Identification of maximum solar heat integration potential via Pinch Analysis and optimization of the operation policy of a PTC field in grape juice Chilean industry

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INTRODUCTION AND MOTIVATION

The Chilean company Jucosol S.A dedicated to grape juice production uses a 696 m² parabolic trough collector (PTC) to pre-heat the feed water of a LPG boiler from 20 up to 90 °C. In 2017 the solar field generated 241 MWh of heat. However, according to theoretical simulations, the maximum potential of the solar field is 1.107 MWh per year. The analysis of monitoring data and collector operation suggests that the low solar fraction was due to non-optimal policy of the operation of the solar field and low working temperatures in the collector and therefore the system could be optimized.

This work presents an optimization based on parametric analysis of different operational parameters of the solar collector field and of the sizes of the heat exchanger and storage tank 3 (ST3). Furthermore, Pinch Analysis, has been used to identify the maximum heat integration potential of the solar field at the temperature of 90 °C.

IDENTIFICATION OF MAXIMUM SOLAR HEAT INTEGRATION : PINCH ANALYSIS

Pinch Analysis (PA) and Time Average Model (batch profile over 24 hours) were used to identify the maximum possible integration of solar heat in the company processes for a given temperature of 90 °C as inlet boiler temperature. To apply PA, it was necessary to identify the most cost-effective minimal temperature difference (ΔT_{min}) in the heat exchangers network. This value was 22 °C, calculated based on Chilean prices of LPG and electricity and on estimated prices of heat exchangers [1-2].

PA identified 1.806,5 kWh/day as maximum solar heat integration potential at 90 °C (see Figure 1) when a 881,7 kWh/day of maximum heat recovery between process streams is reached, which added up to 565,1 MWh in 2017, which is the goal to reach for solar heat integration of the optimization.

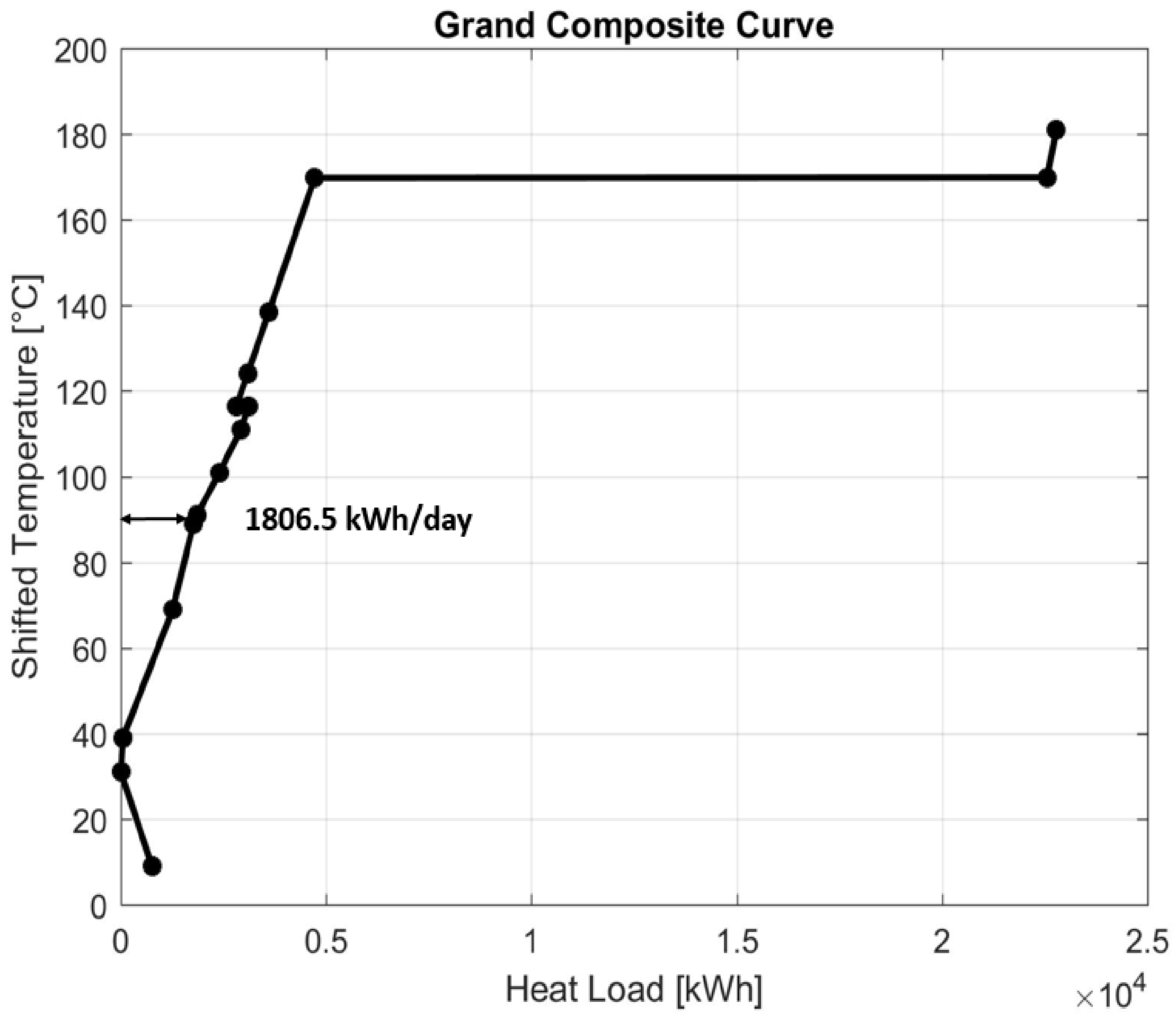

Figure 1: Grand Composite Curve of the process streams

CASES CONSIDERED IN THE PARAMETRIC ANALYSIS

The real and simulated solar system consists of a 696 m² PTC field and three storage tanks (see Figure 2). Currently the solar field works with a water constant flow of 22.000 kg/h and a maximum working temperature of 115 °C, which is controlled with an unfocusing system. According to theoretical simulations performed in TRNSYS 18, the energy supplied by the solar field to the boiler in 2017 is 414,5 MWh. This value is way below of the 565,1 MWh/year identified by PA.

Therefore, in order to reach the values identified by PA a set of optimization cases were performed to study the influence of different variables in the supplied solar heat to the boiler. The optimization cases are shown in Table 1. The flow management considered between storage tanks are two: without recirculation of water (case A) at night when there is process demand and with recirculation (case B).

Table 1: Variables considered in the optimization

Variable name	Collector´s flow (m³/h)	Collector´s maximum working temperature (°C)	Size of heat exchanger (m²)	Volume of storage tank 3 (m³)
Values	10,16, 22, 28	115, 140	3, 6	50, 100, 150

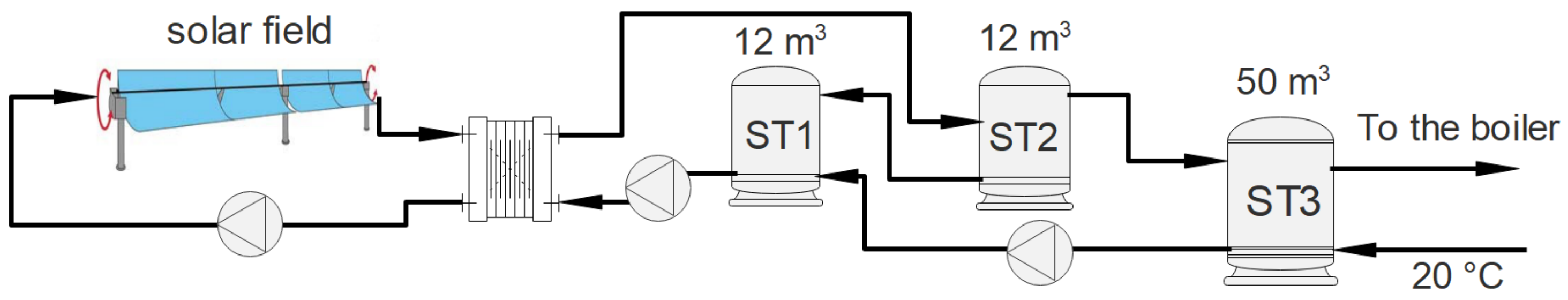

Figure 2: Simplified current configuration of the solar field and storage tanks

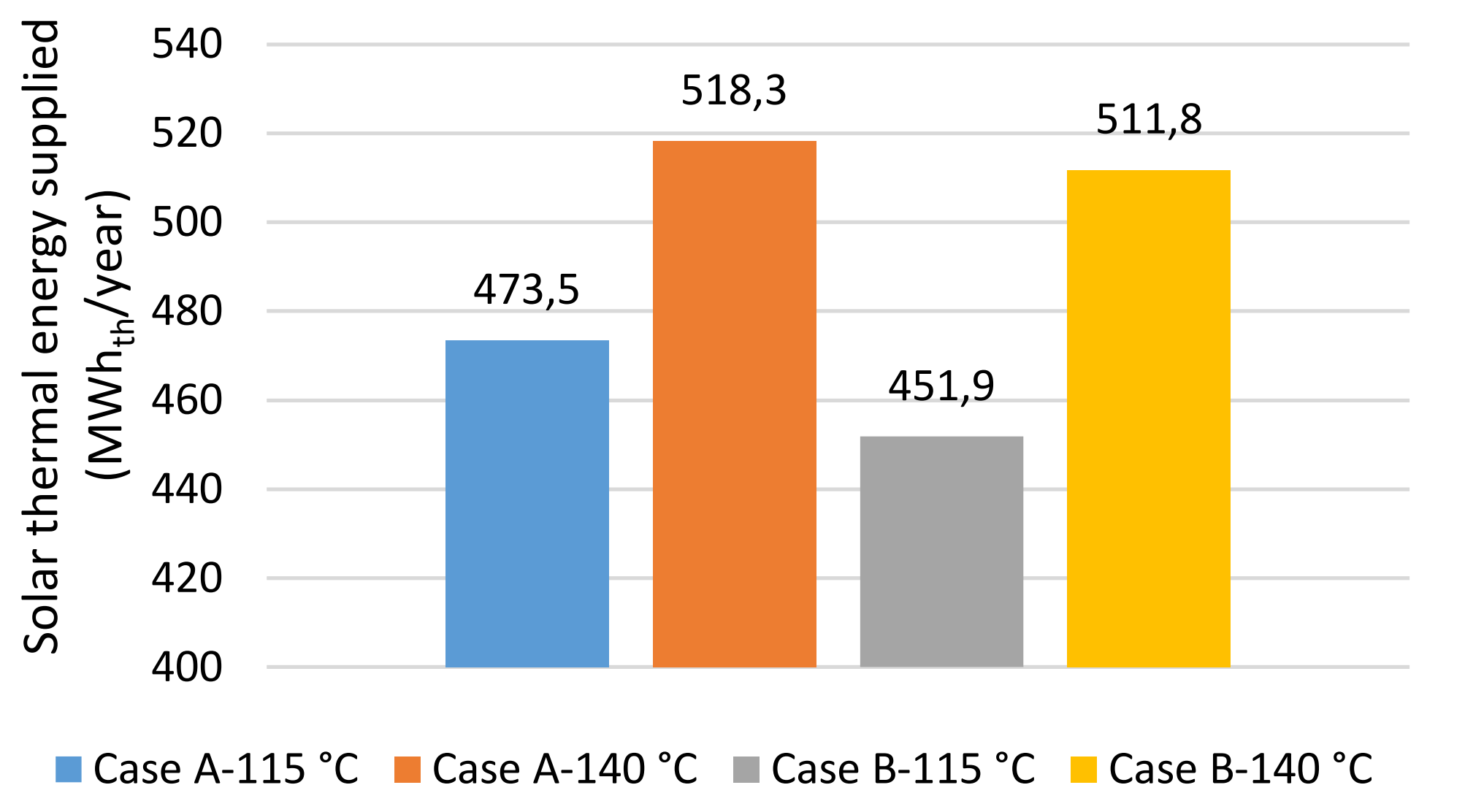

Figure 3: Cases A and B with collector´s flow of 22.000 kg/h, ST3 volume of 50 m³, heat exchanger area of 3 m² and different maximum temperatures

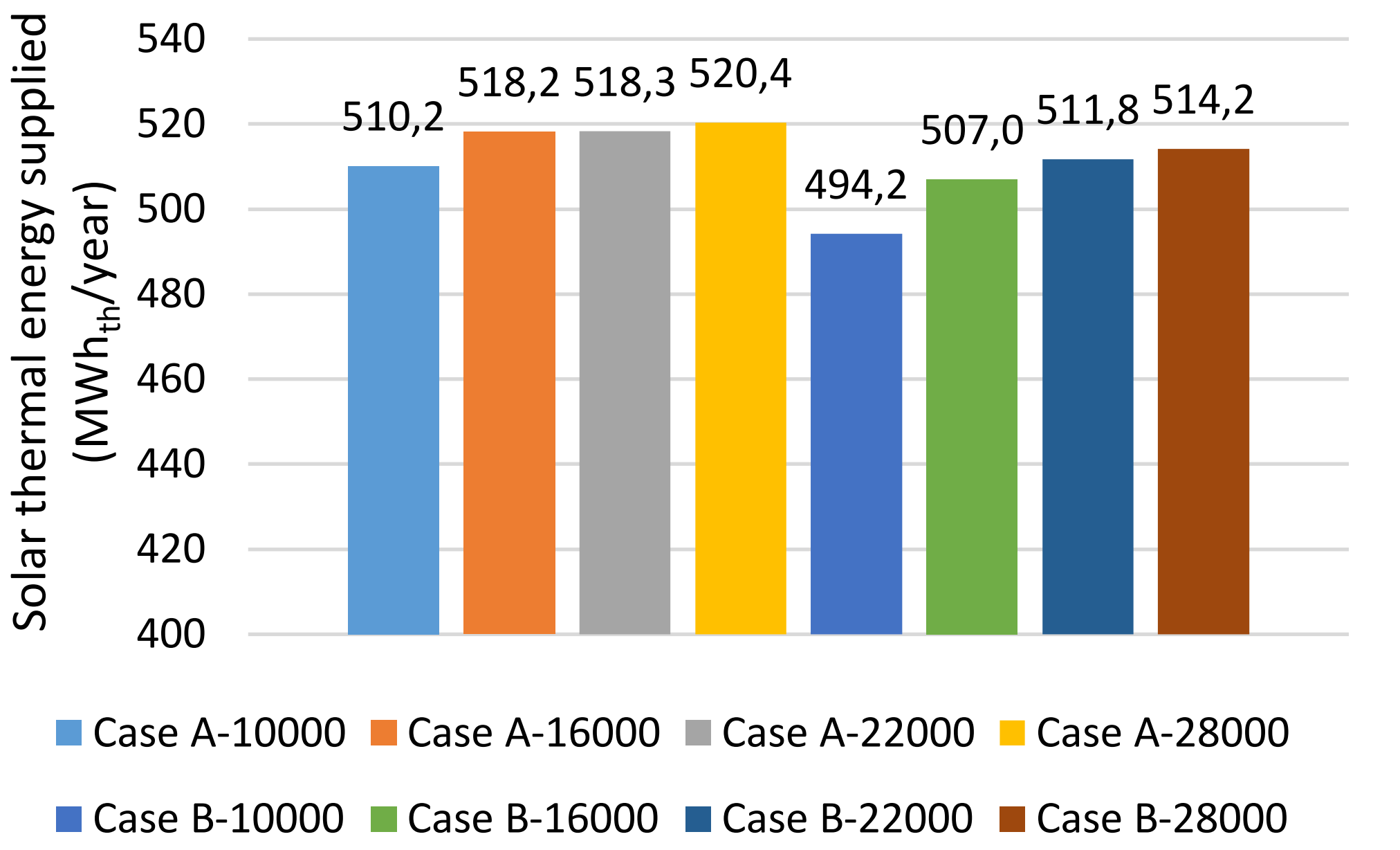

Figure 4: Cases A and B with different collector´s flow (in kg/h), maximum temperature of 140 °C, ST3 volume of 50 m³ and heat exchanger area of 3 m²

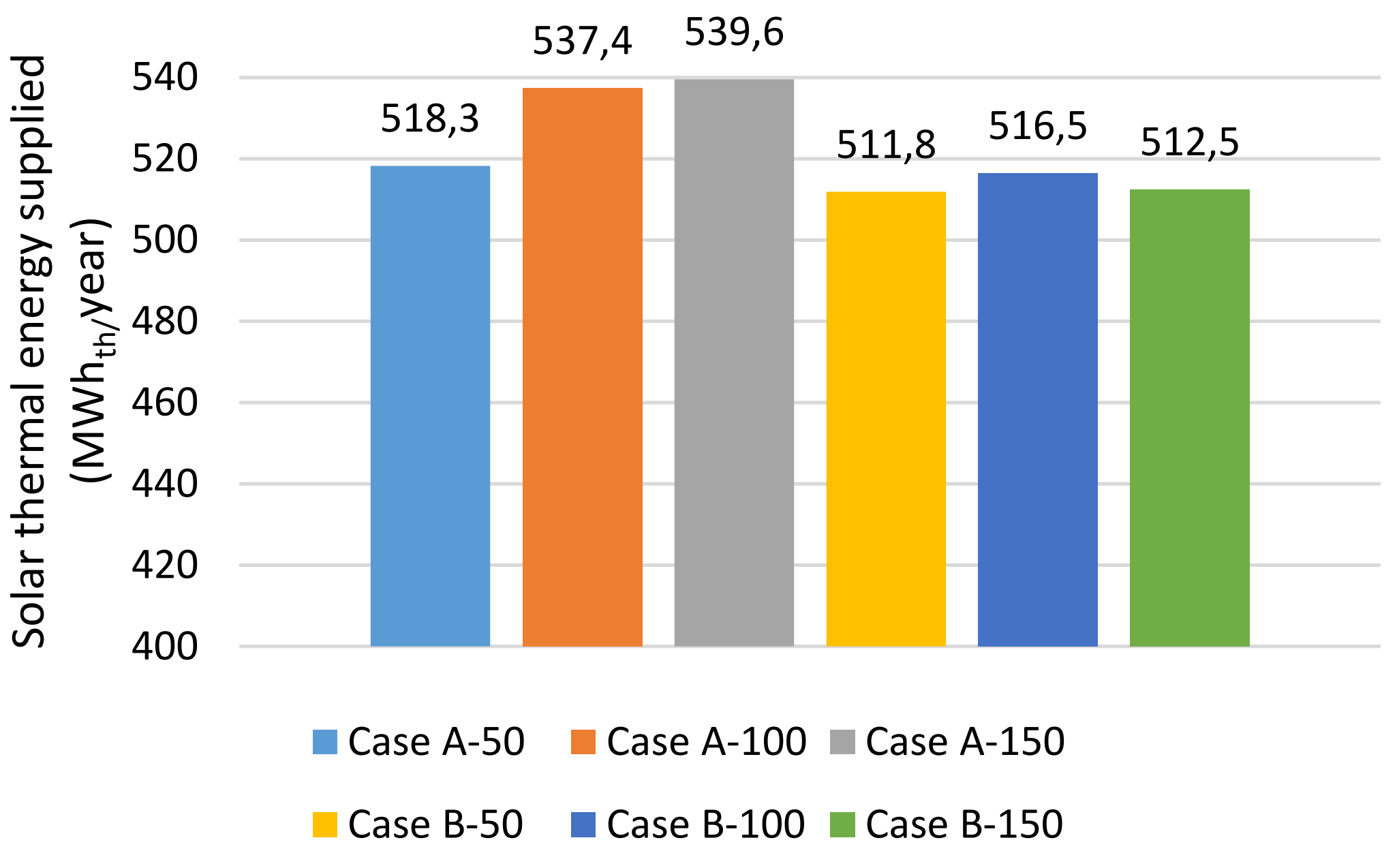

Figure 5: Cases A and B with different volumes of ST3 (in m³), maximum temperature of 140 °C, collector´s flow of 22.000 kg/h, heat exchanger area of 3 m²

RESULTS AND CONCLUSIONS

The results determined that:

- With the current solar field control and storage tanks configuration, it was not possible to reach the solar integration value defined by PA of 565,1 MWh_{th}/year at the integration temperature of 90 °C.
- The configuration of the tanks and the solar thermal field, the low demand of the processes (tanks are hot and the collector suffers frequent unfocusing) and the current solar field control make difficult to increase the solar energy integration at an average temperature of 90 °C.
- According to the PA, if the integration average temperature were 80 °C, the solar field would be capable of delivering the required heat by the processes.
- Avoiding the recirculation of water between tanks (case A) when there is process demand at night supplies between 1,2 and 5 % more energy than with recirculation (case B) with the same operation parameters (see Figure 3).
- The higher the flow of the collector is, the higher is the energy supplied to the processes.
- The volume of the tank affected the supplied energy in different ways. For case A the highest supplies corresponded with a volume of 150 m³ and for case B corresponds with a volume of 100 m³.
- The maximum solar energy integration is reached with an unfocusing temperature of 140 °C, a collectors flow of 28.000 kg/h, an effective area of 3 m² and a volume of storage tank 3 of 100 m³. This configuration corresponds to a supply of 550,5 MWh_{th}/year with an average integration temperature of approximately 80 °C.

[1] K.Shah, P.Sekulic. Fundamentals of Heat exchanger Design. ISBN: 978-0-471-32171-2. Published: 2003
[2] Chemical Engineering Design, Principles, Practice and Economics of Plant and Process Design, Second Edition.Published: 2012. Gavin Towler, Ray Sinnot, Elsevier.

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