EVOLUTION OF SURPLUS POWER GENERATION IN BRAZILIAN SUGAR/ETHANOL MILLS

By

H.M. LAMONICA, A. FIORANELI, F.A.B. LINERO and M.R. LIMA VERDE LEAL

Centro de Tecnologia Copersucar - Fazenda Santo Antônio, Piracicaba - SP – Brazil
lamonica@copersucar.com.br

KEYWORDS: Cogeneration, Electricity, Power, Bagasse, Sugar.

Abstract

This work intends to show the cogeneration development in the Brazilian sugarcane industry. Today, Brazilian power generation remains basically hydro, around 82% (84% in 1985 and 87% between 1992 to 1999). Until 1985, the Brazilian sugar industry was not self-sufficient in power generation, the power system belonged to the government, and the electricity price was very low. But the power market was indicating around 1990 that a power shortage could be expected, and some sugar mills began to invest in power generation, mostly to become self-sufficient. In a first step, they increased power generation efficiency using live steam at 22 bar 300°C (some using 42 bar 400°C) and multi-stage steam turbo generators. The second step was to test the power market, selling a small amount of surplus power, still using 22 bar live steam and changing the mill and generator drives to multi-stage steam turbines; this situation continued until 1998, when almost all the sugar industry was at least self-sufficient in power during the season and a few sugar factories were selling a small amount of surplus power to the grid (around 5 kWh/tc) during the season. In the third step (around year 2000), the sugar industry began to improve power efficiency by increasing live steam pressure (62 to 82 bar) and installing extraction/back pressure steam turbo generators; with this arrangement, the surplus power could reach 50 kWh/tc. Today, sugar mills produce 6.1% of power consumption in the area of CPFL (Paulista Company of Light and Power), a power utility in São Paulo state (~350 MW, 1400 GWh), and they are beginning to install condensing/extraction steam turbo generators, improving the sugar/ethanol process to reduce steam consumption and to recover part of the trash (leaves and top); these actions can bring the surplus to 150 kWh/tc. In the future, the use of biomass gasification in combined cycle will lead to surplus power levels around 300 kWh/tc.

Introduction

The purpose of this work is to share with other countries the Brazilian sugarcane industry’s experience in the Brazilian power market. The figures are based on studies done by Copersucar.

In 1998, the Brazilian government, along with the privatization program of the electrical sector, started to change the rules of the power market, aiming to facilitate independent power generation. The figures of the independent power producer (IPP) and self producer were regulated, and the transmission and the distribution systems were forced to open, charging government regulated wheeling tariffs.

During this process, the country experienced a serious drought in 1999 causing a nationwide power shortage that forced the government to seek alternatives to hydro power generation, that provided around 82% of the electricity consumed in the country.

At that time, almost all sugar mills were self-sufficient in power production and a few had already some experience with the power market, selling a little surplus power to the grid. That scenario stimulated the sugar factories to invest in power generation, increasing electrical efficiency, changing the older boilers to new high-pressure boilers (steam pressure higher than 60 bar), and installing new turbo-generator sets driven by extraction/back pressure steam turbines.

Today, sugar factories in Brazil are producing an important amount of electrical energy.
Copersucar 1981 boiler evaluation

In 1981, the Centro de Tecnologia Copersucar did a study to evaluate 323 boilers, and the main results of this study are shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHV efficiency (%)</td>
<td>66</td>
<td>70</td>
<td>78</td>
</tr>
<tr>
<td>Steam/bagasse rate (kg steam/kg bagasse)</td>
<td>2.01</td>
<td>2.15</td>
<td>2.25</td>
</tr>
<tr>
<td>Evaporation rate (kg steam/m³/h)</td>
<td>24</td>
<td>27</td>
<td>30</td>
</tr>
<tr>
<td>Number of boilers</td>
<td>107</td>
<td>78</td>
<td>138</td>
</tr>
<tr>
<td>Boilers % of the total</td>
<td>33</td>
<td>24</td>
<td>43</td>
</tr>
</tbody>
</table>

Group A: Saturated steam (10 to 19 bar), horse shoe furnace, natural flue gas draft, no air pre-heater.

Group B: Saturated steam (22 bar), horse shoe furnace, water wall, forced flue gas draft, no air pre-heater.

Group C: Superheated steam (22 bar, 280°C), dump grate furnace, water wall, forced flue gas draft, with air pre-heater.

The average efficiency of those boilers was 72% (at lower heating value).

That study concluded that, for the retrofitting of boilers, the following steps should be considered:

- Replacement of boilers with operation pressure below 22 bar.
- Installation of dump grate furnace, air pre-heater and forced draft fan.
- Automation of combustion and secondary air control.

That work estimated that, if all boilers were replaced or retrofitted as indicated, the average LHV efficiency could be increased to around 81%.

Copersucar 1997 boiler evaluation

In 1997, the Centro de Tecnologia Copersucar did a new study that evaluated only LHV efficiency. Only 17 of the 149 boilers surveyed were tested.

That study showed great technological changes in the boilers (compared with the 1981 study):

- 75% of the boilers had steam pressure above 20 kg/cm².
- The wide use of superheated steam production, air pre-heater and forced draft fans.
- Only 6% of those boilers were producing steam with pressure above 30 kgf/cm².
- Wide use of economisers, installed in around 35% of the boilers.
- Combustion section with wide use of dumping grate and automatic combustion control and secondary air.
- The use of emissions control equipment became standard; such equipment was not used 20 years ago.
- Use of deaerators and demineralisers became standard, equipment that was seldom used in the past.
- LHV efficiency between 79% and 84%.

Those figures confirmed the predictions, from our 1981 study, that were used to guide sugar mills in the retrofitting and replacement of boilers.

Mills electric power surplus

In 1999, with the privatisation program of Brazilian’s electricity sector, mainly with the law that created the independent power producer (IPP) and gave the right of access to the public grid, a new paradigm was created for the sugar mill power sector, namely the generation and sale of surplus electrical power.

The National Bank for Social and Economic Development (BNDES) created a credit line to finance new installations, aiming to replace the oldest boilers in sugar mills by new high-pressure boilers (above 60 bar), to install high pressure extraction (22 bar)/backpressure turbo sets, and to replace the mill drives by multi-stage steam turbines.
Regarding the production of power, the situation did not show a significant change: pure cogeneration with backpressure steam turbines (2.5 bar) remained strongly used, with power production still depending on the sugar factory operation.

Turbo sets and steam turbines generally had a faster evolution, because their investment costs are considerably lower when compared with that for boilers. The turbo sets had changed from small (around 1 MW) units driven by low-pressure single stage steam turbines (overall efficiency around 50%) to high-pressure multi-stage with extraction turbo sets of sizes that frequently exceeded 20 MW (overall efficiency above 75%). The operating live steam pressure moved together with the boiler’s evolution, and now we are getting surplus rates above 40 kWh/t of cane. Figures 1 and 2 show simplified power production diagrams, based on Copersucar modelling work:

Fig. 1—Basic medium-pressure power system arrangement.

Fig. 2—Basic high-pressure backpressure/extraction steam turbine power system arrangement.
The near future

To produce much more surplus power, sugar mills will have to improve power efficiency and get supplemental fuel. The use of high-pressure condensing/extraction steam turbines will increase power efficiency. Additional fuel could be obtained by reducing process steam consumption, and raising bagasse surplus and using trash (leaves and tops).

Reducing steam consumption to 34% of cane, using condensing/extraction steam turbo set and trash, we can get surplus power around 150 kWh/t of cane (Figure 3). Today, in Brazil, around 80% of the sugarcane is burned before harvesting.

![Diagram](image)

Fig. 3—Basic high-pressure condensing/extraction power system arrangement.

The future

The BIG/GT-CC (Biomass Integrated Gasification/Gas Turbine – Combined Cycle) is a promising technology that can increase power efficiency considerably.

Applying this technology with reduction of process steam consumption to 28% of cane and trash recovery, the mill will produce surplus power around 300 kWh/t of cane (Figure 4).

![Diagram](image)

Fig. 4—Basic BiG/GT-CC power system arrangement.
Evolution of electric power exportation by Brazilian sugar mills within CPFL concession area

The Paulista Company of Light and Power (CPFL) is a power distribution utility in São Paulo state. Approximately 80% of the sugar mills of São Paulo state are in its area; the sugarcane production of São Paulo state is around 60% of the Brazilian production. Figure 5 shows the evolution of sugarcane electrical power produced by sugar mills in CPFL area:

![Graph showing the evolution of sugarcane electrical power produced by sugar mills in CPFL area](image)

Fig. 5—Evolution of selling electric energy by sugar mills with CPFL.

Comments

As we can see in this short report, Brazilian sugar mills have made important technological changes in power generation in the past 20 years, beginning from a power deficit and low efficiency steam power systems to surplus power of efficient steam power systems, even with our present low electricity price. In recent years, the international sugar price has helped the sugar mills’ power investments because, when the mill increased sugar production and/or its quality, the project usually considered an up-grade in the mill power system.

The development of sugar mill power generation is very important to the country, because it is renewable. Important technological changes must be made in the future, by using new systems that are not yet available commercially, such as biomass integrated gasification with gas turbine. Sugarcane trash, today burned before harvesting, must become an important fuel, to be added to the bagasse for year-round power generation.

EVOLUTION DE LA PRODUCTION D'UN SURPLUS D'ENERGIE DANS LES USINES DE SUCRE/ETHANOL AU BRESIL

H.M. LAMONICA, A. FIURANELI, F.A.B. LINERO et M.R. LIMA VERDE LEAL

Centro de tecnologia Copersucar-Fasenda, Santo Antonio, Piracicaba-sp-Brasil

lamonica@copersucar.com.br

MOTS CLÉS: Cogénération, Electricité, Energie, Bagasse, Sucre.

Cette étude a pour but de retracer les développements dans le domaine de la cogénération dans l'industrie sucrière brésilienne. Aujourd'hui, la production d'énergie au Brésil est essentiellement hydroélectrique, à environ 82% (84% en 1985 et 87% entre 1992 et 1999). Jusqu'à 1985, l'industrie sucrière brésilienne n'était pas autosuffisante en électricité. Le système de production appartenait au gouvernement et le prix de l'électricité était très bas. Dans les années 1990, il était évident qu'une pénurie d'électricité était à prévoir et quelques sucreries ont alors commencé à investir dans la cogénération, principalement dans le but d'atteindre l'autosuffisance. Dans un premier temps, l'efficience de la production d'électricité a été améliorée en utilisant la vapeur vive à 22 bars, 300°C (certains utilisaient 42 bars, 400°C) pour tourner des turbogénérateurs à vapeur à multiples étages. La deuxième étape consistait à jauger le marché en vendant une petite quantité de l'électricité produite en surplus – toujours en utilisant la vapeur vive à 22 bars et des
Las turbinas a múltiples etapas para las máquinas y los generadores. Esta situación ha sido mantenida hasta 1998, cuando presque toda la industria azucarera estaba de automasía en electricidad, al menos durante el periodo reciente, lo que significaba que las máquinas de vapor eran una parte de la energía residual en el red (momento 5 kWh/ct), aunque durante el periodo de recogida. A la tercera etapa (ancho de la línea 2000), la industria azucarera comenzó a mejorar su eficiencia energética al aumentando la presión de vapor vivo (62 a 82 bar) y en instalando los turbinogeneradores a contra presión y extracción. Ainsi, le surplus d'electricité pouvait atteindre jusqu'à 50 kWh/ct. Aujourd'hui, les sucreries produisent 6,1% de la consommation d'électricité de la région de CPFL (Paulista Company of Light and Power), un service d'énergie électrique dans l'etat de Sao Paulo (~350 MW – GWh 1400). Elles ont initié l'installation de turbogénérateurs à vapor, à condensation et extraction, améliorant leur procédé de fabrication du sucre et de l'éthanol pour réduire leur consommation de vapor et récupérer une partie de la paille de canne (les feuilles et les bouts blancs); ces actions pourraient permettre d'augmenter l'excedent d'électricité jusqu'à 150 kWh/ct. À l'avenir, avec la gazéification de la biomasse dans un cycle combiné, le surplus d'électricité pourrait atteindre des niveaux allant jusqu'à 300 kWh/ct.

**EVLUCIÓN DE LA GENERACIÓN DE ENERGÍA ADICIONAL EN LAS FABRICAS DE AZÚCAR Y ALCOHOL DE BRASIL**

H.M. LAMONICA, A. FIURANELI, F.A.B. LINERO y M.R. LIMA VERDE LEAL

*Centro de tecnologia Copersucar-Fasenda, Santo Antonio, Piracicaba-sp-Brasil*

lamonica@copersucar.com.br

**PALABRAS CLAVES:** Cogeneración, Electricidad, Energía, Bagazo y Azúcar.

**Resumen**

El presente trabajo pretende mostrar el desarrollo de la cogeneración en la industria azucarera brasileña. Actualmente, la generación de energía en Brasil es básicamente hidráulica, alrededor del 82% (84%–1985 y 87% entre 1992 y 1999). Hasta 1985, la industria azucarera brasileña no era autosuficiente en la generación de energía, el sistema energético pertenecía al gobierno y el precio de la electricidad era muy bajo. No obstante el mercado energético indicaba alrededor de 1990 que la escasez de energía era exportable; así algunos ingenios comenzaron a invertir en la generación de energía, la mayoría para ser autosuficiente. En su primer paso, las fabricas azucareras incrementaron la eficiencia de generación de energía empleando vapor vivo a 22 bar 300 grados C (algunos empleando 42 bar 400 grados C) y turbo generadores de vapor multietapa. El segundo paso fue probar el mercado energético, vendiendo pequeñas cantidades de energia sobrante, empleando todavía vapor vivo de 22 bar y combinando el molino y el movimiento del generador a turbinas multietapas; esta situación continuó hasta 1995, cuando casi todas las industrias azucareras en los menos autosuficiente energéticamente, durante la zafra y algunas pocas fabricas de azúcar vendían pequeñas cantidades de energia sobrante a la red (alrededor de 5 kWh/ct) en zafra. En el tercer paso (alrededor del 2000), la industria azucarera comenzó a mejorar la eficiencia incrementando la presión del vapor vivo (62 a 82 bar) instalando turbogeneradores de vapor de contrapresion; con este esquema, la energía sobrante puede alcanzar 50 kWh/ct. Hoy, las fabricas de azúcar producen 6,1% del consumo de energia en el área de CPFL (compañía paulista de luz y energia) y están comenzando a instalar turbinos de generación de vapor de condensación-extracción, mejorando el proceso de azúcar-alcohol para reducir el consumo de vapor y recuperar.