Health-Conscious Fast Charging Using a Multistage-Constant-Current Temperature-Controlled Strategy

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Abstract

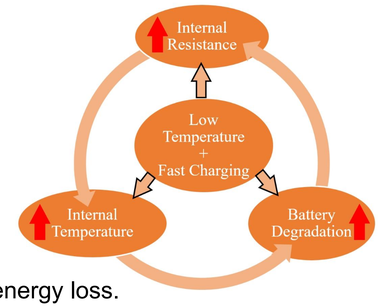
The efficiency and adoption of electric vehicles depend heavily on their energy storage systems. While fast charging minimizes charging time, it can degrade battery health by raising temperature and accelerating chemical wear, especially under subzero conditions where higher impedance intensifies heat generation. This poster presents a closed-loop Multistage Constant-Current, Temperature-Controlled (MCC-TC) fast charging strategy that adjusts current based on real-time temperature feedback. Experimental results show that MCC-TC significantly reduces temperature rise (ΔT) and rate of temperature rise (ΔT/Δt) compared to the conventional CC-CV method by 47.68% and 65.35% at −5°C, and 49.74% and 38.96% at 30°C enhancing battery health and efficiency.

1. Problem Statement

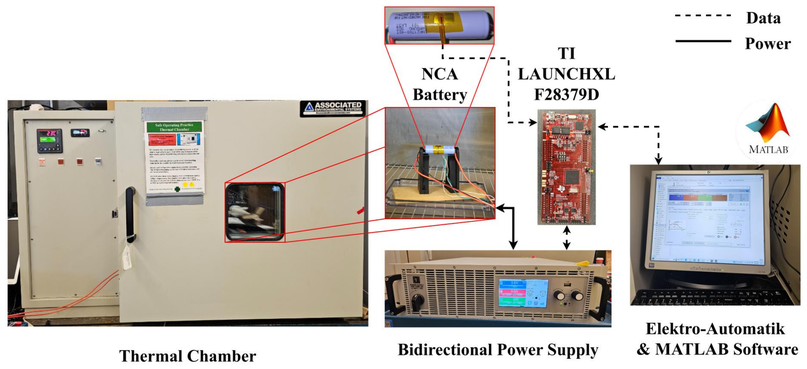
Impact of Temperature on LIB Performance

- Effects of Low Ambient Temperature:
  - ✓ Reduced Ionic Conductivity: Lower efficiency.
  - ✓ Decreased Charge Transfer Kinetics: Slower reactions.
  - ✓ Increased Resistance: More energy loss.
- Fast Charging at Low Temperatures:
  - ✓ Promotes dendrite growth.
  - ✓ Leads to multiple SEI layers.
  - ✓ Causes voltage dip due to polarization.
  - ✓ Potential for lithium plating.
- Risks and Challenges:
  - ✓ Short Circuits: Increased risk.
  - ✓ Higher Internal Resistance: More energy loss.
  - ✓ Rapid Temperature Rise: Affects battery health.
  - ✓ Thermal Runaway: Potential for severe damage.

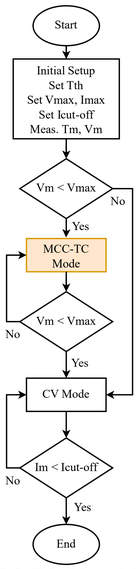
LIB Degradation Loop



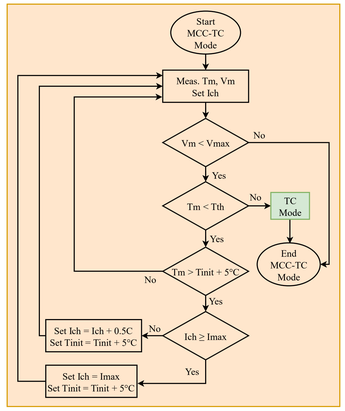
2. Experimental Setup



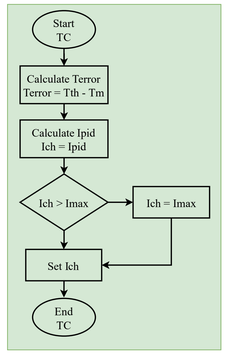
3. Proposed Charging Algorithm



MCC-TC Algorithm

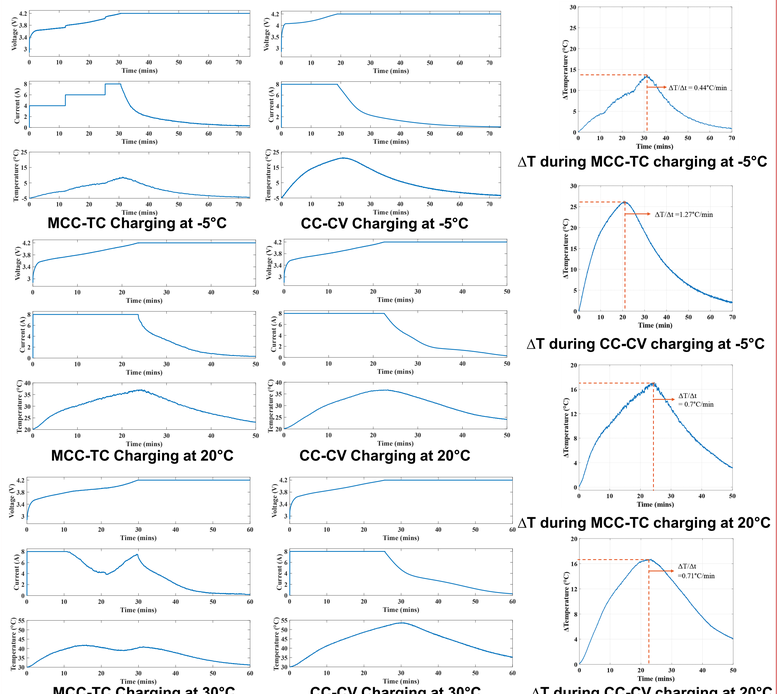


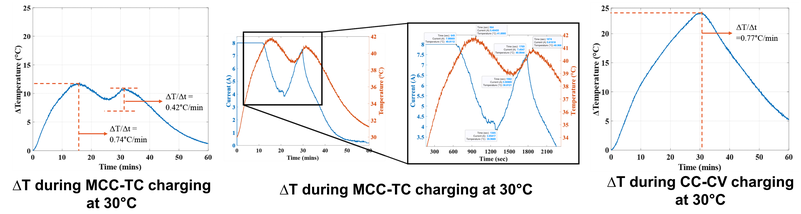
MCC Mode



TC Mode

4. Results and Discussion





ΔT during MCC-TC charging at 30°C

ΔT during MCC-TC charging at 30°C

ΔT during CC-CV charging at 30°C

Amb. Temp.	Parameters	MCC-TC	CC-CV	Relative Improvement	Percent Improvement
-5°C	Total Charging Time	72.7 mins (4362 secs)	60.76 mins (3646 secs)	-11.93 mins (716 secs)	**-19.65%**
	ΔT	13.8°C	26.38°C	12.58°C	**47.68%**
	ΔT/Δt	0.44°C/min	1.27°C/min	0.83°C/min	**65.35%**
20°C	Total Charging Time	48.41 mins (2905 secs)	49.93 mins (2996 secs)	1.52 mins (91 secs)	**3.04%**
	ΔT	17.13°C	16.96°C	-0.17°C	**-1%**
	ΔT/Δt	0.7°C/min	0.71°C/min	0.01°C/min	**1.4%**
30°C	Total Charging Time	55.36 mins (3322 secs)	59.96 mins (3598 secs)	4.6 mins (276 secs)	**7.67%**
	ΔT	11.89°C	23.66°C	11.77°C	**49.74%**
	ΔT/Δt	0.74°C/min	0.77°C/min	0.03°C/min	**38.96%**

5. Conclusions and Future Work

- MCC-TC charging shows better control of the total temperature rise and temperature gradient.
- This lower temperature rise using the MCC-TC algorithm leads to:
  - ✓ Slower battery degradation, leading to longer battery life.
  - ✓ Helps maintain consistent battery performance.
  - ✓ Exert lower stress on thermal management systems.
  - ✓ Facilitate the need for less complex thermal management systems.
- MCC-TC thus enables faster, safer, and more durable charging, mitigating temperature-related stresses on cells.
- Integrating real-time internal temperature feedback and active thermal management could further improve charging speed and efficiency.
- The proposed MCC-TC algorithm represents a promising solution for next-generation electric vehicle battery management systems.

References

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