



RELIABILITY ANALYSIS · TECHNICAL ARTICLE

Southeast Asia EV Charger Reliability Design Guide

High temperature, humidity, and salt spray design requirements for magnetic components in EV charging stations deployed across Southeast Asia

Markets: Thailand · Vietnam · Indonesia · Malaysia · Philippines · Singapore

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1. Key Finding

Key Finding: For EV chargers deployed in Southeast Asia, high ambient temperature, humidity, and salt spray force three design decisions before inductance value: (1) current derating at elevated ambient, (2) insulation class upgrade to at least Class H, and (3) corrosion-aware material and coating selection. Chargers designed to northern European or temperate-climate specifications frequently fail in Southeast Asian field conditions within the first two years of service.

2. Southeast Asia Market Environment

Southeast Asia — covering Thailand, Vietnam, Indonesia, Malaysia, the Philippines, and Singapore — is one of the fastest-growing EV markets globally. The region's combination of rapid urbanisation, government EV incentive programmes, and rising vehicle ownership is driving significant deployment of both AC slow chargers and DC fast chargers.

Unlike EV charger deployments in Europe or North America, Southeast Asian installations frequently face extreme ambient conditions that are outside the design envelope of products developed for temperate climates. Engineers specifying magnetic components for Southeast Asian charger programmes must understand these environmental conditions and their implications before selecting or approving components.

2.1 Temperature

Country / Region	Annual Average Temp.	Peak Ambient Temp.	Typical Charger Installation
Thailand	28–34°C	42–45°C	Outdoor parking, no shade; coastal areas
Vietnam	25–33°C	40–43°C	Urban outdoor; rooftop parking
Indonesia	25–32°C	38–41°C	Outdoor; equatorial high humidity
Malaysia	26–33°C	38–40°C	Outdoor; tropical rainforest climate
Philippines	25–32°C	38–42°C	Typhoon season; coastal salt spray
Singapore	26–32°C	35–38°C	Urban heat island; high overnight humidity

The key implication for thermal design: at 45°C ambient, an inductor rated for $\Delta T = 40^\circ\text{C}$ above ambient will reach 85°C winding temperature at rated current. If the ambient rating used during design was 25°C (European standard), the same component at 45°C ambient will run 20°C hotter than designed — approaching or exceeding Class F insulation limits without any design change.

2.2 Humidity

Relative humidity in Southeast Asia ranges from 70% in the dry season to near-saturation (>95%) in the rainy season. Condensation occurs regularly when equipment cools overnight after a hot day, or when cold air-conditioned units are brought into the humid environment. The effects on magnetic components are:

- Moisture absorption by winding insulation: reduces dielectric strength over time, particularly for PET film (polyester) which is hydrophilic; polyimide (PI) film is far more moisture-resistant

- Corrosion of exposed metal surfaces: copper winding terminations, steel core mounting hardware, and aluminium housings all corrode faster at high humidity, particularly in coastal installations with salt aerosol
- Biological growth: mould and fungus grow readily above 80% RH; fungal growth on PCBs and winding surfaces can create conductive paths that degrade insulation resistance
- Condensation on cold surfaces: if the charger is installed in a location that cools significantly overnight (outdoor coastal areas), condensation on internal surfaces can cause immediate leakage current events

2.3 Salt Spray

Coastal installations in Thailand, Vietnam, the Philippines, and Indonesia face salt aerosol concentrations that can be 10–100× higher than inland industrial environments. Salt spray has two principal effects on magnetic components:

- Accelerated corrosion of copper terminations and winding leads: salt deposits on exposed copper create galvanic couples that accelerate oxidation. Within 12–18 months of outdoor coastal exposure, untreated copper terminations can develop high-resistance oxide layers that increase contact resistance and generate heat at the termination point.
- PCB creepage path contamination: salt deposited on PCB surfaces between high-voltage traces can form conductive films when wet, effectively reducing the functional creepage distance between conductors. This is particularly dangerous for 800V bus systems where the designed creepage distance may be marginally adequate under IEC 60664-1 clean conditions.

3. Thermal Design for Southeast Asian Conditions

3.1 Current Derating at Elevated Ambient

All magnetic component specifications for Southeast Asia deployments must include a current derating analysis at the maximum expected ambient temperature. The relationship is not linear: thermal resistance from winding to ambient is fixed, so a higher ambient temperature directly increases the operating temperature for the same dissipated power.

$$T_{winding} = T_{ambient} + (P_{loss} \times R_{th_winding-ambient})$$

For a component designed with $T_{ambient} = 25^{\circ}C$ and $\Delta T = 55^{\circ}C$ (reaching $T_{winding} = 80^{\circ}C$ at rated current): at $T_{ambient} = 45^{\circ}C$, the same $55^{\circ}C$ rise gives $T_{winding} = 100^{\circ}C$. If the insulation is Class F (rated $155^{\circ}C$), this appears safe, but the $20^{\circ}C$ additional thermal stress roughly halves the insulation lifetime per the Arrhenius model.

Design Ambient	Rated Current for $\Delta T = 55^{\circ}C$	Winding Temp.	Insulation Life Impact
25°C (European standard)	100% (baseline)	80°C	Full rated life
35°C (mild tropical)	~92% of rated	90°C	Life reduced ~50%
40°C (tropical)	~85% of rated	95°C	Life reduced ~75%
45°C (extreme tropical)	~78% of rated	100°C	Life reduced ~87%

Design Requirement: For Southeast Asia deployment, derate rated current by 15–22% versus the temperate-climate rating, or alternatively use a component with 15–22% higher rated current than required at nominal operating point. Verify both options against the actual thermal design with the enclosure, airflow, and ambient temperature at the installation location.

3.2 Insulation Class Selection

Standard power inductor designs for European or US markets often use Class E (120°C) or Class B (130°C) insulation — adequate for temperate climates with 25–35°C ambient. For Southeast Asia deployment, Class F (155°C) is the minimum, and Class H (180°C) is strongly recommended for the following reasons:

- Higher ambient temperature baseline: a 45°C ambient with 55°C ΔT already reaches 100°C winding temperature, leaving only 20°C margin to a Class B insulation rating
- Humidity-accelerated ageing: moisture absorption by insulation film increases dielectric loss and reduces breakdown voltage, effectively reducing the functional insulation class by one level over time in humid environments
- Cyclic thermal stress: daily temperature cycling between cool nights (25–28°C) and hot afternoons (40–45°C), combined with the thermal cycling of the converter itself, creates mechanical fatigue in winding insulation that accelerates cracking
- Longer service life expectations: EV charging infrastructure in Southeast Asia is often deployed with 10-year design life, requiring the insulation system to maintain its properties over a larger number of thermal cycles than a 5-year European deployment

Insulation Class	Max Continuous Temp.	Suitable for SEA Deployment?	Notes
Class E (120°C)	120°C	Not recommended	Insufficient margin at 45°C ambient
Class B (130°C)	130°C	Not recommended	Only 30°C above 100°C winding temperature
Class F (155°C)	155°C	Minimum acceptable	55°C margin; monitor ageing closely
Class H (180°C)	180°C	Recommended	80°C margin; handles humidity-ageing derating
Class N (200°C)	200°C	For highest reliability	100°C margin; use for coastal/harsh locations

3.3 Core Material Temperature Stability

Not all core materials maintain consistent magnetic performance across the 25–100°C winding temperature range encountered in Southeast Asian deployments:

Core Material	Bsat at 100°C vs 25°C	Permeability at 100°C	Recommendation for SEA
Iron Silicon Aluminium (KoolMu/Sendust)	~85–90% of 25°C value	Stable ±5%	Good — preferred for SEA PFC inductors
Iron Powder (Carbonyl)	~75–80% of 25°C value	Moderate decrease	Acceptable — verify Isat at 100°C with margin
Ferrite MnZn	~80–85% of 25°C value	Peaks ~70°C then falls	Caution — use with additional Isat margin
Nanocrystalline alloy	~90–95% of 25°C value	Very stable	Excellent — best temperature stability

Core Material	Bsat at 100°C vs 25°C	Permeability at 100°C	Recommendation for SEA
High Flux (Fe-Ni)	~90% of 25°C value	Very stable	Excellent — suitable for high-current SEA ESS

4. Humidity and Condensation Protection

4.1 Insulation Material Selection for High Humidity

The choice of winding insulation film has a significant impact on long-term reliability in humid environments. The principal mechanism is moisture absorption, which increases the dielectric constant and dielectric loss factor, and reduces breakdown voltage.

Insulation Material	Moisture Absorption	Humidity Resistance	Recommendation for SEA
PET (Polyester) film	High (0.3–0.5%)	Poor — hydrophilic	Avoid in coastal/high-humidity locations
PI (Polyimide, e.g. Kapton)	Very low (<0.03%)	Excellent — hydrophobic	Strongly recommended for SEA deployment
PPS film	Very low (<0.05%)	Excellent	Recommended — good dimensional stability
Nomex (Aramid paper)	Moderate (1.5–2.5%)	Moderate	Use for mechanical protection only; not primary film
Glass-reinforced PI tape	Very low	Excellent	For high-stress termination areas

4.2 Potting and Conformal Coating

For outdoor or semi-outdoor charger installations in Southeast Asia, potting or conformal coating of the magnetic component assembly is the most effective defence against humidity, condensation, and salt spray damage.

Potting and Coating Recommendations for SEA EV Charger Magnetic Components:

- Epoxy potting (thermal conductivity 0.5–2.0 W/m·K): seals the winding completely from moisture; also improves thermal path from winding to housing. Best option for fully enclosed outdoor chargers.
- Polyurethane conformal coating (IPC-CC-830): moisture-resistant film applied to assembled PCB and components; good for semi-enclosed chargers where the magnetic component is partially accessible for inspection. Lower thermal benefit than potting.
- Silicone conformal coating: excellent moisture and temperature resistance; flexible at low temperatures (no cracking in temperature cycling). Suitable for locations with daily temperature swings >15°C.
- Void-free potting: critical for outdoor coastal applications — any air void in the potting compound becomes a moisture trap. Use vacuum-assisted potting for components near the coast.
- Inspect termination points: the interface between the winding conductor and the PCB solder joint is the highest-risk point for corrosion. Ensure the potting or coating fully covers the conductor-to-terminal junction.

4.3 IP Protection Rating for Enclosure

The IP (Ingress Protection) rating of the charger enclosure directly determines the level of humidity and contamination protection for all internal components, including magnetic components. Recommended minimum ratings for Southeast Asia:

Installation Location	Min. IP Rating	Rationale
Indoor (mall, covered parking)	IP54	Dust and splash protection; low humidity exposure
Outdoor urban (shade structure)	IP65	Full dust protection; water jet resistance
Outdoor unshaded (open car park)	IP65	Full protection; direct rain and sun exposure
Coastal (within 1 km of sea)	IP66 or IP67	Heavy sea spray; potential flooding
Roadside / highway charging	IP65 minimum	Pressure washing during maintenance

5. Corrosion Protection Design

5.1 Winding Termination Protection

The winding conductor termination — the point where the flat copper wire or round wire connects to the DIP pin, bus bar, or PCB solder pad — is the highest-risk point for corrosion-related failure in coastal and high-humidity environments. Corrosion at this point increases contact resistance, which generates additional heat under load, which accelerates further corrosion in a self-reinforcing cycle.

- Tin plating on copper terminations: the standard finish provides basic corrosion protection. Thickness should be $\geq 8 \mu\text{m}$ for coastal applications (versus the standard $5 \mu\text{m}$ for temperate climates).
- Nickel barrier layer: a nickel underplate (2–3 μm) between the copper and the tin coating prevents copper diffusion into the tin, which would form brittle intermetallics and create micro-cracks that allow moisture ingress.
- Conformal coating over solder joints: even if the component body is potted, exposed solder joints on the PCB should be conformal-coated to prevent salt creep under the solder fillet.
- Avoid dissimilar metal contact: aluminium housings in contact with copper bus bars create galvanic couples that accelerate corrosion in the presence of moisture. Use compatible metals or provide an insulating barrier.

5.2 Core and Hardware Corrosion

Magnetic cores themselves are generally not susceptible to moisture corrosion (ferrite and powder cores are ceramic or polymer-bonded), but the mounting hardware — screws, clamps, and brackets — can corrode and create mechanical stress on the core. Specify stainless steel or zinc-coated steel hardware for all components in the magnetic assembly for Southeast Asian deployments. Aluminium hardware is acceptable for non-load-bearing brackets but should be anodised for coastal locations.

6. Electrical Design Adjustments for SEA Conditions

6.1 Insulation Voltage Under Humidity

The effective insulation strength of winding insulation and PCB creepage gaps is reduced in humid conditions. IEC 60664-1 accounts for this through pollution degree classification:

Pollution Degree	Environment Description	SEA Applicability	Effect on Creepage
PD 1	No pollution; hermetically sealed	Laboratory only; not field charger	Smallest creepage distance
PD 2	Non-conductive pollution; occasional condensation	Indoor charger in clean environment	Standard creepage calculation
PD 3	Conductive pollution or condensation expected	Outdoor charger; coastal/humid location	Creepage × 1.5–2×
PD 4	Persistent conductivity; continuous condensation	Coastal; heavy industrial; flooding risk	Maximum creepage requirements

For outdoor Southeast Asian installations, Pollution Degree 3 is the correct classification for most locations. This requires creepage distances approximately 1.5–2× those used for temperate indoor equipment at the same working voltage. For coastal locations (Philippines, eastern Vietnam, Indonesia islands), Pollution Degree 4 should be considered.

6.2 Saturation Current Re-verification at Temperature

The saturation flux density (B_{sat}) of all magnetic core materials decreases with increasing temperature. For PFC inductors in Southeast Asia:

- Iron silicon aluminium (KoolMu): B_{sat} decreases ~10–15% from 25°C to 100°C. Verify I_{sat} at 100°C if the room-temperature design margin is below 30%.
- Iron powder: B_{sat} decreases ~20–25% from 25°C to 100°C. More aggressive derating required; verify I_{sat} at 100°C mandatory.
- Ferrite MnZn: B_{sat} typically increases slightly to ~70°C then decreases sharply above 100°C. The sharpness of the decrease makes it critical to verify I_{sat} at 100°C for any ferrite design approaching saturation.
- Nanocrystalline: B_{sat} is very stable (< 5% change from 25°C to 125°C). Preferred for applications where temperature uncertainty is high.

7. Accelerated Life Testing for SEA Qualification

Charger manufacturers deploying in Southeast Asia should require magnetic component suppliers to demonstrate reliability under accelerated life test conditions that represent the actual field environment. The following test sequence is appropriate for Southeast Asia qualification:

Test	Standard Reference	SEA-Specific Conditions	Pass Criterion
Damp heat	IEC 60068-2-78	40°C / 93% RH / 1000 hours	No breakdown; DCR change < 5%; Inductance change < 10%
Temperature cycling	IEC 60068-2-14	-25°C to +85°C / 500 cycles (30 min dwell each)	No cracking; no delamination; electrical within spec
Salt spray	IEC 60068-2-52	5% NaCl / 35°C / 96 hours (coastal specification)	No corrosion at terminations affecting performance
Thermal shock	IEC 60068-2-11	-25°C to +85°C / 100 cycles (rapid transfer)	No core cracking; winding integrity maintained
Insulation resistance	IEC 60068-2-78 post-test	500 VDC / measure after damp heat	IR > 10 MΩ after conditioning
Hi-pot post-condition	Project-specific	Full hi-pot voltage after salt spray + damp heat	No breakdown at 80% of initial hi-pot voltage

8. Specification Checklist for SEA EV Charger Magnetic Components

Always Specify These Parameters for Southeast Asia Deployment:

- Maximum ambient temperature at the installation location — state 40°C, 43°C, or 45°C as appropriate; do not use the European standard 25°C
- IP protection rating of the enclosure — minimum IP65 for outdoor; IP66/IP67 for coastal
- Rated current at maximum ambient — calculate the derated current, not the nameplate rating at 25°C ambient
- Insulation class — specify Class H (180°C) as minimum for outdoor tropical deployment
- Insulation film type — specify PI or PPS; reject PET for humidity-exposed applications
- Potting requirement — specify void-free epoxy potting for coastal and outdoor installations
- Termination finish — specify tin plating ≥ 8 μm with nickel barrier for coastal; conformal coat over solder joints
- Pollution degree for creepage calculation — PD3 for outdoor; PD4 for coastal/island locations
- Core material and Isat at 100°C — verify, not just at 25°C room temperature
- Salt spray test — specify IEC 60068-2-52 coastal class for installations within 1 km of sea
- Damp heat test — specify IEC 60068-2-78 / 40°C / 93% RH / 1000 hours minimum

9. FAQ

Q1: Can I use the same magnetic component specification as my European or US product for a Southeast Asia deployment?

No. European and US specifications typically assume 25–35°C maximum ambient, moderate humidity (< 70% RH), and low contamination. Southeast Asian outdoor deployments require: maximum ambient 40–45°C, humidity to 95% RH, salt spray in coastal areas, and Pollution Degree 3 or 4 for creepage. These conditions require insulation class upgrade (Class H minimum), current derating, PI or PPS film (not PET), and potting or conformal coating. Reusing temperate specifications directly is one of the most common causes of field failures in SEA charger programmes.

Q2: How much should I derate inductor current for a 45°C ambient installation?

The required derating depends on the component's thermal resistance (R_{th} from winding to ambient) and the insulation class. As a first approximation, derating by 15–22% of the rated current (specified at 25°C ambient, $\Delta T = 55^\circ C$) maintains the same winding temperature. However, the correct approach is to recalculate the thermal budget: $T_{winding} = T_{ambient} + P_{loss} \times R_{th}$. Request the component's R_{th} value from the supplier, calculate P_{loss} at the proposed derated current, and verify $T_{winding}$ remains below the insulation class temperature limit with adequate margin.

Q3: What is the most common failure mode for magnetic components in Southeast Asian EV chargers?

Based on field experience across the region, the three most common failure modes are: (1) Insulation degradation from combined high temperature and humidity — manifesting as reduced insulation resistance followed by winding-to-core leakage or short circuit. (2) Corrosion at winding terminations in coastal locations — manifesting as intermittent high-resistance connections and localised overheating. (3) Core saturation at elevated temperature — manifesting as increased ripple current and converter instability, because the core's B_{sat} is lower at 80–100°C operating temperature than at the 25°C test temperature used during specification.

Q4: Can the values in this guide be used directly in production?

No. All values in this guide are engineering references. Production values must be confirmed through approved samples and qualification testing at the actual SEA operating conditions: elevated ambient temperature, post-damp-heat electrical verification, post-salt-spray termination inspection, and hi-pot testing at the appropriate pollution degree creepage distance before production release.

10. Contact and Related Resources

Resource	URL
20–60 kW PFC Inductor Design Guide	promagtech.com/technical-resources/20-60kw-pfc-inductor-selection-guide.html
800V EV Platform Inductor Selection	promagtech.com/technical-resources/800v-ev-platform-inductor-selection.html
Charging Station PFC Inductor Product	promagtech.com/products/charging-pile-pfc.html
PFC Boost Flat Wire Inductor Product	promagtech.com/products/pfc-boost-inductor.html

Resource	URL
Flat Wire vs Round Wire Selection Guide	promagtech.com/technical-resources/flat-wire-vs-round-wire-inductors.html
AIDC & ESS High-Current Design Guide	promagtech.com/technical-resources/aidc-energy-storage-pcs-high-current-inductor-design.html

<p>Shenzhen PROMAGTECH Co., Ltd.</p> <p>zyong@promagtech.cn</p> <p>WhatsApp: +86 135 3765 8938</p> <p>www.promagtech.com</p>	<p>Response Commitment</p> <ul style="list-style-type: none"> • Preliminary design assessment within 24 hours of complete specification • Formal quotation within 3 business days • Sample delivery: 5–7 business days (standard custom design)
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