Maximizing the Potential of Batch Process Control

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ABSTRACT  
In the recent years, batch process optimization has made significant advances. The efforts that went into the development of ISA-S88/IEC 61512 batch control standard has helped us in this direction. However, in today’s highly competitive environment, optimization of individual manufacturing plants is not enough. In order to maximize the return on investments, control engineers must turn their attentions to site and company wide optimization along with the optimization of the supply chains.

Typically, batch processes use many different raw materials to produce various products and grades of products. Market demands require frequent changes in product mix under short notice. Thus, batch processes offers greater opportunities than typical continuous processes for the optimization of raw material and intermediate supplies, production scheduling, and upstream and downstream transportations.

For the last five years, the ISA-SP95 committee has been developing the standards for integration of control systems with business systems. This effort is significantly helping site and company wide optimization of manufacturing processes. Additionally, the recent developments in Internet and intranet technologies are increasing the feasibility of supply chain optimization. Today, the challenge for control
engineers is to broaden their focus from narrow control issues to wider aspects of enterprise-wide optimization.

**Introduction**

**The Batch Control Market**

The worldwide shipments of batch control systems, including hardware, software, and services is now more than two billion US dollars. Due to increased awareness of the benefits of batch control and the availability of cost-effective solutions, the batch control market is growing at a faster pace than the process control market in general. In addition, the ISA-S88/IEC 61512 batch control standard and IEC 61131-3 standard for PLC programming languages are increasing the level of understanding of less sophisticated users, and making them more receptive to automation.

Europe, including Middle East and Africa, is the largest market for batch control systems. In order, North America, Japan, the rest of Asia, and Latin America follow Europe in terms of worldwide market share. The pattern of average annual growth also varies considerably between these regions. North America and Europe will experience an average growth rate over the next five years, while certain countries in Asia and Latin America are expected to show higher growth and Japan will show a lower growth. (Slide 2).

In the industrially developed countries in North America and Europe, growth opportunities in the process automation market are harder to find and more challenging than ever. The fastest growing markets today are not the refining and petrochemical industries, but the food & beverage and pharmaceutical industries, thus leading to increased demand for batch process control.

**Technological & Business Revolution**

Whether we like it or not, we are now facing a social and business revolution that will rival anything in history. Sometimes called The Fourth Industrial Revolution, this is being driven by fundamental changes in information technology in our private and business lives. The main drivers in process control include standards-based, open systems, Internet & intranet technology, globalization and increased competition, and demand for custom made quality products. This revolution is having profound effect on the manufacturing processes and is putting increased demands on control engineers. (Slide 3).

**Batch Control in the Supply Chain**

Supply Chain Management is a set of coordinated activities that include procurement, manufacturing, storing, and marketing. While every factory and distribution center at a large manufacturer can be operating at peak efficiency, the organization as a whole can still be operating sub-optimally. It is analogous to a sports team with individual players who have great statistics, but cannot play as a team and, therefore, cannot win. Supply Chain Management addresses this problem by optimizing the performance of the system as a whole. (Slide 4).

Understanding the type of supply chain that a company has is an important step in its optimization. For some industries, the critical constraints are likely to be found in procurement, for others it is
manufacturing or distribution. Manufacturers in the same industry tend to be in the same supply chain segment.

Distribution-intensive supply chain manufacturers include Consumer Packaged Goods producers who must meet the demands of large retailers, or lose business. In recent years, there has been a fundamental shift in market power from manufacturers to retailers. Historically, manufacturers dictated the terms of trade with retailers and organized their businesses primarily to increase manufacturing efficiency and output. Today, large chain retailers increasingly are choosing suppliers based on their ability to match product flow to actual customer demand.

Manufacturing-intensive industries include industrial equipment, aerospace & defense, heavy metals, and semiconductors. In this segment, it is not unusual to find manufacturing facilities that cost over a billion dollars. Labor and material acquisition costs are relatively insignificant. The key is to keep those expensive machines up and running, with minimum transfer times and minimum queues. For this reason real-time scheduling is more important for such companies.

Companies that compete in industries with short product life cycles tend to be in the sourcing intensive sector. The two primary industries in this segment are consumer electronics and apparel.

Specialty chemicals, pharmaceuticals, food & beverage, and consumer products constitute a majority of the batch processes. Specialty chemicals and pharmaceutical industries fall between the manufacturing-intensive and distribution-intensive areas, whereas food & beverage and consumer products are mostly distribution-intensive. Therefore, batch-manufacturing enterprises generally require optimization in the manufacturing and distribution areas.

The Three Levels of Optimization

Until recently, process plant optimization was the main focus for control engineers. We were satisfied when the control loops were properly tuned and the recipes and phases ran in proper order producing products that were within the required quality specifications. With globalization of the market, increased competition, and the need for custom products, batch manufacturers are rapidly moving towards flexible just-in-time manufacturing. In this environment, supply chain and enterprise wide optimization are becoming increasingly important. It is no longer sufficient for an enterprise to have islands of automation along with the isolated supply chains. In order to maximize the potential of batch process control, manufacturing plants, enterprises, and the supply chains need to work together closely in optimized fashion. (Slide 5).

In this new environment, with integrated enterprises and supply chains, manufacturing will continue to maintain its central role. In this environment, it is not enough to leave the total responsibility of supply chain and enterprise wide optimization to IT personnel, who have little understanding of the manufacturing processes. Today, in order to maximize the potential of batch process control, engineers need to broaden their focus considerably. (Slide 6).

Process Plant Optimization

While today’s engineering design, training, and model-based control is converging; it is primarily for the benefit of continuous processes. Batch processes bring at least one added complexity: they rarely reach the steady state. Batch-oriented industries such as pharmaceuticals, fine chemicals, and food &
beverage have not used simulation-based tools for process optimization and operator training to the
same extent as their counterparts in the continuous process industries. (Slide 7).

Since the current optimization technology used in refining and other continuous processes must sense
steady state before they can calculate an optimum, they are somewhat limited in their applicability to
batch processes. Many manufacturers, however, have found approaches to optimize their batch
processes. For example, if the best practices of a master brewer can be captured as a series of rules, then
expert system applications have exhibited the ability to optimize the beer production process.

When approaching hybrid and batch processes with the goal of optimizing, other types of simulation and
analysis tools also become useful. Discrete event simulation software can optimize the process by
which the work is done. In this context, the word “process” applies to the procedure or methods used
from start to finish during an operation, whether it is a physical process or a human one. For example,
raw materials flowing through a plant that manufactures finished goods will encounter many processes
or procedures. In question are issues such as how many reactors are needed to handle a number of
batches, how fast a packaging line can move, and how many of them are needed to meet the production
demand.

Efforts are now being made to integrate planning and scheduling tools with on-line batch control
products. In 1998, AspenTech demonstrated the integration of its batch process modeling and
simulation package with Sequencia's OpenBatch package. This is a step towards an integrated batch
solution strategy for design, operation, and management of batch processes. Since then, other suppliers,
such as GSE, AEA Technology, and Simulation Sciences, have begun pursuing similar goals. (Slide 8).

It is not difficult to envision how using integrated simulation and design tools can allow a product
introduction cycle of 18 months to be shortened to as little as 6 months. A pharmaceutical company that
is trying to beat the competition to market with the latest miracle drug could find it is worth millions of
dollars.

Enterprise Wide Optimization

Why Integrate?

The primary objective of a manufacturing facility is to add value. The function of a business process is
to convert this added value into profit. That is pivotal for the success of an enterprise and it is leading
the batch process industry to shift its emphasis from process optimization to business optimization.
Access to manufacturing data is critical for business optimization because continuous improvement is
based on patterns and relationships contained in this data. Manufacturing data originates in plant
systems. Enterprise integration minimizes or eliminates duplication of data. (Slide 9).

An enterprise needs to understand its manufacturing requirements, its business needs, and their
relationships before it can come up with a viable integration strategy. A company may have a corporate
business information system or may be in the process of setting up one. It needs to determine the type
and quantity of information the business system will need and provide it to the automation system. The
information exchange between business and automation systems can range from simple production
schedules to elaborate quality, inventory, and process management instructions. The amount and type of
information that a business system will need from the control system can also vary widely. They may
only be averaged process values or could include information on alarm, quality, operator action,
production record, and materials movement. The amount of information exchange will determine the level of integration required between the batch automation and business systems.

There are a number of production management functions such as quality, documentation, maintenance, production scheduling, and quality management. One needs to decide whether these functions are to be performed by the business system or by the automation system, or partially by both. It is important to decide which system will be the main repository for process information. Inventory management and the tracking of material movements in production facilities may be carried out either by the business system or by the process automation system. Often they are shared by both and their interfaces need to be clearly defined. The work of ISA-SP95 Enterprise/Control Integration Committee is helping to make these decisions.

The Issue is not Real-Time vs. Transactional

Successful integration of a batch control system with enterprise management requires proper synchronization. There are a number of synchronization gaps. Time is an obvious gap. While a control system responds in seconds and milliseconds, an enterprise management system measures its time in months, weeks, days, and hours. A control system gathers real-time or event-based information with time frames consistent with plant process dynamics. An enterprise system maintains transaction processing information based on business dynamics. Execution in the enterprise system is oriented towards planning and scheduling, while execution is oriented towards engineering and control at the plant level.

However, the enterprise of the future will need to get closer to the essence of optimization. From a front-office perspective, this involves optimized planning for business requirements. Optimization from a back-office perspective involves manufacturing responsiveness to business requirements. For the enterprise of the future to satisfy its performance requirements, the front office and the back-office need to be synchronized, not in a time sense but in an information sense. Both need to be mutually supportive, driving toward the same goals, and operating on the same information. This level of optimization requires both business and manufacturing processes to interoperate in a single environment and information domain. This single environment will require a new generation of open plant systems based on a common component model. (Slide 10).

Cultural gaps between control and business management are a major problem in many organizations. Effective integration of these two worlds requires significant technical, educational, and planning efforts.

Typical Incremental Value to Manufacturing

A number of batch control system users have reported significant benefits from the integration of their manufacturing control systems with enterprise systems. They include increases in asset utilization and response to supply chain demand targets and reductions in off-specification products and cycle time variability. (Slide 11).

Current Status

Most integration to ERP tends to be done on a custom basis to solve specific problems. However, as enterprise software companies develop standard interfaces to manufacturing, standard integration products are emerging such as Hewlett Packard’s Enterprise Link, AspenTech’s ERP Connect, and IBM’s Production Connect. While the General and Site Recipe concepts in ISA-S88/IEC 61512
standard and the work of ISA-SP95 committee are conceptually helping this integration, XML and component technology are the main enablers. (Slide 12).

**Supply Chain Optimization**

Significant improvements in supply chain are taking place with Internet technology as the primary enabler. It is lowering business cost, extending global reach, increasing customer responsiveness, and making made-to-order manufacturing easier. Manufacturers and suppliers alike are rushing to introduce Web sites and business-to-business (B2B) marketplaces that can be used to market and procure all types of goods and services. Most manufacturers currently offer or plan to offer their own products over the Web via their own sites. The next move, which has already commenced among leading manufacturers in the automotive, aerospace, chemical, and other industries, is to align with one of the emerging industry-specific buy-side Internet portals in order to purchase raw materials, finished parts, and subassemblies. The end result is that the Internet is emerging as the great equalizer, leveling the playing field of competing suppliers and giving the manufacturing customer greater visibility and control over a procurement process that should ultimately result in improved procurement processes and significantly lower prices for purchased goods. Projections are that B2B will grow to $1 trillion in 2003. (Slides 13 and 14).

**The Promise of Internet**

However, the promise of the Internet is much greater than just lower prices. Strategic use of Web-based procurement capabilities can drive significant reductions in the costs associated with the procurement process itself, including request for quote, supplier selection, the bid process, and supplier management, among numerous other tasks. This promise of lower prices coupled with drastically reduced procurement process costs is what makes the Internet such a powerful force behind the sea of change currently underway in procurement strategies.

A key element fueling the Internet’s proliferation is its tremendous ease of use and resulting ease of doing business. While some manufacturers may not have moved to actually purchasing products on the Web, a vast majority relies on it to expedite the information-gathering phase due to the zero cost and minimal time associated with Web research. The Web offers a speedier and more efficient search process, particularly relative to the typical loop of asking the distributor a question and then waiting for a response after the supplier gets back to the distributor.

Internally, the greater visibility offered by a Web-based system allows tremendous control over the purchasing process and improved supplier management. Web-based procurement introduces lower transaction costs, particularly if the Web is used to internally standardize, control, and monitor the procurement process. Improved control and visibility over the procurement process throughout the entire enterprise will also result in lower inventory carrying costs since the now-agile procurement system can monitor inventory levels, time elapsed since last purchase, and calculate the optimum time to place a new order.

In the automation space, the Internet has been widely used to provide self-service support. This is true at the level of both supplier to user and within manufacturing companies themselves, where second and third shift operators can access application, machine, or product-specific information via the Intranet. Often, no human contact is required. Furthermore, the information required for service or support is available around the clock.
Availability of Web-based support and information has been a tremendous boon to small and mid-sized manufacturers. With the Internet leveling the playing field, these Tier 2 and Tier 3 manufacturers are now able to access technical databases and other information that was previously available only to Tier 1 manufacturers. Some suppliers are using this market reach to their strategic advantage. For example, Honeywell is using its MyPlant.com B2B marketplace as a means of providing on-line dynamic simulation capabilities to manufacturers who could not afford the technology in its legacy incarnation.

Both single supplier sites and multi-vendor B2B marketplaces can offer transaction efficiencies through Web-based selection, procurement, and post-sales support. Because they contain the offerings of only one supplier and perhaps their partners, however, single supplier sites cannot deliver the added advantage of competitive pricing that can ultimately drive down end costs. Suppliers use customer extranets to present customer-specific negotiated pricing on their Web site, but as recent experience shows, manufacturers can achieve tremendous savings by conducting a reverse auction with project RFQs. Moving from single supplier sites to a B2B marketplace also shifts the focus resoundingly to the buyer’s application requirements rather than the sellers and their products. Thus, the Internet technology is helping the optimization of supply chain in a very positive way.

Technology Issues

Components are the key to the open plant systems of the future. They are standardized software entities, which are reusable by virtue of their standardization and are interoperable through the standardized interfaces that they embrace. Components are another dimension to the mutually supportive requirements of the future enterprise. They provide a platform that facilitates performance through enhanced productivity, information unification, and process collaboration. AspenTech’s Aspen Framework and Honeywell’s Unifomance initiatives, both based on Microsoft’s DNA structure, are steps in this direction.

The underlying technology that makes the extended enterprise happen is Internet technology, in particular XML. This is an acronym for Extensible Mark-up language. Extensible means that the tag structure is expandable and mark-up means that it is self-describing. The fact that people can read it makes it easier to use. It is an evolving standard, precise, and secure. Just as HTML has become a part of our work and private lives, XML will become an integral part of our business infrastructure. XML is a common mechanism that promises to eliminate the business-to-manufacturing and business-to-business barriers. This concept is further enhanced by the emergence of business frameworks based on XML. Frameworks provide an infrastructure for e-business by fostering business transactions, supporting transaction persistence, and representing unique proxies for the transaction that link the customer to the supplier at the transaction level. Simply stated, a customer is empowered with as much or as little information about a purchase and the acquisition cycle as desired. (Slide 15).

Education and Training

Batch control problems have always been very different from continuous control problems. Batch process optimization includes optimizing recipes and phase logics, improving record keeping, and developing better batch and campaign schedules. In batch control, there is a strong emphasis on information flow between the control of various units and sub units and the levels of control. However, rapid advances in software technologies and platforms and increased emphasis on enterprise and supply chain optimization are presenting new challenges and opportunities to batch control engineers. (Slide 16).
In this new enterprise environment, manufacturing will continue to hold its central role. In this situation, it is not enough to leave the total responsibility for supply chain and enterprise wide optimization to IT personnel who have little understanding of the manufacturing processes. In order to maximize the potential batch process control, engineers need to broaden their focus considerably in the areas of enterprise and supply chain optimization. That would require a thorough grounding in the functions and capabilities of the Internet and XML language, along with software engineering and formal methods of analysis and design. (Slide 17).

**Conclusions**

Maximizing the potential of a batch process requires not only the optimization of the manufacturing plant, but also the optimization of the enterprise and supply chain. The transparent availability of information due to industry and de facto standards, open systems, and Internet technology has created a new landscape with many new opportunities. Significant opportunities now exist for control engineers to maximize the potential of batch processes. In order to accept this new challenge, control engineers need broader focus and additional training in information technology. (Slide 18).