SOFTWARE-DEFINED TRANSFORMATION OF INDUSTRIAL CONTROLLERS

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Industrial automation's evolution has been stifled by vendor lock-in, closed, hardware-centric architectures, and siloed organizational structures. The next generation of industrial control will be software-centric platforms that marry the flexibility of IT tools with the rugged, reliable characteristics of traditional automation solutions.

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Executive Overview

Industrial automation is entering a new phase of innovation as the integration of IT and OT tools and environments reshapes traditional industrial automation systems. Historically, industrial automation relied on rigid, vendor-specific hardware and software, limiting flexibility and innovation. However, the emergence of cloud computing, IoT, edge computing, and AI is driving a shift toward open, software-defined frameworks that prioritize interoperability. As industry moves toward this new paradigm, adopting a platform-based approach and fostering a multi-supplier ecosystem will be key to ensuring future-proof and competitive industrial control. While this transformation will take time, incremental adoption guided by industry experts with robust support and partner networks provides a strategic path toward modern, data-driven operations.

The first step along this path of evolution is the controller, one of the foundational building blocks of industrial operations. Historically, controllers have been some of the most closed and proprietary elements in automation architectures. Controllers were black boxes that did not integrate with others easily, used proprietary hardware and protocols that limited how and where they operated, and locked users into restrictive, single-vendor ecosystems. Automation leaders are now moving to open, software-defined controllers that decouple control software from proprietary hardware. This new approach enables solutions where controllers can run on a wide variety of standard platforms and communicate via standard protocols, while providing the flexibility and lifecycle management of modern software tools.

As new domains intersect with industrial spaces, technology users must evaluate if their current tools can adequately serve all functions of a digitally transformed organization.

A New Paradigm for Industrial Controls

Industrial automation refers broadly to the application of control devices, mechanical systems, and automation tools such as PLCs, DCS, and drives to perform repetitive manufacturing tasks with minimal human intervention. However, with the growing intersection of OT and IT technology, tools, and ideas, modern automation increasingly includes cloud integration, edge computing, IoT, cybersecurity systems, IT-level management, and other concepts that continue to transform the way the industrial world operates. In the context of this convergence between the historically disparate domains and the growing need for new frameworks to support advancing technology such as AI, end users must consider if their control strategies can support these diverse initiatives.

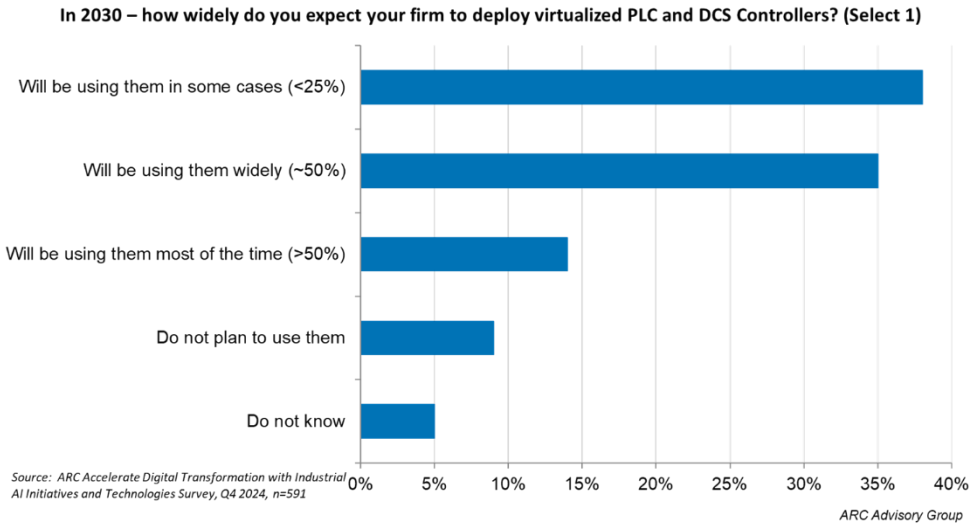
The Evolution of Industrial Control

Historically, industrial systems were singularly dedicated to performing specific tasks, with dedicated hardware and software that needed to be replaced completely should change be necessary. These outdated practices often create a dependency on specific vendors, making it challenging for end users to integrate new technologies or switch suppliers. This model leads to connectivity issues and bottlenecks, as these systems are typically designed to work within a closed ecosystem and may not be easily compatible with other devices or platforms. This lack of interoperability further complicates the process of updating industrial systems, as each update may require custom solutions or vendor-specific support, which can be both time-consuming and costly. As the rigidity of these systems continue to hinder innovation, frustrated end users demand something better.

Dr. Henning Löser, Senior Manager at Audi Production Lab, presenting Audi's new software-centric paradigm at the 2025 ARC Industry Leadership Forum.

The Value Proposition for Virtualization

Industry leaders have grown frustrated with the historic model of closed controllers that hinder integration of new technologies and require costly, vendor-specific upgrades. While the OT world has unique and stringent requirements that off-the-shelf IT technology cannot solve, there is an increasing demand for industrial control solutions that can be easily updated, scaled, and integrated like modern IT systems. Over decades, incremental steps such as standard networking protocol adoption, Industry 4.0, and soft PLCs have set the stage for today's transformation. Now, industry is embracing controllers that are essentially software applications, not fixed hardware devices.



Half of surveyed industry end users plan to extensively deploy virtualized control systems within the next five years.

Consolidating Hardware and Streamlining Software

A hallmark of the new generation of controllers is modularization of control applications. Instead of monolithic software running on dedicated hardware, control tasks can now be broken into modules or microservices. While this modularity would be lost on traditional systems with rigid and specialized operating systems, the software-defined controllers of today run on general-purpose operating systems like Linux that can execute many processes at once. A modern industrial PC or edge device can easily handle multiple controller runtime instances in parallel, along with other applications. In practice, this means one device can host multiple PLCs simultaneously, each as an isolated process or container. Implementing this approach across a

shop floor eliminates redundant hardware, which can represent a significant amount of cost savings.

This strategy of hardware consolidation using virtualization has several other important benefits. When computing resources are pooled together, the system can allocate computing resources where they are needed. If one control task isn't using many resources, another demanding task on the same hardware can load balance by utilizing the extra headroom. Furthermore, because each module or virtualized application is isolated, a fault in one part won't interfere with the execution in another. This isolation improves robustness and makes troubleshooting easier as engineers can restart or modify one container without disturbing others, something not possible with monolithic PLC software.

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In this new paradigm, controllers are hardware-agnostic and can run on any suitable computing platform, which greatly enhances the flexibility of their deployment. Organizations can source their industrial devices from their preferred suppliers, potentially reducing costs or avoiding supply chain bottlenecks from a specific vendor. They can also standardize on common computing hardware for many applications. Instead of stocking model-specific components, a few standard industrial PCs can serve as spares for any number of virtual workloads. If a hardware failure occurs, the control software can be quickly relocated onto a replacement device without needing the exact model on hand. This not only reduces the cost of initial deployment by reducing the need for specialty hardware, it also lowers the financial barrier for upgrades and reduces maintenance costs over the system's life.

Adopting Modern Software Development Principles

By turning controllers into software applications, technology users can unlock modern software development and operations practices for industrial automation. Developers can start up a sandbox virtual controller that mirrors the production controller for testing and development, then easily deploy the controller to the runtime environment, circumventing the typical user-involved process. Instead of relying on engineers doing time-consuming manual field work for patches and updates that often open up security vulnerabilities, automation platforms can distribute and apply updates to the

relevant field devices through standard workflows or orchestration techniques.

Adopting these modern development practices also means continuous improvement of control applications. Traditional automation workflows often followed a cumbersome model where projects would run for years with minimal changes. Now, it is feasible to iterate quickly and respond to changing needs as engineers can add features or improvements on a much faster timescale, and with lower risk of downtime.

Migrating to Linux-based Systems for Operational Consistency

Linux-based operating systems are attractive for the new generation of software-defined controllers due to Linux's stability, flexibility, and strong security track record. Linux is very compatible with containerization and modern development practices. Moving to a single, consistent operating system across a diverse hardware environment reduces system management complexity and the need for specialized training for various proprietary systems.

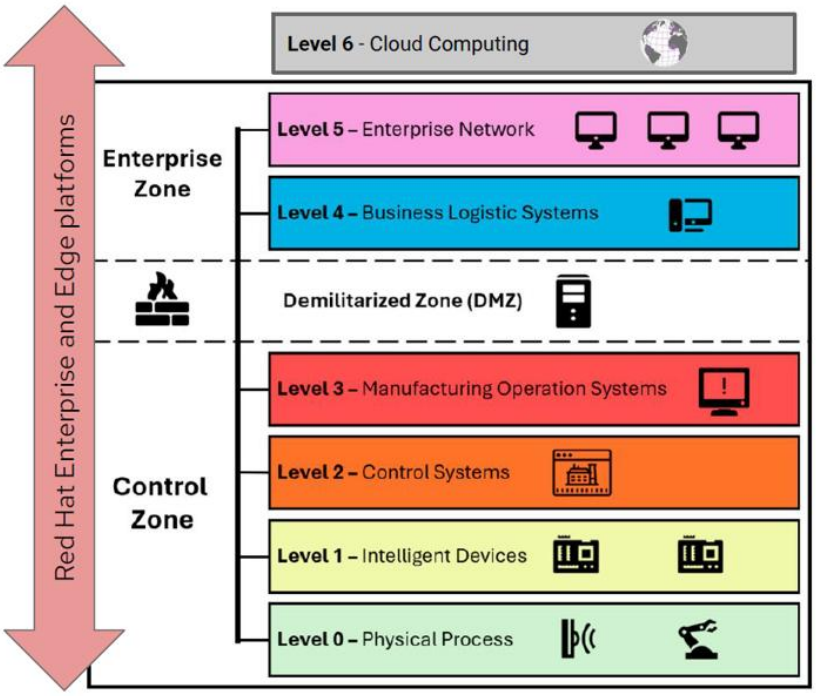
Movement to Linux-based systems is also critical for users with specific security or regulatory compliance needs. Linux allows users to meet highly specific security requirements and manage access to various databases with more granular control. Many hardware and software vendors in the industrial space now certify their development processes according to the stringent IEC 62443 standards, actively integrating these protections directly into the Linux operating system. This proactive approach enables comprehensive security for industrial systems across all operational boundaries, from the factory floor to the enterprise network.

A Unified Platform Strategy for Transforming Control

An open, unified platform approach is crucial for the software-defined transformation of industrial controllers because it provides a consistent foundation that scales from the smallest shopfloor device to the largest enterprise systems. This means the same architecture and standards can be applied at all levels, a unified technology ecosystem that can grow seamlessly as needs expand. Technology users can start with a solution on a

single machine or production line and confidently extend it across multiple lines or plants without reengineering the core platform. Because the platform is uniform, teams can use a common toolset and skill set for development and operations at every scale. When everyone is speaking the same technical language, organizations can scale up or down rapidly and dispense with the complicated and expensive rollouts of the past.

A platform approach comes with a supportive ecosystem of technologies and partners, ensuring that most industrial automation needs can be met without starting from scratch. Rather than being locked into one vendor's limited offerings, companies tap into a broad network of hardware and software providers that collaborate through open standards and protocols. It also provides strong portability, where workflows and control applications are not tied to specific hardware or locations. This flexibility to reallocate and reuse components on demand makes operations more resilient and agile.



Look to platforms that can support every layer of architecture from low-level devices performing PLC functions to cloud computing workloads.

While the software-defined transformation of industrial controllers promises significant advantages, end users and industry stakeholders are rightfully skeptical about the challenges and limitations that must be addressed for their successful implementation. A primary hurdle is the lack of worker expertise, as the shift from traditional hardware-centric automation to

software-defined paradigms requires new skill sets in areas like software development and cybersecurity. Perceptions of high investment cost due to enterprise-scale pricing can also deter adoption, with initial investments in new software, training, and infrastructure perceived as prohibitive, overshadowing the long-term cost savings and efficiency gains. Concerns over real-time and deterministic applications also present a significant challenge. Vendors must ensure that software-defined controllers can reliably meet the stringent timing and performance requirements of critical industrial processes.

Red Hat Platforms are a Validated Pathway to Next-Generation Control

For Red Hat's platforms to effectively serve industrial environments, it incorporates key capabilities that traditional IT-native tools do not provide. Robust self-healing attributes are essential to minimize downtime by automatically diagnosing and resolving system issues without human intervention, keeping production running smoothly. Additionally, deterministic control is crucial for applications with real-time constraints, ensuring predictable performance for time-sensitive industrial processes. To maintain seamless connectivity, the platform also provides network automation and comprehensive systems management, enabling manufacturers to configure their entire infrastructure from a central plane without needing to perform repetitive or hazardous manual tasks.

Red Hat's Device Edge Platform combines an enterprise-grade Linux OS, MicroShift, a lightweight application orchestration solution based on Kubernetes, and the Ansible Automation Platform, which streamlines IT automation and network management.

Legacy solutions from the IT realm have not found significant traction in OT spaces due to their lower suitability for mission-critical applications. In the industrial world, unpredictability and downtime can have significant ramifications for both production efficiency and safety. To solve this historic problem, Red Hat's platform provides a real-time kernel in addition to reliability features that ensure critical applications can stay running without direct human intervention. In collaboration with Intel, Red Hat engineered several tools and benchmarks to prove the platform's fitness for demanding shop floor scenarios.

As landmark regulations like the Cyber Resilience Act come into effect, it is critical that users evaluate their tools for cybersecurity hardening and compliance. In addition to the hardening Red Hat has baked into their solutions at the OS level, they are also in the process of aligning with the IEC 62443 certification for secure industrial automation and control systems. Built on industry-backed open standards and bolstered by Red Hat's enterprise developer support, the platform simplifies software-defined automation strategies while providing mission-critical performance and security.

Want to see Red Hat's performance for yourself? Learn more about the solution in this brief developed in collaboration with Intel: https://builders.intel.com/docs/networkbuilders/intel-red-hat-industrial-edge-platform-solution-brief-1709281876.pdf

Open-Source Software Solutions that Meet Industry Needs

While the open-source software movement has produced countless valuable projects for the IT world, industrial technology users must practice special consideration to deploy open-source software suitable for the needs of OT environments. The technology may be powerful, but the implementation often lacks the feature-rich experience of traditional software products. Red Hat's enterprise-grade open-source solutions draw from a deep well of openness, interoperability, and community-driven development practices, while also providing key integrations, lifecycle management, and ongoing support industry stakeholders expect from a fully commercialized product.

Red Hat's platform strategy is designed to cater to technology end users regardless of their current scale or future ambitions. This means businesses can initiate their digital transformation journey with a small-scale deployment and seamlessly expand to encompass enterprise-wide systems while maintaining consistent underlying technology. This flexibility is complemented by a clear and adaptive pricing model, which ensures that costs align with the actual scale of deployment to avoid prohibitive upfront investment hurdles.

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Red Hat's extensive partner ecosystem enables seamless integration with emerging technologies and existing automation supplier domains, while their understanding of OT requirements ensures solutions that bridge enterprise frameworks with the needs of the shop floor regardless of industry vertical. By unifying core elements from the Red Hat portfolio, Red Hat platforms provide comprehensive shop floor management with an open, standards-driven design to provide the foundation for future growth.

Recommendations

As industrial environments evolve, it's crucial to evaluate whether your control and automation architecture can meet evolving technological, cybersecurity, and connectivity demands. Open a dialogue with Red Hat to discover how their enterprise-grade open-source technologies can help modernize your control systems, enhance security, and prepare your operations for future innovation.

Industrial automation suppliers have a unique opportunity to better serve both their existing customers and new IT/OT stakeholders by embracing modern, open solutions. Partnering with Red Hat enables suppliers to deliver future-ready automation and control platforms that meet the evolving demands of today's industrial environments. Now is the time to invest in partnerships to stay ahead in this competitive landscape.

IT and OT stakeholders have a critical opportunity to further their collaboration and move their operations towards enterprise scale. Red Hat's solutions can create a unified, interoperable platform that connects industrial operations with advanced IT systems, enabling real-time data sharing, enhanced cybersecurity posture, and streamlined management tools.

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