WHITE PAPER

How Digitalization addresses sugar production challenges

The full potential of digitalized sugar production processes lies in a seamless interoperability between people, assets and production process as well as enterprise systems and effective use of the available data.

Abstract
While every sugar producer faces specific manufacturing challenges, there are several that resonate across the industry. Among today's most pressing concerns include the need to optimize energy consumption, reduce material use and inventory costs and increase asset utilization and throughput. Other priorities include the need to improve quality and reduce variations, errors and waste while maximizing material traceability and fulfilling regulatory compliance. Finally, there is a greater awareness and desire to embrace an agile manufacturing environment. Solutions to these challenges can be found in the new world that is emerging with the Internet of Things, Industry 4.0 and the application of digital technologies. Here we examine how the technology can be applied to the horizontal and vertical value chains. We suggest that most of today's digital systems are not fully integrated. Companies, suppliers and customers are rarely closely linked. Nor are departments such as engineering, production and service. Functions from the enterprise to the plant floor level are not fully integrated. Even engineering itself – from products to plants to automation – lacks complete integration. But with digitalization and Industry 4.0, companies, departments, functions and capabilities will become much more cohesive, as cross-company, universal data-integration networks evolve and enable truly automated value chains.

Introduction

The strategic goals of sugar producers are simple: to provide competitive products, boost profitability and grow their business in a climate of increasing globalization and elevated product development costs.

In reaching these goals, every sugar producer faces specific manufacturing challenges, yet there are several that are familiar across the industry including the need to:
- optimize energy consumption
- reduce material use and inventory costs
- increase asset utilization and throughput
- improve quality and reduce variations, errors and waste
- maximize material traceability and fulfil regulatory compliance
- embrace an agile manufacturing environment

So how do we go about harnessing digitalization to ensure companies, departments, functions and capabilities become much more cohesive? How do we better integrate the horizontal and vertical value chains? See Figure 1 (Koch et al., 2014[1]). How can we ensure cross-company, universal data-integration networks evolve and enable truly automated value chains? And most importantly, how can all this work towards solving the six industry challenges above?

Digitalization helps build a solid platform for process data collection. This addresses vertical integration by making sure process data are utilized for management decisions across the plant. Horizontal integration plugs the plant into the digital world, connecting suppliers and customers (Koch et al., 2014).

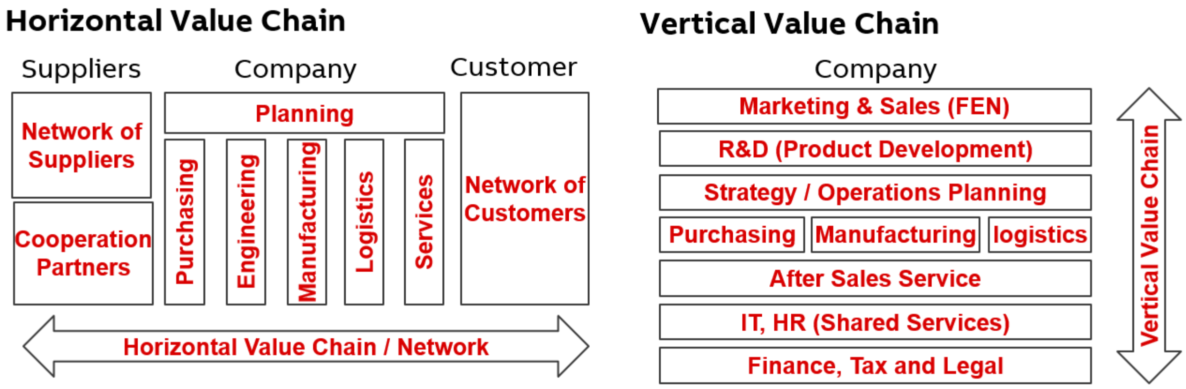

Figure 1: Digitalization helps build a solid platform for process data collection

The starting point is to understand precisely what is meant by "automation" and how the different process control levels affect both the horizontal and vertical value chains found across a sugar production facility.

Understanding automation

Automation helps perform operations that are continuous and repetitive, eliminating manual operations that would otherwise be required. Automation of a sugar production process leads to high yields, uniform quality and high plant utilization with minimized energy losses and environmental impact.

There are, generally, three types of automation:

Supervisory control and data acquisition (SCADA): encompasses network automation for applications needing robust, long-range communication but not necessarily high speed and computing power.

- Programmable logic controller (PLC): deployed for factory automation applications with high speed requirements and many discrete incoming and outgoing (I/O) communication channels.
- Distributed control system (DCS): used in process automation applications requiring high computing power. There are two variants of DCS, essential automation and extended automation. Essential automation is scalable and easy to use, providing automation for small- and medium sized operations. Extended automation is for customers who want to go beyond the classical scope of a DCS, involving a rich context of information whereby telecommunications, video and/or the power supply side of a plant is integrated along with automating the process.

Furthermore, automation is based on three classes of field equipment:

- Measurement products: are the eyes and ears of the operation.
- Actuation products: such as motors and drives, are the muscles that get something done in the field.
- Control systems: are the brain and nervous system of the plant.

To develop an automated interface between enterprise and control systems, ANSI/ISA-95 or ISA-95 standard was introduced and is applied in all industries and in all sorts of processes, like batch, continuous and repetitive. The objectives of ISA-95 are to provide consistent terminology that is a foundation for supplier and manufacturer communications. There are five levels (Level 0 to Level 4) to ISA-95, shown in Figure 2 (Scholten B, 2007[2]).

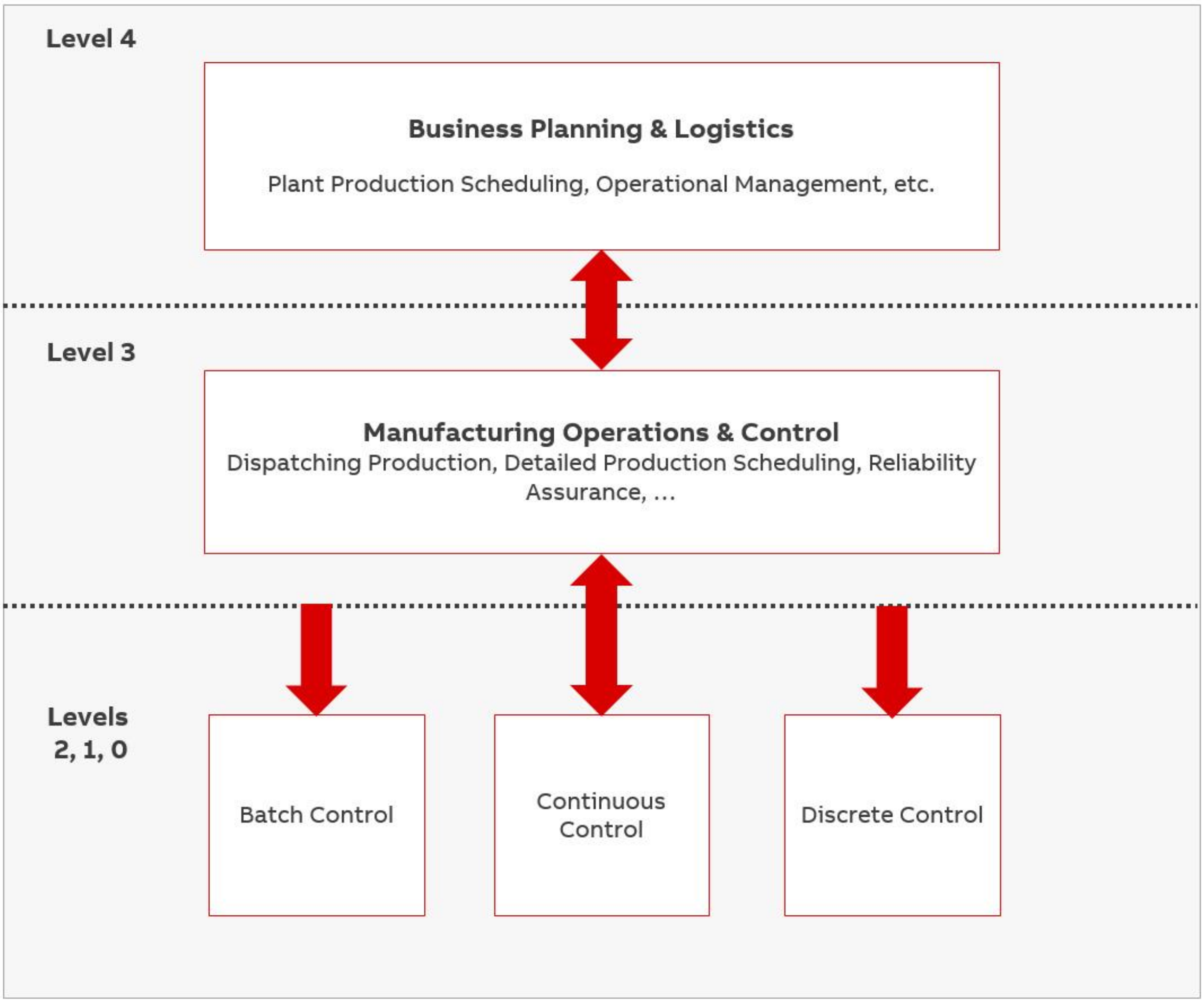

Figure 2: ISA-95 model

ISA-95 – Levels of automation

Level 0 – Field level – defines actual physical processes and contains the field devices such as flow and temperature sensors and final control elements such as control valves.

Level 1 – Direct control – defines activities involved in sensing and manipulating the physical processes and is the traditional instrumentation level with PLC systems and controllers as well as complete process controllers. It contains the Input/ Output (I/O) modules and their associated distributed electronic processors.

Level 2 – Plant supervisory – defines activities of monitoring and controlling the physical processes. It comprises plant control of sub-processes for optimization of yields, often using advanced sensors or automatic analyzers directly in the process. PLC, SCADA and DCS operate here, collecting all process data from Level 1.

Level 3 – Production control **–** defines activities of the work flow to produce the desired end products. It does not directly control the process but monitors production and targets. It includes systems for production coordination across whole plants to minimize costs and maximize yields and quality control. Typically, these are managed via manufacturing execution systems (MES), which analyze and control various elements of the production process (e.g., staff, inputs, equipment) in real-time. This helps decision makers understand how existing conditions in each plant can be optimized to improve output. This is where the Manufacturing Operations Management (MOM) solution comes into play. MOM is a comprehensive, scalable and modular suite that encompasses process intelligence, manufacturing execution, production intelligence and production optimization. Using data from Level 2 MOM undertakes historical trend analysis and key performance indicators.

Level 4 – Production scheduling **–** defines business related activities needed to manage a manufacturing organization. It covers Enterprise Resource Planning (ERP) systems and takes this to the next level by allowing companies to manage similar variables across multiple, geographically dispersed production sites while also automating many back-office functions. ERP passes data back to Level 3 for it to be then translated into action at Level 2.

Transfer of data

Figure 3, shows a practical example of how the ISA-95 model described above can be applied to the sugar industry. Real time data are exchanged between Level 0 and Level 1. Process data are transferred for monitoring and control by Level 2 (represented by material reception to dispatching outgoing goods). Meanwhile, Level 3 (represented by MES and MOM) organizes and analyses the data, and presents it in a format that is easier to make business decisions. Here the operational technology (OT) and information technology (IT) data have been integrated. The data share between Level 3 and Level 4 (represented by ERP) is typically resources (personnel, equipment and material), production capability (what is available to use), product definition (how to make a product), production schedule (what to make and use) and production performance (what was made and used). Level 4 shares this OT/IT for horizontal integrations.

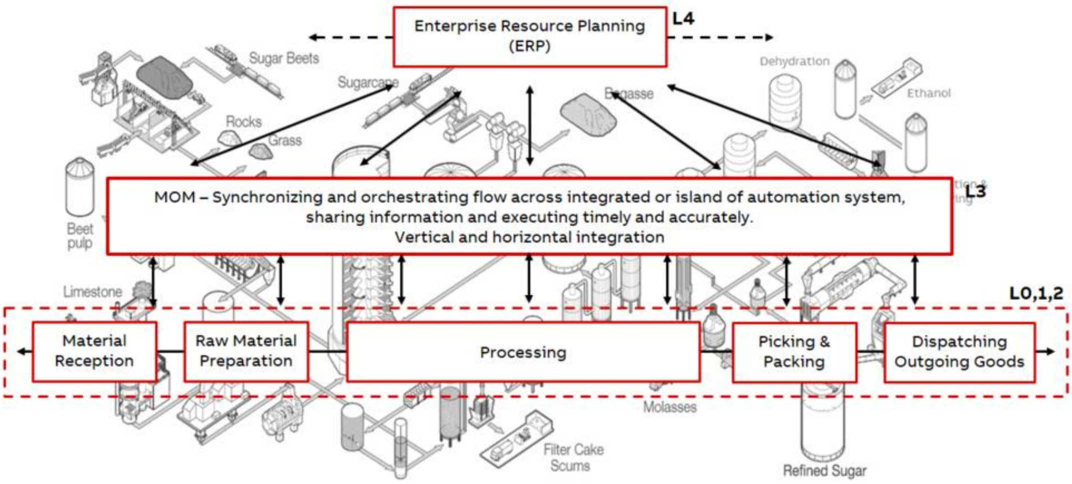

Figure 3: Data exchange between products and solutions in the sugar industry

MOM is a modular system, such that customers select the modules to be implemented. MOM includes many functions, not all of which an end user will need to start with. Figure 4 shows ABB's recommendation, based on experience and customer feedback, to build up the MOM phase by phase. During phase one, OEE and downtime management modules are recommended. This means implementing the most basic data collection type within the MOM function module first and expand the MOM as demand grows. For example, the KPI dashboard, OEE and downtime management are relatively easy to implement and often easier to justify in terms of return on investment. They also provide a solid foundation for other function modules to be added later.

• = Phase 1 • = Phase 2 or beyond

Station	Manufacturing Execution (MES)													Process Intelligence			Production Intelligence		
	Production Mgmt.	ERP Interface	Workflow Mgmt.	Equipment Maintenance Mgmt.	Downtime Mgmt.	Material Mgmt. (Goods Received)	Material Mgmt. (Weigh & Dispense)	Integration (Label Printing)	Warehouse Mgmt.	Material Mgmt. (Genealogy)	Electronic Work Instructions	Workforce Mgmt.	Quality Mgmt. (Lab. Entry)	Reporting Dashboard	Trends & Events	Excel Analyze	OEE	Energy Monitor	Batch View / Investigate
Weighing	-	•	•	•	•	•	•	-	-	-	•	•	-	•	•	•	•	•	-
Crushing	-	-	•	•	•	-	-	-	-	-	•	•	•	•	•	•	•	•	-
Juicer	-	-	•	•	•	-	-	-	-	-	•	•	•	•	•	•	•	•	-
Clarification	-	-	•	•	•	-	-	-	-	-	•	•	•	•	•	•	•	•	-
Filtration	-	-	•	•	•	-	-	-	-	-	•	•	•	•	•	•	•	•	-
Evaporation	-	-	•	•	•	-	-	-	-	-	•	•	•	•	•	•	•	•	-
Crystallization	-	-	•	•	•	-	-	-	-	-	•	•	•	•	•	•	•	•	-
Centrifugation	-	-	•	•	•	-	-	-	-	-	•	•	•	•	•	•	•	•	-
Drying	-	-	•	•	•	-	-	-	-	-	•	•	•	•	•	•	•	•	-
Packaging	•	•	•	•	•	-	-	•	-	-	•	•	-	•	•	•	•	•	-
Weighing	•	•	•	•	•	-	•	-	•	•	•	•	-	•	•	•	•	•	-

Figure 4: It is recommended to implement the MOM project step by step

The impact that MOM can have on the sugar production process is vast. Table 1 gives a sample of some of the challenges, features and benefits.

Challenge	Features and benefits
Improve resources utilization (productivity, efficiency)	– Real-time overview of the material usage and inventory/ WIP – Machines and equipment utilization in the context – Real-time production status and deviations
Reduce error and variation (waste)	– Defined workflows and exception handling – in process quality control – Electronic work instructions and checklists – Trained and certified operators – Paperless manufacturing
Facilitate continuous improvements	– Systematic collection, visualization and analysis of quality test records, deviations and non-conformances – Downtime and interruptions – Operator knowledge
Enable agile manufacturing	– Ease of introducing new products and processes – Responsiveness to customer change – Remove production constraints, control buffers – Integration with engineering and design solutions

Table 1: Impact of MOM on sugar production

Sugar application library

Sitting within Level 2 of the ISA-95 model, is the DCS (ARC Advisory Group, 2017[3]), many of which now host sugar industry specific software. Take for example, ABB's sugar application library. This facility unlocks the data that affect every job function in the sugar industry: from executives with a keen eye on profit to the maintenance teams tasked with continuous production during the critical peak seasons.

The sugar application library is a complete, consistent and comprehensive software databank of all sugar process applications, extending from beet and cane to refined sugar. It fulfils all process area requirements including raw material handling, purification, evaporation, crystallization and sugar handling. All utility areas are catered for including biomass power plant, ethanol and water treatment.

It is built from knowledge attained through collaboration with major process and equipment suppliers and sugar manufacturers. This ensures that the latest process control philosophies are incorporated within the library. One example is the vacuum batch pan library with high performance human-machine interface (HMI), shown in Figure 5. The image shown left shows pattern recognition for better visual monitoring. This latest best practice allows an operator to visually monitor a target introduced to the system. Pattern recognition is more effective than numbers and includes deviation bars and trends that enable the operator to easily verify a stable state while using large amounts of data.

The image on the right shows the sugar library's high-performance HMI focused on boosting operators' situation awareness and their correct and effective response to abnormal conditions.

The library comprises components for control and supervision. Each are complete functional units, ready for use and which can be adapted to specific user needs or process requirements.

What is particularly important is that the combination of the DCS, MOM and sugar library can help resolve the six challenges outlined in the beginning of this paper. It achieves this by bringing together the information technology (IT) and operations technology (OT) aspects of sugar production.

This digital combination provides the most advanced automation platform that, for the first time, optimizes both the process and electrical sides of a sugar processing facility. Working with the automation vendor, the sugar producer can devise a well-defined automation strategy that ensures everything works together effectively, from process control systems, automation and communication, electrical and variable speed drive technology and information technology.

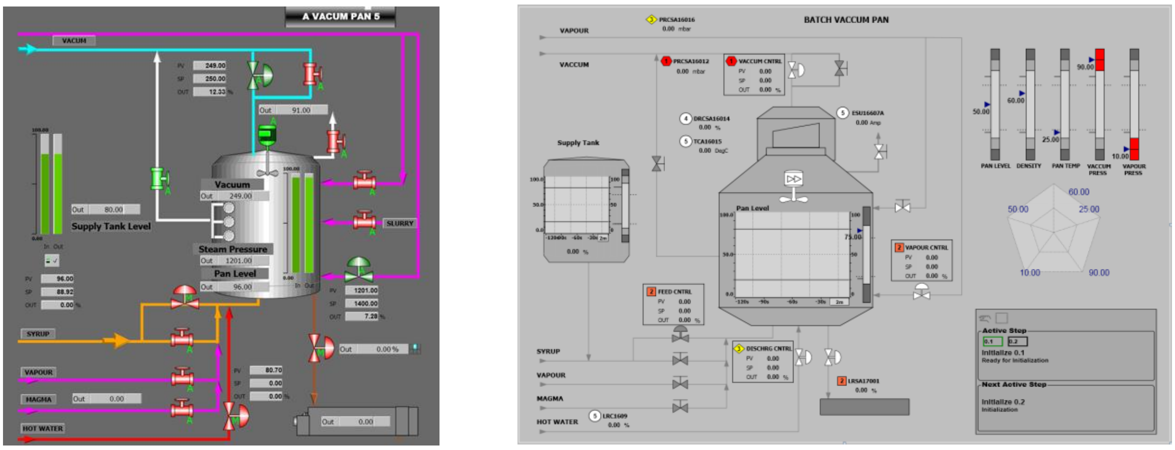

Figure 5: This graphical interface for the vacuum batch pan library enables the operator to increase the operational efficiency while decreasing the operations error

Furthermore, from the vast amounts of data generated during sugar production, users can now convert this into meaningful information, tailored to specific job roles. This leads directly to greater plant efficiency, flexibility and environmental protection.

Here we describe how to tackle the six industry challenges using the latest automation thinking described above.

Optimizing energy consumption

Rising costs of pollution control and energy consumption demands the use of innovative technology. The sugar process is packed with energy intensive applications, each consuming significant amounts of power, and, as a result, costs need to be tightly controlled – see Figure 6 (Pathak A N, 1999[4]).

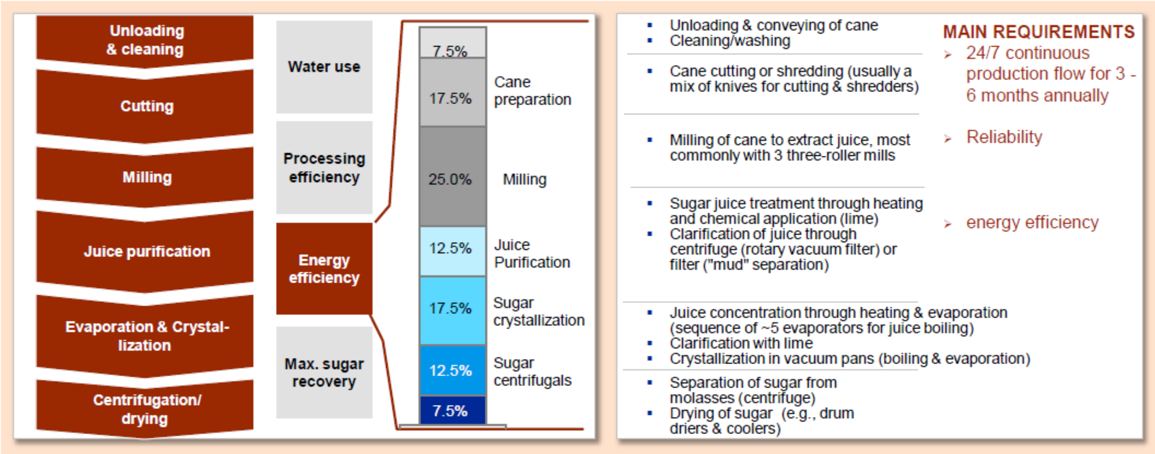

Figure 6: Energy consumption highlights in sugar production

With electrical and steam consumption among the sugar industry's biggest costs, there are many energy saving opportunities. Steam consumption, for instance, can be calculated, monitored and controlled to match the actual demand of individual parts of the plant. This can have a direct impact on the overall energy consumption, resulting in a 20 percent reduction.

Those automation suppliers that have a long track record in the sugar sector, have acquired in depth knowledge on every aspect of the sugar producing process. This know-how is being captured in a library of applications (see previously).

At the heart of any efficient sugar producing process is an industrial control system. When integrated with the sugar application library, the process and energy is optimized at the same time, which, in turn, translates directly into energy saving.

One benefit of the library is that it can hold detailed process data that help benchmark operational costs such as energy use. For example, the vacuum pan library is capable of monitoring and controlling the steam consumption during every batch. At the same time, it provides complete process control of level, pressure and temperature, to help stabilize all control loops. A stabilized environment helps reduce or eliminate energy waste.

Another feature available today is an energy management tool, found within the MOM. This energy management tool provides fast web-based access to all energy, production and environment data. It includes a powerful reporting engine. This enables the tracing of energy consumption and production key performance indicators over many years. It is easily integrated into an existing infrastructure such as energy meters or network analyzers and provides easy comparison of days/weeks/months/years or production lines/sites/countries in web dashboards.

The field level and direct control devices (Level 0 and Level 1) of the ISA-95 offer further energy saving opportunities. For instance, variable speed drives applied to the large-scale centrifuges that sit at the very heart of the sugar making process, can save up to 60 percent of energy consumed.

Outcomes/results of automation

- Lower energy and carbon dioxide emissions
- Transparency of energy use across plant
- Increased capacity
- Reduced production costs
- Improved profitability

Reduce material consumption and inventory costs

As raw materials vary, and orders are unpredictable, critical to the success of sugar production is cost control and waste reduction. Inventory, comprising raw material, work in progress and finished goods, is a significant part of the cost of sugar. But storing it, counting it, finding it and picking it becomes harder as the inventory grows.

However, as the product cost is controllable, proper planning, purchasing, handling, accounting and control of inventories is vital if productivity growth is to be achieved economically.

At the heart of good cost and waste control lies inventory management. Active inventory management provides a check against loss of materials through poor production or theft. It ensures an adequate supply of materials, stores and spares, while minimizing stock out and shortages, which could lead to costly interruption in operations. An inventory stock out, for instance could lead to the shutting down of a production line, with costs to re-start being extremely high. Active inventory management reduces the manufacturing cycle to a minimum.

It is also essential if waste is to be eliminated. For example, producers are looking at using bagasse (a by-product of sugar cane) for power generation, paper production, particle board and cattle feed. Molasses is being considered for butanol, yeast, industrial alcohol and high protein molasses. Lime, a by-product of the sugar extraction process, is produced and sold as a soil conditioner, so helping to preserve valuable limestone reserves.

The challenge in managing inventory is to balance the supply of inventory with demand. A company needs enough inventories to satisfy the demands of its customers while ensuring no lost sales due to inventory stock-outs. Equally a company does not want to have too much inventory as this can be costly too. Enough but not too much is the ultimate objective. Inventory should be viewed as cash that could have been spent in other ways. Anything above the customer needs is waste.

MOM provides various capabilities to help with inventory control including

- **Material management –** provides an efficient way for receiving materials, registering and booking to internal warehouse, keeping track of consumed and produced material and reporting back to the ERP system
- **Weigh and dispense –** ensures correct material and quantity is dispensed by verification checks on materials, containers and scales through barcode identification
- **Inventory management –** enables the efficient control of the warehouse structure (warehouses, cells, silos), and elements containing material (packages, silo layers, containers) including information about order, lot, amount, fill date/time, need for refill, expiration date handling, etc.

Another challenge is that many sugar facilities use a variety of programmable logic controllers (PLCs) and distributed control systems (DCSs) from several vendors, creating islands of automation. If one process area breaks down, then the entire process cannot be automatically adjusted to react. This results in material and energy wastage. By consolidating all automation and electrical products and systems through one vendor, operational efficiencies are vastly improved.

Outcomes/ results of automation

- Check against loss of materials through poor production or theft
- Ensures an adequate supply of materials, stores and spares
- Minimizes stock out and shortages
- Reduces manufacturing cycle to a minimum
- Eliminates waste
- Balances supply of inventory with demand

Increase asset utilization and throughput, while decreasing lead times

Sugar manufacturing or refining is resource hungry and as a result costs need to be tightly controlled. Yet changing consumer preferences and the rise of competitive brands emphasize the need for variety while retaining the highest quality standards.

A sugar campaign typically runs between five to eight months. During this time, all process equipment – from vacuum pans to centrifuges - must operate reliably and perform optimally to produce the highest quality end product.

For this reason, production and maintenance departments work closely together to ensure that production never fails during a sugar campaign. Downtime or production lost is defined by Loss Time Available (LTA). LTA measures the lost time or plant unavailability due to equipment failures and breakdown or operational impact due to operational errors.

Any maintenance or production stops, therefore, are arranged on a designated time and day and for a predetermined duration. Good asset practices mean good production output.

Inconsistent system behaviour is a leading cause for concern in the sugar industry. Production can be hampered through these irregularities and more manpower is needed to increase production capacity. There is a lack of process knowledge and automation expertise which leads to low throughput.

Some important measures to reduce the cost of production and improve cane recovery include enhanced production practices, nutrient, water and pest management and post-harvest handling.

With fine-tuned precision, a DCS together with a sugar application library (see section “Sugar application library”), can monitor and coordinate all the key electrical, instrumentation and control assets. It offers the complete solution to seamless manufacturing and business process integration.

The sugar application library provides a comprehensive control and simple operation interface and precise diagnostics and alarm management. This increases the operating efficiency, shortens the troubleshooting time and boosts utilization.

Furthermore, the MOM offers an overall equipment effectiveness (OEE) module and down time management feature.

Outcomes/ results of automation

- Throughput increased by up to 25 percent
- Manpower costs reduced by 50 percent
- Information made available through SMS
- Plant managers receive daily production reports via email

Improve quality and reduce variations, errors and waste

Turning data into accurate information ensures production is right first time, while eliminating waste and avoiding any variations in sugar quality. Among the many challenges facing the sugar industry’s efforts to improve end-product quality is the need for better quality juice clarification, improved pan boiling practices, modern boiling schemes and better sugar handling practices.

A repeatable process is key to maintaining consistent quality and maximizing the output from both processing and refining operations. A DCS and sugar application library provides continuous control and precise handling of all process steps and ensures consistent, high quality product is produced every time.

The sugar application library ensures that recipes are executed consistently from affination through drying, and that critical quality and process data are directly linked to specific phases of each batch cycle. It provides a simple human machine interface (HMI) that makes it easier for the operator to control their equipment. For example, with vacuum pan control only simple setpoints are needed to achieve very complex control that matches the boiling curve lead. This leads to a more consistent and higher quality end-product.

Meanwhile, a MOM system provides:

- Quality management - in process enforcement of quality and compliance measures (checklist, automatic or manual collection of quality data)
- Support for sampling and testing requirements
- Tolerance management - Non-conformance reporting, systematic collecting deviation from the product, process, procedure or compliance specifications
- Electronic work instructions - Guides the operator through important steps with the required production and safety instructions and checks
- Virtual trainer - Helps maintain knowledge about the process, product and safety on the shop-floor

Outcome/results of automation

- Improve sugar quality through consistent and precise control using the sugar application library
- Reduce variations through DCS, MOM and the dedicated sugar application library providing a solid and transparent platform for making the right decision based on the valuable information retrieved from historic data
- Reduce errors as sugar application library provides the simple and efficient operation through HMIs that help operators to eliminate or decrease operation error
- Avoid waste as all signal loops and sequence steps are supervised and controlled by DCS and the sugar application library

Maximize raw material traceability and fulfill regulatory compliance

Ever changing food safety standards emphasize the need for better raw material traceability, laboratory sampling and product control. To help ensure the quality of raw materials and improve plant efficiency, there is a need to optimize production yield and quality by delivering raw material traceability, while complying with the latest regulations.

Sugar producers need to provide different insights into quality and safety, depending on the destination of the product. Refined sugar, packaged as a final product to consumers, must contain records and test data that show complete traceability to satisfy regulators and retailers. Alternatively, when shipping raw sugar for refining, or sending bulk shipments for use as ingredients, then more detailed quality information will be needed. This information will, in turn, form part of the supply chain's quality record as well enabling them to adapt their processes to accommodate specific characteristics of a given shipment of ingredients.

Such complex manufacturing operations requires big data, that can be readily channeled to enable critical process, quality and event information to be received at precisely the right time.

MOMs improves product quality, reliability, tracking and traceability for regulatory compliance. It provides management access to all types of operational data enabling decision support for corrective actions and performance improvement. It provides a window into the production environment, powering process analytics and operational metrics with objective, detailed data.

MOMs material management software handles identification of material, tracking of consumed material, tracking of produced material, prioritization and control of source and destinations for material,

material compatibility, weighing, picking and packing. The material track and trace module also provides powerful product genealogy reporting by allowing searching and analysis of production data.

Outcomes/results of automation
- Tracking and tracing of individual, lots and batches
- Material identification, real-time reporting of material consumed and material produced avoiding product theft
- Management of material compatibility and availability
- Weigh and dispense support
- Material genealogy
- Enabling monitoring of transportation and warehousing activities
- Provide early identification of defective products, avoiding consumer recalls
- Fast, accurate and easy diagnosis of problems
- Less time spent on troubleshooting which hinder regulatory compliance and traceability
- Higher visibility achieved
- Manufacturing costs reduced

Enable lean and/or agile manufacturing

Although sugar manufacturers are rarely affected by changes in consumer tastes or the demand for new product varieties, there is still a need to adapt lean or agile manufacturing techniques to overcome production challenges. Furthermore, some manufacturers, especially those in South America, sometimes change from sugar to ethanol if the market demands, or if the sugar price is fluctuating.

Lean is about doing more with less and applies well in a supply chain with high volume, low variety and good prediction. Agile, meanwhile, describes the ability to respond rapidly to changes in demand, both in terms of volume and variety. During good weather, for instance, a sugar cane supply chain needs to be as lean as possible. However, during rain, or a crisis, agile resources are needed to minimize losses.

Few digital systems in the sugar manufacturing industry are fully integrated. Companies, suppliers and customers are not closely linked and departments such as engineering, production and service are not always communicating with each other effectively. Yet the need for agile manufacturing where production can be adapted to meet specific customer demands, can only be achieved if everyone is talking the same digital language.

MOM brings end-to-end visibility of to an entire sugar production process. It is a scalable and modular suite that extends across:

- Process intelligence
- Manufacturing execution
- Production intelligence
- Production optimization

As such it affords the various plant stakeholders effective decision-making and reliable lean production execution through fully integrated operations. It contains rich, out-of-the-box functionality, comprising easy to configure modules that address specific industry needs.

Outcomes/results of automation
- Consistent volumes and quality as production risks reduced
- Fewer decision makers needed
- Reduced operating cost
- Better management of a plant's asset capacity
- Substantial improvements in the whole supply chain efficiency

About ABB

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