Modern control technology in the process industry – functions, current developments and trends

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Control technology, the technology to control and operate processes, is today intrinsically connected to the concept of process control systems in automation engineering. At first glance, a process control system could merely be seen as a computer system that allows the operator to control and monitor a process or a production plant. In fact this function, referred to as process visualisation, is only a part of the functionality that a process control system encompasses. Other important functions include the process-related components of the control system, using which the process is controlled and regulated. Nowadays, the integration of the process control system in the information network of the company is also considered of particular importance. The basic concepts and functions that a process control system should possess are regulated by DIN IEC 60050-351, which has replaced the former DIN 19222. The most important functions, display and control components, which every control system should feature, is presented and specified in the VDI/VDE 3699 directive. (VDI = German Association of Engineers/VDE = German Association for Electrical, Electronic & Information Technologies)

Process control systems in the information network of companies

Process control systems are now considered part of a holistic production system, in which a continuous flow of data right from the point of measurement up to corporate management level is required. Data once entered into the system or captured by the system, i. e. measured or calculated data, should be available everywhere and should be evaluable at any point. This requires a paradigm shift away from the traditional way of thinking, which considered the process control or automation system a self-contained unit of production [Schu09]. Figure 1 shows the integration of the process control system in the company and the control systems used on the different management levels, their tasks and the hardware components used.

Architecture and scope of functions of modern process control systems

Process control systems are divided into two component groups in accordance with the layer model (Fig. 1), as process-related components (PRC) and as display and control components (DCC) [Thi08]. Figure 2 gives a schematic overview of how the individual components of a control system are interrelated, with the various control system suppliers providing different solutions to the actual connection and especially to the design of the bus system.

The task of process-related components is to control and regulate the process as well as to capture the measured values and to perform safety or quality-related monitoring functions. For this purpose, well-equipped process control sy-

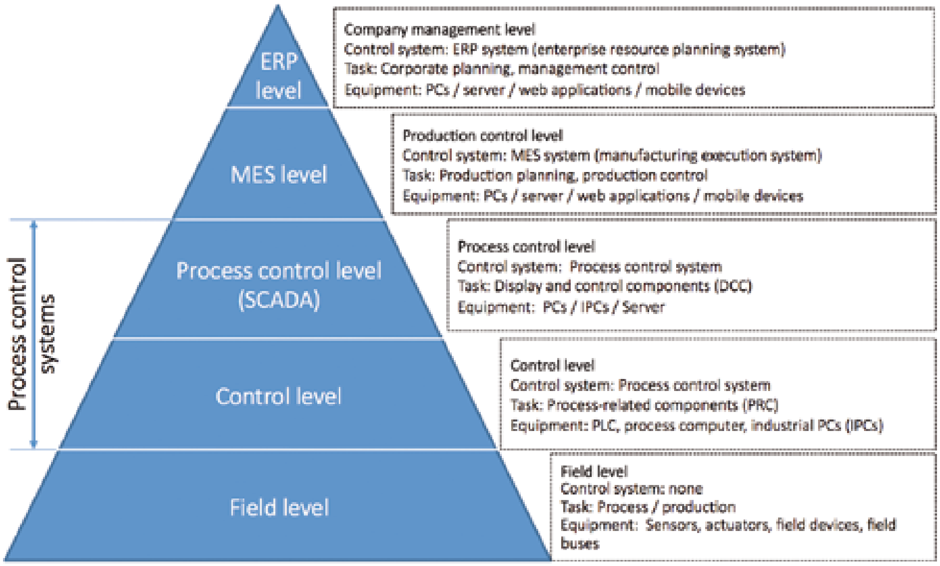

Fig. 1: Level model of process automation (automation pyramid), according to [Pol95]

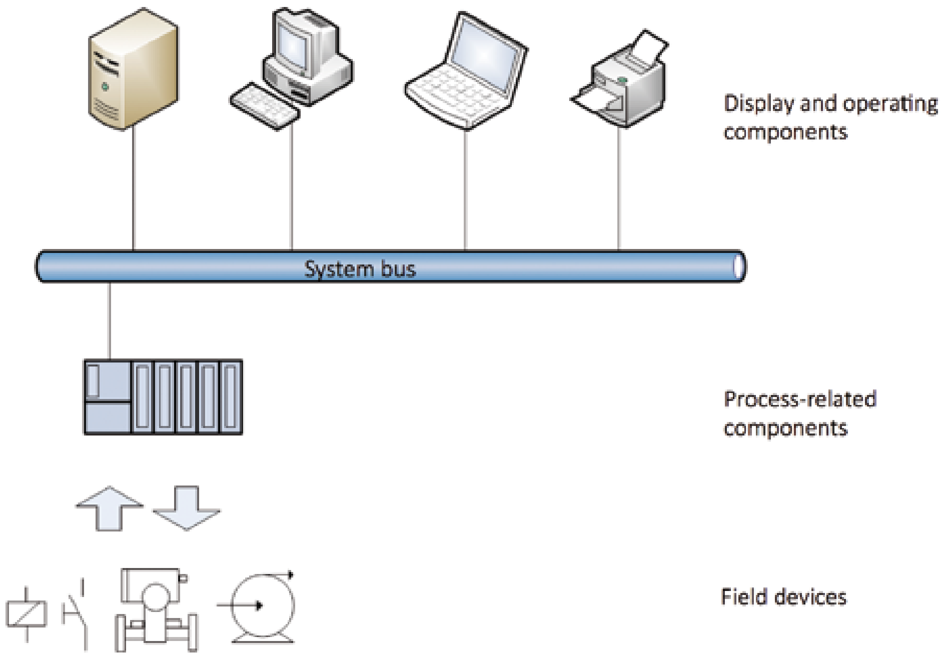

Fig. 2: Schematic diagram of a process control system with server-client architecture

stems provide a variety of pre-built functions (software modules) that allow significant reduction in engineering time and thus acquisition costs compared with automation solutions without control system support. The field devices (sensors and actuators) are also connected to the control system via the process-related components. The functions of contemporary process-related components are usually implemented in programmable logic controllers (PLC) or PC-based computer systems. Several process-related components communicate via the system bus, for which real-time characteristics are generally required [Tau09]. PLC-based systems are considered to be more reliable and have a higher availability, whereas PC-based systems, owing to the ample memory and computing capacity of modern computer systems, are often much more powerful and can therefore also be cheaper to implement. Due to the increasing reliability of PC systems and a careful selection and matching of hardware components, the disadvantages of PC-based systems could gradually disappear. However, the greater vulnerability of PC systems to attacks by viruses, Trojans and other malicious software compared to traditional programmable logic controllers still remains a matter of concern. This is particularly critical in an open network with integration in the information network of the company. Today, the display and control components (DCC) are realised almost exclusively on PCs or industrial PCs (IPC). The panels that are still widely used for on-site operation in the field are now generally based on PC technology and touch operation for these devices is considered an established state of the art technology. The functions of the display and control components are often grouped under the terms HMI (human-machine interface) and operation and monitoring. Systems that concentrate solely on this function are available in the market under the name of SCADA systems (Supervisory Control and Data Acquisition Systems). The typical type of process visualisation is the display of measuring points with the current values of machinery and equipment parameters with their current status as well as of material and energy flows in the form of dynamised process images (Fig. 3).

However, the display and control component functions of a modern process control system far exceed the simple SCADA functions of visualisation and production data acquisition. Typical functions of a well-equipped process control system are, for example, formulation (Recipe) and production parameter management, systems for alarm handling, functions for investigation and evaluation of messages, measurement values and production data as well as production logs and a reporting system with which users can create, retrieve or adapt custom reports. Diagnostic functions for the process as well as for parts of the plant, for process equipment such as measuring instruments, drives,

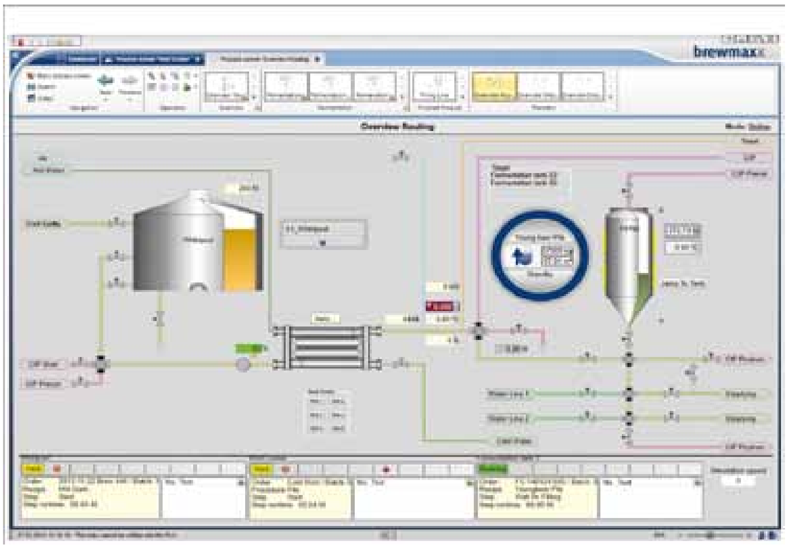

Fig. 3: Visualisation of process flow on a process control system

pumps, compressors and valves, and of course for the process control system itself, have already been integrated in many process control systems and are considered state of the art. Furthermore, classic MES (Manufacturing Execution System) functions (second level in Fig. 1), such as production order lists, bill of materials, PI sheets, materials management and functions for product or batch tracking are increasingly integrated by control system manufacturers in their process control systems and it provides the necessary added value compared to control systems without such functions. This way, especially small and medium-sized plants can benefit from using a control system with these additional functions instead of a separate MES system.

Different manufacturers have different concepts in terms of data storage and communication between components. Essentially, two basic architectures have established themselves: Single bus systems in which the display and operating components as well as the process-related components are directly interconnected via a bus system and client-server architectures, where the communication and data storage takes place on a central server. Figure 2 shows a schematic of the server-client-based system having a common system bus. Sever-client architectures have the advantage of simpler and consistent data management and with an appropriate server design are often more efficient than the distributed single bus systems without a central server. The disadvantage, however, is that the server is a so-called 'single point of failure'. This means that the failure of the server could possibly lead to a complete shutdown of the entire process. This risk can be minimised by suitable redundancy strategies and consistent maintenance of the server during operation, which, by the way, should also not be neglected in the distributed systems.

Current trends from research and development

Current developments are aimed at two closely interlinked objectives. On the one hand, the focus is on measures that contribute to a reduction of the lifecycle cost of the entire automation system. On the other hand, the urgent need to improve the usability of systems has been identified. The latter shall also lead to a long-term reduction in costs, since time and possibly even operating and maintenance staff can be cut down by improving usability. It is also expected that the corresponding improved operator guidance and process control due to the reduction of operator errors and the associated improvement in product quality and yield could have a positive impact on the cost of production.

Reduction of costs for the engineering of the control system and the operation of the plant

The primary measures to reduce the lifecycle costs focus on the engineering of the control system. Through new and innovative engineering tools, the cost of acquisition and commissioning of the control system can be significantly reduced. Efforts in this regard are, for example, strategies which have been extensively discussed in the literature under the catchphrase 'parameterise instead of program' and have been used successfully by some control system manufacturers and system integrators for many years. Other control system manufacturers, especially those with their own proprietary hardware components, however, rely on tools that facilitate programming or code generation. Exemplary for many publications in this regard please refer to [Now08] or [Kle11].

Another important contribution to the reduction of engineering costs is the reuse of already generated planned services and control codes. To achieve this, a consistent modular configuration and programming method, which is supported by the provision of so-called equipment and control modules on the part of the control system, is required. To this end and partly in close cooperation with mechanical engineers, some manufacturers of control systems developed pre-fabricated modules for the control of very commonly used equipment such as pumps, compressors, valves or certain measuring instruments. Manufacturers of control systems with a profound process understanding have also integrated pre-fabricated modules for more complex equipment and whole units, such as filter systems, separators, heaters, metering stations and other commonly used equipment in their respective target sectors within their control systems.

Other trends are the development of novel and improved control and regulation algorithms that can lower operating costs by avoiding or reducing unnecessary or unfavourable energy or resource-intensive control and regulation interventions.

Use of usability methods in process control technology

Usability methods have proved to be successful in the development of interactive systems for quite some time now and can also be applied to the design of human-machine interfaces in the field of process control technology [Pus12]. Usability engineering is the systematic application of usability methods to create a usable interactive product. The basis for this is established by the DIN EN ISO 9241-210 standard in an iterative human-centred process. Figure 4 shows the human-centred design process and the applicable usability methods with some examples from process control technology.

The process begins by ascertaining the context of use. This data is collected per user group by means of semi-structured one-on-one interviews, so-called context interviews. The usage requirements/Use-cases with the system are derived from this data, and in turn incorporated in the creation of the design solutions. Other usability methods shown in Figure 4 [Deu10] are used in the evaluation phase. The adaption of these methods to the special challenges in the design of human-machine interfaces in process control technology is presented in [Pus13].

High-performance HMI

High-performance HMI is another topical and important development trend towards a better human-machine interface. The basic idea is to provide the process operator with optimal awareness of the current state of the process and the system through better presentation of information. This includes the selection of appropriate indicators, so-called KPIs (key performance indicators) and matching status information that should supply the plant operator with adequate information during normal operation. It is only in the event of an error (exception) that the user should be provided with further details. These must then be selected and presented in such a way that the operator is immediately able to recognise the exceptional situation and intervene. So the goal is to always keep the overall condition and the probable development of the process in mind, without being distracted by too many details. In the event of an error, the time required to introduce measures needs to be minimised and the success rate in the handling of exceptional situations needs to be maximised [Hol08] [Hol10]. This will require the development of entirely new visualisation concepts and display variants for process data. But the decisive factor is also the correct configuration of the process control system, away from unstructured process images overloaded with details towards clear indicators and status values that are presented with the new findings from high-performance HMI research. Likewise, new and improved alarm management is necessary to meet the demand for a high-performance user interface in exceptional cases.

Conclusion

Process control systems provide extensive functions in support of solutions for automation tasks and for the safe and efficient operation of equipment and processes. They include interfaces for integration into the IT environment of the production plant and furnish systematic and standardised methods for the design of human-machine interfaces. The current development trends of control system manufacturers support the efforts of mechanical engineers

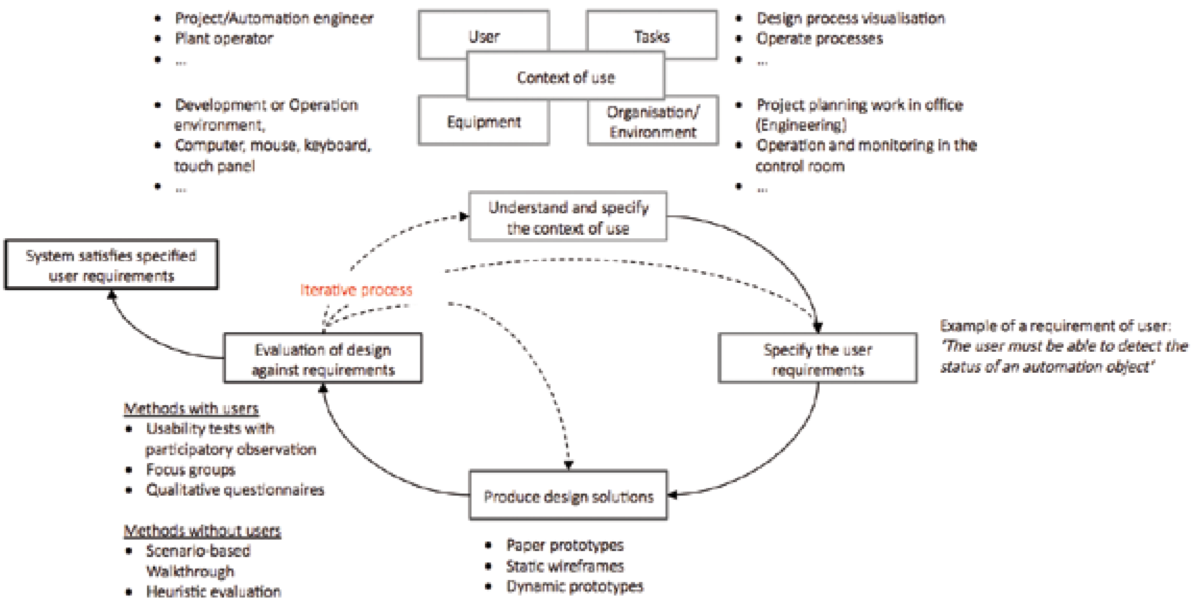

Fig. 4: Human-centred design process for interactive systems based on [DIN9241]

and manufacturers of machinery and equipment to reduce the life-cycle costs in the operation of process plants.

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