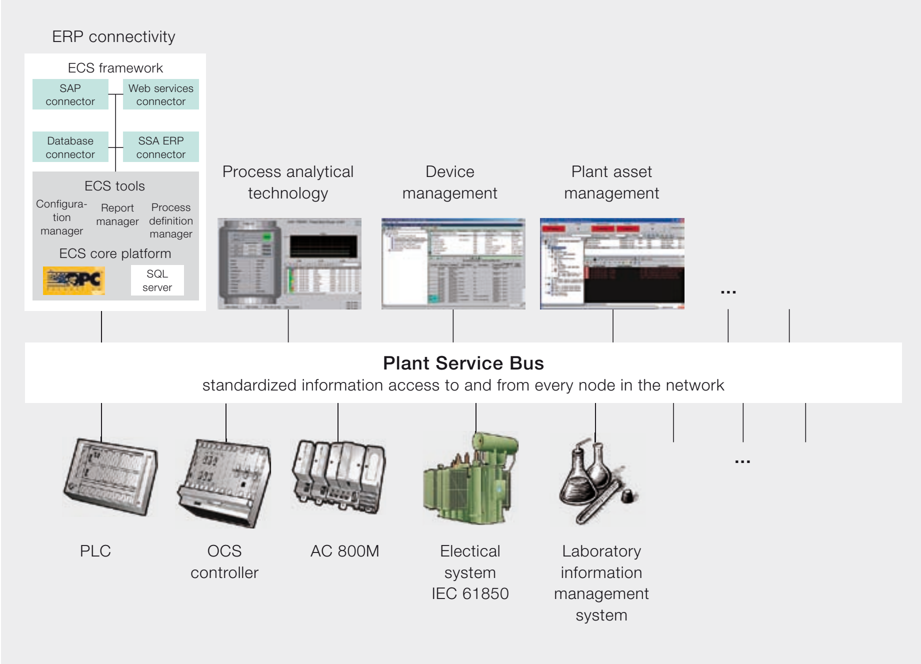
Collaborative process automation systems

ABB's System 800xA as a perfect example

MARTIN HOLLENDER, IIRO HARJUNKOSKI, ALEXANDER HORCH, ALF ISAKSSON, CHRISTIAN ZEIDLER – Control systems that automate and manage production are at the heart of process industries. These systems are networks of interconnected sensors, actuators, controllers and computers, often distributed across vast processing plants that help manufacturers run their operations safely and cost-effectively, minimizing waste and ensuring consistent product quality. In the past three decades, ABB's innovations have dramatically improved industrial productivity by expanding traditional automated control to provide a common platform for a plant's entire operations, from engineering to process optimization and asset management.

1 Plant service bus



In today's globalized economy, production sites face intense world-wide competition. In the longterm only those plants that simultaneously manage to optimize quality, availability, flexibility and cost will remain competitive. Production must adhere to increasingly complex, all-embracing regulations. The public image of a company can be damaged by one single incident, if the company is not able to prove proactive and systematic safety management.

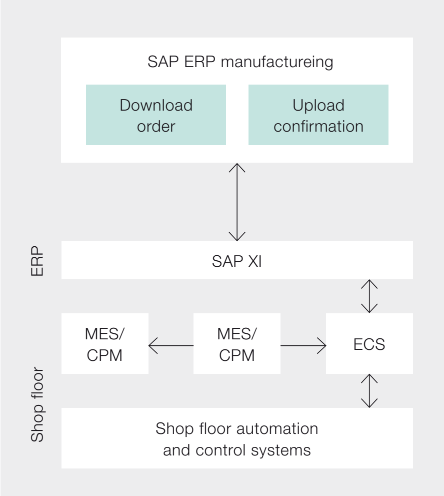
A collaborative process automation system (CPAS) is often defined as a method to unify previously diverse systems in order to achieve operational excellence. CPAS allow plant personnel, from operators to managers, to get away from complicated workflows where they must interface with multiple systems in order to assess situations and perform tasks. This unified workflow environment enables collaboration and helps the different functional roles to work together with an understanding of their specific requirements with regard to the bigger picture. Sharing the data, knowledge and functional views ensures that each functional group in the plant understands the operational situation, their interdependencies, and their role in improving it. In essence, this is the integration needed to truly deliver on the promises of collaborative process automation.

The automation of technical processes with the help of computers has a history of almost 50 years. During this time various terms have been established to describe computerized automation systems:
- Distributed control system (DCS) originating in refineries,
- Programmable logic control (PLC) originating in discrete manufacturing, and
- Supervisory control and data acquisition (SCADA) for geographically distributed processes like pipelines and utility networks.

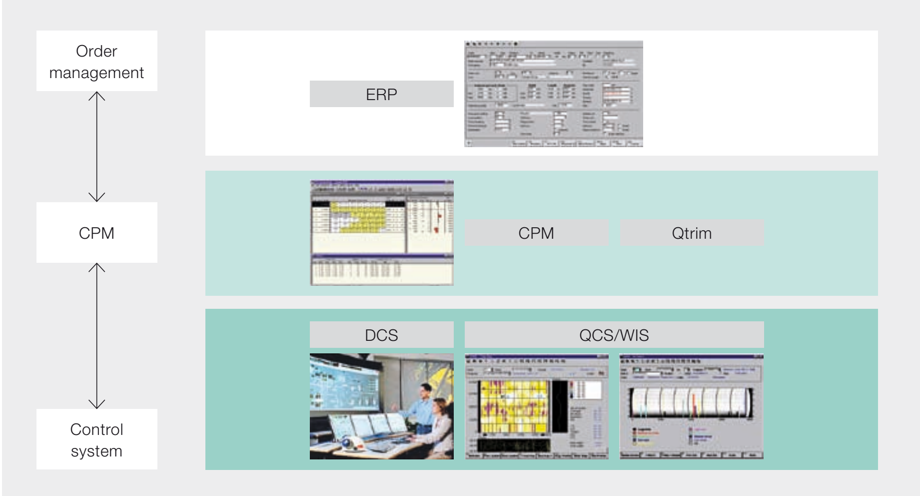
Unfortunately none of these terms has a widely agreed "official" definition and they are often used inconsistently. During the last decades, systems have been steadily improved and extended. Current state-of-the-art systems can no longer be described precisely by these dated terms. New terms are required to better categorize current state-of-the-art systems.

Around 2002, the ARC Advisory Group, a research and advisory firm based in Boston, Massachusetts developed the CPAS vision [1]. This vision is an excellent guideline for the planning, selection, engineering and operation of process automation systems. Since then, many automation vendors have started to market their systems as CPAS. Key principles of the ARC CPAS vision include:
- Continuous improvement
- Common actionable context
- Single version of the truth
- Common infrastructure based on standards

A CPAS architecture must support these principles. A core element of a CPAS is its common object model, which supports reusable and generic solutions. It allows the deep integration of automation controllers from different vendors and different technology generations, fieldbus devices, electrical components (IEC 61850) and higher level operations with management execution system (MES) or enterprise resource planning (ERP) systems. All relevant information is inherently available at all workplaces. ABB System 800xA is based, from the ground up, on the very powerful Aspect Object™ technology. One reason for ABB to create a systematic architecture to enable a common object model was the need to integrate several different classic controller families coming from different parts of the company. The Aspect Object framework organizes standardized access to information to and from every node in the network. It can be seen as a "plant service bus" with analogy to the enterprise service bus (ESB) of business system architectures. It is the basis for the seamless evolution capabilities of System 800xA and allows the integration of previously heterogeneous systems, 2 ECS solution for vertical integration



3 Functional integration overview



eg, process and power automation, through IEC 61850. Each vendor has focussed on different aspects of the vision and some have implemented these better than others.

Manufacturers have been forced to optimize production to comply with trends to reduce their carbon footprint. Many forward looking companies want to replicate best-in class solutions to all their production facilities world-wide. Leading production companies have gone along way to implement the CPAS concepts. A CPAS architecture supports the creation of context-independent solutions that can be applied in a wide range of scenarios. This reuse of proven solutions has a high potential for cost savings and ensuring a consistently high quality.

Thus CPAS like System 800xA empower efficient and effective vertical and horizontal integration of data access and system functionalities to serve the ever spiraling and demanding needs. After a discussion of the CPAS common information infrastructure, four examples of typical CPAS functionalities will be presented, many other areas can be found in [2].

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Common Information Infrastructure

CPAS have a common infrastructure, are functionally transparent, logically concise and standards based. Standards like Ethernet, ISA88 and ISA95 as well as IEC61131 should be deeply integrated in a CPAS. Other important standards like OPC (DA, AE, HDA and, more recently UA), IEC 61850 and FDT/EDDL should be used wherever they make sense.

Only few vendors can offer global data access (GDA), which allows access to any information from anywhere to anywhere at any time for any valid purpose ("the five anys" according to Dave Woll) ➔ 1.

In ABB's System 800xA every information item – be it a measurement value or a production schedule – can be published as an Aspect Object property. These properties can be accessed system wide from any interested application in a uniform way, no matter where the original information comes from. Lookup functions exist that allow generic information access, enabling reusable solutions. System 800xA provides a framework that automatically distributes information to all workplaces in the system. For example, an external OPC server can be accessed from all nodes without the need to know on which machine this OPC server is running.

The Aspect Object technology inherent to System 800xA provides the unifying platform base. It allows each application to maintain data in its source application, while providing association to a production asset. This allows access to the data directly from its source in the context of the production asset without the need to know where the data is coming from, and without concern about data integrity and concordance. System 800xA supports late binding: data can be referenced in an abstract and generic way without forcing the engineer to hardcode specific server names or I/O positions. This adds flexibility and facilitates housekeeping when changes are made. Late binding is a very important basis for generic solutions that can be reused in many different contexts. Class concepts known from programming languages like C++ or Java, allow generic solutions to be built.

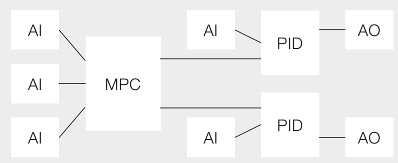
ERP Integration

ABB's Industrial IT cpmPlus enterprise connectivity solution (ECS) bridges the vertical integration gap between business and manufacturing systems. ECS is fully scalable and includes event handling, transaction handling, error and application logging support and fail-over (fail-safe) support. The main components and their connectivity are displayed in ➔ 2. ECS is the information broker that connects to the MES, to the control system on the shop floor and to the ERP system via SAP's [1] external interface SAP XI.

Footnote

1 SAP is the leading ERP software company.

4 Schematic of MPC configuration



AI analog in
MPC model predictive control
PID proportional integral derivative
AO analog out

Full data integration enables various novel applications. One such cross application, which combines the online quality information with offline planning and customer order data, is the ABB quality-based retrimming solution (qtrim). qtrim complements ABB's fully integrated production management suite for the paper industry. The suite includes state-of-the-art technology, such as leading quality control (QCS) and web imaging (WIS) systems.

The qtrim solution comprises a mathematical model [3] that is able to consider quality profiles along the paper jumbo-reel as well as the customer order requirements attached to each paper roll. Thus, the solution provides a complete geometric representation of the trim-loss problem. The model can generate cutting plans, which reduce the quality loss significantly. Quality loss is the economic loss based on degraded quality. Better cutting plans result in reduced energy and raw-material consumption, that is, a minimized environmental load, improved reliability for customers and, finally, higher profit through lower total production costs.

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The key enabler of such a solution is data availability. During the paper-making process, quality information is collected by the QCS that performs continuous scans along the paper reel. Properties such as moisture, caliper and brightness are measured frequently. Even for small paper machines, there may be tens of thousands of measurement points for each quality property per jumbo reel.

In the WIS, a number of high-speed cameras track all visual defects (holes, cracks, wrinkles) and the images are efficiently analyzed using neural network-based methods. These methods ensure fast and reliable processing of data to classify and determine a defect's type. The challenge is to handle large amounts of data and to ensure that the actual information can be extracted efficiently.

These very specialized systems are fully integrated and the solution will work silently in the background creating additional profit to the customers. The most important issue is to put everything together into one robust and uniform concept that will deliver the best results. The functional components and their integration are shown in → 3. The measurement data of the quality systems are provided with geometric information from the control system. Customer order quality requirements are collected from the order management system and compared with the actual quality. Potential customer roll positions are mapped to the actual produced roll; this mapping is then used as "raw data" for optimization. Information can flow in all directions through well-defined interfaces, and the intelligent solution ensures that the current planning is always up-to-date with respect to the known quality data. Summing up, the cross-application integrates all levels (ERP, CPM, DCS) seamlessly and contributes to an economically and environmentally optimized production process.

Advanced Process Control

In an automation hierarchy following the ISA 95 standard [4], advanced process control (APC) corresponds to coordinated control of a production unit or parts thereof.

In principle, APC means any closed-loop control, using automatic feedback from process measurements, which is more advanced than using decentralized PID controllers. However, in recent years APC has become more or less synonymous with model predictive control (MPC).

MPC is a multivariable controller, which optimizes future process variables every time new measurements are available, using the model as an equality constraint. The MPC's popularity is due to a range of properties, which no other control method can match: When executing the optimization process MPC can take account of:
– Constraints on both manipulated as well as predicted process variables
– Future known changes of the setpoints

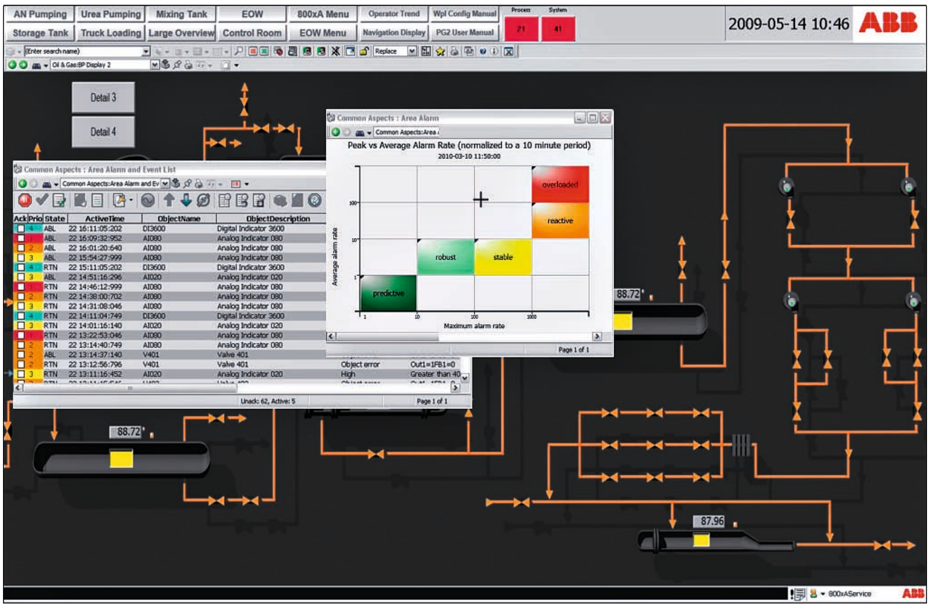
Traditionally MPC has been implemented in a PC separate from the control system, communicating with the control system using, for example, OPC. The output from the MPC is usually connected to the setpoint of underlying PID (proportional integral derivative) controllers. However, there is a lot to be gained if the MPC is an integrated part of the CPAS. In particular if the configuration can be made by drag and drop in a IEC61131 editor. For a schematic of an MPC configuration with three process variables delivering two manipulated variables to two PID controllers see → 4.

To appreciate the benefit of this, one needs to understand that a line connection in → 4 may represent the bi-directional flow of information. For example a line between the MPC and a PID, in addition to sending the setpoint to the PID, receives the following information back to the MPC:
– Logical flags, if the PID output is saturated or not (high and low limit respectively)
– The mode of the PID (manual or automatic)
– If the PID is using an external (ie, from MPC) or internal (ie, from operator) setpoint
– If PID uses an internal setpoint then the MPC also receives the value of this setpoint

All this information is needed to properly take the state of the PID into account when running the optimization.

By having the actual execution integrated in the CPAS, benefits like automatic

5 Continuous improving alarm system



backups, automatic re-start when CPAS is re-started, possibility of redundance, etc, can be achieved. This may however, still be in a PC server belonging to the CPAS. Execution in a hardware controller carries potential additional advantages like faster and more secure communication.

Plant Asset Management

Plant asset management (PAM) is a multidisciplinary task that spans organizational and structural boundaries. PAM focuses on various aspects of operations, maintenance and production management.

Recent NAMUR and VDI/VDE GMA publications have established a widely shared definition and understanding of PAM [5,6]. In particular, relevant PAM functions have been described in a common model framework. The three main aspects of this framework are asset monitoring, information processing and information management. Each of these areas may represent complex functionalities depending on whether a complete PAM-system or a single function is targeted.

Implementing PAM as part of a CPAS, benefits from self-evident collaborative properties as described previously. One main feature of CPAS is the easy connection to a large variety of data sources. PAM strongly relies on this connectivity in order to receive information such as real-time process data, historical asset information, plant topology, economic information and maintenance work orders.

This information, which is available to the PAM system, forms the background for asset monitoring. Asset monitoring is the supervision and assessment of the most vital plant equipment such as reactors and heat exchangers. It needs to host both simple and as advanced algorithmic functionality in order to cope with the large number of different assets to be monitored. Monitoring is performed with respect to both performance and condition. Performance relates to high energy and material consumption due to asset deterioration and the impact of poorly performing assets in production. Condition relates to the identification of harmful operating conditions and diagnosing as well as predicting relevant asset faults.

PAM has often disappointed users because it tends to generate a high number of noncritical asset alerts. In order to generate useful asset information, powerful information concentration and aggregation has to be applied to the basic asset monitoring data. This can only realistically be achieved if plant topology information is used together with asset monitoring results and maintenance history. Such a procedure is well supported by a CPAS architecture that enables simple and flexible access to different kinds of information from various data sources.

ABB's System 800xA help manufacturers stay competitive by implementing world-class process automation.

The third aspect of PAM is the user-specific delivery of information. Since information is unique and accessed flexibly, different users may efficiently use the system based on their requirements. Operator information differs significantly from maintenance information and each is delivered according to their specific needs. Integration of PAM into enterprise-level applications such as CMMS (computerized maintenance management system) is enabled by the consistent use of standards for vertical integration. Any maintenance-related information can thus be transferred efficiently from shop floor to top floor.

Alarm Management

Originally the word alarm meant an important event that required an urgent reaction. In today's plants many so-called alarms are completely meaningless for plant operation. During the last decade it has become apparent that many automation systems generate so many nuisance alarms that human operators can't handle them any more. If most of the generated alarms have no meaning for the operators, this reduces their vigilance and trust in the alarm system. Even important alarms are ignored or overlooked during a flood of nuisance alarms. This means that many alarm systems are of low quality and provide the operators with little support. Guidelines like EEMUA 191 and ISA 18.2 show how alarm systems can be systematically engineered to create a high-quality alarm system. One important reason for the low alarm system quality of many automation systems is that a high quality configuration of alarms requires lots of expertise and effort. The high upfront investment cost has in some cases impeded better alarm configurations. Sometimes the information required for a perfect alarm configuration is not available before operational experience exists.

Some companies report good results from continuous improvement activities, 6 The CPAS book

where the operating team continuously monitors the quality of the alarm system. System 800xA supports such continuous improvement processes by providing easy-to-configure monitoring tools fully integrated into the operator environment. During regular meetings, operating teams can go through preconfigured alarm management reports, which help them to pinpoint the most urgent alarm management problems. In the light of this philosophy, an alarm is always a call for action: either to fix an operational problem, to repair a faulty component or to reconfigure a suboptimal alarm configuration. A perfectly running plant should produce no alarm at all ➔ 5.

This kind of continuous alarm management system provides a kind of plant hygiene, like brushing teeth each day. It is a nice example of how System 800xA supports the continuous improvement culture of the CPAS vision.

Meeting the challenge

Modern CPAS like ABB's System 800xA help manufacturers stay competitive by implementing world-class process automation. As the goals of the CPAS vision are very ambitious and broad, there is still much work to be done until we see automation systems fully supporting all aspects of this vision. ISA has published a book on CPAS (see http://isa.org/CPAS) edited by ABB's Martin Hollender. It contains chapters explaining modern aspects of CPAS like security, engineering, operator effectiveness and much more. Dave Woll has contributed a chapter describing the original ARC CPAS vision ➔ 6.

ARC is currently updating the original vision and calls this CPAS 2.0 [7]. The introduction of OPC-UA [8] will have a large impact on the technological front. In the first phase OPC-UA will supersede the classic OPC standards. This will remove the headaches some systems had with the flawed DCOM and enable the use of OPC on systems running without Microsoft Windows, eg, many intelligent field devices. In a second phase, the use of standardized information models, eg, the DI specification for devices will be the basis to provide more generic functionality without the need to specify every little detail differently for each system. Complete process of manufacturing automation systems can be described even more with Automation ML [9], and their interaction and date exchanges described by applying a specific automation XML dialect. Examples are loop monitoring and asset management functionality that can be specified at a very abstract level, which then works for all connected systems independent of vendor or technology generation. As hardware becomes cheaper and powerful digital fieldbuses become available, there are fewer and fewer reasons to run control algorithms in a central location. IEC 61499 extends IEC 61131 to include object-orientation and event-driven execution and is therefore a good candidate for truly distributed control scenarios. The upcoming field device integration (FDI) specification [10] will harmonize and unify the existing field device tool (FDT) and electronic device description language (EDDL) standards. It will improve easy access to value-added functionality of modern field devices like calibration and diagnostics. Other features that future CPAS will offer are a very tight integration of telecommunication, workflow and video supervision systems.

ABB's System 800xA provides a framework that automatically distributes information to all workplaces in the system.

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