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IEC 61499: The Industrial Automation Standard for Portability that Unleashes Industry 4.0

by John Conway

Executive summary

The benefits of Industry 4.0 and IIoT use cases for industry are well documented. But, failure to adopt digital age industrial automation standards that are truly open is costly on all fronts: unnecessary expense, delays in rolling out innovative manufacturing plant designs, and lost business opportunity.

The IEC 61499 standard sets a foundation for industrial automation application portability that creates wide-ranging benefits, including easy IT/OT system convergence, improved return-on-investment on software applications that can run independent of any hardware platform, and engineering design efficiency that radically speeds up new product time-to-market.

Introduction

Global economic and market uncertainties are forcing manufacturers to rapidly adjust to more frequent, high-speed changes in demand and in raw material and energy pricing. Such trends are prompting process manufacturers to rethink the way industrial automation systems need to work. Part of that reassessment involves an increasing need to accommodate increased product variants and shorter sourcing, production, and product delivery lifecycles.

Industrial organizations and their stakeholders also face the challenge of accommodating significant workforce changes as Baby Boomers retire and take their industrial automation systems knowledge with them. The new, Digital Native generation of employees coming in expect that knowledge will be embedded in the systems they will be required to work with.

Many industrial stakeholders are hoping that Industry 4.0 and the Industrial Internet of Things (IIoT) will help to address these new challenges. Early benefits of Industry 4.0 have been well documented—artificial intelligence and machine learning algorithms that greatly improve the quality of operational processes, the prediction of equipment failures before they happen to reduce unplanned downtime, real-time optimization of production based on raw-material spot prices, and real-time optimization of production scheduling to maximize throughput. In fact, industry analysts estimate that the new, more flexible production techniques could boost manufacturer productivity by as much as 30%.[1] However, research has also shown that 60% of enterprises fail to take IIoT projects beyond the pilot stage.[2]

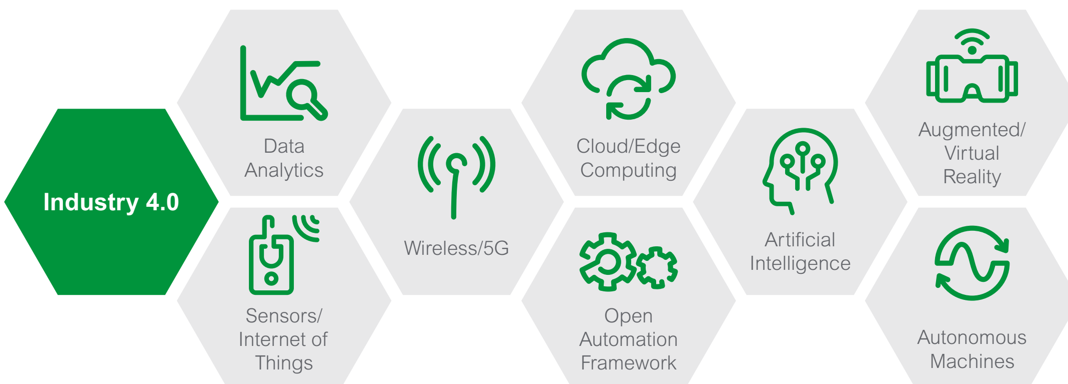

Figure 1
Operating from an open, as opposed to a proprietary industrial automation framework, suddenly renders accessible the entire new range of Industry 4.0 benefits

The reasons for this are numerous and linked to people, processes and technology. With regards to technology, the biggest factor that keeps most mainstream manufacturers from attaining such benefits is the closed proprietary nature of the plant systems that support their operations. Operating from a truly open, as opposed to a proprietary industrial automation framework, suddenly renders accessible the entire new range of Industry 4.0 benefits.

This paper proposes an approach, based on the IEC 61499 standard, that not only addresses the shortcomings of proprietary systems, but also facilitates the convergence of operation technology (OT) and information technology (IT) systems.

[1] https://www.accenture.com/us-en/insight-industrial-smart-production
[2] Capgemini "Unlocking the Business Value of IoT in Operations" March 13th 2018

Barriers to Overcome

For manufacturers to move forward into the new world of open industrial automation systems, engineering teams need to be cognizant of the barriers that need to be overcome:

- Non-digital architecture – Most of today's automation systems are based on principles developed in the 1970s and 80s. Highly optimized for real-time control, the technology has not taken advantage of the recent and rapid changes in IT. It is precisely these technologies (analytics, artificial intelligence/machine learning, object orientation, service-oriented architectures, etc.) that are required to realize the promise of Industry 4.0.
- Hardware-centric business model – Although advancement in hardware can serve to optimize an existing environment, it will not lead to the breakthroughs required to enable the true benefits of the digital transformation. This will require the intelligent application of software-based innovation to OT problems. This will result in a steady shift from hardware-driven to software-driven business value.

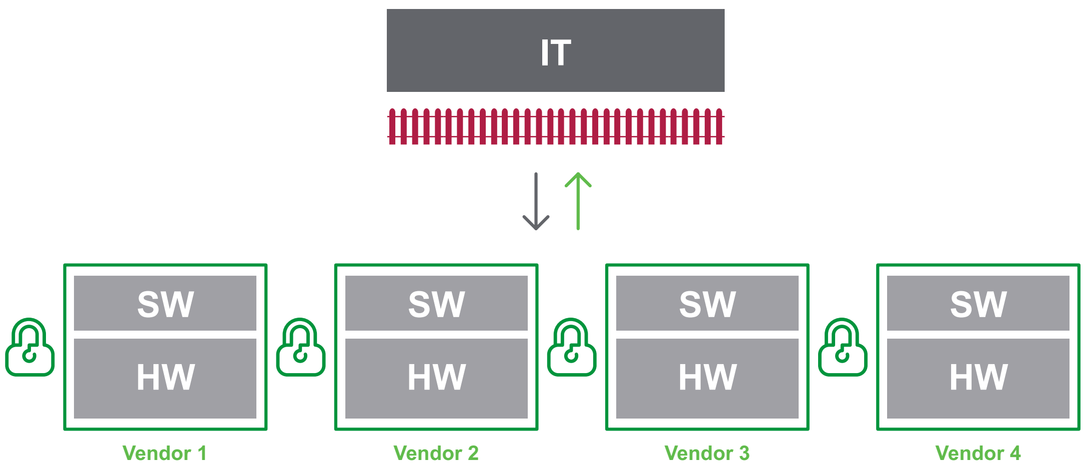

Figure 2

Proprietary automation cannot leverage advances in IT technologies and lack of application code portability hinders innovation and investment in software

- Constraints of proprietary systems – Today, automation software applications written for one system will not run on another system. In the IT world, standardized operating systems such as Linux have, for decades, encouraged the rapid expansion of an active third-party application development ecosystem. As a result, software of all kinds support IT-related business needs across a wide swath of industries and niches. Unfortunately, in the industrial world, proprietary systems act as a barrier to innovation: Users are unable to improve their production systems at reasonable cost and are unable to mix and match best-of-breed offers from different suppliers. Their rate of innovation is "imposed" by the suppliers of the proprietary platform they use.

Together, these barriers increase total cost of ownership. And since upstream design tools and downstream operations tools cannot be closely coupled with automation systems without a huge investment, the creation of an efficient digital thread covering the full process/machine lifecycle is next to impossible.

Why the time is ripe to move to an open automation framework

On the engineering side of the equation, value chain members such as machine builders and systems integrators also face their own set of limitations working within the constraint of the current industrial automation infrastructure paradigm.

Machine builders are facing new challenges. On the one hand, there is a trend towards modular machine design using virtual testing capabilities to mix the virtual and physical worlds. On the other hand, increasing the added value of their machines requires services and innovative business models to help differentiate themselves and to help market and grow their business. The current automation construct does not favor their ability to expand into software and services offerings.

For systems integrators, automation systems do not provide the tools to bridge the IT and OT worlds. As a result, they find themselves having to craft solutions that are overly complex and labor-intensive thereby limiting the widespread marketplace acceptance of such services.

On the End User side, organizations such as the Open Process Automation Forum (OPAF), and the User Association of Automation Technology in Process Industries (NAMUR) are advocating for changes to the existing proprietary automation systems paradigm.

For all of these reasons, the time is ripe to move to an open automation framework. The key that unlocks this new world is the emerging IEC 61499 standard. Technological evolution has finally caught up enough to allow the standard to exercise its full potential. That is, IEC 61499 can now serve as an essential building block for the development of a truly open industrial automation environment where software applications are portable across multi-vendor hardware platforms.

What characteristics of the IEC 61499 standard make it well-suited for exploiting the benefits of Industry 4.0 digitization and for creating a foundation for truly open systems? Table 1 summarizes the key aspects.

Table 1

Highlights some of the key characteristics of the standard and describes the relationship of the standard to the new digital IT/OT convergence world that is beginning to emerge.

Desired Characteristics	IEC 61499 Support
Object-orientation	The event driven function block structure of IEC 61499 with processing of data inputs, outputs and local internal variables closely matches the IT notion of objects, methods and parameters. This strong encapsulation is a key characteristic of software components.
Nesting of objects	The unlimited nesting of networks of function blocks within composite function blocks allows the user to build up complex objects based on simpler proven-in-use software components. This is a key driver of quality and engineering efficiency.
Black-box software components	IEC 61499 does not define the programming language used inside function blocks. The function block can be considered as a "wrapper" in which a developer can encapsulate his IP. If desired, the developer can protect his IP and deliver a black-box software component that can then be used within an application. This black-box approach is a key enabler of an app-store business model for automation.
Graphical design language	The event-driven function block is a graphical design language very familiar to automation engineers. The standard also defines "adapters" that serve to hide the spaghetti of multiple event/data connections between different composite function blocks. The adapter defines interfaces in the form of plugs and sockets. In this way, complex composite function blocks can be linked together using "single line engineering". Plugs will only connect to the corresponding socket if they are compatible. This encourages a graphical model-based or "low-code" design approach allowing non-automation specialists to plug together black-box software components to form complex automation applications.
Hardware abstraction	The IEC 61499 standard enables application-centric design by separating the application model from the system model. Application programming is performed independently of the underlying control devices/resources and communications infrastructure topology which is defined by the system model. This separation of the application from the underlying hardware is one of the enablers of portable software applications across multi-vendor hardware platforms.
Architectural flexibility	The standard lends itself to both distributed and centralized architectures. The system model maps/distributes one or more applications by defining which parts of the applications are executed on which particular devices/resources. A device/resource model manages the connection to the process interface (sensors/actuators via the device IO bus) and the communication interface to other devices used by the distributed application. The combination of application, system and device/resource models enables applications to be designed independently of the underlying automation hardware, to be distributed across heterogeneous devices with zero programming effort, and for those devices to interoperate following standardized communications/data models across networks (again without additional programming). Distributing the application across multiple devices or centralizing it on a powerful edge controller becomes in effect a customer choice.
Realtime and anytime performance	The event-driven nature of IEC 61499 is a natural fit for interfacing to transactional IT systems. Now developers can combine real-time OT functions and "right-time" IT functions in one application, for example, a pump control block that can initiate the creation of a maintenance work order based on built-in predictive analytics.

To summarize, IEC 61499 defines a high-level system design language for distributed information and control systems. The standard allows encapsulation of functionality, graphical component-based design, event-driven execution and distribution of automation applications for execution across a broad range of automation & control devices, as well as edge computing devices.

With the emergence of the IEC 61499 standard and the interest of key automation vendors such as Schneider Electric to adopt open automation systems platforms, many of the ingredients are in place to help reshape the industrial automation systems playing field.

Early Schneider Electric field tests of tools based on the IEC 61499 standard suggest that engineering gains of three to four times can be achieved compared to conventional programming approaches.

More than a simple technology change

Plug and Produce Systems

The move to automation systems based on IEC 61499 is more than a simple technology change. It has the potential to fundamentally change the way processes and machines are designed.

The technical features described above will drive **portability & interoperability of application software across multi-vendor platforms and will enable an app-store model for industrial automation.**

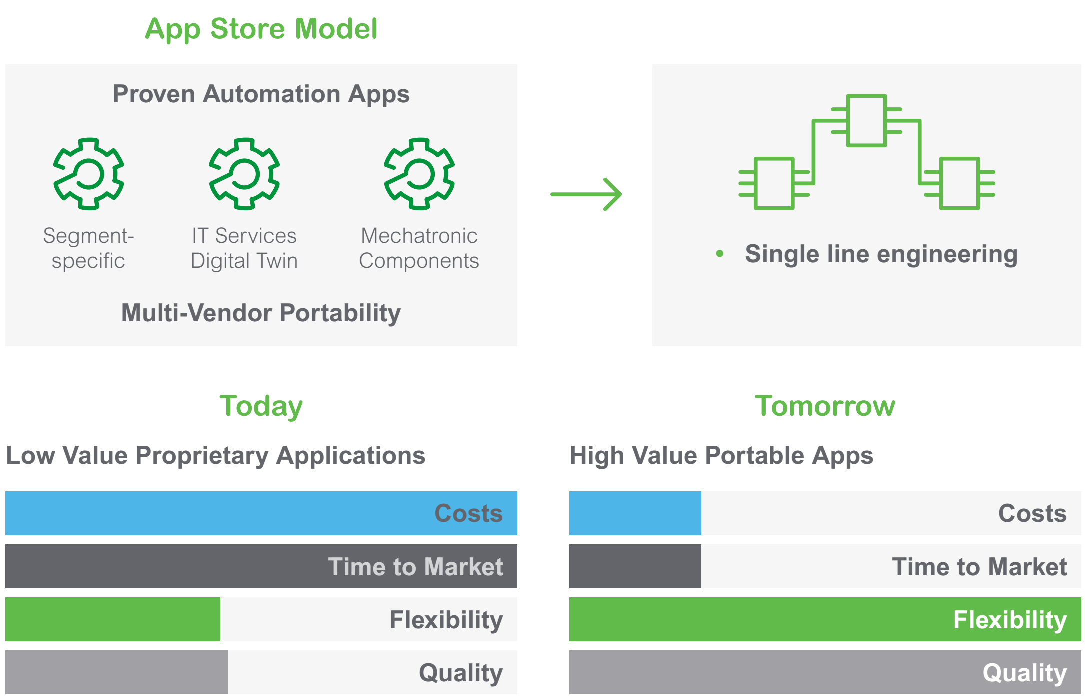

Figure 3
Plug and Produce

This will drive a long-term shift from low-value programming of proprietary controllers to **plug & produce automation systems** using proven-in-use automation apps developed by a broad Ecosystem. Applications will run on a broad range of multi-vendor devices ranging from embedded SoCs to powerful edge computers.

The reduction in engineering costs and the simplification of the implementation of complex Industry 4.0 use cases, will unleash a step-change in productivity, flexibility and speed for industry.

About the author

John Conway has worked over 30 years in the automation industry in a variety of technical & commercial roles. His current mission is to drive the adoption of an open, software-centric automation platform that can address the needs of Industry 4.0. John has a B.Sc. in Mechanical Engineering from Manchester University UK and a Diplome d'Ingenieur in the Design of Machine Systems from the Technology University of Compiegne, France.

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