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Electrification in Pulp & Paper:

A System-Level Approach to **Thermal** and **Power** Architecture

Industry: Pulp & Paper

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Summary:

The pulp and paper industry is undergoing a structural transformation in how thermal energy is generated, controlled and managed. For decades, gas-fired systems have provided the heat required for drying and steam generation. Today, however, tightening emissions regulations, volatile fuel costs and the growing pressure to decarbonize are accelerating the shift toward electrification.

Yet electrification is not simply a substitution of fuel sources. As thermal demand scales into the multi-megawatt range, the challenge extends beyond heat generation into system design. It becomes a question of how thermal processes, electrical infrastructure, power control, and grid interaction are engineered as an integrated whole. Successful electrification therefore, requires a coordinated approach that aligns thermal and electrical engineering from the earliest stages of design.

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Transitioning from Gas to Electric: A System Redesign

The transition from combustion-based systems to electric heating represents a structural shift in plant operation. Traditional systems rely on centralized heat generation with relatively simple control architectures, whereas electrified systems distribute thermal generation across multiple electrically driven loads.

This shift introduces both opportunities and constraints. Electric heating enables precise and repeatable control at the point of use, improves process consistency, and eliminates on-site emissions. At the same time, it introduces new dependencies on electrical infrastructure, requiring careful consideration of load management, system integration, and power quality.

As a result, electrification should not be approached as a one-to-one replacement of burners with heaters. Instead, it must be treated as a redesign of the plant's thermal and electrical architecture, where performance, reliability, and cost are addressed simultaneously.

System Architecture: Integrating Thermal and Electrical Design

Electrified thermal systems are most effectively understood as a layered architecture in which different voltage levels and heating approaches serve complementary roles.

Low-voltage systems, typically operating up to 690V, are well suited for distributed heating applications such as process air systems and modular retrofits. Their primary advantage lies in flexibility, allowing heating to be deployed close to the point of use with high precision. However, as power demand increases, these systems require higher current, which in turn drives larger conductors, increased panel sizes, and more complex distribution design.

Medium-voltage systems, typically operating in the range of 4 to 15 kV depending on plant infrastructure, address these scaling challenges. By increasing voltage, they reduce current requirements and simplify power distribution, making them more suitable for large, centralized thermal loads. Rather than being defined by a fixed power threshold, medium-voltage systems enable scalable delivery of high-capacity thermal energy through more efficient electrical architecture.

In practice, most pulp and paper facilities benefit from a hybrid approach. Distributed low-voltage systems provide flexibility and control, while medium-voltage systems support high-capacity applications. Together, they form a coherent architecture that allows phased implementation, alignment with existing infrastructure, and optimization of both capital and operating costs.

Engineering Execution: From Concept to Operation

Electrification projects are inherently multi-disciplinary and require alignment between process requirements, electrical constraints, and long-term operational strategy. Early-stage engineering plays a critical role in defining system feasibility. Thermal modeling, airflow analysis, and electrical capacity assessments establish the foundation for system design and identify potential constraints before implementation begins.

This front-end engineering phase enables accurate system sizing and informs the development of control strategies. It also ensures that electrification solutions are grounded in real plant conditions rather than theoretical assumptions.

Execution then progresses through detailed design, manufacturing, and delivery. Clear definition of load profiles, process dynamics, and infrastructure constraints ensures that all stakeholders, including plant engineers, OEMs, and integrators, remain aligned. Commissioning is equally critical, particularly for high-capacity systems. Power delivery, control response, and thermal performance must be validated progressively under increasing load conditions to ensure stable operation in real-world environments.

Reliability by Design

In electrified systems, reliability is achieved through deliberate design choices rather than assumed as an outcome of installation. Robust system architecture, combined with advanced control systems and real-time diagnostics, ensures stable operation under varying conditions.

Redundancy in critical components, along with preventive maintenance strategies, supports high availability in continuous processes. When integrated with lifecycle support and monitoring, these systems maintain consistent performance while minimizing unplanned downtime.

Process Air Heating Within the System Architecture

Process air heating represents a key application within electrified pulp and paper operations, particularly in drying and air handling systems. In this context, low-voltage electric duct heaters provide a distributed solution that enables uniform heat transfer across large airflow volumes.

Because these systems operate at low voltage, they are particularly well-suited for retrofits and phased electrification strategies. They allow heating capacity to be added incrementally while maintaining compatibility with existing infrastructure. Their modular nature also supports efficient maintenance, with modern designs incorporating withdrawable heating elements that simplify inspection and replacement.

As system power requirements increase, however, the limitations of low-voltage distribution must be considered. Higher current levels drive complexity in electrical design, which is why these systems are often deployed alongside medium-voltage solutions in larger installations. In this way, process air heating becomes one component within a broader system architecture rather than a standalone solution.

Electric Duct Heater

Modular Duct Heater

Large-Scale Power Delivery and System Scaling

As thermal loads increase beyond the practical limits of low-voltage systems, medium-voltage heating becomes a key enabler of electrification.

By operating at higher voltage levels, these systems deliver large amounts of power with reduced current, simplifying plant electrical architecture and improving overall efficiency.

This approach is particularly effective for centralized heating applications

and high-capacity process requirements. It reduces the need for multiple transformers and extensive low-voltage distribution, enabling a more streamlined and scalable system design.

POWERSAFE™ Medium Voltage Electric Thermal Solution

Load Management and Power Control Strategy

EPower™ Controller with Predictive Load Management

In electrified systems, thermal demand and electrical demand are directly coupled. Managing this relationship is essential for maintaining system stability and controlling operating costs.

Predictive Load Management (PLM) integrates two primary functions: load balancing and load shedding. The core objective is to maintain a stable and balanced overall power profile while delivering the required thermal output.

Load balancing distributes power across multiple heating zones in a coordinated manner. Each zone operates with defined power levels and timing characteristics, and the control system synchronizes these loads to avoid overlapping peaks. Importantly, this approach does not reduce thermal output. Instead, it redistributes power over time, ensuring that total demand remains stable and eliminating fluctuations that can stress electrical infrastructure.

Load shedding complements this function by providing a mechanism to limit or shift demand when required. Through prioritized control and communication with plant systems, load can be adjusted dynamically in response to operational conditions or energy pricing signals.

Together, these strategies enable a high degree of control over electrical demand. By maintaining a balanced load profile, PLM minimizes peak demand, reduces flicker, and improves interaction with the grid. It also enables the use of synchronized full-cycle firing, eliminating the need for phase-angle control. This significantly improves power factor, reduces reactive power consumption, and enhances overall power quality.

In installations where total connected load approaches infrastructure limits, this capability becomes critical. By continuously managing and balancing demand, PLM prevents overload conditions and ensures stable operation without compromising production performance.

Electrification Pathways in Pulp and Paper

Thermal demand in pulp and paper operations spans a range of applications, including process air heating, surface heating, and steam generation. As a result, electrification strategies must consider multiple pathways rather than a single technology solution.

Direct electric heating is well-suited for distributed applications requiring precise control, while electrified steam generation offers a pathway for replacing combustion-based systems in larger processes. In many cases, hybrid configurations provide the most practical solution, combining electric and conventional technologies to balance performance, cost, and infrastructure constraints.

The optimal approach depends on plant-specific factors, including process requirements, existing infrastructure, energy pricing structures, and available grid capacity.

Infrastructure and Energy Considerations

Electrification introduces new system-level considerations that must be addressed early in the design process. Electrical connection capacity, demand charges, and utility interconnection requirements all influence the feasibility and cost of implementation.

While electric heating offers improved controllability and high point-of-use efficiency, total operating cost depends on how energy is sourced and managed. Effective load management, combined with an understanding of energy pricing structures, is essential to achieving economic viability.

Conclusion: Electrification as a System Transformation

Electrification in pulp and paper is not simply a change in energy source. It is a transformation in how thermal and electrical systems are designed, integrated, and operated.

When approached as a coordinated system, combining robust architecture, advanced control, and disciplined execution, electrification delivers reliable and scalable performance. It enables improved process control, optimized energy use, and long-term operational resilience.

In this context, electrification becomes more than a sustainability initiative. It becomes a structured and engineered pathway toward improved performance, efficiency, and competitiveness.

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11 - 59951 Issue -

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