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Solar & Energy-Storage Magnetics: The Selection Reference (Pillar)

One map for PV inverter and ESS PCS magnetics — positions, axes, environment, validation

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Author / Reviewer	Zhang Yong — Electronics Engineer & Founder, ProMagTech
Date	EN-1.0 / 2026-07-26
Website / Contact	www.promagtech.com · +86 13267069291 · zyong@promagtech.cn

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Summary & key takeaways

Bottom line

Every conversion node in a PV inverter or energy-storage PCS carries a magnetic: boost inductor, LCL grid-filter inductors, high-current DC inductors, isolation transformer, common-mode choke. Selection reduces to four axes: (1) efficiency (EU/CEC-weighted — core loss and DCR go straight to yield), (2) DC bias (powder-core soft saturation), (3) high-current temperature rise (flat wire + thermal design), (4) outdoor environment (wide temperature, IP65 sealing, potting, humidity/salt-fog). This reference unifies positions, axes and validation, and links to each deep-dive.

Key takeaways:

- **Two chains:** PV: panel → boost → inverter bridge → LCL filter → grid; ESS: battery → DC-DC → PCS inverter → LCL → grid (bidirectional).
- **Five magnetics families:** boost/high-current inductors, LCL filter inductors, isolation transformers (HF/LF), common-mode chokes, auxiliary magnetics.
- **Efficiency is money:** PV is judged on weighted (EU/CEC) efficiency; magnetic loss eats generation yield directly — low DCR and low core loss are revenue, not cost.
- **Outdoors is the fourth axis:** -40…+85 °C ambient, IP65, humidity/salt-fog, potting and CTE — half the work in outdoor PCS magnetics is the environment.
- **Bidirectionality is the ESS trait:** PCS charges and discharges; check DC bias and rise at the worst direction.

Note A ProMagTech engineering reference (not an official standard); the sister volume to the 800 V Power Magnetics Selection Reference — 800 V covers EV & datacenter, this covers solar & storage.

1. What this reference is and how to use it

This is ProMagTech's second selection pillar: it gathers the magnetics scattered across PV-inverter and ESS-PCS chains into one table, with a common set of axes and a validation baseline, linking to each deep-dive. Three steps: locate your magnetic in §2; identify your binding constraint with the §3 axes; set the DVP from §5, and follow §8 for depth.

2. The map: where the magnetics are

Position	Magnetic	Key challenge	Typical form
PV boost stage	Boost inductor	DC bias, efficiency, wide MPPT range	powder core + flat wire
Inverter → grid	LCL filter inductors	high current, low loss, saturation margin	powder core/Fe-Si, toroid/block
ESS DC-DC	High-current DC inductor	bidirectional DC bias, temp rise	Fe-Si/High Flux + flat wire
Isolation (if any)	HF/LF transformer	isolation, efficiency, cost	per topology
Full-chain EMI	Common-mode choke	broadband impedance, high through-current	nanocrystalline/ferrite
Auxiliary supply	Aux transformer/inductor	wide input, reliability	standard

Table 1 — Magnetic positions, challenges and typical forms in PV / ESS chains

Relation to the 800 V pillar High-voltage-side magnetics for 20–60 kW DC fast charging and AIDC-adjacent storage live in the 800 V reference; this volume focuses on PV grid-tie and the ESS PCS itself. Together the two pillars cover ProMagTech's full application span.

3. Four selection axes (solar & storage edition)

Axis 1 — Efficiency: magnetic loss eats yield

PV inverters are rated on European (or CEC) weighted efficiency, with heavy weight at light load. Winding DCR and core loss subtract across the whole power range, so the first question is always the loss budget:

EU efficiency: $\eta(EU) = 0.03\cdot\eta5\% + 0.06\cdot\eta10\% + 0.13\cdot\eta20\% + 0.10\cdot\eta30\% + 0.48\cdot\eta50\% + 0.20\cdot\eta100\%$
Magnetics' contribution: low DCR (flat wire) cuts full-load loss; low-loss material cuts light-load loss (core-loss dominated)

Axis 2 — DC bias: powder-core soft saturation

Boost, LCL and ESS DC inductors all run under heavy DC bias; powder cores (Fe-Si/Sendust/ High Flux) are the default, and turns must be derived from the biased inductance (method and pitfalls in the powder-core and case articles).

Axis 3 — High-current temperature rise: flat wire + thermal design

At tens to hundreds of amps DC/low frequency, copper loss dominates; edge-wound flat wire (~30 % lower DCR) is the first lever, and rise is judged by the ΔDCR method (see the thermal article).

Axis 4 — Outdoor environment: the solar/storage specific

Environmental stress	Requirement on magnetics	Design lever
Wide temp -40…+85 °C (ambient)	L/loss valid across range	material temp behavior check, insulation margin
IP65 / outdoor	water & dust proof	sealed structure, full potting
Humidity / salt fog	no insulation decay, no terminal corrosion	potting choice, terminal plating, 85/85 bias test
Thermal cycling + vibration	no core cracks, no lead breaks	CTE-matched potting, mechanical fixing
High altitude (some projects)	insulation derated by altitude	enlarged creepage/clearance

Table 2 — Outdoor stresses and the corresponding design levers

4. Application quick-reference

Application	Main magnetics	Axis focus
String PV inverter (20–150 kW)	Boost + LCL filter inductors	efficiency, DC bias, high current
Residential PV+ESS (5–15 kW)	Boost / DC-DC inductors	efficiency, size, quiet
C&I storage PCS (50–250 kW)	High-current DC inductor + LCL	bidirectional bias, rise, current sharing
Utility / container storage	High-current inductors + LF/MF transformer	rise, reliability, serviceability
Outdoor all-in-one / PV-storage-charging	full set + sealed potting	the four outdoor stresses
Full-chain EMI	Common-mode choke	broadband impedance, high through-current

Table 3 — Application—magnetics—axis quick reference

5. Validation & quality baseline (DVP)

Validation item	Method / instrument	Acceptance (example)
Inductance & DC bias (both directions)	LCR + bias source	L ≥ spec at rated current, both directions
Loss / efficiency contribution	power analyzer	meets loss budget (EU-efficiency terms)
Temperature rise ΔT	ΔDCR + hot-spot	≤ limit (derived from insulation class)
Wide temperature	chamber + LCR	L/loss valid -40…+85 °C
Humidity bias	85/85 with bias	insulation resistance, appearance pass
Salt fog (outdoor parts)	salt-fog chamber	no corrosion failure
Thermal cycling + vibration	chamber / shaker	no core cracks, drift within limit
Batch consistency	sampling statistics	spread < ±spec %

Table 4 — Common validation baseline for solar & storage magnetics (acceptance per project)

6. Frequently asked questions (FAQ)

Q Why do PV magnetics care so much about light-load loss?

A Because EU efficiency weights 5–50 % load heavily (the 50 % point alone counts 0.48). At light load copper loss is small and core loss dominates, so low-loss material is unusually valuable in PV.

Q Can boost and LCL inductors share the same material?

A Often yes (both in the powder-core family), but operating points differ: boost is bias-driven, LCL is ripple-loss and saturation-margin driven. Same material, different permeability/ structure is the norm.

Q What extra care does a bidirectional PCS need?

A Check DC bias and temperature rise in both charge and discharge directions and spec to the worse one; with paralleled units, inductance consistency also affects current sharing.

Q Must outdoor magnetics be potted?

A For IP65 outdoor all-in-ones, essentially yes — potting solves moisture, vibration and heat in one step. But the compound's CTE must match core and winding, or thermal cycling cracks it and makes things worse.

Q How does validation differ from 800 V automotive magnetics?

A Same framework (bias, rise, insulation, consistency); the difference is the environmental side: solar/storage stresses outdoors (humidity, salt fog, wide temp, IP), automotive stresses AEC-Q200 Grades and mechanical loads. Read the two pillars side by side.

Q What can ProMagTech deliver in solar & storage?

A Boost/LCL/ESS high-current inductors (powder core + flat wire), common-mode chokes, outdoor potting solutions; loss budgets in EU-efficiency terms and DVP data per Table 4.

7. Glossary

- **PCS —** Power Conversion System — the bidirectional converter between battery and grid.
- **MPPT —** Maximum-power-point tracking; sets the boost inductor's wide input-voltage range.
- **LCL filter —** The inverter's grid-side L-C-L filter suppressing switching ripple.
- **EU efficiency —** Load-point-weighted inverter efficiency, heavy at light load.
- **DC bias —** Roll-off of inductance under DC current.
- **IP65 —** Dust-tight and water-jet-proof rating, common for outdoor units.
- **85/85 humidity bias —** 85 °C/85 %RH moisture test under electrical bias.
- **Potting —** Encapsulation in thermally conductive/insulating compound for moisture, vibration and heat.

8. Further reading (deep-dives)

This page is the hub of the solar & storage magnetics set; the spokes below are clickable:

A. Solar & storage topics

- Solar energy-storage magnetic components white paper
- Outdoor ESS PCS magnetics design guide (sealing/IP65/potting)
- Toroidal flat-wire power inductor for PV / outdoor ESS
- Energy-storage PCS magnetic components white paper
- 20–60 kW PFC inductor selection guide (chargers/industrial)
- AIDC / energy-storage PCS high-current inductor design

B. Methodology (cross-cutting)

- Choosing a powder core: Fe-Si / Sendust / High Flux / MPP
- Thermal design & temperature-rise testing for high-current magnetics
- Common-mode choke selection: impedance curves & core materials
- Flat wire vs round wire inductors

C. Sister pillar

- 800 V Power Magnetics Selection Reference (EV & AI datacenter)

9. About ProMagTech

SHENZHEN PROMAGTECH CO.,LTD (founded 2013, Shenzhen) designs and manufactures flat-wire inductors, planar transformers, common-mode chokes and PFC inductors for PV inverters, energy-storage PCS, 800 V EV OBC and DC charging, AI-datacenter power and industrial power.

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