Industry 4.0 Changes Selection Criteria For Machine Control Architecture:

Why IPC Now Prevails over PLC and PAC for Machine Control

WHITE PAPER

KINGSTAR

Introduction

For over 20 years, machine builders have struggled to choose the right machine control architecture that would deliver the desired performance and quality, while protecting their investment and long-term interests. Programmable logic controllers (PLCs), industrial PCs (IPCs), and programmable automation controllers (PACs) all offer merit and promise, so decisions are usually made based on the specific requirements that address the complexities and scalability of the target machine.

Industry 4.0 and IIoT completely change the decision criteria in favor of IPC. Today's machine control requirements demand unprecedented integration and adaptability that can best be achieved with an all-software based IPC that runs on x86 hardware. In addition to the basic machine controller functionality, machine automation in the Industry 4.0 era, must now: adapt to feedback from cloud analytics to optimize performance, embrace standards like OPC-UA, EtherCAT, PLCopen to simplify machine communication and construction, and run third-party software on the controller, like end-point analytics packages to add value yet shorten time to market.

This new requirement that a machine controller must run best-of-breed third party software completely changes the decision criteria favoring the IPC over PLC or PAC. Only the x86-based IPC running Windows or Linux offers a vast array of third-party, off-the-shelf software that is immediately available to the machine builder. Contrast this with a PAC or PLC which are largely closed and the vendor or the machine builder must re-develop the high-value network and analytics applications that are already available for the IPC.

This white paper will describe the differences between PLC, PAC and IPC based machine controls, while exploring how Industry 4.0 changes the requirements for a valuable machine control architecture and explains why the IPC now offers, by far, the best machine control architecture compared to PLC or PAC.

Comparing three basic machine Control Architectures: PLC, PAC, & IPC

Today's control systems are far more powerful and flexible; are easier to configure and program, and offer more diverse and simplified communication mechanisms than ever before. With so many control vendors in the market the competition is fierce and the ability for an engineer to compare and understand the feature and value differences in the control systems architectures is difficult. Over the past 20 years, an engineer had three basic machine control architectures to install in a machine: programmable logic controllers (PLCs), industrial PCs (IPCs), and programmable automation controllers (PACs).

Until the late 1960s control systems were comprised of relays controlling discrete functions, with independent loops controllers overseeing and controlling analog functions. This design caused many challenges, including the consumption of large spaces for the relays between controllers, expensive changes, and complicated troubleshooting when problems would arise.

The PLC was created in the early 1970s, and began to be used in industrial applications replacing the relay systems. The first PLCs that were developed, although smaller than the original relays, were still large and programming was done with dedicated terminals and a limited instruction set. By the late 1970s distributed control systems (DCSs) started to replace the individual loop controllers, centralizing the process analog control environment. Historically DCSs are comprised of multiple input/output (IO) racks that are located close to the end control devices and a PC-based visualization and engineering station. The engineering screens are integral to the DCS, as they are used to interact with the process loops. By the early 1980s, PLC systems began to take the path of DCS systems and contained distributed components and racks.

PLCs have seen many advances since their initial conception, including increased processing power, increased memory, increased bit handling, and decreased size. These significant advances have also paved the way for many other classifications of automated systems. Two of these classifications are process automation controllers (PACs) and industrial PCs (IPCs). Although PLCs do contain favorable qualities, PACs and IPCs add new functions and capabilities that help set them apart. To compare these three architectures requires a baseline understanding of the basic benefits of each.

PLC – Programmable Logic Controller Overview

PLCs are powerful and capable controllers, and remain to the de facto standard for many automation projects. PLCs are commonly used in a broad number of systems and including original equipment manufacturer (OEM) machines, a few examples in material movement might include packers, palletizers, fillers and conveyors. PLCs are often paired with a machine-level, human-machine interface (HMI) package for visualization. They handle high speed I/O, digital and analog I/O, and sequencing. PLCs are also capable of handling high speed counting, network interface, and motion control.

Practically all PLCs have a built-in field-, device-, or Ethernet-level communications. Examples of these include EtherCAT, Modbus, Profinet, and Ethernet. These networks are for PLC to PLC communication, distributed I/O capabilities, and HMI/SCADA communications. PLCs are often very cost effective as well, staying competitive with other control systems, but there is a limit as to the amount of I/O they can handle.

There are also limits in the kind of programming sophistication or logic that can be applied. For example, hardware-based PLCs usually support ladder logic and do not support a C++ or object-oriented logic. Although based on demands from IoT, some leading-edge software-based PLCs already support 21st century object oriented programming (OOP) techniques and the OpenPLC standards body is now considering new OOP constructs to the PLC standard

PAC – Programmable Automation Controller Overview

PACs were designed with all the same basic capabilities of the PLC systems, but with added features to increase functionality. Namely, PACs were designed with the intent of handling a much larger distributed control for applications such as large packaging lines, discrete manufacturing control systems, and process control of larger skids or plant processes. PACs have instruction sets that are more advanced and purpose-built, such as sequencing, device-control, process control and batching. They can also be programmed to be industry-specific, with instruction sets focused on oil and gas, nuclear, and other specialty areas. These specialty instruction sets are very powerful, requiring increased capabilities of the PAC to execute commands correctly in a black-box manner. This can limit the end user's ability to debug a system. Be that as it may, PACs can be used with enterprise-level supervisory control and data acquisition (SCADA) systems for total plant-wide control and data collection and processing. PACs are often based on an architecture that are similar to an IPC and even use x86 chips, but they do not run third-party PC software. Machine builders usually become locked into a given vendor's PAC modules. The lines between PACs and DCSs have been blurred with the further advancement of PAC instruction sets and corresponding HMI libraries. Most of the functionality, integration, and power of a DCS is now provided by the PAC manufacturers. PACs are capable of advanced control, which previously had been reserved for large DCS systems, and are used in complicated closed-loop control where PID would be inadequate.

The key advantage to a PAC can also be its biggest liability. Most PACs are modular hardware which makes expansion easier and they have a powerful development language. The challenge arises if there is a task that cannot be handled by the PAC and the vendor "locks" the machine builder in. As one example, in the Industry 4.0 era, more and more companies are seeking to put edge-analytics on the machine controller and not rely on the cloud. If the PAC does not have the ability to load third party software, then the machine could miss out on offering competitive and valuable functionality or could end up being charged a lot for sending data to the cloud for all the analytics processing

IPC – Industrial PC Overview

Industrial PCs made their emergence in the 1990s when automation companies began designing software to emulate a PLC environment that could run on a standard PC. At the beginning, using PCs for automation were unreliable as the host operating system (OS) was not always stable.

However, there have been significant advances in the IPC field with the use of hardened industrial computers and significantly more stable OSs. Some manufacturers have even created their own IPC with real-time kernel for automation. This real-time kernel allows the automation to be separate from the OS environment and take priority over the OS for certain tasks and features, such as with I/O interfacing. An example of a real-time kernel is RTX64 from IntervalZero. RTX64 transforms Microsoft Windows into a Real Time Operating System (RTOS).

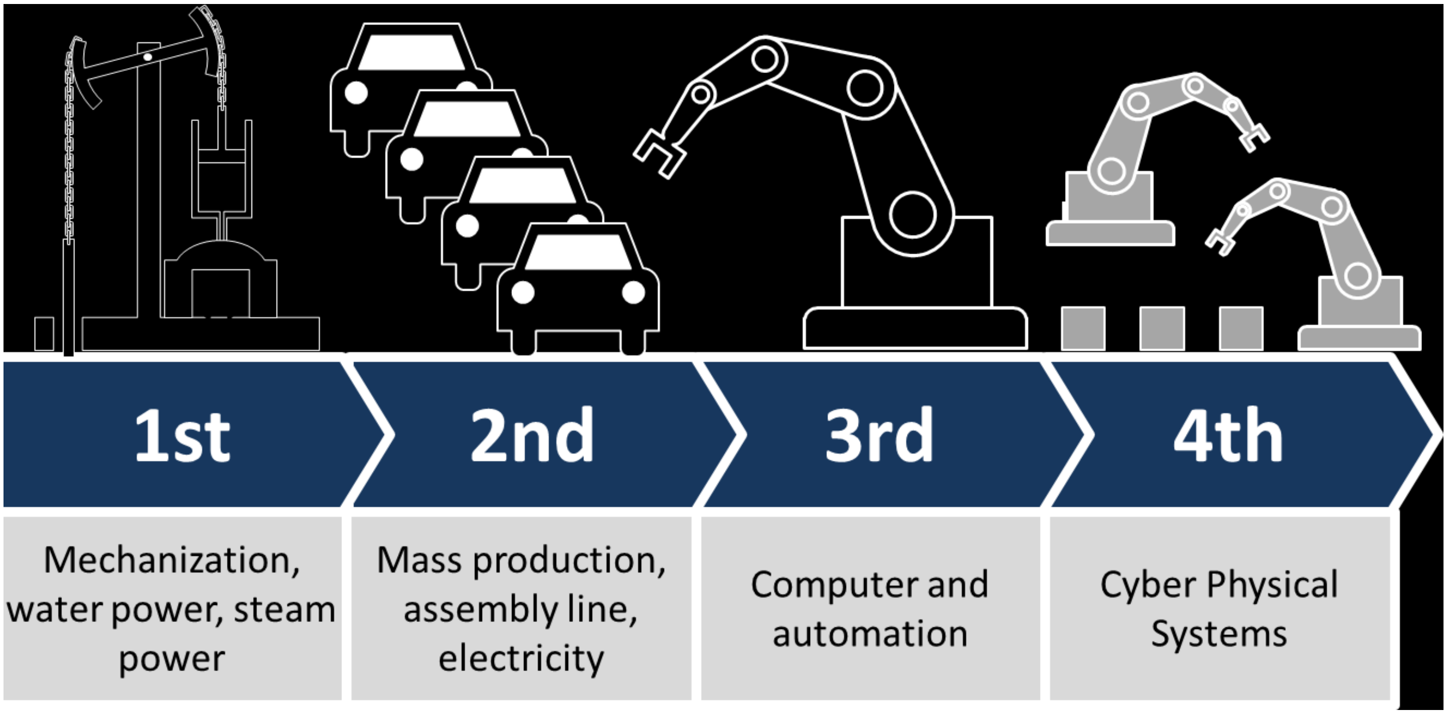
Since IPCs run on PC platforms, they contain more modern processors and more memory than standard PLCs. A significant advantage of IPCs is that it possible to run the HMI application on the same machine as the automation program, therefore decreasing the cost of machinery. Some uses of IPCs included OEM machines and other smaller projects where space may be more limited. Utilizing an IPC allows machine builders to utilize 3rd party software right on the same IPC as the machine control. Examples of such a package might be secure communications like OPC-UA for cloud connectivity or a 3rd party analytics package that summarizes and analyzes data before it gets sent to the cloud.

Demands from Industry 4.0 Changes the Decision Criteria for the Optimal Control Architecture

Until recently, when choosing between PAC, PLC or IPC, there are many factors that come into consideration, such as budget, size, support, complexity and future expansion. You also cannot ignore systems requiring safety integrity level (SIL) certification for safety and mean time between failure (MTBF) times.

Often the machine design engineer determines the brand of a control system. This is typically related to the type of existing programming licenses a customer owns, maintenance and engineering training that will need to be done, and regional contractor support. All of these criteria factor into the Total Cost of Ownership and brand familiarity reduces retraining and usually has consistent quality.

Because it so dramatically changes the optimal machine control architecture, the importance of Industry 4.0 cannot be overstated. Amazon transformed retailing and Google dominated advertising by applying a tightly integrated digital strategy to a traditional industry. The Industry 4.0 applies the same concepts in manufacturing that Amazon did in retailing in order to disrupt and innovate the supply and value chain. Machine builders and manufacturers that embrace Industry 4.0 techniques and implement them in their factories stand to dominate their respective vertical markets, while those that don't will be rendered uncompetitive. Initiated by the German government, the Industry 4.0 movement is focused on creating smart manufacturing facilities by digitalizing the value chains. This will have a profound and long-term impact on manufacturing businesses worldwide. In fact, most recognize that the 4th revolution in manufacturing has already begun.



Further, as demonstrated by a Gartner citation, the often-overlooked but equally-important component of Industry 4.0 is a "smart" machine controller. The machine controller is just as critical and possibly more critical than the cloud functionality. It is the source of the real architectural breakthrough where information collection, aggregation and secure delivery to the cloud begins and ends – in short, where the actionable insights get implemented. Gartner also believes that endpoint analysis will become extremely sophisticated and predictive over time to improve system-wide responsiveness. If the machine controller is not "smart" enough to adapt to changing manufacturing conditions based on actionable insights or insights that the controller can generate itself, then the Industry 4.0 vision will not be achieved.

Further, as Deloitte points out in their 2019 perspective paper entitled, Software really is "eating the (tech) world", the most effective solutions are all software on an IPC – no proprietary hardware. They document the trend over 25 years where the market has shifted from a mostly hardware-driven economy to a software & digital driven economy. And this is true for machine controllers which have been resisting change but can no longer do so because of the demands of Industry 4.0.

Industry 4.0 changes everything because all machine control architecture must now consider Industry 4.0 requirements if they want to be relevant in a software-dominated world. Until Industry 4.0, most machine builders and machine users assumed that the machine would largely be an island of automation. Yet, Industry 4.0 demands unprecedented connectivity to achieve a breakthrough in quality, shop-floor performance and value. And it is not just connectivity to the cloud; it is connectivity amongst machines on the shop floor so that a controller can share information with other controllers and they all can improve overall shop floor performance. Industry 4.0 expects the endpoints to become smart machine controllers and intelligent edge devices which are the cornerstones to building smart factories.

But Industry 4.0 isn't just focused on a single controller for a single machine either. Today's industrial networks with a tightly integrated plant floor can support multiple controllers on a single PC - a line controller for multiple machines within the network. The integration of the plant floor will allow customers to be more flexible as technology advances and everything becomes more integrated over time as we move towards an Industry 4.0 future.

So while the factors that come into consideration when choosing the machine control architecture, such as budget, size, support, complexity and future expansion are all still relevant when making an machine control architecture decision, all these factors must be viewed with an additional filter for how it helps or hurts the machine builders ability to plug into Industry 4.0. In the end, Industry 4.0 adds three principle features that must be considered when selecting the ideal machine control architecture.

First, Industry 4.0 demands an all-software approach to machine automation that transforms a typical controller into a "smart controller." Only an all-software approach can offer the flexibility required to take insights from the cloud or other controller and make a decision on the fly to change the machine operation. Second, an all-software-based architecture that utilizes a real-time kernel is key but not just any software. The ideal all software architecture demands the kind of openness that can run multiple controllers on a single platform ad can run third- party software like a digital twin or analysis package directly on the controller. And third, the ideal machine control architecture must embrace standards to lower the barriers to integration and digitization of the manufacturing value chain.

In the end, as documented by Deloitte and predicted by one of their sources by Marc Andreessen, only an all-software approach will be strategic and satisfy the future needs, therefore, only an open, IPC-based controller can transform the typical controller into a smart controller. A PLC and PAC are not sufficiently open or designed to support an all software approach nor run third-party software. PACs and PLCs are not able to anticipate or adapt to the future requirements that will emerge from the increased connectivity that is demanded from Industry 4.0 goals. Choosing the correct control platform based on an IPC from the beginning will increase the odds that a project will be a success, and ultimately be prepared for an Industry 4.0 compatible future.

Conclusion

Today's more flexible, faster, smarter machines can communicate with one another and process/analyze data in real-time, creating game-changing economic and productivity opportunities. Importantly, information sharing via Industry 4.0 standards combined with artificial intelligence will only increase the speed with which demands will be put on the system. Companies offering machine-automation and machine-control systems that are the most flexible, precise and highest-performing will generate the most value for their customers.

Until recently, PLCs, PACs and IPCs architecture offered similar functionality in the context of stand-alone machines or islands of automation and companies struggled could struggle to choose the right architecture. Industry 4.0 changes all that by eliminating the islands of automation and replacing it with a network of cloud-connected controllers that form a fabric of smart manufacturing. PLC and PAC based machine control architectures will not have the same longevity because of Industry 4.0 demands. These network and smart controller requirements demand an all-software approach which is only offered by an IPC control architecture.