Impact of Fast Charging on NCA cells

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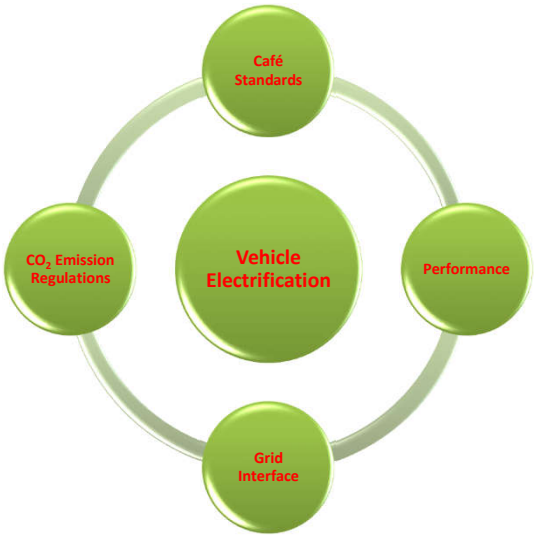
Outline

- Introduction
- Background
- Sample Results from Research
- Summary

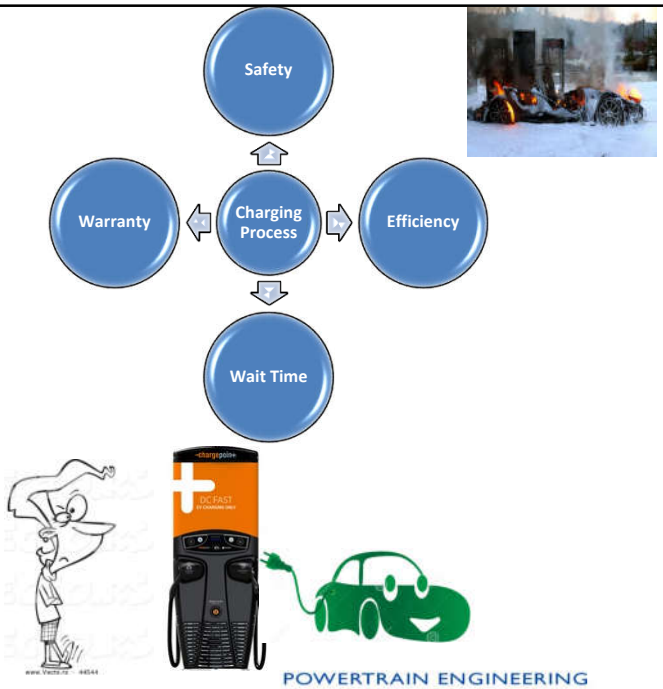
Introduction

- To meet CAFÉ standards of 54.5 mpg and reduce CO_2 emissions to 163 g/mile vehicle powertrains need to be electrified
- Energy Storage System is the key component that drives both cost and efficiency of electrified powertrains
- Electrified powertrains are capable of very high accelerations at low speeds making them attractive candidates for sports cars
- Electric powertrains can plug into grid at home and work as a UPS when needed



Metrics of Charging

- For plug in and battery electric vehicles charging process is a key aspect to be managed
- To minimize life warranty costs and charging time, a deeper understanding of the charging process is required



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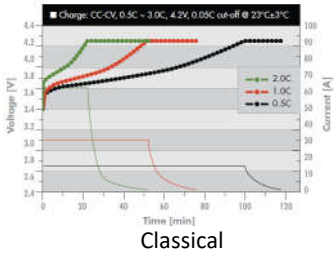
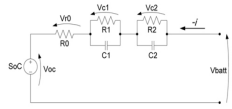
State of the Industry and Research

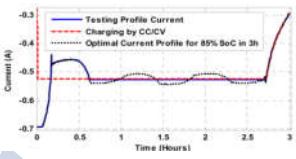


Classical

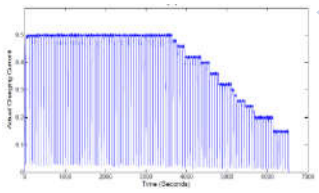
CC-CV

Optimal Control





Minimize Heat Loss



Lower Average Temperature

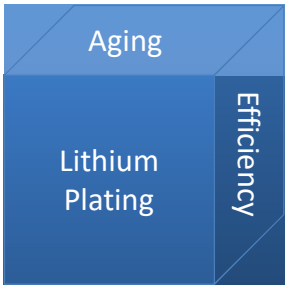
TPC

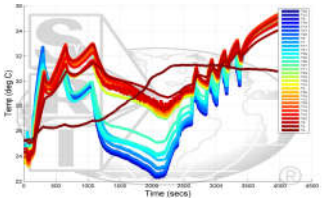
Tesla Model S

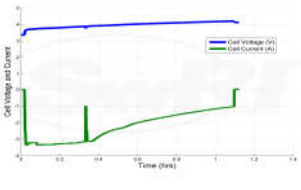
240 miles in one hour

SwRI Project Insights

- Fast charging research funded by Southwest Research Institute
- Project focused on Panasonic 18650 NCA Cells
- Objective was to compare and contrast various classical and state of art charge methods
- Look at trade offs between charge time, Lithium plating, aging and tolerance to overcharge with age







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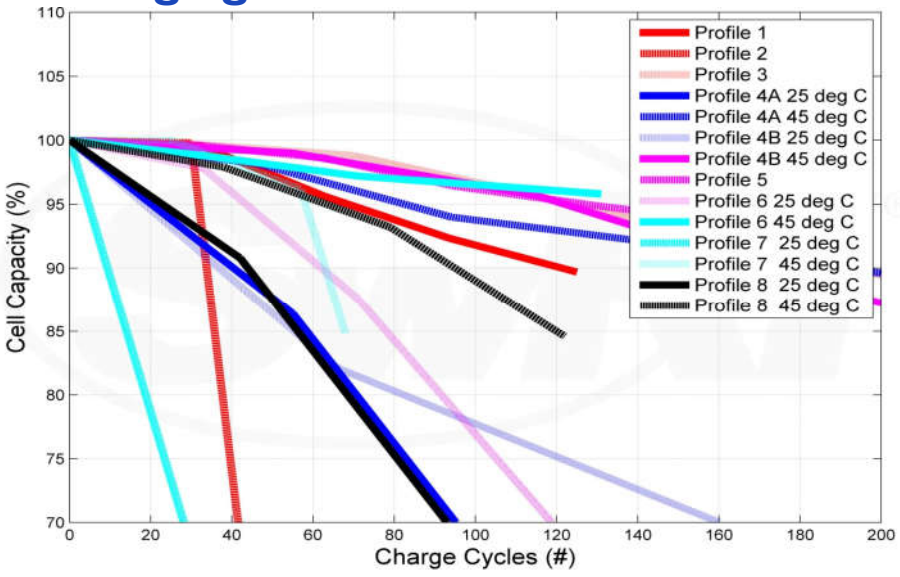
Tested Profiles

Profile	Charge Profile Label	Description	Comments
1	CC-CV	Use an optimum constant current until Vmax and switch to constant voltage mode	Current state of the art
2	Vmax-based Constant Voltage Mode	Use constant voltage mode (CV) only with target voltage as Vmax	Most aggressive possible charge rate at the given temperature
3	Stepped Voltage-Controlled Charging	Real time pseudo-OCV profile is targeted with a voltage step above to drive charging	OCV curve is the inherent characteristic of cell at equilibrium at each SOC
4 (a)	Pulsed Current with period of 15 seconds - Controlled Charging at 25 ˚C and 45 ºC	Pulsing charge current allows for reducing temperature and increasing charge acceptance at various duty cycles	Reduction of polarization voltage could increase charge acceptance
4 (b)	Pulsed Current- With period of 60 seconds - Controlled Charging at 25 ºC and 45 ºC	Pulsing charge current allows for reducing temperature and increasing charge acceptance at various duty cycles	Reduction of polarization voltage could increase charge acceptance
5	Piecewise Constant Current Charge Profile based on Charge Acceptance at 25 ºC	Change current as a function of SOC based on minimum charge acceptance metric (dV/dQ)	Strategy maximizes current in each SOC domain with minimal increase in voltage there delaying onset of Vmax
6	Tesla Model S Super Charger Profile	Consists of a constant current mode followed by a complex voltage track profile	This is the state of art in EV industry today.
7	1.5 C CC + CV	1.5 CC until Vmax and CV mode	Trade off between fast aging at 2C and Tesla Profile of 1.1C
8	Piecewise Constant Current Charge Profile based on Charge Acceptance at 25 ºC and 45 ºC	Profile 5 with 0.2 C steps removed	Minimizing charge time with no thermal impact compared to Profile 5

Impact on Aging



Lithium Plating Measurement

- Uses signature hump in discharge profile as a relative measure

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Studies on Charging Lithium-Ion Cells at Low Temperatures

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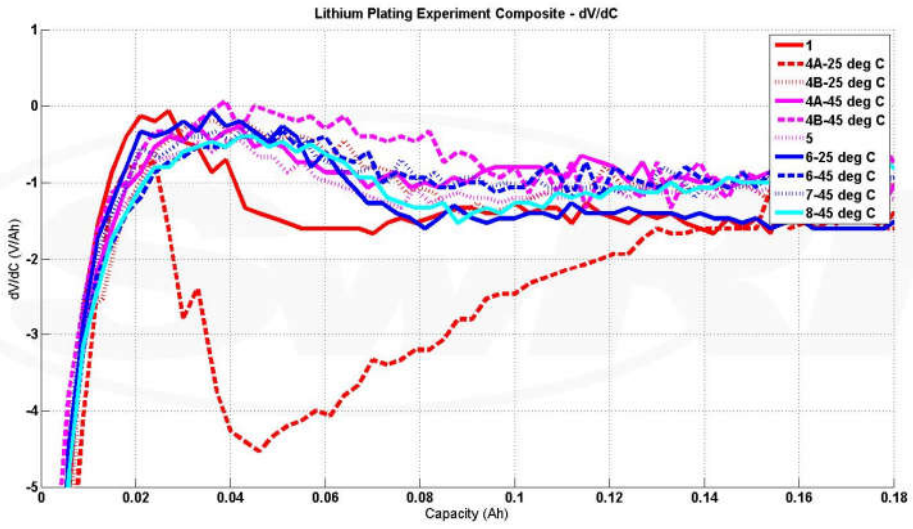
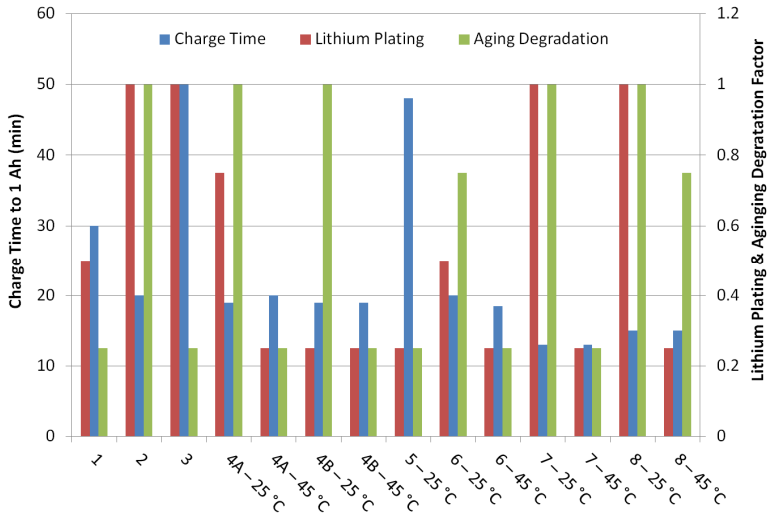
Impact on Lithium Plating



Charge Profiles with Best Trade Off



Overcharge Tolerance

	Battery Capacity in Ah					
Fast Charge Profile	BOL	EOL	Before OC	OC before failure	% OC Tolerance	SAE J2464 Rating
1	2.946	2.520	2.538	0.840	28.513	7
2	2.984	1.088	1.081	0.371	12.433	2
3	3.010	2.654	2.749	0.839	27.874	7
4A - 25 °C	2.965	1.365	1.757	0.445	15.008	2
4B - 25 °C	2.964	1.696	2.060	0.528	17.814	7
4A - 45 °C	2.960	2.478	2.569	0.838	28.311	2
4B - 45 °C	2.983	1.364	1.600	0.466	15.622	2
5	2.843	2.756	2.689	0.726	25.536	3
6 - 25 °C	2.949	1.931	2.433	0.648	21.974	2
6 - 45 °C	3.009	2.877	2.874	0.059	1.961	3
7 - 25 °C	2.899	2.688	2.721	0.678	23.387	6
7 - 45 °C	2.958	2.730	2.624	0.919	31.068	7
8 - 25 °C	2.896	1.539	1.564	0.653	22.548	2
8 - 45 °C	2.995	2.055	2.153	0.730	24.374	2

Summary

Fast Charge Profile	BOL 1 Ah Charge Time/ Target Charge Time	BOL Rated/Actual Capacity	OC Risk Factor	Charge Metric (CM)
4A - 45 °C	1.0	0.65	0.72	0.03
4B - 45 °C	0.95	0.5	0.84	0.02
7 - 45 °C	0.65	0.97	0.69	0.03