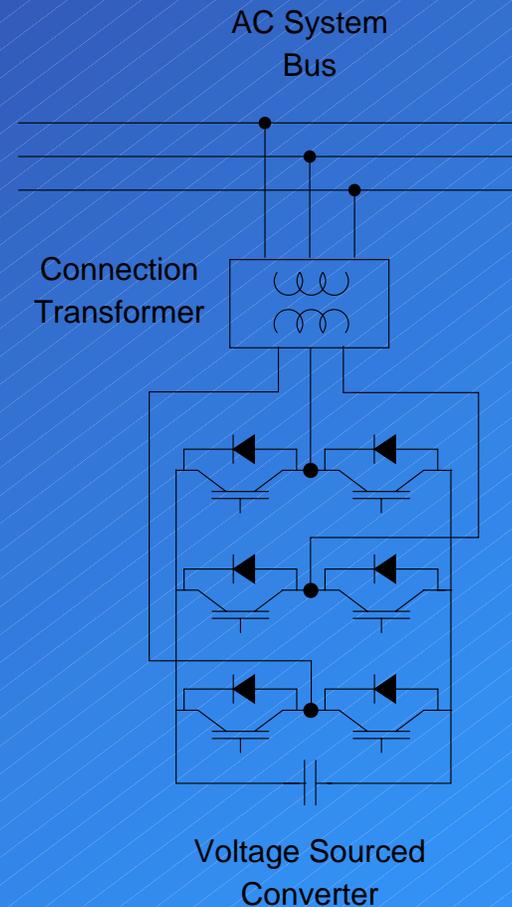


StatCom

- Voltage Support
- Reactive Power Support
- Limited impact on transient stability
- Limited impact on oscillation damping

StatCom with ESS

- Voltage Support
- Reactive Power Support
- Active Power Support
- Oscillation damping and transient stability improvement

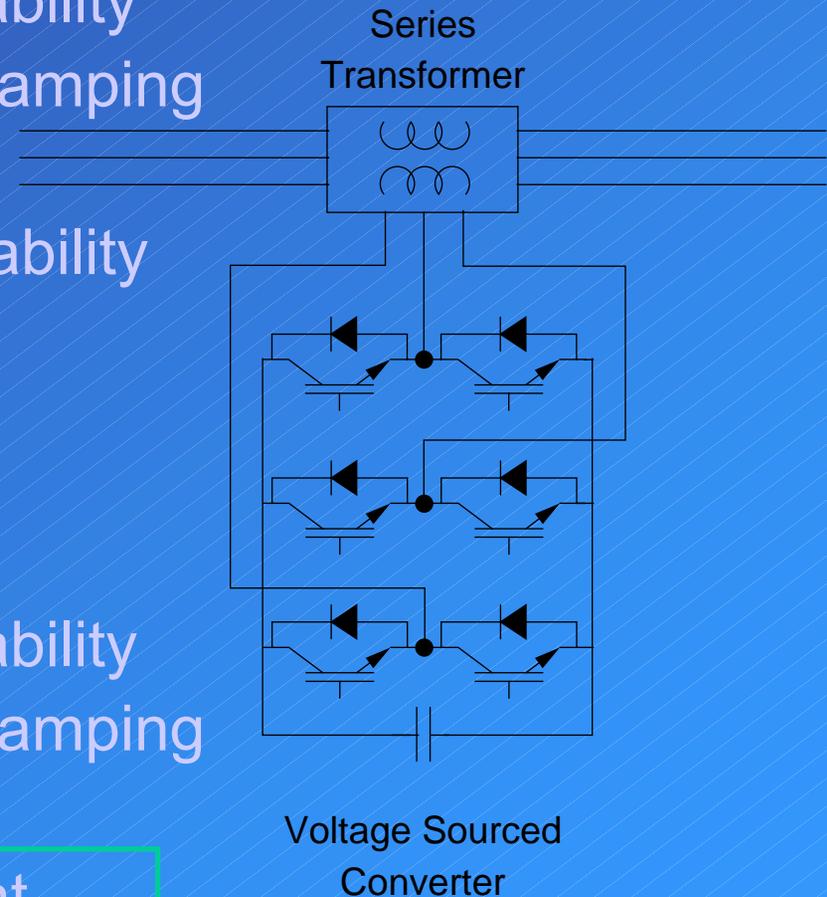


SSSC

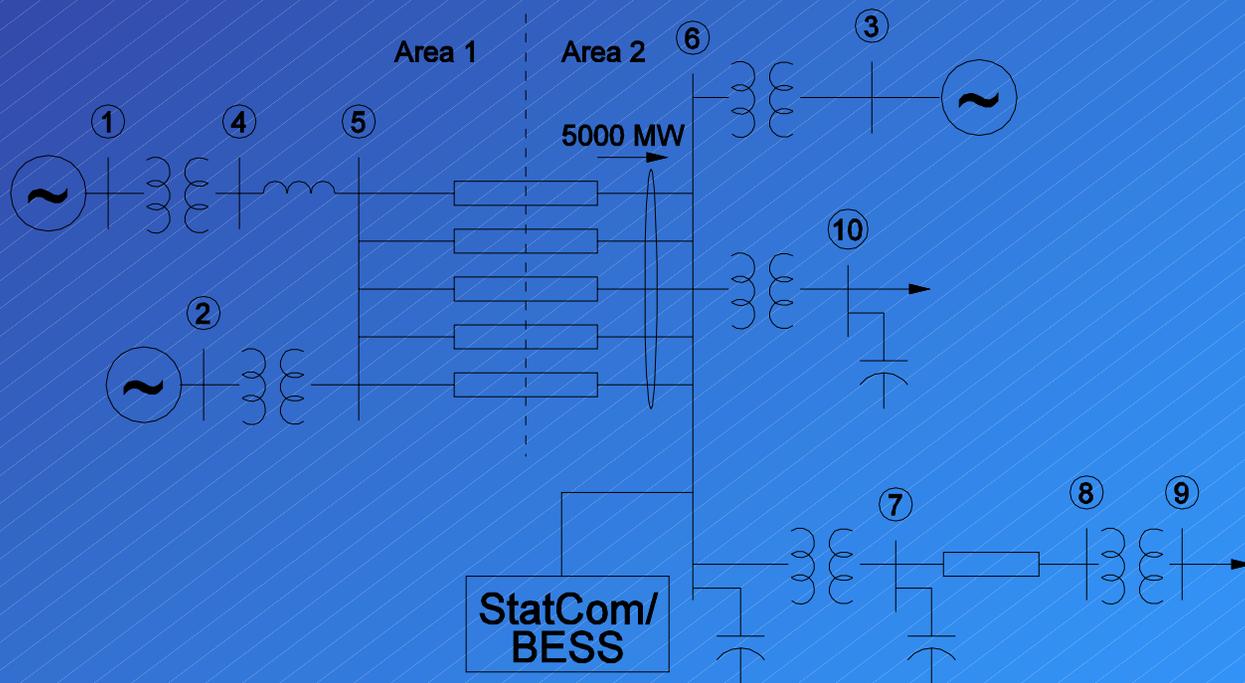
- Active Power Control
- Good impact on transient stability
- Good impact on oscillation damping
- Limited Voltage Support
- Limited impact on voltage stability

SSSC with ESS

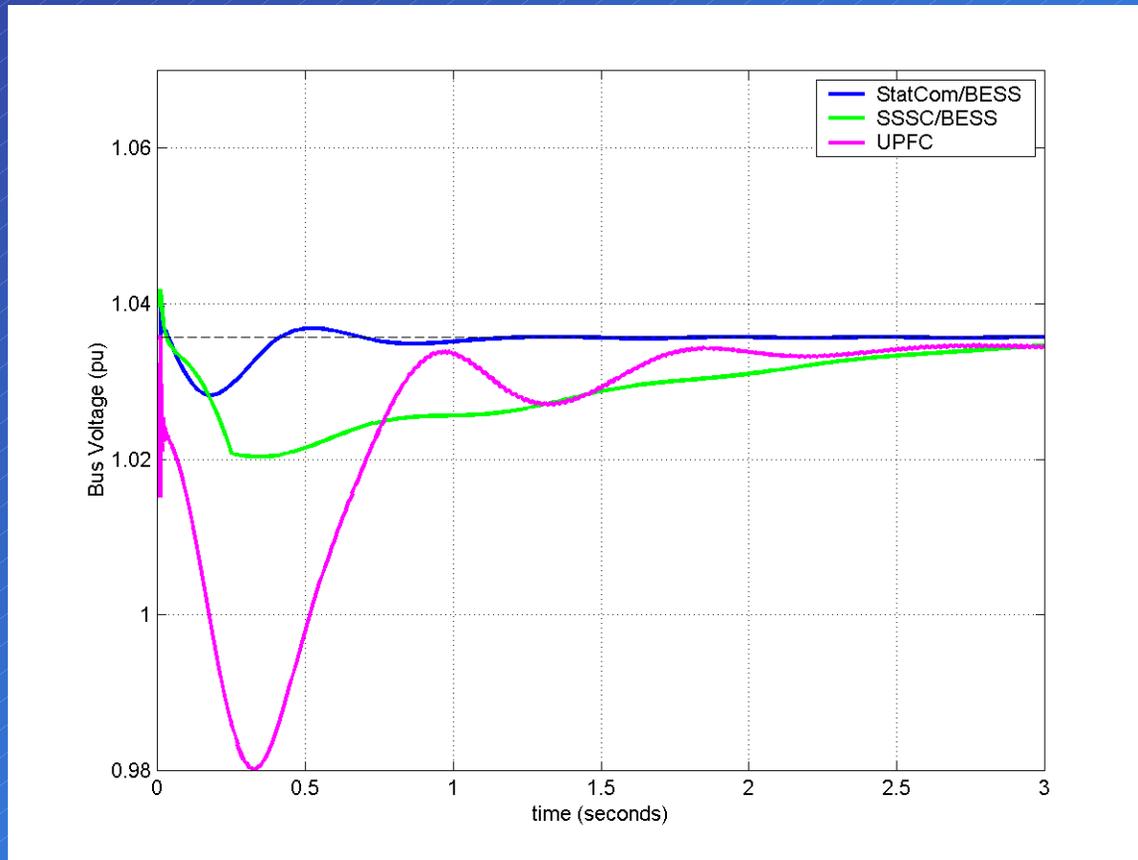
- Active Power Control
- Good impact on transient stability
- Good impact on oscillation damping
- Improved Voltage Support
- Voltage stability improvement



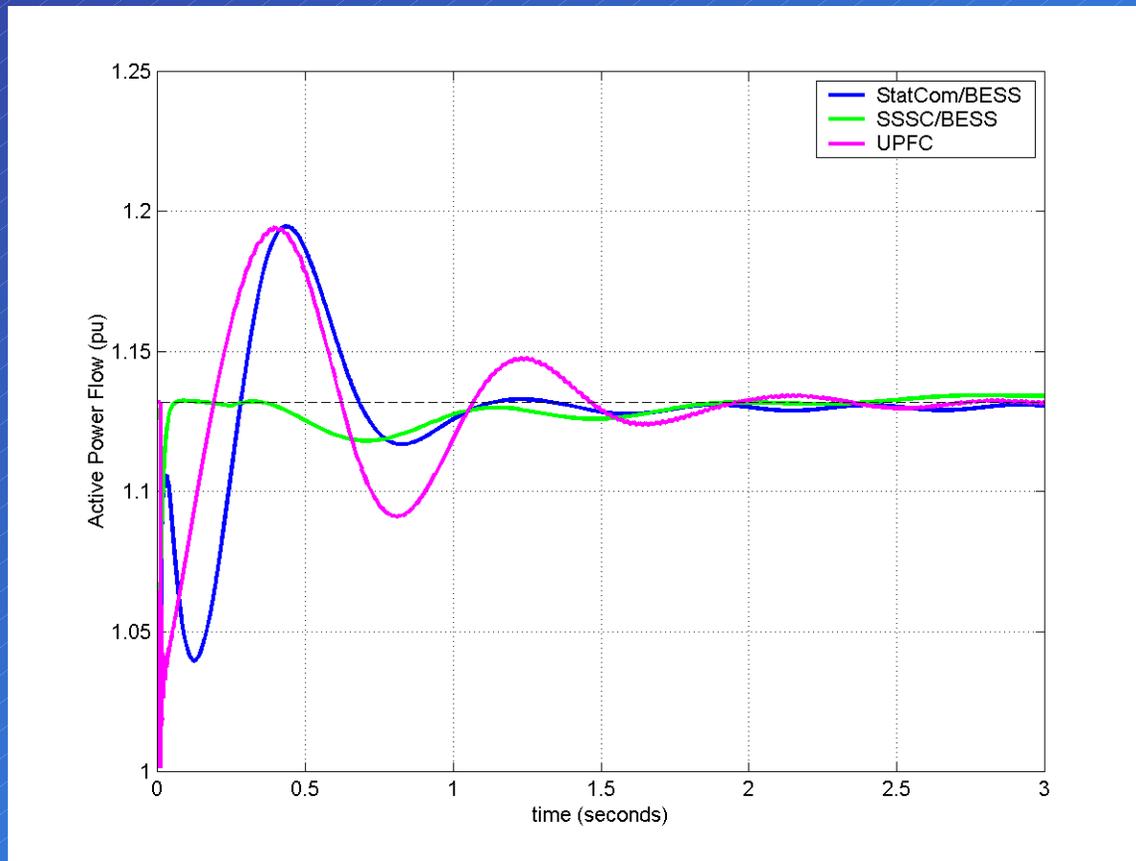
Multi-Machine Test System Performance Comparisons



Summary Voltages



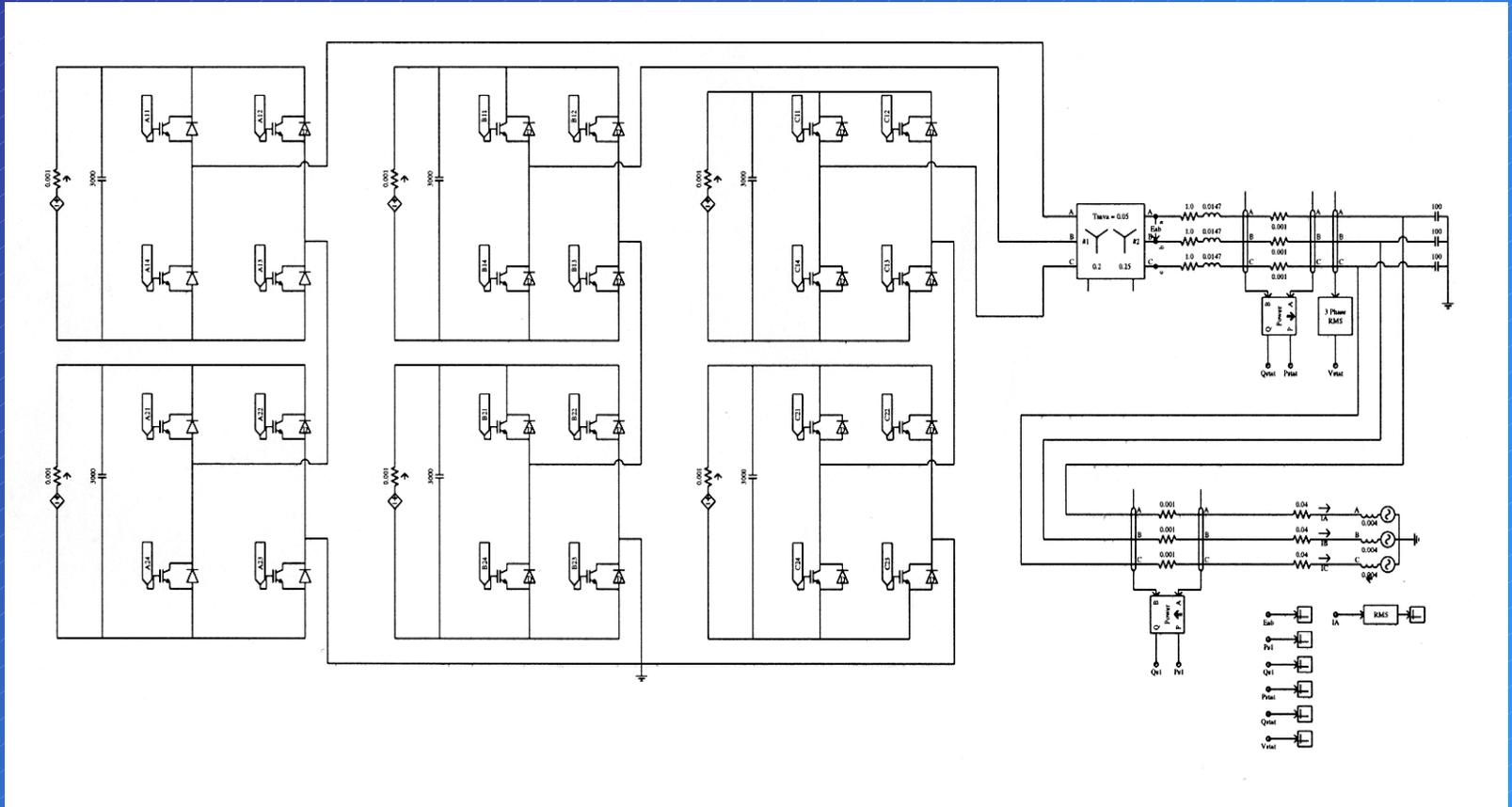
Summary Active Powers



Current Work

- Develop Multi-level converter topologies to reduce BESS size
- Multilevel topologies offer
 - improved voltage quality,
 - decreased switching frequencies, and
 - decreased voltage stress and power losses on the individual devices.

5-level Cascaded Converter



Cascaded Converter StatCom

Advantages

- Uses fewer components to achieve the same number of levels
- Has modularized circuitry which makes packaging possible
- Does not have balancing problem when with batteries

Disadvantages

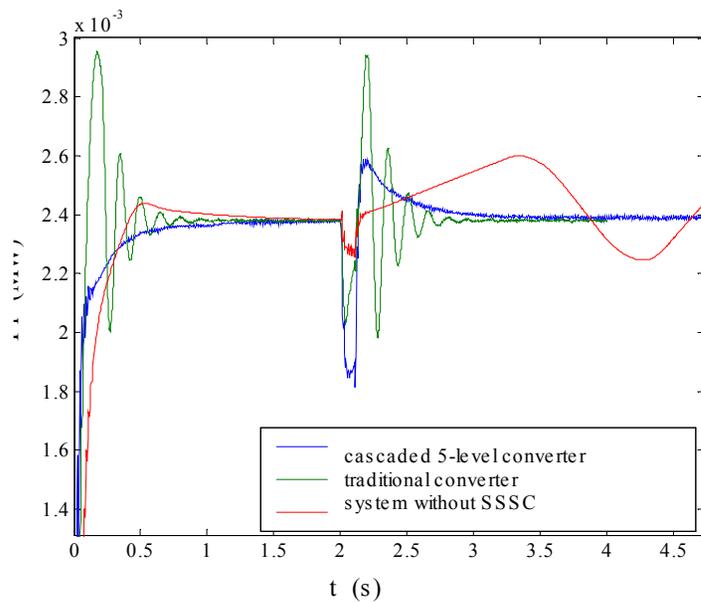
- Needs separate DC sources for active power conversion

Rack Mounted Converter

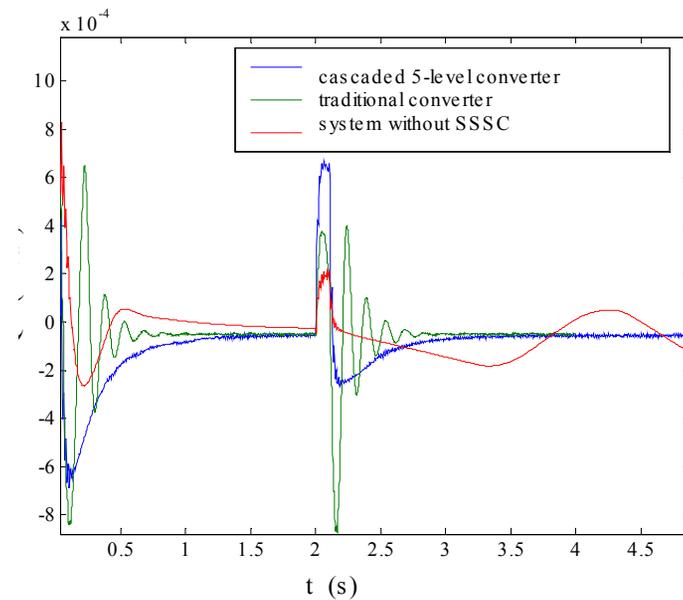


- All three phases with driving boards

Cascaded SSSC/BESS

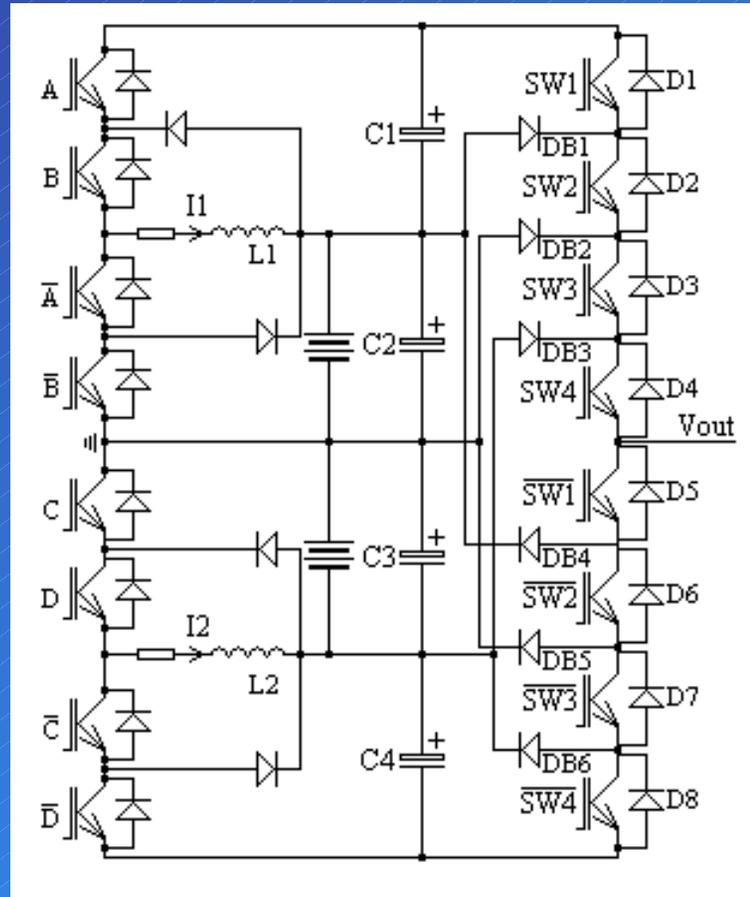


Active Power Response



Reactive Power Response

Diode-Clamped Multilevel StatCom



Diode-Clamped Multilevel Inverter

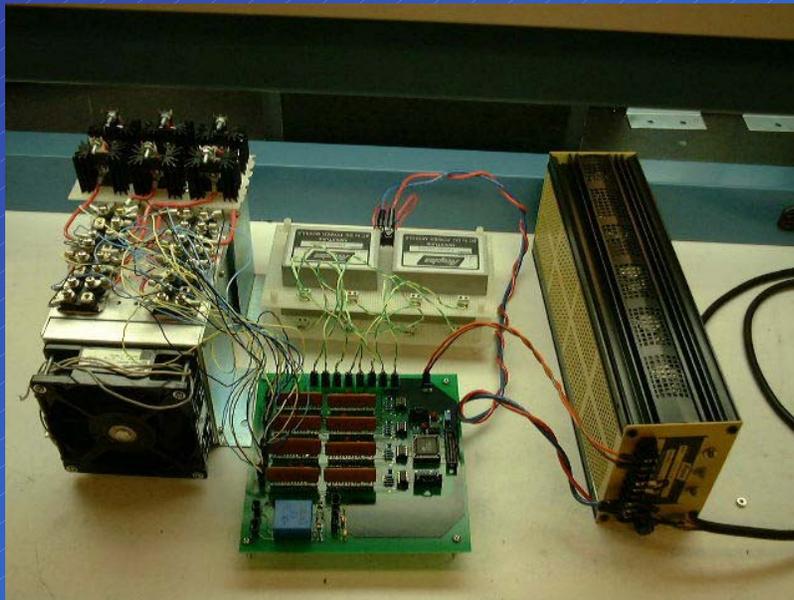
Advantages:

- The harmonic content decreases as the number of levels increases, thus reducing the size of filters
- Efficiency is high since devices are switched at the fundamental frequency
- It is easy to realize bi-directional active power flow with a BESS or other energy storage system

Disadvantages:

- Requires a large number of high power clamping diodes if the number of levels is high
- A high voltage rating is required for the blocking diodes
- There is potentially a voltage balancing problem

Single phase-leg of diode-clamped converter



- Power supply (back)
- Converter circuit (left)
- Driving board (front)
- Signal generator (right – used for testing only)

Conclusions

- FACTS/BESS controllers offer improved performance over FACTS-only controllers
- Multi-level topologies offer improved performance with decreased electronics and BESS size

Future Work

- Laboratory verification of multi-level topologies in system studies
- Development of system-level controls for coordinated FACTS/BESS systems
- Placement studies (in progress)