Integration and Simulation of Solar Thermal Energy to Dairy Processes

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1. Introduction

The application of Solar Thermal Energy (STE) to the dairy industrial processes has received considerable attention in the resent years due to its great potential to reduce the use of fossil fuels and greenhouse gas emissions. The current STE systems used in the dairy industry mainly use solar collectors like flat plate, parabolic through and Fresnel reflector to supply heat for the temperature range of 140ºC - 200ºC and pressure of 4 - 12 bar. It was reported that those systems had various operational issues that affected their efficiencies like blocking the solar collectors and the tracking system sensors, variable temperatures that have an impact on the control systems, and the use of the same components like heat exchanger and pipes, etc to supply heat from the solar and conventional sources [1]. Those issues can mostly be avoided by previously simulating and evaluating of the operation of the system using various simulation software that also consider weather conditions and operational efficiency [2]. The aim of this study was to investigate the current STE systems used in the dairy industry and recommend more efficient STE configurations to improve environmental and economic performances of the dairy processes.

2. Methodology

The real dairy plant located in Greece is presented in this study. It uses different processes including: pasteurization, separation, homogenization, mixing and fermentation. The plant requires 491.8 kW per hour, to produce around 7.3 tons of dairy products like milk, yogurt and cream, that is manly generated from two boilers and a cooler. All the data from the process lines, production rates and energy consumption were provided by the company. ASPEN Plus software (Aspen Technology Inc) was used to design and simulate the steady state operation of the existing plant with integrating the STE system. In order to ensure maximum contribution of the STE two different configurations were proposed, as follows: (i) includes a solar heater and cooler (ii) a solar preheater and solar cooler. The energy consumption, CO_2 emission and cost at the steady state operation of the existing plant and integrated STE configurations were calculated using the results obtained from the simulation, emissions [3][4] and cost [5] rates for electricity and fossil fuels in Greece.

3. Results and Discussion

Figure 1 presents a schematic of the simulated plant. The production line (green) contains dairy processes like pasteurization, separation, homogenization, mixing, fermentation and production. The heating line (red) contains two boilers that provide steam to a header, which splits between the three lines in parallel: pasteurization, fermentation, and cleaning in place (CIP). The steam produced from the three lines returns as a condensate to the hot tank. The cooling line (blue) contains a chiller that cools a cold tank, which provides coolant to two lines in parallel: pasteurization process and raw milk tanks, and (ii) pasteurized milk tank. Configuration 1 include integration of the STE system to: (i) the cooling line as a cooling component connected to the cold tank in parallel to the chiller and (ii) the heating line as a heating component which was connected between the hot tank and the header in parallel to the existing boilers (Figure 1). Configuration 2 include integration of the STE system to: (i) the cooling system and (ii) the heating system as a preheating system. Steam was provided from the header to pasteurization and fermentation processes on a single line and then preheated using the STE system before returning back to the hot tank (Figure 1). The integration of the STE system as a direct heating/cooling system directly to the hot/cold tank may ensure the maximum contribution of the solar system, while the use rearrangement of the pasteurizer and fermenter on a single line eliminate any losses in the existing system and reduce the required heating load.

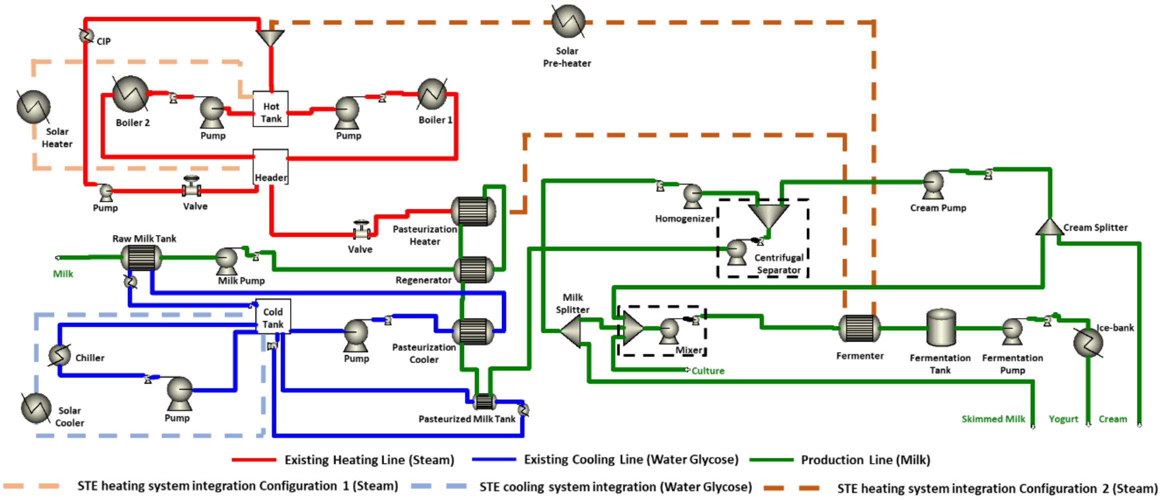

Figure 1. Schematic of the two configurations of the integrated STE system to the existing dairy plant

The integration of the STE system reduced the capacity of the conventional heating system from 285.6 kW to 199.9 kW for Configuration 1 and 152.7 kW for Configuration 2 while the capacity of the conventional cooling system from 206.2 kW to 144.3 kW for both configurations. The solar contribution for Configuration 1 was 23.5% while Configurations 2 25.5%. Consequently, the operational emissions reduction and cost reduction for Configuration 1 were 24.4% and 10.7% while for Configuration 2, 20.8% and 6.95%. Configuration 2 showed to be the more technically, environmentally, and economically efficient due to the rearranging of the pasteurizer and fermenter on a single heating line and using the STE for preheating of the existing boilers.

4. Conclusions

This study proposed two configurations for integrated and simulated STE system that could be used in the dairy plant and considered their technical, environmental and economic benefits. The first configuration includes a solar heater and cooler while the second a solar preheater and solar cooler. The results demonstrated that configuration 2 showed a higher solar contribution of 25.5%, reduced operational emissions of 24.4% and cost of 10.7%.

5. Acknowledgment

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