Data, not paper

Transforming shopfloor connectivity

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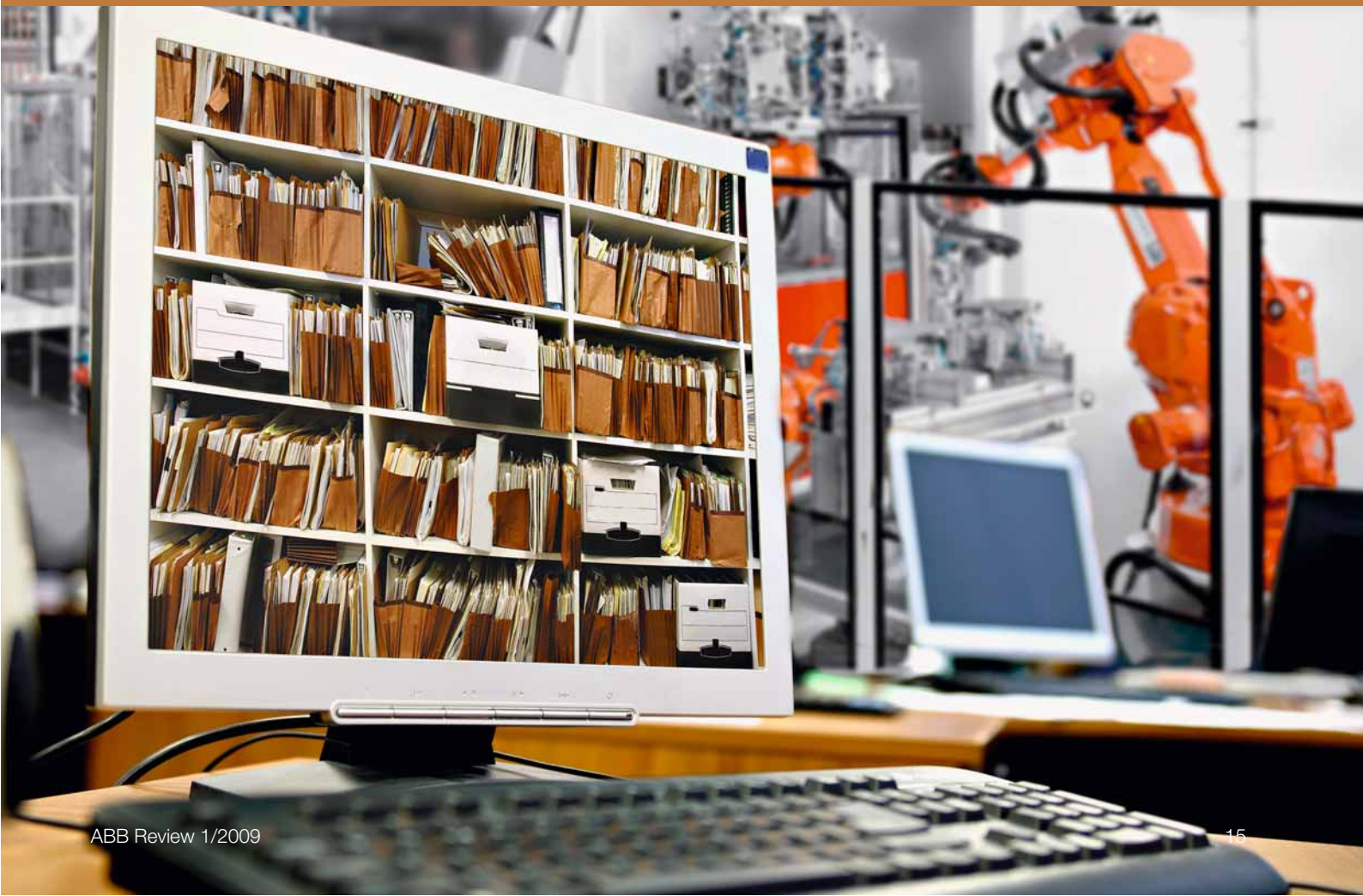
It has often been said that we are currently living in the Information Age. This is definitely true of manufacturing, where as a product passes through all steps from the release of the initial order to the delivery of the final product, it is accompanied by a dynamic mass of documentation. Production line personnel need to know exactly what steps are required and which parts or ingredients must be used. The results of individual actions may also be recorded for quality assurance and tracking.

In most cases, this process is strongly reliant on paper. Instructions are issued on paper; actions are recorded on paper; and even if data is eventually stored electronically, paper records must be transferred to a computer by hand. Not only is this time-consuming and error-prone, but it impedes the accessibility of up-to-date information.

ABB's cpmPlus Enterprise Connectivity software is changing all this and introducing truly paperless production: Records now follow the product in electronic form, and at every step, only those data are displayed that are directly relevant to that task. Ergonomics are leveraged and errors reduced.

The software is seeing successful use, for example, in ABB's own switchgear plant in Ratingen (Germany) and with the food manufacturer, Wander.



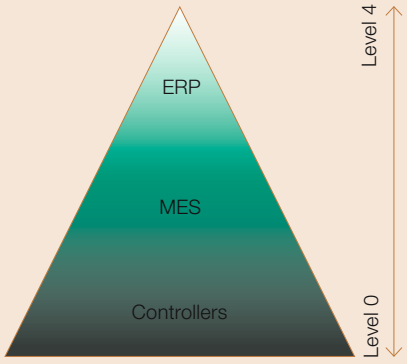
Connectivity is an important aspect of a manufacturing execution system (MES). It sits in the middle of the automation pyramid as defined by ISA-95 [1] Factbox 1, bridging the gap between enterprise resource planning (ERP) systems (level 4) and control systems (level 2 and lower). As such it offers level 3 functionality. A significant challenge in implementing this link lies in translating between different levels of information granularity: ERP systems concern themselves with time horizons of hours or longer, while controllers typically operate much faster than at minute rates.

ABB's cpmPlus Enterprise Connectivity (ECS) was initially marketed as Enterprise Connectivity Solutions [1]. It has become the centerpiece of the company's product suite for collaborative production management (CPM).

Factbox 1 The automation pyramid

The automation pyramid groups the devices and systems of a production environment into levels. Many different automation pyramids have been devised with a grouping criteria best suited for the domain. The most relevant to this work is the model used by the ISA-95 standard. Levels instill communication boundaries, as there should only be connections within a level or to neighboring levels. The pyramid shape indicates that there are many more devices in the lower levels than in the higher levels. Typically one ERP is on the highest level and a large number of controllers on the lowest. By placing systems and devices in this hierarchy, their relative degree of influence on production becomes visible.

As often happens with models, reality does not always adhere to them. Complex systems may provide functionality for the whole plant (eg, inventory) while also interacting with controllers, thus spanning multiple levels.



ERP: Enterprise resource planning
MES: Manufacturing execution system

Hand-written notes are a thing of the past – and with them the dangers of illegibility and errors in entering data into the ERP.

Going paperless

One important reason for introducing connectivity to the shopfloor is to achieve paperless production. Operational advantages and cost savings include:

- *Availability of real-time production data:* Management has comprehensive and up-to-date access to the status of the plant and production.
- *Contextual aids for operators:* Instead of forcing staff to flip through stacks of reference manuals and report cards, only information pertinent to the current product and production step is presented. This makes for a cleaner, safer, and more efficient work environment. Documentation can be updated easily and inexpensively by a central authority.
- *Elimination of transcription errors*: Information follows the semi-finished products from order to shipment in electronic form. Hand-written notes are a thing of the past – and with them the dangers of illegibility and errors in entering data into the ERP.
- *Wealth of new information:* Much more data can be recorded electronically with automated systems than with a traditional pen-and-paper approach. This benefits both the factory, for process optimization purposes, and the client, who can obtain more quality data on the purchased goods. Such record keeping may also be necessary to fulfill regulatory requirements.
- *Ease of access to historical data*: Electronic storage of data simplifies the tracing of material and limits potential recalls by helping identify contaminated or dangerous goods. This can save a company both money and reputation.

In view of these benefits, what does a paperless ECS-equipped workplace look like? Changes are most pronounced on the shopfloor. In traditional manufacturing, instructions are taken from written records passed along with the product. With a paperless system, and if so configured, operators select the next unit of work from a graphical user interface that contains a prioritized list of upcoming tasks. Alternatively, this can be achieved by scanning a barcode. Such a check also helps verify whether the part is compatible with the current production step. Required assembly steps, support documentation and requested test values or mount options are subsequently displayed on a screen in the workplace 1.

Changes also occur on the operations level: Standard PCs are placed in offices, or software clients installed on existing computers. These are used to administrate the system, release orders and view reports. This improved accessibility of information provides manifold advantages: Sales staff gain better insight into the capacity available at factories and can negotiate orders accordingly; management can

1 The user interface consisting of a touch-screen monitor, a keyboard, and a wireless scanner for barcodes.

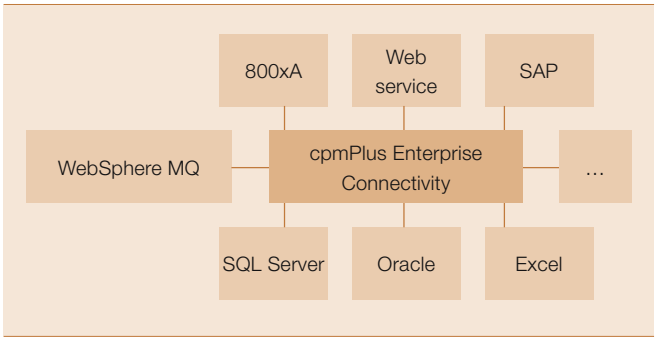
analyze the productivity and profitability in conjunction with the ERP system on a real-time basis; and maintenance crews can obtain detailed historic data on equipment and can schedule inspections appropriately.

ECS overview

ECS employs the ISA-95 standard to establish a common terminology for communications. Envisioned as the interface description between levels 3 and 4, it also provides an excellent basis for modeling enterprise connectivity. Furthermore, ISA-95 is extremely valuable when equipment suppliers and customers talk to one-another. Over the years, people in factories (and their consultants) have adopted their own terminology when talking about their infrastructure. A well-defined international standard simplifies the communication across different naming cultures.

Because ECS is resource-focused, it provides convenient ways of instructing personnel about their various roles, equipment, and material. Each modeling element within the system can be assigned properties of different types that hold run-time values of the processes. These resources can then be combined to yield segments, each of which represents a production step. By smartly transitioning from one segment to another along the workflow diagram and in accordance with the production requirements, orders become products.

2 ECS architecture with central connectivity service: Because of its openness, ECS can easily incorporate new external systems.



Code can be entered either traditionally with a text-based editor or using a graphical event editor.

ECS and integration

Architecturally, ECS sits at the center of the shopfloor communication system 2. It connects external systems such as ERPs with equipment and personnel. Information from connected systems is mapped to ISA-95 and made available within ABB's industrial automation platform, System 800xA. This tight coupling to 800xA means it is possible, for instance, to make selected ERP data available to OPC. This enables a seamless exchange of information between levels 2 and 4, and the ability to access enterprise data and functionality through the process graphics of 800xA.

Many connectivity systems tout interoperability with third-party products. What this often boils down to is an interface through which a connection can be facilitated. Development of this connection, however, is often left as an exercise to the customer or offered through an additional consulting contract. In stark contrast, ECS connects to the commonly used external systems by means of supplied adapters as part of its out of the box functionality. Such adapters exist for many standard scenarios, such as connectivity to SAP, WebSphere MQ, all common databases, and Web services. Further adapters can be dropped in using a plug-in architecture as required by the project. ECS connects all these systems seamlessly, translating between different data representations and rates as needed.

Once information exchange is established, the next natural step is to send commands from one system to another. A sales person can thus not only enter a new order into SAP, but also, hypothetically, directly start some aspects of production. More realistically, though, there are scenarios in which shopfloor conditions (ie, properties) have certain characteristics that automatically trigger actions:

- A complex alarm condition involving properties from multiple sources

3 The Process Definition Tool is the primary modeling tool. It supports ISA-95 based resources and modeling of custom event code using both graphical and text-based editors.

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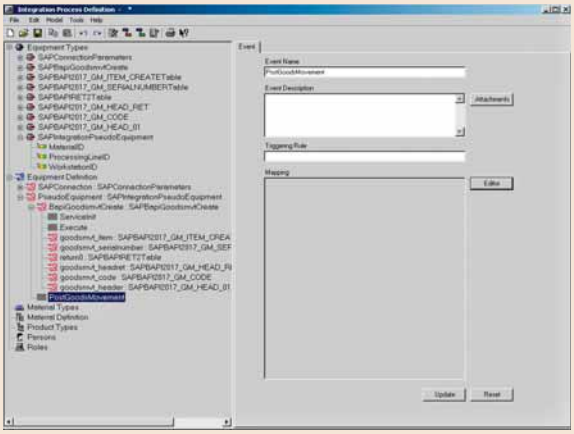

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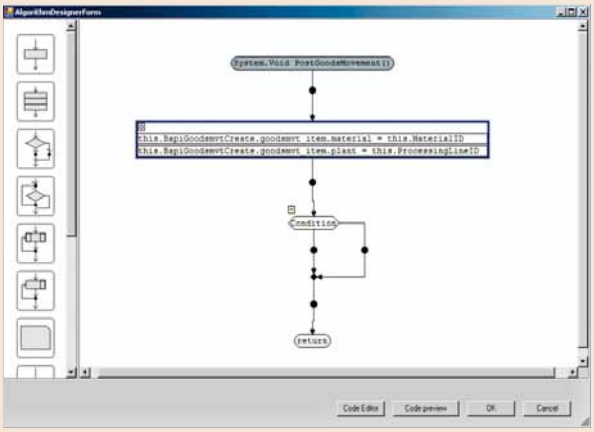
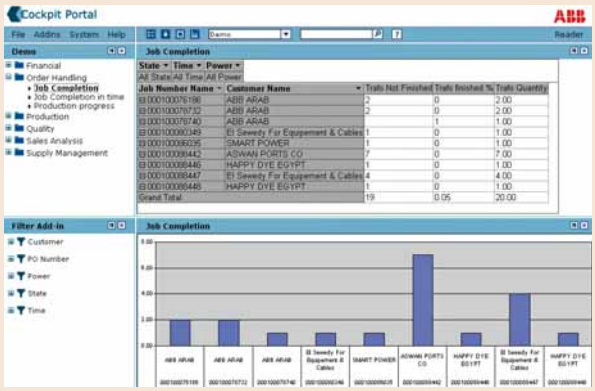


4 The Cockpit tool offers a simple graphical configuration to create advanced production reports.



5 A RESIBLOC transformer made in ABB's Brilon factory.

causes messages to be sent (eg, by SMS) to human operators, or immediate emergency shutdown procedures to be executed.
- The completion of a production step automatically starts the next.
- A mixer is automatically loaded with the right amount of ingredients from silos at the appropriate time.

The concept of "events" is offered by ECS to implement such behaviors. Such an event consists of custom code, whose execution can be started manually by an operator or through a Boolean expression over any combination of properties. By writing pithy events, an intelligent shopfloor connectivity solution can be created that is capable of relieving operators from tedious tasks as well as providing real-time supervision.

Tools

For engineers to benefit from a fruitful development environment, concepts must be translated into tools. ECS provides three such engineering tools.

Process Definition Tool (PDT)

PDT is the primary environment for creating models that represent a solution to a given shopfloor connectivity scenario 3. It is used to create this solution and then adapt it to new requirements at run-time. The left pane of the application window renders the current resources in multiple tree views. The right pane shows details for each modeling entity that can be manipulated by the engineers. Basic resources are modeled with this tool and their relationships set up. The engineer can include additional properties and custom code written in C# and Visual Basic, opening up the whole world of .NET. Code can be entered either in the traditional way with a text-based editor 3a or using a graphical event editor 3b. The latter allows the drawing of algorithms and provides immediate insight into the event's workflow. Event code makes it easy to create simple functionality and connectivity mappings. More complex functionality can be embedded using DLLs.

ECS connects to the commonly used external systems as part of its out of the box functionality.

Admin tool

The Admin tool is used to configure a running ECS installation. It serves as an easy-to-use interface to the central SQL-server database. Using this tool, administrators maintain users and permissions, monitor the system and can view rudimentary reports.

Cockpit

The third tool, Cockpit, provides advanced reporting functionality 4. A large number of production data are collected continuously by ECS without the system needing to be specially configured. Cockpit uses this wealth of information and can relate it to additional sources (eg, historic data). The tool permits data to be presented graphically, making it easier to identify otherwise hidden correlations.

In its most recent release, 3.5, ECS gained a number of usability and engineering performance improvements, further speeding up project-realization time. Among them are single-button model redeployment with times that are cut down to mere seconds, model debugging support through Visual Studio, improved logging, and collaborative and simultaneous model creation by multiple engineers on different workstations. ECS 4.0, to be released in the first half of 2009, will no longer require System 800xA as a host environment, but a tight integration is still possible. A graphical workflow engine will provide a much simplified and more intuitive way of configuring the production processes. New projects can be started at an advanced state by using the ECS Template Repository that will be available to customers online. It offers ready-to-use integration

Factbox Acronyms

CPM	Collaborative production management
DLL	Dynamic link library
ERP	Enterprise resource planning
MES	Manufacturing execution system
OPC	(a connectivity standard for industrial automation)
SMS	Short message service
SQL	Structured query language (a database language)

models as starting points for new development efforts or learning best modeling practices.

Shared responsibilities

ECS is employed in numerous ABB factories and external companies. While project complexities vary, the path to a successful implementation is the same.

Operators embraced the new system because they were actively involved throughout the project.

After the initial contact, a team of ECS engineers visits the site for several days to interview the domain experts involved in the project. This is taken as input for the requirements document that specifies the complete system. Aside from a general overview, the document describes all system aspects in detail. Priorities are assigned to use cases to guide the project engineers during the implementation phase. Other use cases are marked as nice-to-have or for-future-extensions. Care is taken to clearly identify the system boundaries. The requirements document is verified with the customer.

Design and implementation of the solution are performed off-site. As pieces of the solution start to form a whole, and especially as user interfaces are added, the customer is again involved in the verification phase. Toward the end of the project, the focus shifts back to the customer site, as servers are installed and live tests are run.

The involvement of experts on both sides is a prerequisite for success, but certainly does not guarantee it. A system only proves valuable if it is accepted by its users. It is all too easy to forget that the little boxes in the documented model correspond to real people in the real world, and without their support, the implementation is likely to fail. In many ECS installations, operators embraced the new system because they were actively involved throughout the project. For instance, several factories held design competitions, open to all operators, to create workplace computer stations, such as shown in 1.

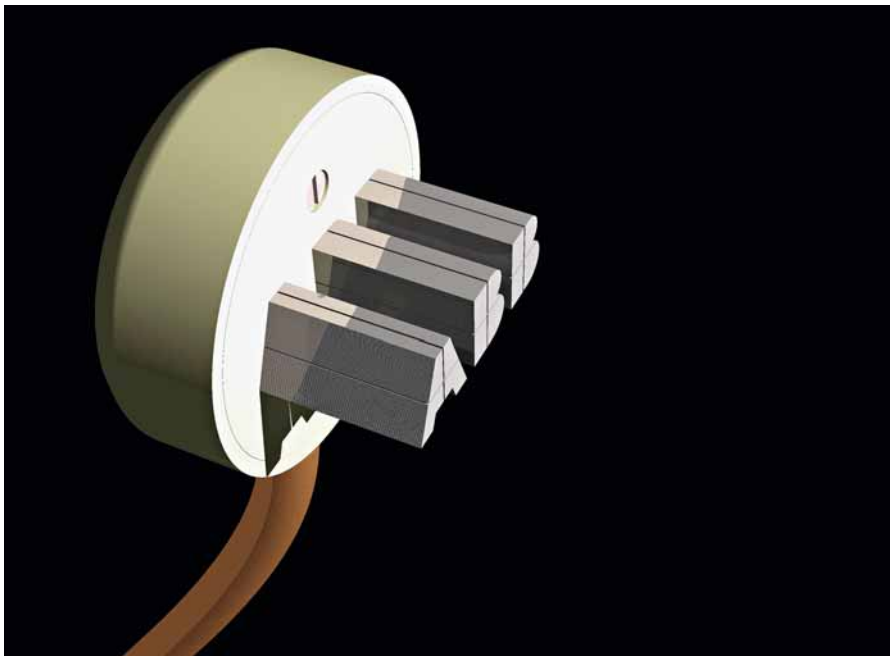
Benchmarking and application

A benchmarking exercise was carried out in ABB's transformer plant at Brilon in Germany 5. Multiple challenges that the product's flexibility elegantly handled included interfacing with an exotic ERP system and a scheduling application with flexible routing in the process workflow dependent on ERP-related constraints, integration of an existing document repository, and multi-lingual user interfaces to serve the multi-cultural workforce.

Another successful implementation was established with the Swiss food company, Wander, makers of the world-famous Ovomaltine (Ovaltine).

Several factories held design competitions, open to all operators, to create workplace computer stations.

The benefits of shopfloor connectivity shine with ABB's flexible cpmPlus Enterprise Connectivity solution. Coupled with its simple and straightforward configuration, customers can expect low engineering and maintenance costs, a high degree of flexibility allowing future system extensions, and reliable up-to-date information of the process state available at all levels of the enterprise.



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[2] **Dondi, P., Berisa, D., Milenovic, D., Milenovic, T., Tellarini, M.** Enterprise solutions for discrete manufacturing. *ABB Review* 2/2004, 34–38.