SHORT, NON-REFEREED PAPER

SOLAR LIVE STEAM GENERATION AND SOLAR BAGASSE DRYING FOR SOUTH AFRICAN SUGAR MILLS

KROG W.[1], HESS S.[2], HOFFMANN J.[1] and DINTER F.[1]

[1] *Stellenbosch University, Private Bag X1, Matieland 7602, South Africa*

Email: wkrog93@gmail.com, hoffmaj@sun.ac.za, frankdinter@sun.ac.za

[2]*Karlsruhe Institute of Technology, P.O. Box 6980, 76049 Karlsruhe, Germany*

Email: stefan.hess@kit.edu

Abstract

Two solar heat integration concepts have been identified as promising options for implementation in South African sugar mills in the near future as a result of work with the steering committee of the Sugarcane Technology Enabling Programme for Bio-Energy. These are the drying of bagasse using solar heated air and the generation of live steam using concentrating solar thermal collectors.

By generating live steam from solar energy, electricity production can be increased up to 34.5 %, and bagasse or coal can be saved as well. Solar drying of bagasse can reduce bagasse usage up to 20.8 % and increase the boiler's efficiency. The average solar fractions for live steam generation and bagasse drying are 12.34 % and 17.34 % respectively. This can be increased if the integration points are allowed to operate outside of the crushing season, if thermal storage is implemented or if the solar collector area is increased.

Keywords: solar process heat, bagasse drying, sugar mill electricity generation

Introduction

The aim of the research reported here is to assess to what extent solar thermal energy can be used to reduce the running costs of South African sugar mills and to open up additional income streams. This study forms part of the Sugarcane Technology Enabling Programme for Bio-Energy (STEP-Bio) project and it builds on the work of Hess *et al*. (2016), which identified and ranked various solar integration points for sugar mills. This study further develops concepts for the drying of bagasse using solar heated air and live steam generation (LSG) using concentrating solar power (CSP) collector technology.

This short paper contains an integration scheme for LSG along with monthly estimations of the performance of both integration points. Values regarding the sugar milling process are all based on the updated results from the Biorefinery Techno-Economic Modelling project (Starzak and Zizhou, 2016).

Live Steam Generation with CSP Collector Technology

LSG with solar energy will allow the sugar mill to either save bagasse/coal or generate more electricity during the crushing season. Furthermore, it can help with the energy needs for refining factories outside of the crushing season and enable year-round electricity exportation.

Figure 1 shows a hydraulic scheme for the integration of solar LSG based on the work of Hess *et al.* (2016). The solar field consists of parabolic trough collectors (PTC), which will provide solar process heat to the conventional sugar milling system.

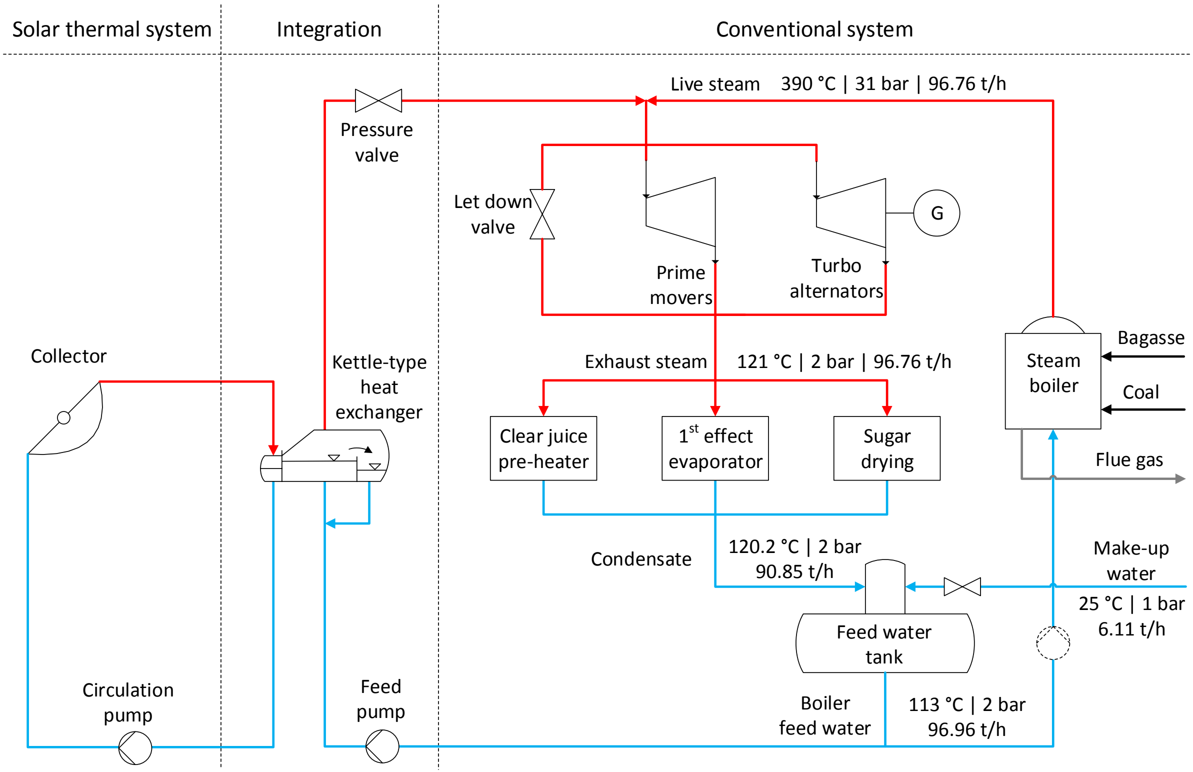

Figure 1: Hydraulics scheme for the integration of solar generated live steam based on the work of Hess *et al* (2016)

Three different configurations were considered for this study. The first configuration is what is shown in Figure 1. This configuration will allow the mill to save bagasse or coal, with the solar power easing the boiler's load. However, the amount of electricity being generated will stay the same, because the same turbine is being used and it cannot function outside of the CS. For the second configuration the back pressure steam turbine (BPST) is replaced with a condensing extraction steam turbine and the third configuration is where an additional condensing steam turbine is placed in parallel with the BPST. Both options will allow the mill to produce more electricity and operate throughout the whole year.

This study assumes that the boiler can operate at 40 % load, the minimum load for boilers in the sugar industry, with the efficiency differing with less than 0.5 % compared to normal operations ([1]personal communication). This means that the maximum solar thermal energy delivered should be 60 % of the boiler's load. The boiler in the BRTEM model (and in Figure 1) has a capacity of 73.28 MW_{th}, therefore, the solar field should produce a maximum of 43.97 MW_{th}. A specific thermal peak power output of 514 W/m^2 for the PTC is assumed following the method set out by Günther *et al.* (2013), corresponding to a collector field size of 85 552 m^2.

[1] Dr R. Laubscher, Stellenbosch University, Email: rlaubscher@sun.ac.za

Estimations were made with hourly averaged weather data from the Southern African Universities Radiometric Network (SAURAN) for Durban, which will be used as a representative location for SA sugar mills.
The following formula was used to estimate the solar thermal energy generated:

$$Q_{th} = \eta_{opt} \times \eta_{abs} \times \eta_{SG} \times \cos\theta \times A \times DNI \quad (1)$$

Here *A* represents the collector field size, θ is the incidence angle which is calculated each hour and DNI is the direct normal irradiance. The η_{opt} and η_{abs} represent the optical and absorber efficiencies of the PTC's respectively and η_{SG} represents the steam generating efficiency, all based on the values used by Giostri *et al*. (2012).

Bagasse Drying with Solar Heated Air

Dry bagasse has a higher calorific value, allowing the boiler to produce the same amount of steam from less bagasse. Dry bagasse releases less water vapour during combustion, resulting in reduced heat losses by exit flue gas, increasing the boiler's efficiency (Wienese, 2001). Furthermore, less excess air is needed for effective combustion. This along with the decreased amount of vapour, will decrease the power usage of the boiler's induced draft fans (Sosa-Arnoa *et al*., 2006).

For this integration point ambient air is heated in evacuated tube air collectors (ETAC) to 120-180 °C after which it travels through an industrial dryer to evaporate the moisture from the bagasse. Exhaust steam will be used in a backup air heating system for when the solar resource is not enough. A simple drying software package called Simprosys (http://www.simprotek.com) was used to determine specifics of the drying process. By using Simprosys, it was determined that the necessary solar thermal energy to dry the bagasse coming from the bagasse dewatering mills from 50 % to 40 % moisture content (MC) is 6.92 MW. A specific thermal peak power output of 700 W/m^2 was assumed for the ETAC, corresponding to a collector field size of 9 895 m^2.

For the estimations it was assumed that the ETAC's will face directly north and that they are tilted at 29.85° from the horizon. Furthermore, it was assumed that the ETAC has a relatively low efficiency of 50 % due to the high temperatures in the collector.

Results and Discussion

Table 1 shows the monthly results of the estimations for the first configuration of solar LSG and bagasse drying to 40 % MC. This study took the CS to be from 1 April to 20 November and for Table 1 it was assumed that the mill does not operate outside of the CS. However, for the solar integration to be a viable option it will be imperative that it operates outside of the CS as well. The low solar fractions displayed in Table 1 can be increased by adding thermal storage systems or by increasing the collector field size. The key findings of the estimations were:

- The conventional system can generate 35.7 GWh electricity during the CS and with the solar LSG as in the first configuration, 25 268 tons of bagasse or 6 317 tons of coal can be saved during CS.
- With the second configuration electricity generation can increase with 28.6 % per annum from the conventional system, mainly due to the fact that electricity can be generated outside CS.
- With the third configuration electricity generation can increase with 34.5 % per annum from the conventional system.

- By drying the bagasse to 40 % MC, bagasse usage can decrease by 20.8 %.

Table 1: Estimated monthly solar gains and fractions for the integration points

	Live Steam Generation With CSP		Bagasse Drying With Solar Heated Air	
Month	**Specific Solar Gains [KWh/m²]**	**Solar Fraction [%]**	**Specific Solar Gains [KWh/m²]**	**Solar Fraction [%]**
January	85.20	-	78.54	-
February	68.81	-	65.11	-
March	87.20	-	72.16	-
April	67.49	9.48	66.23	16.48
May	71.05	13.79	65.92	15.87
June	56.75	11.38	72.34	18.00
July	62.84	12.20	64.98	15.65
August	85.02	16.50	67.45	16.24
September	51.55	10.34	66.58	16.56
October	51.87	10.07	81.76	19.69
November	49.67	14.94	82.51	20.23
December	80.43	-	77.55	-
Annual	817.87	12.34	861.13	17.34

The study will now go on to create detailed simulation results for the annual heat production of the solar thermal systems which will form part of an economic assessment of the integration concepts.

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