NEMESIS

Factory excellence solutions

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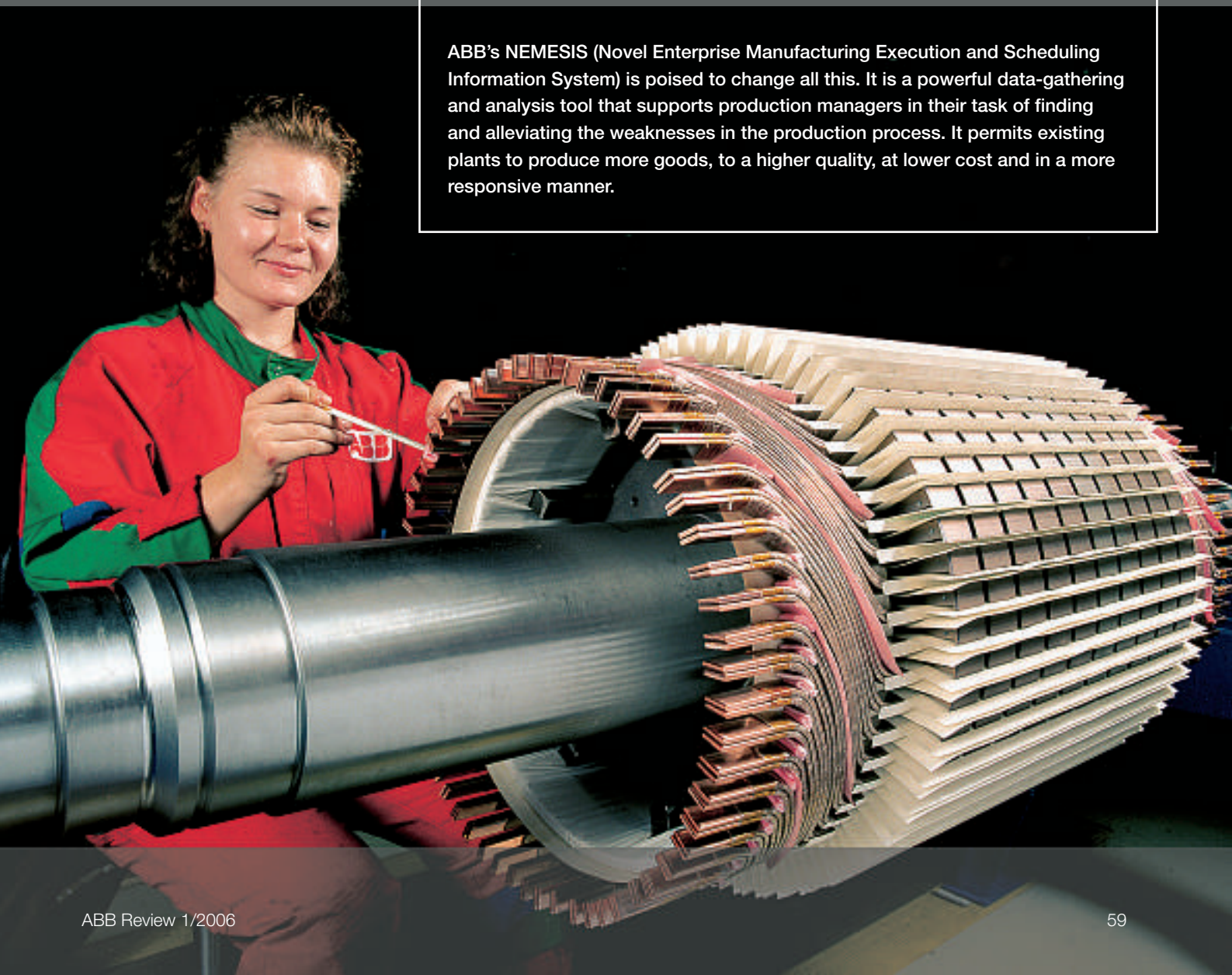
"Knowledge is power" according to an old dictum. To get the best out of a factory in terms of resource efficiency, reaction times and product quality, there is no way around accurate and up-to-date knowledge of problems and their root causes. So much for the theory! In practice, such information is often distributed over several incompatible IT systems in different locations and in a form that does not facilitate the drawing of the right conclusions. The absence of a meaningful joined-up view means potential problems often languish until it is too late to prevent them from striking.

ABB's NEMESIS (Novel Enterprise Manufacturing Execution and Scheduling Information System) is poised to change all this. It is a powerful data-gathering and analysis tool that supports production managers in their task of finding and alleviating the weaknesses in the production process. It permits existing plants to produce more goods, to a higher quality, at lower cost and in a more responsive manner.



In manufacturing, there is always a delicate balance between time, resources, materials and capacity. Even the slightest change in this can affect productivity. To successfully manage this balance, a manufacturer needs adequate information providing a certain degree of foresight. However, for far too long, manufacturers have been forced to react to events rather than being able to anticipate problems to satisfy customer commitments.

IT systems, by definition, supply data; however, owning information is not enough. More important than having appropriate data is to know how to interpret and use it. The purpose of the IT system is to empower management in drawing the right conclusions from data and to support proper methodologies and practices. The Theory of Constraints (TOC)[1] concept which is implemented in many ABB manufacturing plants addresses these issues. A suitable IT solution was required to support this approach.

The implemented approach, NEMESIS (Novel Enterprise Manufacturing Execution and Scheduling Information System) 1, covers plant scheduling, execution, quality management and reporting. Orders are automatically transferred from the plant's Enterprise Resource Planning (ERP)[2] to the scheduling system. There they are scheduled against the current factory load. The selected jobs are transferred to the Manufacturing Execution System (MES)[2]. This system supports managers in controlling the factory's workflow and it aids in gathering process and quality data for further analysis. While a production order is in execution, production and quality managers, factory management and the sales force can track production, analyze reports and set priorities appropriately.

With the support of such scheduling and execution systems, the factory can be more responsive and reach its full potential. Beyond that, the system increases plant visibility and flexibility, which can permit an informed and safe reduction of inventory levels.

Reduction of Work-in-Progress (WIP)[2] shortens cycle times, thus allowing better responsiveness to customer demands using customized products. When connected to the scheduling system, online feedback from MES strengthens the customer service department's ability to accurately quote due dates and provide status updates to customers.

1 NEMESIS – integrated enterprise system consisting of IT tools for scheduling, execution, quality analysis and reporting

2 Scheduling system providing full support for TOC and Finite Capacity approach

Integrated solution components

Production Planning and Scheduling

When dealing with plants dispatching many different product variants every day, optimal management is close to impossible without computerized support. The most important and indispensable aid for today's planner and production manager is the right scheduling tool. But what is a good scheduling tool? During scheduling workshops, various ABB factory representatives, business area managers and R&D experts were asked to answer this query. A detailed map of required functionality was derived from their responses. The most important elements of this are: support for scheduling principles – Theory of Constraints (TOC) and Finite Capacity Scheduling (FCS), support for buffer management, load vs. capacity and Work-in-Progress (WIP) control, and interconnectivity with different ERP and MES systems 2.

Two main production types can be differentiated in discrete manufacturing: project environment and production environment. The key differentiator between them is the level of uncertainty. For a project environment where the level of uncertainty is high, TOC provides the Multi Project Critical Chain (MPCC) methodology. For a production environment, where the risk of the unknown is relatively low, the Drum Buffer Rope (DBR)[3] approach is recommended.

Engineered-to-order products (ETO) are difficult to schedule with Materials Requirement Planning (MRP) systems because they are executed first as an engineering project and then as a one-of-a-kind manufacturing build. Because they are one-of-a-kind and

Footnotes

[1] See page 25.

[2] See glossary on page 74.

[3] See footnote 5 on page 26.

sometimes first-of-a-kind, there is a high uncertainty in the engineering phase, procurement phase and manufacturing phase. Poor on time delivery (OTD), cost overruns and reductions in specification (change of scope) are well-known problems in the ETO product world.

ETO products, such as Power Transformers, Gas Insulated Switchgear and Large Electrical Machines, are essentially unique projects and are affected by the variability described above. The best-in-class method of project management that is able to deliver projects on time, in budget and in-scope is the Critical Chain[4)] method. When many projects are run at the same time, there is a modified Critical Chain method called Multi-Project Critical Chain (MPCC).

MES focuses on value-adding processes – helping reduce manufacturing cycle time, improve product quality, reduce WIP, reduce or eliminate paperwork, reduce lead time, and empower plant operations staff.

Critical Chain has been successfully applied to engineering projects and ETO product manufacturing in ABB and elsewhere. Critical Chain has enabled increases in OTD, reductions in Throughput Time (TPT) and Total TPT (TTPT), and also increased factory capacity. The productivity of highly skilled engineers and designers in multi project environments has been increased by 40 percent using Critical Chain.

TOC can also be successfully applied in production environments. For products with short cycle times, which usually are produced on a massive scale, one of the biggest challenges to factory management is the identification of the production bottleneck (the resource that has just enough capacity or less capacity than is needed to satisfy the demand placed upon it). This resource must be fully exploited. The next step is to subordinate all other shop-floor activities to this resource keeping the factory throughput at a pace not lower than the bottleneck's. DBR is a finite capacity scheduling mechanism that implements these measures.

TOC methodology was the main driver for the new ABB planning and scheduling system. NEMESIS aims to support both types of manufacturing environment by implementing MPCC and DBR methodologies. To keep the whole solution simple allowing final users to focus on their core activities, the system was developed to permit the straightforward realization, configuration and parameterization of scheduling algorithms.

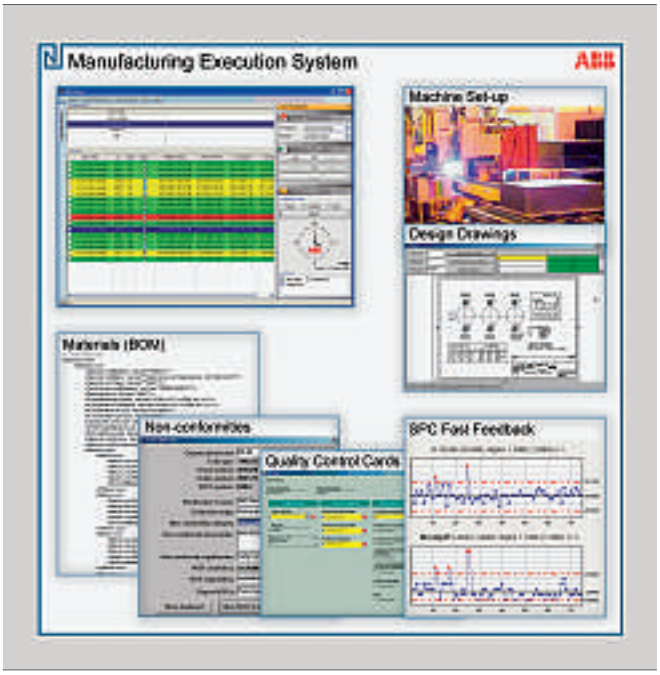
The principal features of the scheduling system developed to address these issues are:

- Fully support exploitation of bottleneck
- Subordinate preceding and succeeding operations to the bottleneck
- Use aggregated buffers in critical locations rather than hidden safety buffers everywhere
- Buffer management for execution monitoring and jobs prioritization
- Use feedback from execution system for corrective actions
- Enable load vs. capacity analysis

To permit one-click deployment in different factories, the scheduling system is fully configurable. A resource pool can be set up almost instantly, calendars configured and network diagrams specified to model the factory. Scheduling results are presented in many types of reports. The user selects different views such as "load versus capacity", Gantt view or buffer management. In addition, the system generates material reports to provide supply managers with the list of required materials together with dates that they are required to be on the shop floor.

An even greater advantage of the scheduling system lies in its analysis of real and up-to-date execution data. The scheduling system is linked to the execution system by real-time feedback from the shop floor. The scheduling system provides long and medium term visibility, comparing planned and expected to real situations.

3 Capabilities of Manufacturing Execution System (MES) for shop floor information and execution control



Manufacturing Execution System (MES)

MES 3 is an essential component of operations in today's competitive business environments. It focuses on value-adding processes – helping reduce manufacturing cycle time, improve product quality, reduce WIP, reduce or eliminate paperwork, reduce lead time, and empower plant operations staff.

The Manufacturing Enterprise Solutions Association (MESA) defines several fields of improvement an MES can achieve. MES delivers information enabling the optimization of production activities from order launch to finished goods. Using current and accurate data; MES guides, initiates, responds to, and reports on plant activities. The result-

Footnote

4) For more information about TOC and Critical Chain, refer to: www.toc.co.uk

ing response to changing conditions, coupled with a focus on reducing non-value-added activities, drives effective plant operations and processes.

MES functions include resource allocation and status, dispatching production units, data acquisition, quality management, performance analysis, operations scheduling, document control, labor management, process management and product tracking and genealogy. As the backbone of the manufacturing systems, MES fills a gap between business control (ERP and Supply Chain) and process control (automated and manual operations) to optimize manufacturing profitability. MES dispatches, monitors, tracks and controls production information to provide real-time feedback so managers can make better decisions about manufacturing operations. MES functionality covers several parts of the manufacturing chain. The most important challenge in discrete manufacturing is to integrate and leverage real-time information from multiple sources to get a product out the door. It requires integration of data from individual parts of the process – from product specifications and components inventory, to assembly, instructions, QA testing, receiving and shipping. The main benefit of such a system is the efficient handling of production data through the integration of information from different sources. MES applications organize and catalog enormous quantities of data and provide easy and immediate access to the right information at the right time. As a result, MES brings the following benefits:

- Information flow improves as a result of integration of multiple systems. MES, as the "window" into these systems enables a "paperless" manufacturing environment that eliminates non-value adding repetitive activities such as routine paperwork and enables real-time flow of information.
- Order tracking capability based on production order tracking within the plant. This assists sales staff and increases the accuracy of the information they provide to the customer.
- Quality improvement and less waste and scrap as a result of improved tracking and reporting of key quality metrics, permitting improved statistical process control and root cause analysis.
- Operator efficiency improvement by providing operators with the information they need. This can include the bill of material, product drawings and product specifications. Documents can be reviewed and the most up-to-date versions pushed to the floor electronically without disrupting production.

In several ABB factories, MES is integrated with the planning and scheduling system, Quality Management System (QMS), design repositories, shop floor machines and reporting systems.

Manufacturing Intelligence

It is easy to become overloaded with raw data but still not have the information that is needed to make critical decisions. In addition to collecting and viewing historical information, a modern manufacturing business needs to gather real-time data from many sources within the plant, analyze it, and turn it into useful information. Such processes combined with manufacturing and business logic provide the basis for building operational excellence based on real time management, strategic decision support and tactical decision-making 4.

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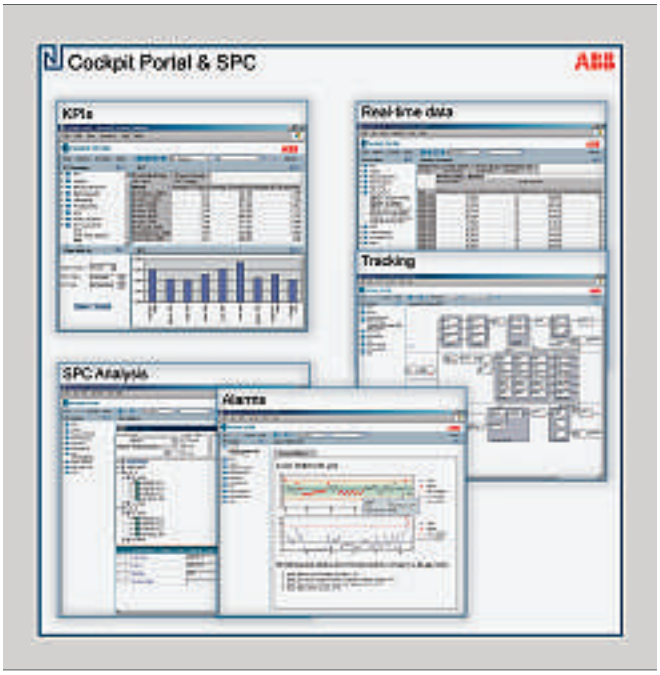
The Cockpit system provides reporting and analytical functions for problems in the manufacturing processes. It supports manufacturing excellence by aggregating and disseminating data from multiple disparate back-end sources and delivering personalized views to authorized users through browsers or other internet-enabled devices. While aggregated totals of production counts may satisfy corporate management, the call for relentless cost reduction, raising of quality and boosting the count of produced units using existing resources can be met only by the availability of intelligent information from factory processes. Hidden constraints must be identified; these are the root causes of the quality issues that are masked by process variability, large buffers, and excess inventory levels. There also needs to be a high-level view of the plant that shows how processes function together across the entire plant. Only in such a case can the right change be effected.

The Cockpit system provides these capabilities by bridging the data from different sources of disjointed views in the factory. It closes the loop between the data generated

4 Manufacturing Intelligence Portal providing integrated information about factory for in time monitoring and analysis of business processes

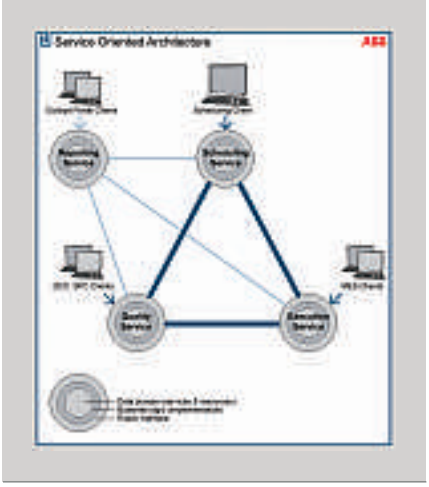


on the plant floor and other systems used to drive the plant. Cockpit imports data from IT systems from across the entire plant, storing the data in a single database and transforming it into one cohesive, integrated view of operations. The key technologies supporting this goal are data warehousing and on-line analytical processing with web access and portal functionality. Managers become empowered to act, by having access to reports on KPIs, machine utilization, quality and other key elements of factory operations. This results in increased productivity, quality, and reduced costs.

The Cockpit system not only tracks production information in real-time, but also alerts staff to problems on the floor in time to overcome them. The system gives managers and staff the opportunity to analyze the issue, drill down to the detail of single product or even its component, and identify the cause. They can determine what needs to be done about it and take timely action. By viewing relevant graphical data in real time, people are empowered to make rapid, proactive, and informed decisions. These benefits have a critically positive impact on the manufacturing business.

A manufacturing process always deals with a sequence of interdependent events, each with its own variation. Variation can be natural, inherent to the process, or caused by extraordinary factors. A systematic identification is required of the source of variability that is causing the most problems across the system. Statistical Process Control (SPC) is an important methodology for the analysis of process fluctuation and for the pinpointing of conditions that cause the process to pass its control limits. This is a process charting technique that allows quick determination of variation causes. Based on a root cause analysis, the preventive action plan can be defined. The process of problem investigation using SPC methodology and the subsequent definition of a corrective plan involves people from different areas of manufacturing. Therefore it is regarded as one of the important tools in a Total Quality Management strategy.

5 Service Oriented Architecture enabling integration



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SPC System is a web-based service completing Cockpit's analytical capabilities by delivering a tool for measuring, understanding, and controlling variation in the manufacturing process. It targets quality experts that are equipped with extensive capabilities for observing either statistical control charts (showing measurements in context of control limits) for selected parameters and their variation. The user can apply several filters to specify what components, measurements and features should be used in the analysis. As the analysis can be very tedious, the SPC system provides functionality that helps efficiently track down suspicious parameter values and, if necessary, raises an alarm.

SPC also plays a very important role on the shop floor as part of the manufacturing execution system. It provides the so called "fast feedback" that gives an operator a simplified SPC analysis of collected measurements. The main goal of this fast feedback is to permit floor operators to react immediately when process parameters pass given limits.

When a new measurement is acquired by the MES system, it is automatically checked for correctness, ie, against boundary conditions as well as against statistical variation. The system gives the shop floor operator a prompt view of generated charts, especially if alarms are found. Thanks to this functionality, the shop floor operator is continually informed on abnormal parameter variation and can react immediately.

Implementation of SPC System results in reduction of cost of poor quality (COPQ) by providing alarms on the shop floor as well as analytical capabilities for process investigation. It enables proactive detection of problems early enough to prevent current and future problems.

Solution architecture

The integrated NEMESIS solution for discrete manufacturing factories is based on the idea of Service Oriented Architecture (SOA). The concept of the service as an independent, autonomous and self-contained piece of functionality is crucial to SOA. Service based on SOA can be considered as an element of business process logic that can be mixed and matched, and called into use by whomever or whatever needs it from anywhere within the architecture. An SOA-based system is a set of such loosely coupled but collaborating services. The success of the "Services" thinking lies in the recognition that, because systems must evolve over time, they must be flexible enough to accept additional or changing requirements. Applications should exchange data and provide services regardless of the respective platform. Today's IT world is a world of heterogeneous, distributed and yet deeply integrated systems. A product containing three main services is shown in 5.

All collaborating services can have their own data storage. This data is imported to the data warehouse and processed and made accessible on different levels of factory management via Cockpit Portal.

Thanks to SOA, different underlying technologies and even different operating systems can cooperate and improve overall performance. This approach to IT systems facilitates their

development, structuring and use. SOA services can be swapped in or out or replaced, without any effect on the users or the environment. Any individual component can easily and painlessly be replaced with a new, better, or expanded component. The choice of modern technologies such as Microsoft.NET or J2EE also supports the future growth of ABB's customers because it facilitates the delivery of scalable systems, capable of supporting the required performance as load increases. It establishes high availability of the system, which is very important as in many cases it must work 24/7 with uptime of close to 100 percent.

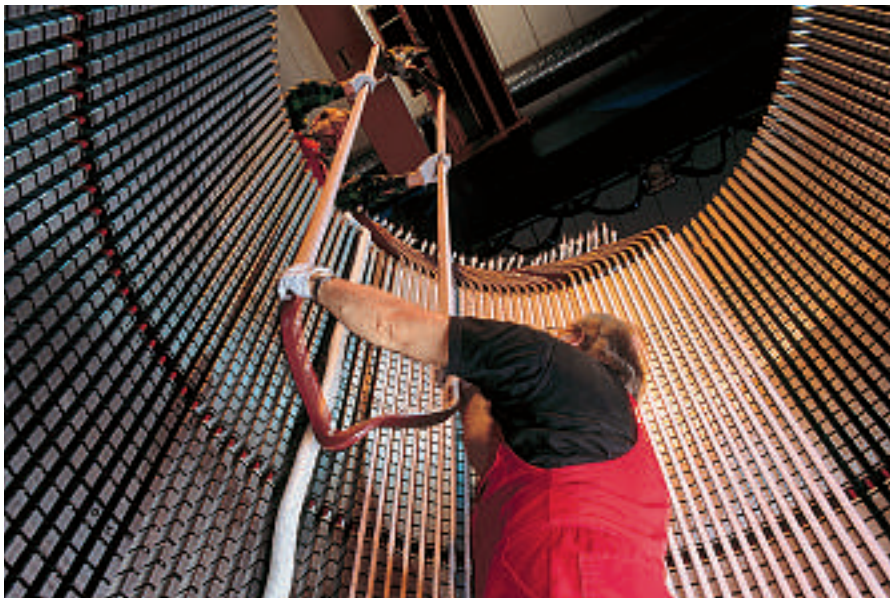
This choice also speeds up development and significantly increases reliability by facilitating security and transactions management.

In today's fast-moving economy, a company that does not use IT systems to optimize production processes, shorten lead-time, increase throughput and improve on-time-delivery is exposed to an increased risk of losing out to competition. Raising throughput, improving OTD, minimizing WIP and reducing inventories are ABB's strategy. IT solutions are critically important requirements in building manufacturing Operational Excellence. They affect all functions of business execution from sales through engineering to manufacturing by addressing new business demands:

- High flexibility to respond quickly and effectively to changing business requirements.
- Proper scheduling based on real-time status.
- Deep understanding and communication of performance measures throughout the organization with scorecards and other means of monitoring performance that make strategy directly relevant to each employee.
- Ability to understand and assess what is driving performance in every step of the process.

NEMESIS delivers a solid base for building real time enterprise, supported with detailed scheduling and business process management by seamless system reconfiguration, and rapid adaptation to business changes.

ABB marked a huge milestone in this direction by the deployment of an integrated IT solution concept in ABB's transformer factories. The aim of this concept was to integrate and optimize the entire process – including internal factory production processes – from the front-end sales tool through the ERP (Enterprise Resource Planning) system, to the MES (Manufacturing Execution System), along with shop-floor machines and the factory Quality Management System. Its implementation provided the factory with real-time information across the entire plant supported by the business intelligence system, Cockpit, delivering a unified view on plant performance with analytical and reporting capabilities. All together these integrated systems significantly improved plant visibility and manufacturing effectiveness. The implementation of NEMESIS required the building of an enterprise architecture platform supporting the integration of various existing IT systems and the development of new business components such as MES – providing shop floor control capabilities with order tracking and milestone realization monitoring. The solution delivers an enterprise system architecture model and a well defined development process allowing effective management of the system, increasing reusability, consistency and integration among subsystems. The fundamental component of this model is service-oriented architecture (SOA) utilizing web services, enabling integration across technology barriers, and higher flexibility in system management. When started, NEMESIS was alone in taking full advantage of emerging technologies and IT trends. These trends include web services, open source and commercial off the shelf components. As a result, development time was shortened, costs reduced and a highly flexible IT environment provided to meet new business requirements. The system also delivers a solid base for building real time enterprise supported with detailed scheduling and business process management by seamless system reconfiguration and rapid adaptation to business changes.



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