Central vs. distributed control technology – a matter of philosophy

The choice of control architecture – centralized or distributed – is ultimately a philosophical question. Josef Papenfort, TwinCAT product manager at Beckhoff, summarizes the arguments for and against these approaches using an assembly line as an example.

Assembly lines, a machine for assembling mobile phones, for example, are characterized by modular structure. This consists of modules for the different manufacturing stages, such as pick-and-place units, robots, welding stations and, of course, a logistics unit that transports the individual parts between the modules and controls the supply of assembly parts. In addition, critical services such as recipe management, quality statistics and parts tracking are required.

An assembly line called "modutec" was recently automated by Feintool Automation, based in Aarberg, Switzerland (a detailed description of the modutec system can be found on page 30). In principle, such a machine can be automated with centralized or decentralized control technology. What are the reasons for choosing one or the other control architecture? We will provide a detailed analysis to enable both options to be assessed. In addition to the hardware, software and the fieldbus, the Motion Control aspects of the equation will also be discussed.

Local or distributed control architecture?

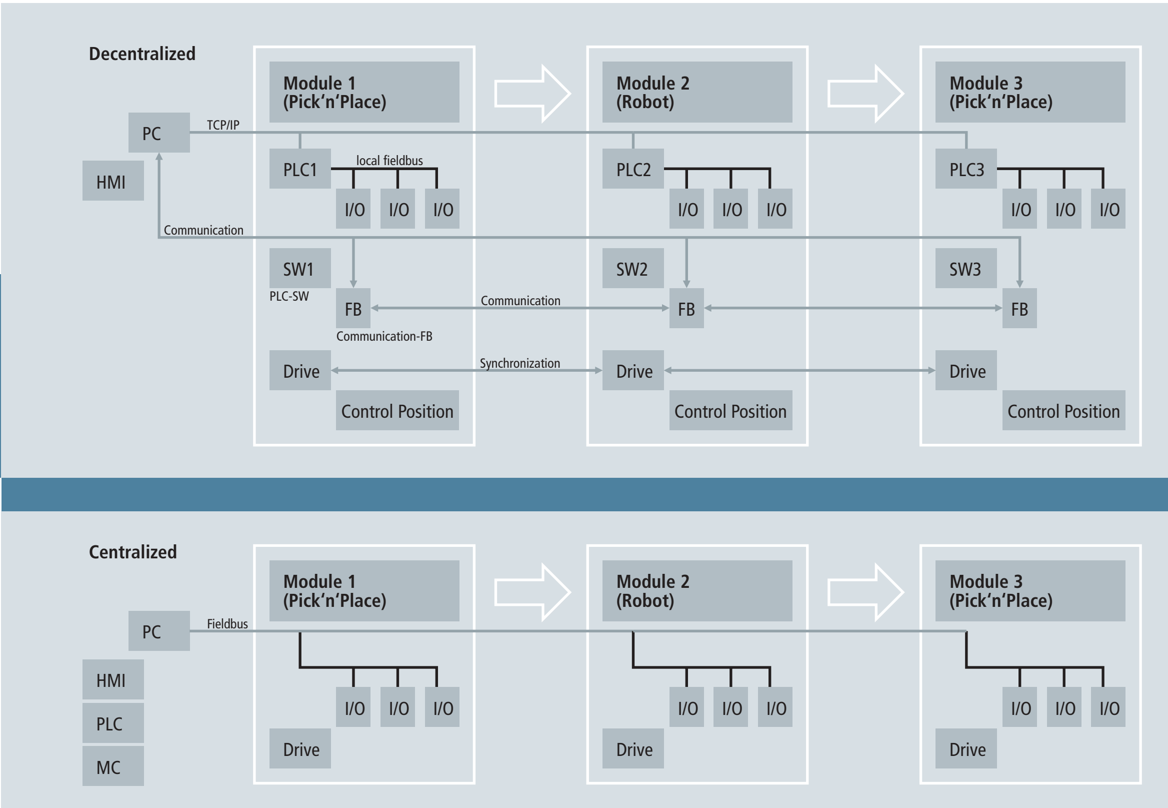
Hardware: With distributed control architectures, the hardware, i.e. the number and quality of the CPUs used, is determined by the number of modules. Each module has a controller. Apart from the distributed controllers, the system usually features a central master PLC, which deals with management tasks such as logistics, parts tracking and central statistics. The module PLCs automate their respective modules. They usually have no visualization or operation facilities.

The master PLC deals with visualization and operation of the complete plant. Since the scope of the control tasks executed in the modules is small compared with the overall automation task, a relatively low-performance and, therefore, low-cost PLC can be used. The module PLCs must be able to communicate with the master PLC via a high-speed bus. Usually an Ethernet-TCP/IP-based network is used for this purpose. Data exchange is either via cyclic exchange of network variables or via acyclic communications modules. The module PLCs have to be synchronized with the master PLC when the plant starts or stops. The machine can only start once all subordinate PLCs have completed their start-up procedure. Shutdown of a distributed control architecture with distributed remanent data is also more complicated.

Software: The PLC programs running on the module PLCs are usually not very sophisticated, since the task to be programmed is simple. A single time level, i.e. a single task, is usually sufficient. The situation for communication projecting and programming on the master PLC side is more complex. The management and distribution of PLC programs to the individual controllers should not be underestimated.

Fieldbus: Of course, the I/Os and fieldbus topologies are just as simple as the PLC programs on the module PLCs. Since only a small section has to be automated, relatively few I/O signals have to be dealt with – local I/O is usually sufficient. If necessary, an additional conventional fieldbus (with few nodes and small spatial extent) may have to be used. The I/Os have to be configured and the fieldbus diagnosed individually for each module PLC.

Motion Control: Due to their low performance, module PLCs can usually not be used for controlling several axes. If several axes have to be moved and possibly synchronized, the use of intelligent and, therefore, expensive axes is difficult to avoid. Position control and synchronization is dealt with via a decentralized architecture on the drives.



Decentralized: Master PC for HMI, PLC per module connected to I/O via fieldbus, communication via FB, intelligent drives with their own positioning control and synchronization methods

Centralized: Master PC running HMI and centrally controlling I/O of each module, thus, centrally coordinating control positioning of drives

Central control architecture

Hardware: In contrast to distributed architecture, a central architecture usually features a powerful computer, often a PC, that deals with all tasks such as I/O, PLC and motion control. Computing capacity, therefore, has to be significantly higher. However, there is only one CPU – which means only one spare part.

Software: The software is certainly more comprehensive. For reasons of reusability and maintenance, the software has to be structured and modularized. IEC 61131 provides object-oriented approaches for this purpose. Since there is only one PLC program, storage and archiving are very simple, and central start-up or shutdown of the PLC is straightforward.

Fieldbus: The central fieldbus master is a crucial advantage for configuration, diagnosis and maintenance, although if conventional fieldbuses are used, it may also be critical, given the extent of the system and the required quantity of slaves.

Motion Control: Since motion control calculations also have to be performed in the central PC, the demands on the fieldbus are even higher. If a fieldbus is to be used for I/O and Motion Control, an additional factor apart from an increased number of nodes are temporal requirements. For position control on the PC, minimum cycle times of 3 – 4 ms are often required. Conventional fieldbuses quickly reach their limits for this type of application. However, Motion Control on a central CPU also offers a number of advantages. Since position control, coupling and axis synchronization calculations can solely be dealt with by software components in the PC, the drives themselves can be 'dumb'. Only current control has to be implemented. Synchronized drives respond very quickly. No potentially troublesome coupling of the drives among each other via special buses is required. The higher performance of the PC CPU and the almost unlimited storage capacity enable very complex table coupling. A standard PIII PC can easily deal with up to 100 position-controlled axes. The performance of new CPUs keeps increasing, so further boosts can be expected. Currently, the fieldbus is clearly the bottleneck.

Against this background, Beckhoff developed EtherCAT, the new Ethernet-based fieldbus. The number of devices or the size of the system suddenly becomes irrelevant. Cycle times of 100 µs for more than 100 axes are possible. Since the price for EtherCAT components is no higher than for standard fieldbuses, EtherCAT can be used to realize complicated topologies with exacting requirements in terms of cycle time.

Conclusions

Distributed, local control technology offers an architecture that is very structured overall. Replacement and testing of individual modules is straightforward. Due to the simple topology, standard fieldbuses can be used without problems. Communication of the modules among each other, with the master computer and for synchronizing the PLCs during start-up and stopping is relatively complicated.

Central diagnostics, commissioning and maintenance are arguments for central control technology, as are simple start-up and stopping of the plant, and simple administration of the single PLC program. If the fieldbus is powerful enough, a modern PC can control and synchronize a large number of axes.

A range of very different criteria are relevant for selecting the architecture: In addition to a clear system architecture, flexibility and reusability are important decision criteria. Costs come into the equation in terms of the hardware, but also for wiring, commissioning and configuration. Training costs are another item that should not be overlooked.

Distributed or central? This continues to be a question of philosophy, although with the hardware 'PC' and EtherCAT as the fieldbus, with IEC 61131 and powerful motion control functions, complex systems can be realized with a central approach. This also brings the advantages of central program development and administration, central fieldbus diagnostics and central motion control.