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Software-defined Automation for Future-ready Machines

Leveraging Ecostruxure Automation Expert to Simplify Machine Integration and Generate New Revenue Streams

A Frost & Sullivan Whitepaper

In Partnership with Schneider Electric

Schneider Electric

Summary

OEMs are contending with significant market volatility and uncertainty, rapid changes in the way their customers operate, decarbonisation, digital transformation, and workforce challenges. To remain competitive, they need to explore innovative business models to achieve revenue stability, new revenue stream growth, enhanced agility, flexibility, scalability, improved use of resources, optimal ways to extract value from digital tools, and portable, modular solutions to support multiple platforms. However, this calls for not only transforming how they interact with customers, but also how they leverage technology to achieve promised outcomes.

Against this background, OEMs are beginning to explore the idea of replacing hardware automation with software-defined automation.

A hardware-independent and software-defined automation approach can deliver portable and interoperable solutions that bridge the IT-OT gap. This approach brings flexibility, scalability, and upgradability to OEMs, while helping them offer new high-growth and high-margin data-driven services to their customers.

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Images from Frost & Sullivan Image Resource and Schneider Electric.

Table of Contents

The Strategic Imperative

From pneumatic to electronic controls; from relays to PLCs;[1] from first-generation HMIs,[2] SCADA,[3] and DCS[4] to second-generation systems and PC-based systems; from proprietary to open industrial protocols; from wired to wireless communication, industrial automation has had a long and successful track record in helping original equipment manufacturers (OEMs) to achieve efficiency gains and enhance machine reliability.

For decades, machine builders have been investing in operational technology (OT) to bring machines to a higher level of performance, efficiency, and connectivity with real-time accuracy. However, despite the convergence of information technology (IT) and OT systems and the leverage of the industrial Internet of Things (IIoT),[5] the potential of IIoT still remains largely untapped. OEMs face significant challenges when trying to leverage digital capabilities across the whole value chain, both from a business and technology perspective.

Conventional automation struggles to address the more demanding needs of a radically different world of today. This is a world in which OEMs face intensifying external and internal pressures, as summarised below:

Top 4 Challenges Impacting OEMs Across the Machine Lifecycle

Workforce Challenges

Skilled automation workforce shortage hindering OEMs from supporting different OT platforms

Connectivity

Moving from simple machine connectivity to IIoT readiness

Servitisation

Offering relevant services such as remote monitoring and predictive maintenance

Future-proofing through Engagement with the Wider Ecosystem

Partnering with the wider ecosystem - IT vendors, automation vendors, and consultants

Source: Frost & Sullivan

Workforce Challenges

Difficulties in finding, training, and retaining skilled employees are aggravated by the skilled workforce shortage. In addition, the automation workforce is ageing, and this translates into significant investment in upskilling/reskilling to move the workforce away from outdated ways of

[1] Programmable Logic Controllers
[2] Human Machine Interfaces
[3] Supervisory Control and Data Acquisition
[4] Distributed Control System
[5] IoT is when objects are connected, virtualised, and imbued with data measurement capabilities (giving physical and virtual objects an identity, interconnecting the objects that can monitor and interact with each other and having the ability to generate real-time insights from data that can be incorporated into existing business processes; Frost & Sullivan

working so that new technologies and processes can be leveraged effectively. Also, in many instances, historical investments in specific systems result in end users preferring to stay with those systems that the workforce has been trained on and is familiar with. Consequently, OEMs are often forced to support multiple platforms and libraries across their customer base. Unfortunately, systems today are not fully portable, modular, or adaptable.

Unlike the older generation of automation engineers, the current generation of OT engineers are digital natives and have much higher expectations in terms of user experience in designing, deploying, and maintaining automation solutions. In response to this expectation, the trend toward 'appification' (the shift from web-only interfaces to application- or app-based interfaces), which is already mainstream in consumer and IT domains, is expected to gather momentum in industrial control and automation system environments.

Connectivity

Digital transformation enhances equipment performance, availability, quality of output, scalability, and flexibility. It reduces time to market and enables improvements to maintenance of equipment. It also has a positive impact on sustainability (through reduced energy consumption, waste, emissions, water consumption, etc.).

The digitisation of machines is resulting in new demands for effective support for OEMs through the whole lifecycle of their machines; from design to build, test, commission, operate, maintain, and upgrade. In addition, advanced technologies such as cloud computing, artificial intelligence (AI), machine learning (ML), augmented reality (AR), virtual reality (VR), digital twins, advanced materials, 3D printing, robotics, 5G, edge computing, and IIoT are being leveraged more widely in production and process environments. They help to contextualise information, conduct real-time data analysis to identify patterns, trends, and anomalies, and provide recommendations to help manufacturers make better and faster data-driven decisions.

In particular, AI is predicted to harness the vast amounts of production/process data (that has, this far, remained unused or underused) to enable its various tools such as computer vision,[6] natural language programming (NLP),[7] ML, deep learning,[8] and cognitive computing[9] to deliver the promise of continuous operational learning.[10] The potential global investment to 2030 in various key automation and manufacturing technologies is summarised below.

Global Total Addressable Market (TAM) by 2030

Industrial AI	Industrial Ethernet	Industrial 5G	Industrial AR/VR
$80 billion	$200 billion	$160 billion	$65 billion

Source: Top 10 Growth Opportunities for the Automation and Manufacturing Industries, Frost & Sullivan, April 2023

OEMs are challenged by end-customers to extract maximum value from their digital transformation journeys, and consequently are in search for easier ways of integrating digital

[6] Computer vision is the science that provides computers with the ability to perceive and process images in much the way that humans do. It enables machines to process and extract useful information from an image or a sequence of images.
[7] NLP is a machine's ability to understand unstructured human language data and provide an appropriate response.
[8] Deep learning is a multi-level ML architecture that uses those levels to analyse problems. The technology approximates a brain-like neural network and can undertake tasks where supervised learning is difficult or too many variables exist to model and analyse underlying relationships in data sets.
[9] Cognitive computing simulates human brain thought processes and problem-solving capabilities and learns from data through explicit programming with rules and regulations.
[10] The Extent of Smart Manufacturing—Global Trends, Frost & Sullivan, November 2023

capabilities with current platforms and the integration of IT with OT. This is particularly challenging for small and mid-sized OEMs.

For OEMs of all sizes, cost of IT-OT integration or the leverage of advanced technologies such as AI, digital twin or AR within conventional industrial automation systems is a key barrier. The historical focus on the metrics of guaranteed availability and performance has led OEMs to rely on their proprietary designs, software, libraries, and implementation. Despite the commoditisation of input/output (I/O), fieldbus, and central processing units (CPUs), overall automation systems are most often closed, and vendor locked. Installing specific hardware or processors still requires deploying in a specific proprietary development environment, which differs from vendor to vendor; thus making true integration across multiple modules or controllers in the site challenging. Also, gaps between IT and OT systems prevent site-wide (and enterprise-wide) visibility and control. Disconnected point solutions result in fragmented data sources, data inconsistency, multiple integrations, inconsistent user experience, inaccurate reporting, forecasting, and scheduling, as well as an inability to pursue continuous improvement.

Whilst other sectors such as consumer electronics, IT, and telecom have been successful in decoupling hardware from software, in industrial automation architecture, this has proven more difficult. Whilst classic PLCs remain robust and reliable (and have been relied on for over half a century), they are challenged by the new demands from digitisation of production and process environments.

Servitisation

OEMs face considerable external challenges, including the following:

- **Market Volatility and Uncertainty:** When the market faces weak macroeconomic conditions, the pressure on revenue and profitability growth intensifies. In these conditions, OEMs – especially those active in equipment segments that are in the mature stage of their product lifecycle – prioritise revenue stability, as well as the opportunity to add new revenue streams (through new solutions or services). However, when their offer to the market does not enable these outcomes, OEMs find themselves under increasing pressure. In addition, in the face of continued supply chain disruptions, OEMs are rethinking their manufacturing, sourcing, and supply chain strategies to minimise disruption. Changing end-consumer preferences, volatile demand, disruptions arising out of geopolitical tensions and other external shocks have driven renewed focus on strategies such as flexible manufacturing, decentralised manufacturing, manufacturing network diversification, re-shoring, nearshoring, and ecosystem partnerships to improve resiliency. Flexible manufacturing also enables cost-effective product personalisation and on-demand supply to cater to fluctuating consumer preferences.[11] This challenge also accelerates new ways of working. For example, geopolitical tensions, economic crises, social unrest, or future pandemic-driven disruptions make remote testing, commissioning, diagnostics, and maintenance crucial to maintaining operations. For production and process environments, often, this also requires multi-controllers to be integrated seamlessly with SCADA, MES,[12] ERP,[13] and other systems.
- **End-customer Shifts:** Rapid changes in end-consumer preferences and demand, as well as increased competitive intensity amongst manufacturers, call for faster new product launches or modifications in existing product design, functions, features, packaging, and quantity. These translate into more frequent production line modifications, or in some instances, the addition of entirely new lines. For OEMs, this translates into the need to quickly make design modifications or add new functions/features or scale up or down rapidly. However, engineering effort and costs using current systems prevent OEMs from

[11] Growth Opportunities Driven by Flexible Manufacturing, Frost & Sullivan, March 2023
[12] Manufacturing Execution System
[13] Enterprise Resource Planning

adopting such a nimble approach. More complex and volatile production also demands the use of more sophisticated equipment. In addition, the legacy installed base in each site is often from a diverse range of OEMs, making it difficult to manage and maintain.

- **Decarbonisation:** Since 1990, global greenhouse gas (GHG) emissions from industrial processes grew by 203%, making it the fastest-growing source of such emissions (followed by electricity and heating – up by 84%, and transportation – up by 78%).[14] This explains why OEMs are looking for ways to optimise their use of resources and are focused on tailoring their equipment and services to enable their customers to effectively operationalise circular processes to repurpose, reuse, and recycle materials, as well as implement sustainability initiatives around industrial waste heat recovery,[15] industrial electrification,[16] energy harvesting solutions,[17] energy efficient manufacturing,[18] etc.[19]

As a response to the above challenges of market volatility and uncertainty, end-customer shifts, as well as decarbonisation (and triggered by the digital transformation of production and process environments), emerging business models promise new revenue streams and improved competitive differentiation for OEMs. Amongst these innovative business models, servitisation is emerging as one of the most attractive, with far-reaching impacts. Servitisation refers to offering the functionality of the product rather than the product itself.

Despite a certain level of reluctance amongst OEMs to explore this model, end-customer demands and the introduction of IIoT technology has helped create new revenue streams for OEMs through service-based business models. This delivers significant benefits for OEMs, including:

- Expanding the revenue-generating phases for OEMs beyond the conventional sell, install and commission phase through the full lifecycle of the equipment,
- Providing customer usage data for future product enhancements and improved visibility for upsell and cross-sell opportunities,
- Allowing OEMs to demonstrate value to customers over an extended period; thus enhancing customer satisfaction and loyalty, and giving OEMs a potential differentiator against the competition,
- Bringing stability to OEM revenues, and
- Increasing overall profitability through higher margins than mere equipment sale.

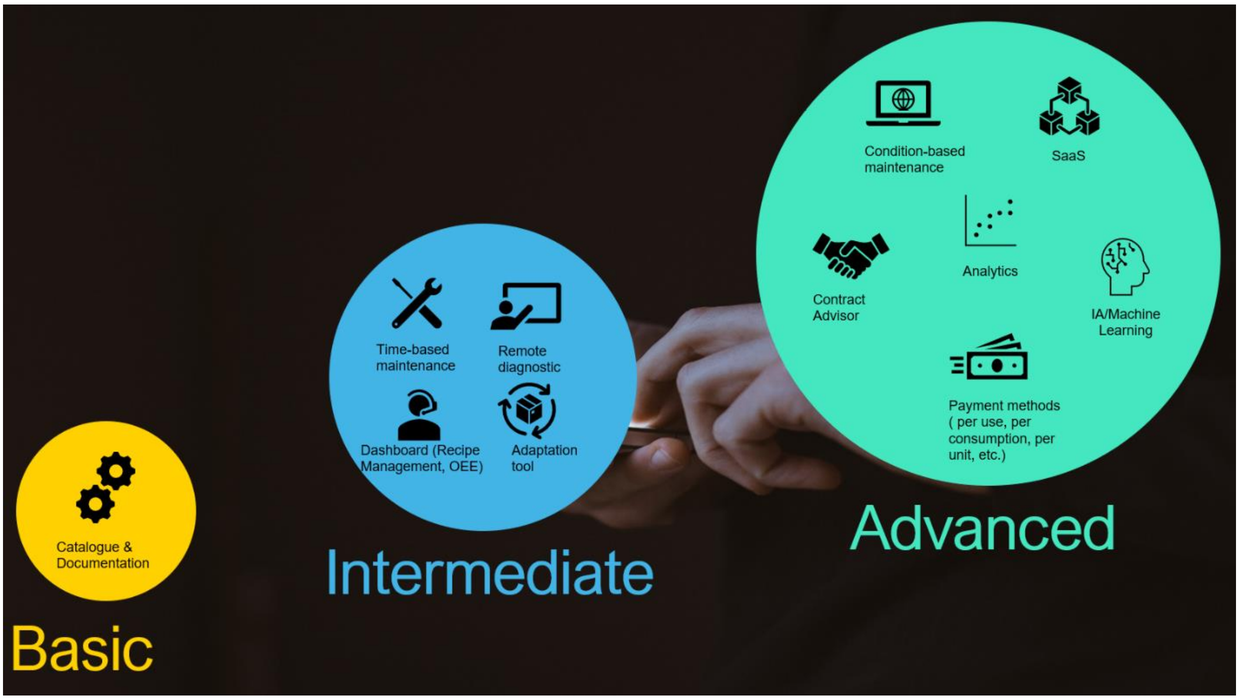
End users want flexible services that allow selection and customisation depending on equipment/plant demands and scalability for expanding service coverage across diverse equipment types, as well as advanced asset management services. In response to this expectation, more OEMs are exploring the launch of new services rather than the historical focus on product sale and annual maintenance contracts only. But they require new competencies, as well as open, data-driven processes to enable proactive and agile responses to changes in markets.

To evolve into service-led organisations, OEMs must shift focus from their product to performance, thus expanding their engagement with the customer well beyond the initial sale. This calls for not

[14] World Resources Institute, February 2020
[15] Industrial waste heat recovery involves capturing the waste heat from manufacturing processes and reusing/repurposing it in secondary on-site processes.
[16] Industrial electrification entails replacing technology and services that use fossil fuels with those that use electricity from renewable resources, such as solar, wind, hydro, and geothermal.
[17] Energy harvesting involves capturing and converting various forms of energy, such as solar, wind, kinetic, piezoelectric, thermoelectric, hydraulic, and geothermal.
[18] Energy-efficient manufacturing includes using energy-efficient drives, heat exchangers, cooling efficiency solutions, conventionally cooled power supplies, thermoelectric coolers, insulated piping solutions, and AC/DC conversion systems. It also entails using energy-efficient heating, ventilation, and air conditioning systems in production facilities.
[19] Sustainable Technologies and Initiatives in the Manufacturing Industry, Frost & Sullivan, March 2023

only transforming how they interact with customers, but also how they leverage technology to achieve promised outcomes.

The Shift to Machine-as-a-Service



Source: Schneider Electric

Future-proofing through Engagement with the Wider Ecosystem

To offer integrated solutions and service, OEMs are challenged to move beyond their own offerings and roadmaps to engage proactively with the wider ecosystem of digital technology providers, automation vendors, and consultants. To do this effectively calls for not only an open mindset, but the leverage of the completely new paradigm of software-defined automation.

The Birth of Software-defined Automation

As the pressures from markets, customers, decarbonisation, digital transformation, and workforce changes intensify the search for innovative business models, OEMs who have historically leveraged and trusted conventional automation to maintain operations now want much more.

Now, with hardware automation reaching a state of maturity, OEMs are beginning to explore the idea of replacing hardware automation with software-defined automation (SDA). The SDA concept, although nascent, is based on using computing power in virtual machines as a substitute for control and automation via hardware assets. This approach helps lower lead times, reduces operating costs, drives creativity, improves flexibility through modularisation concepts, and explores advanced AI- and ML-based use cases with greater ease.

By centralising logic and intelligence in software instead of hardware, SDA allows for the integration of IT and OT, fostering the creation of adaptable and resilient manufacturing processes. SDA deconstructs the traditional automation pyramid through the interconnection and interoperability of automation products, plug-and-play, reuse, and portability of software code. Technologies can now connect with any device or system and system-agnostic solutions can be fitted to any manufacturing setup, enabling technology and manufacturing advancements to be tailor-made to operations without the cost of a custom solution.

In its February 2024 global study of companies at the forefront of driving growth in industrial environments, Frost & Sullivan identified SDA as one of the top 8 growth opportunities.[20]

Disruptive use cases of SDA include developing smart factories across the whole value chain of production through the deployment of virtual PLCs, digital twins, software-defined networks (SDNs), and AI/ML-powered platforms to optimise manufacturing processes, enable predictive maintenance, and improve product quality. As a result, both machine and production line today can be designed based on the software application architecture.

Use Case in Focus: Virtual PLCs

The basic design feature and form of PLCs has not gone through substantive changes in the last 50 years. Although there have been new innovations such as industrial PCs that surfaced in the late 90s and early 2000s, the PLC market only underwent changes in the hardware realm. However, with the advent of SDA, the PLC space is now witnessing a massive wave of innovation. End users in both process and discrete industries are increasingly moving toward operational expenditure (OPEX)-led business engagement with automation vendors. In this regard, the concept of SDA represents an attractive growth opportunity. It offers better manageability (of hardware assets), higher availability, and greater efficiency. In this context, the birth of virtual PLCs is another pivotal moment that will change the future of manufacturing.

Legacy equipment cannot always be updated with new software because of hardware limitations or technical constraints. This not only negatively impacts performance of machine, but also the ability to implement cybersecurity updates. The virtual PLC allows machine builders to easily update new software (including cybersecurity updates), add in digital services, save time on set up, minimise cabling, and optimise space.

The market for virtual PLCs is still nascent, but it will likely grow by double digits over the next 10 years.

Creating the Enabling Tools and Ecosystem to Drive Radical Change

Helping to drive the shift to a new paradigm of SDA application software is **UniversalAutomation.org** - an independent non-profit association that supports a global community of automation users and technology vendors as they work toward leveraging the IEC 61499 standard to design distributed applications using “plug and produce” software components that are independent of the hardware on which they execute.[21]

The IEC 61499 architecture provides an enabling solution for distributed industrial automation systems aiming at portability, reusability, and interoperability for the reconfiguration of distributed applications.

It defines a domain-specific modelling language for developing distributed industrial control solutions. for increased re-usability, providing a vendor independent format, and simplifying support for controller-to-controller communications.

[20] Top 8 Growth Opportunities in Digital Industry Accelerators, 2024, Frost & Sullivan, February 2024
[21] UniversalAutomation.org

Initially developed as an extension of the scan-based IEC 61131 standard, the event-based IEC 61499 standard is now being viewed as a transformational rethink of the approach to automation as it enables the design of universal function blocks that can run on any hardware. In other words, an operating system that is compatible across devices.

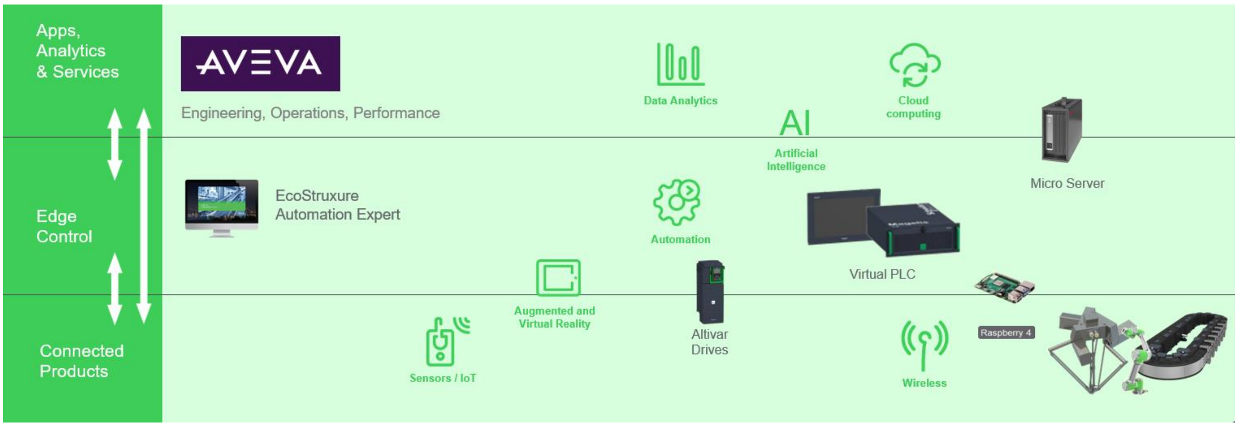
Towards a New Paradigm of Open, Software-centric Machines

Amongst the founding members of UniversalAutomation.org is leading solutions provider for digital transformation of energy management and automation, **Schneider Electric**.

Recognising the need for OEMs and their customers to be freed from hardware constraints in their automation architecture choices, Schneider Electric offers **EcoStruxure Automation Expert** - an open (IEC 61499 PLC programming standard compliant), software-defined industrial automation system with edge level control linked to the IT level of the organisation. It enables interoperable, portable, and "plug-and-produce" automation solutions.

Software-defined automation is the integration of open-source technologies and standards in industrial machines and process to control multiple hardware assets from a variety of containerised software running on shared hardware resources (which could be a virtual PLC or IT-hardware such as a microserver. In contrast with traditional automation architecture, the EcoStruxure Automation Expert platform creates a future-ready machine architecture that is highly data driven in real-time which has become a significant trend in the world of digitisation.

The Software-defined Automation Approach with EcoStruxure Automation Expert



Source: Schneider Electric

For machine OEMs, the simplicity of engineering, that comes from adopting a software-defined approach, improves agility in terms of responding to end user demands for customisation, expansion, integration, or new functionality. This helps avoid the need for manufacturing multiple versions of the same machine, reduces time-to-market, and supports revenue growth for OEMs.

EcoStruxure Automation Expert facilitates application portability and reusability. Moreover, event-driven structures (as opposed to traditional code) make design and implementation easier and faster. By reusing software function blocks and design, engineering time and cost are reduced, eliminating errors, and greatly shortening implementation time.

This speed of implementation is not at the expense of outcomes, as simulation to test the application before commissioning is available. In this way, OEMs can virtually commission and modify control systems using digital twins, so that performance can be validated before the real-world systems are built and deployed.

OEMs can take advantage of open, interoperable, and flexible control that is independent of hardware constraints (hardware-agnostic structure) – across both Schneider Electric and third-party hardware devices. This reduces the complexity of programming and installation for new and expanded or upgraded systems.

Centrifuge Manufacturing

GEA Westfalia Separator Group GmbH

50% savings in commissioning through the use of EcoStruxure Automation Expert

Flexibility in adding, modifying, or removing resources from specific machines/systems based on changed energy, manpower, or quality/quantity needs, enables more efficient use of resources.

Using Schneider Electric's Soft dPAC virtual PLC (that can run on any PC, virtual machine on a blade server, or raspberry pi device), OEMs can take advantage of the openness and operational flexibility now available to them for their hardware (including being able to install new instances of Soft dPAC without stopping the operating production line).

In addition, the ability of OEMs to realise new revenue streams from services on top of equipment sale is dependent on their ability to accurately collect, store, and analyse relevant machine data so that outcomes can be promised, delivered, and monetised effectively. The improved integration and visibility that EcoStruxure Automation Expert enables helps OEMs to understand the performance and maintenance profile of all of their equipment; thus facilitating 'performance-as-a-service' or 'machines-as-a-service' business models.

Hydrogen Production

Wilo SE

Hydrogen plant leveraging EcoStruxure Automation Expert to produce clean, low-carbon energy by integrating photovoltaic system, electrolyser, hydrogen storage tank, and fuel cell

With EcoStruxure Automation Expert, OEMs can achieve a single, consistent diagnostic view to troubleshoot faster, and identify root causes of failure; thus improving maintenance and asset lifecycle outcomes in their as-a-service offerings.

Connectivity to SCADA, digital twins, ML, and analytics, as well as facilitating a library of sharable and reusable apps provides the opportunity to maximise the potential of advanced technologies to transform operations.

The Value of a Trusted Technology Partnership

Vacuum Pump and Roots Blower

Intidaya Indonesia

Embedded EcoStruxure Automation Expert enables an IIoT-ready solution that enhances engineering efficiency while achieving 43% savings in energy consumption

In this journey towards people-centric, resilient, and sustainable operations, it is critical that OEMs partner with a trusted technology expert who not only brings the appropriate software-defined solution, but also has the scale, the track record of using best practice, and the ability to support proactively and effectively. Schneider Electric not only supports all communication protocols for industrial environments, but also, by ensuring role-based access, encrypted communication, as well as user authentication where needed, ensures that cybersecurity is maintained. By delivering a consistent approach to software, Schneider Electric gives OEMs choice and flexibility in platforms and architecture so that the whole ecosystem of key stakeholders i.e. OEMs, systems integrators, distributors, and end users can leverage harmonised solutions.

To make this transformational journey financially viable and sustainable, OEMs may be best positioned by commencing with one system or project that can be tested and validated before roll-out to the wider portfolio. By adding functionality and flexibility on top of the legacy system, migrating to the new approach does not entail a full-scale rip-replace-rewrite effort.[22]

[22] Upfront replacement of equipment, software, and libraries

Conclusion

As the limitations of a hardware-focused approach to automation become evident, more OEMs are exploring the possibilities of leveraging a software-defined approach for strategic advantage.

Schneider Electric's EcoStruxure Automation Expert – using the IEC 61499 standard – provides OEMs and their end users portability and interoperability that enhances flexibility and scalability, whilst also helping unlock the full value of IT-OT convergence for new and highly profitable revenue streams. This vendor-agnostic tool can help them thrive even as they reshape business models to become more agile, resilient, and sustainable in the face of transformational change.

FROST & SULLIVAN

About Frost & Sullivan

For over six decades, Frost & Sullivan has helped build sustainable growth strategies for Fortune 1000 companies, governments, and investors. We apply actionable insights to navigate economic changes, identify disruptive technologies, and formulate new business models to create a stream of innovative growth opportunities that drive future success. www.frost.com

About Schneider Electric

Schneider's purpose is to empower all to make the most of our energy and resources, bridging progress and sustainability for all. We call this Life Is On. Our mission is to be your digital partner for Sustainability and Efficiency. We drive digital transformation by integrating world-leading process and energy technologies, endpoint to cloud connecting products, controls, software, and services, across the entire lifecycle, enabling integrated company management, for homes, buildings, data centres, infrastructure, and industries. We are the most local of global companies. We are advocates of open standards and partnership ecosystems that are passionate about our shared Meaningful Purpose, Inclusive and Empowered values. www.se.com