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Optimized energy generation, energy storage, and energy dispatch for a resilient microgrid

Dr. Vyacheslav Solovyov, Director, Center for Integrated Electric Energy Systems, Stony Brook University, Stony Brook, NY 11794

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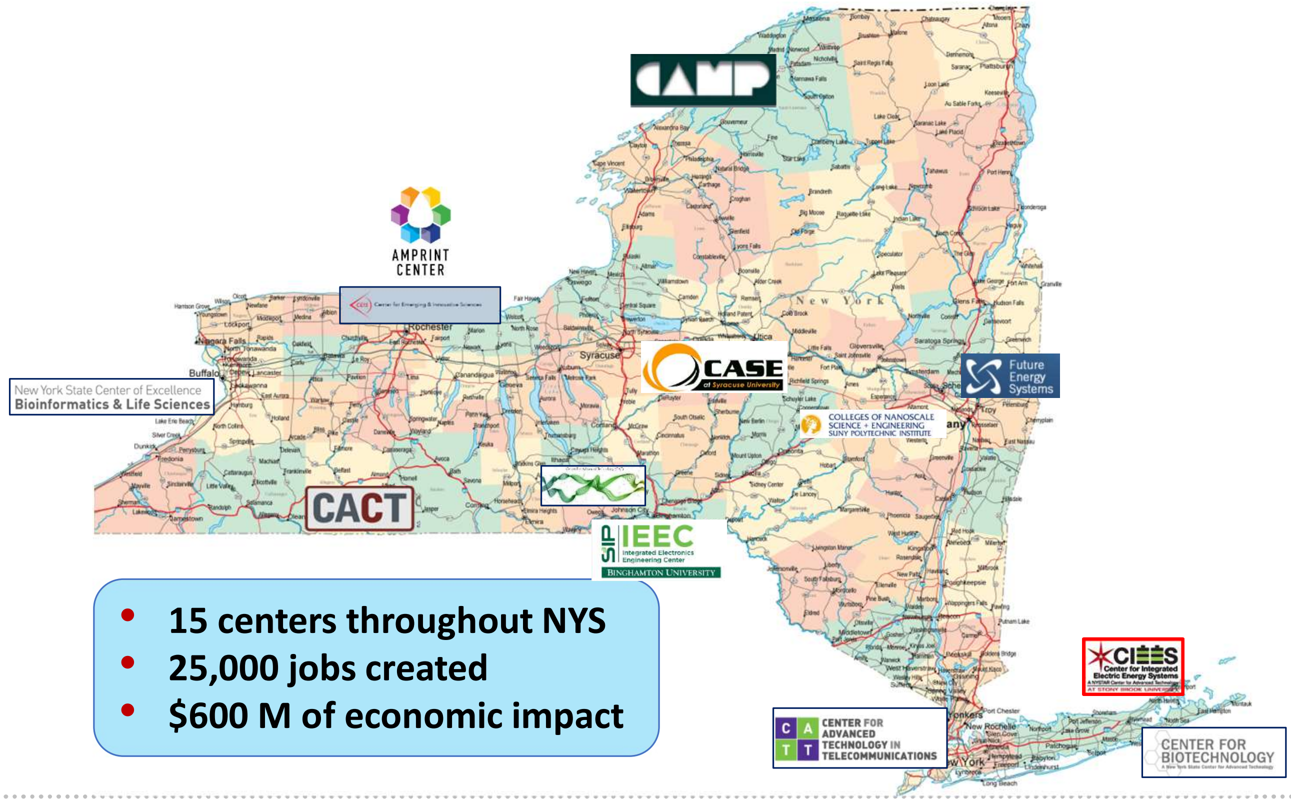
Outline

- Introduction: the Center for Advanced Technology, Center for Integrated Electric Energy Systems
- Grid energy storage projects at CIEES
- Phase I ONR project: improved recovery of isolated network
- Phase II ONR project: managing the pulsed loads
- Power electronics development
- Generation from renewable fuels

CAT network in NY state



- 15 centers throughout NYS
- 25,000 jobs created
- $600 M of economic impact

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CIIES scope

Grid technologies

Renewables and integration

Energy storage

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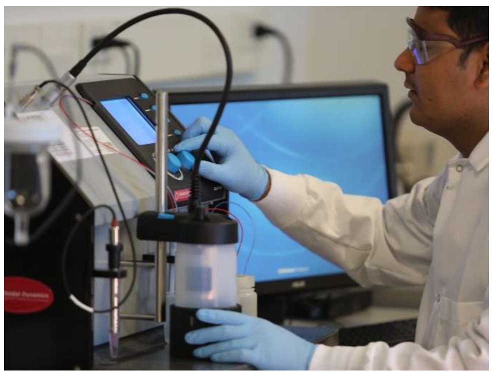
How CIEES is helping NY businesses

Research



- Evaluation and testing
- Product development
- Joint research projects

Workforce development

- On-campus internships
- Training
- Student entrepreneurship

Funding

- Matching of federal funds
- Reduced overhead
- Assistance with proposals

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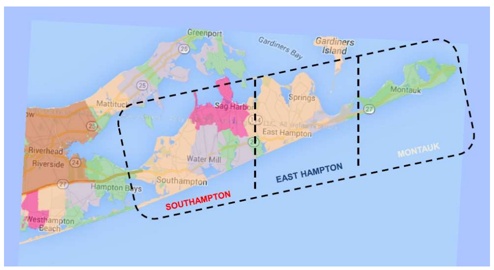
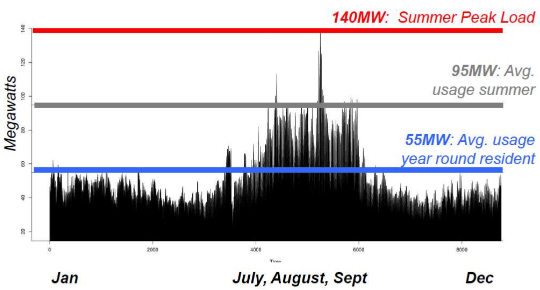
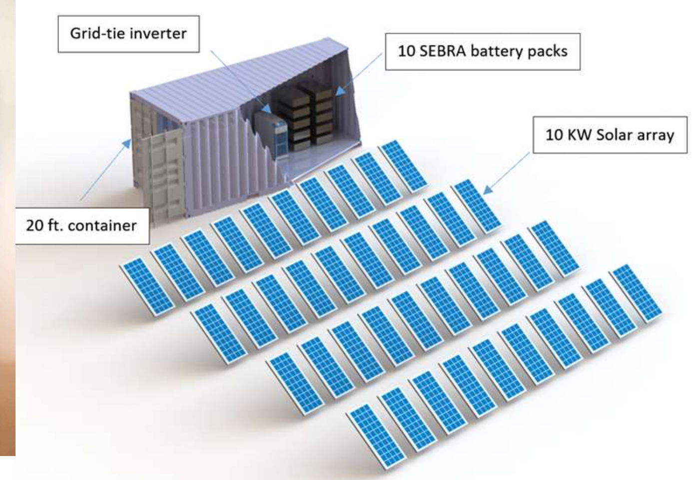
Case: evaluation of molten-salt battery technology

Peak usage at East End of Long Island





Molten salt batteries



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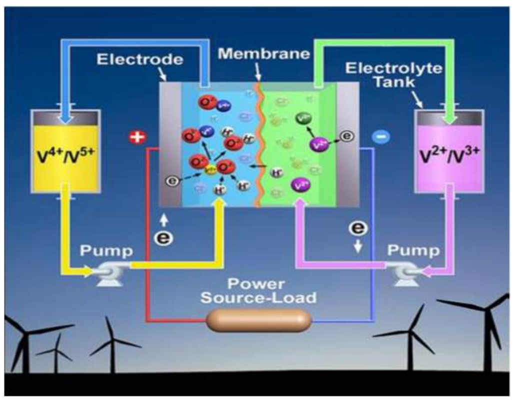
Case: evaluation of grid-tied Vandium flow battery by StorEn Technology



Installation

Installed battery

Tests

Decommissioning

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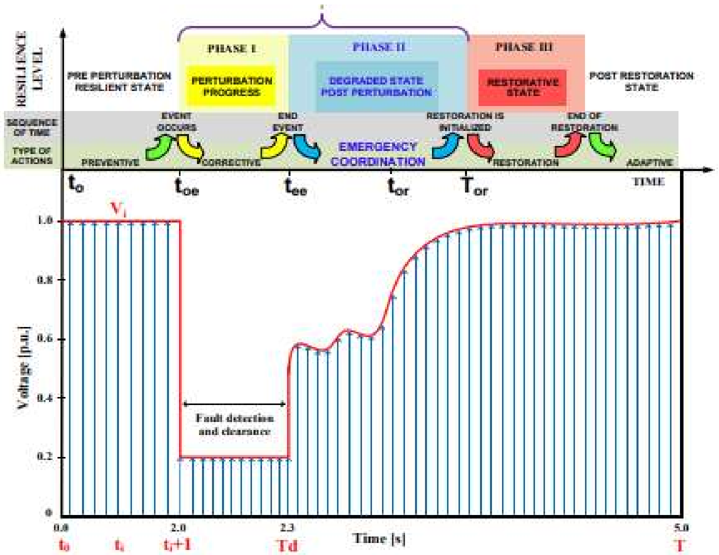
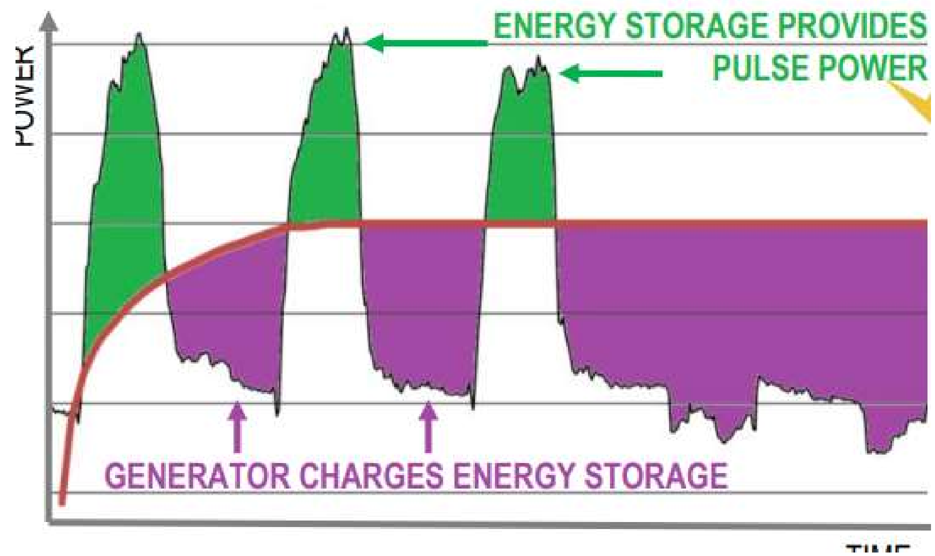
Addressing microgrid resilience

Phase I : Fast recovery after a perturbation



Phase II : Pulsed load management



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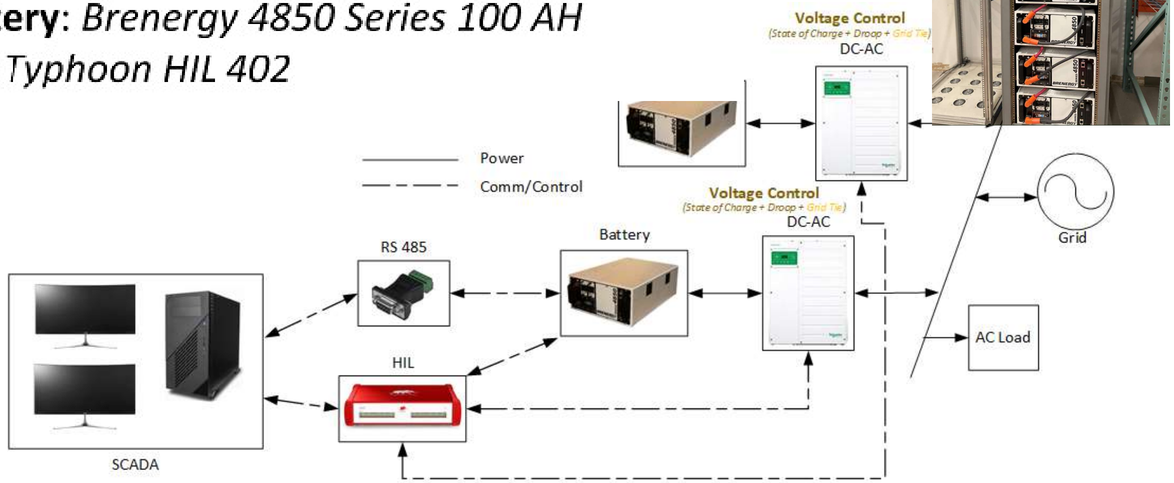
Phase I: test grid Matlab model

Mil-spec Li-ion batteries by a NY company, Brentronics

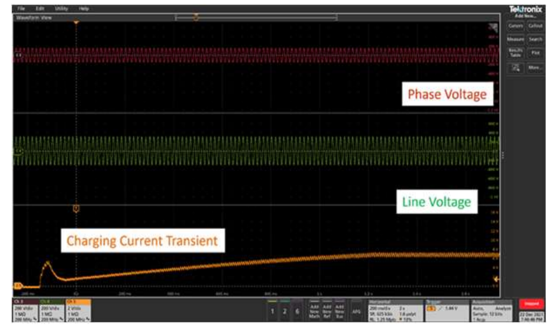
DC-AC: *Schneider Electric Conext XW Pro 6848*

Battery: *Brenergy 4850 Series 100 AH*

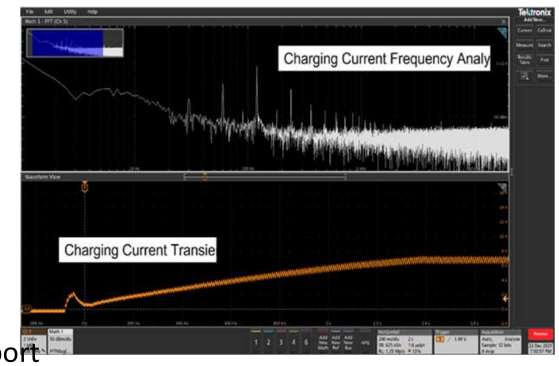
HIL: *Typhoon HIL 402*



Modes of Operation: 1. Charging of Battery



Charging operation waveform of Conext XW pro



Fast Fourier Transform Analysis of Charging operation

- Analysis on data sets under different operating modes: Inverting, Charging of battery, and Grid Support mode has been performed and validated for single inverter.
- These results are then further analyzed on MATLAB.

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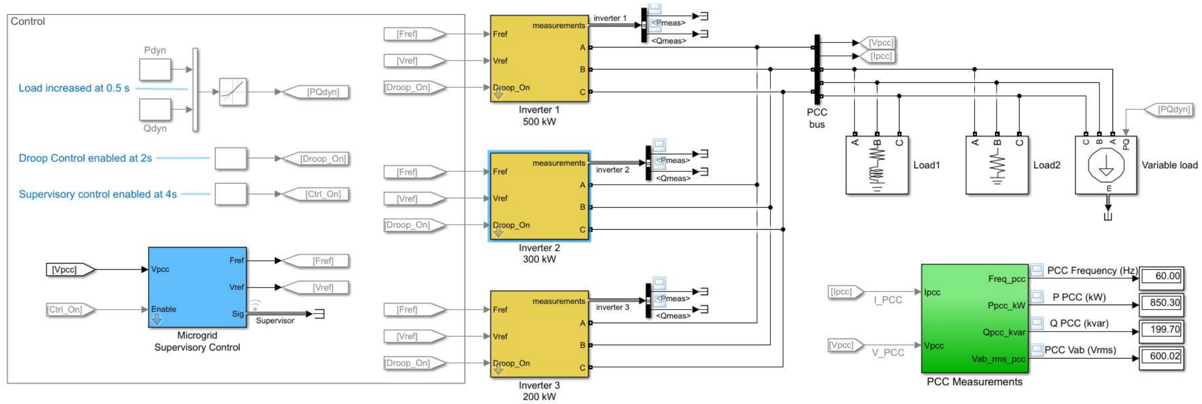
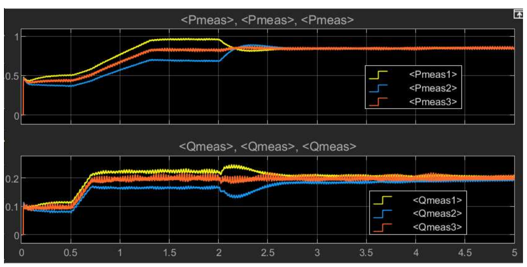
Matlab Simulink model of the test microgrid

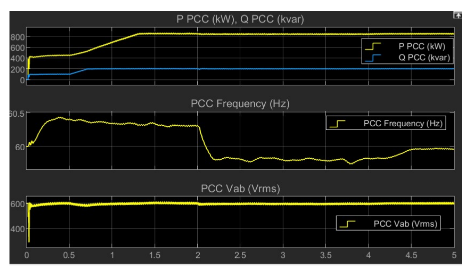


Simulink Block: Droop Control Technique for Multi-Converter Microgrid (Islanded Mode)

- Developed Droop control for parallelly connected Inverters
- Equal load sharing among inverters achieved
- Supervisory control system (t=4s) brings back the Volt. And freq. to nominal values.



Active and Reactive Power Outputs of Inverters (in PU)



PCC Measurements

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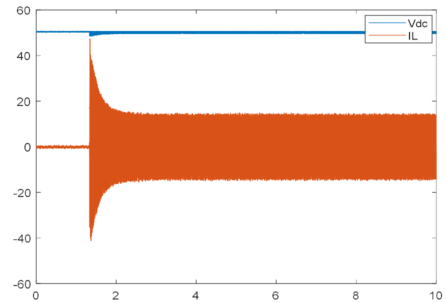
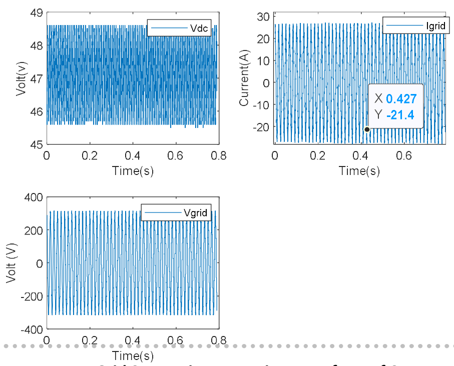
Experiment: grid support and Li-ion charging

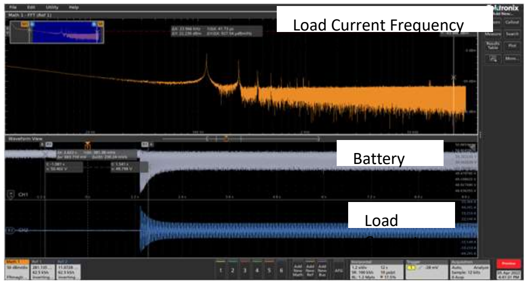


Inverting operation waveform of Conext XW pro

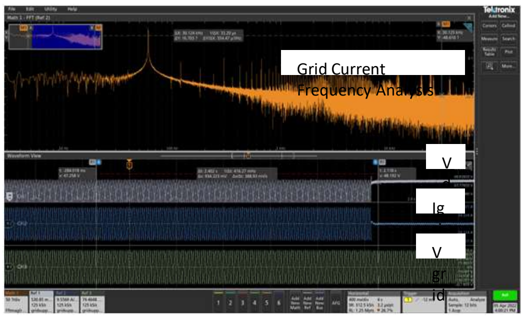
Grid Support



Grid Supporting operation waveform of Conext XW pro



Fast Fourier Transform Analysis of Inverting operation

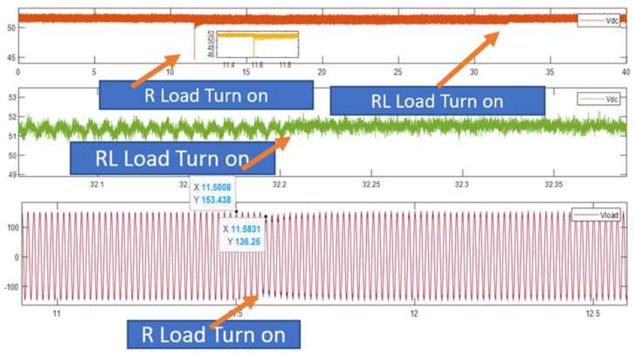


Fast Fourier Transform Analysis of Grid support operation

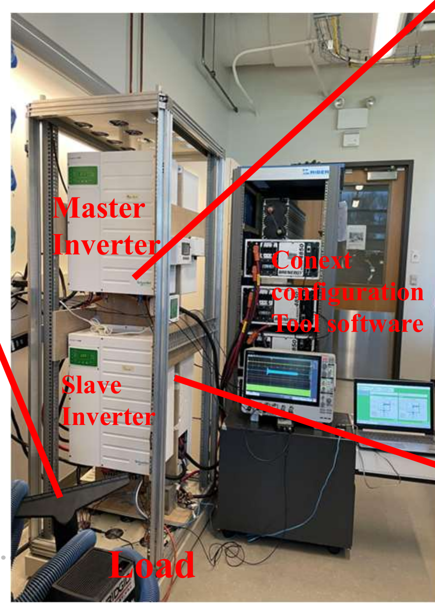
- Analysis on data sets under different operating modes has been performed and validated:
- These results are then further analyzed in MATLAB.

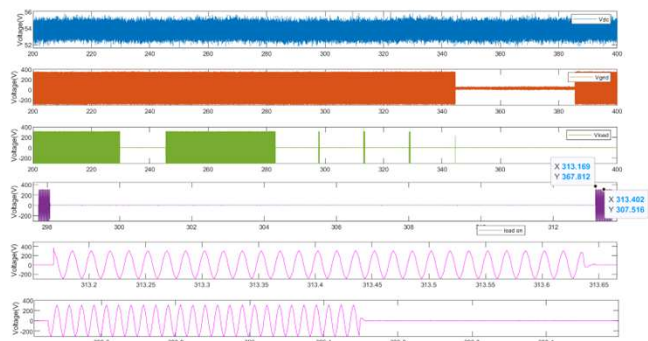
Grid reaction to simulated faults, loads and islanding

Transient analysis at microgrid setup for robustness and resiliency

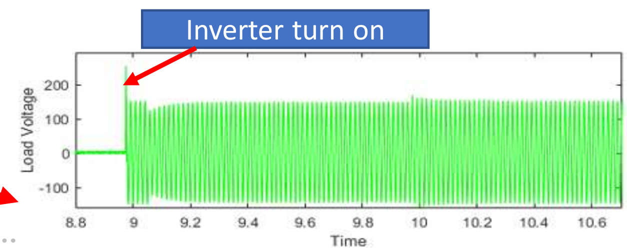


Transients at PCC and load bus because of variation in loads (R and RL loads)





Mode: Master Charging & slave Inverting : (Charging Current = 34 A & Load included), protection circuit breaker trips to avoid over grid current.



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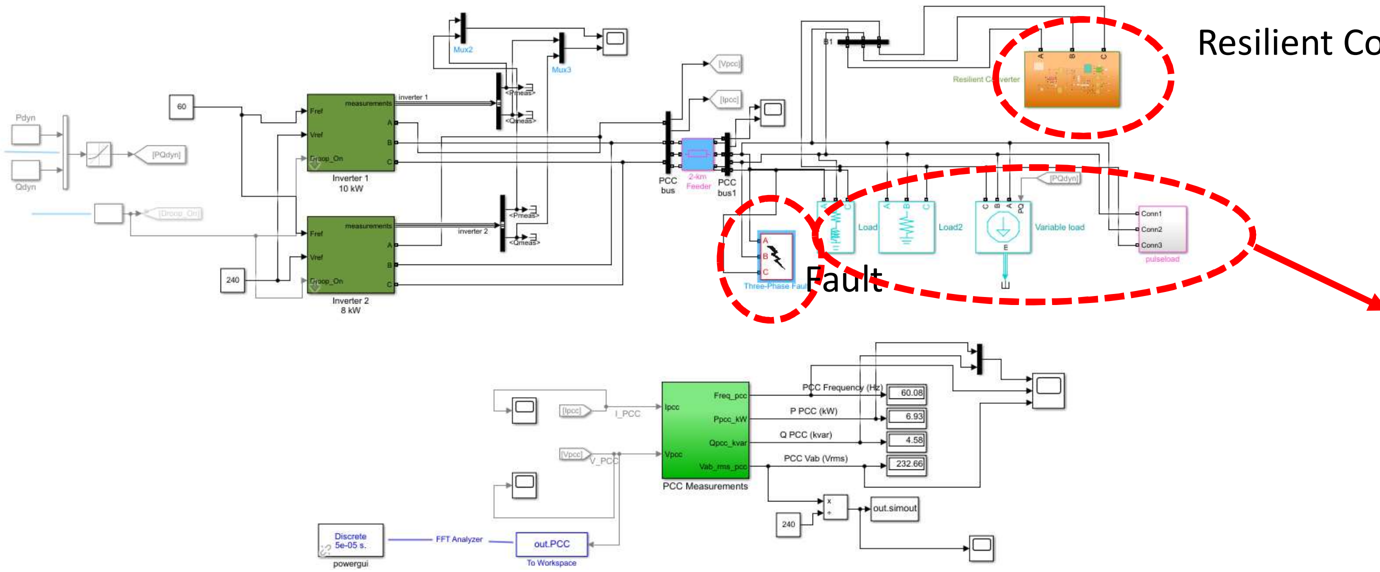
Introduction of fast, connected inverter

Resilient Converter



MATLAB Simulink model of Resilient converter to enhance the resiliency of the setup

Load	Ratings
Three phase RL load	P=3kW, Q=2kVAR
Three phase R load	P=3kW
Dynamic Load	P=4kW, Q=2 KVAR
Pulsating Load	P= 4kW

- 2 inverters (10kW, 8kW) are connected in parallel.
- 4 different loads(RL, R, Dynamic and Pulsating loads) are connected to the PCC through 2km feeder.
- Different faults are applied at bus 2 between t=2s to t= 3s.
- Dynamic load is varied at different time to validate the resiliency of the resilient power converter in case of both **symmetrical and unsymmetrical faults.**

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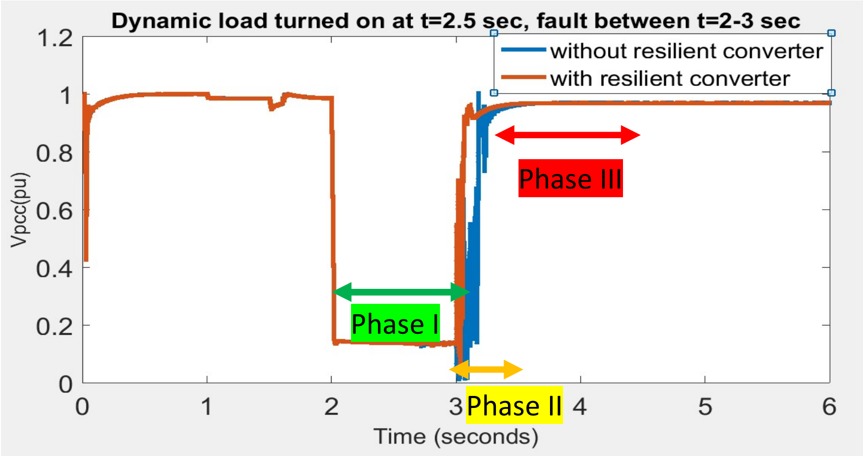
Demonstration of the resilient inverter

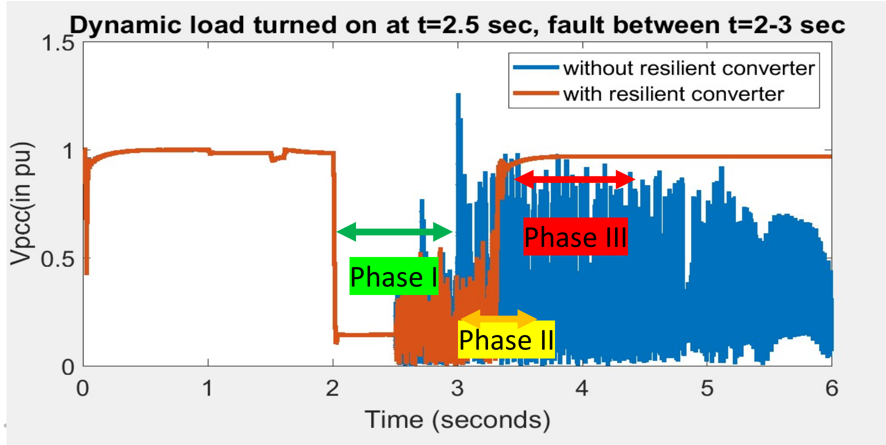
Operational resiliency curve in a microgrid

Phase I: the **disturbance process** ($t \in [toe, tee]$) is the time elapsed by the occurrence of the event.
Phase II: **degraded state** after the occurrence of the disturbance; ($t \in [tee, tor]$) for operational resilience.
Phase III: **restorative state** ($t \in [tor, Tor]$) for operational resilience.

Simulated fault



Operational resiliency curve for symmetrical fault at bus 2



Operational resiliency curve for unsymmetrical fault at bus 2

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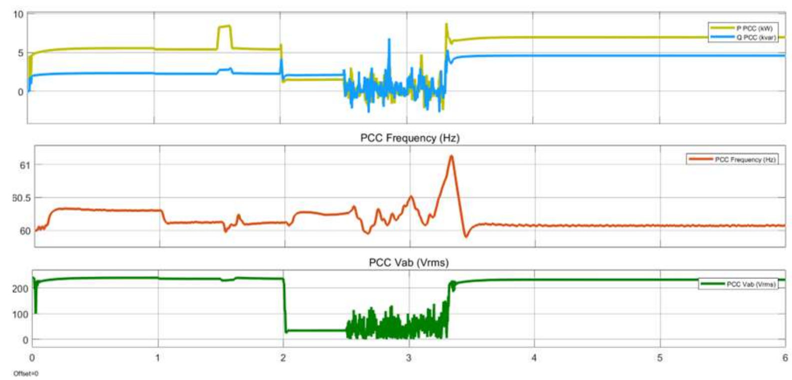
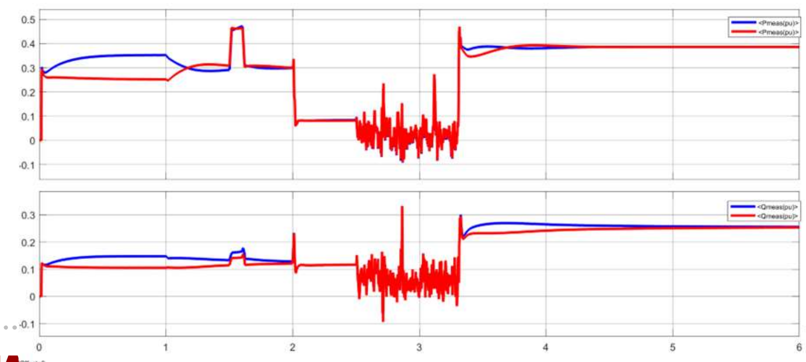
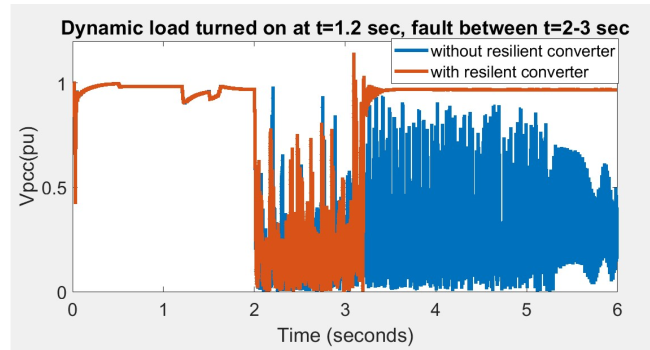
Detailed waveforms of the event

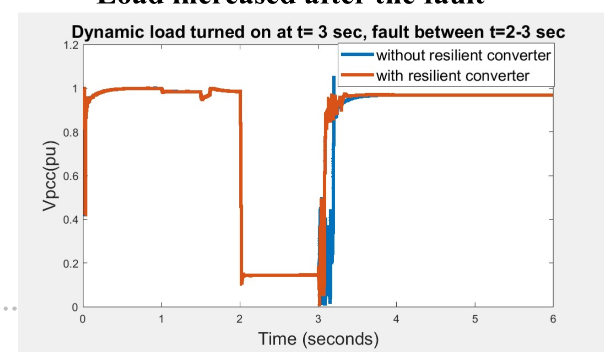






Operational resiliency curve for unsymmetrical fault at bus 2

Load increased after the fault



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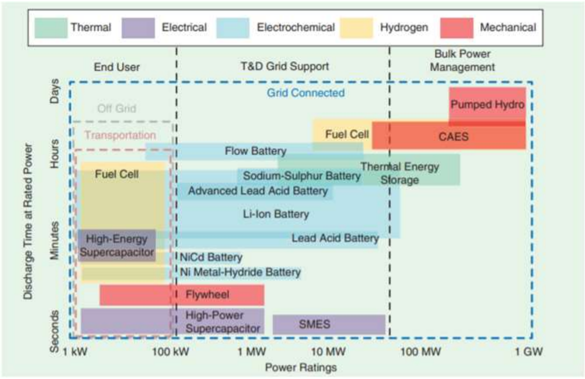
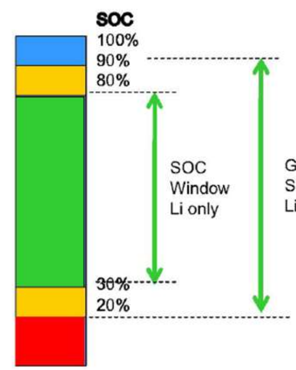
Case for high-power supercapacitive storage

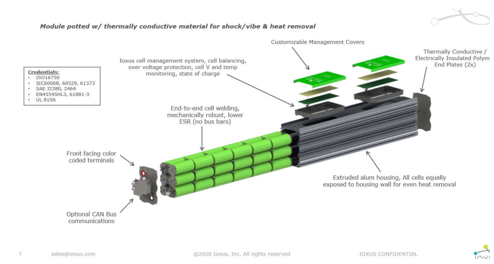
- Cost of the bidirectional dc-dc converter capable of 100 kW power levels.
- Bounds on ultracapacitor power levels that will ensure ultracapacitor plus dc-dc converter overall efficiency >90%
- Resulting charge and discharge rates on the battery versus when in standalone operation
- Value proposition that makes a business case.

The high-power dc-dc converter versus
the case of using twice the amount of battery.



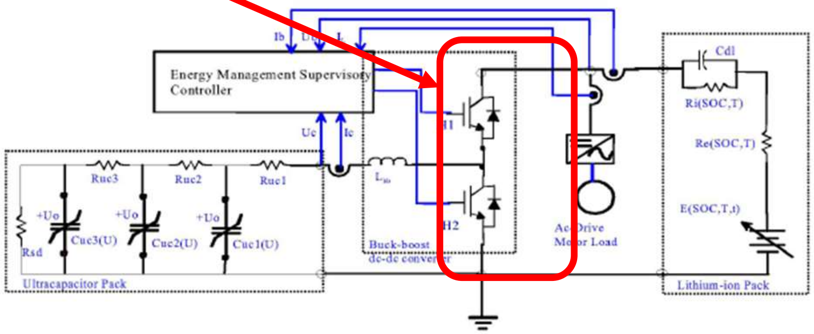
Keeping state of charge in safer limits



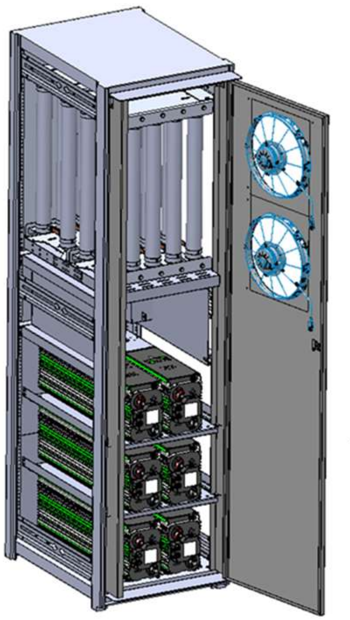


SuperCaps by a small NY company Iouxus

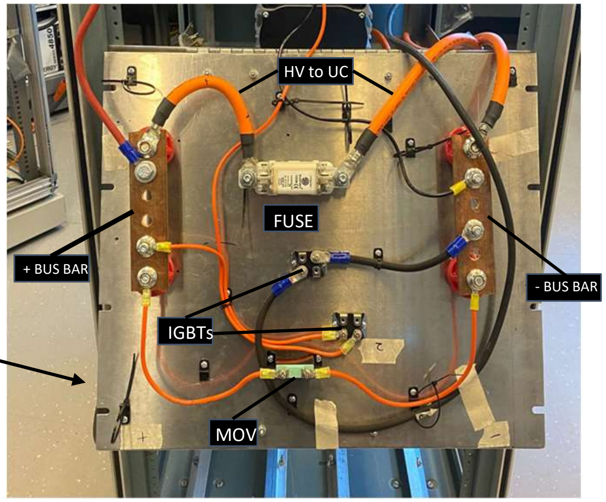
Automotive applications



High voltage test unit: test of balancing and high voltage, high current

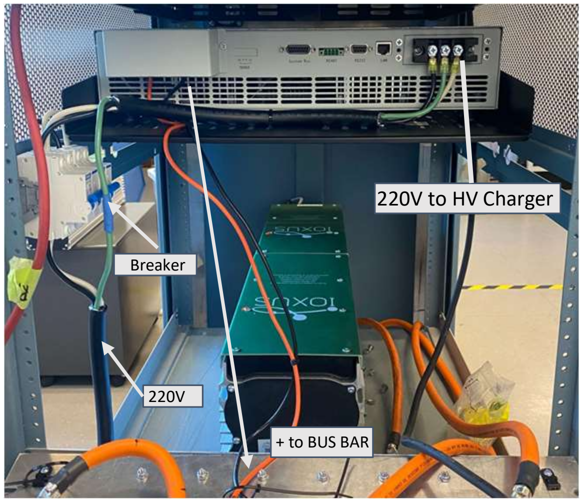


High Voltage Panel



*LV components have not been connected to HV panel

220v Breakdown



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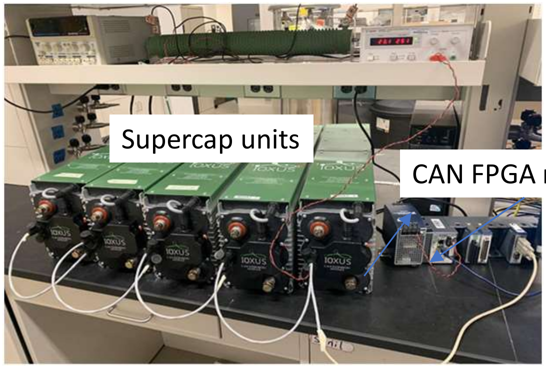
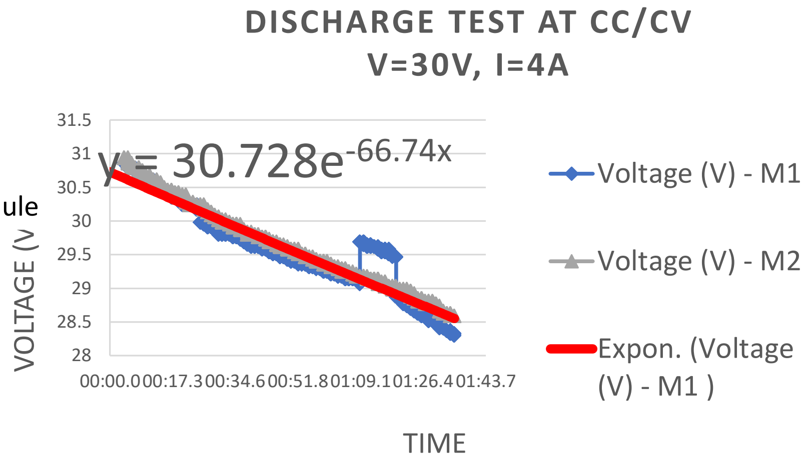
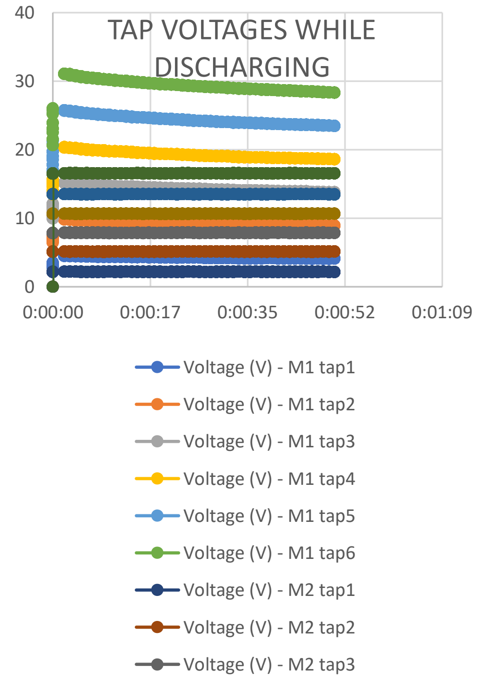
Testing of the charge retention in the modules







✓ Self-discharge time constant 66 hrs

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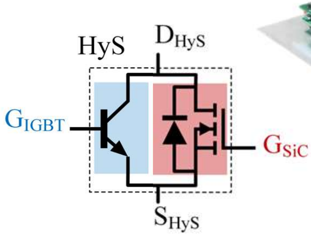
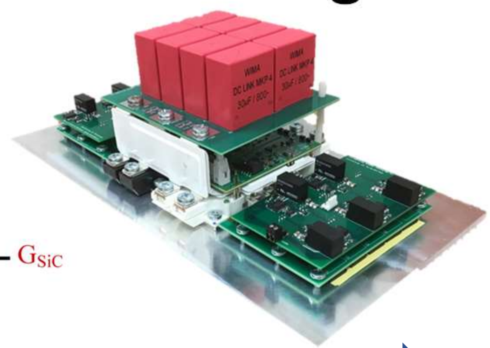
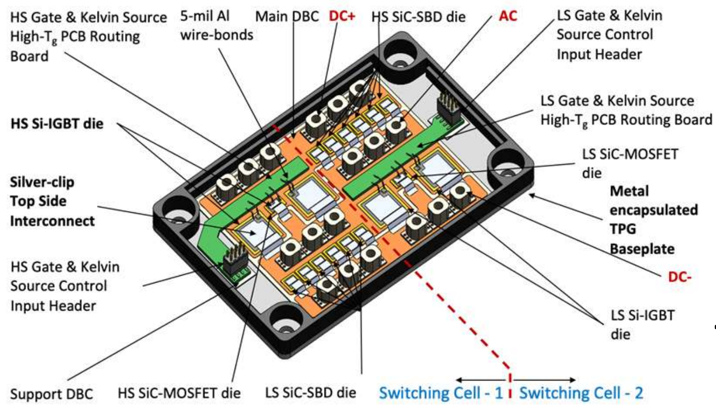
Shrinking the Size: Power Module Development

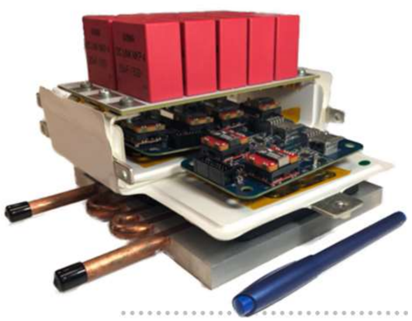


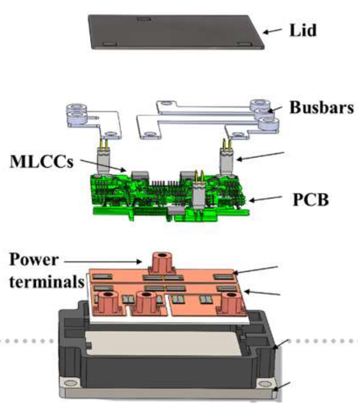
High-current rated Si IGBT
Low-current rated SiC MOSFET

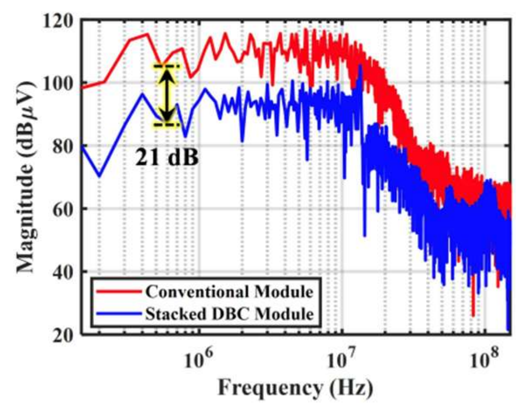




1200V / 350 A HyS TPG Enhanced Thermal Management







d) Comparison of CM noise in frequency domain

3L-TNPC

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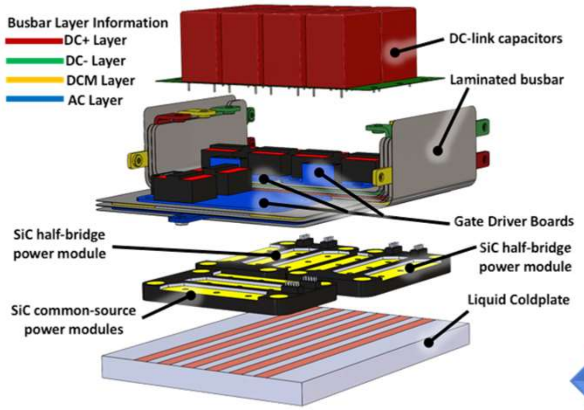
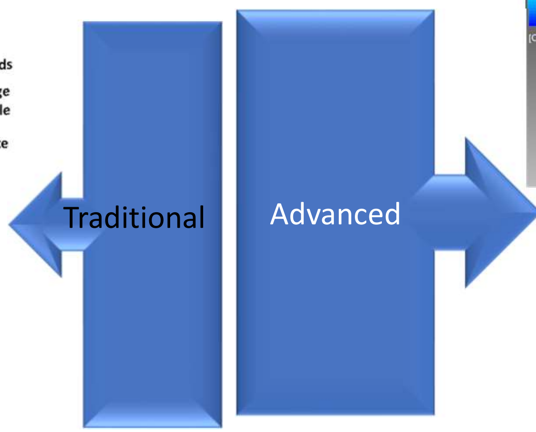
5/15/2023

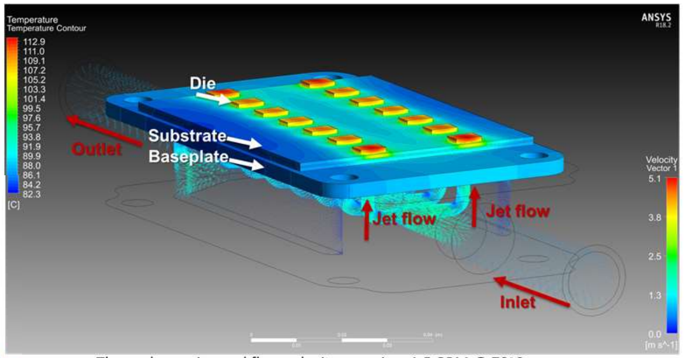
1200V / 450 A

1200V / 150 A

Thermal-Mechanical-Electrical Co-designed Solution

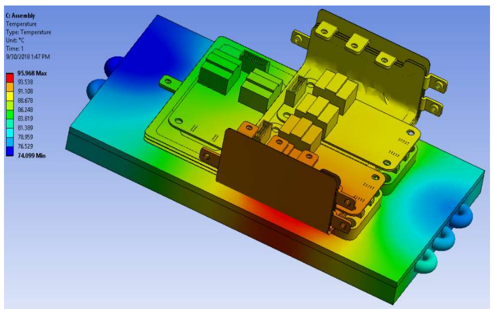




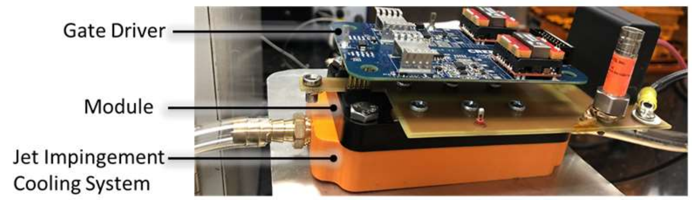


Thermal mapping and flow velocity mapping, 1.5 GPM @ 70°C

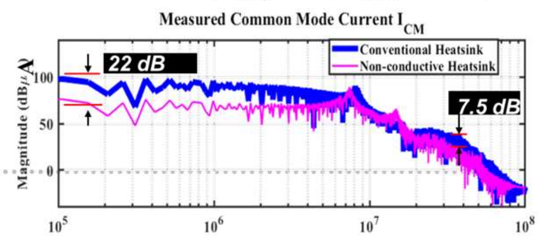
3D Printed Non-metallic coldplate



Temperature distribution, 150 kW, 1 GPM @ 70 °C



Test Setup ($R_{G,ON}$ = 5 Ω, $R_{G,OFF}$ = 2.5 Ω)



Optimized Jet-Impingement coldplate
3D Printed with non-metallic material for EMI optimization
Busbar is optimized for thermal/stray inductance/ stray capacitance

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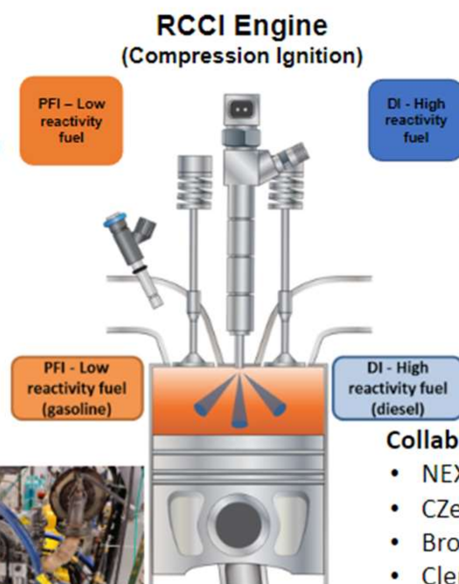
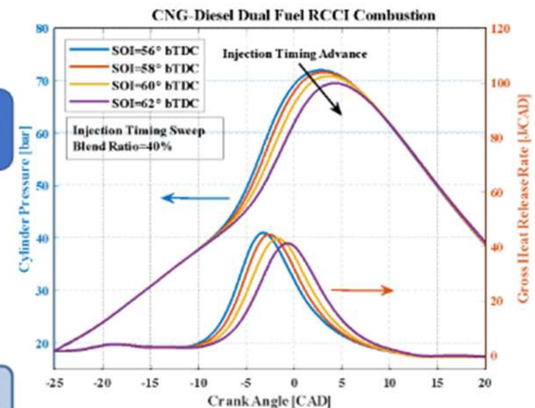
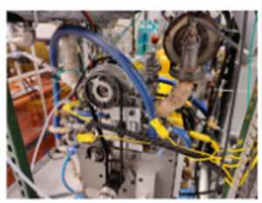
Generation: Dual Fuel RCCI of Anode Off-Gas (Syngas) / Diesel

- **Reactivity controlled compression ignition (RCCI) allows control of heat-release rate**
    - A low-reactivity fuel is introduced early and premixed with intake air
    - A high-reactivity fuel is injected into the combustion chamber and mix with premixed charge before ignition
- **RCCI increases engine operating range for premixed combustion**
    - Global fuel reactivity (control combustion phasing)
    - Fuel reactivity gradients (reduce pressure rise rate)
    - Equivalence ratio and temperature stratification
- **RCCI offers both benefits and challenges to implementation of LTC**
    - Diesel-like efficiency or better
    - Ultra-Low NOx and soot
    - Emissions challenges of THC and CO







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Collaborators:

- NEXCERIS
- CZero
- Brookhaven National Lab
- Clemson University

Funding:

- ARPA-E INTEGRATE

Number of Cylinders	1
Number of Valves	4
Stroke (mm)	86
Bore (mm)	79
Vd (cm^3)	421.5
Intake Valve Opening (IVO)	-354° aTDC
Intake Valve Closing (IVC)	-146° aTDC
Exhaust Valve Opening (EVO)	122° aTDC
Exhaust Valve Closing (EVC)	-366° aTDC
Compression Ratio	15.1
Fueling Method (liquid fuel)	Direct injection
Fueling Method (gaseous fuel)	Fumigated

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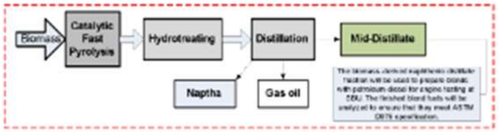
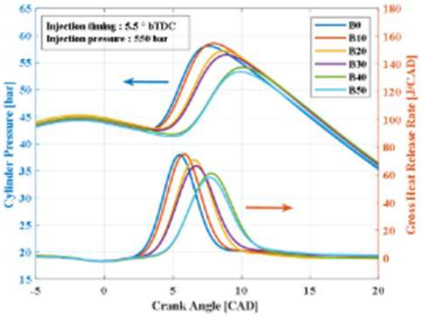
Naphthenic Biofuel-Diesel Blends

Effects of Different Volume of Biodiesel on Engine Cylinder Pressure and HRR

- Injection timing sweep was fixed at 5.5° before TDC
- Injection Pressure was maintained at 550 bar
- Engine cylinder pressure and heat release rate decreases as the volume percentages of the blended biodiesel increases
- Combustion phased later with increased volume of biodiesel





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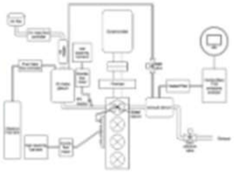

Ricardo Hydra Engine Schematic

- 6 different sample surrogate fuels were prepared at Stony Brook University
- Surrogate fuel No.1 was blended from 10% to 50% by volume with research grade diesel for experimental engine testing

https://youtu.be/D4qP2OdxZic

Collaborators:

- Ofei Mante & David Dayton, RTI
- Gina Fioroni, NREL
- Melissa Legg, SwRI

Funding: DOE BETO

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FAR BEYOND

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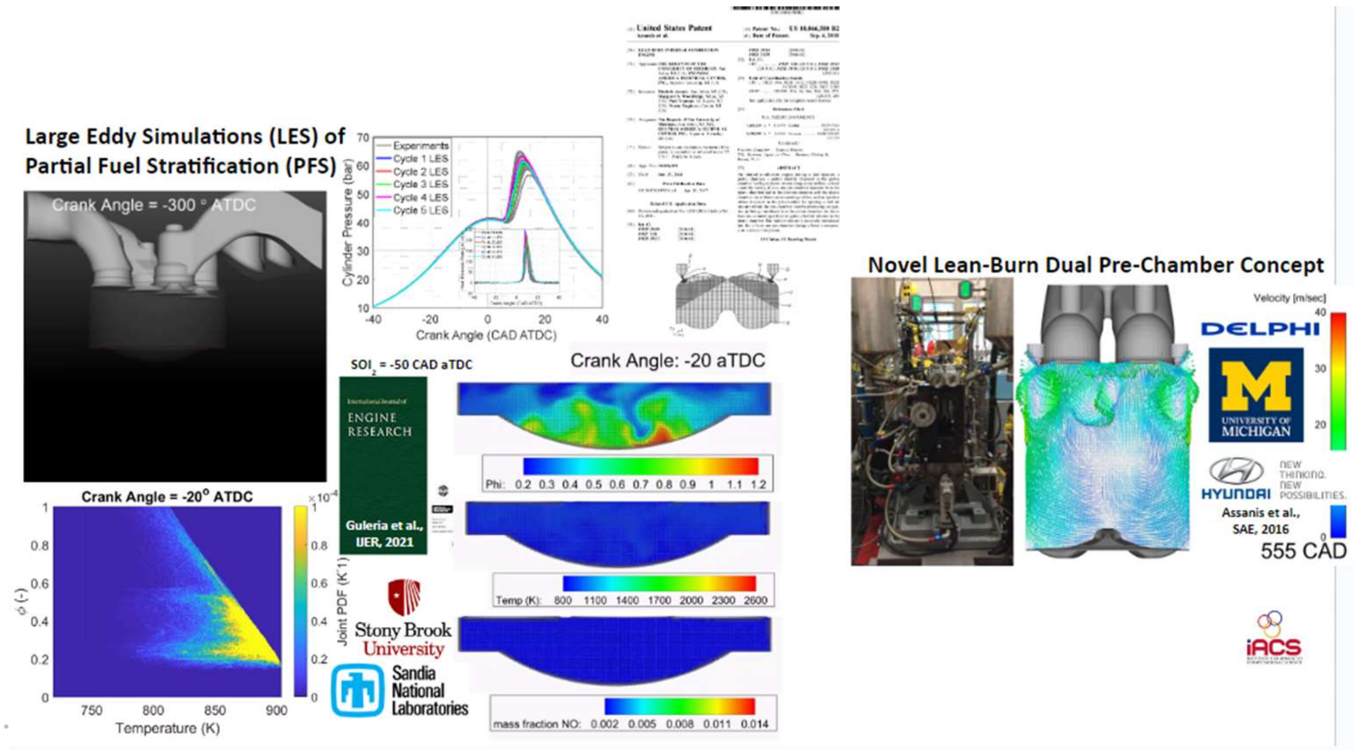
Hydrogen-containing fuels: engines with pre-chamber



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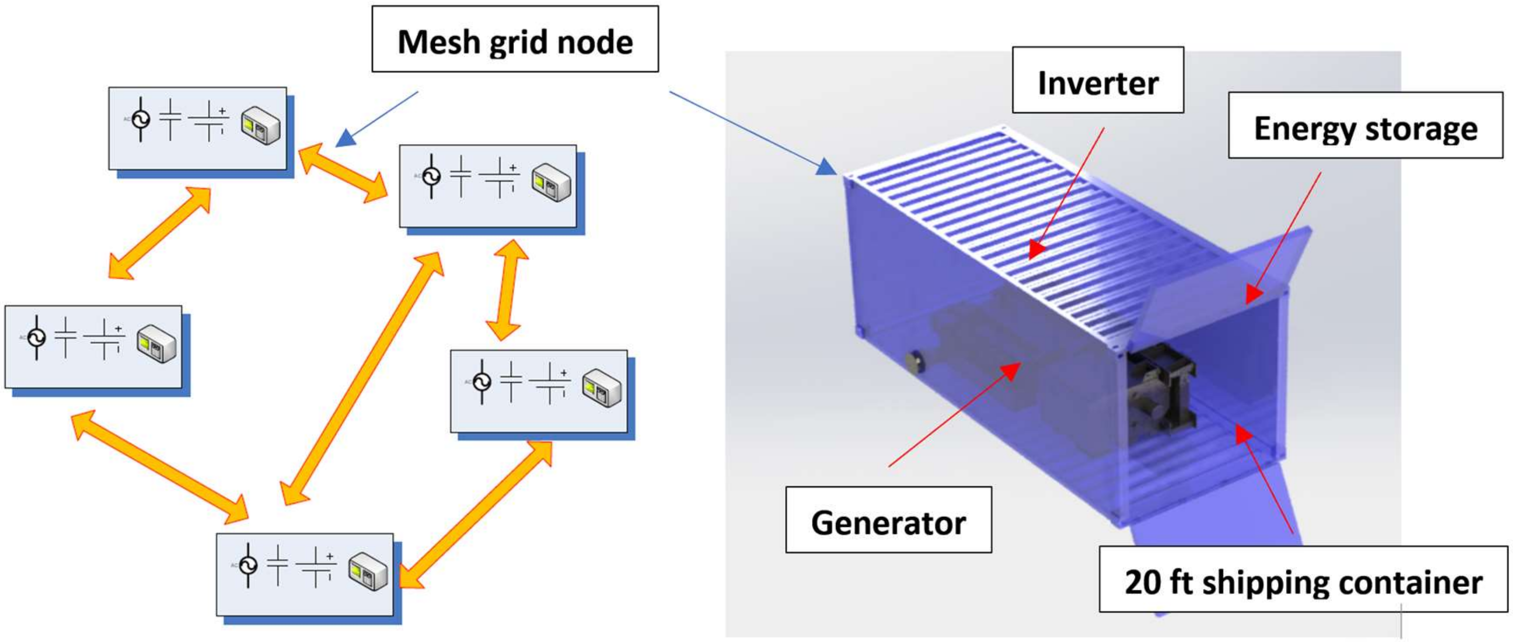
Future development: AC meshed grid



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