WHITE PAPER

How to make sugar production more productive and sustainable using variable speed drives

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Introduction – challenges facing sugar producers

Sugar is a well-established industry and rapidly aging sugar plants are facing a lot of challenges. Increasing costs and highly competitive markets are forcing plants to find new ways to improve their profitability. The problem is that many plants' existing production machinery, like steam turbines, is less energy efficient and reliable than modern equivalents.

Unplanned interruptions in the process cost a lot of money. Plants generally operate on a highly cyclic basis, typically running 24/7 during and directly after harvest time followed by quiet periods when the equipment is maintained and prepared for the next harvest. These intense operating cycles lead to machinery aging faster than in other industries. However it must still provide excellent reliability because downtime has to be avoided during production periods.

Furthermore, ambient conditions in the tropical and sub-tropical regions where sugarcane grows can be tough for both mechanical and electrical equipment. Similarly, in beet sugar production, machinery must withstand harsh conditions like extreme temperatures and corrosive environment. Dust is another challenge in some stages of cane and beet production process.

In addition to producing sugar, many plants generate electricity by burning bagasse, a by-product from the sugar manufacturing process. Producing electricity not only allows plants to be self-sufficient and cover their own energy needs, but also to sell the excess electricity to the local grid, providing an extra revenue stream and helping avoid issues with weak networks in remote cane-growing regions. Using high-efficiency electrical equipment reduces losses and increases productivity to allow for more electricity to be sold.

Another valuable fuel source, bio-ethanol, is created by fermenting the sugars extracted from sugarcane or sugar beets. By upgrading to new equipment, sugar plants can enhance the efficiency and reliability of their ethanol production systems, making better use of by-products, helping further support environmental goals.

At the same time, process data cannot easily be accessed when using older production machinery, making it difficult to obtain information about how processes are running. Getting data from existing systems involves installing sensors or taking measurements, sometimes even manually.

In order to stay competitive, sugar plants simply have to keep up with new technology. The aim of this white paper is to explain how variable speed drive (VSD) systems can help to overcome and to mitigate some of the challenges sugar producers are facing. Furthermore, it explains how sugar plants can achieve improved productivity, increased energy output and a higher return on their investment (ROI) by choosing the right supplier for VSDs and motors.

How can VSD systems help?

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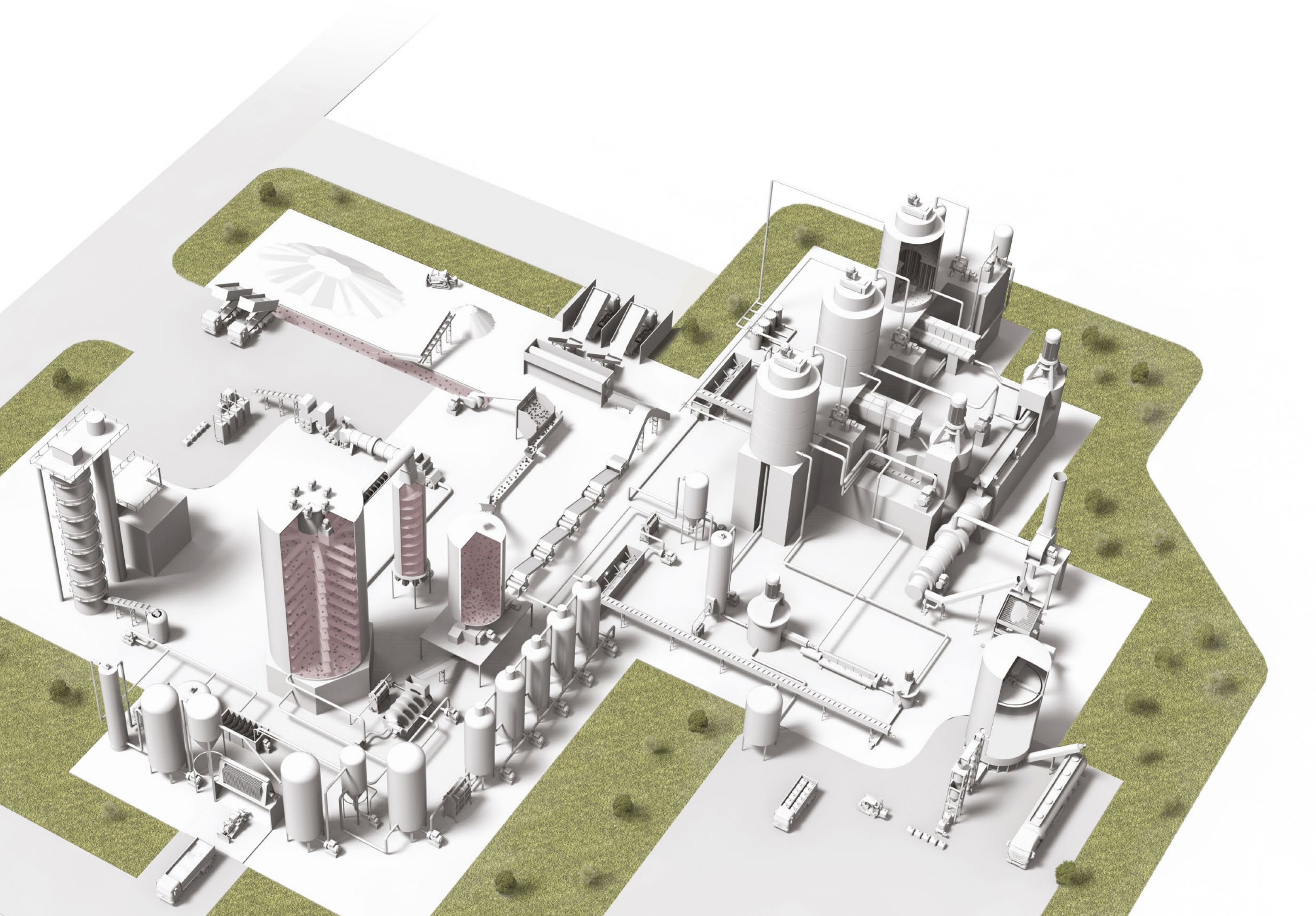
Note about terminology: this white paper uses the term 'variable speed drive (VSD)'. VSDs are also commonly referred to as variable frequency drives (VFDs), adjustable speed drives (ASDs) and adjustable frequency drives (AFDs). In the context of AC motor control, all these terms can be used interchangeably.

VSDs control the speed and/or torque of AC motors by adjusting the frequency and voltage of the motor supply. Using a drive, the speed of the motor can be regulated to match the exact needs of the process. As a result, the motor will only consume the electricity needed to operate the process at the desired speed, and no more. This can lead to major energy savings compared to the alternative of running the motor at full speed and controlling the process output by mechanical means like valves, gearboxes or dampers. By reducing the need for these types of mechanical components, drives also improve overall process reliability, reduce maintenance needs and help to cut downtime.

In addition, VSDs eliminate or reduce many of the issues that sugar plants face when operating steam turbines, such as delicate speed control, high heat and noise, long start-ups (one to two hours), and the frequent need for expensive spare parts. The more efficient use of the generated energy is another major improvement.

In general, drives deliver precise process control. The process can be ramped up and down smoothly, which prevents sudden shocks to the motor and other machinery. This results in reduced wear and tear of mechanical components, significantly reducing the operational costs.

VSDs can provide a wide range of operational data from the process. They can be connected to, or integrated into, other control systems. By connecting electrical controls to higher level systems and deploying modern digital technologies, plants can undertake predictive maintenance and process optimization to boost their reliability and efficiency.



A solution for every application

Drives can be deployed in almost all parts of the sugar production process. As an example, there is a sugar beet plant in North Europe, which has 144 drives installed at its premises. The power generation plant has 36 drives with a total power of around 1 MW, and there are 108 drives with a total power of around 6 MW in the production process. Around 60 percent of the drives operate pumps, 25 percent control presses, mixers and centrifuges, and 15 percent run other applications.

The payback time for an investment in drives and motors depends on many different factors, and it has to be calculated for each individual project. For instance, calculations for medium voltage drive investments typically result in payback times between 1.5 to 4 years, mainly depending on the load cycle and current control methods. In some instances payback can be less then a year based on energy savings alone.

Power plant

Sugar production is an energy intensive process and a typical sugar plant requires 10-12 kWh of electricity per ton of cane milled. Power plants generally operate on a co-generation basis, producing both steam and electricity. Power plants generally operate on a co-generation basis, producing both steam and electricity. The bagasse produced from processing sugarcane generates significant electrical power – around 0.450 MWh per ton. With the large volumes of bagasse processed, sugar plants typically generate enough electricity to cover their operational needs and still have surplus power to sell to the grid. When drives are installed and efficiency increases, sugar plants are often able to sell more electricity to the grid. Some sugar plants have installed drives and motors to replace the old steam turbines that power some process equipment. By further installing efficient, high pressure boilers they have increased power generation and boosted electricity sales. As case study 1 shows, this can produce an important additional revenue stream, especially in areas where electricity is relatively expensive.

Figure 1. The energy train, describing how chemical energy is converted to electric energy

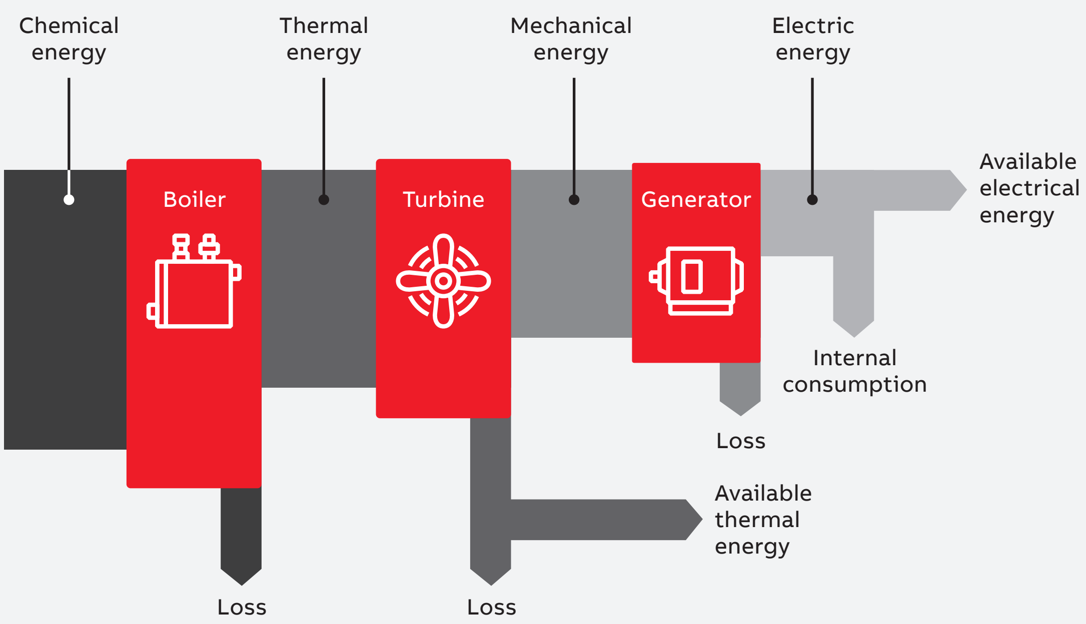
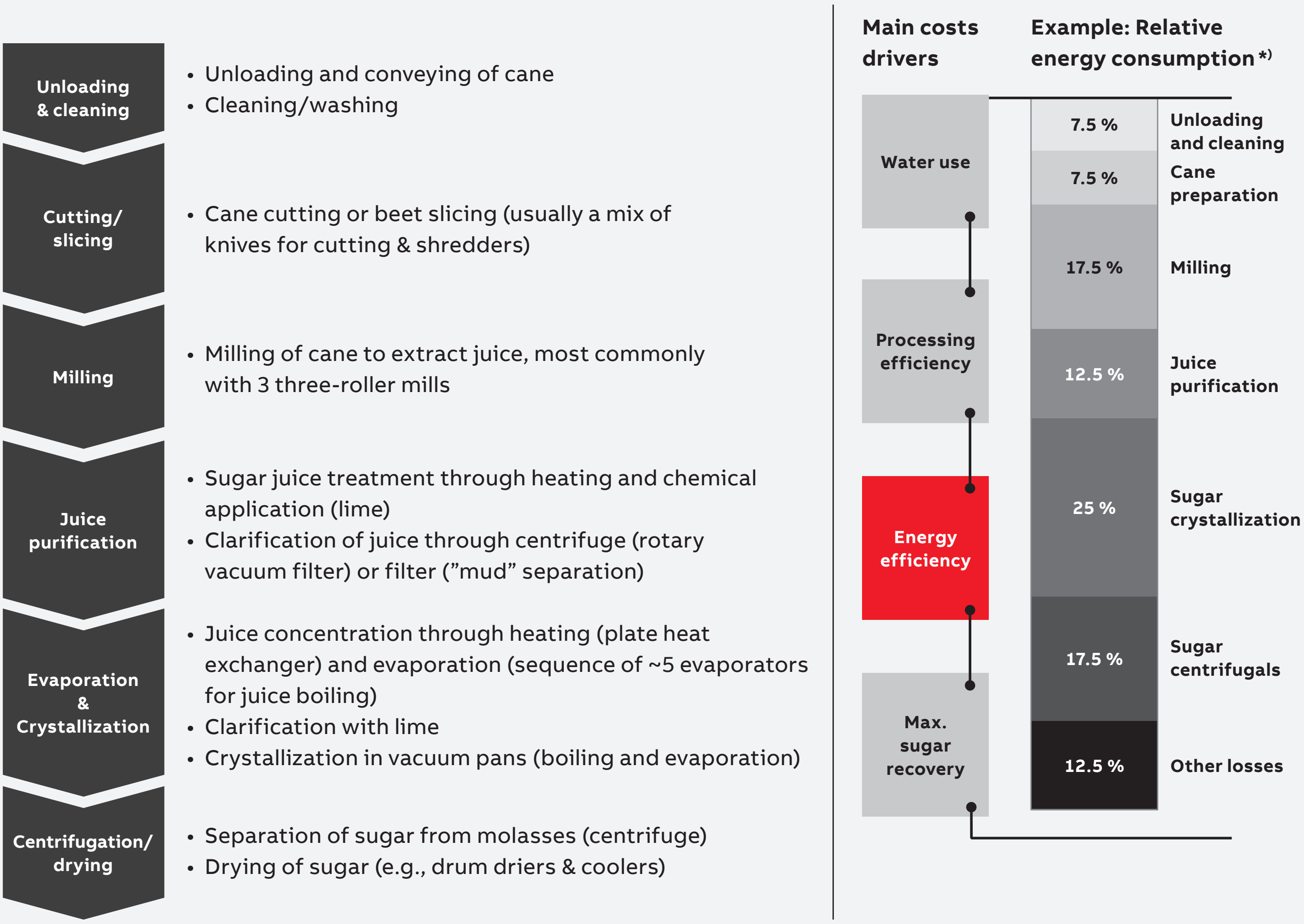


Figure 2. Sugarcane processing: main cost drivers and relative energy consumption of individual process steps



*) Energy consumption calculated for the whole plant 2. Membrane filtration could be on option, if reasonable costs and capacity throughput.
Source: Pathak (1999), Mbohwa (2013), Clarke (1999), BCG analysis.

Production processes

Of total world sugar production, about 80 percent by volume comes from sugarcane and 20 percent from sugar beet. In both the sugarcane and sugar beet processes, raw material preparation, pumping and centrifuges consume the most energy. Figure 1 shows how chemical energy is converted to electrical energy and figure 2 presents the principal cost drivers and relative energy consumption of the different process stages.

The following sections describe how the most energy consuming sugarcane and sugar beet processes can benefit from using variable speed drives. The processes to prepare sugarcane and sugar beet are different in terms of their power consumption, and VSDs work in different ways in the two processes.

Sugarcane preparation

Sugarcane preparation and milling are very energy intensive processes, typically consuming 40 to 45 percent of all the energy used in the plant. These processes are therefore logical targets for efficiency improvement measures.

Sugarcane crushers operated by steam turbines can be upgraded with VSDs and induction motors, as described in case study 1. In addition to improved energy efficiency, other benefits include better uptime, reduced maintenance, and quieter operation, as the noise from electrical machines is almost negligible when compared to steam turbines. Steam turbines that are driven by mechanical regulators can cause enormous maintenance and control problems, and direct readings of the controlled variables are not available. Case study 2 describes how energy efficiency increased by 40 percent at a plant in Pakistan, after steam driven equipment was replaced with new electrical machinery.

Another benefit of using VSDs is stress-free network performance during start-ups. The crushers and mills used to prepare sugarcane have traditionally been driven by steam, or slip ring motors. In these applications, a high torque from zero speed is needed when the machine is started. The problem is that the high torque results in high start-up currents, which can cause a voltage dip in a weak electrical network. High start-up currents might therefore cause tripping and production stoppages at sugar plants which have their own, relatively small power plant or are in a weak network. With a VSD system, by contrast, the start-up is smooth and reliable and does not cause any disturbances to the supply network

Sugar beet preparation
The process to prepare sugar beet uses more energy than that for sugarcane. The first stage in sugar beet preparation is to slice the beet, which is done by energy-intensive slicing machines. This is a process where reliability needs to be high to avoid costly stoppages in the system, and throughput per kilowatt should be kept as high as possible. The machines require good speed control to ensure that the slices are produced in the right quantities and that the process flows in the best way possible. VSDs make it easy to control the speed of the slicing machines, providing precise control of their output in order to optimize process flow.

Later in the sugar beet process, VSDs with built-in master-follower functionality are a good choice to control presses and mixers. Each press or mixer is driven by a number of motors, with each motor operated by its own VSD. For each driven machine, one VSD is configured as the master and the others as followers. A communication link between the VSDs ensures that the followers maintain the same speed and torque as the master.

An important benefit of this configuration is that the load is easier to control when driven by a number of motors rather than just one. Additionally, the use of multiple VSDs and motors provides redundancy: if a drive or motor fails, the process will nevertheless continue running, which helps to reduce downtime.

Pumps
In both sugarcane and sugar beet plants, pumps are used throughout the process to transfer water and juice. Pumps account for approximately 25 percent of the plant's total energy consumption and therefore offer big potential savings through energy efficiency. Conventional systems use valves to control flow: the pump motor is run at full speed and the flow is restricted to the required level by adjusting valves. This is highly inefficient – in fact, it has been compared to driving a car with one foot permanently on the gas pedal while the other foot operates the brake in order to control speed. Upgrading these types of pump system with VSDs will not only save energy but also provide easy pump speed control and smooth process operation, and it will reduce the number of potentially unreliable mechanical components.

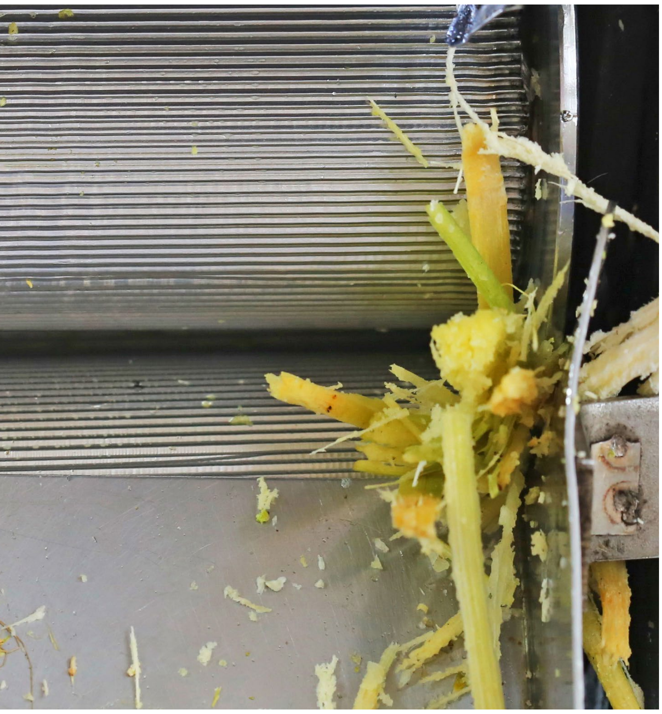
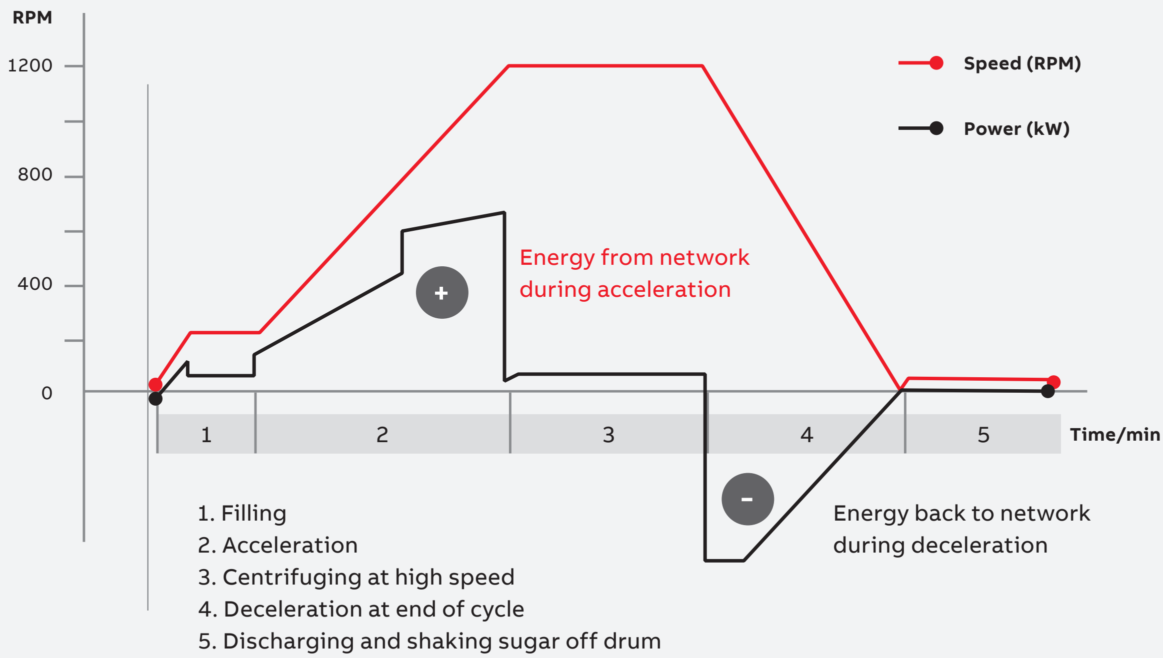
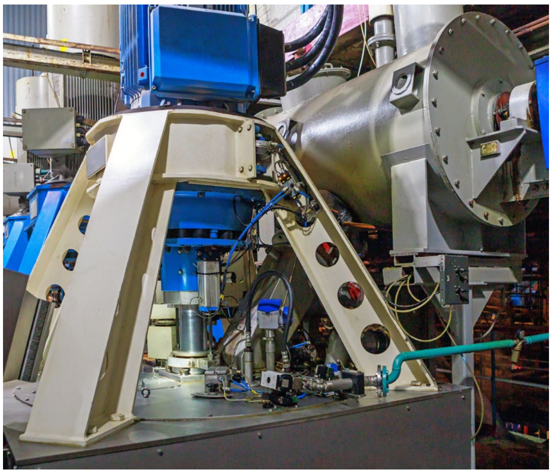


Figure 3. Duty cycle of sugar centrifuge using regenerative drive for energy recovery



Centrifuges
Sugar centrifuges accelerate fast, spin at nominal speed, and then decelerate fast. The cycle time depends on the size and mass of the centrifuge and can be 3 to 5 minutes, which means 10 to 20 cycles per hour. Plants typically have around ten centrifuges.



VSDs with regenerative functionality are the ideal solution for controlling batch centrifuges, because they make it possible to recover energy during the deceleration phase. The operation of the plant's centrifuges can be balanced to smooth the power demand. When one centrifuge is decelerating, the energy recovered by the regenerative drive can be re-used by accelerating centrifuges. Figure 3 shows a typical sugar centrifuge duty cycle, with power consumption and recovery curves. Case study 3 describes how a sugar plant in the US used a regenerative VSD to recycle energy and cut its centrifuge cycle time by 20 percent.

VSDs can produce major energy savings when used to control centrifuges. This is one of the most demanding applications in sugar plants, as the cyclic operation of centrifuges makes it challenging to dimension the components correctly. Vendors should therefore have in-depth know-how covering both the application and drive.

Selecting the optimal vendor for drives and motors

Because the nature of the sugar industry makes special demands on production equipment, it makes sense to work with a drives and motors vendor who understands the process or – even better – has experience in supplying drives and motors for sugar applications.

Furthermore, it is important to select a vendor who understands the bigger picture of the plant's electric network. When choosing the correct components, it is essential that the VSD system does not cause any disturbances to the rest of the system, for example spontaneous tripping of breakers that can cause a production stoppage. Factors such as network harmonic content, power factor and voltage fluctuations need to be taken into account when engineering the updated plant operations. Otherwise, these factors can cause unwanted effects in the network for the sugar plant.

The seasonal operation cycle of sugar plants means that downtime must be minimized during harvests. Equipment should therefore be reliable and easily maintainable, with spare parts, service and support available at short notice.

Tough ambient conditions, with heat, humidity and dust, underline the importance of sourcing proven and robust drives and motors that will deliver good performance in difficult circumstances. For motors, special attention should be paid to high ingress protection (IP class) and the insulation system.

In upgrade projects there are advantages to choosing a vendor who can supply not only drives and motors, but also other equipment like control systems and switchgears. In any project, choosing a combined drive and motor package will provide clear benefits in terms of higher efficiency, reliability and a longer lifetime.

In today's interconnected environment, digital connectivity and cybersecurity are crucial. Plants should implement digitization services that comply with cybersecurity standards like IEC 62443, ensuring both efficient operations and data security. The collected data can then be transformed into actionable insights for continuous process improvement and equipment maintenance.

To leverage modern digital technologies effectively, it is essential for sugar plants to select a vendor who can integrate drives with control systems and enable advanced digitization and digitalization services. This integration should support remote condition monitoring, data collection, and analysis for process optimization and predictive maintenance.

Conclusion

Sugar producers seeking to increase their competitive advantage typically focus on optimizing their plant's energy efficiency, performance and reliability. VSDs combined with reliable, energy efficient electric motors will support their efforts in all three of these areas. Energy efficiency is boosted by using drives to save energy in mills, grinders, mixers, pumps, centrifuges and other equipment. VSDs enhance performance by increasing the overall degree of automation, which makes processes more flexible. They also deliver smooth and precise process control, which helps to ensure steady throughput and good product consistency, and a high sugar recovery ratio. VSDs improve reliability by decreasing the wear and tear on motors and driven machinery, and by reducing the need for mechanical components.

In addition reduced energy consumption will contribute to a more sustainable operation and reduce CO_2 emissions. For instance, VSDs can cut energy consumption by up to 25%. When paired with high-efficiency motors, the reduction in energy use can be even more substantial, contributing to the overall goal of achieving CO_2 neutrality. This combination not only supports energy efficiency but also aligns with global efforts to reduce carbon emissions and combat climate change.

Upgrading sugar production equipment requires investment. The payback time for investments in VSD systems, however, can be relatively short due to higher energy efficiency, higher productivity, and additional income from the sale of surplus electrical energy. In some cases, sugar plants have achieved payback times of less than a year.

Case studies

Case study 2
Customer: Mirpurkhas Sugar Mills, Pakistan
Capacity: 7,500 tons sugarcane per day

A steam turbine operating a crusher mill was replaced with an ABB ACS800 drive and NXR rib cooled motor. While 650 to 700 kW of steam energy was required to drive the crusher mill under the old system, with the new electric solution just 350 to 400 kW is required. The energy required to drive the cane crusher was therefore reduced by 40%.

One of the most beneficial aspects of the upgrade is the very high starting torque produced by the motor. Other advantages include a significant decrease in noise and reduced downtime. ABB's global sales support network, proven quality, technical expertise and extensive application knowledge, which ensured a tailor-made motor-drive package, were all factors in the sugar mill's decision to work with ABB.

Case study 1
Cane crusher upgraded with VSDs and motors
Boiler replaced with efficient, high pressure unit

Customer: Sugarcane plant in Honduras
Capacity: 10,200 tons sugarcane per day
Operation: 155 days per year

A cane crusher in the plant was previously driven by five 750 kW steam turbines for a total power consumption of 3,750 kW. The steam turbines were replaced with ABB ACS1000 VSDs and induction motors. At the same time the power plant's boilers were upgraded to high pressure units.

The steam previously used to drive the turbines can now generate electricity. Allowing for the power consumption of the VSDs and motors, the plant produces surplus energy of about 6,550 kW that can be sold to the grid. This produces additional revenues of approximately $1 million per year.

Other benefits include improved uptime and less maintenance, load-optimized crusher speed, overload protection, faster crusher start-up, longer equipment lifetime due to smooth ramp-up, and reduced noise.

Case study 3
Regenerative drive cuts centrifuge cycle time and recovers energy

Company: Sugarcane plant in the USA
Capacity: 24,000 tons sugarcane per day

At this sugarcane plant in the US, one of the largest centrifuges was controlled by a legacy drive that proved unreliable and inefficient. The drive was replaced by an ABB AC industrial regenerative drive that provides both speed and torque control.

Compared to the previous drive, the cycle time was cut by 20% through precise and rapid motor-speed response based on variations of the centrifuge load. During the deceleration phase the motor is turned into a generator, recovering energy which is transferred via the drive to an adjacent centrifuge. The drive's ride-through ability means it can maintain full power during short-term voltage reductions.

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