SPECIAL:
INDUSTRY 4.0

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The Digital Twin Extends the Business Model

New Control Concepts for Plastics Machinery in the Context of Industry 4.0 and IoT

Currently, the plastics industry is fully focused on the topics of Industry 4.0 and the Internet of Things (IoT). At K 2016, plastics machinery manufacturers presented the first solutions to integrated manufacturing, in which all products speak the same language. Work on a standardized data protocol for Industry 4.0 is now so far advanced that there is a solid basis in place for operating smart factories. There will be an important role here for the architecture of future control systems.

Data storage and processing in the cloud require reliable and efficient transfer protocols. Along with the OPC UA standard (Open Platform Communications Unified Architecture), which was originally designed for client server architectures, publish/subscribe protocols such as AMQP (Advanced Message Queuing Protocol) and MQTT (Message Queue

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Telemetry Transport) are also available as modern communication mechanisms. They permit multicast-based communication in the local machine network as well as – in IoT and Industry 4.0 applications – broker-based communication via a cloud service. That means that a large number of devices can publish information, which the broker in the cloud transmits to the subscriber.

Standardized Protocols for Reliable Communication with the Cloud

For encryption, the protocols use transport layer security (TLS) and thereby ensure secure and reliable data transfer between the communication partners. Cloud services can be rented from so-called cloud-service providers; alternatively, machine manufacturers or end customers can operate their own cloud computer centers, using the same communication mechanisms as in the public cloud.

Beckhoff supports both communication standards. For example, at K2016, the company demonstrated a combination of OPC UA supported communication and publish/subscribe. The data from the plastic machinery were transferred via OPC UA to a gateway PC, which communicated with a cloud via MQTT. In the cloud, the data were subsequently aggregated and processed using analysis programs, which run on a virtual machine (**Fig. 1**). Moreover, Beckhoff demonstrated the administration of password-protected user access rights, allowing the stored data to be effectively protected against unauthorized access. The different user groups, such as machine manufacturers and plastics processors, each use their own stored data and analysis programs to protect their valuable know-how.

A Better Understanding of Processing Techniques, Faster Analysis of Malfunctions

The Beckhoff technology also allows complete machine states to be transferred to the cloud in the form of so-called process images. As with a flight recorder, all the controls inputs and outputs are recorded and stored in the cloud. In the virtual machine in the cloud, the TwinCAT Analytics software is used for fault analysis of rare events, for condition monitoring or for optimizing the machine design (**Fig. 2**). Plastics processors are in a position to use the globally available stored data from their machines with the analysis software – possibly complemented with their own analysis and evaluation tools – for optimizing and redeveloping processes.

The data aggregated in the cloud can also be used for improving and simplifying the machine operation and processing technique. The applications fields could be, e.g., the evaluation of typical operating processes or fault diagnoses by means of artificial intelligence (AI): Instead of the simple, sometimes incomprehensible error message, the machine operator is given accurate troubleshooting information, which the AI program provides based on all historical malfunction states in all machines. In this way, a self-learning algorithm could effectively support the operator.

New Approaches to Process Optimization and Machine Development

The virtualization and complete availability of all data open up new business fields. In this context, the term "digital twin" is increasing in importance: In future, every machine and every process will have a digital twin as a simulation model in the cloud. That means that when new machines and processes are developed, there will be no need to use expensive prototypes in future, but simulation models can be used, which can be optimized in comparison to the real machine behavior of a "total population". In this way, machine manufacturers, plastics processors or other user groups with the appropriate access rights could accumulate and deepen their process knowledge. The measures for increasing productivity and energy efficiency could be offered, for example, as a paid-for service, and thus open up new business models.

The control system architecture will change in future. The trend toward virtualization and providing computer power in the cloud will also have an effect on the control concepts. Beckhoff has already proposed the example of a so-called "world controller", in which the input signals are transmitted to a "virtual controller" in the cloud. The TwinCAT software will then no longer be executed on the local industrial PC, but will run on a virtual machine in the cloud. The computed output signals are transmitted to the outputs by cloud communication.

However, it would also be conceivable to execute some parts of the control software locally on the machine and others in the cloud. For example, motion »

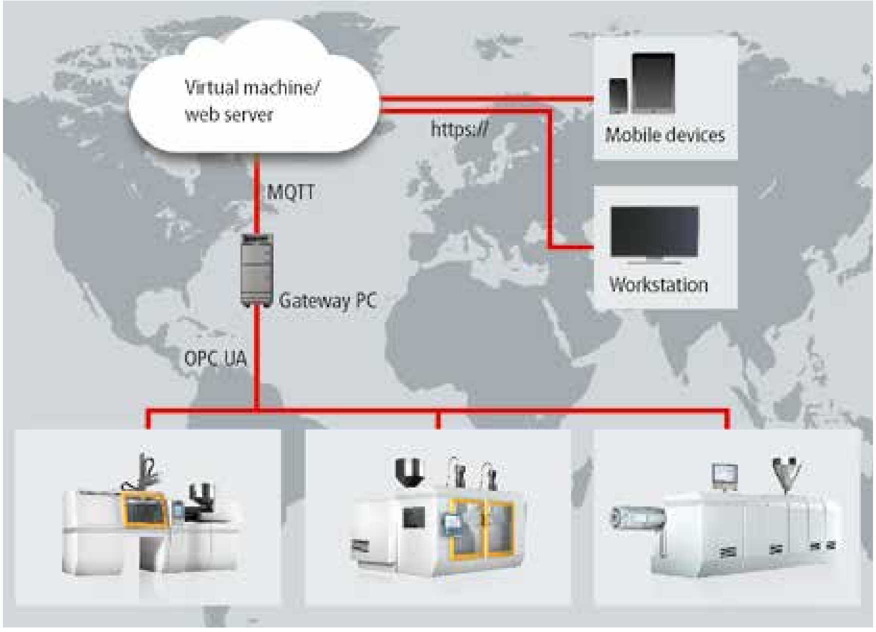

Fig. 1. The data from the plastic machinery were transferred via OPC UA to a gateway PC, which communicates with a cloud via MQTT. In the cloud, the data are subsequently aggregated and processed using analysis programs, which run on a virtual machine. The authorized user can access his machine data in the cloud from any device with a browser function (© Beckhoff)

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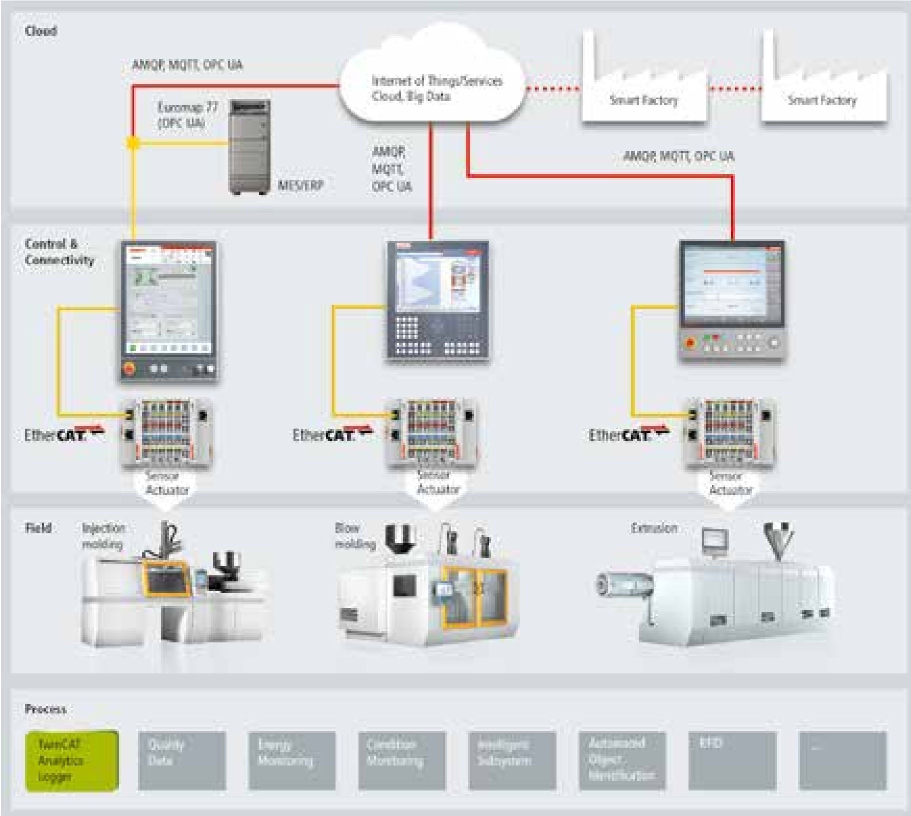

Fig. 2. The TwinCAT IoT software library, which supports standard protocols such as OPC UA for cloud communication, is available for reliable communication between the machine control system and cloud-based services. Built-in security mechanisms prevent unauthorized data access by third parties. With the TwinCAT Analytics software, process data are aggregated synchronously with the machine cycle – the basis for comprehensive analyses (© Beckhoff)

control functions with an EtherCAT field bus and time-critical sequences could be computed locally, while the human-machine interface (HMI) would run in a virtual machine in the cloud. One single machine could then be visualized in "simple" mode in order to simplify operation. At the same time the user interface could be placed in the cloud, where the user could choose between a simple or sophisticated interface, depending on the complexity of the application. It is also conceivable for an intelligent algorithm to analyze the individual user behavior and offer the appropriate user interface.

Options such as a diagnostic wizard, process-engineering support or condition monitoring could be billed separately. The end customer would purchase or rent different user interfaces at different costs, for identical control hardware in the machine. However, business models would also be possible in which, e.g., the usage time is billed.

Using cloud computing, completely new human-machine communication scenarios can also be realized. Here, voice recognition systems from large manufacturers provide the interfaces for third-party applications. For example, a voice-operated digital assistant can make the machine operation simpler and more reliable. Software updates or upgrades could be managed centrally from the OEM's engineering departments. To sum up, the access to the virtual control in the cloud makes troubleshooting easier and can be used for continuous product improvement.

Data Security and Ownership Must Be Clearly Regulated

The perspectives of cloud computing and virtualization of the control system (**Fig. 3**) will lead to a boost in innovation, comparable to that that the implementation of Industry 3.0 brought about with the introduction of computers into industry. Beckhoff has presented its first applications and will be increasingly active in this field in the coming years.

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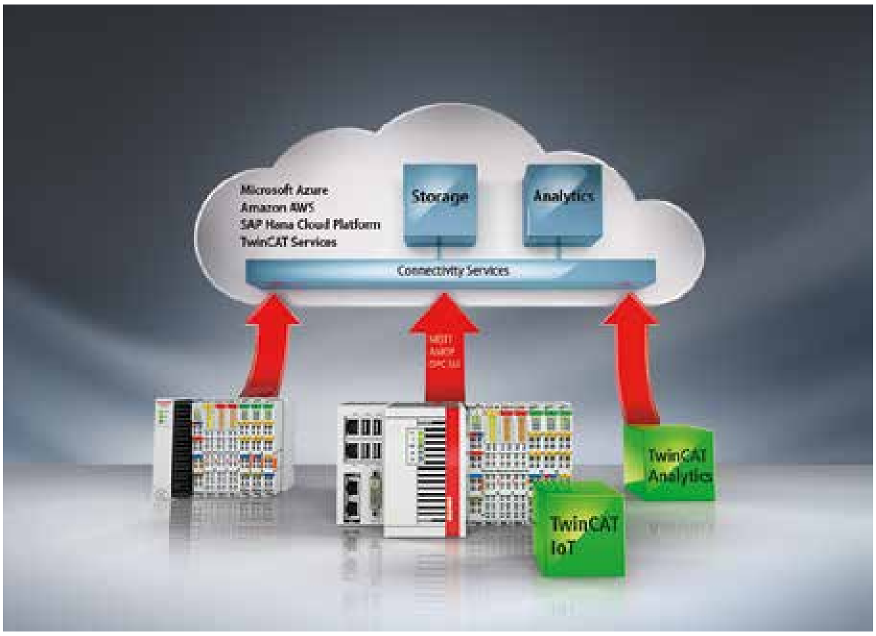

Fig. 3. Programs for fault analysis, condition monitoring or in future for improving or simplifying the machine operation and processing process are executed in the cloud (© Beckhoff)

However, cloud-based control systems will only become established when the secure transmission of data and data ownership are clearly regulated. Many end customers have only responded very cautiously as regards the networking of their machines. And it can be assumed that the industry will need several years to accept and implement the new control concepts. The best example is the PC-based control technology, which took about ten years to become fully accepted in the industry.

Outlook

The current costs of cloud-based systems only generate an economic benefit if they are offset by provable advantages. However, it can be assumed that there will be price declines for cloud computing in future, so that even only a comparably small benefit will make it practical to use them.

The theme of "machine learning" based on data aggregation and analysis in the cloud has only been briefly addressed in this article. If plastics machines are one day capable of autonomous learning efficiently and verifiably, the unmanned plastics machine, equipped with an on/off switch would no longer be a utopia. ■

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