APPLICATION NOTE

REFERENCE CASE

Advanced Thermal Management for Power Converters

Introduction: NEOcore™ - Superior Power Electronics Cooling with Measured Results

When power goes up and size goes down, thermal management of power electronics stops being optional — it becomes a critical design decision. In modern renewable energy industry, more performance is being packed into smaller footprints, and the resulting heat loads are increasingly concentrated and demanding. Traditional aluminum heatsinks and basic air cooling can no longer keep pace with the needs of modern IGBT, SiC, and GaN systems.

This application note introduces the **CooliBlade® NEOcore™** cooling technology for power electronics and the **ULTIMA** cooling solution based on NEOcore™. ULTIMA offers superior performance and cost-effectiveness in a fully integrated, passive thermosiphon design that is leak-proof, maintenance-free, and capable of delivering liquid-like thermal performance without the complexity of liquid cooling. Designed to address thermal hotspots in compact, high-power systems, it enables engineers to increase power density while improving long-term reliability and reducing total cost of ownership.

Key benefits of NEOcore™ cooling technology **— proven in a real MW+ SiC power stack customer case** presented in this document:

- **Lower operating temperatures:** Up to ~25 °C cooler components under full load.
- **Lighter system design:** Over 50% reduction in cooling weight compared to conventional aluminum heatsinks.
- **Simplified reliability:** Passive, sealed system — no pumps, no leaks, no scheduled maintenance.
- **Drop-in compatibility:** Minimal or no system redesign required.
- **Lifecycle efficiency:** Lower noise, longer equipment lifespan, reduced operating costs.
- **Sustainable performance:** No reliance on F-gas refrigerants or environmentally harmful coolants.

In the following pages, you will find measured test results, installation benefits, and a detailed reference case that demonstrate how CooliBlade® NEOcore™ / ULTIMA can meet today's demanding performance targets while simplifying integration for power electronics designers, product managers, and maintenance teams.

Background: Rapid Electrification increases Demands for Power Electronics Design

Modern **power conversion systems** have evolved dramatically to meet the growing demands for efficiency, higher power density, and long-term reliability across industrial, automotive, and **renewable energy** sectors. The **power electronics** landscape today includes both well-established technologies and emerging solutions, each offering distinct advantages and presenting unique thermal management requirements.

At the core of many current **power electronic converter** designs are **Insulated Gate Bipolar Transistors (IGBTs)**. These proven semiconductor devices continue to dominate medium- to high-power applications (typically 1 kW to several MW) thanks to their robust performance, established supply chains, and cost-effectiveness. IGBT-based converters remain the backbone of industrial motor drives, grid-connected inverters, and many traction applications, delivering reliable performance at switching frequencies typically ranging from 5 kHz to 20 kHz. This makes **IGBT cooling** a critical factor in maintaining performance and extending equipment life.

Alongside these mature solutions, **wide-bandgap (WBG)** semiconductor devices such as **Silicon Carbide (SiC)** and **Gallium Nitride (GaN)** are gaining traction in specific applications. These technologies provide higher breakdown voltages, faster switching speeds, and improved thermal conductivity, enabling operation at higher frequencies and power densities — particularly in **renewable energy cooling** applications such as **solar and wind energy power converters** — where these benefits justify the higher component costs.

This technological diversity has transformed **power electronics design** in several ways:

- **Varied switching frequencies** (5–20 kHz for IGBTs, 50–500 kHz for SiC, and up to several MHz for GaN) create different thermal profiles that require tailored cooling solutions.
- **Increasing power density** across all device types enables more compact designs but creates challenging thermal hotspots that must be effectively managed.
- **Improved efficiency** reduces total heat generation but often concentrates residual losses into smaller areas, demanding more advanced **power electronics cooling** techniques.

As a result, modern power converters can now achieve power densities exceeding **50 W/cm³** in some cases while maintaining or improving efficiency. However, this progress also brings a critical engineering challenge: as converters become more compact and powerful, thermal management becomes exponentially more complex - and expensive.

The relationship between conversion efficiency, power density, and thermal management now defines a fundamental design constraint across all power semiconductor technologies. Even with improvements in device efficiency, concentrating more power in a smaller volume creates significant thermal challenges. Effective heat dissipation is essential not only to maintain performance but also to ensure long-term reliability and prevent premature component failure.

These thermal factors influence every stage of **power electronics design** — from semiconductor selection and circuit layout to mechanical packaging and **cooling system integration**. The challenge is especially acute in space-constrained applications such as **electric vehicle powertrains, renewable energy inverters, and industrial motor drives**, where traditional cooling approaches often prove inadequate regardless of the semiconductor technology used.

The Challenges of Power Electronics Design

Modern **power conversion systems** face increasingly complex **thermal management** demands as they evolve to deliver higher efficiency, greater power density, and enhanced reliability. These challenges stem from fundamental shifts in semiconductor technology, application requirements, and system-level design constraints — all of which create a more demanding thermal landscape that requires innovative **power electronics cooling** solutions.

Cooling as critical design factor

The push toward compact, lightweight **power electronic converter** designs has dramatically increased power density across all semiconductor technologies. This trend results in substantial thermal loads concentrated in small areas, creating difficult hotspots that conventional cooling approaches often fail to address effectively.

Research shows clear differences in achievable power densities depending on cooling technology:

- **Traditional air-cooled systems** with basic aluminum heatsinks provide limited thermal performance, restricting achievable power density.
- **Advanced air-cooled systems**, such as **CooliBlade® NEOcore™**, deliver significantly higher power densities — approaching those of liquid-cooled systems — while retaining the simplicity and reliability of air cooling.
- **Liquid-cooled systems** achieve the highest absolute power densities but introduce added complexity, maintenance needs, higher costs, and reliability considerations.

CooliBlade® NEOcore™ technology bridges the gap between air and liquid cooling, enabling **power electronics cooling** performance close to that of liquid systems while preserving the low-maintenance advantages of air cooling.

Design Constraints

Power electronic converter systems must operate within strict physical and operational constraints that directly influence **cooling system integration**:

- **Form factor limitations** from standardized enclosures or integration requirements restrict available cooling space.
- **Weight limits** affect efficiency, installation flexibility, and material usage — a critical factor for example in transportation, portable applications, and also in **renewable energy cooling systems**. In **wind energy converters**, for instance, reducing weight lowers material costs, decreases tower and nacelle loading, and simplifies installation in space-constrained environments where access can be challenging
- **Acoustic performance requirements** in noise-sensitive environments limit fan speeds and airflow rates for forced-air cooling.
- **Maintenance access** must be balanced with environmental protection, often creating competing priorities.
- **Cost considerations** must be weighed against performance and reliability, as cooling design significantly impacts total system cost.

These constraints often conflict with optimal thermal solutions, forcing engineers to make trade-offs between performance, size, noise, and maintainability. Conventional cooling technologies rarely satisfy all requirements, creating demand for innovative solutions that balance performance with practicality while meeting reliability and efficiency targets.

Power Density Evolution

The thermal management requirements in **power electronics design** have evolved alongside semiconductor technology:

- **IGBT-based systems** operate at moderate switching frequencies (5–20 kHz) while handling high power levels, generating substantial heat that must be dissipated effectively. These systems often employ multiple power modules in parallel, creating distributed thermal challenges across larger assemblies.
- **SiC and GaN devices** operate at much higher switching frequencies, reducing switching losses but concentrating heat in extremely small areas. While SiC's higher thermal conductivity helps, the extreme **power density** still demands advanced cooling methods — especially in **renewable energy cooling** for **solar and wind energy converters**.

This technological diversity requires cooling solutions that can adapt to various heat profiles while maintaining optimal operating temperatures across all components.

Environmental Considerations

Power electronics cooling systems operate in diverse and often harsh environments:

- **Industrial applications** expose converters to dust, vibration, and high ambient temperatures — often above 50 °C.
- **Outdoor renewable energy installations** face extreme weather conditions, high humidity, and direct sunlight, all of which significantly increase thermal loads.
- **Wind energy systems** present unique challenges, as equipment is often installed at height in nacelles where space is extremely limited and weight reduction is critical. Lower weight not only reduces structural loads and material usage but also simplifies installation and maintenance in remote, difficult-to-access locations.
- **Solar energy systems** may be installed in remote or elevated areas with minimal maintenance access, where passive, reliable cooling is essential for long-term operation.
- **Climate change impacts:** Rising average temperatures, increased frequency of severe storms, and more unpredictable weather patterns make reliable cooling even more critical. As the global shift toward electrification accelerates, the reliability of **power electronic converter** systems becomes increasingly important to ensure uninterrupted operation in harsher and less predictable environmental conditions.

Environmental factors compound the thermal challenges of **power electronic converter** systems, making traditional forced-air cooling less effective due to contamination risks, high service requirements, and limited accessibility.

In addition, evolving environmental regulations — such as the EU F-Gas Regulation and US EPA restrictions — are tightening controls on refrigerants with high global warming potential. This further drives the need for advanced **air-cooling solutions** that deliver high performance for **renewable energy cooling** applications without relying on environmentally harmful fluids.

CooliBlade® NEOcore™ Thermal Management Solutions for Renewable Energy Power Converters

Power converter applications in modern **power electronics design** demand cooling solutions that balance high thermal performance, exceptional reliability, and practical implementation. As **power density** continues to rise and system form factors shrink, traditional **power electronics cooling** methods face growing limitations that restrict design flexibility, reduce efficiency, and increase operating costs.

NEOcore: Advanced Thermal Architecture

CooliBlade® NEOcore™ technology features a completely maintenance-free thermosiphon cooling system, integrated into a sealed, pure aluminum structure. This advanced architecture eliminates the need for auxiliary cooling components while delivering superior **power electronics cooling** performance in confined spaces.

By leveraging the natural physics of phase-change heat transfer, NEOcore™ moves heat efficiently from concentrated semiconductor hotspots to larger surface areas for dissipation. This is especially beneficial for high-performance **IGBT cooling** and **wide-bandgap** semiconductor devices, where heat flux densities can exceed **100 W/cm²** at junction points — a common scenario in **renewable energy cooling** systems used in **solar power inverters**, **wind turbine converters and energy storages**.

Performance Excellence

The **CooliBlade® NEOcore™** system is engineered to manage the high thermal loads generated by both traditional **IGBT-based power electronic converters** and advanced **wide-bandgap** devices such as **SiC** and **GaN**. Its efficient thermal interface between power modules and control electronics ensures rapid and reliable heat transfer — a critical factor in keeping components within optimal temperature ranges in high-density converter applications.

This capability allows **power electronics designers** to fully utilize the performance potential of their semiconductor devices without being constrained by thermal limitations. The thermosiphon-based cooling system is especially effective at handling multiple hotspots simultaneously, a common challenge in modern **power converters**, where high power density and compact layouts are essential.

The system's compact form factor supports high power density designs while maintaining ideal thermal conditions across all critical components. This not only improves efficiency of power electronics applications but also extends equipment lifespan — both key drivers for lowering total cost of ownership in demanding industries.

System Reliability

Implementing liquid cooling in a **power convertion system** can add significant complexity, requiring pumps, plumbing, and careful coolant distribution. Such systems also introduce potential failure points and unique reliability risks, particularly in mission-critical and remote applications.

The **CooliBlade® NEOcore™** system avoids these issues by offering a passive, fully integrated thermosiphon design that removes the need for pumps, external reservoirs, or complex plumbing. Its sealed construction eliminates the risk of leaks, addressing common concerns about liquid and electricity interaction, while still achieving liquid-like cooling performance. The absence of moving parts reduces maintenance demands, making it ideal for **renewable energy installations** with limited service access.

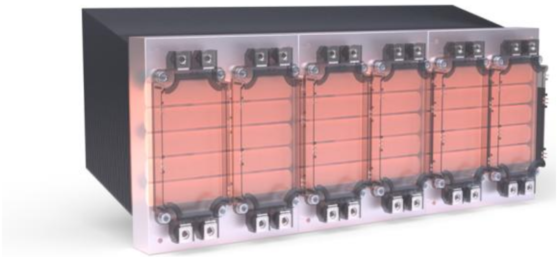
Installation Benefits

The **CooliBlade® NEOcore™** system simplifies installation by eliminating the complexity of traditional liquid cooling systems while providing superior thermal performance compared to standard air-cooling methods.

Its lightweight, compact design is particularly valuable in **power converters**, where reducing weight minimizes space-related challenges, lowers material costs, and eases handling during installation. For example in **solar power systems**, the reduced footprint and passive operation enable easier integration into compact inverter housings without sacrificing performance.
The thermosiphon design adapts to various configurations, supporting both horizontal and vertical mounting for applications such as AC inverter drives, UPS systems, and **renewable energy applications**. This versatility ensures compatibility with diverse layouts and environmental conditions while maintaining optimal cooling performance.

NEOcore™ is particularly advantageous for **power converters in remote locations requiring high reliability**. The efficient thermal management enables designers to fully utilize modern semiconductor performance, including IGBT devices operating at 100-150 W/cm² and wide-bandgap devices reaching up to 1 kW/cm² in advanced SiC applications, translating directly to increased power density and enhanced reliability.

CooliBlade ULTIMA - Next Generation Thermal Management for Power Converters



Low-weight High-performance Small footprint Cost-efficient

CooliBlade® ULTIMA is built on patented **NEOcore™** technology, offering a leap forward in **power electronics cooling** performance for high-demand applications. NEOcore™ uses a phase-change thermosiphon process to transfer heat through a fully integrated and sealed cooling structure, delivering exceptional cooling capability without the complexity or maintenance of liquid systems.

In **power electronic converter** designs, the NEOcore™ thermal channels are formed between the baseplate and the condenser pipes, achieving internal thermal conductivity up to **1,000 times greater than aluminum**. By reducing the number of thermal interfaces, the integrated NEOcore™ structure provides outstanding heat transfer efficiency.

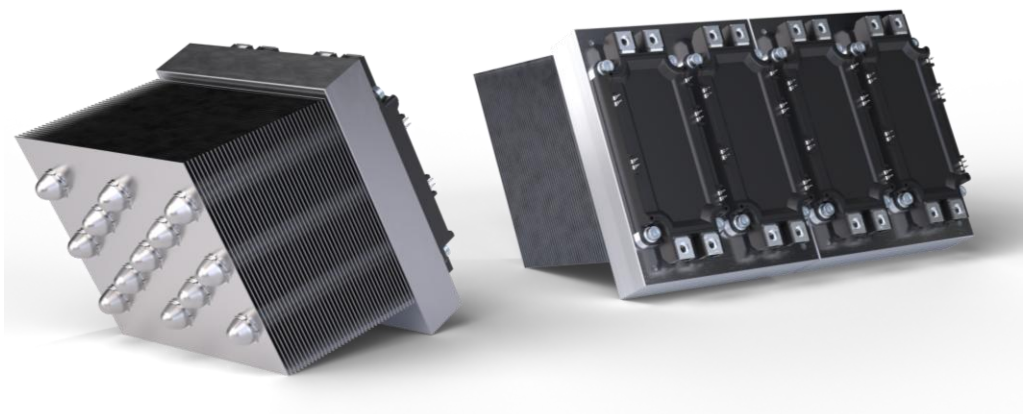
CooliBlade® ULTIMA provides design flexibility for both dimensional optimization and performance scaling, enabling superior results in the most demanding applications, from industrial drives to **renewable energy cooling**.

ULTIMA: Customer benefits

The **CooliBlade® ULTIMA** solution offers:

- **Superior thermal performance** for **IGBT and SiC cooling**.
- **Reduced total cost of ownership** through increased efficiency, lightweight structure and minimal maintenance.
- **Extended equipment lifespan** thanks to stable operating temperatures and reduced thermal stress.
- **Lightweight construction**, critical as power electronics applications size becomes smaller and smaller
- **Zero maintenance requirements**, ideal for remote **renewable energy** sites.
- **Easy installation** with minimal design modifications.
- **Small footprint (baseplate)** for compact **power electronics design** in space-constrained environments.
- **Leak-proof sealed design** for safe and reliable operation.
- **Passive operation** — no pumps or external power required.
- **Optimized airflow and low backpressure** for efficient system integration.
- **Customer-specific adaptations** possible to meet unique cooling requirements.

By integrating **CooliBlade® ULTIMA** into **power electronic converter** systems, manufacturers can address the dual challenge of increasing power density and ensuring long-term operational reliability — particularly important in **renewable energy cooling** applications where maintenance access is limited and uptime is critical



CooliBlade®

REFERENCE CASE

CooliBlade ULTIMA Reference Case: MW+ SiC Power Stack Cooling Problems

Customer Challenge

- A customer operating in the high-performance **power electronics design** sector previously relied on a 39 kg stacked-fin aluminum heatsink for cooling. While adequate for earlier power levels, this approach became insufficient when the customer sought to develop a higher-power, flagship design.

Key issues identified:

- The existing aluminum heatsink could not manage the increased thermal load effectively.
- The customer needed a drop-in thermal solution requiring minimal system modifications.
- Transitioning to liquid cooling would require a complete system redesign, adding complexity and reliability risks.
- Maintenance requirements for active liquid cooling systems were a concern, especially in remote installations such as renewable energy applications.

CooliBlade ULTIMA Solution

- To address these challenges, **NEOcore technology - based ULTIMA** cooling solution was implemented as a direct replacement for the aluminum stacked-fin heatsink.

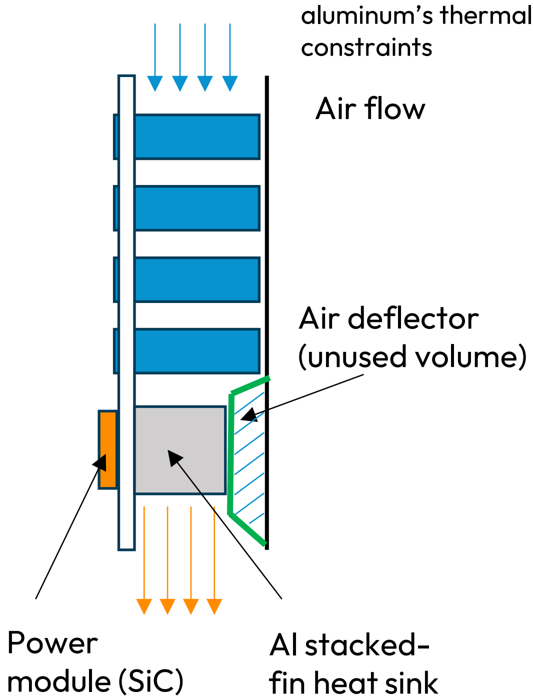
Measured Results

- **Superior cooling performance: 25 °C lower component temperature** under comparable operating conditions
- **50% weight reduction** (39 kg → 18.5 kg), reducing structural loads in **power electronics systems** and simplifying installation in space-constrained spaces .
- **Lower noise levels** due to passive operation
- **Lower pressure drop** for improved airflow efficiency
- Successful deployment of high-power variant without system redesign
- Improved system reliability in demanding conditions
- Compatibility with compact power electronics design layouts

By implementing **CooliBlade® ULTIMA**, the customer achieved their higher performance goals while maintaining the simplicity of their product platform. The drop-in compatibility, combined with significant thermal performance improvements, makes ULTIMA a highly **attractive solution for power electronics** industries where **performance, reliability**, **weight savings**, and **low maintenance costs** are essential — like in **renewable energy converter cooling**.

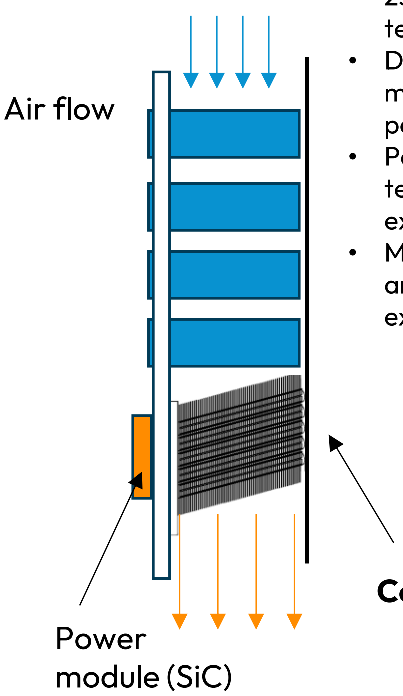
Previous solution

- Aluminum-stacked-fin heat sink
- Weight 39 kg
- Limited size and performance due to aluminum's thermal conductivity constraints



The New solution: CooliBlade ULTIMA

- 50% weight reduction: 18,5 kg
- 25 °C lower component temperature
- Direct replacement requiring minimal design changes to the power electronic converter
- Passive thermosiphon technology — no pumps, no external systems
- Maintained system simplicity and met reliability expectations



CooliBlade: Ready to Solve Your Cooling Challenges.

CooliBlade® specializes in advanced **power electronics cooling** solutions, delivering innovative passive technologies for demanding applications for example in telecommunications, industrial drives, and **renewable energy systems**. Our expertise in **thermosiphon-based** cooling enables us to provide reliable, energy-efficient designs that solve complex thermal challenges in **power electronic converters** used across high-performance sectors.

Ready to Push the Limits of Your Power Electronics Cooling?

Whether you are designing the next generation of **power electronic converters**, optimizing **IGBT cooling**, or building more reliable **renewable energy systems**, **CooliBlade** can help you achieve higher power density, lower operating temperatures, and longer equipment life — without the complexity of liquid cooling.

Our proven **NEOcore**™ technology and **ULTIMA** solutions have delivered superior results in real-world customer cases, from industrial drives to MW-class power energy converters.

📥 **Contact our engineering team today** to discuss your thermal management challenges, request a performance assessment, or explore a drop-in cooling upgrade for your existing systems. Let's turn your cooling bottlenecks into a competitive advantage.

Contact us here: https://cooliblade.com/contact-us

Read more about CooliBlade and NEOcore technology: https://cooliblade.com/