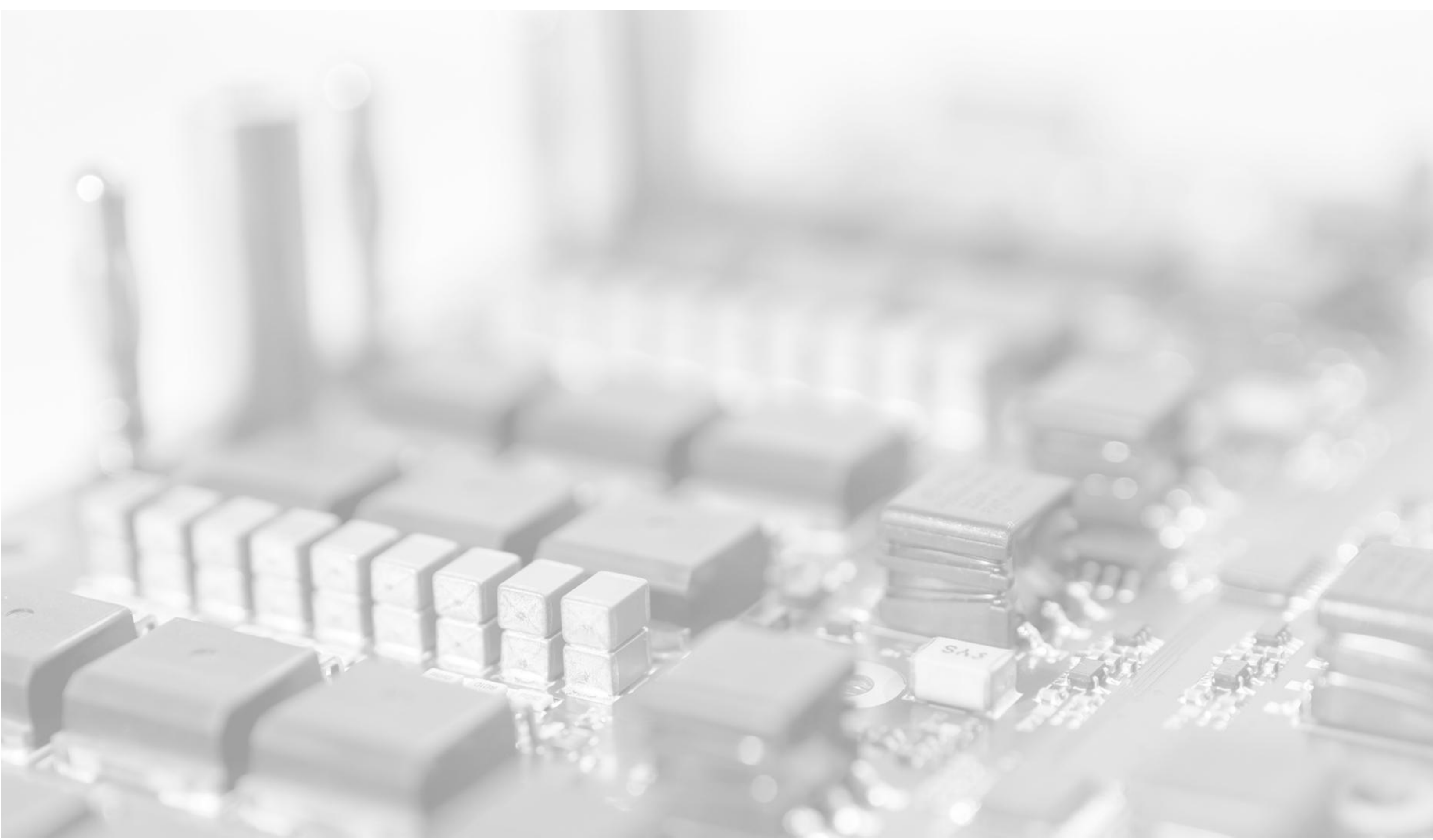
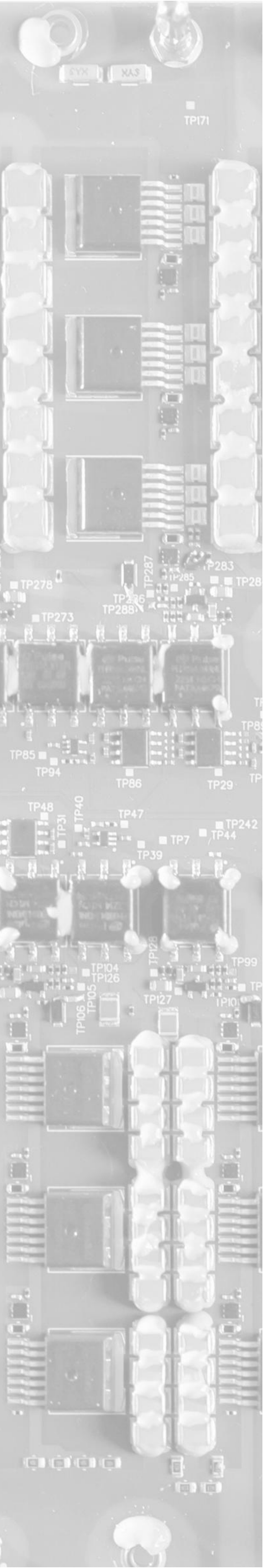
WHITE PAPER

Beyond the 50 Hz Transformer

System Architecture Series

June 6th 2026





Rethinking Galvanic Isolation for Mobile Power Systems with High-Frequency DC Isolation

How a modular AC/DC architecture enables safer, lighter and more compact mobile power systems without relying on bulky low-frequency transformers.

Table of contents

Figure 1 – BrightLoop DC Galvanic Isolator
240 A / 220 kW, up to 1000 V_{DC}, 32 x 28 x 8 cm, <17 kg
30 kW/L and 13 kW/kg power densities.

Executive Summary

The rapid electrification of mobile power applications, including battery energy storage systems (BESS), mobile EV chargers, hybrid generator sets, mining equipment and defense platforms, is driving demand for increasingly compact, lightweight and efficient electrical architectures.

One component, however, has remained largely unchanged for decades: the 50/60 Hz isolation transformer.

While indispensable for galvanic isolation, neutral creation and earthing compatibility, conventional low-frequency transformers often become one of the heaviest and largest components of an electrical system, limiting payload capacity, increasing transportation costs and complicating installation.

Advances in high-frequency power conversion now make it possible to rethink this architecture.

Instead of relying on a single low-frequency transformer to perform every function, BrightLoop separates power conversion and galvanic isolation into dedicated, optimized building blocks. The combination of the ACHV AC/DC converter and the HVI DC Galvanic Isolator delivers the same essential electrical functions while dramatically reducing system size and weight.

This paper explains why low-frequency transformers have traditionally been required, how high-frequency DC isolation changes the equation, and why modular power conversion opens new possibilities for modern mobile energy systems.

1. The Challenge of Mobile Power

The transition toward electrified mobile power systems is accelerating across numerous industries. Applications such as containerized battery energy storage systems (BESS), mobile EV fast chargers, hybrid generator sets, mining equipment and temporary grid support all share a common objective:

Deliver maximum power while minimizing size, weight and deployment complexity.

Unfortunately, one component continues to dominate the overall footprint of many installations: the low-frequency isolation transformer.

Although highly reliable, these transformers often account for a significant portion of the total system weight and volume, creating logistical and economic challenges for mobile applications.

The question is no longer whether galvanic isolation is required.

The question is whether it still requires a massive 50/60 Hz transformer.

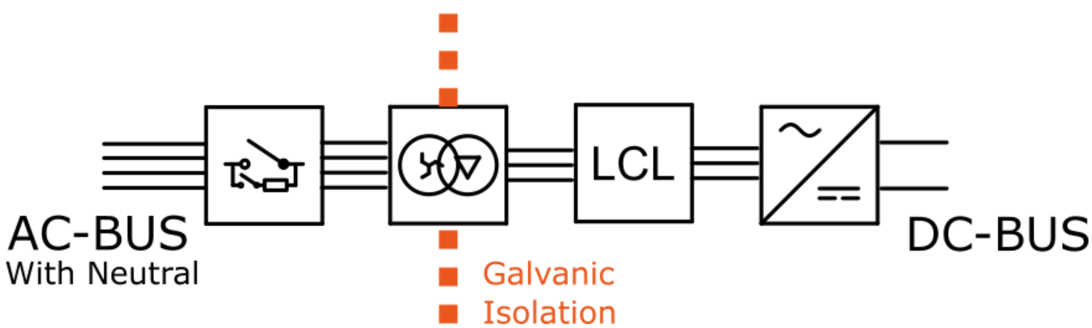


Figure 2: Usual inverter connected / forming the grid through a low-frequency transformer in Delta-Star configuration for neutral creation.

Key Takeaway

Galvanic isolation remains essential, but modern power electronics make it possible to achieve it **without relying on bulky low-frequency transformers.**

2. Why Low-Frequency Transformers Became the Standard

For decades, the low-frequency transformer has been the cornerstone of grid-connected power conversion. While commonly associated with voltage adaptation, it actually performs several critical electrical functions simultaneously.

Voltage Adaptation

The transformer matches the utility grid voltage to the operating voltage required by the power conversion system. Multi-tap designs also enable a single platform to operate across multiple international grid standards.

Galvanic Isolation

The magnetic coupling between primary and secondary windings creates a complete electrical separation between the utility grid and the mobile power system. This isolation protects both equipment and personnel in the event of electrical faults. The transformer inherently isolates the primary and secondary sides from common-mode noise: it fully blocks DC and low-frequency components while strongly attenuating high-frequency ones, helping meet EMC performance, system safety, and robustness requirements.

Earthing System Transition

Mobile power systems frequently operate using IT earthing schemes, while public electrical grids generally use TN or TT configurations. The transformer safely separates these grounding systems and enables compliant grid connection.

Neutral Creation

When a stable neutral conductor is required, the transformer, typically configured in Delta-Star or Zigzag topology, provides a dedicated neutral reference.

These four functions explain why the transformer has remained indispensable for so many years.

3. The Hidden Cost of 50 Hz Technology

Despite its robustness and reliability, the low-frequency transformer is constrained by the fundamental physics of 50/60 Hz magnetic operation.

Large magnetic cores are required to avoid saturation at low frequencies. As power increases, so do the dimensions and mass of the transformer.

For mobile applications, these characteristics directly impact:

- payload capacity
- transportation costs
- installation complexity
- crane requirements
- container utilization
- overall system efficiency

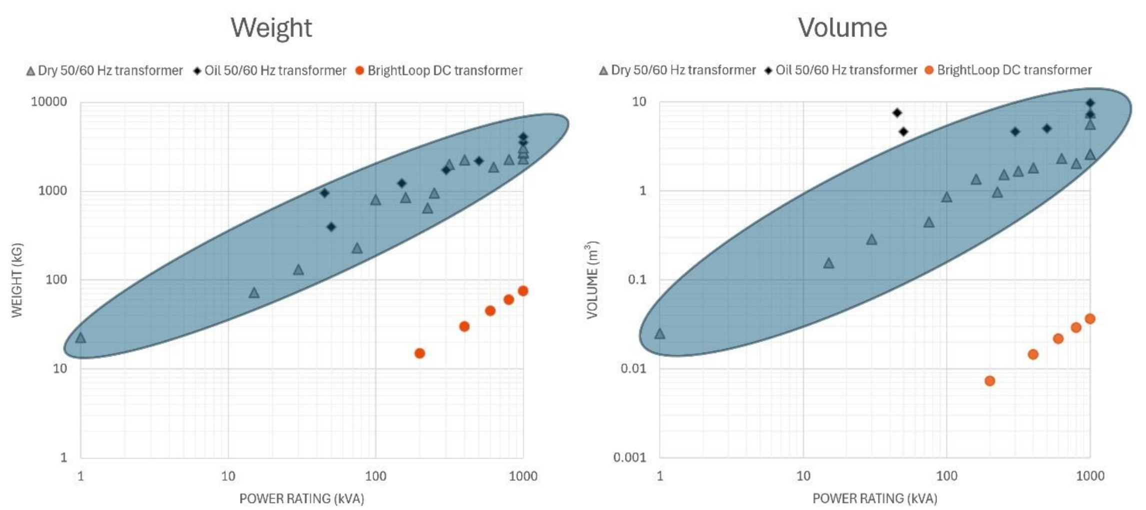


Figure 3: Weight and volume comparison between conventional low-frequency transformers and BrightLoop's high-frequency DC Galvanic Isolator.

The comparison clearly illustrates the limitations of conventional transformer technology. Across a broad range of power levels, high-frequency DC isolation offers dramatic reductions in both weight and volume.

Engineering Insight

Increasing the operating frequency of magnetic components dramatically reduces the required core size.

By moving from 50 Hz to high-frequency conversion, magnetic components become significantly smaller while maintaining equivalent isolation performance.

4. A Different Architectural Approach

Rather than asking a single transformer to perform every electrical function, BrightLoop distributes these functions across dedicated building blocks.

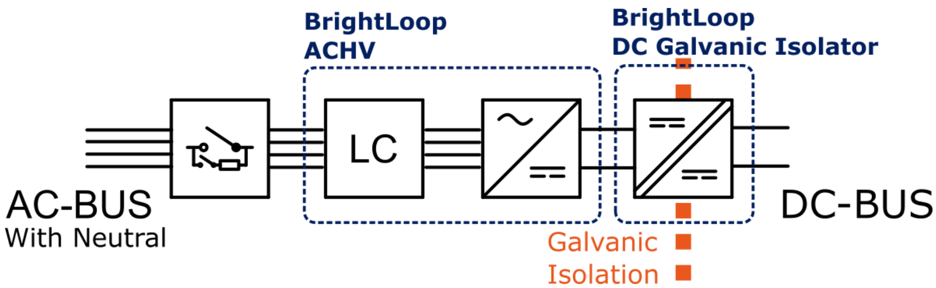


Figure 4: High-Frequency transformer based DC converter used as galvanic barrier in association with ACHV inverter.

The ACHV converter performs AC/DC power conversion while providing advanced power quality and integrated filtering.

The HVI DC Galvanic Isolator provides galvanic isolation directly on the DC bus using high-frequency transformer.

This modular architecture allows each subsystem to be optimized independently, resulting in higher overall efficiency and significantly reduced system size.

Instead of scaling magnetic components, BrightLoop optimizes the electrical architecture itself.

High-Frequency Transformer

The HVI DC Galvanic Isolator replaces traditional low-frequency magnetic technology with a high-frequency transformer based isolated DC/DC converter.

Despite its much smaller dimensions (Cf. Figure 3), it continues to provide the essential functions expected from an isolation transformer.

Reducing transformer size does not mean compromising electrical safety.

The HVI Galvanic Isolator maintains complete galvanic isolation between the DC source and the utility grid, preventing fault propagation in the event of equipment failure.

It also enables the transition between different earthing systems in the same way as a traditional isolation transformer.

For designers, this means that the advantages of high-frequency conversion are achieved without sacrificing the electrical functions required for safe grid interconnection.

Key Performance Benefits

Compared with conventional low-frequency transformers, the HVI Galvanic Isolator offers:

- approximately **50× lower weight**
- approximately **150× lower volume**
- substantially simplified transportation and installation
- improved suitability for mobile applications
- modular integration with BrightLoop AC/DC converters

5. Improved AC Power Quality

The advantages of the BrightLoop architecture extend beyond galvanic isolation.

Unlike conventional inverter systems that typically rely on external LCL filters, the ACHV platform integrates phase-by-phase LC filtering directly inside the converter.

This architecture simultaneously provides:

- differential-mode filtering
- common-mode filtering
- reduced electromagnetic emissions
- lower insulation stress
- improved overall power quality

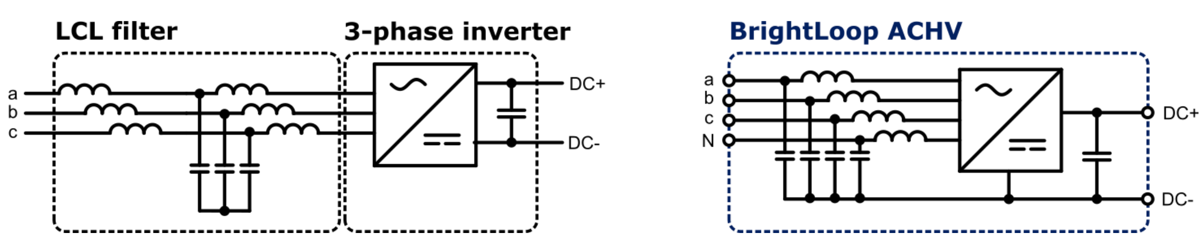


Figure 5: Comparison between a conventional LCL filter architecture and BrightLoop's integrated phase-by-phase LC filtering.

This topology is inherited from BrightLoop's high-performance DC/DC platform and contributes to the exceptionally low common-mode voltage discussed in the companion white paper:

"Reducing Common-Mode Voltage at the Source."

6. System Architecture Example

The flexibility of the modular approach is illustrated below.

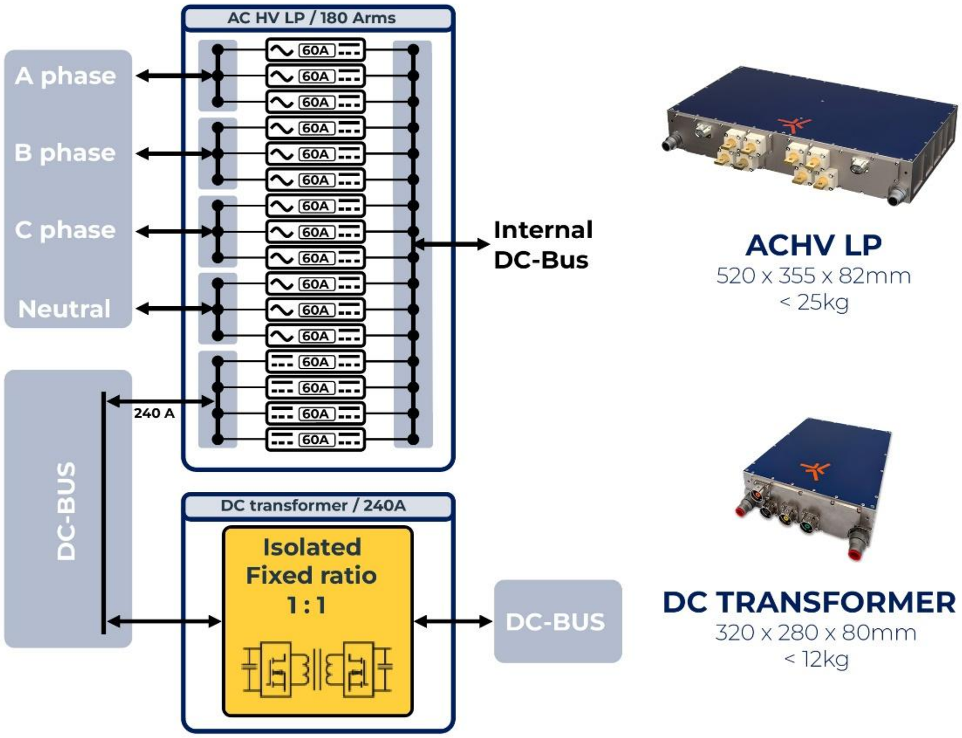


Figure 6: Example of a 125 kVA system combining an ACHV LP converter with a dedicated HVI DC Transformer.

In this configuration:

- ACHV LP provides up to **180 Arms per phase**
- System power reaches **125 kVA** at 400 Vrms, **65 kVA** at 208 Vrms
- Supports **Grid-Following**, **Grid-Forming** and **DC-Bus Control** (Active Front End) operating modes in **Three-phase, single-phase or split-phase** configuration.
- Its neutral connection allows it to support single-phase loads and heavy current phase imbalances.
- The DC-BUS **voltage ranges from 100 V to 900 V** thanks to DC-DC step-up conversion, enabling support for battery voltages at different states of charge.
- The HVI Galvanic Isolator provides transparent 1:1 galvanic isolation on the DC-BUS

Because the isolation stage is physically separated from the inverter, system architects gain greater flexibility when designing future platforms.

7. Benefits for System Architects

The transition from low-frequency transformers to high-frequency DC isolation provides advantages that extend beyond size reduction.

System architects benefit from:

- Dramatically lower weight
- Significantly reduced system volume
- Easier transportation and deployment
- Improved payload capacity
- Modular system architecture
- Maintained galvanic isolation
- Improved AC power quality
- Reduced integration complexity
- Future-ready platform for next-generation mobile power systems

Conclusion

For decades, galvanic isolation and low-frequency transformers have been considered inseparable.

Advances in high-frequency power electronics challenge that assumption.

By separating AC power conversion from galvanic isolation, BrightLoop replaces one of the largest and heaviest components in a mobile electrical system with a compact, modular architecture that preserves the essential electrical functions of conventional transformers while dramatically reducing size and weight.

Rather than redesigning the transformer, BrightLoop rethinks the architecture.

The result is a lighter, more compact and more flexible solution designed for the next generation of electrified mobile power systems.

About BrightLoop

BrightLoop develops high-performance, configurable power conversion platforms for electrification across motorsport, aerospace, marine, mining, defense, industrial automation and energy storage.

Rather than designing application-specific converters, BrightLoop provides modular building blocks that allow engineers to rethink electrical architectures, reduce system complexity and accelerate development from prototype to production.

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