Cogeneration Power Plant

Thermodynamic and economic evaluation of a solar-aided sugarcane bagasse cogeneration power plant

The challenge

The Brazilian sugar and alcohol industry usually operates combined heat power plants (CHP), using sugarcane bagasse from the extraction of cane juice used in the production of sugar and alcohol as fuel. As the sugarcane harvest in Brazil goes from April to December, both factories and power plants remain idle for the remainder of the year.

This project studies the possibility of extending the period of operation of bagasse-fueled CHPs by means of a fuel-saving approach supported by the integration of solar heat.

Extending the operation of CHP plants into the offseason period increases the electricity production capacity factor of the existing facilities, resulting in a more stable power supply to the grid in spite of the seasonality of the sugarcane crop.

Our approach

The first step was to identify a typical state-of-the-art Brazilian bagasse CHP to be the reference power plant for the study. The selected factory processes three million tons of sugarcane per harvest period and is equipped with a CHP in which two 170 t/h steam generators provide live steam at 67 bar and 525 oC. Most of the steam is expanded in a backpressure turbine, whereby the residual heat of the exhaust steam supplies the processing plant’s heat demand. In parallel, the remaining live steam mass flow (roughly one third) is expanded in a condensing steam turbine. The electricity produced by the turbines, in its turn, supplies the on-site power demand; and the surplus is fed to the grid.

A thermodynamic mock-up model of the reference CHP was built. The calculation software Engineering Equation Solver (EES®) and the commercial power plant calculation program Ebsilon®Professional were used in LabCET and LUAT, respectively, providing for a comparison of the simulation results.

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                        • Federal University of São Paulo  
                        • Laboratory of Combustion and Engineering of Thermal Systems (LabCET) |

The overall analysis and evaluation of the acquired data requires an annual yield simulation for a specific site that considers the typical weather conditions and variations of the relevant site. For that purpose, a market research identified the region around Campo Grande, Mato Grosso do Sul, the related weather data to which was taken from the database of Meteonorm 7.

In addition to the parameters necessary to simulate the performance of the power plant, like direct normal irradiance (DNI) and ambient conditions, it is essential to respect the rainfall-related harvesting stops. In this context, research is currently being carried out in order to identify the plant’s capacity factor during harvest. This capacity factor is mainly dictated by rainfall, as it is not possible to harvest sugarcane during the rain or while the soil is still wet.

In the next step, the different solar thermal energy collecting technologies (solar tower, parabolic trough and linear Fresnel) will be integrated to the CHP simulation model; and annual yield simulations will be performed. The economic feasibility of each integration concept will be identified by calculating the Levelized Cost of Electricity (LCOE) of each evaluated hybrid concept.
**Intended Impact**

In October 2014, a Research-Into-Use Workshop will be held in Brazil with potential users, including important equipment suppliers, facility owners and energy suppliers, to discuss the project’s preliminary results and the necessary steps for their commercial application. The intended objective is to provide technical and economical subsidies to establish a consortium for a pilot solar-aided power plant.

In order to enable a wide distribution of the generated knowledge, the results will be published in different formats, such as expert conference talks and publications like conference proceedings or academic theses.

**First conclusions**

There are different options to integrate solar thermal energy in CHPs, which depend mainly on the layout, operational parameters and stage of development of the power plants implemented in the sugarcane sector. Thus, this project focuses on studying different retrofit scenarios based on a typical CHP configuration found in the market. In any case, the solar share is technically limited by the equipment, which was originally designed to operate with bagasse only.

For the selected steam generator model, it was found that the part in which live steam parameters are kept at design condition is limited to 75% of its full capacity. Other components, like condensers and condensing turbines, have limited capacity to provide full solar field load during the off-season, when sugar and alcohol process is out of operation. In this regard, modifications in the steam cycle and the installation of a solar field are necessary to maximize solar share during both harvest and off-season periods.

Finally, the solar field capacity factor tends to be lower than that of a solar-only plant. This depends largely on CHP rain starts during harvest and on the possibility of not closing year-round operation with economized bagasse during harvest. These points need to be closely evaluated by the economic analysis, as in the opposite side there is the possibility of lower LCOE as the existing infrastructure of CHP plants can be used.

**First recommendations**

The installation of an additional low-pressure turbine to expand the steam from the outlet of the backpressure turbine with the objective of producing electricity when the process is out of operation should be considered as a possibility for CHP modification. This would enable the cycle to operate at full load even in the off-season period.

In the case of solar integration, a higher solar share could be realized during this period as well. These aspects should be discussed with equipment manufacturers during the Research-Into-Use Workshop in Brazil.

Yet, the operation mode needs to be redesigned when considering the integration of solar energy. The integration of a sugarcane straw collection procedure might be a feasible way to increase the capacity factor of solar part and lowering electricity generation costs. The collection of straw and its cofiring with bagasse is an option to increase exports of electricity to the grid and solar thermal energy can give an additional contribution in that sense.