Understanding modular automation

Answers to the most commonly asked questions for those entering the world of modular automation

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Large-scale automation systems have been at the heart of production line control for decades. Now, driven by changes in consumer demands, an alternative plug and produce modular automation approach is emerging. For many production lines, particularly in the pharmaceutical, fine chemical and food processing sectors, modular-enabled automation could be the cornerstone of bringing to life the concepts embodied in the Internet of Things and Industry 4.0.

What changing market conditions are affecting pharmaceutical, fine chemicals and food & beverage sectors?

These sectors are facing uncertain times and unprecedented challenges. The need to maintain uptime and reliability, synchronise supply with customer demand, maximise available capacity and deliver smaller batches in shorter lead times has resulted in the need for new technologies to keep pace.

Energy and raw material prices are increasing, eroding profit margins for end products. Changes in regulatory requirements, such as in energy and water, also impact on installed production plant.

Meanwhile, customers and wholesalers are demanding higher quality, faster delivery and lower prices. This is squeezing margins and forcing industries to find new areas in which efficiency gains, however marginal, can be achieved.

Furthermore, industry is facing harsh global competition and changing market requirements such as:

- More customized products
- Shorter delivery times
- Smaller batch series down to a batch size of one
- Quick and simple integration of pre-packaged modular solutions

In emerging markets, the production capacity of fine and specialty chemicals and the pharmaceutical industry is growing. In addition, product life cycles and installation run-times are decreasing steadily.

How are these changes affecting production line control?

Today we have large-scale plants and, particularly in batch, we have multi-purpose plants. Large-scale plants tend to produce single products, and while they are efficient they tend to be inflexible. With multi-purpose plants, products can be routed through different vessels. Such plants have flexibility but are often inefficient. However, large-scale production remains a good solution for mass-produced products.
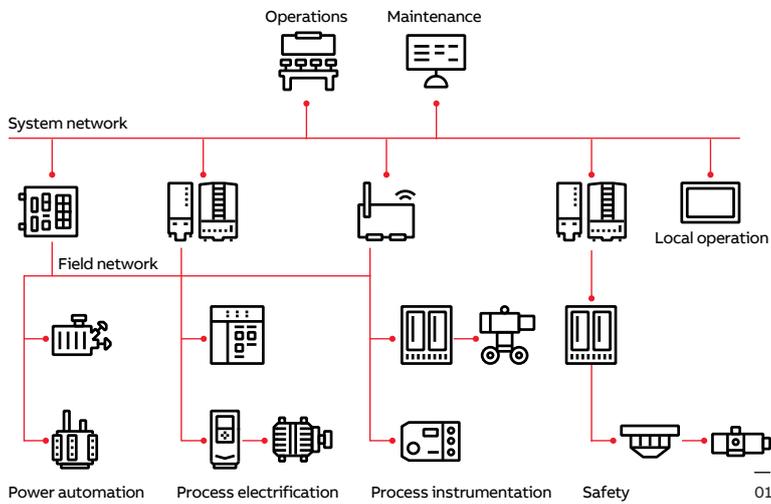
The automation systems controlling large-scale production are custom made with line-by-line source code executed by a master controller that governs sequencing, motion and I/O from the start to the end of the production line. These large automation systems have advantages, particularly for continuous production with highly predictable or constant demand cycles.

Decades of refinement and standardization mean that these systems are typically optimized at the design stage for a particular plant layout, specific product types and a defined level of throughput.

Monitoring and optimization become easier as most setpoints typically remain the same, and engineers who are familiar with the process can more easily spot and rectify any processes operating outside of normal parameters.

However, meeting the modern-day challenges described above requires a new approach.

Operations Maintenance

System network

Field network

Power automation · Process electrification · Process instrumentation · Safety

Local operation

01

Orchestration layer

Operations Supervisory control

Architecture network

Module layer

MTP MTP MTP

02

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What are the specific challenges affecting distributed automation?

Production needs to be faster and more agile to meet the changing market demands. In the pharmaceutical industry for example; it needs to focus on the individual needs of a patient and this brings challenges in creating personalized medicines. As such, end products can no longer be commodities with thousands of tonnes being produced at a time. The move today is towards very small batches.

Processes must be reliable, repeatable and error-free, with the ability to adapt on the fly and quickly ramp production up or down to match sudden changes in demand. The market is moving faster than ever, and manufacturers must move with it, combining the agility of batch production with the speed of flow production, all while keeping efficiency high and costs low.

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What new automation solution meets these challenges?

To develop customer-specific products and small batch series, there is a demand to develop flexible modular concepts that bring:

• Reduced time to market
• Standardization of processing modules
• Increased automation efficiency through quick and efficient module upgrade or exchange
• Higher flexibility

Modular automation brings an agility and flexibility to production never before seen. By acting like building blocks, the modules can be replicated and used to number up or number down in order meet rapidly changing capacity demands. By simply changing a few modules, a completely new product can be produced.

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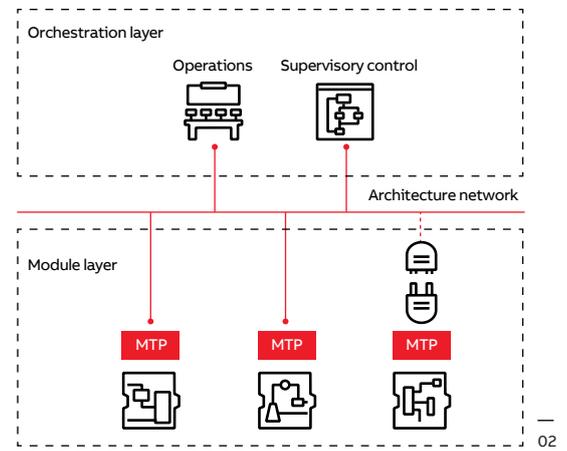
What are the benefits of modular-enabled automation?

There are several benefits in process-encapsulated, reusable modules, including:

For brownfield sites:
• Up to 50 percent less downtime
• Up to 50 percent less capital expenditure for automation engineering
• Up to 20 percent lower life cycle management
(03)

For flexible production plant
• Up to 40 percent faster time to market
• Up to 80 percent faster rearrangement of production equipment
• Almost zero automation engineering to copy and adapt production line
• Up to 50 percent less capital expenditure
(03)

In addition, customer-specific product adaptations can be rapidly and flexibly carried out by exchanging individual modules, bringing the cost of producing a batch size of one in line with that of mass produced products.

Overall, modular automation offers a more flexible and service-oriented plug and produce solution and:

• Simplifies engineering, making production more flexible
• Speeds-up time to market because of reduced effort required to build plants
• Increases plant efficiency
• Enables scaling capacity by numbering up and down the production according to the market
• Increases productivity through ability to create recipes and equipment logic in parallel
• Improves the capability and speed of product changes
• Improves overall competitiveness
• Lowers total cost of ownership for automation

How is a typical process plant transformed into modular-enabled automation?
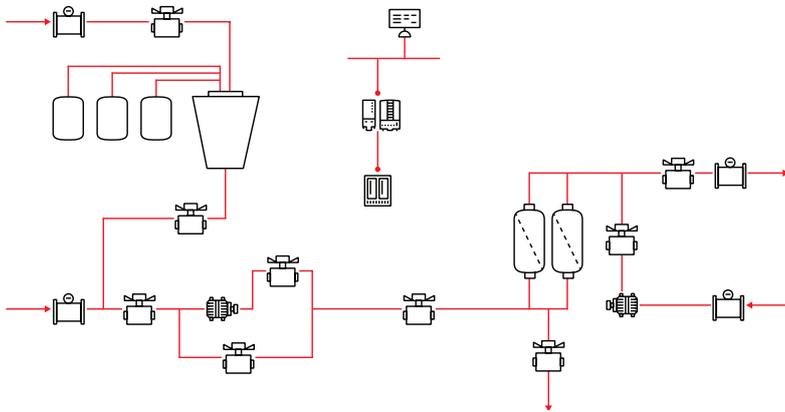

Step 1: Modular automation brings a completely new way of thinking by subdividing process line tasks into smaller, more manageable building blocks. Consider a traditional process plant design.
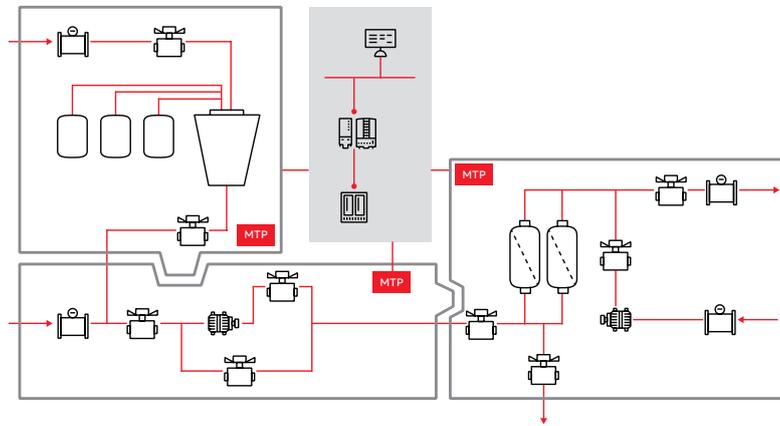
Step 2: Individual modules are pre-automated and then added together, like Lego blocks, to create a process line function. Each block acts as a plant within a plant, equipped with its own control functions and intelligence.
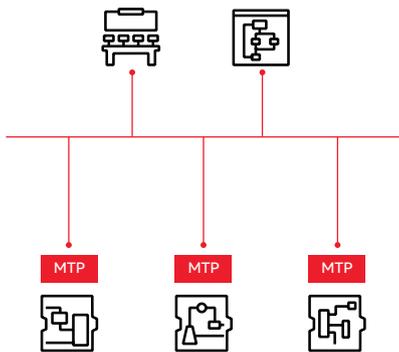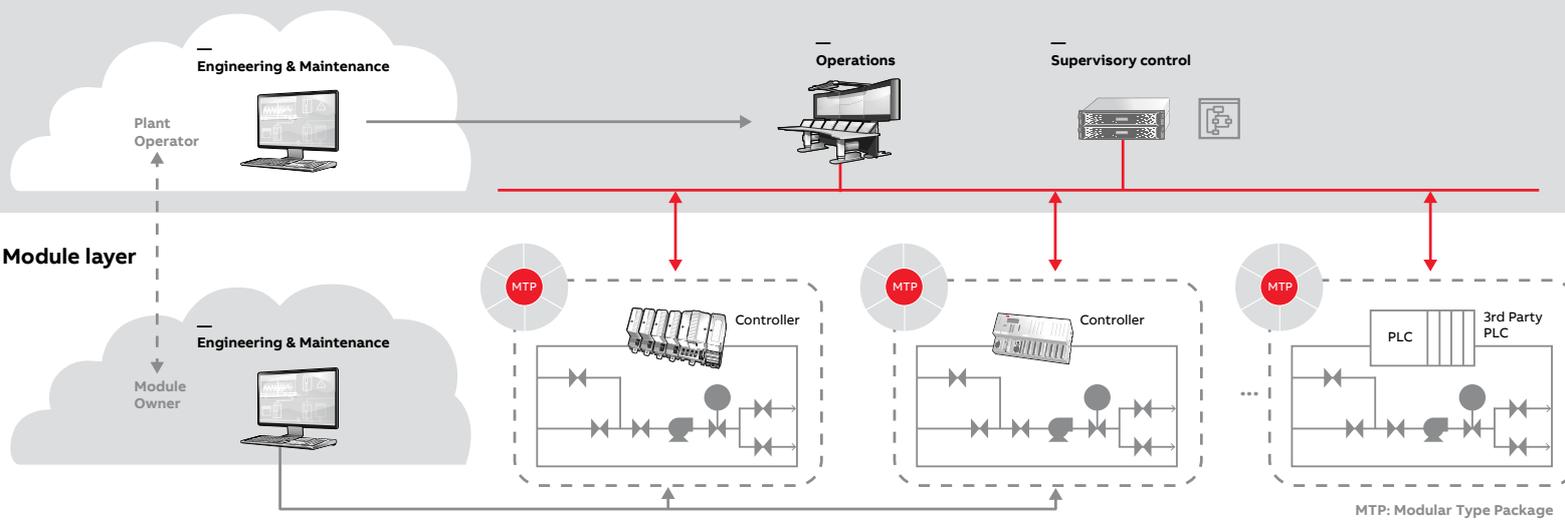

Step 3: A modular architecture still uses a central controller, but it needn't be anywhere near as powerful since control functions are distributed to smaller, less expensive controllers governing each module.
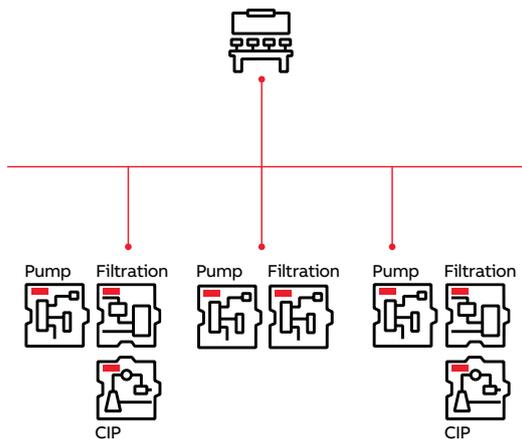
Step 4: Modules are thus equipped with their own intelligence to allow them to carry out tasks with less reliance on the master controller. Parts of a process can now be inserted, removed or adapted without affecting others around it.
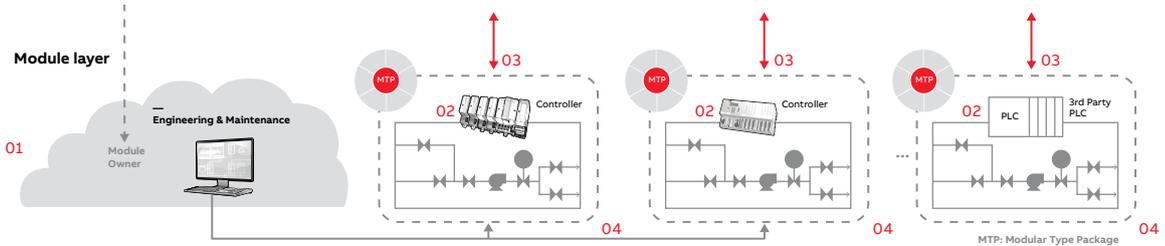
- Automated modules operate autonomously and in a network
- Reduced software complexity
- Process control system is agile and lean
- Standardization of modules is possible
- Numbering up/ numbering down instead of scaling up/down. Production is adapted by numbering up for higher demand and numbering down when demand falls.

Engineering & Maintenance

Plant Operator

Operations

Supervisory control

Module layer

Engineering & Maintenance

Module Owner

MTP — Controller

MTP — Controller

MTP — PLC — 3rd Party PLC

MTP: Modular Type Package

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What is the control infrastructure surrounding the modular approach?

To support the modular plants a new type of automation is required. This involves a plant orchestration with a local controller and visualization. As such, modular automation introduces several new terms to the industry. Here we will build up a system and introduce the new terms as we go.

Module layer

Engineering & Maintenance

Module Owner

01

02 — Controller — MTP — 03 — 04

02 — Controller — MTP — 03 — 04

02 — PLC — 3rd Party PLC — MTP — 03 — 04

MTP: Modular Type Package

Module layer
01: The module layer contains pre-automated modular units that offer encapsulated process functions as services. The units can be easily added, arranged and adjusted according to the production needs.

02: Controllers within the modules do not have many I/O.

03: Connectivity is via OPC UA and every module comes with a description language, where the file specifies an interface to the network.

04: The modules will require their own software, for instance for pump functions, but they needn't worry about what's going on in other modules, thanks to the use of Module Type Packages (MTPs) – see following page.

Orchestration layer – The distributed control system (DCS) will evolve into an orchestration system that manages the operation of the modular units.
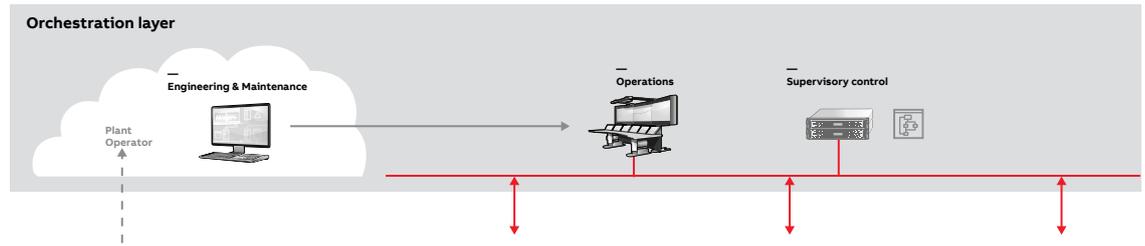
The DCS imports the MTPs from its built-in library of process objects.

The Intelligent Module contain services which are orchestrated by the plant operator in the DCS to reach the optimal production process.

Process line control helps each module anticipate the actions of other modules.

The DCS triggers the production process, collecting feedback of the services, handling the information and returning the commands for each process module.

All the information on the current state of the plant is available on the HMI of the DCS.

Module Type Packages (MTP) - The MTP approach is the key to opening the door for modular automation. MTP is a standardized methodology that creates the framework of interoperability between module and orchestration system - it allows a seamless integration of process modules into an orchestration system. Adhering to this standard should allow any module to plug into any automation system.

MTP XML files specifies the automation interfaces required for the communication between the module automation system and the orchestration system.

Upscaling is easier, as entire pre-tested control sub-system programs can be connected with other controllers. This is much quicker than writing new code from scratch.

MTPs describe the modules, and contain information on process control integration, the functions of operation monitoring and batch functions.

MTP is a new way of defining the description for process technology system modules. In this module description, information is stored that is necessary for integration into the automation system. The MTP comprises: Archive, HMI, Process control, History and Safety etc.
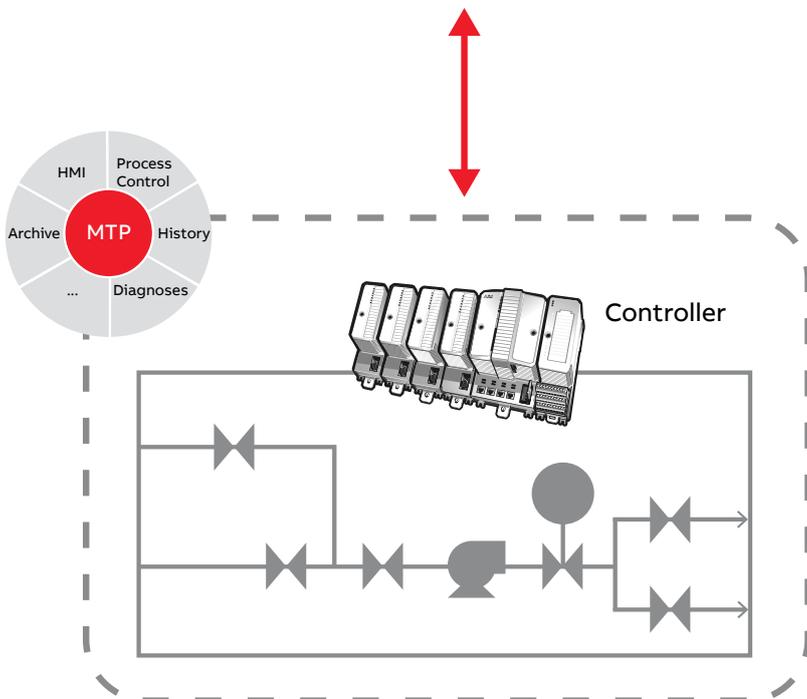
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What is the impact of MTP on process plants?

The MTP approach is the key to opening the door for modular automation.

MTP provides an open, standardized exchange platform whereby, on one side the supplier or vendor defines all the required functions and services offered by their modules. Meanwhile, on the other side of the platform, the user can access these modules and present them to their orchestration layer.

VDE/VDI/NAMUR 2658 recommends that automation solutions for modular process systems clearly divide functions between module controls and higher-level supervisory controls.

MTPs describe the modules, and contain information on process control integration, the functions of operation monitoring and batch functions.

The module supplier configures the module while the system designer uses the appropriate MTP in system design before configuring the overall system, eliminating the need to plan and programme the automation system manually while reducing the likelihood of errors.

Communication between management-level and module is through service-oriented architecture.

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How is modular automation a service-oriented approach?

Companies now have a choice between large-scale automation systems, whereby everything is controlled in detail, to a service-oriented, modular automation approach.

Thus, when plants are designed, the services needed to produce a product are defined. Each service has an associated module which is easily combined to produce the desired automation production line.

These modules are automated within their own functions, with safety integral to that module. This ensures that the modules can be plugged together to rapidly build the production line for bespoke products.

Users will need to change their ideas about micro-controlling a plant with valves, temperature and pressure measurement to a more service-oriented control strategy.

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What are the value propositions of modular automation for the various stakeholders?

	Challenge	Opportunity	Benefit
Module vendor/ OEM	Reduce cost, risk and schedule by standardizing control solutions	MTP allows integration to any orchestration system	Low risk of integrating module at any modular enabled site
	Developing customer relationships and business growth	Increases business scope as can add automation to modules	With regular customer contact, gain better understanding of their processes and add more services such as fleet management
	Increase automation expertise as intellectual property resides within modules and not with end user	Rather than being a supplier of valves and pumps, vendor needs to offer services that are embedded within modules	Individual modules achieve control of the hardware so no need to understand how entire process works. Intellectual property of a process plant, or specific process recipes, remains with the end-user.

	Challenge	Opportunity	Benefit
System integrator	Reduce cost, risk and schedule	Reduce non-standard interfaces by converging to one interface	Engineering design, installation and commissioning is quicker for Intelligent Modules
	Reduce cost, risk and schedule	Reduce commissioning time as module is complete	MTPs can be sent ahead for integration tests or it can be simulated so that it is much easy to integrate the orchestration system levels in the factory and not at site

	Challenge	Opportunity	Benefit
Plant owner	Standardisation	Partner with module vendors	Development time is substantially reduced. Higher production flexibility as can easily scale up, by simply ordering another module
	Reduce cost and risk	Specific production applications defined as packaged services	Module supplier delivers exactly what is needed. Simply integrate module into process automation system via MTP. Intellectual property remains with end-user. Upscaling is also easier, as entire pre-tested control sub-system programs can be dropped into other controllers. This is clearly far quicker than writing new code from scratch.
	Time to market with product variance critical and product life cycles getting shorter	Modular automation offers flexibility needed	Faster delivery of bespoke products
	Maintenance costs	If fault occurs, problems can be isolated to affected module	Quickly diagnosed and fixed with less disruption – in some cases while production continues around it. Maintenance teams hold instant spares for critical modules.

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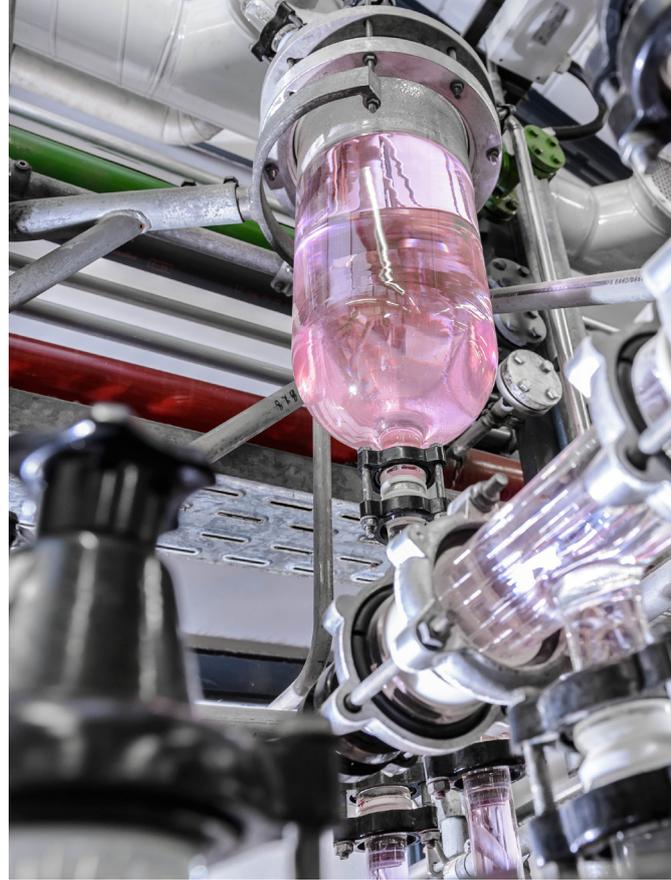
How will relationships between automation vendors and end-users change?

As modules move into the plants, the entire automation ecosystem changes, with questions being raised as to who owns the module. The future could see the module builder leasing the modules from one site to another.

Engineering could then be carried out locally within the module. Alternatively, it could be in the cloud, whereby the module owner uses a cloud-based solution to carry out the engineering and maintenance for the modules.

Meanwhile, the plant team becomes more focused in the orchestration level, while the modules are maintained by a third party.

However, the solution needs to be scalable, for scenarios needing a small number of I/O or tags. One idea is to deploy the whole solution onto a panel PC which has engineering and maintenance, module configuration and execution within one box.

Modular automation technology helps module vendors and plant owners meet the new demands of the process industry.

Modular automation changes the way end-users interact with engineering and automation vendors. Now, end-users define the "services"

they need and approach module vendors for an operational system that meets this service. As such, engineering automation now rests with the module supplier. This, in turn, reduces the commissioning time as the modules themselves are fully programmed and ready to run.

Now, the end-user needs to combine the process layer and production automation layer leading to shorter qualification and validation because the modules are already qualified with the vendor and then combine it together to do the validation.

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Is modular automation suitable for brownfield or greenfield projects?

Modular Automation can not only be implemented in greenfield projects but also brownfield projects as intelligent modules can be integrated to an existing DCS. Beyond cost, another major benefit is risk reduction in brownfield, greenfield and migration projects.

Proof points

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Where do you see the applications of modular automation?

Industries:
- Any industry requiring small batches
- Food & beverage
- Chemicals
- Pharmaceuticals
- Medical
- Textiles
- Printing & packaging
- Marine

For industries like food and beverage, where recipes and ingredients frequently change yet homogenisation and end quality are essential, a modular approach can allow food processors to add, remove or change recipes from a function library, with almost no interruption to production.

Modular machinery can also be easier to clean, as processes that aren't required for a particular production run can be stopped and maintenance carried out without necessarily having to shut down the whole process. This is ideal for industries such as medical supplies, where regular washdowns are essential to prevent contamination.

Even if an entirely modular approach is not necessarily a perfect fit for every production line, almost every industry could benefit from modularizing discrete processes where possible, reducing reliance on a single point of control.

If production no longer needs to be paced by the slowest operation then modules can be optimised individually, which is far quicker and easier than having to reprogram and extensively test an entire process from a central controller.

Modular automation is about creating several plants within a plant, making each segment of the production process more manageable, more flexible and cheaper to run. The idea of infinite granular customisation, whereby each individual product can be fully tailored to the customer's particular preferences, and instantly manufactured and dispatched from the same automated product line one after another, is now technologically feasible using modular solutions. Such systems require careful design but afford unprecedented agility to react quickly to market changes while keeping wastage and downtime to a minimum.

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Where has modular automation been tested?

A pilot is currently ongoing with one of the major life science companies, Bayer AG.

ABB has developed a solution for cost-effective modularization with plug and produce capabilities and a pilot is currently ongoing with one of the major life science companies, Bayer AG. Several so called Module Type Package (MTP) control sub systems and a module designer have been delivered and are currently running with a modular enabled ABB Ability™ System 800xA for the orchestration.

ABB

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