

## MarSum Solutions: Smart Factories Need Smart Drives - Digitalized Power Electronics in Industry 4.0

Advanced manufacturing is becoming more connected, more automated, and more dependent on power electronics. Smart factories rely on motor drives, servo systems, robots, conveyors, compressors, pumps, thermal equipment, and motion-control platforms that must operate efficiently while feeding useful data back into the production system. In that environment, a drive is no longer just a box that changes motor speed. It is a power conversion device, a control node, a sensor platform, and a source of operational intelligence.

Digitalized power electronics connect variable speed drives, regenerative drives, servo amplifiers, DC/DC converters, sensors, and plant-level controls into a data-rich manufacturing architecture. The engineering goal is not simply to add connectivity. The goal is to improve uptime, reduce energy use, recover wasted energy, detect faults earlier, and optimize equipment behavior before production losses appear on the factory floor.

### Why Industry 4.0 needs smarter power conversion

Industry 4.0 programs often focus on software, analytics, robotics, and connected production data. Those capabilities matter, but the physical work of a factory is still done by motors, drives, heaters, converters, actuators, and power distribution equipment. If those systems are inefficient, poorly instrumented, or difficult to diagnose, the digital layer cannot deliver its full value.

Motor-driven systems are especially important because they appear everywhere in manufacturing: pumps, fans, compressors, conveyors, machine tools, robotics, mixers, material handling, and process equipment. Variable speed drives (VSDs), variable frequency drives (VFDs), and servo drives can reduce energy use by matching motor output to real demand instead of wasting energy through throttling, braking, or constant-speed operation. When those drives are digitalized, they also become sources of data for maintenance, energy management, process optimization, and lifecycle planning.

### What is inside a digitalized industrial drive system

A smart drive architecture can be described as a coordinated stack of power conversion, sensing, control, software, and plant integration functions. The exact implementation varies by machine and factory, but the major engineering blocks are consistent.

#### Power stage and motor interface

The inverter, rectifier, DC link, gate drive, current sensing, and motor connection determine efficiency, torque response, overload behavior, switching noise, and thermal stress. These fundamentals still define whether the drive can do the job reliably.

#### Control firmware and drive logic

Drive firmware manages speed control, torque control, braking, protection limits, fault response, safety functions, and communications. Digitalization increases the need for clean state machines, robust error handling, and validated control behavior.

#### Energy and regeneration path

Regenerative drives, active front ends, braking choppers, shared DC buses, and energy-storage interfaces determine whether deceleration energy is wasted as heat or recovered for reuse elsewhere in the plant.

#### Embedded sensing and diagnostics

Modern drives can monitor current, voltage, temperature, speed, torque estimate, vibration-related signatures, fault history, and operating hours. The useful output is not raw data volume, but reliable indicators of stress, degradation, and abnormal behavior.

#### Industrial communications

Ethernet-based networks, fieldbuses, edge gateways, and supervisory systems connect drives to programmable logic controllers (PLCs), supervisory control and data acquisition (SCADA), manufacturing execution systems (MES), and cloud analytics where appropriate.

#### Digital twin and simulation model

Physics-based and data-driven models can represent the drive, motor, load, and process behavior. They support virtual commissioning, control tuning, energy analysis, failure-mode exploration, and faster troubleshooting after the equipment is deployed.

## Predictive maintenance: from fault codes to useful warnings

Traditional drive maintenance is often reactive: a fault occurs, production stops, and the maintenance team begins troubleshooting. Digitalized drives can shift that workflow toward condition-based maintenance by using electrical, thermal, mechanical, and process data to identify developing problems before they become unplanned downtime.

A drive already sees information that is difficult to measure elsewhere. Motor current signatures, DC-link ripple, temperature trends, start-stop behavior, overload events, torque estimates, speed deviations, and fault history can all point toward mechanical wear, bearing issues, misalignment, blocked filters, process changes, insulation problems, or incorrect tuning. Additional sensors can improve visibility, but the drive itself is often the first practical edge-computing node in the system.

The engineering challenge is to turn drive data into trustworthy decisions. Predictive maintenance fails when it produces nuisance alarms, vague dashboards, or recommendations that maintenance teams cannot act on. Successful systems define which failures matter, which signals are reliable, how thresholds adapt to operating mode, and how alerts connect to maintenance work orders and spare-parts planning.

## Energy efficiency and regenerative operation

Smart drives reduce energy cost in two main ways: they avoid unnecessary motor power, and they recover energy that would otherwise be dissipated as heat. Variable speed operation is most valuable in applications with changing load demand, especially fans, pumps, compressors, conveyors, and material handling systems. When speed can be matched to process need, the system can reduce electrical losses, mechanical stress, acoustic noise, and thermal load.

Regenerative drives add another layer of value in machines with frequent braking or descending loads. Instead of burning braking energy in resistors, a regenerative front end can return energy to the plant bus or utility supply when the application and local power system allow it. Hoists, cranes, elevators, test stands, unwinders, centrifuges, robotics, and high-inertia machines can all benefit when the energy path, protection strategy, harmonic behavior, and utility rules are engineered correctly.

Energy savings are not automatic. A poorly selected drive can add losses, create harmonics, or complicate maintenance without improving the process. The best projects start by understanding duty cycle, load type, operating profile, motor efficiency, mechanical constraints, and production requirements. Power electronics must be sized and controlled for the real factory, not just the peak rating on a datasheet.

## Digital twins, simulation, and virtual commissioning

Digital twins are valuable when they connect engineering models to real operating behavior. For industrial drives, that can include motor models, load models, converter loss models, thermal models, control logic, and networked-machine behavior. Simulation helps engineering teams answer questions before hardware is installed: How much braking energy is available? Where are the thermal bottlenecks? Which drive settings reduce current ripple? How will the machine behave during a jam, restart, or line-speed change?

Virtual commissioning can also reduce risk in complex factories. Drive logic, PLC sequences, safety states, alarms, and recovery modes can be tested against a simulated machine or process model before commissioning begins on the shop floor. This is especially useful for high-cost manufacturing operations where lost production time is expensive and where equipment must be integrated with robotics, inspection systems, conveyors, and plant-level scheduling tools.

## High-value industrial use cases

Digitalized drives matter most where downtime, energy use, and process variation are expensive. These applications are common in advanced manufacturing, high-throughput production, and highly automated facilities.

**Automotive manufacturing:** Robotics, conveyors, paint lines, presses, weld cells, test stands, and material handling systems depend on coordinated motion and high availability. Smart drives can support energy monitoring, predictive maintenance, faster fault isolation, and reuse of braking energy from high-inertia equipment.

**Semiconductor fabrication:** Fabs rely on pumps, fans, chillers, vacuum systems, material handling, precision motion, and environmental control. Drive data can help protect uptime, maintain process stability, reduce energy waste, and detect degradation in equipment that supports sensitive production steps.

**Robotics and machine automation:** Servo drives and motion controllers define speed, repeatability, torque response, and safety behavior. Digitalized drives can expose motor loading, thermal margin, cycle trends, tuning drift, and axis-level diagnostics that improve machine availability and quality.

**Process industries and utilities:** Pumps, compressors, blowers, mixers, extruders, and rotating equipment often operate across variable demand profiles. Smart VFDs can support energy optimization, remote monitoring, soft-start behavior, power quality management, and maintenance planning.

## Markets where smart-drive upgrades matter

Interest in digitalized drives is rising because energy cost, labor constraints, uptime expectations, and sustainability targets are all moving in the same direction. Recent market analysis points to strong confidence in drive digitalization, including a reported finding that 99 percent of companies building motors into their equipment expect digitalized drives to improve operational efficiency. The same analysis estimates potential global electricity savings of roughly 164 TWh from digitalizing industrial drives.

**United States:** Advanced manufacturing, automotive investment, semiconductor capacity, food and beverage, chemicals, logistics, and data-driven maintenance programs all create demand for smarter drive systems. Energy savings are important, but uptime and serviceability often drive the business case.

**Western Europe:** High energy prices, strong efficiency expectations, industrial decarbonization programs, and mature automation ecosystems make European factories strong candidates for connected drives, regenerative energy recovery, and lifecycle-oriented maintenance strategies.

**Japan and advanced Asian markets:** Highly automated production, robotics, precision manufacturing, and aging workforce pressures increase the value of diagnostic-rich power electronics. Smart drives can help preserve productivity while improving energy and maintenance visibility.

## Integration challenges that determine project success

The hardest smart-drive problems usually appear at the interfaces between machines, drives, plant networks, analytics tools, maintenance processes, and safety requirements. A digitalized drive project succeeds when the power electronics, data architecture, and operational workflow are engineered together.

### Data quality and signal meaning

Drive data must be interpreted in context. Current, torque estimate, temperature, and vibration-related signatures depend on load, speed, process state, tuning, and equipment age.

### Power quality and EM/EMC

Large drive populations can create harmonics, conducted emissions, common-mode currents, and grounding challenges. Filters, cables, shielding, grounding, and front-end topology matter.

### Legacy equipment integration

Retrofits must account for mixed drives, motors, controls, documentation gaps, obsolete interfaces, spare-part limits, and short downtime windows.

### Controls and plant coordination

Drive settings, PLC logic, safety states, process recipes, and line-level coordination must align across operating modes.

### Cybersecurity and access control

Connected drives expand the factory control surface. Remote access, firmware updates, credentials, segmentation, logging, and recovery procedures must be engineered intentionally.

### Validation and maintainability

Smart drive systems should be tested for normal operation, faults, sensor failures, network loss, energy recovery, alarms, and recovery modes.

## How MarSum supports digitalized industrial drive programs

MarSum Solutions supports industrial power electronics, motor-drive, controls, and system-integration programs with an engineering-first approach focused on performance, robustness, and manufacturability. Smart-drive projects sit at the intersection of power conversion, motor control, sensing, software, EMI/EMC, thermal design, and factory integration, which is where early engineering decisions have the largest effect on project risk.

Our work can include drive architecture review, VFD and servo-drive support, regenerative front-end assessment, motor-control tuning, power quality and EMI/EMC mitigation planning, thermal and reliability assessment, data and diagnostics strategy, digital twin support, and validation planning. We also help teams translate broad goals such as predictive maintenance, energy savings, uptime improvement, and smart-factory integration into testable engineering criteria.

For manufacturers, equipment suppliers, and automation teams modernizing industrial power electronics, digitalized drives should be treated as a core system architecture decision rather than a connectivity add-on. A disciplined system-level approach can reduce commissioning risk, improve reliability, and support a faster path from drive data to real operational value.

## Engagement models

We support customer teams through focused technical consulting, design reviews, modeling and controls support, and deeper co-development efforts depending on program phase. Typical engagements range from early feasibility and requirements definition to prototype validation, field-debug support, retrofit planning, and production-readiness support for industrial drive and smart-factory power systems.

**Selected sources:** IoT Analytics Digitalization of Industrial Drives report summary; ABB, Siemens, Danfoss, and Rockwell Automation smart-drive and VSD application materials.

**Contact us today to scope your smart-drive, predictive maintenance, regenerative drive, or Industry 4.0 power electronics project!**