

Power Electronic System Safety and Reliability

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Power Electronics Systems Integration

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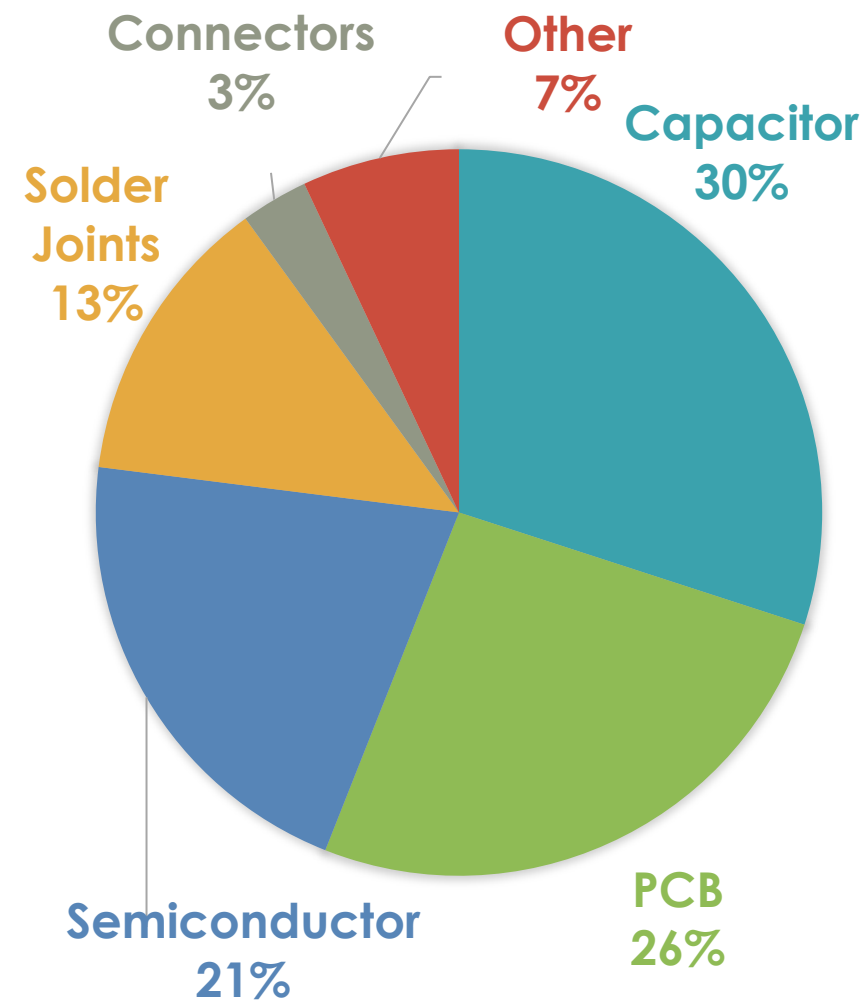
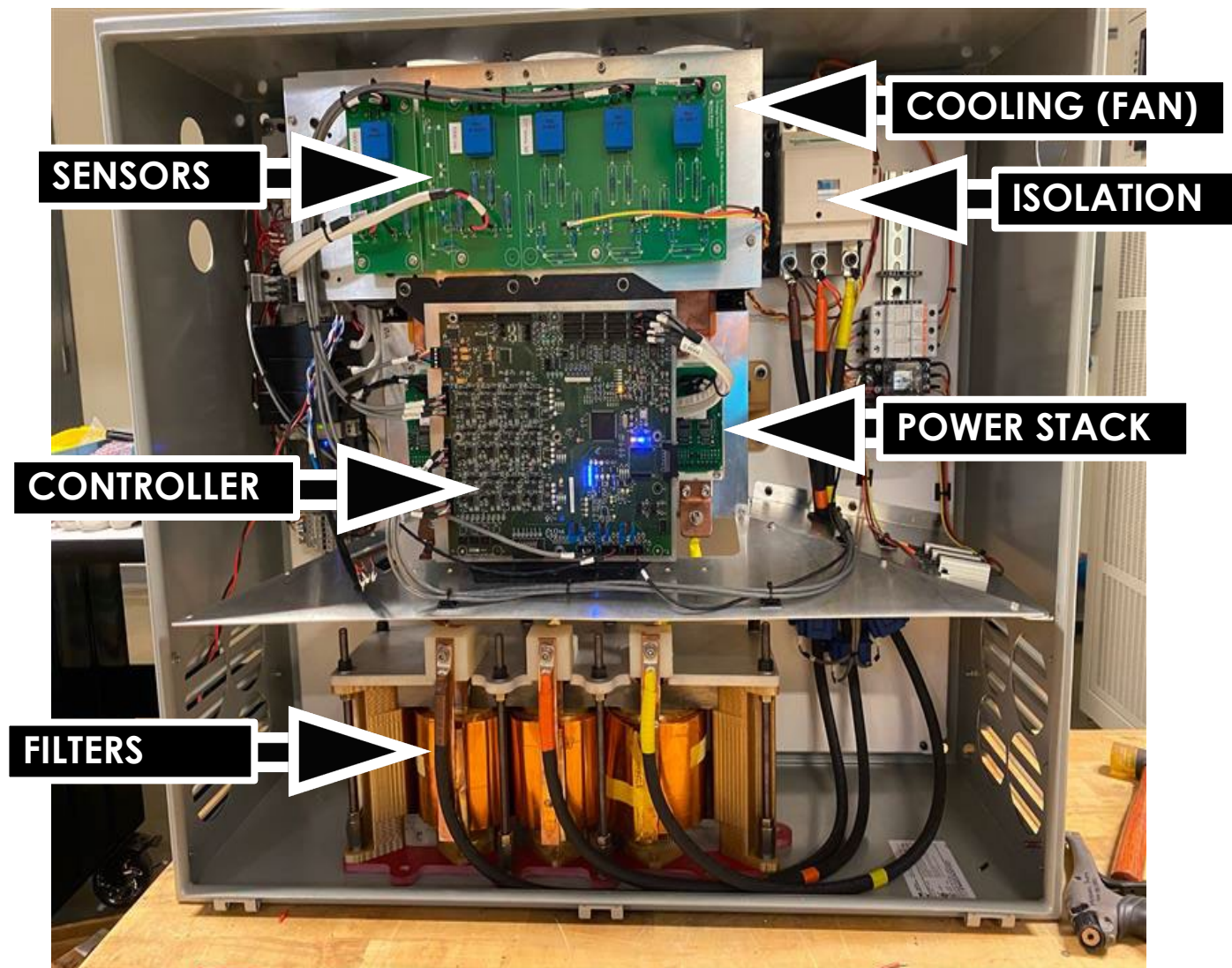
Thoughts and Contributions from the PESI Group

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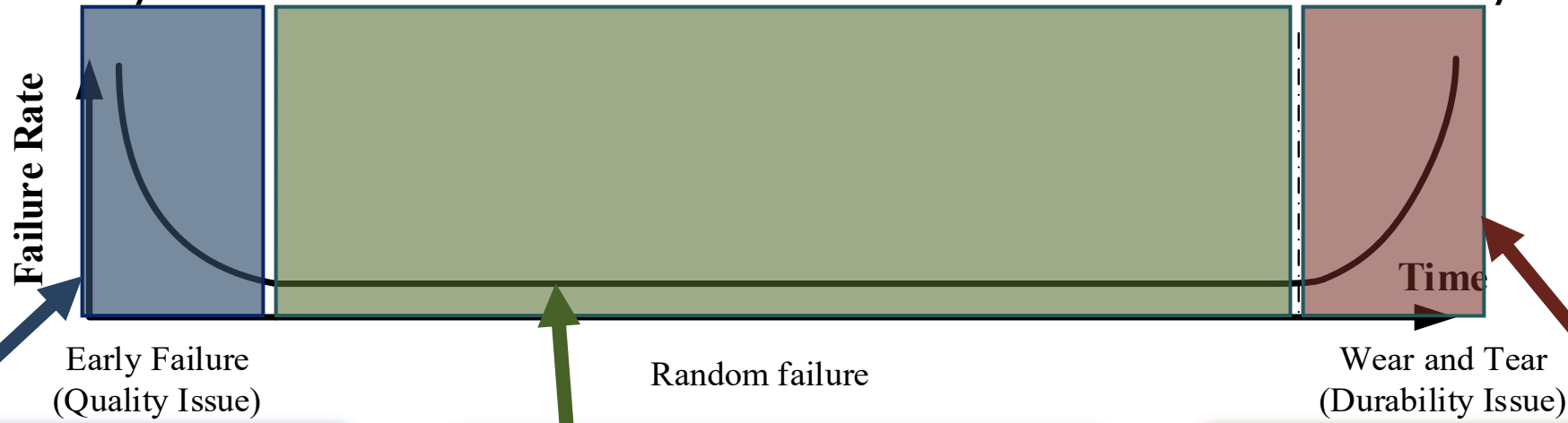
U.S. DEPARTMENT OF
ENERGY

Power Electronics System



Power Electronic Failures

Failure: Many Reasons and Different Times in the Life Cycle



Design, Manufacturing, Install :

- Design
 - Ergonomic Issues
 - Operating Environment
 - Specification Errors
 - Inadequate Testing
- Manufacturing:
 - Solder voids
 - Process control
- Install
 - Lack of Training
 - Procedure Issues
 - Installation Error
 - Updating Error
 - Programming Error

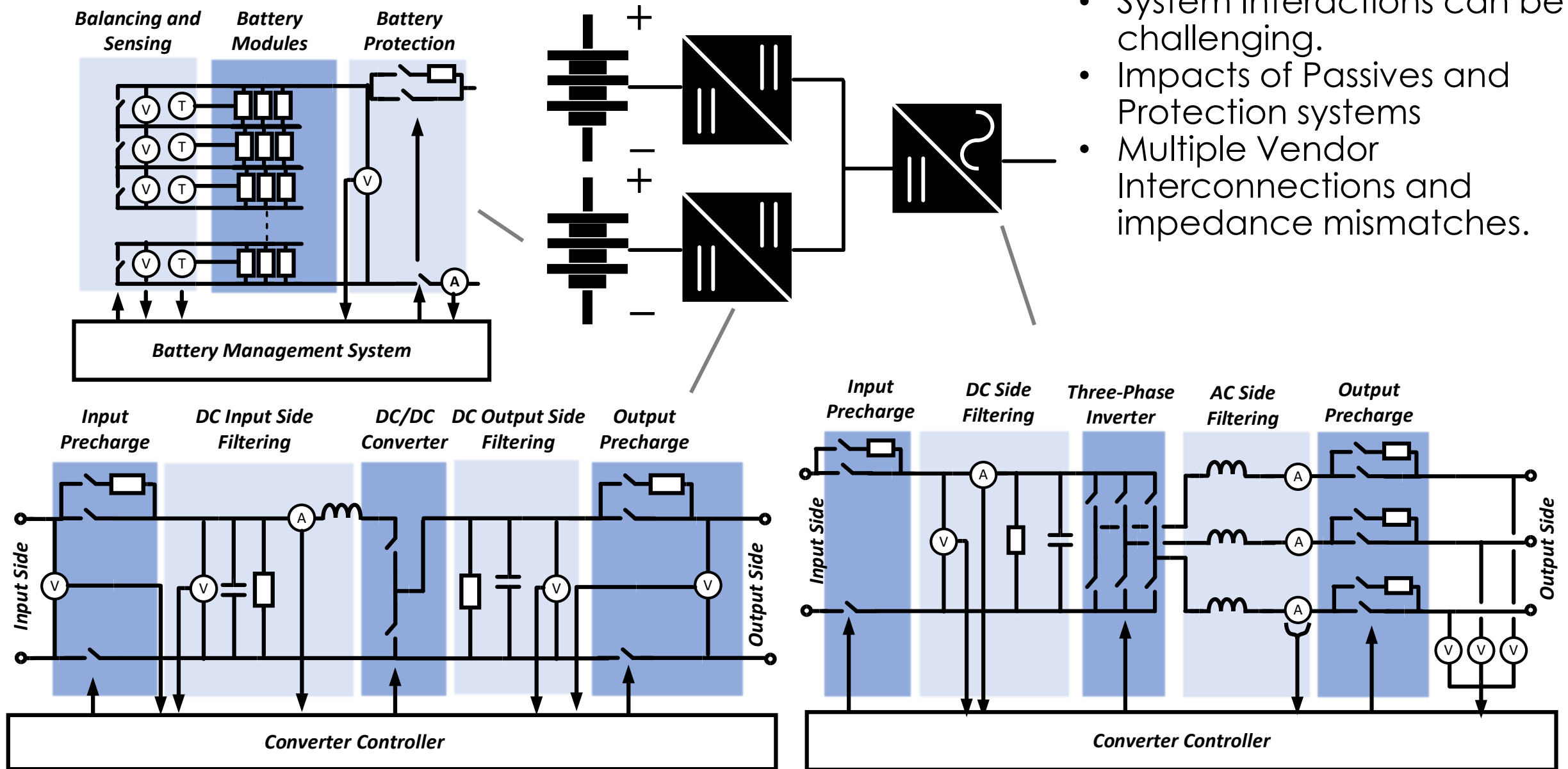
Maintenance and Early Fatigue:

- Maintenance
 - Software Updates
 - Accrual of error over time in measurements
 - Environmental (Filters in converter cooling)
- Early Fatigue
 - Unforeseen stresses
 - Non-routine operation
 - Omissions in routine operation

Lifetime Failures:

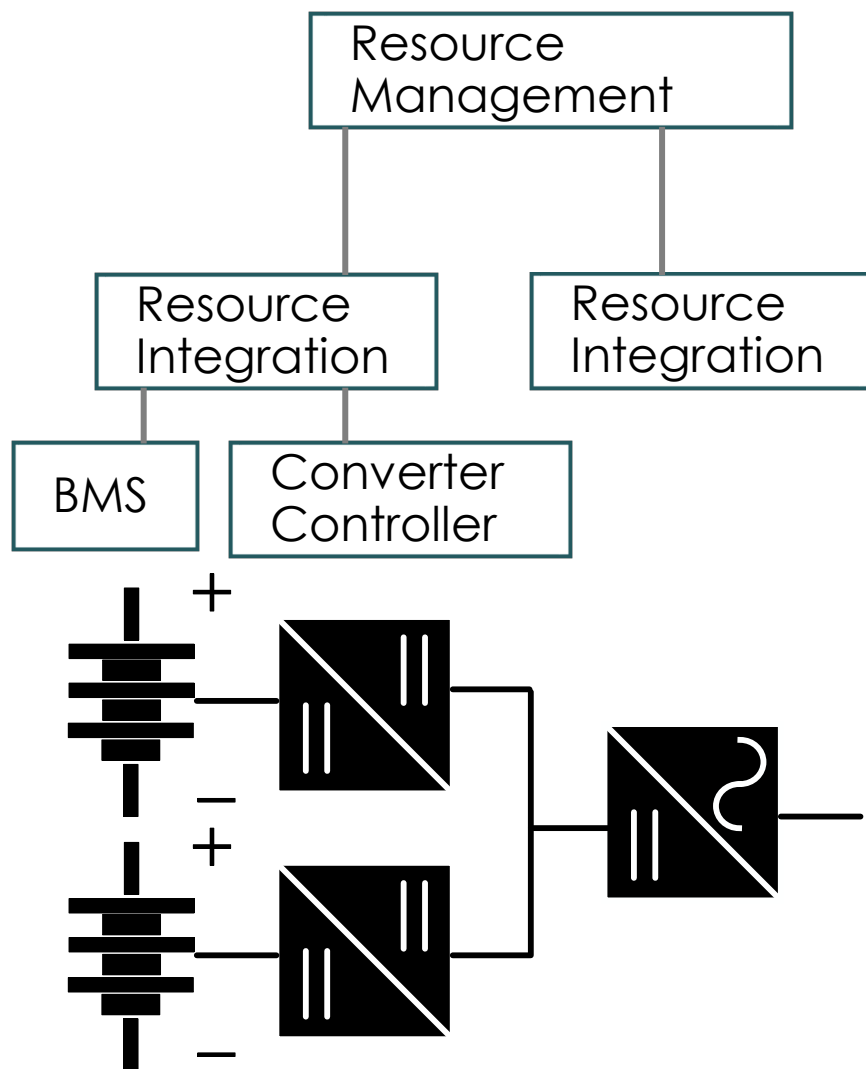
- Fatigue (cycling)
 - Die degradation (leakage current)
 - Contact terminal resistance increase (heat increases)
 - Interconnect failures due to dissimilar metal oxidation
 - Wire bond liftoff
- Accruing error over time (thermal and electrical)

Evolution of PE subsystems



Designs Impact Safety

- Safety must be baked into all the layers from the ground up.
- Resources support distributed monitoring and control
- Integration layers to ensure proper coordination between PE and assets



Integrated Resource

Connection Type: DC

Power Rating: 10kW

Voltage: 400 VDC

Converter

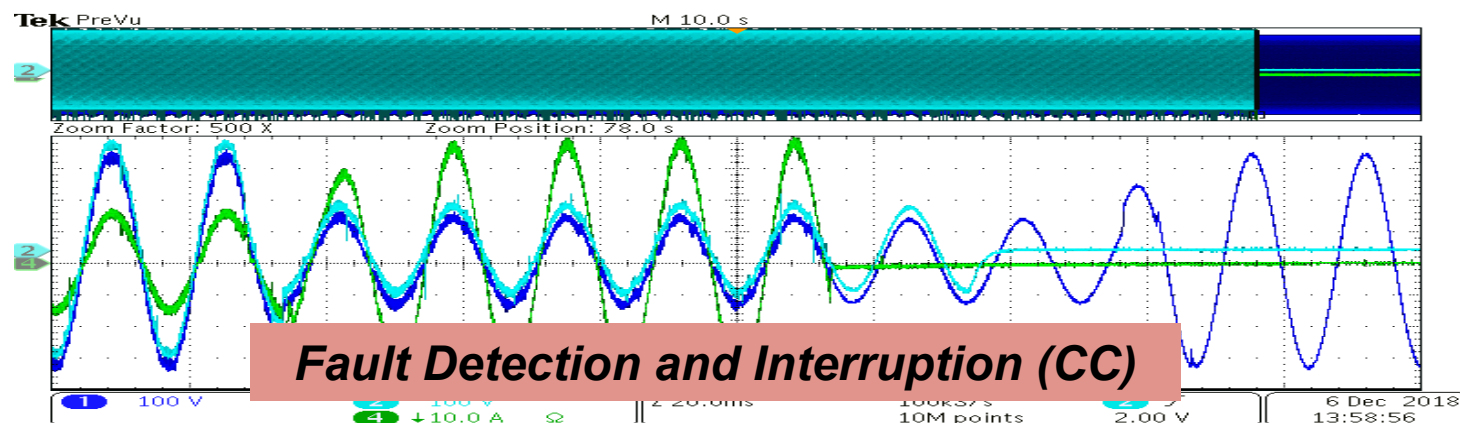
Connection Type: DC

Power Rating: 15kW

Voltage: 1000 VDC

FAIL

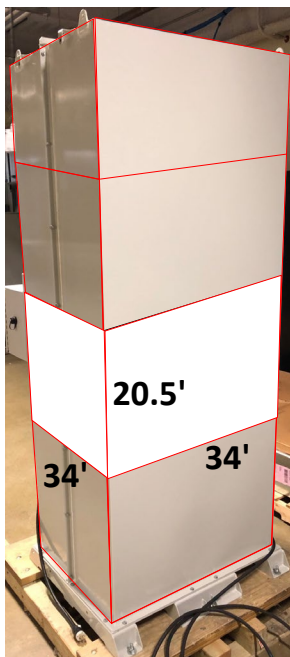
System Verification and Checks (RIC)



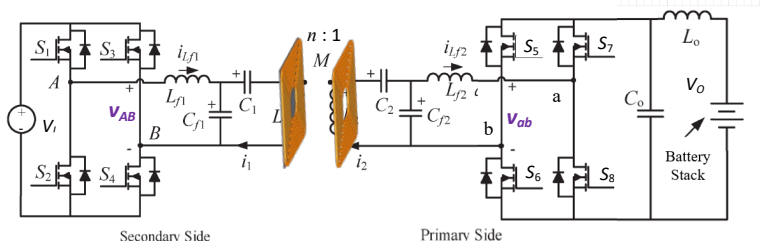
Fault Detection and Interruption (CC)

Looking Forward

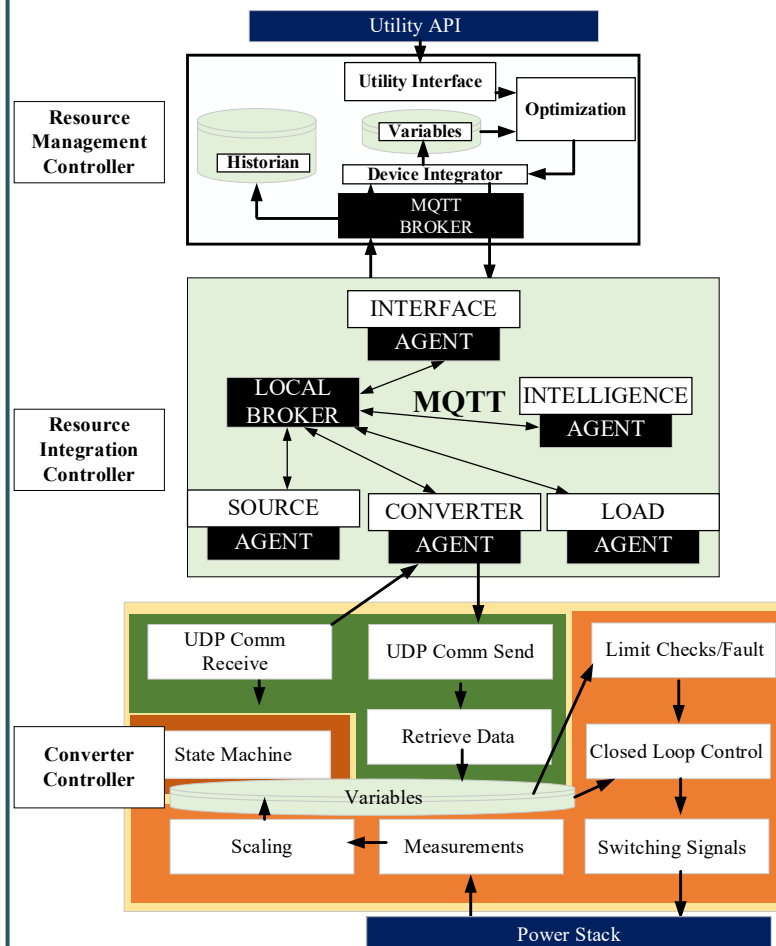
Wireless Power Transfer Modules



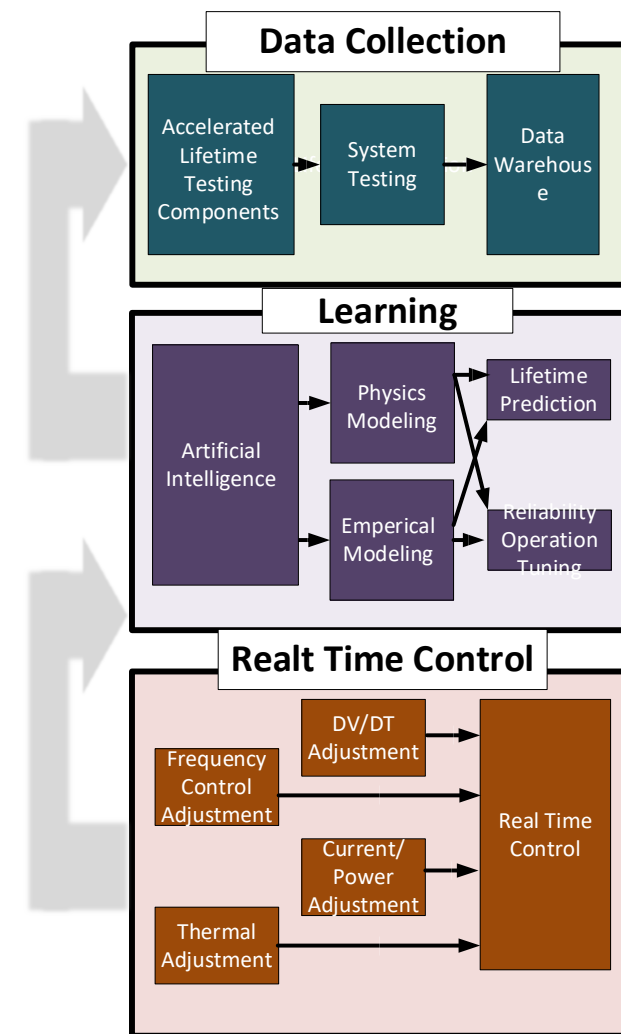
- Integrated safety within ES system.
- Highly modular and easy to maintenance.



Intelligent System Monitoring and Control



Artificial Learning and Detection



Supporting References

- Y. Song and B. Wang, "Survey on Reliability of Power Electronic Systems," in IEEE Transactions on Power Electronics, vol. 28, no. 1, pp. 591-604, Jan. 2013.
- H. Wang et al., "Transitioning to Physics-of-Failure as a Reliability Driver in Power Electronics," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 2, no. 1, pp. 97-114, March 2014.
- T. Dragičević, P. Wheeler and F. Blaabjerg, "Artificial Intelligence Aided Automated Design for Reliability of Power Electronic Systems," in IEEE Transactions on Power Electronics, vol. 34, no. 8, pp. 7161-7171, Aug. 2019.
- M. Shahzad, K. V S Bharath., M. A. Khan and A. Haque, "Review on Reliability of Power Electronic Components in Photovoltaic Inverters," 2019 International Conference on Power Electronics, Control and Automation (ICPECA), New Delhi, India, 2019, pp. 1-6.
- S. Peyghami, P. Davari, H. Wang and F. Blaabjerg, "Reliability and Risk Assessment in a Power Electronic Based Power System (PEPS): Using Non-Constant Failure Rates of Converters," 2018 20th European Conference on Power Electronics and Applications (EPE'18 ECCE Europe), Riga, Latvia, 2018, pp. P.1-P.9.