PC-based control – the ideal technology platform for the "Internet of Things"

Industry 4.0: Realization today with proven control architectures

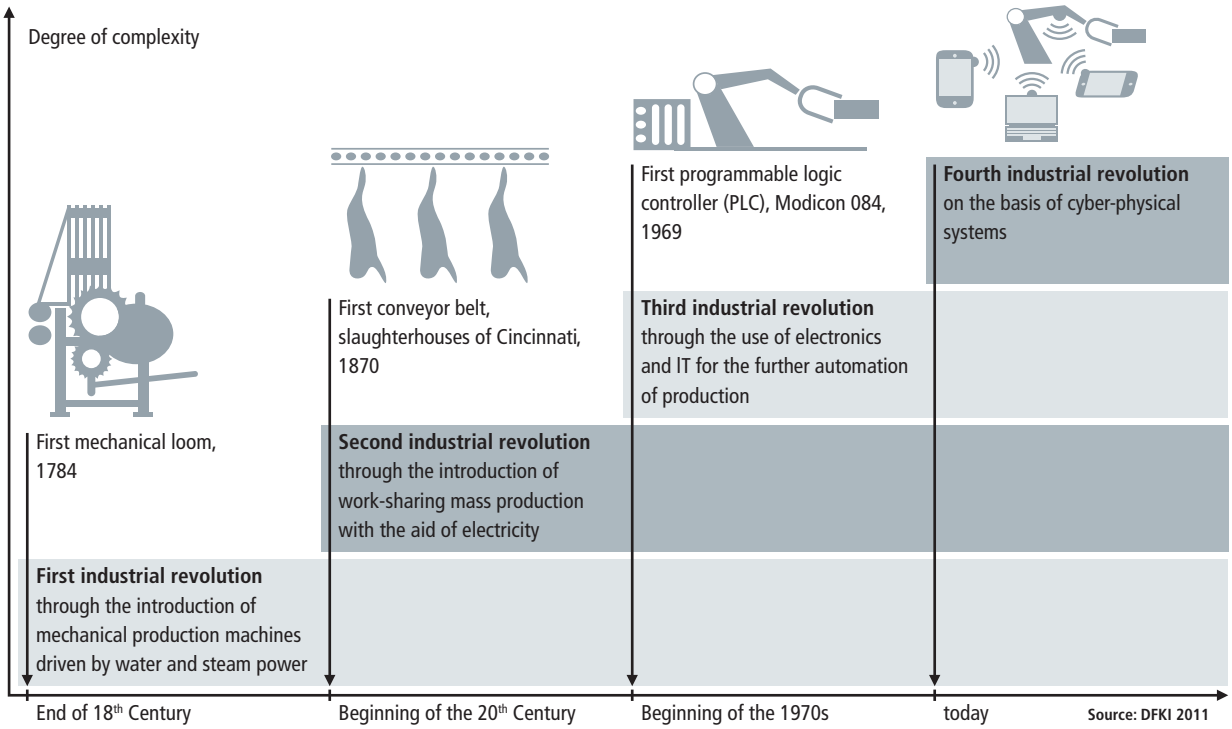
A revolution is by definition a radical change of existing conditions. As history classes stress, certain points in time are strongly associated with revolutions; however, close examination often reveals more subtle, evolutionary developments. This particularly applies to the ongoing industrial revolution as currently discussed in its fourth embodiment: Industry 4.0. At the core of this development is the convergence of information and automation technology, a phenomenon for which Beckhoff has already laid the foundation more than 25 years ago with PC-based control – which still offers the optimum control architecture for the concepts of the future.

Following the introduction of mechanical production systems at the end of the 18th century, the work-sharing mass production started at the turn of the 20th century and the automation of production processes beginning in the mid-1970s, a fourth industrial revolution is now on the horizon. The term introduced for this phenomenon – Industry 4.0 – already points toward intelligent, networked systems: Information Technology (IT) and Automation Technology (AT) combine traditionally separate production environments to produce universal production worlds which are partly physical in nature, yet they attain new functionality in the cyber space of web connectivity.

It is no coincidence that the term "Industry 4.0" was coined in Germany, since the conditions are ideal for such a (r)evolutionary development in this part of the world. Despite the business challenges inherent to high-wage countries, Germany has maintained its excellent reputation as a manufacturing nation thanks to high quality and efficiency and, last but not least, high-performance automation technology. It is exactly this combination that gives Germany a unique, globally competitive advantage: this is not due only to the manufacturer companies themselves, but also the associated machine builder companies and their suppliers, the automation specialists. This synergy and focus on high-tech solutions create ideal conditions for the development and implementation of trend-setting concepts such as Industry 4.0. The German government has recognized this and is funding the interdisciplinary future project Industry 4.0 within the context of the High-Tech Strategy 2020.

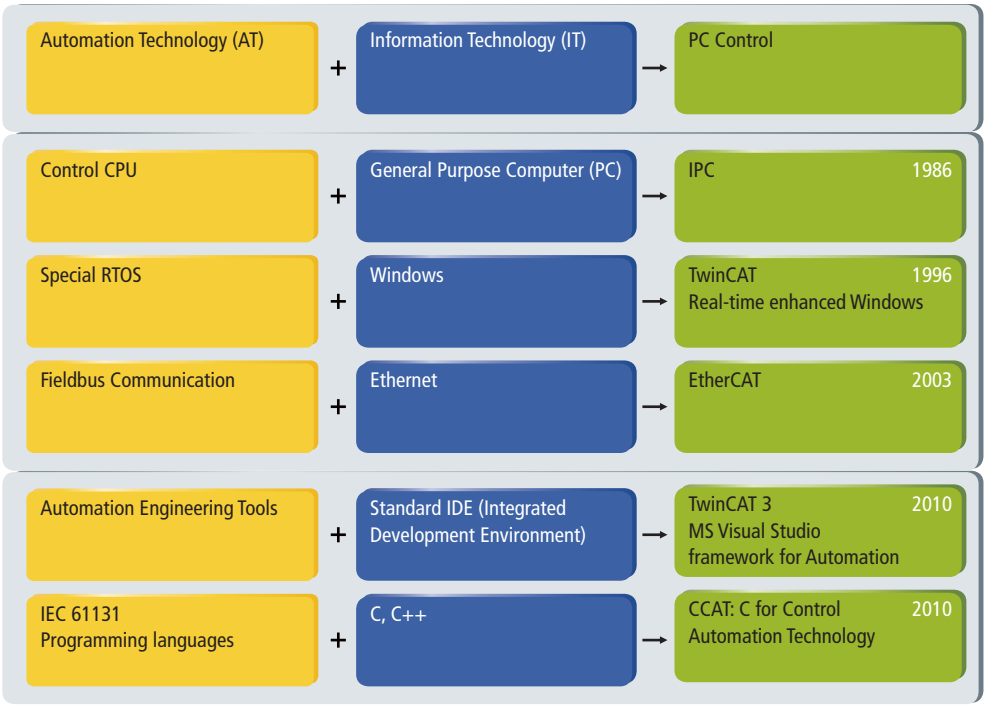
Industry 4.0 – defining a vision

But what does Industry 4.0 really mean? One clear definition can be found in the funding guidelines of the BMBF (Bundesministerium für Bildung und Forschung), which is the German Federal Ministry of Education and Research: "The flexibility that exists in value-creating networks is increased by the application of cyber-physical production systems (CPPS). This enables machines and plants to adapt their behavior to changing orders and operating conditions through self-optimization and reconfiguration. This interaction between the real and digital world in a modern factory creates the basis for an "Internet of Things." The main focus is on the ability of the systems to perceive information, to derive findings from it and to change their behavior accordingly, and to store knowledge gained from experience. Intelligent production systems and processes as well as suitable engineering methods and tools will be a key factor to successfully implement distributed and interconnected production facilities in future 'Smart Factories'."



The fourth industrial revolution on the basis of cyber-physical systems enables the consistent convergence of automation and information technology.

Source: DFKI 2011 (German Research Center for Artificial Intelligence)



The advantages from the convergence of IT and AT (automation technology) were made possible for industrial applications by PC-based control from the very beginning.

The underlying concept for Smart Factories is the "Internet of Things," a phrase coined in 1999 in conjunction with RFID and sensor technologies describing the networking of and with everyday objects. The prerequisites for a consistent implementation are the cyber-physical systems (CPS) which were first described in 2006. This means cyber components are closely intermeshed at all levels – for discrete processing of information and communication – as well as physical components. The BMBF funding guidelines also reflect this where they explain: "Cyber-physical systems – as an extension of today's mechatronic systems – are equipped with intelligent sensors for perceiving their environment and actuators for influencing it. They differ from existing technical systems by their ability to interact with their environment, to plan and adapt their own behavior in relation to this environment and to learn new modes of behavior and strategies, optimizing themselves as a result."

Flexible centralized control architectures are future-proof

Granted, the CPS definition is open to wide interpretation. It extends as far as workpieces or blanks which, thanks to their own intelligence, move independently through the production process, specifying processing parameters to the production units. Since as far back as the 1980s, when for example, the idea of self-configuring multi-processor systems was born, such autonomous subsystems have proven to be intellectually inspiring concepts that, however, do not translate into working practical solutions.

In principle, PC-based control offers enough flexibility to implement both centralized and decentralized control architectures. Within the field of automation, however, a hierarchical organisation will remain the first choice for some time to come, as will I/O systems with reduced intelligence. This concept relies on clearly defined levels as well as the interfaces between them. With Industry 4.0, it is just the universality of communication that will be emphasized more strongly, for example, by assigning an IP address of its own to a limit switch. An automation device will have to provide direct access to devices in order to enable such an "Internet of Things."

Ultimately, in order to realize Industry 4.0 following a genuinely holistic approach, three aspects must be implemented: horizontal integration across value creation networks – i.e. beyond the limits of individual companies – vertical integration or networked production systems and the universality of engineering over the entire product life cycle. In close connection with appropriate business management application software this approach should enable companies to tap into significant optimization potential as well as additional business models – e.g. via an "Internet of Services." PC-based control offers a future-proof basic structure for all of this, especially since it can be adapted very flexibly to varying application requirements: intelligence can be arranged in a hierarchically modular fashion under the central controller, but also decentralized, i.e. with equal rights if need be. It is with good reason that the traditional automation pyramid is already used very successfully everywhere, and the analogy with biological evolution, for example, shows that precisely this hierarchical structure is a guarantee of success. It has produced largely centralized concepts – in the case of man and animals with a central brain and decentral sensors and actuators. The brain as the center for data processing enables optimized movement and control sequences in nature as well. Beyond that there are social concepts, as in an ant colony, in order to coordinate centrally controlled individuals.

Accordingly, managing director Hans Beckhoff sees excellent opportunities worldwide for further growth with PC-based control technology in mechanical engineering and plant construction as well as in building automation and process technology: "With our PC-based control technology both we and our customers are ideally positioned for exactly the kind of high-tech strategy pursued by the German government under the designation of "Industry 4.0". The convergence of IT and automation technology in particular is the core principle underlying both Industry 4.0 and PC Control. We are pleased that this concept is now making further inroads into the awareness of the general public and, in particular, of the technical public. We are sure that Germany as a manufacturing nation as well as the international automation community

will benefit greatly from this philosophy as Beckhoff's customers already have since the beginnings of PC Control technology more than 25 years ago."

This revolution starts with PC-based control

This idea of the convergence of IT and AT (automation technology) had its true genesis in 1986 with the beginnings of PC-based control. As a pioneer of industry-compatible IT hardware, Beckhoff has been supplying PC-based control technology for over 25 years – a technology that not only provides an incredible increase in performance (still in accordance with Moore's Law), but also fully exploits the advantages provided by the convergence of these two worlds of technology. Even at the beginning it was recognized clearly that the Industrial PC enables the design of high-performance controllers in the most diverse form factors and, thanks to its openness, optimum IT orientation.

With respect to Industry 4.0, Beckhoff has shown an outstanding clarity of vision, not only in terms of technology but also in terms of philosophy, i.e. with the introduction of the Industrial PC and thus the convergence of IT and AT. In addition to that, the company took part in research projects with comparable approaches to Industry 4.0 – long before the term was even defined (see box text, "History of the vision").

After the Industry 4.0 project was conceived from the perspective of the information and communication technologies and adopted into the German government's High-Tech Strategy, a working group, "Industry 4.0" was established in late 2011 on the initiative of the Business & Science Research Union. This working group was chaired among others by Prof. Dr. Henning Kagermann from the German Academy of Technical Sciences (Acatech). Accordingly in April 2012, Acatech published a research agenda on CPS, to which Beckhoff, among other companies, had contributed in co-operation with Prof. Dr. Birgit Vogel-Heuser from the Technical University of Munich. The research was conducted from the point of view of production technology and automation for the "Smart Factory" scenario.

Moreover, Beckhoff is one of the core companies of the technology network "it's OWL" (intelligent technical systems Ostwestfalen-Lippe, or East-Westphalia-Lippe) which was distinguished in 2012 by the BMBF as a "Leading-Edge Cluster" and represents the first large-scale project supported in the context of Industry 4.0. On the way from mechanical systems or mechatronics to intelligent technical systems in the sense of Industry 4.0, Beckhoff is heading two important innovation projects as the consortium leader: "ScAut" – short for Scientific Automation – deals with the integration of findings from engineering science into standard automation, while the idea behind "efa" – Extreme Fast

History of the vision

Gerd Hoppe, Corporate Management, illustrates that the idea behind Industry 4.0 has a long history at Beckhoff.

PC Control: How long has Beckhoff been focused on the ideas surrounding Industry 4.0?

Gerd Hoppe: The general strategy behind Industry 4.0 is the fusion of standard IT with other technical domains, including the manufacturing industry. Beckhoff has been pursuing this idea for over 25 years with the use of standard PC technology for machine control. A good example of the holistic approach from the early beginnings is the 4-year EU research project, Eupass which started in 2004 and where Beckhoff was in charge of the control technology working group. The goal was to achieve a flexibly adaptable manufacturing environment without high mechanical engineering expenses – the approach that we call "zero engineering." This was realized using standardized machine modules that each had an assigned set of tools and corresponding software support. With this component family it was possible – with software support – to automatically assemble a control solution for a manufacturing plant by intelligently combining units, supplies, materials and tools. At the same time, entirely in keeping with the concept of Industry 4.0, an Internet-supported database or "repository" provided support with descriptions of the modules, tools and their capabilities as well as libraries with software function blocks for the respective skills of the machines, i.e. the production characteristics and manufacturing relationships.

PC Control: Has this early Beckhoff know-how contributed to the considerations for Industry 4.0?

Gerd Hoppe: The Industry 4.0 strategy originated from the desire to integrate the technologies of the IT world more closely with physical systems. With the Industry 4.0 working group initiated by the Forschungsunion Wirtschaft-Wissenschaft (Business & Science Research Union) in 2011, the views of the manufacturing industry and automation technology were incorporated more strongly. Even at that time Beckhoff was able to contribute: A cooperation with the Fortiss Institute at the Technical University of Munich gave rise to a corresponding study that was published by Acatech and incorporated into their Industry 4.0 position paper.

Automation – is to leverage the performance potential of multi-core processors for standard processing machines (see box text "Leading-Edge Cluster for intelligent systems").

PC plus Ethernet equals a globally-accepted platform

Today there is hardly a technical system that cannot be operated by PC or at least connected to a PC via software. If you consider the great variety of system environments and technologies that are used in industrial enterprises, the role of PC technology as an open platform and defacto industry standard for automation becomes quite obvious. Future Industry 4.0 concepts will strongly benefit from the variety of communication systems and architectures supported by the PC world. It is the openness which will enable the easy implementation of innovative concepts.

This applies in equal measure to Ethernet as an industrial communication standard. Owing to the extremely high – and still by no means exhausted – data transmission rates, Ethernet is now widely accepted throughout the manufacturing industry. A contribution to this has certainly been made by the advanced Ethernet-based industrial protocols, EtherCAT and Safety over EtherCAT which meet the toughest industry-specific demands for short cycle times, determinism and efficient safe data communication.

The development of data communication with ever more complex contents and increasing usability requirements is leading in the same direction: Modern communication is Ethernet-based and is able to meet all requirements created by vertical integration. PC-based control from Beckhoff is also optimally suited to this development because, with the company's Automation Device Specification (ADS), the EtherCAT Automation Protocol (EAP) and the OPC Unified Architecture (OPC UA) standard, it already offers excellent options today to cost-effectively implement a communication solution that extends all the way "from the sensor into the cloud":

- ADS is a message-based, routing-capable transport layer within the TwinCAT software system. It enables acyclic communication with other tools from any point in TwinCAT. In a networked system, all data can be accessed from any point.
- The real-time protocol EAP can transmit process data between EtherCAT masters at speeds in the µs range using the publisher-subscriber mechanism.
- OPC UA is a manufacturer-independent, Ethernet- and Web service-based communication standard which can be seamlessly integrated into MES and ERP systems.

Universal engineering for integrated production

With the PC as a globally accepted platform and the support of the ADS, EAP and OPC UA protocols mentioned above, the prerequisites for the universal vertical and horizontal integration demanded by Industry 4.0 already exist. This setup will be essential, at the latest when the cyber-physical systems of the future are actually able to organize production processes automatically, autonomously and via Internet – all with minimized engineering effort.

The required modularity and object-orientation for Industry 4.0 must be reflected in the associated software tools. TwinCAT 3 automation software enables an application to be executed by a single-core CPU just as easily as it can allocate individual application tasks to different cores of a multi-core processor in order to optimize the control of modular production machinery. Moreover, the integration of TwinCAT 3 into Microsoft Visual Studio® serves as the ideal basis for a universal engineering environment over the entire product life cycle, providing the automation specialist with access to the modern software engineering tools of the IT world. Furthermore, additional languages such as C/C++ and Matlab®/Simulink® can be used efficiently and be fully integrated with classic IEC 61131-3 programming languages which are now extended by object-orientation. So for each automation task, the programming language that is best suited to the application at hand can be used.

During his tour of Hannover Messe fairgrounds on April 9, 2013, Germany's Federal Minister for Economics and Technology, Dr. Philipp Rösler, visited the Beckhoff main booth in Hall 9. As an existing example for the application of Industry 4.0 – the guiding theme at this year's Hannover Messe – Hans Beckhoff pointed out the benefits of the intelligent transport system XTS to Dr. Philipp Rösler.

First evolutionary steps have already been taken successfully

In practice, production systems, especially those implemented in Germany, are already connected to each other, even if they evolve further toward better networking and connectivity in a horizontal and vertical direction. If you look at it this way, modern production facilities which are connected to just-in-time suppliers or distributors and are capable of producing lot sizes of one, are in many cases the first existing examples of Industry 4.0.

An example for PC-based control showing its full potential is kitchen manufacturer Nobilia which incredibly manufactures around 2200 kitchens per day. Only thanks to consistent, computer-integrated production at all levels – starting as early as 1990 by linking the production to an Oracle database – the company has been able to advance to its industry's number one position in Europe and do it in the high-wage country of Germany. In the sense of Industry 4.0, the closest possible linkage of manufacturing and IT systems has facilitated the success of Nobilia. This linkage consists of the integration of the PC controller into the overall manufacturing process as well as binding production to the in-house system for complex production data acquisition and to the higher-level ERP system. In the context of Scientific Automation, the main project "ScAut" of the Leading-Edge Cluster "it's OWL", the constantly growing power reserves of PC technology can now be used for the additional implementation of scientific findings in standard machine controllers. A specific example of this is process-optimized drilling, where spindle current and power, feed current and power, vibration of spindle and workpiece as well as drill-hole temperature, chip formation and drill hole-pattern are recorded and used as control parameters for optimizing the manufacturing process.

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Leading-Edge Cluster for intelligent systems

Dr. Ursula Frank from Beckhoff Project Management R&D explains how strongly Beckhoff is involved as a core participating company in the Leading-Edge Cluster "it's OWL".

PC Control: How active is the participation of Beckhoff in "it's OWL" and how is the research work structured?

Dr. Ursula Frank: Beckhoff was involved from the very start as a key company in the Leading-Edge Cluster "it's OWL" (intelligent technical systems Ostwestfalen-Lippe, or East-Westphalia-Lippe), the first large-scale project to be supported within the context of the Industry 4.0 future project. The research work into networked and intelligent systems is structured, among other things, into five university-driven interdisciplinary projects for self-optimization, human-to-machine interaction, intelligent networking, energy efficiency and systems engineering. These are intended to provide a technology platform for the innovation projects – 34 in all – of the cluster's core companies. In addition there are eight so-called sustainability measures, for example, for technology transfer. Funding for five years of work has been provided, amounting to a total of 40 million euros.

PC Control: Which are the most important research projects for Beckhoff?

Dr. Ursula Frank: As consortium leader, Beckhoff is in charge of two innovation projects. With the main project, ScAut, the intention is to integrate findings from engineering science more closely into standard automation technology. The goal is a Scientific Automation platform for the development and real-time-capable operation of technical systems that possess inherent partial intelligence and the following characteristics: ability to adapt with situation-based autonomous adjustments of the plant operation in order to reduce energy consumption; robustness for bridging a defective sensor by interpolating data from other functioning sensors; proactivity via condition monitoring to identify the first signs of wear, among other concerns. The goal of the innovation project "efa" (Extreme Fast Automation) – essentially on one level below – is to increase the performance of control technology. There are plans to implement eXtreme Fast Control (XFC) technology from Beckhoff in large and complex projects extending up to complete factories. Important topics include optimizing cycle times and determining the highest possible performance of multi-core processors in automation devices.

Further Information:
www.beckhoff.com/its-owl