Standex EDGE Electronics

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Smart Grid Thermal Management

How Temperature Managing Magnetics Improve Efficiency, Reliability, and Power Density in Smart Grid Systems

Introduction

The modernization of electrical grids is driving unprecedented demand for compact, efficient, and highly reliable power conversion equipment. As utilities integrate renewable energy, battery energy storage, electric vehicle charging infrastructure, and intelligent monitoring systems, power electronics must handle higher current levels while operating in increasingly compact spaces.

These evolving requirements place significant thermal stress on magnetic components such as filter inductors, transformers, and common mode chokes. Excessive heat not only reduces efficiency but also accelerates insulation aging, affects magnetic performance, increases cooling requirements, and ultimately shortens equipment life.

For engineers designing Smart Grid systems, thermal management is no longer simply a cooling challenge—it has become an essential aspect of magnetic component design.

Standex Edge addresses this challenge by combining advanced magnetic materials, optimized winding technologies, and application-specific engineering to reduce losses at the source. Rather than relying solely on external cooling, custom magnetic solutions are designed to improve efficiency, minimize temperature rise, and support long-term reliability across demanding Smart Grid applications.

This white paper explores the sources of thermal losses in magnetic components, discusses engineering strategies for improving thermal performance, and highlights how Standex Edge's portfolio of Custom High Current Filter Inductors, Planar Power Inductors, Planar Transformers, Common Mode Chokes, and other custom magnetic solutions help engineers build cooler, more efficient Smart Grid systems.

The Growing Thermal Challenge in Smart Grid Systems

Global investments in renewable energy, energy storage, and grid modernization are transforming power conversion technologies. Modern systems require higher switching frequencies, increased power density, and continuous operation under demanding environmental conditions.

Applications such as Battery Energy Storage Systems (BESS), photovoltaic inverters, wind energy converters, EV fast chargers, and Flexible AC Transmission Systems (FACTS) all rely on magnetic components to regulate current, suppress electromagnetic interference (EMI), and maintain power quality.

As current levels increase and system footprints shrink, every watt of electrical loss becomes heat that must be effectively managed. If excessive temperatures are not controlled, magnetic components can

experience reduced efficiency, increased cooling requirements, reduced equipment lifespan, lower inductance stability, and accelerated insulation degradation. Consequently, thermal management is no longer an afterthought—it is a key design objective that influences the performance and reliability of the entire power conversion system.

Understanding Heat Generation in Magnetic Components

Magnetic components generate heat through a combination of electrical and magnetic losses. Understanding these mechanisms is fundamental to designing components capable of sustained operation under high-current conditions.

Copper Losses

Copper losses result from the electrical resistance of the winding conductors. As current increases, resistive losses rise according to the I^2R relationship, making conductor selection and winding design critical for thermal performance.

Standex Edge engineers optimize winding geometry, conductor cross-section, and current distribution to reduce DC resistance and improve efficiency.

EDGE *INSIGHT*

Thermal management begins with magnetic design. Reducing losses through optimized materials, winding configurations, and component geometry is often more effective than relying solely on external cooling methods.

Core Losses

Core losses occur as the magnetic material is repeatedly magnetized and demagnetized during converter operation. They consist primarily of:

- Hysteresis losses
- Eddy current losses

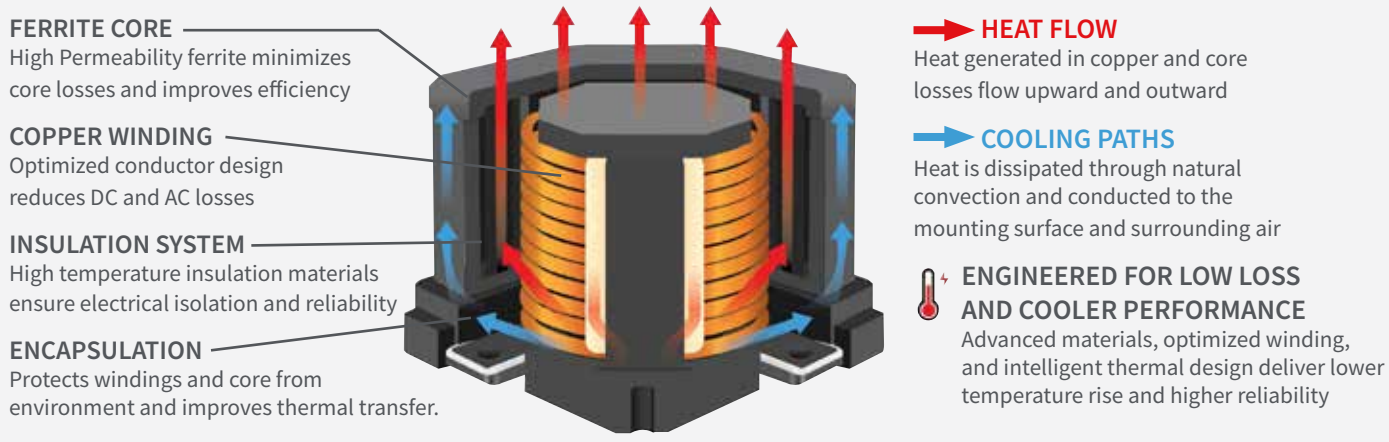
These losses increase with switching frequency and magnetic flux density, making core material selection an essential aspect of thermal management.

AC Effects

At higher frequencies, skin effect and proximity effect increase AC resistance, resulting in additional heat generation within the winding. Standex Edge addresses these challenges through optimized conductor configurations and custom magnetic designs tailored to each application.

CROSS-SECTION OF A HIGH CURRENT FILTER INDUCTOR

Core, Winding, Heat Flow, and Cooling Paths



EDGE *ENGINEERING TIP*

When designing high-current filter inductors for Battery Energy Storage Systems, evaluate continuous RMS current, ripple current, and ambient operating temperatures together. Optimizing these parameters early in the design process can significantly reduce temperature rise and improve long-term reliability.

Engineering Thermal Performance Through Magnetic Design

The most effective thermal strategy is to reduce losses before they become heat. Standex Edge approaches magnetic design holistically by evaluating electrical, thermal, and mechanical requirements simultaneously. Key design considerations include:

- Selecting low-loss magnetic materials
- Optimizing winding configurations
- Reducing DC resistance
- Minimizing AC losses
- Managing magnetic flux distribution
- Designing for efficient heat transfer

This integrated approach enables magnetic components to maintain stable electrical performance while operating at lower temperatures.

Standex Edge Magnetic Solutions

Rather than offering a one-size-fits-all approach, Standex Edge develops magnetic components optimized for the specific electrical and thermal requirements of each application.

Custom High Current Filter Inductors

Designed for high-current power conversion systems, these inductors provide:

- Low DC Resistance
- Stable inductance
- Reduced temperature rise
- High saturation current
- Optimized thermal performance

Typical applications include Battery Energy Storage Systems, renewable energy inverters, industrial converters, and grid-support equipment.

Planar Power Inductors

Planar technology improves heat dissipation through flat conductor geometries that reduce AC losses while supporting compact converter designs. Advantages include:

- Improved thermal performance
- Higher Power Density
- Lower winding profile
- Consistent manufacturing quality

Common Mode Chokes

Common Mode Chokes reduce conducted electromagnetic interference while maintaining reliable thermal performance. Applications include:

- EV charging infrastructure
- Industrial drives
- Solar power conversion
- Grid-connected converters

Planar Transformers

Planar transformers combine compact construction with efficient thermal characteristics, making them ideal for high-frequency power conversion systems where both power density and cooling are critical.

- Low DC Resistance
- Stable inductance
- Reduced temperature rise
- High saturation current
- Optimized thermal performance

Table 1 - Matching Products to Applications

Smart Grid Application	Standex Edge Solution	Primary Benefit
Battery Energy Storage Systems	Custom High Current Filter Inductors	High-current thermal stability
Solar Inverters	Planar Power Inductors	Reduced AC losses
Wind Energy Converters	Custom Magnetics	Improved efficiency
EV Fast Chargers	Common Mode Chokes + Planar Magnetics	Thermal and EMI performance
Utility Grid Monitoring	Current Transformers	Accurate sensing & reliability
Industrial Power Supplies	PQ32 Fixed Power Inductors	Stable thermal performance

Engineering Magnetic Components That Stay Cool

Thermal management begins long before a magnetic component is manufactured. It starts during the design phase, where every decision—from material selection to winding geometry—affects efficiency, temperature rise, and long-term reliability.

Rather than treating heat as a secondary problem, Standex Edge engineers magnetic components to minimize losses at the source. This approach helps reduce cooling requirements while supporting higher power density and longer service life.

Optimized Core Material Selection

The magnetic core is central to the electrical and thermal performance of an inductor. Different materials exhibit different characteristics with respect to core loss, saturation, operating frequency, and temperature stability.

Standex Edge evaluates application-specific operating conditions—including switching frequency, ripple current, current density, and ambient temperature—to identify the most appropriate core material. Key considerations include:

- Low hysteresis losses
- Reduced eddy current losses
- Long-term material reliability
- High saturation flux density
- Stable performance over wide temperature ranges

Selecting the correct core material helps reduce internal heat generation while maintaining consistent inductance under varying load conditions.

Winding Design for Lower Temperature Rise

Copper losses remain one of the primary sources of heat within magnetic components. These losses increase with current and can significantly impact efficiency if conductor design is not optimized.

Standex Edge employs custom winding techniques to reduce both DC and AC resistance. Depending on the application, engineers may incorporate:

- Foil windings for high-current applications
- Litz wire for high-frequency converters
- Interleaved winding arrangements to minimize leakage inductance
- Parallel conductors to improve current distribution
- Optimized conductor cross-sections to reduce DCR

These techniques help lower operating temperatures while improving electrical performance.

Designing for Efficient Heat Dissipation

Even the most efficient magnetic components generate some heat. Effective thermal management therefore includes designing components that can efficiently transfer heat to the surrounding environment. Standex Edge considers:

- Component geometry
- Airflow paths
- Cooling methods (natural convection, forced air, or liquid cooling)
- Mounting orientation
- Enclosure constraints

By integrating these factors into the design process, engineers can achieve more uniform temperature distribution and reduce localized hot spots.

Smart Grid Applications

Having reviewed the thermal management principles designed into Standex Edge components, here are how some Smart Grid Applications are improved by integrating these efficiently designed, temperature-managing magnetics:

Battery Energy Storage Systems (BESS)

Battery Energy Storage Systems are a cornerstone of modern Smart Grids, enabling energy balancing, peak shaving, and renewable energy integration. Power Conversion Systems (PCS) within BESS operate continuously, requiring magnetic components that can withstand sustained high currents without excessive temperature rise. Standex Edge's **Custom High Current Filter Inductors** are engineered to deliver high saturation current, stable inductance, low DC resistance, and efficient thermal performance. These features help improve converter efficiency while supporting long operational life.

Renewable Energy Inverters

Solar and wind energy systems rely on high-frequency power converters to synchronize generated power with the grid. Thermal management is essential to ensure reliable operation under variable load conditions and changing environmental temperatures. Standex Edge's **Planar Power Inductors** and **Planar Transformers** provide reduced AC losses, improved heat dissipation, compact form factors, and high power density. These characteristics support efficient and reliable renewable energy conversion.

EV Charging Infrastructure

High-power EV charging stations require compact power electronics capable of delivering significant current while maintaining thermal stability. Standex Edge solutions—including **Common Mode Chokes**, **Planar Magnetics**, and **Custom High Current Filter Inductors**—help designers reduce electromagnetic interference (EMI), improve thermal performance, increase power density, and enhance system reliability.

Grid Monitoring and Protection

Accurate monitoring of current and voltage is essential for maintaining grid stability and protecting critical infrastructure. Standex Edge **Current Transformers** provide precise current sensing for protective relays, distribution monitoring, metering equipment, and utility automation systems. Their robust construction and reliable performance support accurate measurements across a wide range of operating conditions.

Industrial Power Conversion

Industrial automation systems, UPS units, and variable frequency drives require magnetic components that can operate continuously under demanding conditions. Standex Edge's **PQ32 Fixed Power Inductors** and **Custom Magnetic Assemblies** are designed to provide consistent inductance, long service life, reliable thermal performance, and compact integration into power electronics systems. Their robust construction and reliable performance support accurate measurements across a wide range of operating conditions.

Conclusion

As Smart Grid technologies continue to evolve, thermal management has become one of the most important considerations in magnetic component design. Higher current levels, increased switching frequencies, and more compact power conversion systems require magnetic components that deliver reliable electrical performance while minimizing heat generation.

Rather than relying solely on external cooling, engineers are increasingly adopting design approaches that reduce losses within the magnetic component itself. Optimized core materials, efficient winding configurations, and application-specific magnetic architectures help improve efficiency, maintain stable electrical performance, and extend equipment life.

Standex Edge supports this approach through a broad portfolio of custom magnetic solutions engineered for demanding Smart Grid applications. From High Current Filter Inductors and Planar Power Inductors to Current Transformers, Common Mode Chokes, and custom magnetic assemblies, each solution is designed to address the unique electrical and thermal requirements of modern power conversion systems.

By integrating magnetic expertise with application-specific engineering, Standex Edge helps OEMs develop power systems that operate more efficiently, remain thermally stable under continuous load, and deliver long-term reliability across renewable energy, battery storage, EV charging, industrial automation, and utility infrastructure.

As the demand for cleaner, smarter, and more resilient electrical grids continues to grow, advanced magnetic technologies will remain fundamental to improving power quality, increasing efficiency, and enabling the next generation of Smart Grid innovation.

A Standex **Electronics** Business

The new brand name for the Standex Electronics Magnetics division exemplifies the position occupied by Standex Magnetics engineers in relation to magnetic component innovation.

Standex Edge expertise spans transformers, inductors, current sensors, chokes and other advanced magnetic components used across multiple industries.

Combining decades of engineering innovation with global manufacturing capabilities, Standex Magnetics Engineers are leaders in component miniaturization, thermal management, robust design, and efficient production. They have firmly established their position at the **Edge** of innovation, where energy meets possibility.

Welcome to **Standex Edge**.

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