Industrial Experience on the Implementation of Real-time On-line Energy Management Systems in Sugar and Alcohol Industry

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Abstract

Sugar and alcohol market are increasing, due humanity needs to find alternatives for fossil fuels dependence. Brazil joins climactic and technologic features to place itself at the forefront of this industry. Sugar-alcohol industry is professionalizing and rising portfolio of product and the electric energy became an important product of these new ones. In this context, an increase in energy efficiency and actions to maximize this product shows it essential for these sites become competitive and reach their goals. Visual Mesa is a process on-line analysis tool to support decisions on energy reduction costs. This work describes how Soteica and Usaçúcar teams have modeled the site and implemented this new way to evaluate energy on this kind of industry. A full model of the energy system has been developed. All the constraints have been included and the model is continually being updated with live data. Performance monitoring was done and it includes the tracking of equipment efficiencies by utilizing updated data for its continuous calculation. By auditing the energy system, imbalances can be identified and reduced. Planning for a better operation of the energy system by performing case studies is usually done by using the validated model. As a result of the project, new sensors have been installed and a completely new way to evaluate energy on the site was implemented.

Keywords: sugar and alcohol industry, on-line energy analysis software, electric energy.

1. Introduction

In the last 30 years it was become clear that here are humanity concerns about the scarcity of fossil fuel supplements. It gets worse with the growth of the worldwide consumption and the geopolitics changes of the period.

This scenery intensified the humanity needs of a substitution of the energetic matrix, based on the oil, by a renewable, less pollutant and that cut down the carbon emission on the atmosphere.

Sugar and alcohol market are in constant expansion and it shows as an alternative to Brazil dependence of oil.

Brazil has the suitable climatic and technologic features to the development of an industry that produces a clean fuel, according to this new order and that stand on the leadership of the sector, as we can notice nowadays.

To maintain this leadership, sugar-alcohol industries are focusing in process optimization and costs reduction and one of the most important points of optimization is energy balance as described in the work of Sartori et al (2007), who developed a mathematical model to improve industries profits and better use of energy potential.

On this change of scenery, the sugar and alcohol industry has also been changing and improving its portfolio and adding new products, as a sale of electric energy to the energy supply network and carbon credits appear as a promising market in the next 20 years in Brazil as described by La Rovere et al (1994).

The alcohol and industry engagement on the electric energy production is very important to maintain the supply and increase the fraction of energy produced (in %) by sustainable process. Lora et al (2007) shows that it is an innovation in Brazilian market that was supported by the government and electricity companies and achieve d approximately 4.4 % of the total electric energy amount generated and this participation is growing.

The energy comes from the steam generated in the boilers that burn sugar cane bagasse from the milling process.

For the sugar and alcohol industry carries on producing energy and it is economically suitable, the energy balance must be monitored and improved.

To achieve this goal, Soteica used its on-line energy management system, Visual Mesa, which is the worldwide market leader on petrochemical sector to supervise and optimize the energetic balance in the sugar and alcohol industry.

The work of Ruiz et al (2005) describes how this tool is being used successfully around the world to optimize Energy Systems in petrochemical industries.

This is the first time that a tool for on-line management system is used to manage energy balance in real time on the sugar and alcohol market.

Soteica and Usaçúcar join their teams to develop a model for an industrial plant that produced sugar, alcohol and electric energy.

This work consists of experiences exchanged between the teams, one that knows about energy management and the other that knows about sugar-alcohol production technologies.

2. Project objectives

The main objective of the project was to have a tool available for the on line optimization, auditing and monitoring of the energy system of Tapejara Plant.

The secondary objective is to gain knowledge, develop a methodology and mapping the difficulties on the implementation of this kind of software in sugar-alcohol industries.

3. Usaçúcar Company

Usaçúcar is a company with about 50 years of experience in sugar and alcohol production and today at the forefront sector in the State of Paraná, where it is located in Brazil.

In Usaçúcar Group there are also trading companies and a distribution center at Paranaguá's Port, where the production is exported to many countries, mainly to Asia.

In the productive arm of company it has 7 productive units distributed in the North of Paraná State, in Brazil. Two of these productive units have alcohol as unique product and others units work with sugar too.

As the entire sugar-alcohol sector in Brazil, Usaçúcar is booming and improving its portfolio and one of those new products is the electric energy.

This improvement on the portfolio took optimization focus to the plants energy balance and how to achieve contracts and product specification, producing energy to export.

Nowadays Usaçúcar Group has two plants that are producing electric energy and selling to distribution companies. One of them was chosen to place the first implementation of a real time on line energy management system in sugar and alcohol industry.

4. Tapejara Plant

The plant chosen for the implementation was the Tapejara Plant. This plant has a capacity to process about 19.5 kt of sugar cane per day and produces 62.000 m^3 of alcohol and 316 kt of sugar each season. It is the largest productive plant of Usaçúcar Group.

Based on these numbers and in the expectation of higher profits, Tapejara Plant was chosen for the first implementation.

The layout can be organized in 7 sectors. A similar division was used in model building.

- **Steam generation:** This sector has two boilers that burn sugar cane bagasse and produce superheated steam with pressure of 65 bar and a temperature of 400 °C.
- Boiler 3 can produce 100 t/h of steam and Boiler 4 produces 300 t/h of steam. Boiler 4 is the biggest biomass boiler operating in the world.
- All steam produced here feed electric generator or is used in productive process.
- **Electric generation:** Electric generation sector has two generators that are fed with the superheated steam produced by the boilers, generates electric energy and reduces steam to 21 bar. The steam that was produced here will be used in the milling process.
- **Sugar cane preparation and milling:** This sector is a consumer of steam at 21 bar and it is used to operate machines that prepare and process the sugar cane to remove juice that will be used in other stages of production process.
- **Evaporators:** Tapejara Plant has two lines of evaporators, this equipment is used to concentrate sugar cane juice and specify the flow, raising the brix to about 65 °C.
- Evaporation is the plants energy core, because here is consumed steam at a high pressure and generates steam at a low pressure.
- **Crystallization:** Crystallization is a sector that consumes steam at a low pressure and the consumption depends on the amount of equipments that is on-line at each moment.
- **Distillation:** As with the crystallization, the distillation sector is a low pressure consumer and depends on the alcohol types that are produced.

5. Visual MESA

Visual MESA software was developed to work with global optimization of energy systems in an industrial plant and lead with its restrictions in order to bring the operation of system utilities for the lowest possible cost. It is a computer program designed to model steam, Boiler Feed Water, condensate, fuel, electrical systems and CO_2 emission costs.

It operates on-line with Plant Information System via standard OPC interface and it is also capable of dealing with historical data used in the optimization.

Visual MESA is installed for two types of use, the Stand Alone use and Client Server use:

- **Client Server use:** The purpose of this installations is to share the solutions, supporting multiple users. Visual MESA server runs as a service on a PC and gives solutions automatically with no interruption every 5 minutes, writing results on the plant information system and generating reports. With this architecture any PC connected to the plant network can be configured to access the model and the reports. So teams from operation to management, including engineering monitoring is able to evaluate and use the results supplied by the tool.
- **Stand-alone use:** The purpose of this installation is for individual users able to run cases studies on their own PC, using a snapshot of the current data or historical data. Data can be achieved automatically taken from the plant information system via standard OPC Historian Data Access. This kind of use also supports "What If" studies that are useful to assess revamps and changes in production schema.

In terms of optimization, Visual MESA has mathematical features and built-on optimization routines that make it possible to calculate how to the steam runs and electrical systems operate at a minimum overall cost while still meeting the required plant steam demands and other constraints.

The software determines which boilers or steam generators should make incremental steam and which turbines or letdown valves will most efficiently let the steam down between pressure levels. It uses a successive quadratic programming (SQP) optimizer, which is grouped into four levels:

- **Level 1:** includes the pressure control-related devices; boilers, letdown valves and vents are optimized to minimize cost.
- **Level 2:** adds the optimization of other continuous variables, including turbo generators and extraction/ induction/ condensing turbines.
- **Level 3:** adds turbine-motor switching optimization, like discrete variables.
- **Level 4:** optimizes variables that are potentially unsafe or affect process yield.

The program's objective function is able to optimize the total operating cost of the system, which is described in equation (1).

$$\text{Operating cost} = \text{total fuel cost} + \text{total electricity cost} + \text{inlet costs} \qquad (1)$$

The SQP optimizer's job is to minimize this objective function, subject to operating constraints in the system. Total fuel cost is determined by the fuel use of each boiler and combustion turbine, multiplied by their respective fuel prices. Total electricity cost is determined by the electrical use of each motor, load and generator, multiplied by their respective electricity prices. The model takes into account the fact that electricity costs vary throughout the day.

Inlet costs normally include charges for demineralized water coming into the system, but can cover other arbitrary costs too.

6. Implementation Description

Soteica's teams in Brazil and Argentina in partnership have worked together with Usaçúcar – Tapejara Plant, Operations and Process teams, in the implementation project on the following activities:

- Layout analysis,
- Data collection,
- Linking of Visual Mesa to the Plant Information System,
- Build of Interface to the Historic Plant Information Data,
- Model building,
- Build on-line optimization,
- Model adherence analysis,
- Reports generation

The model built is the most important step of the implementation and is the basis for others steps.

It contemplates an overall and detailed description of the Energy System that includes bagasse stock, steam qualities, boilers, water, condensate, valves and electrical system.

Tapejara´s Plant was divided into 8 main areas on the Visual MESA model.

- **Steam generation:** that includes 2 boilers, one of them that produces 300 ton/h of superheated steam and the other produces 100 ton/h.
- **Reduction valves 67->21:** modeling of valves that reduce steam of 65 bar to 21 bar. That is a valve where condensate water is input in the steam and the pressure was reduced.
- **Reduction valves 21->1.5:** modeling of valves that reduce steam of 21 bar to 1.5 bar.
- **Electricity generation:** comprises two turbines to generate electricity to feed plants consume and exportation to energy supply network.
- **Sugar cane processing**: comprises turbines that move equipment of sugar cane preparation and milling. These equipments consume steam of 21 bar
- **Evaporators:** evaporation sector is composed by 2 evaporators lines, A and B. these lines consume steam of 1,5 bar and produce vegetable steam, that is the steam generated by sugar cane juice, of various levels of pressure below 1,5 bar that will feed distillation and crystallization sectors.
- **Crystallization:** modeled as a consumer of vegetable steam.
- **Distillation:** modeled as a consumer of vegetable steam as crystallization sector.

A main view of the models and the areas can be seen in Figure 1. By navigating through the model, each individual Unit of the system can be monitored in detail.

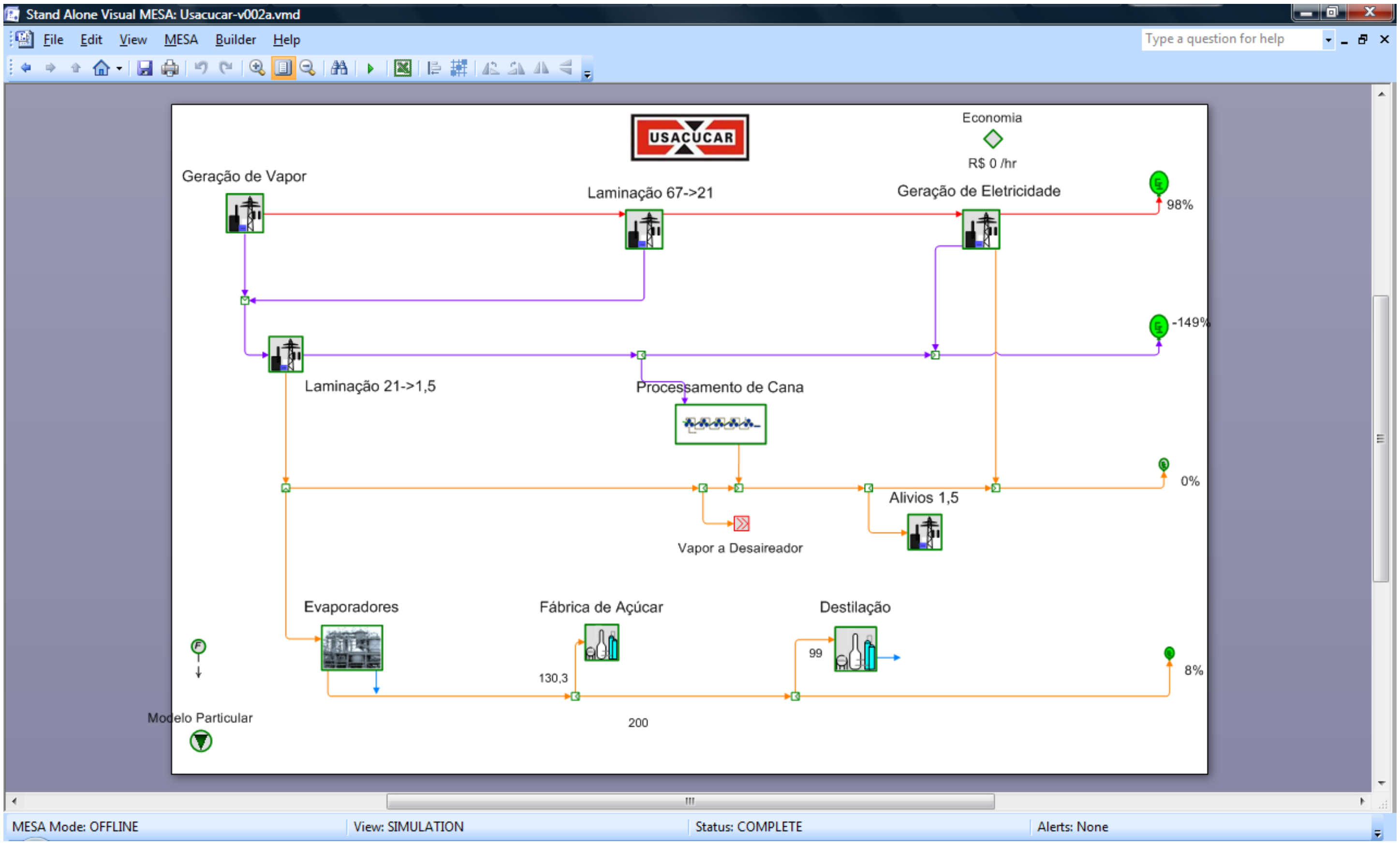

Figure 1: Main view of Tapejara Plant model

Electricity contracts and details of purchase and sale have been included in the model that made the model capable to evaluate energy trade.

Bagasse stock purchasing is modeled in order to manage the purchase of others Usaçúcar Group units and others companies too, focused on maximizing the production of electric energy.

During the implementation lacks of measurement was identified and programmed to be installed in the maintenance period.

7. Model adherence analysis

The model was run on-line under test conditions at the end of the 2008 season and obtained good results in adherence and ability to represent and optimize energy process.

First profits achieved in test phase are around 90,00 USD/h. Taking into account these profits and a season of 220 working days, it has estimated an annual profit of 475 kUSD.

The plant instrumentation will be improved on an annual maintenance and this work will give more data to the model, making the optimization more efficient and improving the reliability of the system.

8. Conclusions

The target was achieved, the model was built and the first implementation on sugar-alcohol industry was in course and presented initial results within the expected in terms of implementation time and costs.

With the implementation of new measurements, the model will be on-line in 2009 season and it will be the most important tool for monitoring and optimization of energy balance on Tapejara´s Plant.

This work will be used as a basis for new implementations of the software on others units in the Usaçúcar Group and others groups of the sugar-alcohol sector.

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