High-tech steam turbines and generators leverage efficient cane sugar and electricity production

1 Introduction

Cane sugar is manufactured in sugar mills in tropical and semi-tropical regions. For every 10 t of sugarcane crushed, a sugar factory produces nearly 3 t of bagasse as a byproduct. The bagasse contains enough energy to allow the mill to be self-sufficient with respect to steam and power requirements. Depending on the mill’s efficiency, location, and the local electricity grid, excess power may also be fed into the grid for additional revenue.

As a rule of thumb, in a typical cane sugar mill approximately 500 kg of low-pressure process steam are required to process 1 t of cane. Along with generating steam for the process, steam turbines are also used to drive the cane milling tandems. Either condensing or backpressure turbines in a single or multistage design are used in the sugar-making process. They can also be equipped with single extraction options or multiple controlled (pass-out) and uncontrolled (bleeding) extraction options.

Single-stage back-pressure impulse-type turbines have about 25 to 30% efficiency. A condensing steam turbine (multi-stage steam turbines) can operate at efficiencies from 80% to 89%. The condensation path maximizes the electrical power output. The low-pressure steam required for the sugar/ethanol manufacturing process can also be extracted from the appropriate stage of a condensing turbine.

If the factory due to appropriate energy-saving equipment has excess steam, the energy contained in the steam can be recovered as electricity using a condensing turbine.

2 Example 1: Looking for an efficient solution in Brazil

Grupo Delta Sucroenergia, one of the Brazil’s many sugar producers, was looking for solutions to maximize its power generation during and between the cane processing season, which last roughly from April to December. The company planned to expand its sugar and ethanol plant in the city of Delta (Usina Delta) in the southeastern state of Minas Gerais, and also wanted to make it fit for the future. The Delta plant was founded in 1950 and was acquired by Delta Sucroenergia in 2000. Two important pieces of the puzzle were the steam turbine and its connected generator.

After a thorough analysis and help from the sugar industry and steam turbine experts, Sucroenergia needed to answer the following questions:

- What do they want the mill’s maximum sugarcane crushing capacity to be over the long term?
- What should the production mix be (sugar and ethanol) in the next crops?
- How would this mix impact the demand for process steam?
- What were their plans, and what are the possibilities for optimizing process steam consumption?
- How do these scenarios work in terms of the available volume of bagasse?
- How much of sugarcane trash can be brought from the fields to complement the bagasse as fuel?
- What are the most suitable pressure/temperature pairs for thermoelectric expansion? How can they optimize the water-steam cycle?
- What would be the cost benefit in the heat balance of keeping the old turbines rather than concentrating on acquiring a new one?

At the end of the analysis process, it was clear that a new and single machine would be the best option. The reasons included: increasing power generation by more than 13% compared to the previous turbine configuration, and the possibility to burn more field trash in the future. The Brazilian sugar mill opted for Siemens. Why? “We chose Siemens for its high-quality solutions for the sugar industry, its superior expertise, and its proactive consultancy at the beginning of the project,” says Lyra. “And because of the very trustful relationship we built during the last years.”

For the sugar industry, turbines of up to 50 MW are the most relevant. Small sugar mills use the SST-060, which have a power capacity up to 6 MW. Larger sugar mills may use, for example, the SST-300 with a power capacity up to 45 MW. But for Usina Delta, it needed to be even bigger due to the high milling rate: In 2016, the entire company Sucroenergia processed 9.6 mn t of cane, of which 4.2 mn t were processed at Usina Delta. The factory ordered the SST-600, a turbine family with a maximum output of up to 150 MW. With this machine it would have the capacity to cover its internal consumption requirements and sell the excess power to the national grid.

3 New steam turbine powers 200,000 homes per year

On April 30, 2016, the largest turbine manufactured in Brazil for the sugar and ethanol industry began operation at Usina Delta. The 73.4-MW SST-600 turbine was manufactured in Jundiaí, about 50 km from São Paulo. It measures 8.5 m in length and weighs 130 t.
The plan worked: Today roughly 50 MW can be fed back into the Brazilian grid, which is four times more than the power consumed by the plant. Before the installation, the Delta plant only fed back about six MW. Leandro Martignon, Delta Sucroenergia spokesperson, says: “We went beyond our generation target with this turbine.” It’s capable of a total output of 376,503 MWh per year, enough to power 200,000 homes, which is the equivalent of a city the size of Ribeirão Preto in São Paulo. The previous equipment produced 51,368 MWh per year. This is also the first steam turbine in the industry in Brazil to dispense with the gearbox (Fig. 1). It features an innovative layout concept for outdoor installation that significantly reduces the cost of civil works and of lifting machines in the power house. It can be used both for condensation and back-pressure operation and is suitable for conditions of high steam pressure and temperature. On average, steam of nearly 520 °C and pressure of about 67 bar produced drives the turbine. This turbine family is appropriate for a variety of installation conditions, including radial and axial exhaust solutions. For this project, Delta Sucroenergia decided for the radial downwards exhaust with the outdoor layout.

5 Flexible solution for seasonal work and off-season

But there’s another reason why high-tech sugar mill equipment needs to be flexible. In Thailand sugarcane is harvested from December to April. They produce sugar for only four months of the year. During the off-season, many sugar mills use stored bagasse as a fuel, and when the bagasse supplies are depleted they turn to alternative fuel supplies in order to generate power year-round. Most of them have traditionally used coal as their alternative during the off-season, but they are now also considering low-GHG-emission solutions, such as co-firing with wood pellets. This means that equipment like turbines must be flexible and robust enough to easily handle load and fuel switches, different steam parameters.

6 Example 2: Best use of a valuable natural resource in Thailand

The family-owned Mitr Phol Group is Asia’s largest sugar and bio-energy producer. Ethanol production is also part of their core business. In two of its six sugar mills in Thailand, Mitr Phol runs SST-300 steam turbines. Phu Khieo 1 has been using an 11.4 MW condensing SST-300 since 2010 (Fig. 2). Phu Khieo 2 started operating its 26 MW backpressure turbine SST-300 after a plant modernization in 2015. In April 2017 the company ordered an SST-400 and an SST-300 steam turbine (Fig. 3), for a total of seven steam turbines in use in five Mitr Phol operational plants. The connected boilers produce between 120 and 140 t/h of steam. The backpressure turbine is powered by steam at about 70 bar and at a temperature of 510 °C. Together the two factories Phu Khieo 1 and 2 crush 40,000 t/d sugarcane and produce among other products 1,500 t of refined sugar per day and roughly 502 GWh/year of electricity. In Phu Khieo roughly half of the bagasse is burned during the cane harvesting period; the rest is stored to generate power during the...
off-season, which is fed into the grid. In 2011, Phu Khieo won the ASEAN Energy Awards as best biomass power plant at the ASEAN Energy Business Forum Conference in Brunei.

7 A 360-degree view: More than just turbines and generators

Siemens has been developing solutions for the sugar industry for more than 100 years and can lay claim to a profound understanding of sugar production. Sugar industry expert Murilo Sgobbi Teixeira says, “We are very familiar with the processes and objectives involved, as well as the challenges that producers face. Our work aims to boost output with reduced expenditures and resources, allowing them to acquire greater independence, sustainability, and profit in the future.”

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