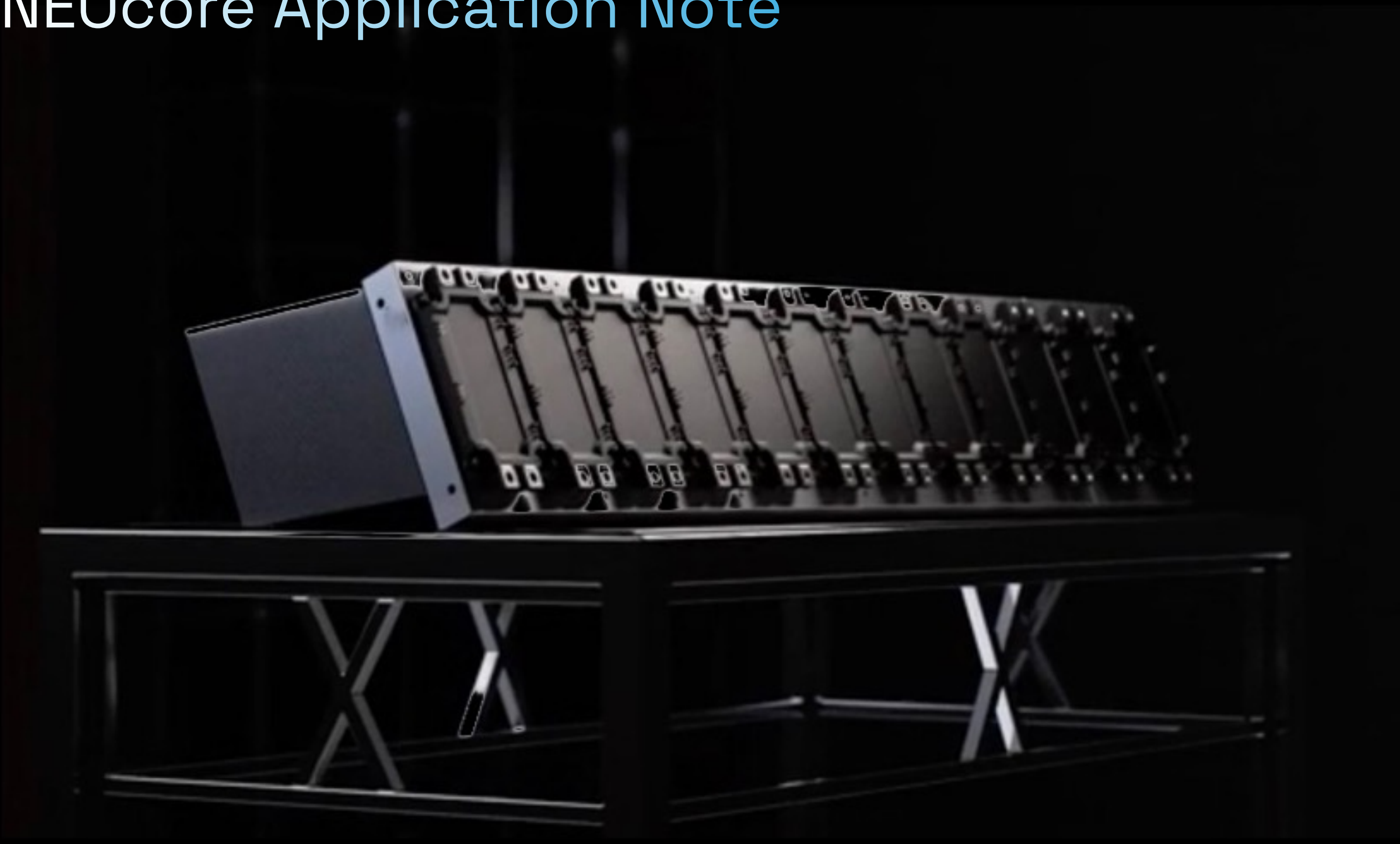
AC Drives

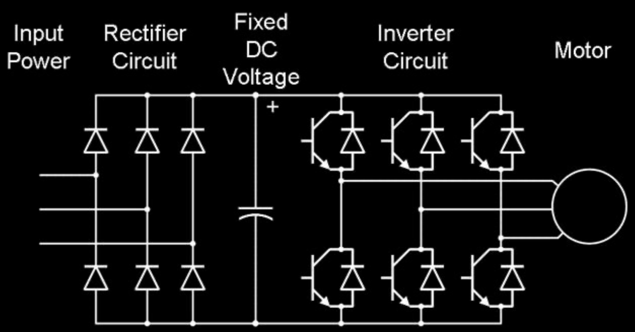
NEOcore Application Note



1. Introduction to AC Drives

Variable Fequency Drives enables efficient motor control and saves energy

Variable frequency drives (VFDs) control AC motor speed and torque by adjusting the voltage and frequency supplied to the motor. A VFD typically comprises a rectifier (converts grid AC to DC), a DC bus (filters and smooths, containing capacitors and sometimes inductors), an inverter (converts DC back to AC) and variable voltage AC using PWM driven power modules such as IGBTs or MOSFETs), and a control system responsible for motor regulation and protection.



The main components of Variable Frequency Drives

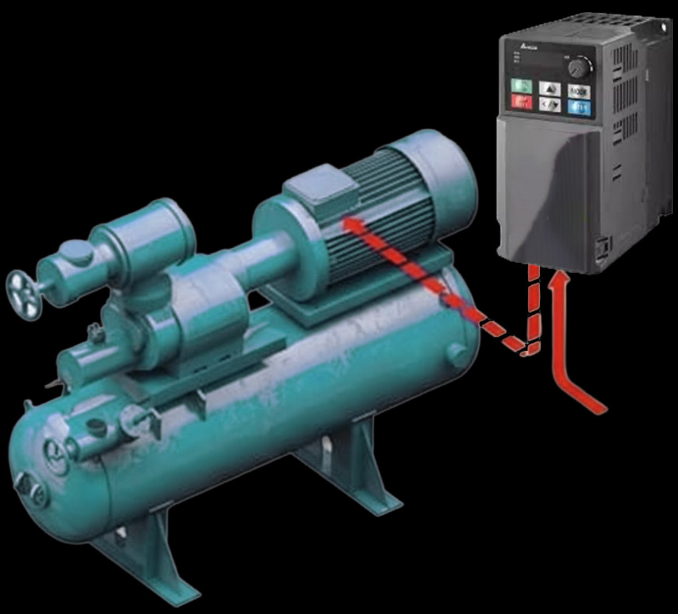
AC drives (also called variable frequency drives) control the speed and torque of AC motors by converting fixed-frequency grid power into a variable-frequency, variable-voltage output. A typical AC drive has three main power stages:

Rectifier (converter): Converts incoming AC to DC using a diode bridge or Active Front End (AFE), setting input power quality and a large share of total losses.

DC bus: Stores and smooths the DC voltage with capacitors (and often inductors), providing a stable link between rectifier and inverter.

Inverter: Uses IGBT or MOSFET power modules to convert DC back to AC at the desired frequency and voltage, generating most of the drive's heat under real-world load.

In most industrial AC drives, the rectifier and inverter are mounted on a common heatsink inside a standardized frame or cabinet, which tightly constrains the available cooling footprint and makes thermal headroom a primary design bottleneck. This is exactly where the limits of aluminum and embedded heat pipes show up most sharply.



Why Thermal Management matters

Because losses concentrate in the rectifier, inverter power modules, magnetics, and DC bus capacitors, thermal management is critical to **power density, reliability, and lifecycle cost**—especially in industrial, sealed cabinets and elevated ambient conditions. This use case outlines the baseline thermal profile, design constraints, and the principles of an optimized cooling solution (improved heat paths, material selection, and airflow management), and shows how these measures reduce hotspots, improve efficiency, and increase reliability without performance derating.

By optimizing heat paths, TIM selection, and airflow or cooling performance, VFDs can cut hotspot temperatures by 20 °C, which boosts MTBF exponentially, enables quieter operation or higher switching frequencies, reduces fan count and maintenance, and lowers total cost of ownership.

Effective thermal management in variable frequency drives (VFDs) is essential because junction temperature directly constrains power density, efficiency, and reliability. Hotspots in the rectifier, inverter power modules, magnetics, and DC bus capacitors accelerate failure mechanisms (dielectric aging, solder fatigue, electromigration), increase conduction and switching losses, and force derating.

In many VFDs the rectifier and inverter are mounted on a common heatsink to minimize cost, parts count, and mechanical complexity. Two distinct thermal scenarios dominate. First, with a passive diode bridge rectifier plus inverter, the rectifier's losses are typically much lower than the inverter's, so heatsink sizing is driven by inverter hotspots. However, diode bridges often have more restrictive allowable junction/case temperatures than the inverter's power modules, so careful heat spreading, low resistance TIMs, and local airflow management are needed to prevent rectifier peak temperatures even when average loss is modest. Second, with an active front end (AFE) plus inverter, both stages use similar controlled power modules and exhibit comparable conduction and switching losses (including during regeneration), making the rectifier a co-driver of total thermal load. AFE systems, therefore, demand higher cooling performance overall—larger fin area and airflow or a liquid/cold plate solution.

NEOcore technology – the first modular fully aluminium thermosiphon

CooliBlade's NEOcore is a passive two-phase thermosiphon built as a, 100 % aluminum structure. It eliminates the fundamental weaknesses of both plain aluminum heatsinks and embedded heat pipe solutions, while fitting into existing drive architectures

1. **Evaporation:** Power modules are mounted directly onto the integrated aluminum evaporator base. Heat from the modules vaporizes a working fluid inside the sealed chamber.
2. **Vapor transport:** The vapor flows naturally through the internal cavity and reaches the condenser section, the integrated aluminum fins, where it releases its thermal energy.
3. **Condensation and return:** The condensed fluid returns to the evaporator by gravity, completing a continuous passive cycle with no moving parts. Internal geometry allows for both vertical and horizontal mounting orientations, offering cabinet designers maximum flexibility.

Key Advantage: Because NEOcore is a fully aluminum structure, it spreads heat uniformly across the whole stack of fins with zero interface losses, solving the thermal inteface bottlenecks seen in embedded heat pipe designs.

The principle of NEOcore technology combines high performance, cost-efficient manufacturing and modular customizable structure.

CooliBlade provides advanced, modular, and easily configurable thermal management platforms for a wide range of variable frequency drive (VFD) use cases. Built to simplify integration and customization across different power levels and mechanical envelopes, the AURORA and ULTIMA product families enable application-optimized heat spreading and airflow interaction without sacrificing scalability. AURORA is particularly well suited for designs featuring narrow air channels, where effective vertical heat distribution is essential to utilize available cooling capacity across the channel height. ULTIMA, in turn, is optimized to spread heat efficiently in the depth direction, supporting applications where the air channel geometry enables the buildup of a thin layer of warmer or cooler fluid along the surface and robust heat transfer along the flow path.

AURORA

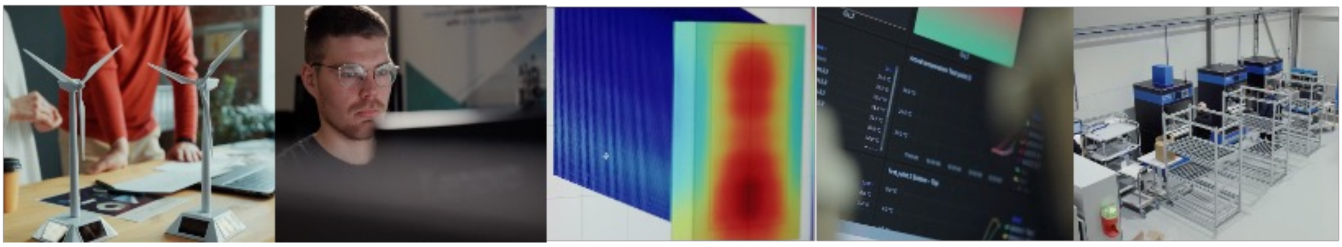
AURORA is CooliBlade's solution for narrow air-channel applications where cooling volume is constrained and all heat-generating components can be mounted on a single shared heatsink plate. It efficiently spreads and equalizes heat across devices—rectifier, inverter modules, and DC-bus components—flattening hotspots and stabilizing the overall temperature profile. This enables simpler mechanics, consistent thermal margins for the most stressed components, reduced fan requirements, and higher reliability in compact cabinet designs.

ULTIMA

ULTIMA is CooliBlade's flagship thermal solution for high-temperature power electronics, engineered to deliver strong cooling performance during high power levels and high power densities. Its modular design simplifies integration across different frame sizes, while its efficiency typically enables about a 20 °C reduction at hotspots, supporting higher power density and reduced derating. ULTIMA is cost-effective and highly reliable, and it avoids the dry-out failure modes seen in conventional heat-pipe solutions, ensuring stable performance over long product lifecycles.

From design to pilot production process has several stage-gate points

All custom products are based on mature product platforms, which provides a reliable foundation for customization and scalable production. Our well-defined customization process ensures consistent and dependable results. Products are designed by our experienced engineering team using CFD modeling tools and proprietary design parameters, typically achieving a design accuracy of approximately +/-1%. All prototypes are tested by CooliBlade engineers and further validated by customers in their own test environments. Once performance has been confirmed, the transition to pilot batches and subsequent production ramp-up can be carried out efficiently and with low risk.



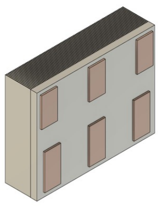
Use Case: AURORA is an ideal solution for narrow air duct frequency converter applications

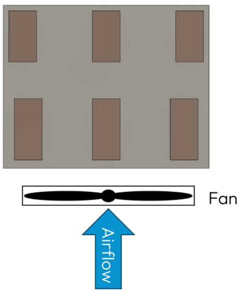
CooliBlade AURORA products are ideal for narrow air duct applications. AURORA is a perfect solution for direct retrofit cases where the improved performance would be required. In this use case, we replaced a traditional skived aluminum heat sink with the CooliBlade AURORA heat sink solution, which combines an efficient, high-density skived air interface with CooliBlade's powerful integrated thermal channels. AURORA utilizes free-form integrated thermosyphon structures to seamlessly distribute heat from hotspots throughout the structure, thereby reducing the highest temperatures of critical components.

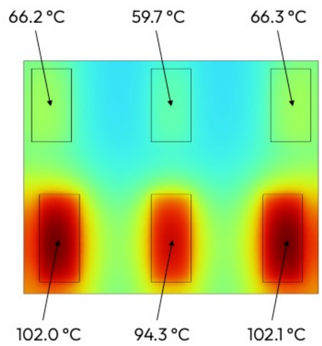
This advanced heat spreading effectively flattened the thermal profile, dropping the critical IGBT module temperature by an impressive 18.8 K while simultaneously reducing the overall mass by 1.6 kg. This immediate drop in peak temperature enables higher power output, operation in higher ambient temperatures, and can effectively triple component lifetime. Furthermore, while these exceptional results were achieved within a strictly constrained retrofit envelope, applications with more available space would allow AURORA to yield even greater performance advantages over standard aluminum solutions.

Reference aluminium heat sink

Aluminium heat sink
Dimensions: 370 mm x 293 mm
Mass: 13,0 kg
ΔT: 102.0 K

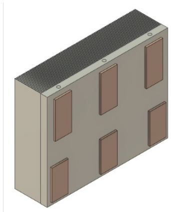


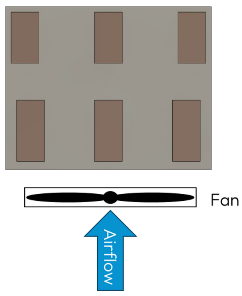


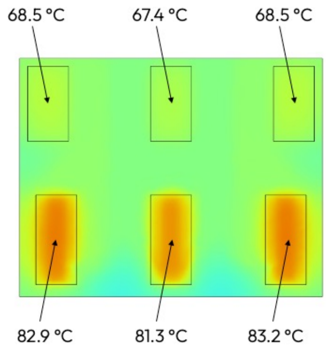


AURORA

CooliBade AURORA heat sink
Dimensions: 370 mm x 293 mm
Mass: 11,4 kg
ΔT: 83,2 K







Results:

- 18,8 K lower heat sink temperature at the critical point
    - More power / higher ambient / triple the life time
- 1,6 kg (8,8 %) lighter structure
- Identical heat sink footprint

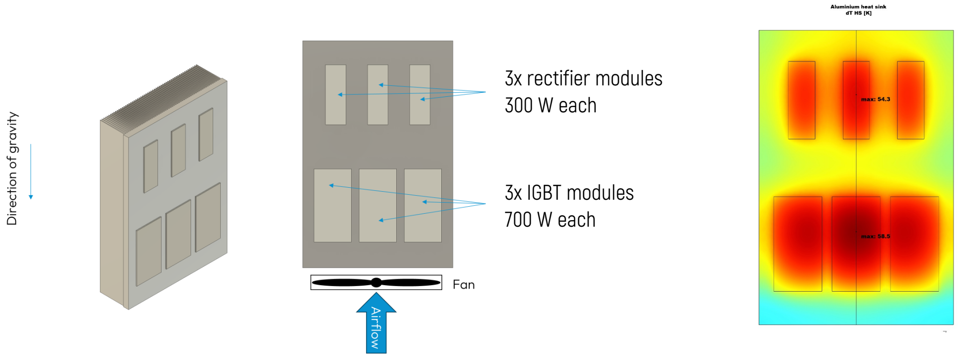
Use Case: ULTIMA maximal performance for high power frequency converter

This redesigned, more compact design produced excellent results by reducing the critical component temperature by 11.5 K while reducing the heat sink face area by 26%. In this use case, the hottest components were only 700 W, and the performance improvement was still limited, although significant.

The ULTIMA evaporator performs particularly well at extreme power densities, where the performance gap between ULTIMA and traditional solutions increases even further. At higher thermal loads, where individual component powers can reach up to 1500 W – the relative cooling improvements would be even more significant.

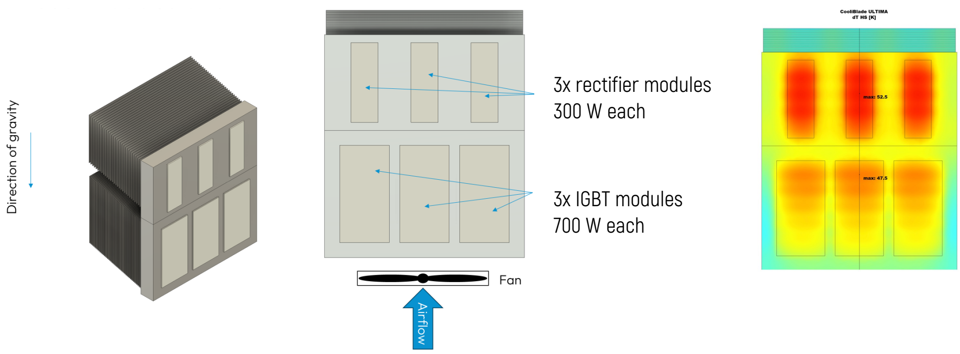
Refence aluminium heat sink

Aluminium heat sink
Dimensions: 380 mm x 250 mm
Mass: 9.1 kg
ΔT: 58,9 K
Pressure loss: 340 Pa



ULTIMA

CooliBade ULTIMA heat sink
Dimensions: 280 mm x 250 mm
Mass: 8.0 kg
ΔT : 47,4 K
Pressure loss: 200 Pa



Results:

- 11.5 K lower heat sink temperature at the critical point
    - More power / higher ambient / double the life time
- 1.1 kg (12.1 %) lighter structure
- 26 % reduction in heat sink footprint

The results

CooliBlade NEOcore technology delivered 11.5 and 18.8 °C improvements in thermal performance while distributing heat more evenly across the cooling structure. This enabled the customer to reduce the required airflow, which in turn significantly lowered the VFD's acoustic noise level. In addition to improved peak temperatures, a key benefit was a more balanced temperature distribution and the elimination of high-power-density hot spots at elevated power levels. This proved especially critical in the platforms, where high power levels led conventional heat pipe-based solutions to show limitations due to heat pipe dry-out under demanding operating conditions.

The Conclusion

Next-generation SiC-based VFD platforms will increasingly challenge today's conventional cooling approaches. In particular, rising component power densities put pressure on traditional aluminium heat sink solutions, where local thermal spreading and peak temperature control become limiting factors. Heat pipe-based designs are also often insufficient at very high heat flux levels, and their long-term reliability can represent a significant risk—especially in demanding operating conditions where dry-out effects may occur.

CooliBlade's NEOcore technology introduces a new path to ultra-high-performance thermal management, typically enabling more than a 20 °C improvement compared to conventional solutions. This advantage is highly relevant to future VFD product development, supporting drives that are more efficient, reliable, and quieter by reducing cooling airflow requirements. To address diverse mechanical envelopes, CooliBlade's modular AURORA and ULTIMA product families are designed for both narrow and wider air-channel applications and can be readily tailored—leveraging CooliBlade's design expertise—to meet product-specific customer requirements.

Business Impact

✓ **Better cooling in the same cabinet** – Higher powers in the same cabinet – Enables higher power levels in VFD system within the existing cabinet footprint. Higher value for the customer.
✓ **Cost-efficiency -** Modular air cooling offers an attractive price point.
✓ **Lower air flow -** Smaller fans, less energy, and less noise.
✓ **Faster time-to-market –** Modular structures and professional thermal design know-how speed up the R&D cycle times.