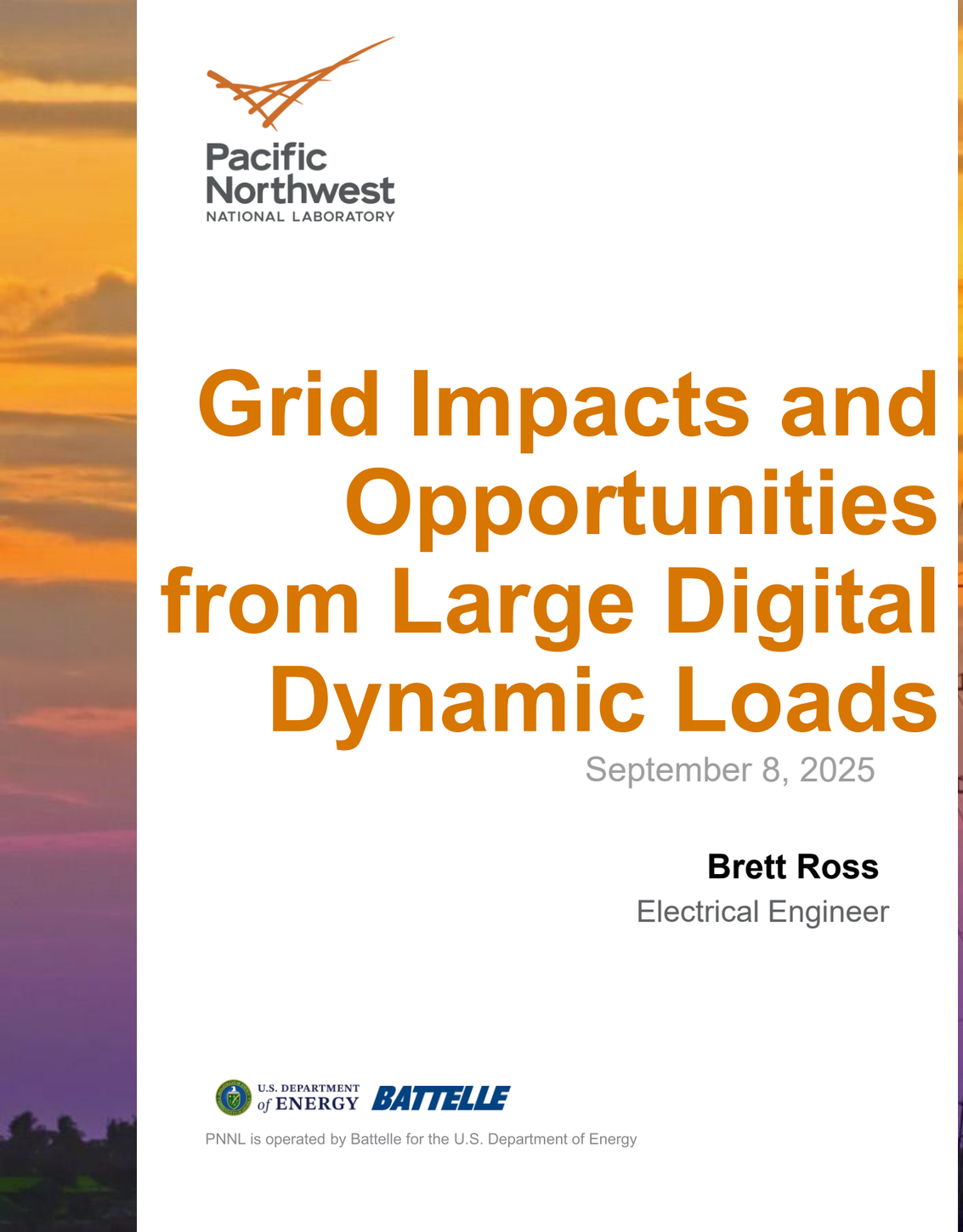
Pacific Northwest
NATIONAL LABORATORY

# Grid Impacts and Opportunities from Large Digital Dynamic Loads

September 8, 2025

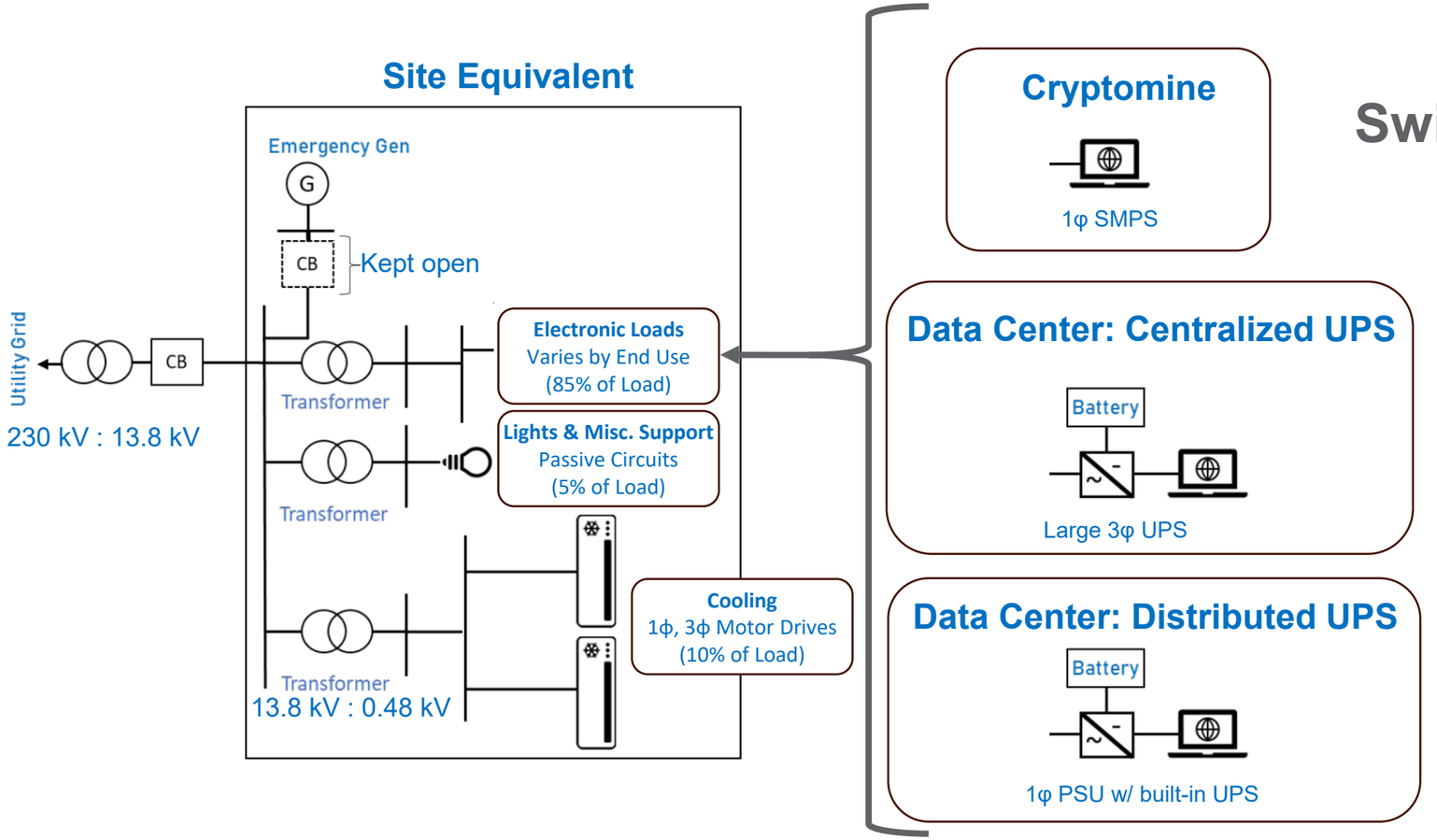
**Brett Ross**
Electrical Engineer



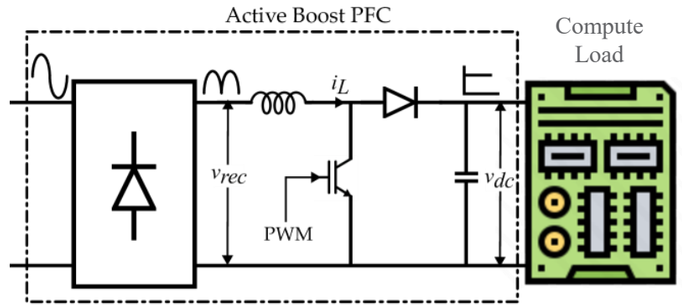
U.S. DEPARTMENT of ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

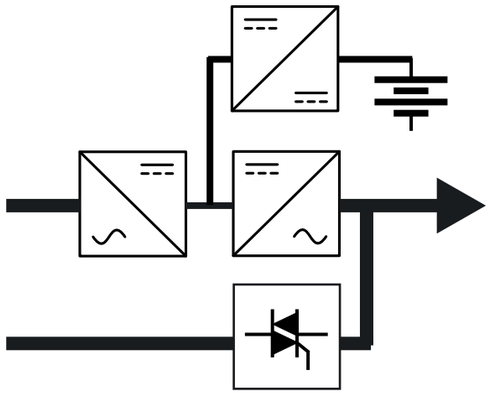
# Typical Power Electronics Designs




## Switched Mode Power Supply[1]




## Double Conversion UPS



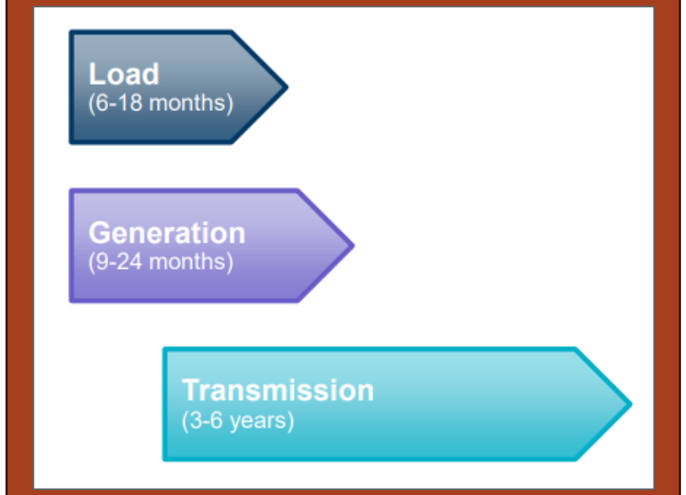
Variations: 1 PH VSC PSU; no UPS

Recommendation: NERC questionnaire

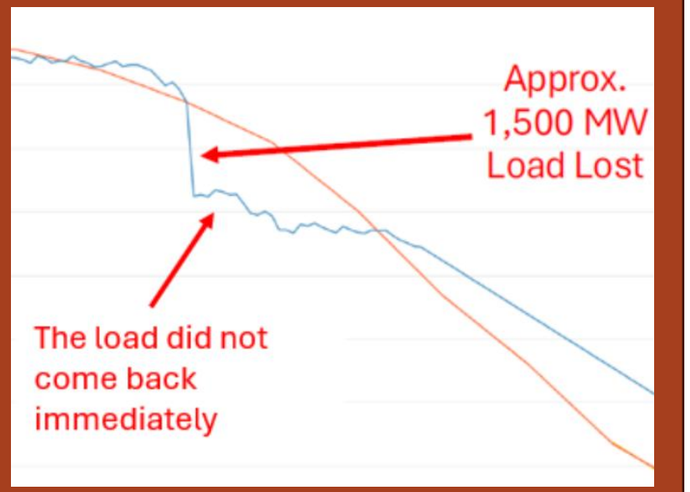
[1]Samanta et al, Electromagnetic Transient Model of Cryptocurrency Mining Loads for Low-Voltage Ride Through Assessment in Transmission Grids

# Challenges

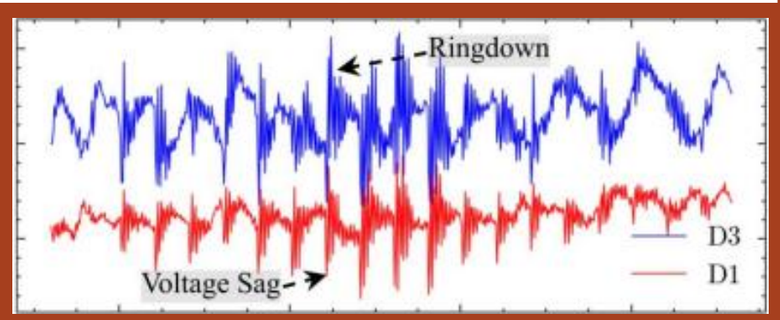
## Short Interconnection Timeline[1]



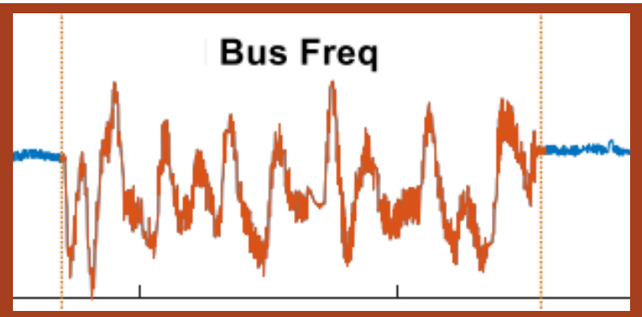

## Fault Ride-Through Performance[2]




## 14.7 Hz at Virginia Datacenter[3]




## ~10 Hz at Offline Datacenter[4]

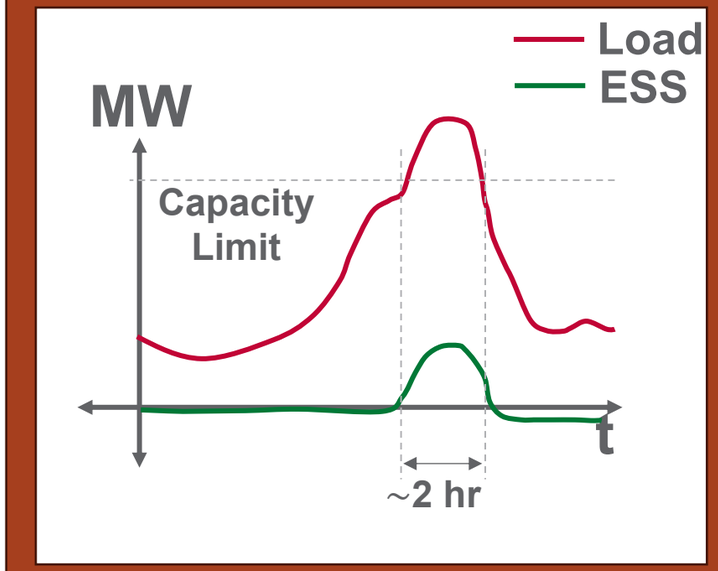



[1] Large Loads and the Changing Grid, an ERCOT Perspective, NERC LLTF April Meeting
[2] Incident Review, Considering Simultaneous Voltage-Sensitive Load Reductions
[3] Understanding the Inception of 14.7 Hz Oscillations Emerging from a Data Center
[4] Battery Storage Applications at Data Centers, NERC LLTF April Meeting

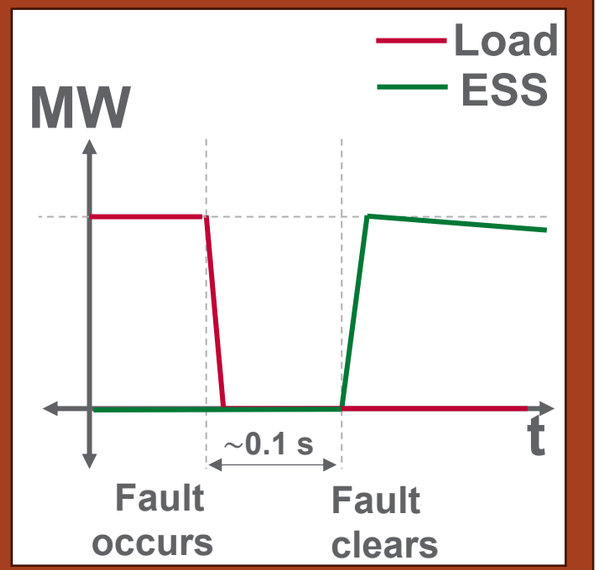
# Energy Storage Applications

- Additionally: fast frequency response, synthetic inertia, reactive power

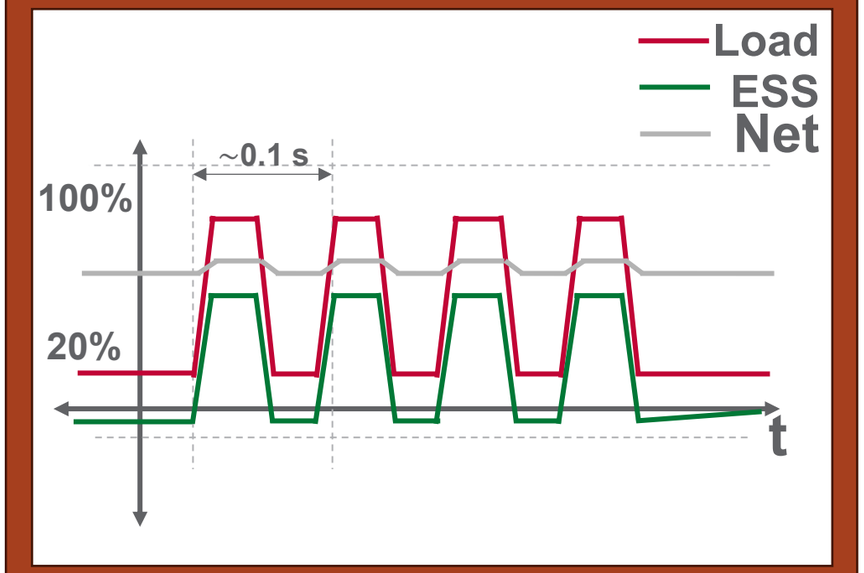
## "Unlock" transmission capacity with congestion relief




## Stabilize system by replacing tripped load



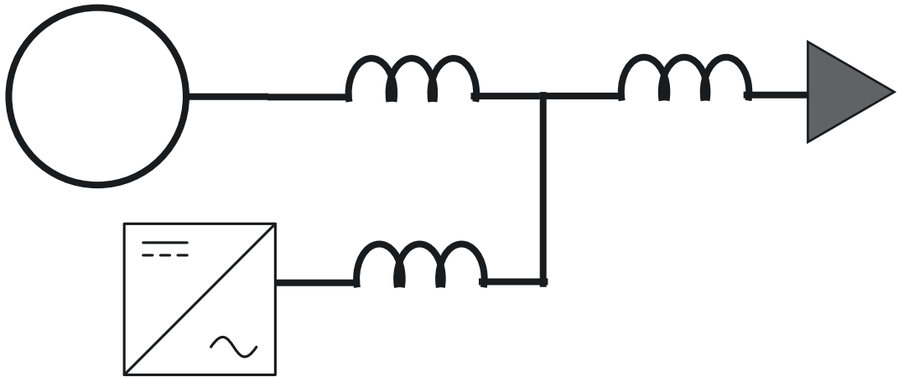

## Attenuate load oscillations before they enter the grid



# Key Design Factors

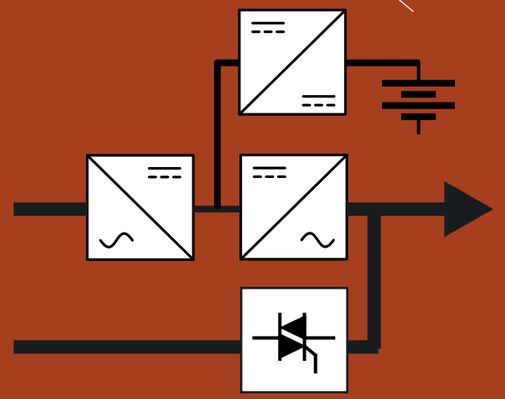
## Storage technology

- Key is the power electronics interface:
  - Match rapid shifts in active power consumption
  - Dynamic reactive power not the pivotal feature
  - Measurement delay, system impedance
- Options include supercapacitors, hydrogen fuel cells, batteries



## Integration with Load Electronics

**Use for both load *and* grid support functions?**

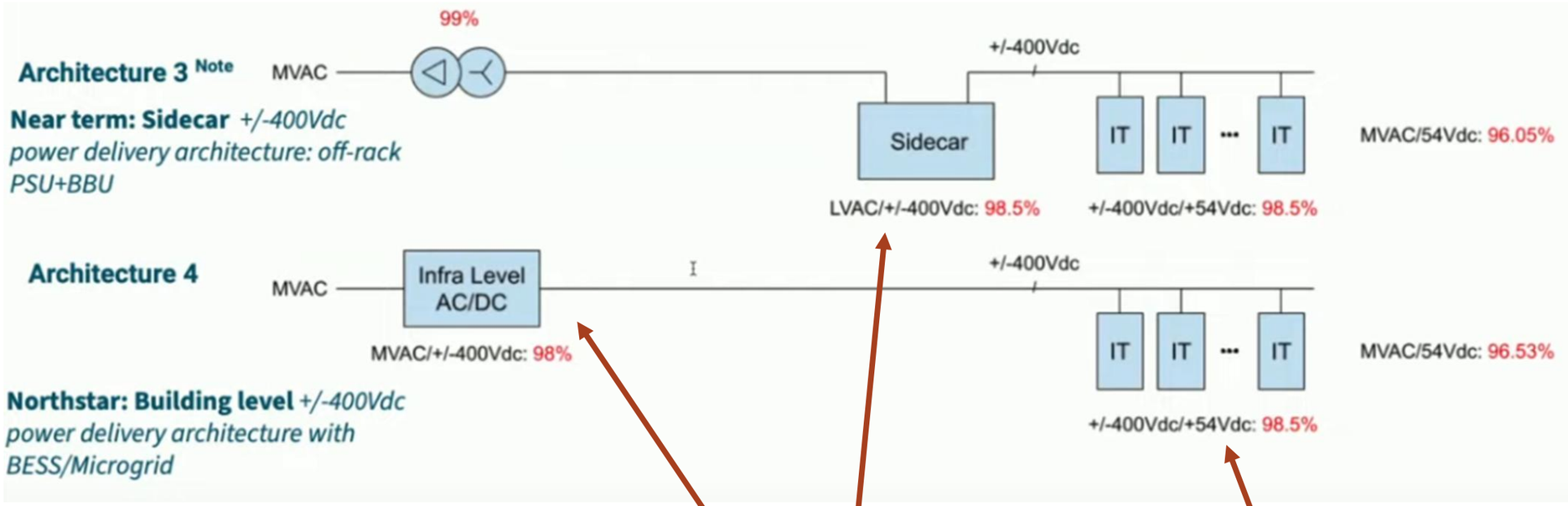


## Sizing (MW, MW-Hr)

- Can't escape conservation of energy
- Battery MW-Hr technology-dependent (Li, flow, etc.)

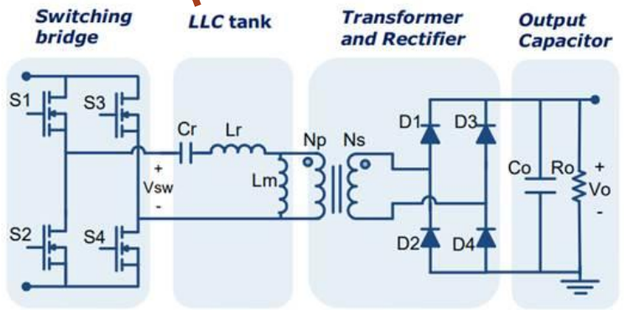
# Near-Future Architectures

- Trend towards LVDC (0.4 to 1 kV) distribution (hardware under R&D)




Fall 2024 OCP Global Summit

VSC-based Inverter
(GFM or GFL)




Infineon DC-DC Resonant Converter

Pacific Northwest
NATIONAL LABORATORY

# Thank you