COMPLETE GPC SOLUTION SET · FIRST CHARGE / PACK COMMISSIONING

FIRST CHARGE UNITS

Pack manufacturers · OEM assembly lines · Module commissioning · BESS integrators

Cells leave formation at ~30% SoC — set by IATA air-transport limits and storage chemistry. The first full charge (~30% → 100%) after cells are 100%) after cells are assembled into modules and packs — "pack commissioning" — is an electrochemically distinct event: the SEI enters the the SEI enters the upper voltage region for the first time since formation, the BMS interacts with the cells for the first time, and the pack is and the pack is electrically inhomogeneous from cell one. A conventional CC/CV first charge treats this as an ordinary cycle — and pays for it in — and pays for it in unequal SOC, localized thermal stress, and risk to the interface formation so carefully built. GPC first charge makes the charge makes the pattern the control variable: one current profile, four pack-level objectives.

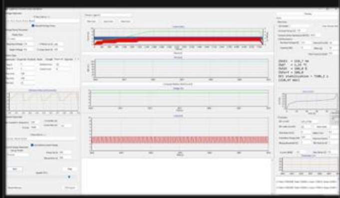
ONE ECOSYSTEM — FROM CHEMISTRY TO COMMISSIONING BAY

1 · SYNTHESIZE

GP ChemPat

First-charge GPC pattern derivation → .gpchem / 1024-pt LUT

2 · SIMULATE



GP Sim — First Charge

Full pack commissioning simulation — cells, busbars, BMS, thermal

3 · VALIDATE

GP Lab R&D

4-ch module validation + full data recording, in your lab

4 · DEPLOY

GP Module

Validated pattern on licensed firmware, per power source

PACK FIRST CHARGE DYNAMICS — WHAT CC/CV IGNORES

SEI TRANSITION STATE

Formation ends at ~30% SoC; the SEI has little history above 60% above 60% SoC. First charge takes it into the upper voltage voltage region — near the electrolyte-decomposition threshold threshold — for the first time since formation. The temporal temporal structure of the current decides whether that transition is controlled or uncontrolled.

INTRA-PACK CURRENT ASYMMETRY

R_total = R_cell + R_busbar + R_contact differs for every cell; in cell; in parallel groups, low-resistance cells systematically draw systematically draw more current. GPC's low-current intervals intervals damp the asymmetry instead of letting it compound compound through the charge.

THERMAL ASYMMETRY — THE ARRHENIUS LOOP

$k(T) = k0 \cdot \exp(-Ea/RT)$: hotter cells react faster, widening the SOC spread, which heats them further. Under CC/CV this positive feedback runs uncontrolled; GPC's thermal-equalization windows break the loop.

FIRST BMS INTERACTION

First charge is the first time the BMS actively balances cells. cells. GPC's periodic low-current intervals naturally align with with optimal balancing-circuit conditions — balancing, polarization relaxation, and thermal equalization happen in the happen in the same windows.

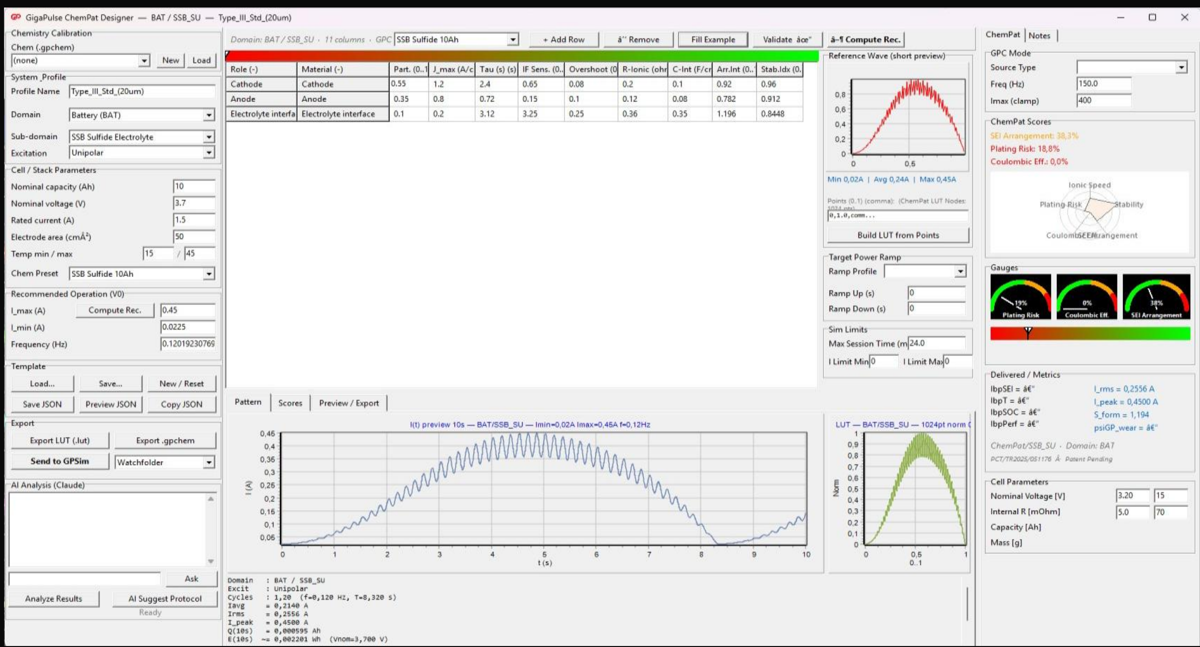
One pattern, four pack-level objectives: $J = w1 \cdot \Delta SOC + w2 \cdot \eta\_RMS + w3 \cdot \Delta T + w4 \cdot E\_loss$. GPC first charge simultaneously optimizes SOC equalization, SOC equalization, polarization, thermal uniformity, and energy loss — and cooperates with the BMS instead of fighting it. Typical rates C/10–C/3 · ≤100 C/10–C/3 · ≤100 kVA single-source · >100 kVA Dual-Power-Source (DPS).

GP CHEMPAT

CHEMISTRY-NATIVE PATTERN DESIGNER · FIRST CHARGE DOMAIN

Not a template library — a derivation engine. GP ChemPat is scientific software in its own right: a universal electrochemical pattern synthesis platform spanning 17 domains, with First Charge as a native domain. Input your cell parameters, pack topology constraints, and thermal response — ChemPat derives the minimum-stress commissioning pattern for that exact pack.

20+	95+	101+	1024,...
MAIN DOMAINS	SUBDOMAIN PRESETS	CHEMISTRY PRESETS	POINT GPC LUT



THE SCIENCE INSIDE

Physics-based waveform synthesis

Every chemistry has a distinct electrochemical fingerprint: LFP a fingerprint: LFP a flat plateau, LTO square, NMC811 sigmoid with sigmoid with harmonic damping, solid-state an ultra-slow S-slow S-curve. The LUT is computed per chemistry — never a never a generic Gaussian.

The Jensen inequality principle

In nonlinear electrochemical systems, f(I-bar) ≠ (1/T)∫f(I(t))dt. (1/T)∫f(I(t))dt. GPC exploits this gap: at the same average current average current — same commissioning throughput — pattern pattern shape alone delivers better balance and lower stress. stress.

19 battery chemistries built in

Incl. Solid Power (Si EV, Li-Metal, Conversion) and Maxwell dry-Maxwell dry-electrode presets: LFP · NMC811 · NMC622 · · NMC532 · NCA · LCO · LTO · LMO · Na-ion · Li-Metal · SSB Oxide · SSB Oxide · SSB Sulfide · LMR · LNMO · LFMP · High-Si · Graphite Graphite

Same library, different objective

In formation, the pattern's primary objective is SEI control. In control. In first charge, it is pack-level balancing and stress stress distribution — S_charge = (I_RMS/I_ref)^α × f_T × f_mode × f_mode × f_slew. The same derivation engine serves a different optimization target.

INTEGRATED AI — ON EVERY PRODUCT

AI ANALYZE — protocol assessment

Analyzes the current parameter set, interprets scores, raises physics-grounded warnings (upper-voltage SEI stress, thermal-runaway margins, balancing-window spacing...) and proposes concrete improvements.

AI SUGGEST PROTOCOL — full grid proposal

From chemistry, pack size and cell parameters, generates the complete protocol grid — every row, I_min / I_max / f values — and writes it in. A physics-based starting point in one click.

AI ASK — free-form domain questions

"Why does my pack's SOC spread widen above 80% SoC?" — answered with domain physics knowledge, inside the tool. Commissioning engineers get formation-level insight without formation-level experience.

WORKFLOW

Select First Charge domain → Enter chemistry & pack parameters → Compute Recommendation → Preview GPC pattern → AI analysis & refinement → Export to GP Sim

EXPORT & INTEGRATION

Direct hand-off to GP Sim — First Charge: all physics parameters, pack model, thermal block, and cell limits in a single file. .gpjson — GP Sim pattern · .gpchem — ChemPat template · .lut — binary LUT · .csv — tabular · .pdf — ChemPat report

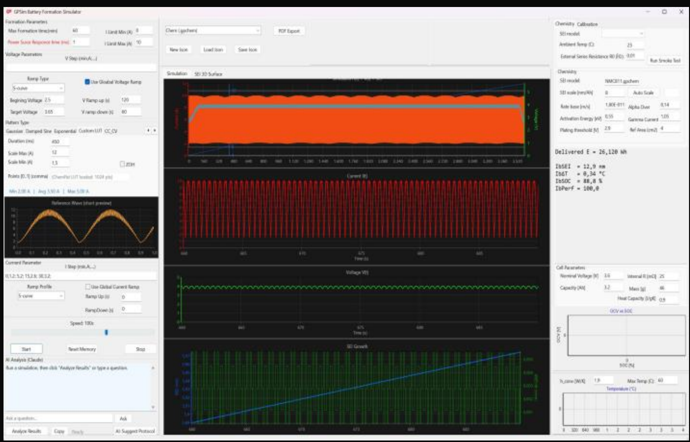
$$J = w1 \cdot \Delta SOC + w2 \cdot \eta\_RMS + w3 \cdot \Delta T + w4 \cdot E\_loss$$

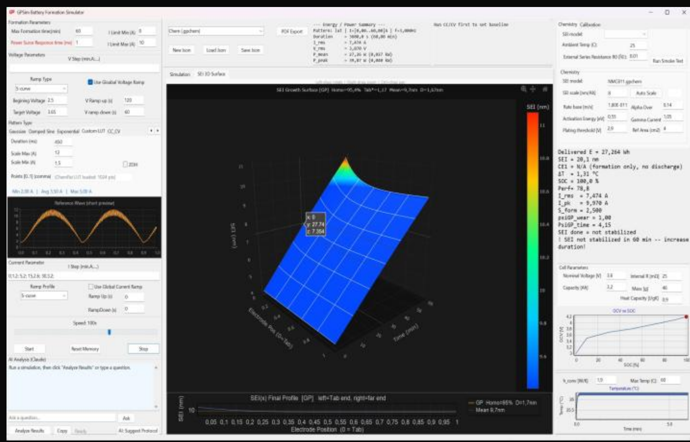
The four-objective cost function: SOC equalization error, mean polarization, thermal gradient, and I²R energy loss — minimized by a single pack current profile I_pack(t).

GP SIM — FIRST CHARGE

PACK COMMISSIONING SIMULATOR · A PACK MODEL, NOT A CELL MODEL × N

GP Sim — First Charge simulates the full ~30% → 100% commissioning charge at pack level: cells with distributed resistance and capacity variation, capacity variation, busbar and contact resistances, thermal coupling between neighbors, and the BMS balancing circuit — under any electrical form, with electrical form, with conventional CC/CV built in as the benchmark reference. Commission the pack on screen before the first real pack reaches the bay. pack reaches the bay.





THE PACK ENGINE

Full pack electrical & thermal model

Per-cell equivalent-circuit model, SOC dynamics and state-space state-space formulation; per-path $R_{total} = R_{cell} + R_{busbar}$ + $R_{busbar} + R_{contact}$; thermal balance $C_{th} \cdot dT/dt = I^2R - hA(T -$ $- hA(T - T_{cool})$ with neighbor coupling. Not a single-cell cell simulator with a multiplier — a pack.

SOC spread, watched live

Per-cell SOC trajectories through the whole charge. In the model the model scenario, GPC reduces SOC spread by 54% vs CC/CV CC/CV — and a narrower end-of-charge voltage distribution distribution means more cells reach target SoC before the the highest cell hits V_{max}.

DPS — dual-source for >100 kVA

$I_{pack} = I_{main} + I_{control}$: the main source moves SOC, the SOC, the control source regulates polarization. Model results: results: polarization peak-to-peak −49%, peak I^2R loss −24%, −24%, average energy loss −14%. And 2×100 kVA costs less than less than one 200 kVA unit.

Chemistry sensitivity, built in

Capacity and resistance drift across the commissioning charge charge for 7 chemistries — NMC532/622/811, NCA, LFP, LNMO, LFP, LNMO, LTO — at 25°C and 40°C. LTO ultra-stable, NCA NCA flagged for thermal care.

EVERY RUN, FULLY MEASURED

PACK BALANCE

ΔSOC spread — live, per-cell
End-of-charge ΔV distribution
Per-cell SOC trajectories
Per-path R (cell+busbar+contact)

THERMAL

ΔT gradient across the pack
Hot-cell identification
Arrhenius-coupled reaction rates
Cooling-limit alerts

EFFICIENCY & STRESS

$\eta = E_{stored} / E_{input}$
I^2R loss — average & peak
Polarization η_{RMS}
S_{charge} stress index

REPORTING & FILES

One-click PDF report

Every metric, every per-cell trace, and the AI analysis in a single a single commissioning document your team can archive per archive per pack. File system: .gpsim · .gppat · .gpchem · .gpcal · .gpcal · PDF / CSV

AI PROTOCOL DESIGNER

Selects the optimal pattern for the chemistry and pack topology; proposes I_{min}, I_{max}, balancing-window spacing; estimates commissioning duration; raises critical warnings (hot-cell risk, V_{max} early termination, BMS conflict) — and states the rationale: why this pattern, this window structure, this current band.

GP Sim turns first charge from a checkbox at the end of assembly into a measured, balanced commissioning step. New pack design? New pack design? Load the topology. New chemistry? One .gpchem file. Warranty dispute? The per-pack commissioning record is in commissioning record is in the archive.

GP LAB R&D

4-CHANNEL ADAPTIVE GPC CONTROL PLATFORM · TEST & DATA-LOGGING INSTRUMENT

CONTROL

Transforms any standard power supply into a synchronized, synchronized, high-precision adaptive GPC control system — no system — no hardware change. Four independent channels, full channels, full pattern library, real-time waveform generation generation and behavioral analysis. The physical validation validation platform for GP Sim — First Charge outputs, at at module scale.

RECORD & REPORT

GP Lab is far more than a GPC application tool — it is a precision precision measurement and data-logging instrument. It samples samples current and voltage at sub-millisecond resolution resolution through the entire run and derives the complete complete picture from the raw stream — capacity (C), internal internal resistance, charge efficiency, thermal response — — delivered as a full report. CC/CV runs included; full CSV export. CSV export.

ADAPTIVE CONTROL ENGINE

- Real-time I/V/T measurement
- Dynamic impedance (Rdyn)
- Capacity & charge efficiency
- Thermal response analysis
- dV/dt · dI/dt tracking
- Current offset adaptation

- Frequency & duty control
- Balancing-window timing
- A/B channel comparison
- FIFO deterministic timing
- JSON recipe load
- 24V industrial I/O · rack

MEASURED

- Current (0-10V)
- Voltage (0-10V)
- Temperature (ext. sensor)
- 8× digital inputs

CONTROLLED

- I_CTRL waveform output
- V_OUT limit signal
- 8× digital outputs
- 4-channel synchronization

VALIDATE IT IN YOUR LAB — NOW

GPC commissioning patterns are derived from your chemistry chemistry and your pack topology — so the only validation that validation that matters is the one you run on your own modules. A 4-channel GP Lab unit and a representative module module is everything needed: full pattern library, live per-per-channel I/V/T, .gpchem support for any cell type, CC/CV CC/CV side-by-side on the A/B channels. Don't take our word for word for it — measure it on your pack, on your bench, with your with your data. Paper IV defines the five measurements:

ΔV spread	ΔSOC spread	ΔT gradient	η efficiency	DCIR check
end-of-charge voltage distribution	per-cell, full charge	across module / pack	E_stored / E_input	DC internal-R consistency

Module first, pack next

The 4-channel GP Lab unit is the reference platform for small module configurations — validate the commissioning pattern on a commissioning pattern on a representative module string, A/B against CC/CV on parallel channels. Full pack validation scales onto validation scales onto GP Core (8–40 channels) with the same pattern, unchanged.

Your chemistry · your data · your IP

All GP software runs locally — nothing leaves your facility. Your commissioning protocol is as proprietary as your pack design; only pack design; only optional AI features touch the internet.

FROM YOUR BENCH TO THE ASSEMBLY LINE

THE FULL HORIZON — WHAT THE FIRST CHARGE KIT UNLOCKS

The GP Lab kit is not a lab-instrument purchase — it is the entry point of a commissioning trajectory. The pattern you validate on one module is, unchanged, the pattern that will commission every pack on your line. This is exactly where that investment leads.

THE SCALING PATH — ONE PATTERN, THREE STAGES

TODAY — VALIDATE

GP LAB R&D

4 channels on your bench. Validate the the commissioning pattern on a representative module, A/B against CC/CV, with a full per-cell measurement measurement record.

NEXT — FULL PACK

GP CORE

Industrial cabinet scaling 8 → 40 channels. Full-pack validation, pilot commissioning lines, certification programs — the same pattern, more more channels.

THEN — PRODUCE

GP MODULE FLEET

One module per power source on every every commissioning bay. Your validated validated patterns on licensed firmware firmware — at assembly-line scale.

GP MODULE — THE FIELD EXECUTION LAYER

"From Pattern to Power — Deterministic Control for Electrochemical Systems."

Standalone and deterministic: Pattern Storage → Playback Engine Engine → Feedback Processing → Control Layer → I/O. The pattern pattern executes at hardware level — no PC PC dependency, no OS jitter. DIN-rail mount, licensed firmware, one node per power source. source. Real-time I/V/T feedback, closed-loop optimization, Rdyn, I_ref I_ref modulation, thermal thermal correlation.

THE PAYOFF AT SCALE

THE COMMISSIONING LINE EFFECT MODEL-DERIVED SCENARIO

SOC spread −54% — vs CC/CV across the full ~30→100% charge	Polarization −49% — peak-to-peak, DPS config on >100 kVA packs	I^2R loss ↓ — peak −24% · average −14% (DPS)
ΔV narrowed — more cells reach target SoC before V_max cutoff	BMS-cooperative — balancing windows built into the pattern	Changeover ≈ 0 — one Ethernet download per pack variant

Scenario-based simulation results (Paper IV). The path to these numbers runs through GP Lab validation — measure them on your own modules first.

An Ethernet-controlled fleet, not a box count

Patterns upload to every commissioning bay over the network. GP Module Writer is the licensing gateway: every deployed pattern passes through it — a traceable, auditable IP chain from simulation to bay. GP Module Control orchestrates the floor: multi-bay synchronization, per-node monitoring, pattern distribution, and a line-level analytics dashboard.

One download, instant switchover

New pack variant? New cell supplier? A single download to the download to the GP Modules switches every commissioning bay commissioning bay instantly — no line rebuild, no re-engineering, no requalification cycle on the hardware side. side. Product changeover becomes a network event, not a a project.

What you will have gained

Every pack leaves the line with equalized SOC and a narrower narrower end-of-charge voltage distribution — a directly smaller directly smaller warranty-risk tail. A per-pack commissioning commissioning record from every bay. A pattern library that that follows your pack variants. And a first-charge step your your team measures and owns — instead of checks off.

It all starts with a 4-channel kit and one module

The GP Lab kit is the smallest possible step onto this trajectory — and the only one that requires no line commitment. Validate first. Scale when your own data says your own data says so.

START YOUR VALIDATION

Feasibility report · lab kit · NDA package

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