Codes and Standards as Drivers for ESS Battery Design

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a company of TOTAL

Increasing energy density in NCA / NMC containers

2012 – 0.6 MWh

2015 – 1.0 MWh

2020 – 2.5 MWh

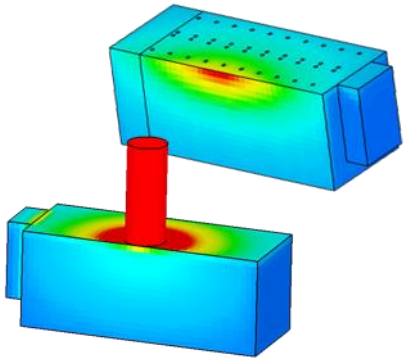
- Elimination of internal aisles allows for increased energy density and avoids potential code issues with occupied spaces
- Thermal runaway propagation with high-density container requires more aggressive fire suppression

Container qualification

- Overall, qualification of an ESS battery system costs around $1M
  - UL 1973
  - UL 9540 (battery system tests)
  - UL 9540A
- If water-based FSS required
  - Automatic actuation requires plumbed-in supply or external tank
  - Accidental actuation will destroy the battery

Multi-container layouts

- Containers must be spaced so that uncontrolled fire in one will not initiate thermal runaway in adjacent containers
- Design features
  - Deflagration panels to direct heat upwards
  - Insulation along container sides
- Container needs 3m (10ft) space all around
  - With overall footprint, spacing can easily nullify improvements in container energy



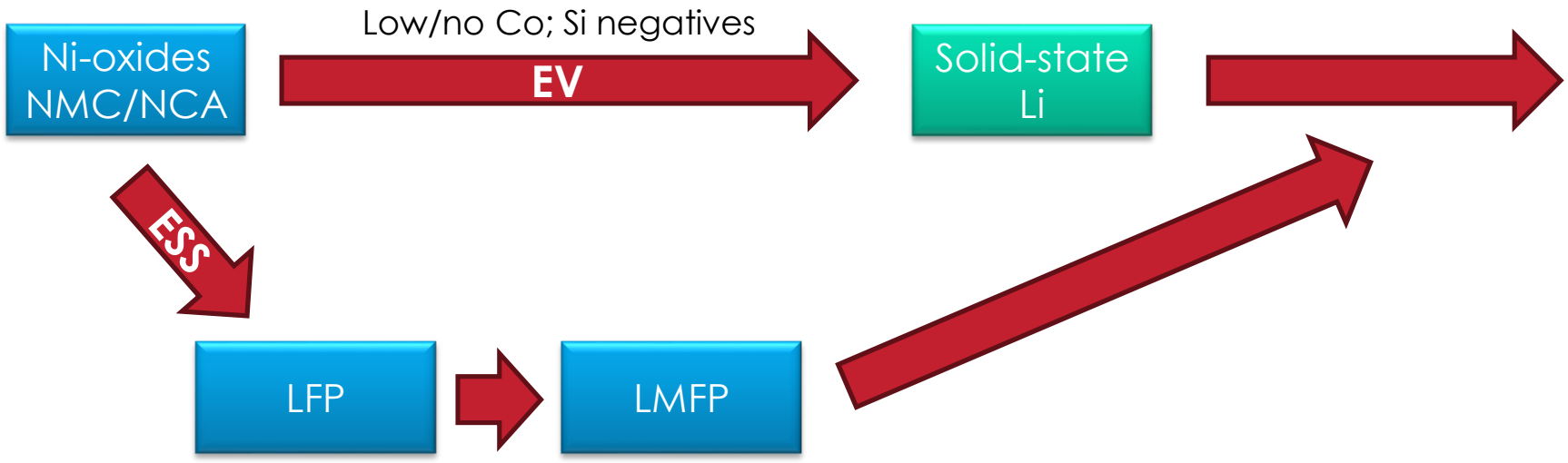
Stopping propagation

- The easiest way to stop cell-to-cell propagation is to prevent it in the first place
- Passive safety features
- Drive to safer lithium iron phosphate (LFP) chemistry
  - Considerably lower cost material
  - Not impacted by cobalt and nickel price volatility
  - Lower cell voltage reduces energy density
- Lower cost for product qualification

Containers versus cabinets

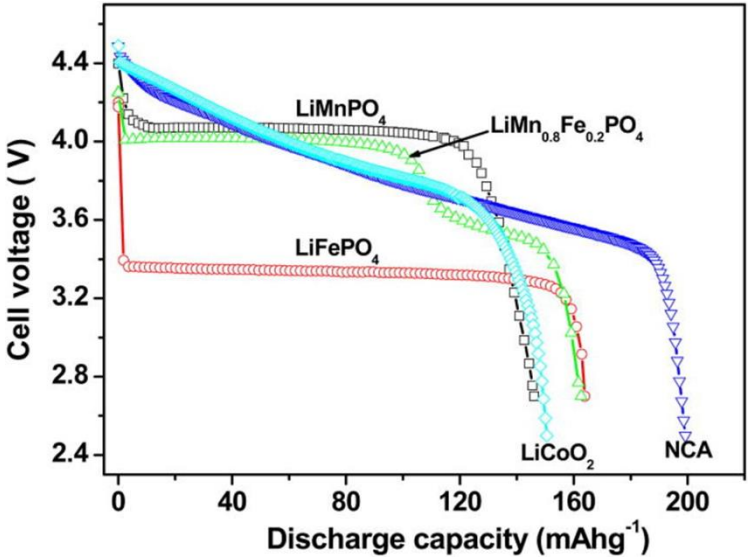
- Passive features to avoid propagation eliminate spacing requirement for safety
  - But containers still need space all around for maintenance access
- Overall system footprint favors modular cabinet designs
  - Arranged side-by-side and back-to-back
  - Smaller energy increment allows more tailored system and easier augmentation
- Optimized footprint mitigates energy reduction from adopting LFP

ESS and EV roadmap divergence / convergence



Battery management issues with LFP

- Flat voltage profile of LFP (and LMFP) presents challenges for SOC management in continuous-cycling applications
  - Battery SOC
  - Cell balancing
- Cumulative error from current sensing
- Spread in cell self-discharge rates
- Expect to see innovations in battery management algorithms and strategies



Summary

- Tightening regulation from codes and standards has caused battery system integrators to place more emphasis on passive safety features
- Need to anticipate future evolutions in C&S
- Earlier Li-ion cost declines driven by EV markets
  - Divergence to LFP for safety and cost reasons
  - Re-convergence around solid-state Li chemistries
- Evolution in ESS products
  - Trend towards modular cabinets
  - Innovations in battery management

Questions?

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