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Durability and Reliability of EV Batteries Under Electric Utility Grid Operations: Impact of Frequency Regulation Usage on Cell Degradation

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Objective/Significance

- Number of electric vehicles (EVs) on the road continues to rise
- Collectively constitute a significant distributed energy storage reservoir
  - EV batteries could provide ancillary grid services such as operating reserves, power curtailment, frequency regulation, and voltage smoothing
- Network could give (G2V) or take (V2G) energy.
- Benefits and drawbacks for vehicle owner and for energy provider
  - Main obstacle was identified to be the additional usage on the cells

- Few experimental studies of battery degradation with grid applications
  - Path dependence of degradation needs to be considered in the estimation,
  - Each of these ancillary grid services can affect degradation differently and certain conditions can lead to accelerated capacity loss.

- This work will investigate the impact of frequency regulation

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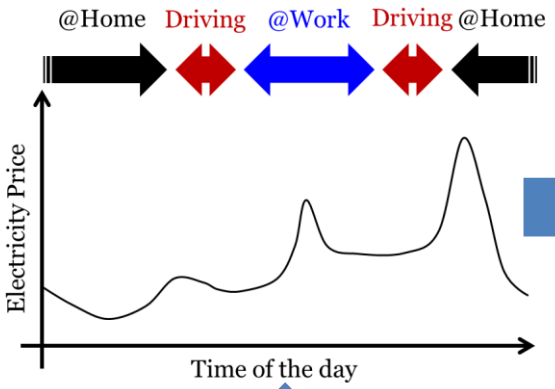
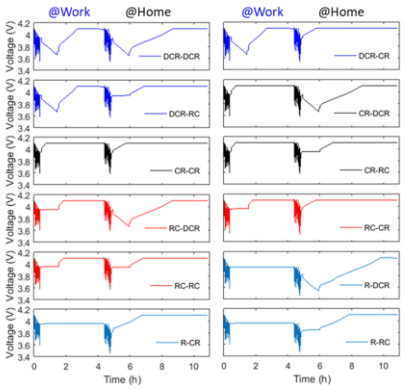
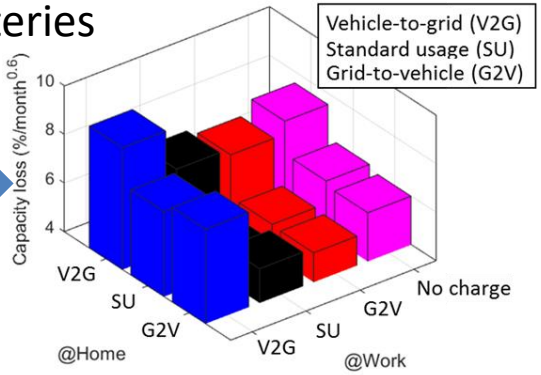
Follow up to previous work

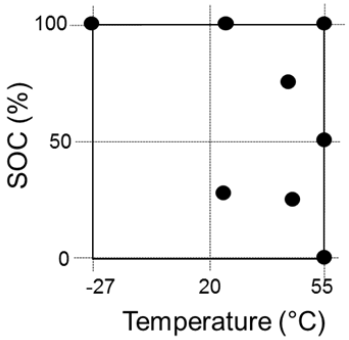


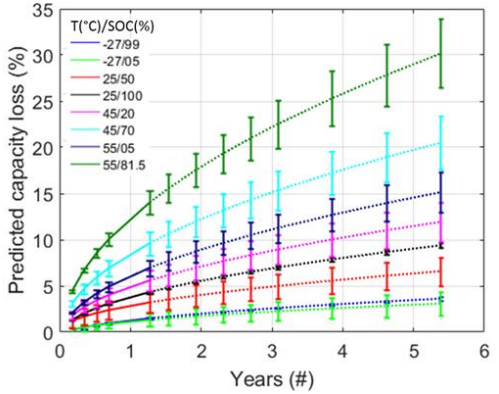


Constant power 25% energy arbitrage bad for the batteries



Calendar aging experiment





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Dubarry et al., J. Power Sources 358 (2017) 39-49, doi:10.1016/j.jpowsour.2017.05.015
Dubarry et al., Journal of the Electrochemical Society, 165(5), A773-A783 (2018), doi: 10.1149/2.0421805jes
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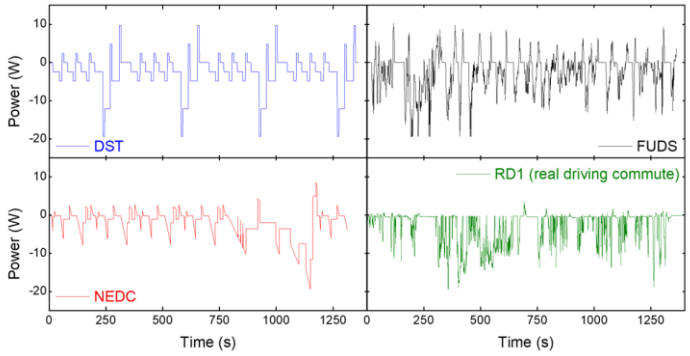

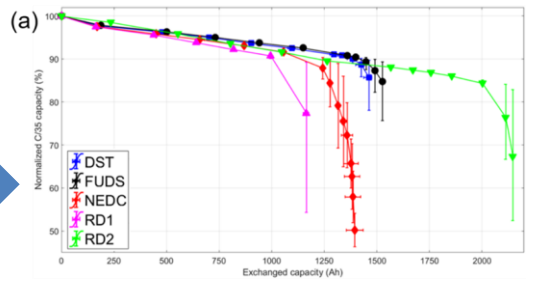

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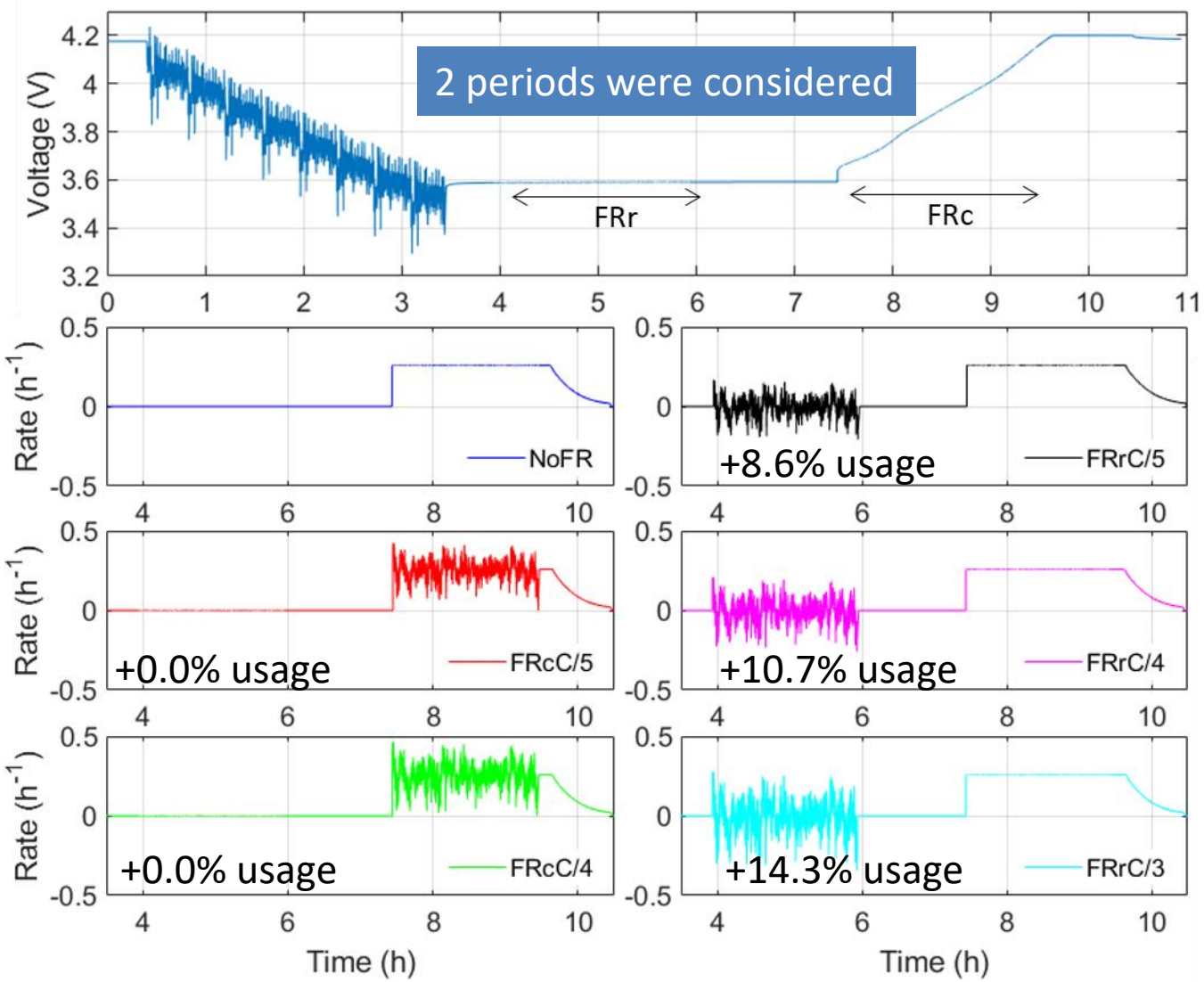
Study the impact of frequency regulation usage



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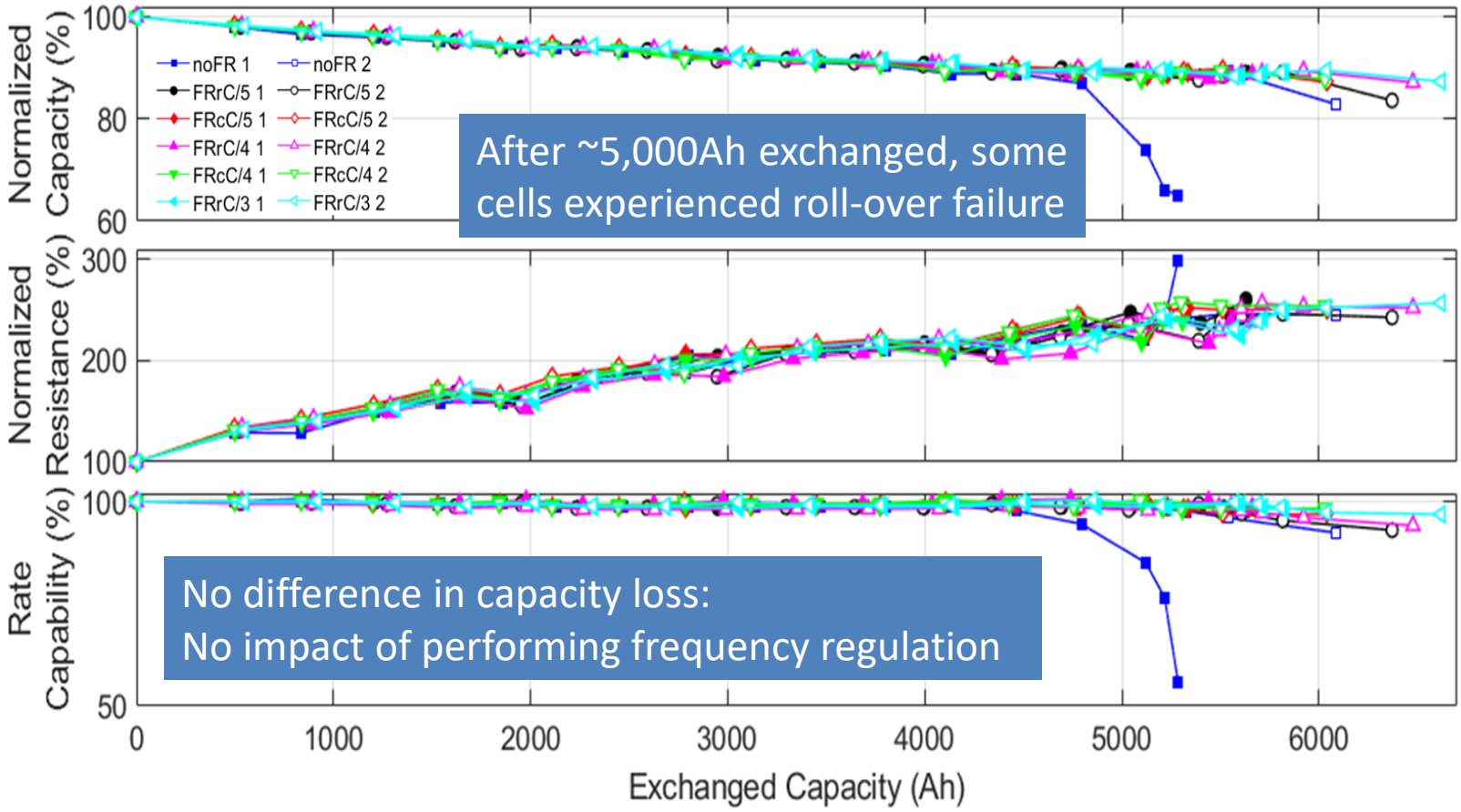
Similar performance degradation up to nearly 5,000Ah exchanged (1,500 cycles)



Same degradation? Origin of roll-over failure?

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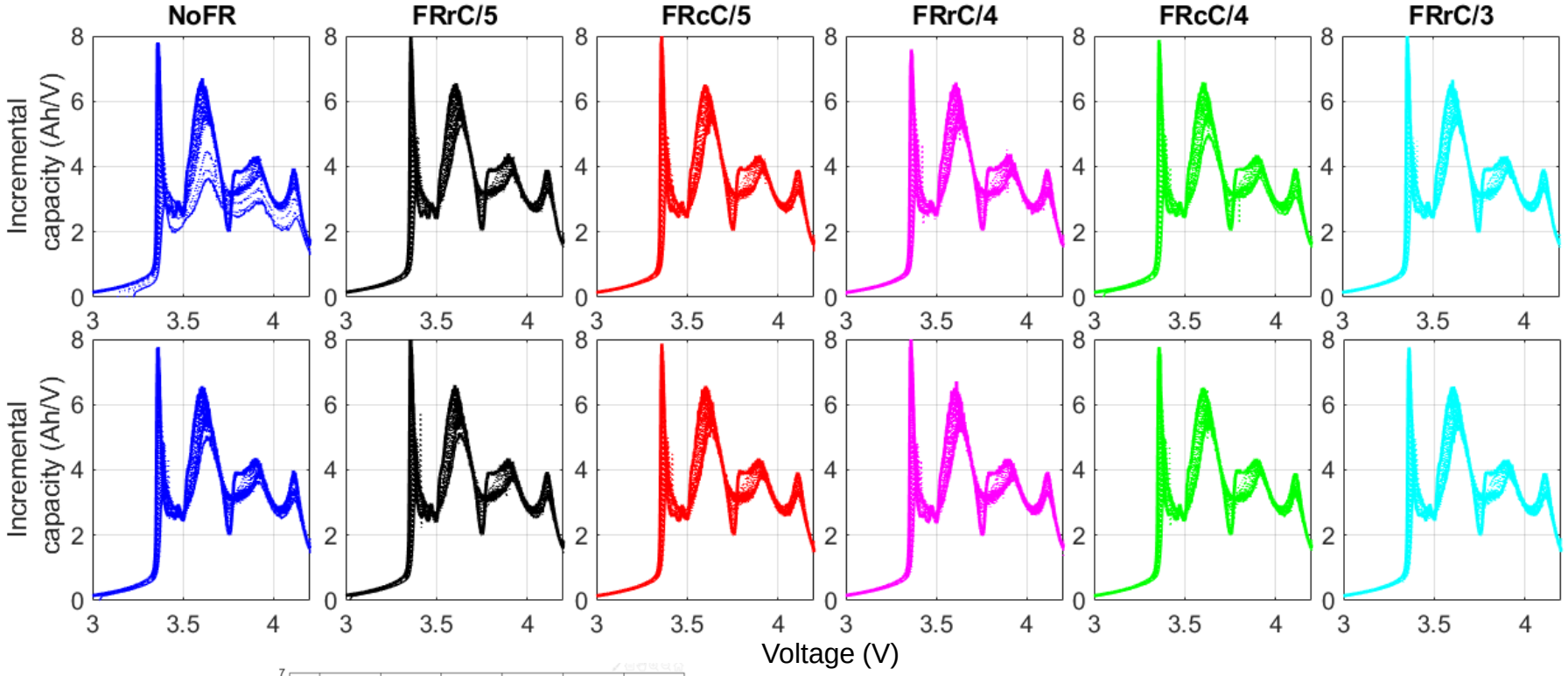
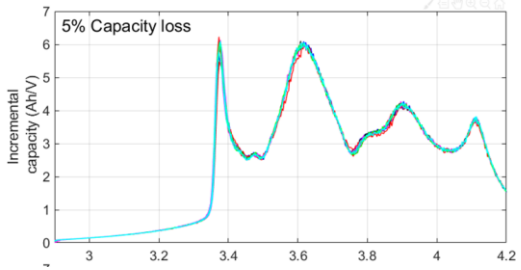
Same degradation?

Investigate difference in voltage response upon aging





Up to the beginning of 2nd stage of aging, no real differences between the cells

Frequency regulation usage for up to 15% of the capacity did not affect the cells.

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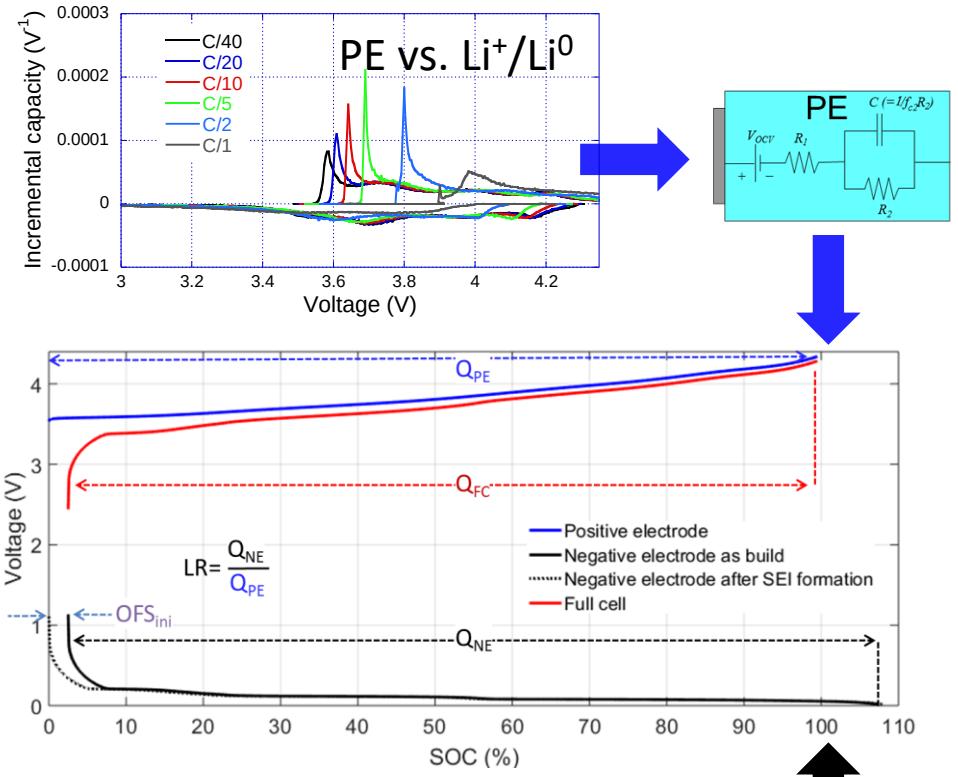
Mechanistic modeling



'alawa

https://www.soest.hawaii.edu/HNEI/alawa/

M. Dubarry et al. / Journal of Energy Storage, 29, 101391 (2020); doi: 10.1016/j.est.2020.101391

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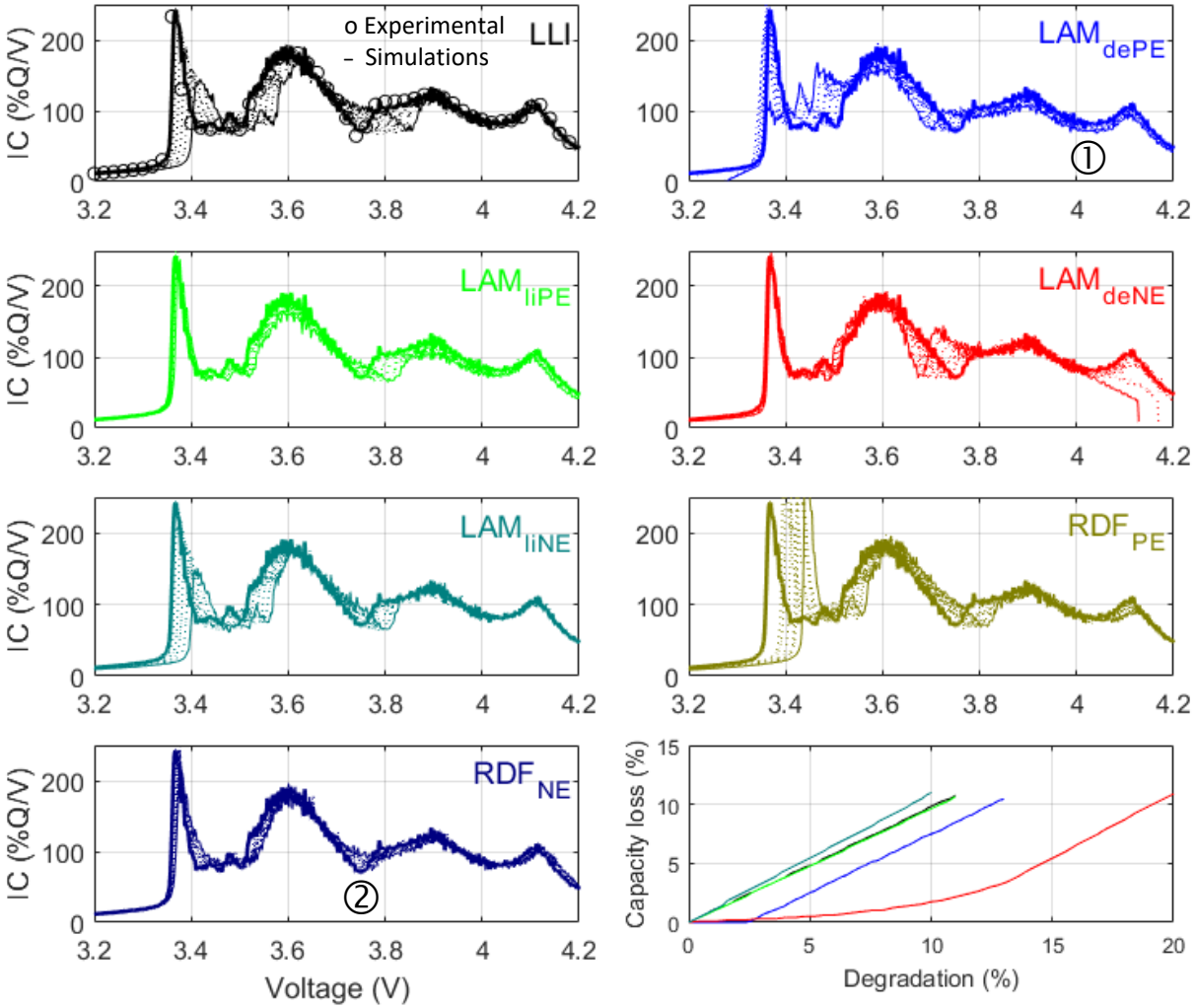
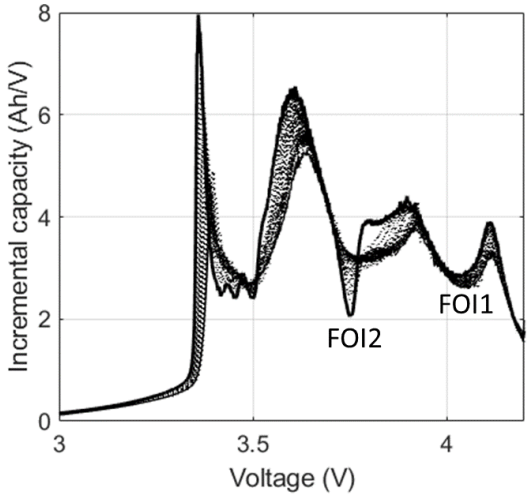
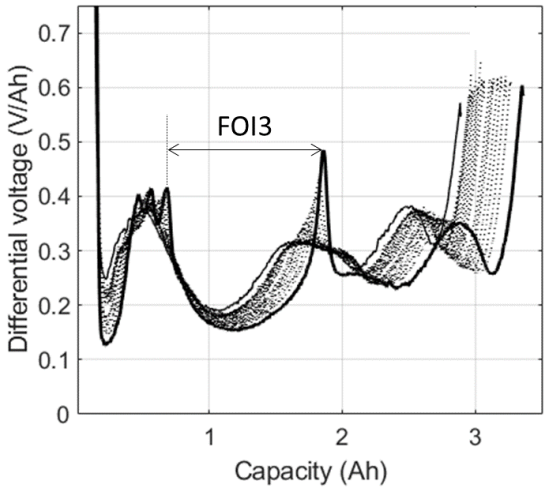
Compare experimental variations to the signature of individual degradation modes



Experimental:





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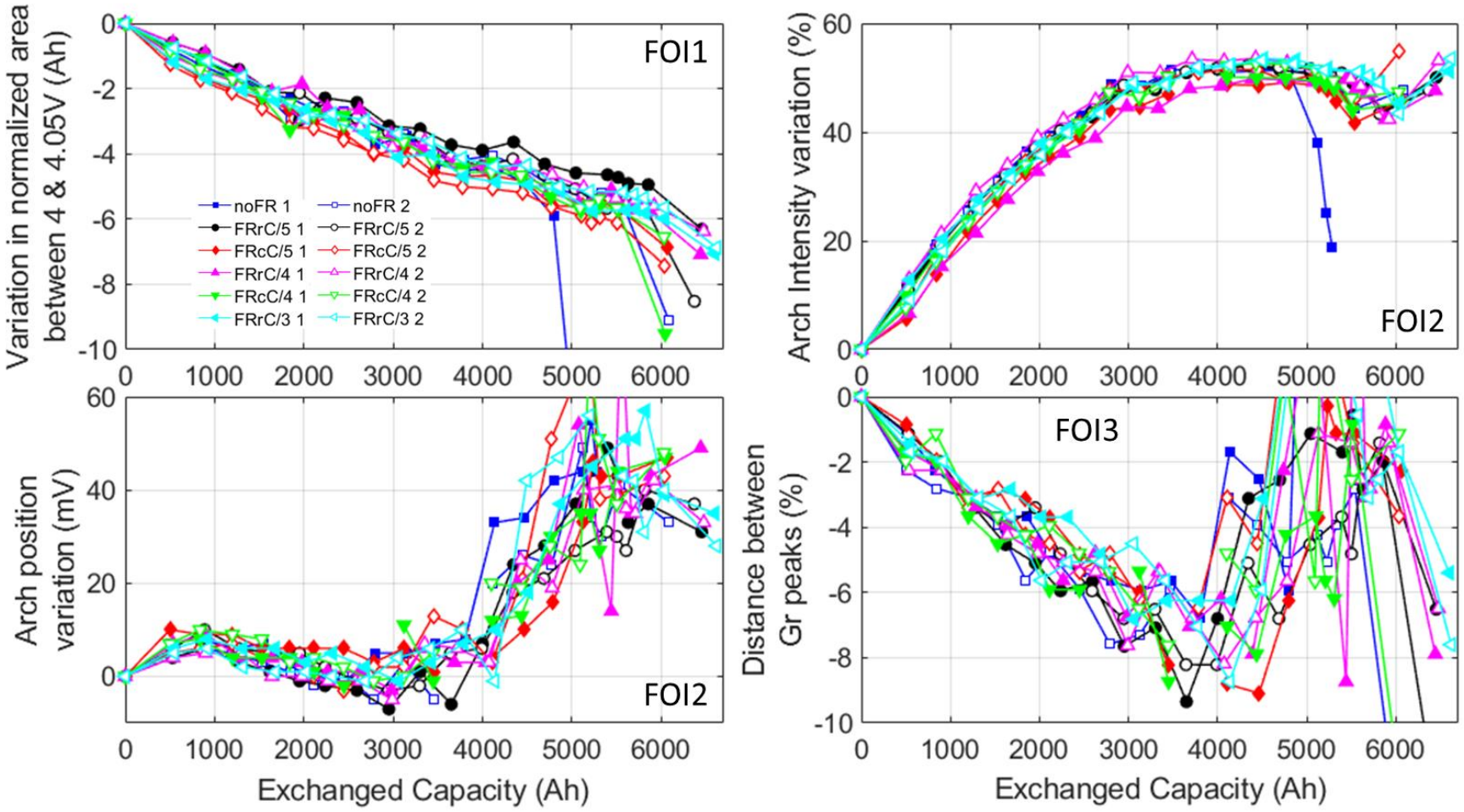
Track evolution of FOIs



Confirms same degradation for all cells.
Allows to quantify LLI and LAMs before 2nd stage of aging

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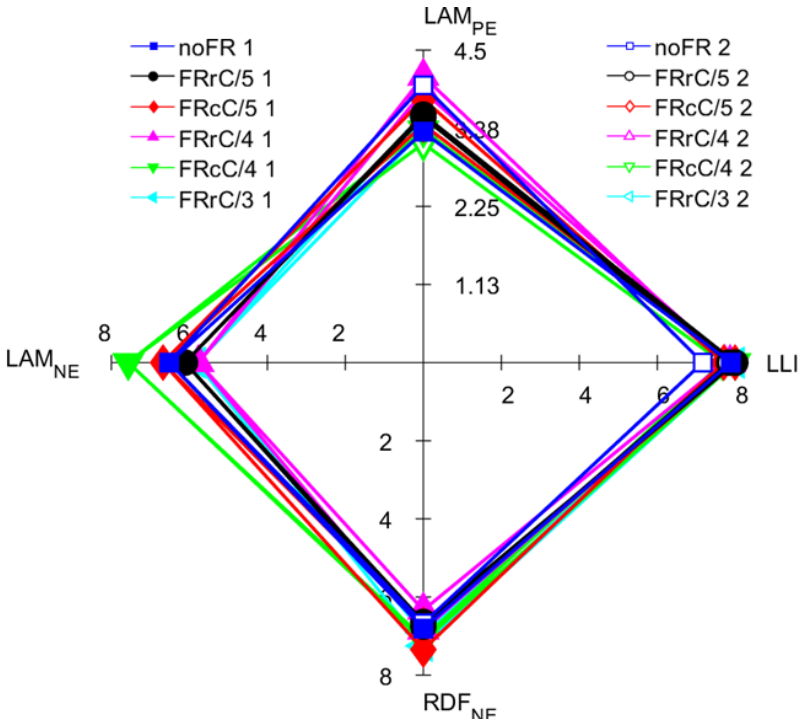
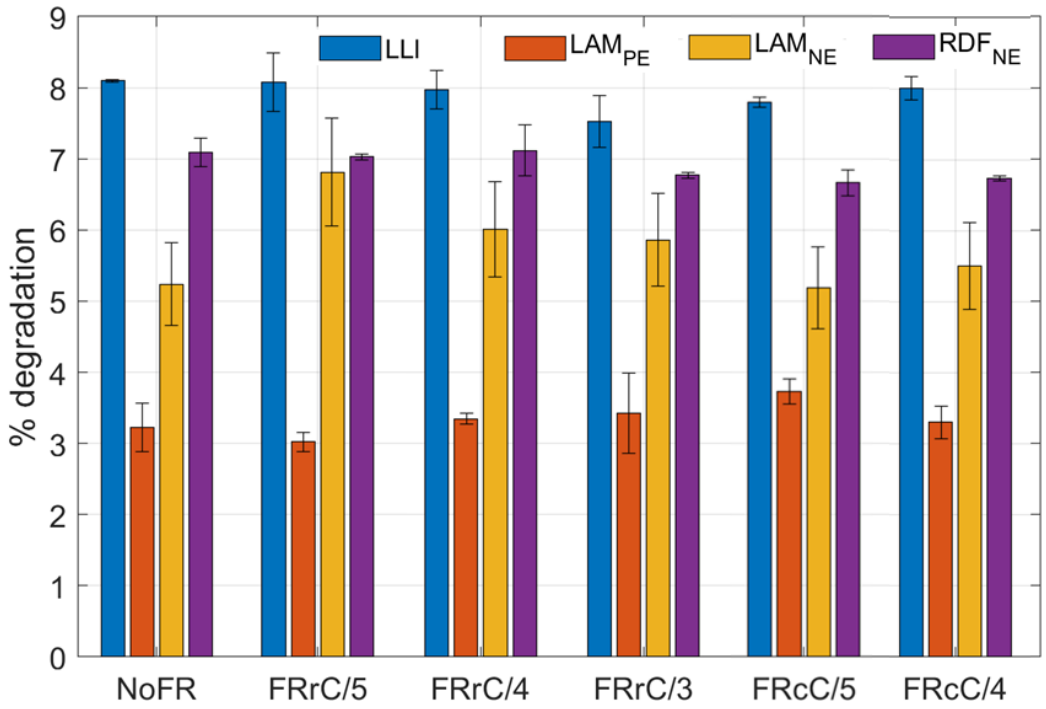
Diagnosis



Variations between conditions < Cell-to-cell Variations



LAM_{NE} and LAM_{PE} < LLI: 2nd stage do not have a thermodynamic origin

M. Dubarry et al. / Journal of Electrochemical Energy Conversion and Storage, 17(4): 041101 (2020) doi: 10.1115/1.4045008
G. Baure et al. / Energies, 13 (10) 2494 (2020) doi: 10.3390/en13102494

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Conclusions

Main takeaway: some frequency regulation V2G usage at moderate rates did not accelerate the cell degradation despite close to 15% additional usage.

In addition, no noticeable difference between performing this ancillary service during rest or charge

- Extremely positive for possible application of V2G/G2V strategies.
- However, results hold for these specific cells and the duty cycle.
- More research is necessary to generalize the results: wide variety of frequency regulation cycles and driving cycles on different cell chemistries.

Due to the lack of differences in the degradation between duty cycles, the benefits of modulating the charge to eliminate the additional usage on the cells could not be verified.

Finally, some cells showcased the 2nd stage of aging and we were not able to predict it from the voltage variations. This suggests that it was not induced by a widespread degradation of the electrodes but was more likely because of localized effects.

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Acknowledgments

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Thank you for tuning in!

Other presentations at PRIME: A01-0052 & A06-1063

A01-0046

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