Data-driven methods & AI in electrode manufacturing

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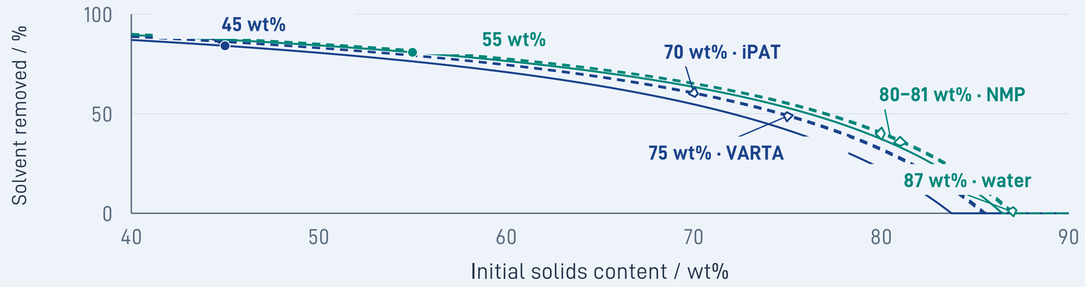


GranuGoln: NMC722 / Carbon / PVDF = 93 / 5 / 2 wt% dry solids; NMP as solvent.

$n = 300\,\mathrm{min}^{-1}$, $\dot{m} = 2\,\mathrm{kg\,h}^{-1}$, $T = 60°\mathrm{C}$, $v_{\mathrm{coating}} = 1\,\mathrm{m\,min}^{-1}$

GranuGoln: Granulate-based semi-dry electrode manufacturing goes industrial

End of film shrinkage: process references



Fraction of initial solvent; calculated at 38.5% porosity at shrinkage end.
Literature: Wiegmann (2023), Rucci (2019), Reinkensmeyer (2026), Leeb (2026).
VARTA semi-dry trials: LFP 75%; NMC 80–81%. Route-specific examples.

Mass–volume conversion and pore saturation

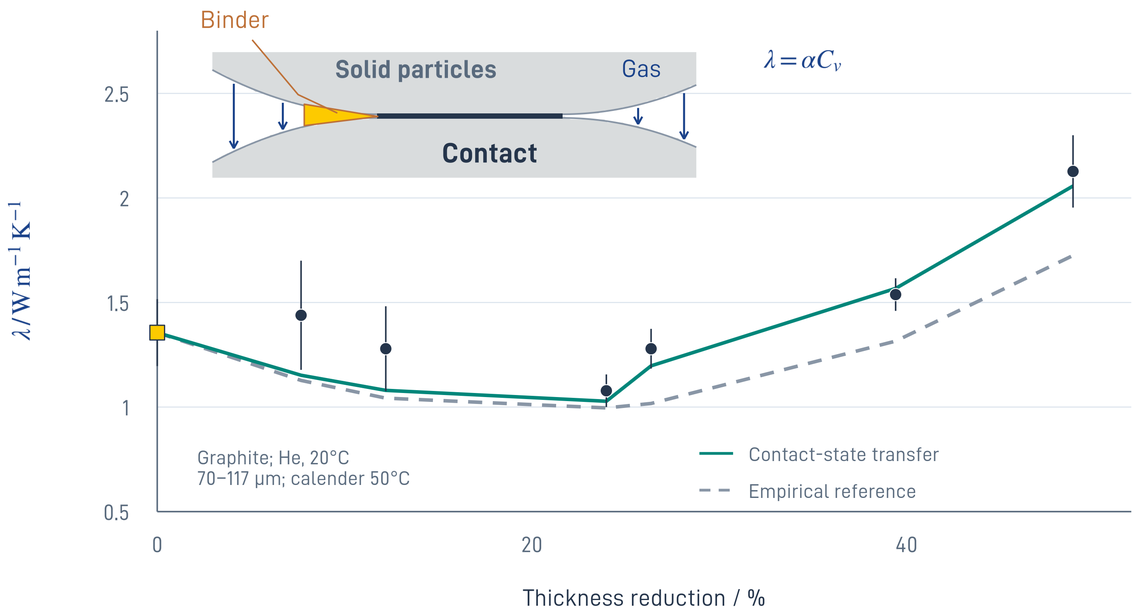
$$\phi_s = \frac{V_s}{V_s + V_L} = \frac{w_s/\rho_s}{w_s/\rho_s + (1 - w_s)/\rho_L}$$

$$\rho_s^{-1} = \sum_i \frac{y_i}{\rho_i}, \qquad \text{solids vol\%} = 100\,\phi_s$$

$$S = \frac{V_L}{V_{\mathrm{pore}}} = \frac{1 - \phi_s}{\phi_s}\,\frac{1 - \varepsilon_w}{\varepsilon_w}$$

w_s, y_i	Solid and dry-component mass fractions.
ρ_s, ρ_L	Solid-mixture and liquid densities.
ϕ_s, ε_w	Solid fraction of solid + liquid; wet-film pore fraction.

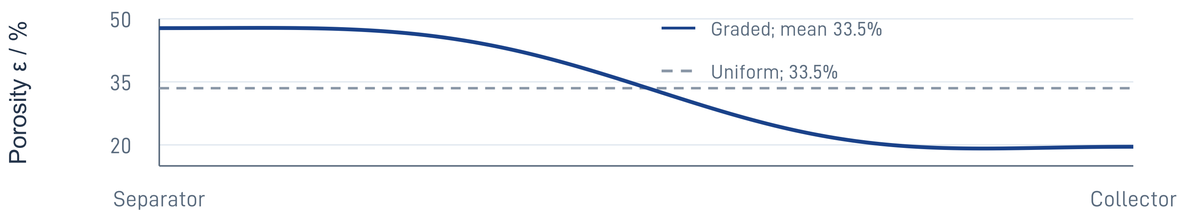
Thermal transfer with one calibration point



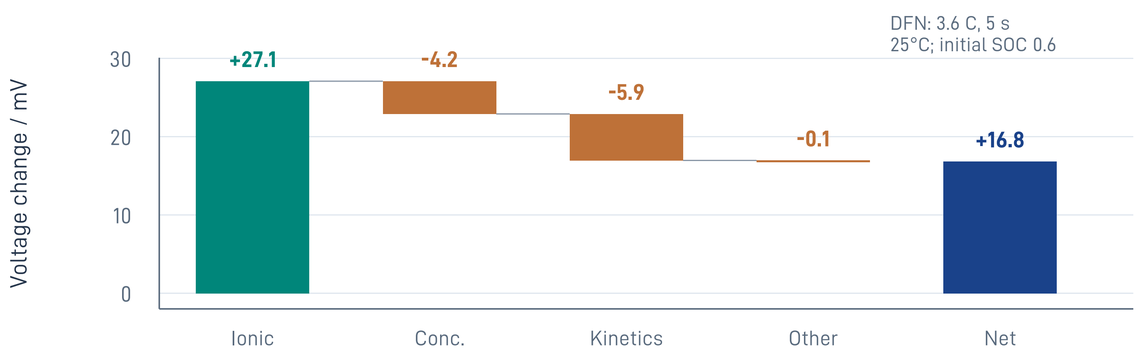
MAPE: 8.6% vs 16.9%; reverse transfer: 5.1% vs 11.1%
(49–54% lower prediction error).

11 states; three equal-parameter references.
Data: Gandert (2026); calendering at 50°C.
NMC622 stack: heat capacity per volume +15.1%, without diffusivity recovery.

Spatial porosity redistributes polarization



ε(x) is the local pore fraction of the dried electrode.
More electrolyte-filled pores near the separator reduce ionic losses.
Mean porosity and dry-solid loading remain fixed.

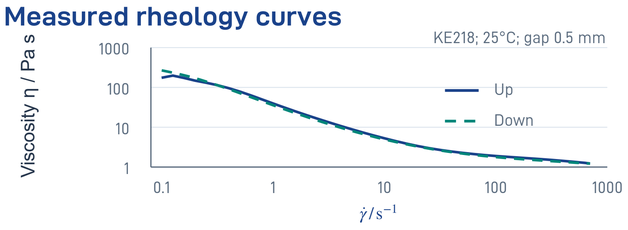


Both electrode profiles varied; fixed loading and geometry.
Simulation: Chen2020, 1.5× thickness; 80/120 grids.

AI across the electrode manufacturing chain

Integrated process history (mixing · coating · drying · calendering · cell testing) + measured loading, thickness and porosity, via paste–roll–cell IDs.

Measured rheology curves



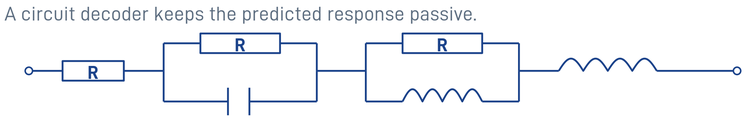
Rheology: learned curve shape



Leave-one-curve-out validation across 11 rheology curves.
Per test curve: 3 observed points; MAPE evaluated on 38 withheld points.

Impedance: passive neural head

A circuit decoder keeps the predicted response passive.

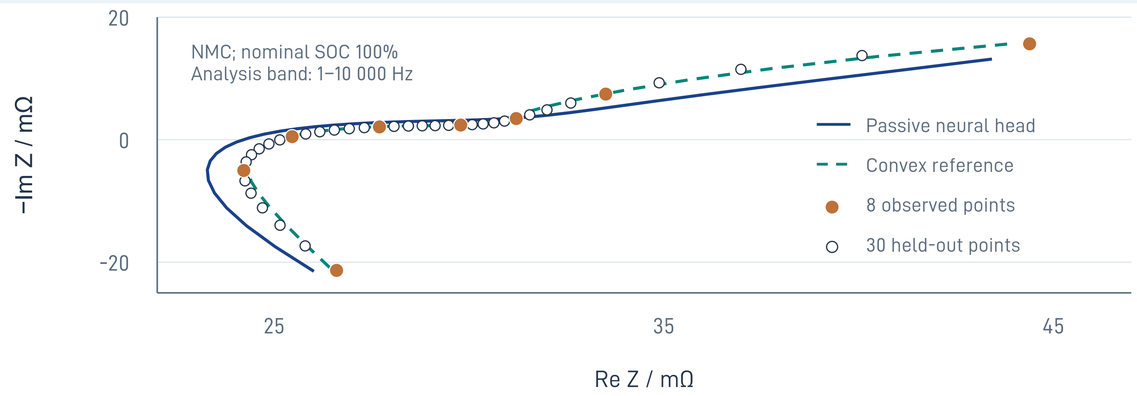


Relative RMSE: 1.97% vs 10.87% (free neural decoder).

Impedance reconstruction

$$\widehat{Z}(\omega) = R_s + \sum_k \frac{a_k}{1 + \mathrm{i}\omega\tau_k} + \sum_j \frac{b_j \mathrm{i}\omega\vartheta_j}{1 + \mathrm{i}\omega\vartheta_j} + \mathrm{i}\omega L$$

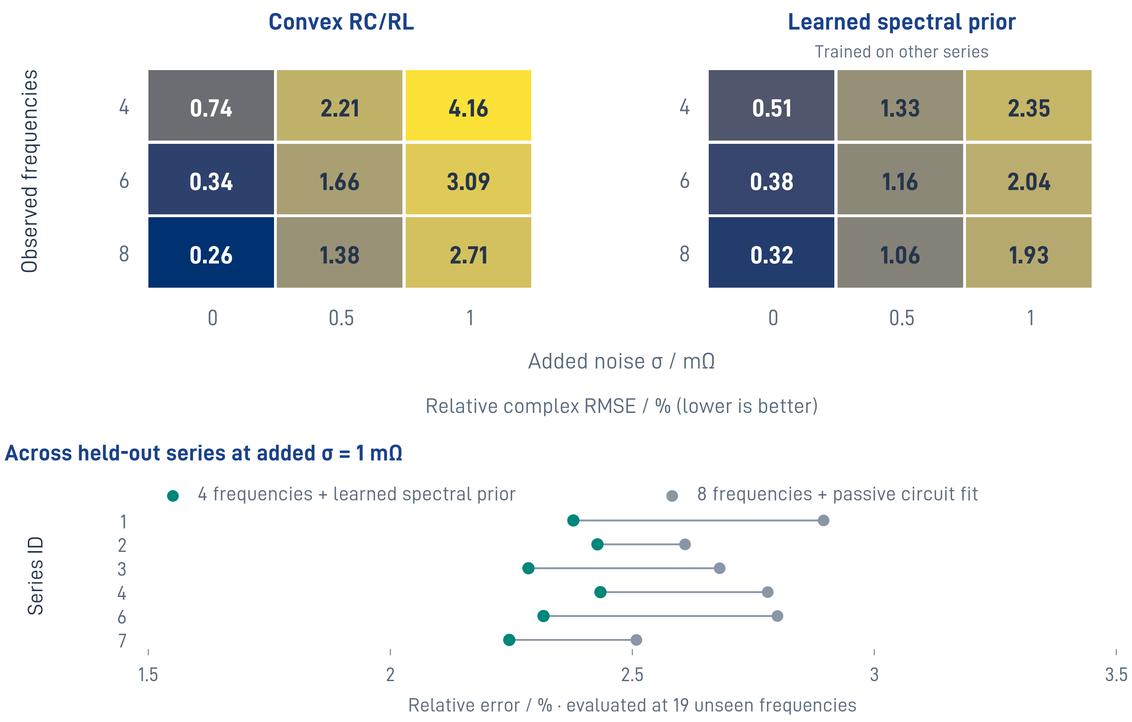
Learned resistive, capacitive and inductive contributions; ω = 2πf.



Relative complex RMSE across all test series

Free neural decoder	10.87%
Passive neural head	1.97%
Neural head with convex correction	0.48%
Convex RC/RL reference	0.28%

Measurement budget and noise sensitivity



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03XP0635A (VARTA) · 03XP0635B (TU Braunschweig)

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Saturation: Reinkensmeyer et al. (2026), 10.1002/ente.202502356
Thermal data: Gandert (2026), 10.5445/IR/1000193601
Cell model: Chen et al. (2020), 10.1149/1945-7111/ab9050
EIS data: Chen et al. (2026), 10.1016/j.ensm.2026.105339; Zenodo 18494770
Models: Störk et al. (2026); rheology: KE218 (VARTA)