Achieving Industry 4.0:

Four Critical Features for Machine Automation

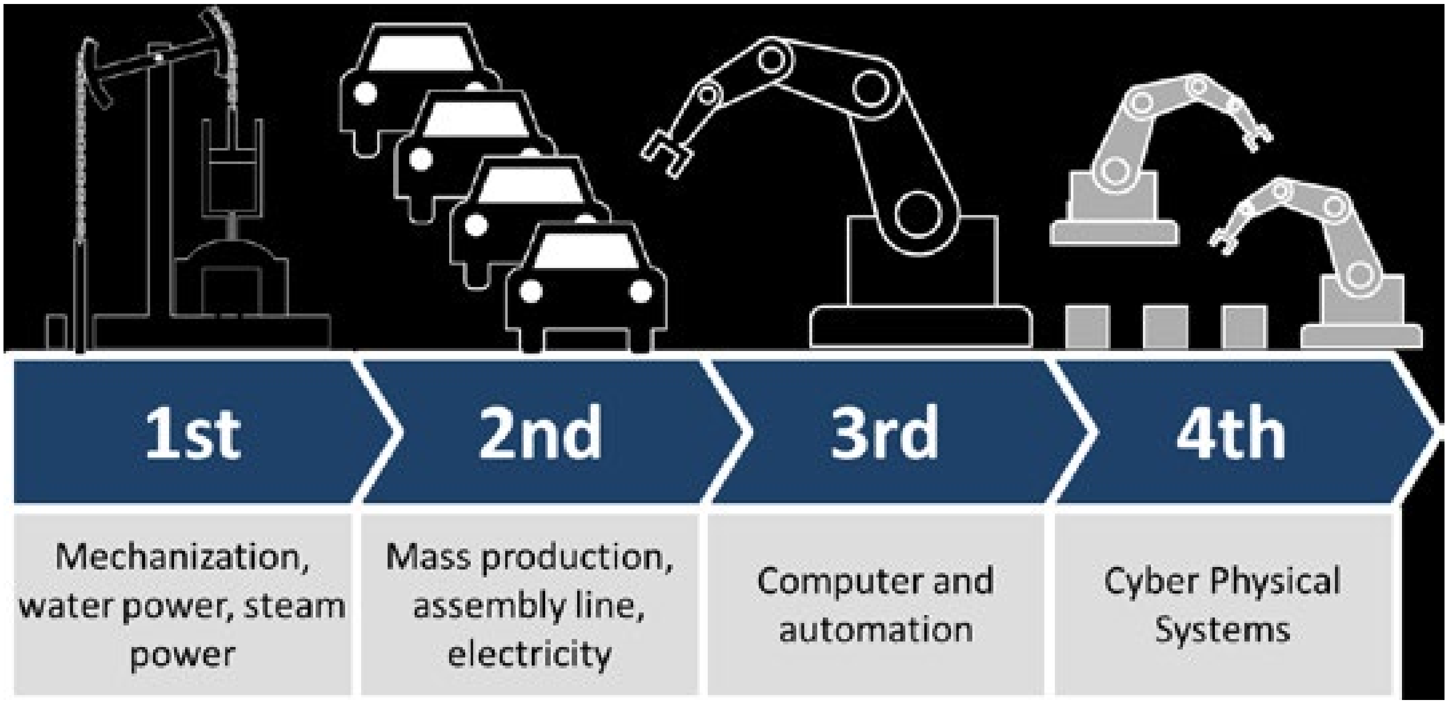
WHITE PAPER

KINGSTAR

Executive Summary

Industry 4.0 is reshaping manufacturing in the same way that Amazon transformed retailing. The initiative seeks to drive manufacturers and machine builders to integrate all machine automation and machine controller information. By doing so, machine builders can discover new information-based products and identify opportunities to build smarter factories capable of automatically taking corrective or optimizing actions.

To capitalize on the Industry 4.0 trend, machine builders must implement four feature sets which enable the integration of different levels of the manufacturing environment, from sensors to cloud servers. But perhaps an even bigger challenge for machine builders is the transition from traditional hardware-based controller architectures to a smart machine automation software architecture capable of executing on any industrial PC (IPC). Only a software-based machine automation approach can deliver the integration and flexibility demanded by Industry 4.0.



The Importance of Industry 4.0

Amazon transformed retailing and Google dominated advertising by applying a tightly integrated digital strategy to a traditional industry. The Industry 4.0 concept applies the same framework, seeking to disrupt manufacturing by implementing similar digital strategies as Amazon and Google in the manufacturing setting. Machine builders and manufacturers that embrace Industry 4.0 techniques and implement them in their factories stand to dominate their respective vertical markets, while those that don't will be rendered uncompetitive.

Initiated by the German government, the Industry 4.0 movement is focused on creating smart manufacturing facilities by digitalizing the value chains. This will have a profound and long-term impact on manufacturing businesses worldwide. In fact, most recognize that the 4th revolution in manufacturing has already begun. This is the classic diagram that documents the Industry 4.0 context.

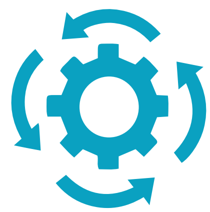
Industry 4.0 creates new product opportunities for machine builder companies in multiple ways:

TRANSFORMING THEIR PRODUCTS INTO SOFTWARE-AS-A-SERVICE

OFFERING UNPRECEDENTED CUSTOMIZABILITY AND VALUE FOR THEIR CUSTOMERS

CREATING NEW REVENUE STREAMS

GAINING NEW INSIGHTS TO STREAMLINE THEIR BUSINESS PRACTICES



IMPROVING OVERALL EFFICIENCY

Alongside cloud computing, smart machine controllers and intelligent edge devices are the cornerstones to building smart factories. Today, according to Forbes research, while only one third of manufacturers describe the degree of digitalization in their value chain as high, more than 80% expect to have digitized their value chain within five years.

Moreover, between 2017 and 2023, the **consulting firm PwC projects** that the manufacturing and engineering industries will invest roughly $31 billion per year in Internet of Things (IoT) and Industrial Internet of Things technologies (IIoT). Notably, the global IoT/IIoT market is expected to grow from $157B in 2016 to $457B by 2020.

Frequently overlooked in Industry 4.0 forecasts, however, is the role that the smart machine controller will play. The focus tends to be on cloud computing technology that executes predictive analytics and artificial intelligence (AI) to identify actionable insights that can be fed back to the machine controller. But there is more to the Industry 4.0 architecture than just connecting to the cloud. Gartner Group **predicts** that while in 2018 only 10 percent of enterprise-generated data in an IoT/Industry 4.0 deployment is processed by the machine-controller edge device, by 2025 that figure will reach 75 percent.

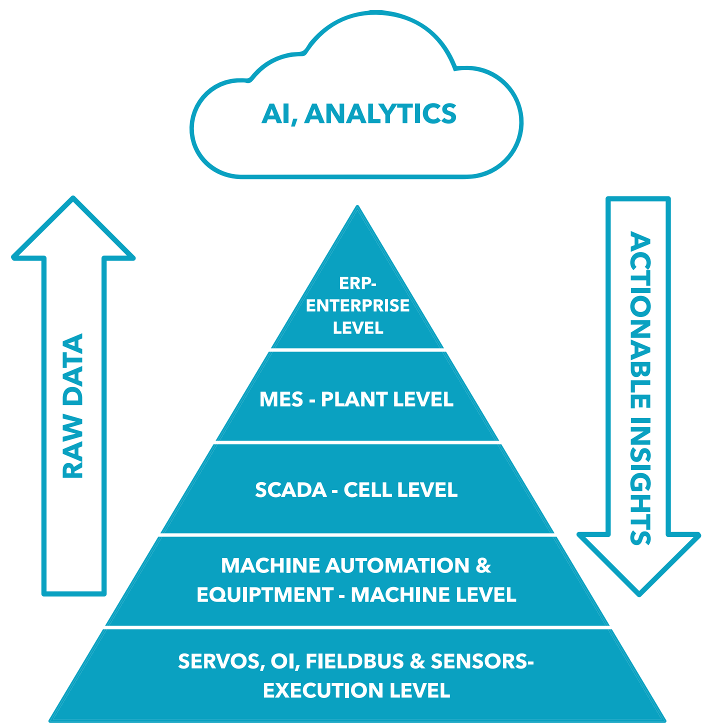
The Role of a Machine Controller in Industry 4.0 Architecture

The main goal of Industry 4.0 is to collect and share all automation information generated by every manufacturing component and machine so, collectively, the manufacturing ecosystem or factory performs optimally. Real success is achieved by analyzing this information to discover actionable insights that come in the form of corrective action or operational streamlining, which can be continuously implemented in a smart factory setting to become more competitive. This is no small task because data must be aggregated, analyzed and re-distributed to all the levels of processing between the sensor and the server.

To meet this objective, Industry 4.0 seeks to integrate and digitize the following six levels of execution and information processing within a corporate manufacturing and supply chain setting:

1. **CLOUD** (artificial intelligence generates actionable insights and product opportunities)
2. **ENTERPRISE LEVEL** (ERP servers)
3. **PLANT LEVEL** (manufacturing execution systems or MES)
4. **CELL LEVEL** (SCADA)
5. **MACHINE LEVEL** (machine automation, machine controller)
6. **ENDPOINT LEVEL** (sensors, motors, drives, IO)

The resulting ecosystem of roundtrip communication for Industry 4.0 is characterized by the following diagram:



The success of an Industry 4.0 deployment depends on a seamless, secure connection and integration with all enterprise information as depicted above. The most success will come when the data is first collected, consolidated and aggregated from the sensors at the machine level and then passed up via SCADA to MES, then to the ERP, and ultimately to the cloud where artificial intelligence can be applied. But that is not all.

With all the focus of Industry 4.0 on generating actionable insights via cloud connectivity and artificial intelligence, there is one very important notion that is often overlooked:

Actionable insights are useless if they are not acted upon.

If the factories and the machines are not "smart" enough to incorporate and act on the insights quickly enough, then the full potential of Industry 4.0 will never be achieved.

Further, as demonstrated by the previous Gartner citation, the often-overlooked but equally-important component of Industry 4.0 is a "smart" machine controller. The machine controller is just as critical and possibly more critical than the cloud functionality. It is the source of the real architectural breakthrough where information collection, aggregation and secure delivery to the cloud begins and ends – in short, where the actionable insights get implemented.

Gartner also believes that endpoint analysis will become extremely sophisticated and predictive over time to improve system-wide responsiveness. If the machine controller is not "smart" enough to adapt to changing manufacturing conditions based on actionable insights or insights that the controller can generate itself, then the Industry 4.0 vision will not be achieved.

The 4 Key Requirements that Industry 4.0 Demands from Machine Automation

A smart machine controller must have a diverse set of features and capabilities to ensure that the machine can play its vital role in a smart factory pyramid. These features fall into four crucial categories:

1. World-Class Machine Automation

The foundation of an Industry 4.0-enabled machine controller must deliver the best possible machine automation performance and determinism available to the manufacturing industry. It must also achieve these results while embracing the most accepted open standards to protect engineering investments, and it should be flexible enough to adapt to changing requirements for the future.

Given its networking demands and digitization focus, Industry 4.0 demands a standard, widely accepted digital field bus. While there are many proprietary digital fieldbus solutions and some high performing,

"open" digital fieldbus standards, **EtherCAT stands alone as the most widely accepted standard for digital fieldbuses.** Quite simply, it is the safest and best choice for an Industry 4.0 implementation.

In terms of performance and determinism, the closest competing fieldbuses to EtherCAT include PROFINET and Sercos. Both generate solid value but at a premium price. Worse, only a dozen servo drive manufacturers have embraced either standard whereas hundreds of servo drive manufacturers have embraced EtherCAT. Having more choice drives the standard forward and lowers prices. A standard is proportionally more effective as the percentage of the vendors in the market embrace it. Hands down, EtherCAT has the best adoption in the market.

There are other standards that are vital too, like PLCopen IEC 61131 standard for PLC work. Ideally, the machine automation platform supports 3rd party components and the ecosystem can expand. For instance, real-time vision processing directly on the controller reduces machine setup time and increases machine throughput. This requires a robust, time-tested real-time operating system (RTOS) as the underpinning of the machine automation software. The number of third-party vendors that port their solution to a platform attests to its credibility. Third parties would be reluctant to port their solution to a machine automation platform unless they felt it was a trustworthy and revenue-generating effort.

2. System-Wide Machine Controller Integration

Industry 4.0 is also reshaping the architecture of machine control. Previously, each machine builder provided a controller for their own machine and the machines performed tasks as islands of automation. Industry 4.0 not only demands that machines and machine controllers connect to the cloud, but that they also connect to other machines and to sensors that monitor the machines and the environment. All this connectivity opens the door for remote monitoring, remote management and even remote deployment. By combining these elements, a new manufacturing paradigm is driving the creation of smarter factories capable of mass customization and more. (Mass customization is effectively a batch of 1 or even the ability to make different products on the same assembly line.)

To illustrate the value of the multi machine controller integrations that are required for Industry 4.0 deployments, here are two examples.

Many companies are already using collaborative robots (co-bots) to load and unload parts to a CNC machine. Co-bots dramatically reduce integration costs so even small manufacturing sites can take advantage, as demonstrated by **this article about Lowercase Inc. and Axis Integration.** But as the job gets more complex, PLC or software-based state-machines are required to serve as the traffic cop for process flows between multiple robots, part feeders, vision systems, collision avoidance and other operations. The Co-bot scripting can be complex and often needs to be hidden. And upstream to the CNC, there are typically CAD / CAM systems that feed the CNC, and all the load and unload mechanisms need to be adjusted to accommodate different part shapes and sizes.

Even with integration-reducing solutions like co-bots, there are so many machine controllers and moving parts in a machining cell that need to be integrated to achieve the Industry 4.0 vision. Machine builders and factory owners must ensure that the machines and machine controller development platforms that they choose can integrate easily with all the controllers in the system. The integration requirements demand that the platform used to integrate all the controllers is powerful, open and standard enough to stitch all the controllers together into a holistic system. Ideally, all controllers would run on a single PC to simplify integration, but at the very least, machine builders must embrace integration standards like VDMA for robot control integration and PLCopen to enable faster integration and more seamless execution.

Why should the platform be open and powerful? The development tools used to integrate the controllers must offer the functionality that matches a given task. If the task demands ladder logic, then PLC languages might be most appropriate. If a controller component requires an object orientation, then C++ would be most appropriate. For building the HMI to optimize the user experience, then maybe .Net or a 3rd party GUI development application like LabView would be appropriate. Conversely, it may not make sense to force a machine developer to use C++ to do ladder logic if that machine developer feels most comfortable with PLC logic. The point is that the optimal integration environment for building Industry 4.0-enabled machine control must support a wide variety of development languages to better match the requirements of the demands of the machine being built.

We must also look to the future, where smart factories will seek to deliver on the vision of mass customization (a batch of 1). For example, once upon a time, an auto company would build a factory for building 2-door cars and a factory for building 4-door cars. At Jeep today, 8 different models of Jeep – both 2-door and 4-door models – can be built on the same assembly line. Using Industry 4.0 concepts, Jeep depends on the cloud and a group of robots that can download the operating instructions to perform a weld on a 2-door car and then receive instructions to weld a 4-door car next. This takes tremendous integration and coordination but can be achieved like a concert, conductor and all the musicians playing from the same song book, all the robots executing from the same score that is delivered depending on model type.

This will not immediately lead to a lights-out factory. It is conceivable, however, because all the connectivity enables remote monitoring, remote management, and importantly, remote deployment. Engineers that design work flows for machined parts will soon be able to develop in the cloud and then deploy remotely.

3. Information Sharing and Intelligence Consuming

It is vital for Industry 4.0 deployments that machines and controllers can be easily networked together. This requires adding support for standard communications protocols like OPC-UA, MQTT, TSN, Modbus and more.

In the Industry 4.0 model, the smart edge machine control will often do some pre-processing to aggregate and roll up data before sending to the cloud. Machine control is capable of dynamically changing the workload flow or parameters of the flow based on actionable insights but being dynamic is hard. The system must be very flexible to accommodate input and an open, smart, software-based architecture is the only approach that can deliver that flexibility.

Hardware-based controllers and PLCs are a fixed form factor and are not able to run 3rd party analytics on data that is collected; data must be passed to a PC. Only a software-based control software can optimize the information sharing and intelligence consuming process. The machine automation software that runs on a PC must be flexible enough to ensure that the RTOS can be assigned to certain CPU cores and that other 3rd party software can be assigned to other cores on a single PC, yet support direct access to share memory. This way, both the control system and 3rd party can communicate directly and can operate on the same data. This is known as affinity masking and is far superior to virtualization techniques. Virtualization doesn't allow for direct share memory access but rather depends on buffering or mailboxing, which adds unneeded latency. Of course, latency reduces performance and quality.

Additionally, PC-based environment communication protocols come for free with the software. Hardware-based controllers often demand additional IO cards to accommodate various protocol connections at a charge, which is unnecessary.

Finally, connected systems increase the vulnerabilities for cyberattacks, so safeguarding the data and the machine control is paramount. Systems must have world-class security to protect against such threats. Using PC-based machine automation software that runs on Windows is now a safer bet because Microsoft has invested heavily to ensure that the OS and Azure infrastructure is super secure.

4. Smart Edge IoT Enablement

Edge computing is a method of optimizing cloud-based computing systems by performing data processing at the edge of the network, near the source of the data. Intelligent edge IoT machine controllers are an emerging example of how individual devices can be customized to function within a user's environment. Collecting controller, sensor, IO, and drive data, executing locally predictive analytics, and 3rd party AI processing makes the whole system more responsive.

Additionally, often a machine controller will benefit from having 3rd party commercial software packages (e.g. business intelligence, AI, remote management or deployment release control) execute on the same platform. No machine control vendor can offer every functionality, so augmenting tools are always valuable. For example, Microsoft offers Azure IoT Edge that puts AI on the edge device.

Further, building machine controllers, machines and a system of machines is time consuming, complicated, risky and expensive. Today, increased computing power and connectivity are making it possible to virtualize this "building" task by quickly creating and maintaining a digital representation, or "digital twin", of any real machine control, equipment or plant. The digital twin technologies become increasingly valuable as the system gets commensurately more complex. Before a machine or a system of machines is physically built or the first part is even machined, engineers will be able to leverage software-based visual simulation to understand whether the machine or part design is optimal. For instance, bottlenecks or collisions can be identified so the system can be redesigned to address flaws before the first system is physically built.

Of course, all the components must work in concert via a tight integration, so choosing the right software or technology to integrate and build an industry 4.0-enabling smart machine controller is critical to success.

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In Summary: Industry 4.0 Requirements for Machine Automation

When reviewing the four feature sets needed to achieve Industry 4.0, it's clear that the only viable approach to deliver the flexibility required to integrate a system of controllers is one based on software.

In other words, Industry 4.0 can only reach its full potential when the system-wide integration of all the machine control is integrated, so choosing the right software tools or technology that can stitch the system of machine controls together seamlessly is the key to success. To summarize the four sections above, the features critical to that end include:

- **World-class machine automation technology**
- **The most open development and deployment environment that can enable cooperative processing with the cloud**
- **Machine automation technology that can generate insights with AI at the edge**
- **The ability to dynamically adapt and execute actionable insights**
- **The option to benefit from 3rd party applications that are co-resident on the controller**

While there are many subtle features in a machine automation development solution that can determine the ultimate success of an Industry 4.0 initiative, the machine builder, factory owner and machine controller designer should not lose sight of the fact that they are not selecting a widget that goes into a machine or factory. Instead, they are investing in a relationship with a partner who supplies the smart machine automation software that will last a decade or more.

Mission-Critical Feature that Predicts Success: Machine Automation Software for Industry 4.0

There is a common thread that makes it possible for a single machine controller to stitch all four requirements into a cohesive fabric of execution: that the controller must be built with software and deployed on an industrial PC (IPC). But not just any software. Machine builders will require standards-based, smart machine automation software that runs on an industrial PC and can concurrently run both the control system and 3rd party software that supports Industry 4.0 initiatives.

By contrast, proprietary hardware controllers (like name-brand PLCs or PACs or motion cards) are nice because of the fixed format and ease of use. However, they are completely inflexible for implementing Industry 4.0 initiatives. Hardware-based solutions quickly become islands of automation when a fabric of networked machines is required. These products can't run third-party analytics applications or communication applications. In fact, with hardware solutions, customers often need to pay more for additional i/o or communications cards just to plug into the network.

Worse, hardware-based controllers are just that: hardware. The future is digitization of the machine so that the machine can adapt, take corrective action, or act dynamically on new insights while in production. Only software-based controllers can deliver that kind of flexibility.

Remember, Industry 4.0 is really the digitization of the machine itself, which captures all the information about the machine and then shares that digitized data for analysis, improvement, corrective action and new products. Software is the only way to achieve this. But not all machine automation software is the same either.

Most software-based controllers limit the number of other controllers or 3rd party applications that can run concurrently on a single IPC. Also, most focus on supporting one language interface like PLC-languages or C++ or .Net, but not all three, without the ability to use the language that is purpose-built for the task at hand. Finally, many software-based solutions are not truly open because you can only purchase the industrial PC from the vendor that sells you the control software. Conversely, many software-based machine automation vendors do not let you run their software on competing PCs.

The bottom line is that only PC-based, standards-based machine automation software for Industry 4.0, which is based on a general-purpose operating system (GPOS) like Microsoft Windows and enhanced with a real-time operating system (RTOS) on that same IPC, can become the optimal platform for delivering on the promise of Industry 4.0.

A truly open machine automation software solution should be able to run on any industrial PC whose hardware is architected for industrial automation, with minimal system management interrupts. This type of machine automation software can:

- **Handle all the core motion control and determinism that machine automation demands**
- **Address the specific integration and communication tasks associated with Industry 4.0**
- **Rely on Microsoft for many critical features like security and AI**
- **Respond to actionable insights that return from the cloud**
- **Scale and support 3rd party packages that other software-based machine control technologies can't**
- **Serve as a smart edge device that is flexible enough to protect against unanticipated feature demands due to the minimal constraints of open, PC-based software**

One example of such a solution in the market today is **KINGSTAR** which is a standards-based industrial machine automation software solution for Industry 4.0.

The Key to Success: Embrace Digitization

Although international governments are embracing Industry 4.0, offering industrial policy and creating incentives, most manufacturers are adopting Industry 4.0 because they can see that it is changing manufacturing forever in the same way Amazon changed retailing.

The key to success is to embrace digitization throughout the entire manufacturing value chain. The cloud is important, but the cornerstone of Industry 4.0 is transforming the proprietary machine controller into a smart machine control platform that can create a smart factory enabled by Industry 4.0. To achieve this goal, machine builders must rethink their machine control architectures, eliminate hardware-based islands of automation machine control systems, and embrace IPC-based, standards-based machine automation software for Industry 4.0. Smart, open software is the only foundation that can support all the features required to build the optimal platform for delivering on Industry 4.0's incredible promise.