At the core of Industry 4.0 is the flexibility to rapidly align with changing markets. The ability to change will be driven by edge-based architectures that optimize both operations and the operations technology infrastructure.

Edge-Based Automation as the Foundation of Industry 4.0 Agility and Resilience

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Introduction to Edge in Industry 4.0

Existing Factory Automation Holds Industry 4.0 Back

In its simplest form, Industry 4.0 relies upon using data and automation across entire factories, not just individual assets or processes. Specifically, the focus of this paper is how edge computing enables a fundamental change in automation by manufacturing companies looking to Industry 4.0 to transform their operations.

The core of most manufacturing operations is process automation. For the past 40 years, automation has been mostly isolated in individual processes, equipment, or production assets. Historically, this automation focused on throughput, quality, and productivity gains. However, most of the automation is inflexible and proprietary, limiting value opportunities and increasing the overall cost of automation.

This paper discusses a new automation strategy, based on converged edge computing, that is the linchpin for realizing the full value potential of Industry 4.0 through adaptive, flexible automation.

Using Edge to Free Automation from Silos

Most discussion about Industry 4.0 is about connecting data silos to share and make data more visible. It's not what Industry 4.0 is but what it does — that is, the significant benefits derived from connecting data silos and making data more visible. The true heart of Industry 4.0 is about being able to reconfigure operations and automation in an agile manner in near real time. A flexible and connected plant can deliver the following:

- **Pervasive access to data** — across all operations for local and real-time analytics and processing
- **Provide rapid reconfiguration** — outside of existing hardware-defined systems with software-defined automation (SDA) to allow agile process reconfiguration without disruption to existing control systems

**AT A GLANCE**

**KEY TAKEAWAY**

Edge-based virtualization is what lays the foundation for the flexibility and resiliency that Industry 4.0 requires.
» Scale and optimize — using edge computing and hybrid cloud to create a distributed software environment that enables businesses to scale and optimize their compute, storage, data, and analytics needs to match production and use case requirements

» Innovate and modify — providing a secure, open, and adaptive automation environment that enables engineering and operations to continually adapt and deliver new process improvements

Figure 1 shows that manufacturing companies are prioritizing technology that enables transformation to Industry 4.0.

**FIGURE 1: Priorities in Investment for Edge for Industry 4.0**

**Q. Are you currently using or planning to use edge computing in your operations?**

<table>
<thead>
<tr>
<th>(% of respondents)</th>
<th>2016</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>No, we are not currently using edge computing and have no current plans for edge computing in the next two years</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>No, we are not currently using edge computing, but we will be conducting one or more pilots in the next two years</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Yes, we are currently piloting edge computing, and we plan to move to production in the next two years</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Yes, we are currently using edge computing in production</td>
<td>40</td>
<td>60</td>
</tr>
</tbody>
</table>

*Source: IDC’s IT/OT Convergence Survey, June 2018*

Digital transformation requires changes in how operations and production processes are performed and automated. Processes need to be based on a foundational architecture that enables the transition from existing individual controllers (often aligned statically and directly with specific processes or equipment) to a platform that is more agile and open. Agile automation requires an edge-based architecture that puts distributed intelligence closer to the data sources and where the insights need to be consumed. It also must allow full orchestration from a central function for dynamic configuration. This edge-based architecture contains several critical capabilities that legacy automation configurations can’t support, including:

» Ensures usable and trustworthy data is ingested and available for analytics and reference

» Distributes logic and analytics across multiple edge devices simultaneously to enable dynamic allocation and control, creating resilience through redundancy and fail-safe backup
» Automatically optimizes compute or workloads across the entire system of edge devices

» Automates advanced decision making on production issues using local analytics

» Provides more resilient decision making by distributing insights to the right roles at the right time using artificial intelligence (AI)–based algorithms

» Automates data communications to optimize use and retention locally or in the cloud

This edge-based intelligence and processing architecture benefits from an IT-like mindset regarding the disaggregated and therefore flexible relationship between hardware and software. “IT-like” means realigning from rigid controller-based solutions where hardware and software are inseparable to containerized and virtualized workloads where logic and control can be executed on any capable and available device. The main change to OT is the separation of the device-specific logic typically provided by the OT equipment manufacturers and the new automation potential provided by logic execution through virtualization of the edge. The advantages of convergence at the edge are as follows:

» IT hardware that supports direct connectivity to OT devices to extract data without disruption to existing control systems

» IT hardware that can be managed with the same datacenter management tools (i.e., compute, storage, and networking) and hybrid cloud tools used to manage datacenter workloads to reduce the need for local IT skills

» Unified security environment between IT and OT (IT can now operate securely and seamlessly at the industrial edge.)

» The flexibility to manage control systems as intelligent networked devices (Each device and asset is now a manageable device on the network, improving auditability and making it easier to provision and deploy new or retrofitted assets.)

With more companies converging IT/OT functions to gain greater alignment and efficiencies and drive innovation, leveraging best practices from both IT and OT is critical. Adopting IT such as virtualization and containerization is necessary to enable IT and OT convergence at scale. Leveraging edge-based local logic and control principles from OT to ensure real-time capabilities is also critical to the adoption of innovative new technologies within operations settings. Edge-based virtualization combines both to lay the foundation for the adaptability, flexibility, and resiliency required by Industry 4.0.

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**Software-Defined Automation at the Edge**

The fundamental architecture change that Industry 4.0 needs is based on software-defined automation — the same software-defined automation that has been transforming IT for years. This applies to virtualization of factory automation and operations. Virtualization has been used in IT datacenters in response to unprecedented rates of data growth to optimize capabilities and provide flexible operations of servers. This virtualization enabled the managed security, analytics-based workloads, automated workload adjustments, and agile computing required to handle data growth and provide the speed and resiliency that datacenters need. The same data growth and requirements are now pervasive in operations settings, particularly those undergoing Industry 4.0 initiatives. For companies in pursuit of Industry 4.0, software-defined edge computing will enable a distributed network of intelligent devices that, together, provide flexible data collection, aggregation, conditioning, logic execution, and actionable insights in a timely and scalable manner.

Unlike legacy control systems, SDA is not about every asset, device, and process having its own dedicated controller. Software-defined automation is about distributed intelligence and compute power at the edge that are capable of reconfiguring themselves by virtualizing the orchestration that happens between the control hardware, the logic software, and the process. Accomplishing this automation isn't defined by physically linking hardware and software together with heavily structured logic for specific physical assets. Instead, an edge-based environment promotes agility through:

» A secure and unified platform in which hardware has been decoupled from the software environment to provide maximum agility and resiliency

» A virtual automated operating system that reconfigures itself in near real time to adjust to changing operational requirements

» Intelligent edge computing devices that optimize logic execution, decision making, data management, and network traffic

» Central management tools that provide local and cloud-based hybrid orchestration of data and workloads for maximum agility and optimization

» A convergence in the skill sets of IT infrastructure staff and OT staff to mitigate talent risk associated with legacy automation skills
Figure 2 shows the high-level architecture in an edge-based SDA environment compared with a legacy environment.

FIGURE 2: The Software-Defined Automation Environment on the Edge

Legacy 1:1 Automation

Edge-Based Virtualized Automation

Each asset is controlled by dedicated hardware and logic is pre-programmed.

Assets are controlled by a network of edge devices with logic distributed across the network.

Source: IDC, 2020

For example, a traditional heavily automated factory is defined by the control hardware and architecture with the logic embedded in the controller hardware, such as a PLC using ladder logic to monitor and operate equipment. The PLC and its logic are hardwired together and are typically proprietary. An engineer must directly access the PLC to make changes to the logic. This process can be time consuming and costly, and the necessary skills are quickly disappearing from the workforce. PLCs can be networked together, but they are still managed as single entities.

In an SDA, independent controllers’ capabilities and resources can be pooled and virtualized across the entire network of edge devices for intelligent allocation and execution. Edge devices are not necessarily dedicated to specific equipment or processes. The control logic is capable of automatically reconfiguring itself to change logic and data workloads. This distributed execution of logic is the foundation of SDA. An edge-based and SDA-architected system helps ensure:

» Secure connectivity to the cloud (It also safeguards against data loss in the event of temporary interruption.)
» Resilient failure where a device failure causes immediate redistribution of logic and physical connections to other resources with no loss in operation

» Scalable compute capacity that supports distributed application containers, industry-standard device drivers, and data management applications

» A converged platform whereby an IT device supports physical I/O with analog-to-digital conversion for digitalization of analog signals to reduce the number of required devices and complexity

» Physical platform security, which is necessary for assets at the edge where personnel may be limited

The edge-based SDA environment can be managed in a parallel network environment, separated from "hands off" control systems and networks.

**Examples of Edge-Based and SDA-Operated Processes**

A good example of the deployment of this type of architecture is in material handling. In a traditional operation, material handling devices such as conveyors each have a dedicated controller that’s programmed to manage a specific conveyor. If the controller is to support any task other than the conveyor’s task, it must be defined and programmed up front. In an Industry 4.0 world, a conveyor could be controlled from any number of intelligent devices. If it’s a mobile conveyor, it most likely connected wirelessly and may even have an edge device on board. If it’s static, it can be controlled and orchestrated from any edge device on the distributed network.

Therefore, instead of a dedicated control device and static configuration, the edge-based SDA architecture allows the control logic for the asset to be distributed to any number of connected edge devices. The orchestration of the asset operation is developed on a unified development environment rather than for a single instance.

When the logic is sent to the device for execution, the edge device makes the final decision on how that logic is distributed.

Brief examples include the following:

» A CNC lathe’s logic senses a peer struggling to meet demand due to an unforeseen operating issue. The CNC responds by redirecting work to itself and makes the decision to call for a newly sharpened cutting tool to cope with the new demand with no human intervention.

» A line of annealing furnaces senses the imminent failure of another edge device bringing materials into or out of the furnace line. The furnace line’s device then redistributes the logic on the failing device to its own devices to support the compute power needed, ensuring the line does not stop unexpectedly.
A press operation notices on its own that data surges are causing network issues. The local edge devices decide to buffer collected data until local network issues are resolved.

As maintenance is performed on a machine tool, its local edge device reroutes its compute power to analyze production information and notifies engineering and production staff that a recent supply of defective cutting tools is causing chatter-related quality loss on products.

These examples show how the edge-based architecture with SDA provides automated decision making and the flexibility that defines Industry 4.0. Production and engineering staff don’t need to worry about which device is operating the logic or collecting the data. That is the value of virtualization through SDA.

**Benefits**

The following benefits are gained from edge-based SDA:

- Converging the needed IT and OT skills to support the operational infrastructure
- Highly flexible and configurable automation systems leading to agile operations
- Edge-controlled near-real-time analytics on production operations with no latency
- AI on the edge that can make real-time adjustments to production operations by redefining the automation systems
- Providing a secure, but controlled environment for innovation in the SDA environment, bringing IT-level security to OT systems

**Key Trends**

The following important trends are impacting the growth of edge-based SDA:

- IT tools being used in OT environments, enabling easier integration into SDA architecture
- Convergence of IT skills and the technical skills of operations staff
- Prevalence of edge devices implemented in operations
- Cloud, IoT, and analytics use in OT environments

**Considering HPE**

Hewlett Packard Enterprise is a global edge-to-cloud platform-as-a-service technology company that helps organizations accelerate smarter operations, make better business decisions, and ignite innovation. Together with the company’s analytics and industrial partners, HPE helps customers deploy solutions to acquire, secure, analyze, and act upon data-driven insights across industrial workflows.

Using a broad range of computing, networking, and storage solutions, HPE can help customers deliver a seamless experience from the edge to the datacenter. For edge computing, HPE Edgeline Converged Edge Systems, featuring Intel second-generation Xeon Scalable Processors, are built for rugged environments and designed for power-efficient operations.
HPE Edgeline brings datacenter-grade computing, storage, and near-real-time analytics to the factory floor, the refinery, the power grid, or a freighter. More importantly, customers can integrate operations and IT data into a single dashboard. This single-pane-of-glass view provides visibility across assets, processes, and sites to optimize operations, reduce maintenance costs, and improve worker productivity.

**Customer Use Cases**

HPE has helped customers deploy asset performance analytics in the oil and gas, energy distribution, and manufacturing sectors. The following examples are offered by the company:

» A process manufacturer reportedly uses persona-based condition monitoring and predictive maintenance to better track asset utilization and anticipate maintenance requirements to prevent equipment failures, increase productivity, and lower costs. Machine sensors collect real-time operational data and feed into customized, persona-based dashboards. Tuning the dashboard to specific roles enables workers to more efficiently gather job-specific insights to make decisions more quickly and improve operational effectiveness. Improvements realized, according to the company, include:

  - Improved return on assets by reducing spare equipment inventory
  - Reduced unplanned downtime by anticipating equipment failures and scheduling repairs during planned outages
  - Reduced worker safety incidents by automating data collection
  - Expected 20% reduction in downtime
  - Estimated 50% reduction in planned maintenance costs

» A distributor of electricity and natural gas is fully digitizing operations to monitor energy consumption, improve power quality, prevent outages, and more quickly respond to customers. The smart grid collects data from 221 million meter reads daily. The introduction of new value-added services has reportedly increased data volumes over 830% in five years. The utility is now able to leverage its smart grid data to prevent and detect outages more quickly to improve power restoration times. Results achieved, according to the company, include:

  - 10% improvement in customer satisfaction due to faster resolution of power outages and customer inquiries
  - Thousands fewer truck rolls annually since implementing smart meters and analytics

» A manufacturer of environmentally conscious, reusable food containers has deployed an industrial IoT solution to gain real-time insights from plant floor machine assets to improve throughput and quality. This growing company recently added state-of-the-art injection molders to meet growing customer demand and sought to connect both new and legacy molders to monitor asset performance and production processes. The reported results achieved include:

  - 50% reduction year-over-year in quality issues
  - 45% improvement in throughput
  - 45% increase in output
A European energy company and distributor of natural gas, with over 12,000km of natural gas pipeline, underground storage, and regasification terminals across Europe and Latin America, is seeking to achieve the following:

- Optimize the gas delivery pipeline with improved measurement processes
- Reduce operational and maintenance costs
- Enhance security, predict maintenance, and forecast demand

An IoT solution was deployed to deliver improvements to safety, security, and profitability, according to the company, through a combination of machine learning algorithms deployed on edge computing. The new data platform captures and analyzes up to 352 million measurements per hour across the company’s pipeline assets in near real time, allowing more accurate demand forecasts and the ability to predict maintenance issues before they occur. The platform supports real-time management and control and offers cloud-based flexibility to enable proactive and automated rollout of new master data management (MDM) software to ensure data accuracy and consistency.

**Challenges**

Manufacturers face the following challenges and will require assistance from HPE:

- Manage legacy assets and automation
- Develop skill sets in operations to support IT-like tools
- Create a multivendor environment for edge and SDA

**Conclusion**

IDC predicts that edge computing will become the dominant architecture type as the drive to Industry 4.0 continues to accelerate. An edge-based architecture operating an SDA capability is the only way to get the flexibility needed for true Industry 4.0 operation.

**About the Analyst**

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Kevin Prouty is Group Vice President for IDC Energy Insights and IDC Manufacturing Insights. He is responsible for managing a group of analysts that provide research-based advisory and consulting services that will enable energy executives in oil and gas and utilities to maximize the business value of their technology investments and minimize technology risk through accurate planning. Kevin’s research specialties are Utilities, Manufacturing, Enterprise Applications, and Product Innovation research.
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