Solar Polygeneration in Northern Chile

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Introduction
This project proposes a novel plant configuration allowing producing power, process heat, desalinated water and cold from one and only solar plant (solar polygeneration). As no other project of this type has presently been proposed or studied, a base case had to be designed. Then, a steady state simulation using PSim software was done and performances of such base case are evaluated using exergy analysis and financial indicators such as the Net Present Value (NPV) and the Internal Rate of Return. Performances are expressed according to Northern Chile irradiation conditions and market. This specific region is chosen due to Northern Chile exceptional solar resources and strong demand of the four outputs coming from the mining industry, mainly localised in that region. The exergy analysis is chosen because various types of energy are considered and one product is not even energy (desalinated water). It will thus allow to characterize each module on a common basis and express an overall energy efficiency.

Design conditions
- Solar Field (SF): Collectors: Parabolic trough Heat Transfer Fluid: Dowetherm A
- Drastic team: 94 persons
- Plant area: 120 ha
- Plant capacity: 265 MWth
- 12 effects parallel cross feed MED
- 5 extractions, 1 reheat
- Total balance: 43.69 M$/yr
- Total balance: 39.95 M$/yr
- Yearly OPEX: 1.5 MW
- Power: 12.8 MW
- Cooling water: 0.2 MW
- Cooling water: 282 kg/s from 25°C to 35°C
- Cooling power: 5 MW
- Cooling water outlet temp: 6°C
- Cooling water inlet temp: 10°C
- Top Brine Temperature: 65°C
- Rejected seawater temp: 35°C
- Feed seawater intake salinity: 0.042 kg/kg
- Feed seawater intake temperature: 25°C
- Rejected seawater temp: 35°C
- Maximum salinity in each effect: 0.072 kg/kg
- HP turbine inlet pressure: 100 bar
- HP turbine inlet temperature: 373°C
- Preheater inlet temperature: 294.85°C
- Solar Field inlet temp.: 293°C
- Irradiance at design day: 720 W/m²
- Solar Field outlet temp.: 389°C

Economical performances
- Power: $346.65 M
- Freshwater: $6.6 M
- Heat: $42.2 M
- Cold: $1.2 M
- Net Present Value (NPV): $74 M
- Internal Rate of Return (IRR): 7.1%

Sensitivity
- Extraction pressures
- Sensitive but range of variation relatively small.
- Taking best case for each pressure:
  \( \eta = 0.20 \text{ %}, \text{Ac = 365}/378 \text{ m²} \) (Gain: 0.12%, 2.243 m²)

Conclusions
- Overall exergy efficiency in optimum case: 24.02 %
- Polygeneration: NPV = 1'247'543 USD, IRR = 10.1 %
- Economical performances
  - Most influential economical parameter: CAPEX
  - Polygeneration is economically more interesting comparing to stand alone solar production (considering PT in all stand alone cases)
  - Exergy performance is more appropriate to characterize a polygeneration plant

Exergy results
- Power: 201.7 MW
- MED: 130 MW
- Chiller: 3.0 MW
- PH: 1.5 MW
- Energy Analysis:
  - Work: \( E_{\text{Work}} = E_{\text{In}} - E_{\text{Out}} \)
  - Heat Transformation: \( E_{\text{Out}} = E_{\text{In}} \times \epsilon_{\text{T}} \)
  - Solution: \( E_{\text{Out}} = E_{\text{In}} \times \epsilon_{\text{Sol}} \)
  - From sun: \( E_{\text{Out}} = E_{\text{In}} \times \epsilon_{\text{Tsol}} \)
  - Energy balance: \( E_{\text{Out}} = E_{\text{In}} \times \epsilon_{\text{Bal}} \)
  - Energy efficiency: \( \epsilon_{\text{Eff}} = \frac{E_{\text{Out}}}{E_{\text{In}}} \)

MAIN RESULTS
- Overall exergy efficiency in optimum case: 24.02 %
- Polygeneration: NPV = 1'247'543 USD, IRR = 10.1 %
- Stand alone: NPV = 7'420'613 USD, RRR = 7.1 %
- Most influential economical parameter: CAPEX