Understanding Smart Machines: How They Will Shape the Future

By Dr. Rainer Beudert, Leif Juergensen and Jochen Weiland

Executive summary

Powered by smart machines, the new industrial revolution is changing how machine builders design and manufacturers operate today and in the future. To remain competitive and profitable, plants and machines will have to be smarter – better connected, more efficient, more flexible and safe. This paper explains the impact of smart machines on the industrial automation and controls business and provides guidance for adapting to a changing industrial landscape.

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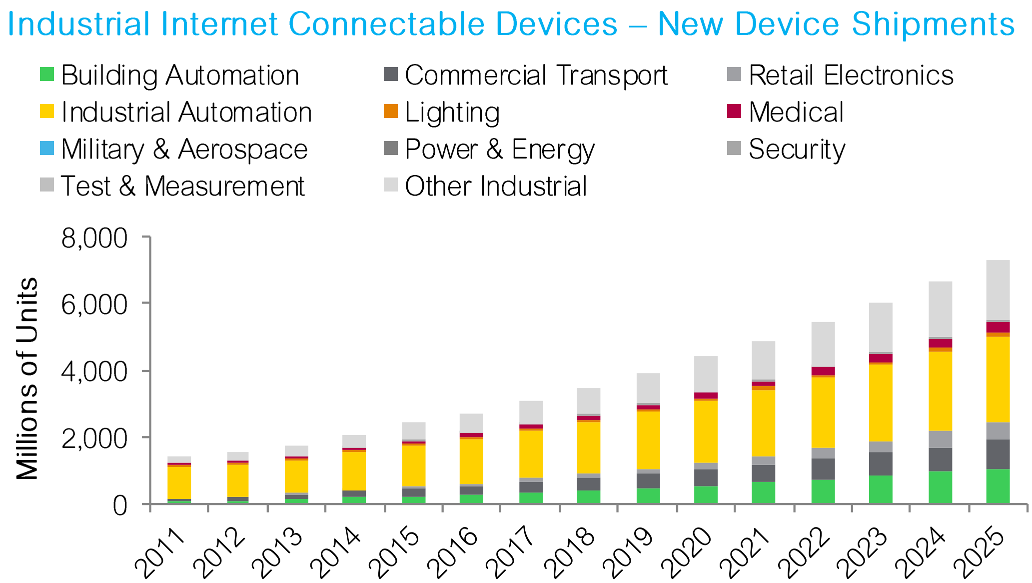
Introduction

Two trends that are creating a lot of buzz today are about to unleash a profound change throughout global industry: Industry 4.0, the German based approach for smart manufacturing, and the Industrial Internet of Things (IIoT) with a focus on connected devices and analytics. These trends and the underlying technologies that support them are impacting a broad range of industrial sectors – everything from building automation, transportation, medical, military, security and retail. In this whitepaper, however, the focus is on how industrial automation and machinery will be impacted.

There are some obvious similarities and differences between IIoT and smart manufacturing (Industry 4.0), as well as areas of convergence. Smart manufacturing or Industry 4.0 initiatives are focused on manufacturing flexibility, increasing automation levels, and digitization. This is not so much the next industrial revolution but an evolution. In the long run this will reshape complete factories and the way they operate. Such evolution requires embracing a multitude of technologies and ideas which will have a massive impact on end-users and OEMs. This will take some time and IIoT, with all its connected devices, will act as a key enabler.

Figure 1 illustrates the projected growth of connected devices within the industrial automation domain (along with other sectors).



Source: HIS © 2014 IHS

Figure 1
Industrial devices connectingto the internet

Implications of IIoT

The IIoT vision of the world is one where smart connected assets (the things) with varying levels of intelligent functionality, ranging from simple sensing and actuating, to control, optimisation and full autonomous operation, operate as part of a larger system. These systems are based on open and standard Internet and cloud technologies that enable secure access to devices and information in order to leverage big data and analytics and mobility technologies to drive greater business value.

Additional guidance

For more information on the related topic of IIoT, go to the Schneider Electric white paper entitled "The Industrial Internet of Things: An Evolution to a Smart Connected Enterprise".

Original Equipment Manufacturers (OEMs) and end-users can leverage IIoT to better monitor and control machinery. Within industrial environments, some devices today are connected, but many are not. IIoT applications will include not only machine-to-machine (M2M) communication but also machine-to-people, people-to-machine, machine-to-objects, and people-to-objects communication. These connections enable the ability to collect data from a broad range of devices and applications. This "big data" can then be accessed via the cloud and analyzed using sophisticated analytics tools.

Some of the elements that encompass this new world of IIoT have actually been around for quite some time. Communications, for example is not new to the industry. Fieldbus communication, for instance, has been around for decades. This is why IIoT should be viewed as more of an evolution rather than a revolution. However, new elements like the cloud, cyber security, big data, and pervasive sensing are only just now reaching levels of maturity that enable widespread adoption. The challenge is how to implement all of these disparate yet connected elements into an industrial environment.

IIoT initiatives are also converging with some of the new smart manufacturing (Industry 4.0) momentum that is influencing stakeholders. The basis for both of these market trends is to enhance networked resources so that distributed intelligence can lead to improved visibility and management of production.

In order to benefit from the potential that now exists for the development of new levels of operational intelligence, industries will need to migrate, over time, to a plant infrastructure that enables the exploitation of these new capabilities. This is where the next generation of machines – the "smart machines" – enters into the picture.

Smart machines

Manufacturing floor machines will evolve their level of intelligence in order to accommodate more predictive planning and more flexible business needs. The term "smart machine" implies a machine that is better connected, more flexible, more efficient and safe. It can quickly respond to new demands. Based upon a collection of smart, connected products, it maximizes efficiency through intuitive collaboration with its users. A smart machine is also capable of participating in predictive maintenance practices while minimizing its own environmental footprint and total cost of ownership.

Smart machine development is influenced by three principal drivers: technology, consumer market trends, and end-user demands.

Technology

On the technology side both innovation and lower costs are making new generations of equipment accessible to industrial sites in need of migration. Below is a list of some highlights:

- Ethernet connectivity – Enables integration of networks and improved data access; provides the basis for service-based models and management of security
- Wireless (e.g. RFID) – Allows for rapid, automatic data entry
- Mobile technologies – Allows for safer, more remote operation of equipment
- Increasing CPU power – More throughput is now enabled at lower cost
- Multiple Ethernet ports on automation devices – Enable enhanced connectivity
- Memory cost decreases – Allows for advanced data management and better decision support
- Digitization – Allows for low cost development of machine automation simulation programs

- Reduction of component footprint and heat dissipation – Allows for higher power densities per square foot
- Ability to connect a wider range of actuators and sensors (smart sensors) – Enables the gathering of more accurate data from which to base operational decisions
- Augmented reality and biometric recognition – Improve both machine-operator interaction and security

Consumer market trends

The release of new technology increases the expectation of machine operators and system users, and also alters training approaches for both new and veteran employees.

- With internet use common place in many people's lives, the expectation of workers to have access to production information in real-time continues to increase
- More mobility is increasing the use of mobile and wearable devices to gain access to information at any location
- Machine operators expect devices (and machinery) to be "plug-and-play" (e.g. as easy to use as an iPhone, television, USB stick, or Bluetooth devices)
- An interactive web mentality is promoting an expectation that smart machines and distributed control centers collaborate much in the same way that people do on social networks

End-user demands

End-user demands for ultimate flexibility will drive the manner in which IIoT applications are designed. In order to accommodate these demands, the following requirements will need to be built into any smart machine design.

- Machines will need to be built to accommodate orders on a mass scale. The ability to manufacture customized products that can be quickly released to the marketplace is also a key consideration. The manufacturing line will need to be flexible enough to allow modification in real-time.
- High availability of production and reduction of manufacturing costs
- Traceability and transparency of products, goods and information
- Improved asset utilization by intelligent planning
- Lower total cost of ownership of assets
- Real-time data management including improved supply chain management
- Easy integration of new technology; ensuring compatibility for retrofit and upgrade installations
- Improvement of product quality and reduction of environmental impact (energy and resources)
- Immediate accessibility to information (50% of maintenance spend today is focused on searching for information)
- Assurance of security and safety in order to protect user and machine

Tight control of production costs and the improvement of overall production line performance will also require machinery that is more functional, flexible, connected and efficient.

Ethernet-based networking of components and resources are key elements of smart machines. Open standards will be a key enabler of adoption, allowing integration of systems, better visibility and an overall improved level of business control. The benefits will be an accelerated product time to market, reduced costs and downtime, better quality, lower energy consumption and increased customization.

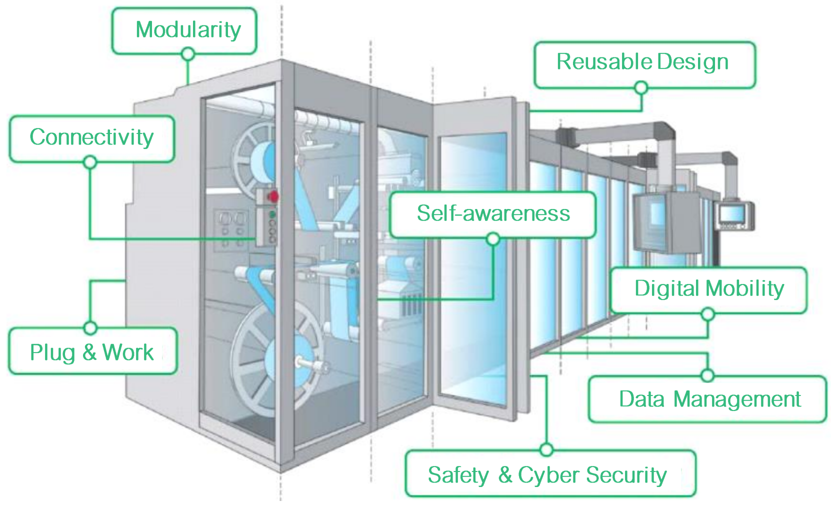


Figure 2
Aspects of smart machine technologies

Characteristics of smart machines

The four key characteristics of smart machines include the following:

Efficiency

- Self-awareness – With the use of sensors and the intrinsic knowledge regarding its own capabilities and features, a smart machine will be able to monitor its own key components as well as environmental conditions. Embedded intelligence will correlate upstream and downstream behavior and adapt its own parameters within given business rules. By providing relevant information to both operators, connected data consumers at the OEM, and the end-user, the smart machine enables manufacturing lines to produce in a more reliable, flexible and efficient manner. Such optimisation can be implemented with respect to energy, time, OEE, load shedding, quality or other parameters via upstream systems that provide set points based on analytics.

  This level of machine monitoring also enables preventative maintenance supported by the OEM, helping to avoid component failure and associated downtime or damage to the machine or components. It also allows for maintenance to be scheduled, in order to minimize the impact on production while increasing business opportunities for value added services.

  Machines at the forefront of development will increasingly use sensors, both wired and wireless, with embedded intelligence helping to distribute and automate decision making on the factory floor. As the cost of these technologies continues to decrease, more machines will integrate sensors, allowing better real-time visibility.

- Data Management – Smart machines must have the appropriate level of intelligence to assess data quickly and in a decentralized fashion. Routing all data to a central control for analysis will quickly lead to delays as it is a non-scalable structure. Sensors, components and machinery with the intelligence to only share data that falls outside of set parameters will lead to better overall data management. Improving the level of data shared with the broader network/community will accelerate decision making and reduce backlogs (where critical information could be delayed or missed altogether).

Storage of data is also an important consideration. To date, hardware has largely been used to store production data, but this method can be very time consuming and expensive to manage. The cloud is increasingly becoming a viable option to help better manage data in a more cost-effective manner.

Safety & Security

- **Safety & cyber security** – With security built into their fundamental designs, smart machines will improve the safety of operators and minimize the security risk of increased networking. Improvements in machine performance and lifetime cost reductions cannot be offset by reducing the safety or security of the machine or production line.

  In terms of safety, machine builders need to offer a broad range of flexible options. This will include dedicated safety components, such as laser scanners and safety cameras, together with automation components with embedded safety, such as safety PLCs and safety drives. The ability to utilize a mix of safety components and controllers, will allow machine builders to fit the solution to specific end-user application requirements, helping to improve overall performance and productivity.

  Today, data security is the leading inhibitor of end-user adoption of new networking technologies and work processes. The perceived risk of networking components and machinery in order to achieve production benefits is high.

  Particularly with IIoT and increasing levels of connectivity, security needs to be considered at numerous levels. Security provision needs to be multi-layer, incorporating hardware, software and services. Machine builders (and automation component vendors) need to assure that end-users are aware of security vulnerabilities, and can manage network infrastructure to minimize the risk of a breach.

  To help with education of end-users as to the benefits of smart machines, and how security can be maintained with increased I/P connectivity, use cases and success stories need to be highlighted.

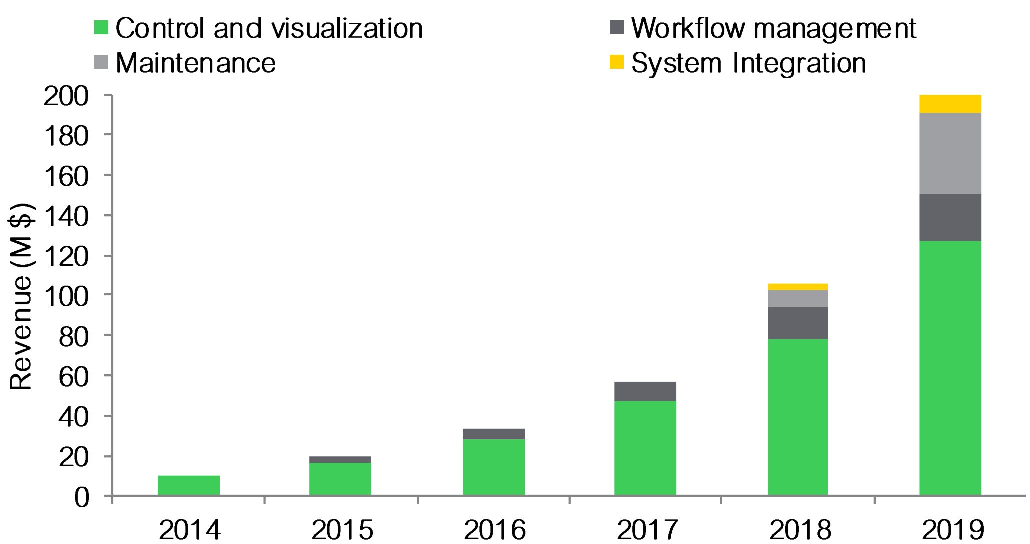
Flexibility

- **Plug & work** – Any new smart machines will need to be compatible with the existing installations or machinery from multiple OEMs; End-users want devices that can be installed within a short timeframe. Integration into the rest of the system must be easy.
- **Modularity** – The lifecycle of today's machines does not allow monolithic or single purpose design anymore. The fast development driven by time-to-market constraints force OEMs to shift towards Mechatronic Design and modularity. This trend also continues in the software and application part of modern machines. Smart machines will benefit from templates of proven design form simple software functions up to fully functional modules describing mechanics, electrical, motion and interfaces, features and behavior.
- **Reusable design** – Machine builders embrace concepts that are proven, reliable and validated. Modularity is one enabler where the paradigm to reuse software and hardware in a different context requires a new level of thinking. The concept of clear and strict interfaces with well defined behavior that can be tested comes from the IT world and finds its space in automation with some adaptation. This becomes another key smart machine differentiator.

Connectivity

- **Connectivity** – Smart machines will connect directly to the broader (Ethernet-based) network. This enables data sharing and production planning, which goes far beyond the capabilities of traditional standalone machinery and automation. Smart machines will bridge the information technology (IT) and operations technology (OT) gap, making available production data that can be used in numerous management settings (e.g., stock control, operator scheduling, maintenance, energy management, and product replacement). A basic requirement for this: standards to put values and parameters in a meaningful context and a common language.
- **Digital mobility** – Machine operators and factory floor engineers are embracing in ever greater numbers the concept of using mobile devices at work (see Figure 3). Personnel no longer need to be in close proximity to a machine in order to monitor or manage performance. These devices provide operators with the flexibility to move around while still accessing machinery data. Machine engineers can also diagnose problems and offer guidance remotely, which also speeds up implementation of a solution. This reduces downtime and losses from component failure.

Figure 3
Global market projections for industrial mobile applications (courtesy of IHS)



Communica-tions

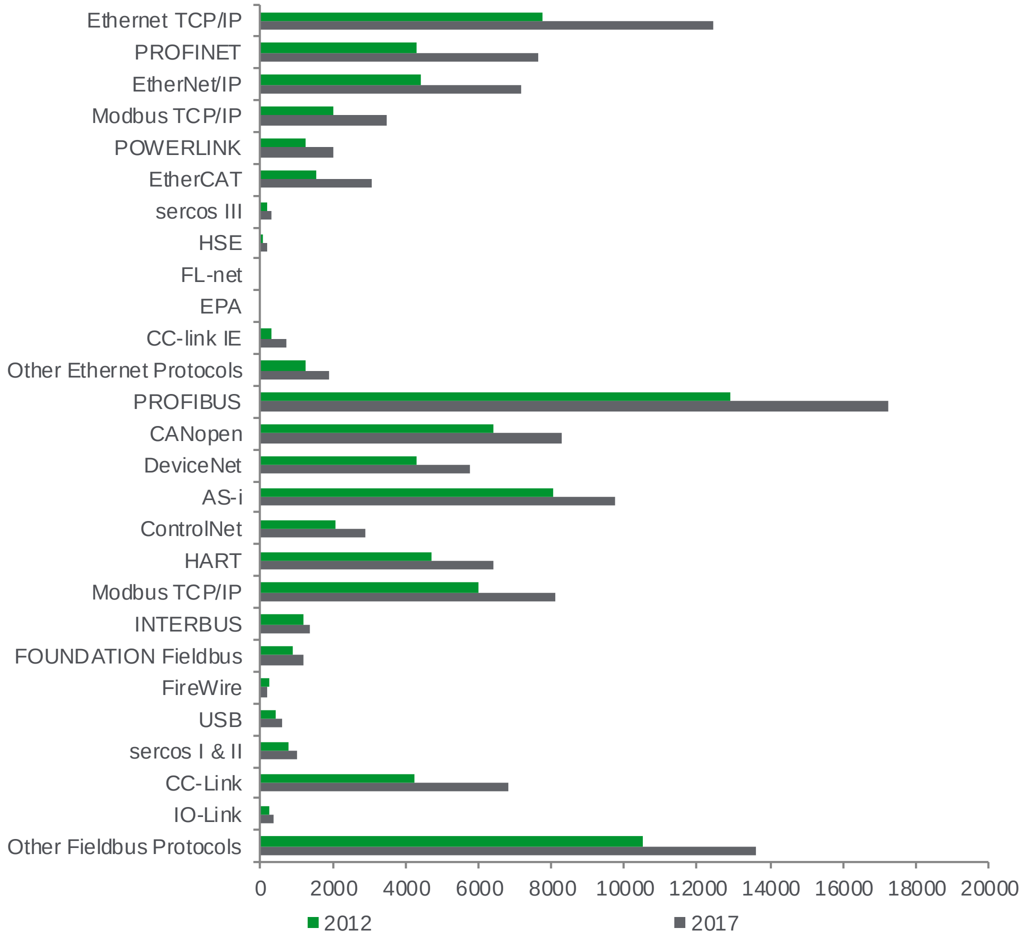
With smart manufacturing and IIoT a transition is now underway to replace fieldbus protocols with industrial Ethernet variants. The outlook suggests that adoption of industrial Ethernet will future-proof end-user facilities in terms of industrial communication. Continuing reliance on and adoption of fieldbus, without consideration for Ethernet-based alternatives, will likely hurt overall production in the long term.

Today, fieldbus protocols still account for about 66% of new node connections, with industrial Ethernet increasing its share by about 1% per year. The move to Ethernet-based networking is slow currently, but is likely to accelerate as smart manufacturing and IIoT benefits become more substantial and widely recognized.

Industrial Ethernet facilitates the integration of operational and office-based networks, which will form the basis for data sharing and smarter decision making. However, there will remain a wide variety of variants (see Figure 4), with a mix of application-aligned technologies and those with broader, multipurpose specifications. No single industrial Ethernet standard is expected to emerge in the near future but will certainly develop within the next 10-15 years.

Figure 4
Networking technology fragmentation

World Market for Industrial Ethernet & Fieldbus Technologies by Protocol 2012 to 2017 (Thousands of Nodes Connected)



Source: HIS

The transition from dedicated fieldbus to industrial Ethernet protocols and the emergence of smart manufacturing initiatives are reflected in the evolution of Open Platform Communications (OPC) towards OPC UA (Unified Architecture) as a harmonized data transportation and exchange layer. OPC consists of a series of standards and specifications that act as a transport medium between a variety of established industrial communication protocols. It ensures that the correct data is received and transmitted within a set time period, thereby assuring that critical production information is easily accessible.

This increased connectivity, however, brings along with it some new security concerns. End-users need assurance that the risks associated with networking machinery do not outweigh the benefits. Training and education is required before making changes to an existing manufacturing line or when formulating the design of a new line. Here OEMs need to adopt early as this domain requires skills and technologies that are mostly new to their engineering teams. Cyber-Security is also a learning curve for the technology providers. Products that simplify the life of OEM and end-user will become differentiators and show a significant opportunity for the automation market.

Continuing development (and networking) of smart machines will need to coincide with management of large data volumes and identification of key pieces of data versus those that are less critical. As these networks grow, the key issue will become what to communicate and not just how to communicate.

Standards and standardisation

Perhaps one of the biggest barriers to the adoption of IIoT, smart manufacturing and smart machines is the creation of suitable standards. This is not a simple question of communication protocols. New standards need to encompass creation of standard semantics that will allow smart devices to connect and "talk" to each other without the need for custom programming (as is the case today). These smart devices will also need to "discover" each other and interact.

The development of open standards will provide structure and guidance to OEMs and to end-users, helping them to implement new working processes and to leverage the benefits of IIoT. These standards will need to focus the overall integration of systems and uniformity across the factory floor.

End-users often drive the establishment of local standards. They want to make sure that the hardware and software they have invested in will deliver on their security, safety, and performance expectations. Industrial automation component suppliers, OEMs and associations must collaborate to outline and establish standards that provide end-users with the confidence they need with a more global scope.

Associations that work closely with leading automation companies, such as ODVA, MESA, OMAC or PLCOpen which support open standardization with the aim to facilitate interoperability and information sharing in the industrial ecosystem.

Similarly, associations like the Smart Manufacturing Leadership Coalition aim to create standards that will enable end-users to merge systems. Rather than maintaining, managing and gathering information from numerous independent systems, the ultimate goal is to work with leading companies to create an open smart manufacturing platform.

Integration trend

Convergence of networks and systems will depend on communication protocols that are compatible with one another. If the compatibility is lacking, data will remain isolated and sharing (in real-time) with key stakeholders to aid in strategic decision making will become impossible. The integration of IT and OT networks and systems is critical to achieving the benefits of smart manufacturing – e.g., reduced downtime, lower energy consumption, operator safety, preventative maintenance and manufacturing flexibility.

Therefore, beyond the factory floor end-users (and OEMs) need to consider how smart machines integrate into the wider organization and supply chain, in order to fully reap the benefits of smart manufacturing. Those on the factory floor will be most concerned with uptime, safety and security. Those in the office environment will be most concerned with data analysis and cyber security. Establishing personnel roles for each aspect of the overall system (e.g. data security) is also likely to prove difficult.

Integration is occurring at a number of levels as technology enables devices to be more functional and capable of a wider spectrum of applications. Examples include control products – e.g. PLCs and drives – that integrate safety functionality and wireless field devices that incorporate processing power. Beyond hardware integration, higher-level system and software integration is now the next step in merging factory floor operations with the enterprise and wider supply chain.

To achieve this level of integration, considerable obstacles need to be overcome, particularly from a safety and security perspective. New fields of activities will emerge for system integrators and consultants on software defined networks (SDN) and software defined automation (SDA) as these technologies are quite new and build a new domain of knowledge and expertise.

Software role

The significance of software as an enabler has increased in recent years and this trend will continue. In some cases, software will be replacing hardware in the smart machine environment. It also forms a link between disparate systems, enabling interoperability, and helps to link logical and physical worlds.

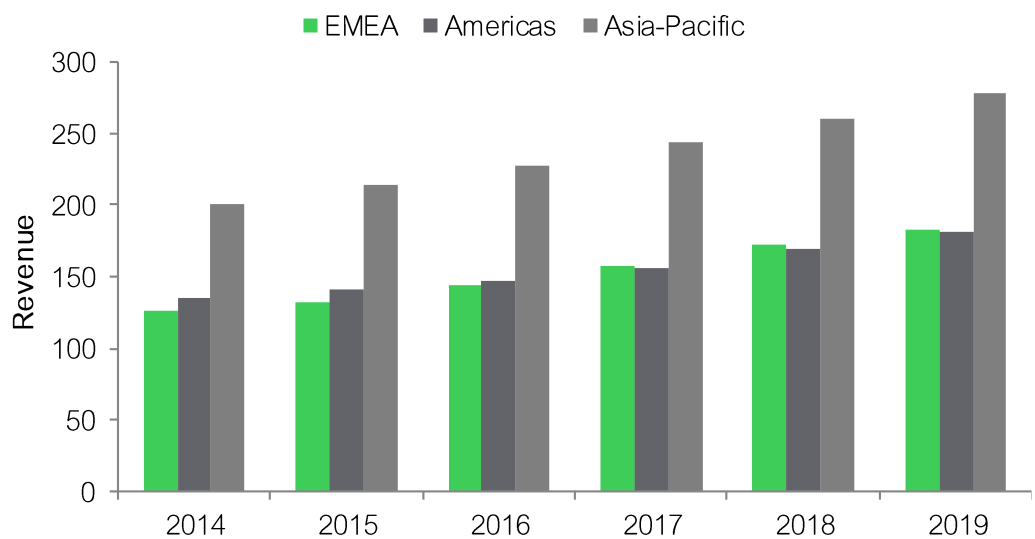


Figure 5
Digitization of industrial control system design and simulation (courtesy of IHS)

Digitization of control system design is an interesting example of the positive impact of software. Simulation/prototyping software is capable of creating a virtual model. This makes it is easier to capture numerous control system requirements, which speeds up the implementation of a design project. This is especially true for the programming phase. In these cases, inaccurate specifications can waste many hours of precious (and costly) time. Such software simulation tools also allow operators to familiarise themselves with a new system before it is installed. This enhances both efficiency and safety. Figure 5 illustrates projected growth of software driven simulation tools across geographies.

From a machine builder perspective, the focus is often on practical solutions and simplification of design for mechatronic and control systems. An example of digitization in this capacity is the ability to simulate the automation program without any hardware, which is a substantial advantage.

As CPU power and differentiation on I/O and even sensors become more difficult for OEMs, smart functions will differentiate machines by added values based on software and application. As a consequence, OEMs are encouraged to develop new business models to monetize on new services and features that enable smart integration, data availability, advanced analytics or a wide range of other future options all based on software.

Migration to the cloud

In the enterprise environment use of the cloud for storing and accessing data is relatively commonplace. The factory environment is more reluctant to adapt this technology. However, IIoT will drive cloud usage in the coming years.

With increasing amounts of production data being gathered and automation devices and machinery being networked, the demand on hardware to store, manage and analyse data will grow exponentially. The cloud storage and platforms now becoming available to end-users are secure and reliable, providing a cost-effective method for accessing, storing and integrating data so that it becomes actionable information. Benefits to end-users include reduced hardware costs, utilization of external experts for data management and secure access to production data to aid decision making. For machine builders, this, again, represents a new field of expertise. How to present information from a machine to analytics systems in a machine readable way will be key for integrating shop floor equipment into an IT infrastructure. OEMs that master this will maintain a competitive advantage in the coming years.

In addition to the key challenges of Ethernet-based device networking and the conservative nature of the industrial automation sector, overcoming the concern of security will be pivotal. Educating and training engineers on the benefits of cloud adoption and helping to manage the process of network migration and modernization represent key success factors.

Partnerships are being formed between automation component suppliers and cloud specialists in order to leverage the expertise of both. Large machine builders and end-users are sharing industry application knowledge and technology expertise. The idea is to maximize benefits of cloud adoption while minimizing risks.

Conclusion

Traditional machines were characterized by high-cost and limited communication technology. New smart machines are using established communication protocols, IIoT devices, and the cloud, to enable life cycle cost reductions, machine performance improvements, and new ways to interact with blue – and white-collar workers.

The new IIoT technologies and practices are evolving over time. Before a large-scale transition to smart machinery occurs, affected workers will require education and executives will require a clear demonstration of payback if they are to invest in improvements. The new technologies will need to prove themselves over time in an industrial environment, and inhibitors such as security concerns will need to be overcome.

Machine builders that want to maintain or improve their market position will make use of control systems that capitalize on the potential of using distributed intelligence in machines. Leveraging new technologies to improve performance and efficiency, while reducing downtime and energy consumption, will allow both machine builders and end-users to differentiate themselves from the competition. Those who fail to take any new action will be left behind in a transitioning market place.

In addition, the development of new services to support IIoT and smart machine processes and systems represents a significant opportunity for machine builders, especially in the areas of predictive maintenance and remote access.

Partnerships with specialists in communications, IT, OT and software, will emerge as a critical success factor for end-users and machine builders.

Now it’s up to standardization groups and the automation suppliers to pave the way for OEMs into the new evolving world. This will enable a smooth transition into a smart production and manufacturing environment, one that is based on Industry 4.0.

About the authors

Dr. Rainer Beudert joined Schneider Electric in 2007 as Director of ELAU global internal and customer training. He's currently the Marketing Director for the system and network Machine Solutions activity in Schneider Electric's Industry business unit. Prior to joining Schneider Electric, he worked for 10 years at INAT in Nuremberg, Germany where he was responsible for training and services. He consulted on the topic of Industrial Ethernet networks for companies like Arcelormittal, Audi and BMW. He received a Dr. Rer. Nat. degree in Physical Chemistry from the University of Würzburg.

Leif Juergensen is the Director, Customer Projects Program for the OEM Segment within Schneider Electric's Industry business unit. He previously held several positions within the Machine Solutions organisation, where he was responsible for software and sales strategy. He has over 20 years of experience in machine automation and innovation. Prior to joining Schneider Electric in 2001, he worked for Klockner Moeller GmbH as automation key account manager. He received a Dipl.-Ing. degree in Automation, Electrical Engineering from the Fachhochschule Karlsruhe University of Applied Science.

Jochen Weiland is the Vice President of customer support for Machine Solutions activity in Schneider Electric's Industry business unit. He rejoined Schneider Electric in 1998 and has more than 15 years of experience in industrial communications, software development and automation solutions. He holds degrees in Automation, Electrical Engineering and Business Administration from Hochschule Darmstadt University of Applied Science.