Optimization of parameters for heat recovery steam generator (HRSG) in combined cycle power plants

Muammer Alus, Milan V. Petrovic

University of Belgrade - Faculty of Mechanical Engineering
Laboratory of Thermal Turbomachinery

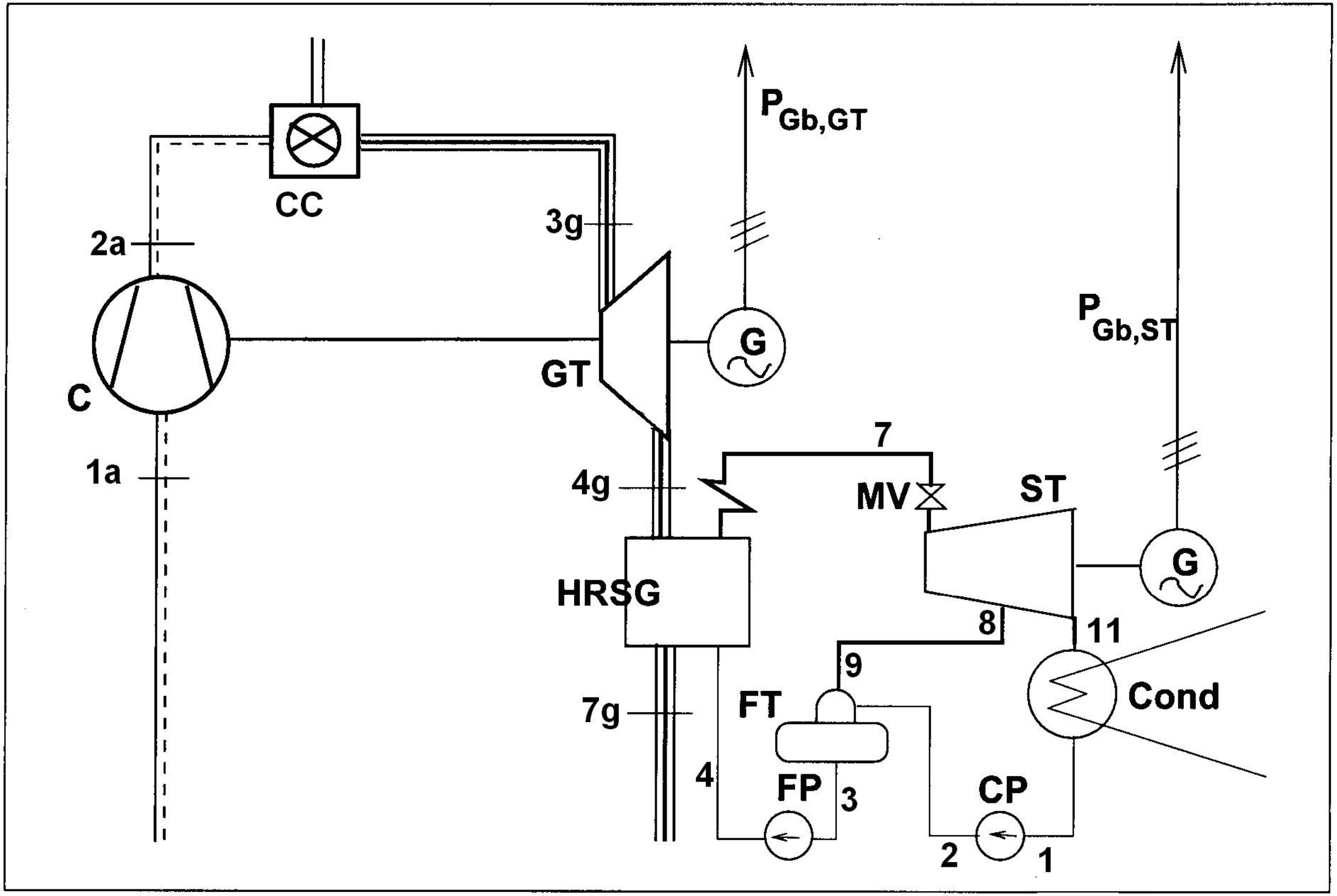
Introduction

This work illustrated thermodynamic and thermoeconomic optimization in HRSG of combined cycle power plants.

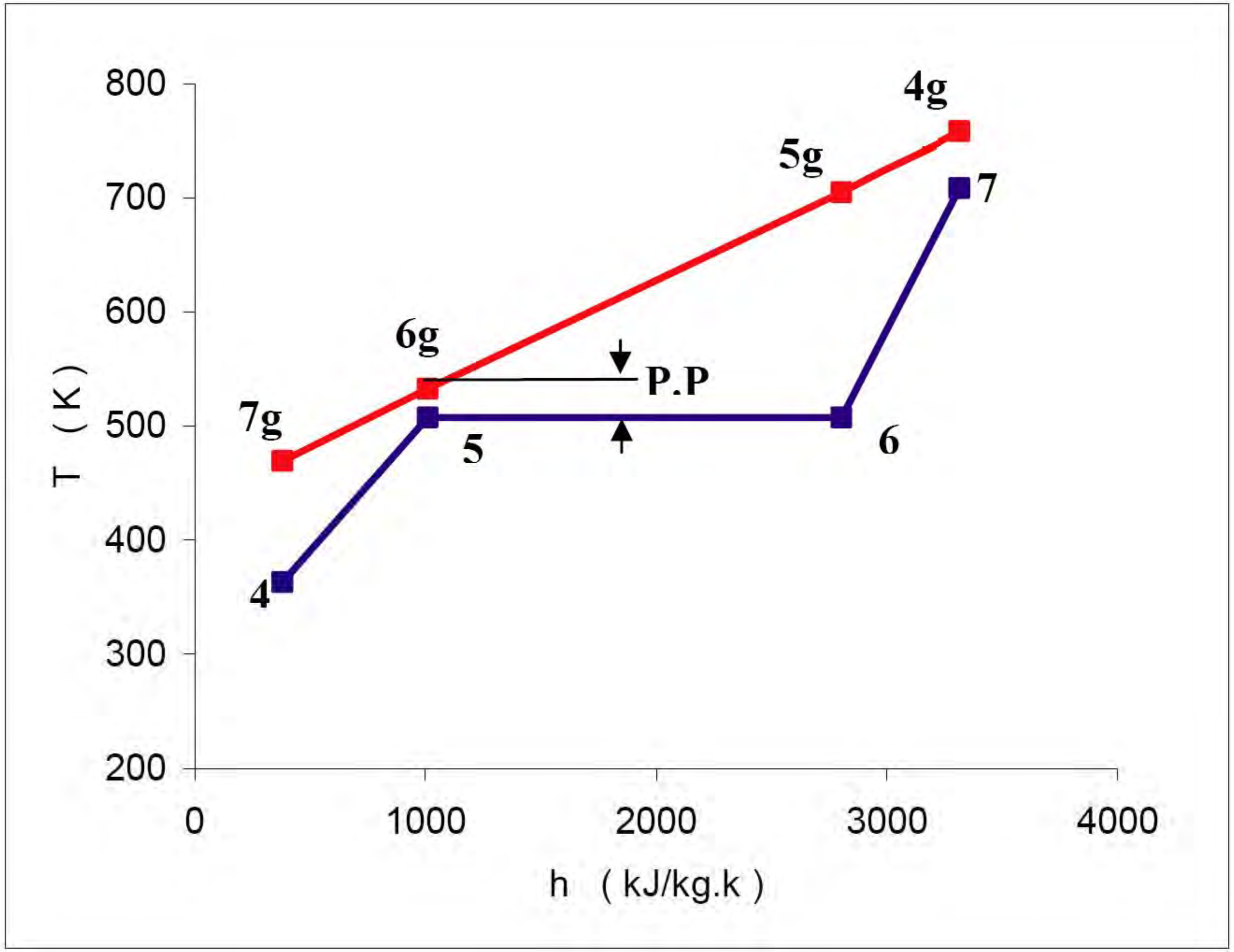
- **Thermodynamic** optimization is minimization of the thermal **exergy losses** due to decreasing the pinch point (**P.P**).

- **Thermoeconomic** optimization is minimization of the total HRSG cost: **cost of exergy losses + installation cost**.

Heat Balance Diagram of CCGT



Pinch Point (P.P) Definition



P.P: Δ between *t* of gas leaving the evaporator and the water saturation t.

Example of Optimization

Main characteristics of the CCGT plant:

Gas Turbine:

Gross Power	200 MW
Gas turbine inlet temperature	1423 K
Efficiency	0.393
Gas exit temperature	758 K
Air mass flow	571.60 kg/s

Example of Optimization

Steam Turbine:

Gross power	103.68	MW
Maximum steam pressure	28	bar
Steam condenser pressure	0.08	bar
Feed water temperature	363	K
Steam mass flow	70.12	kg/s
Min. designed Δt for P.P	10	K

Example of Optimization

Assumptions of economic parameters:

Life of plant	20	year
Operating hours	7446	$h.year^{-1}$
Selling price of power	0.0625	$/kWh

Installed costs of the sections of the HRSG

• Economizer	45.70	$\$/m^2$
• evaporator	34.80	$\$/m^2$
• Superheater	96.20	$\$/m^2$

The overall heat transfer coefficients for the sections of the HRSG

• Economizer	42.60	W/m^2K
• evaporator	43.60	W/m^2K
• Superheater	50	W/m^2K

Thermodynamic Optimization

- The **thermodynamic optimization** of the HRSG due to min. of exergy losses.

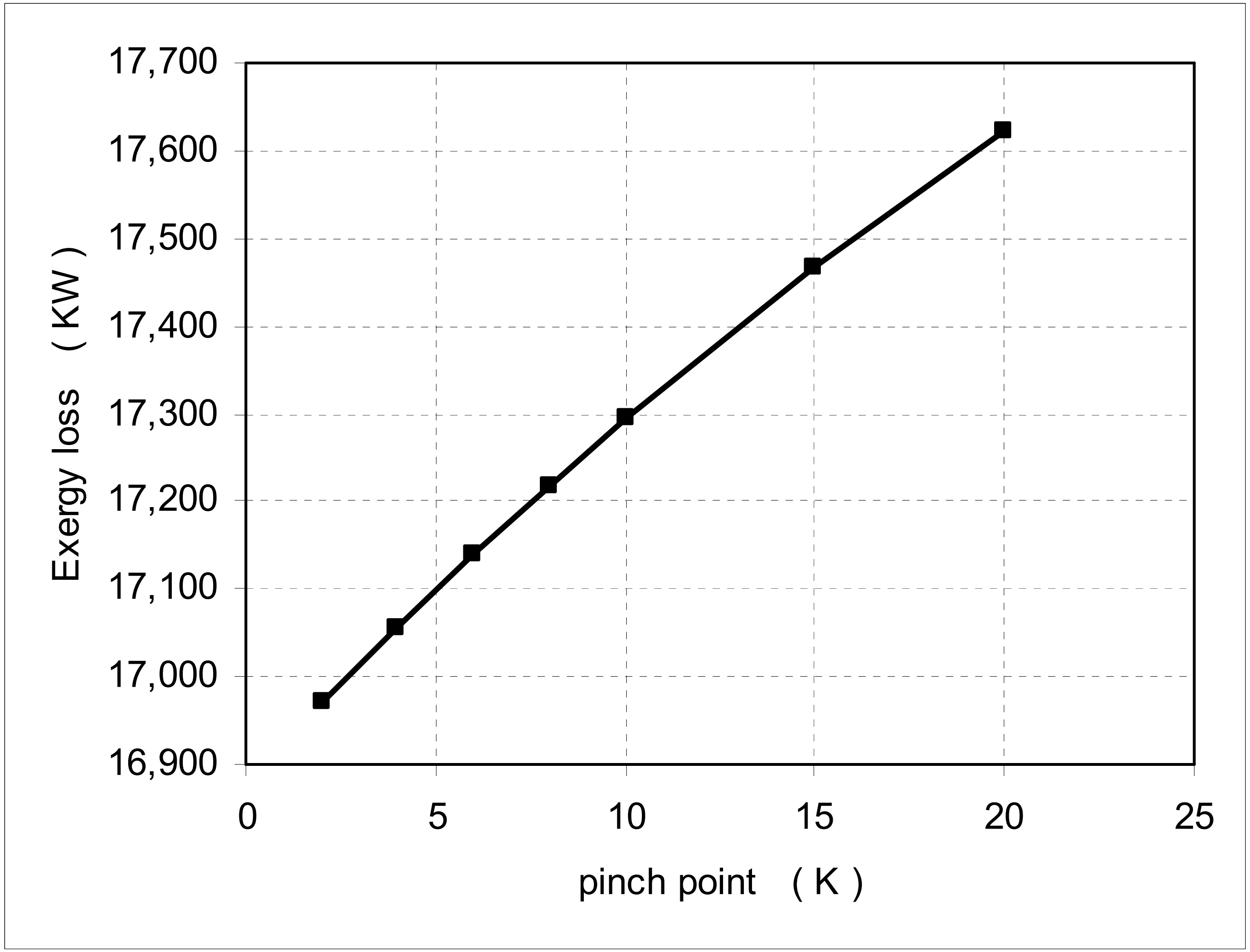
- For a heat exchanger at steady state, the availability balance equation is given by:

$$I_{HRSG} = \dot{E}_{in} - \dot{E}_{out} = \sum (\dot{m}e)_{in} - \sum (\dot{m}e)_{out}$$

- The HRSG **exergy losses** can be calculated as :

$$I_{HRSG} = m_g.[(h_{4g} - T_0 s_{4g}) - (h_{7g} - T_0 s_{7g})] - m_s.[(h_4 - T_0 s_4) - (h_7 - T_0 s_7)]$$

Thermodynamic Optimization



The relation between **exergy loss** and **P.P** is linear.

Thermoeconomic Optimization

1. Cost of exergy loss of the HRSG:

$$K_I = k_I . H . I_{HRSG}$$

2. Cost of the HRSG:

$$K_{HRSG} = \sum_e k_e A_e + \sum_V k_V A_V + \sum_{sh} k_{sh} A_{sh}$$

Thermoeconomic Optimization

3. The total cost of HRSG:

The **total annualized cost** of the HRSG is:

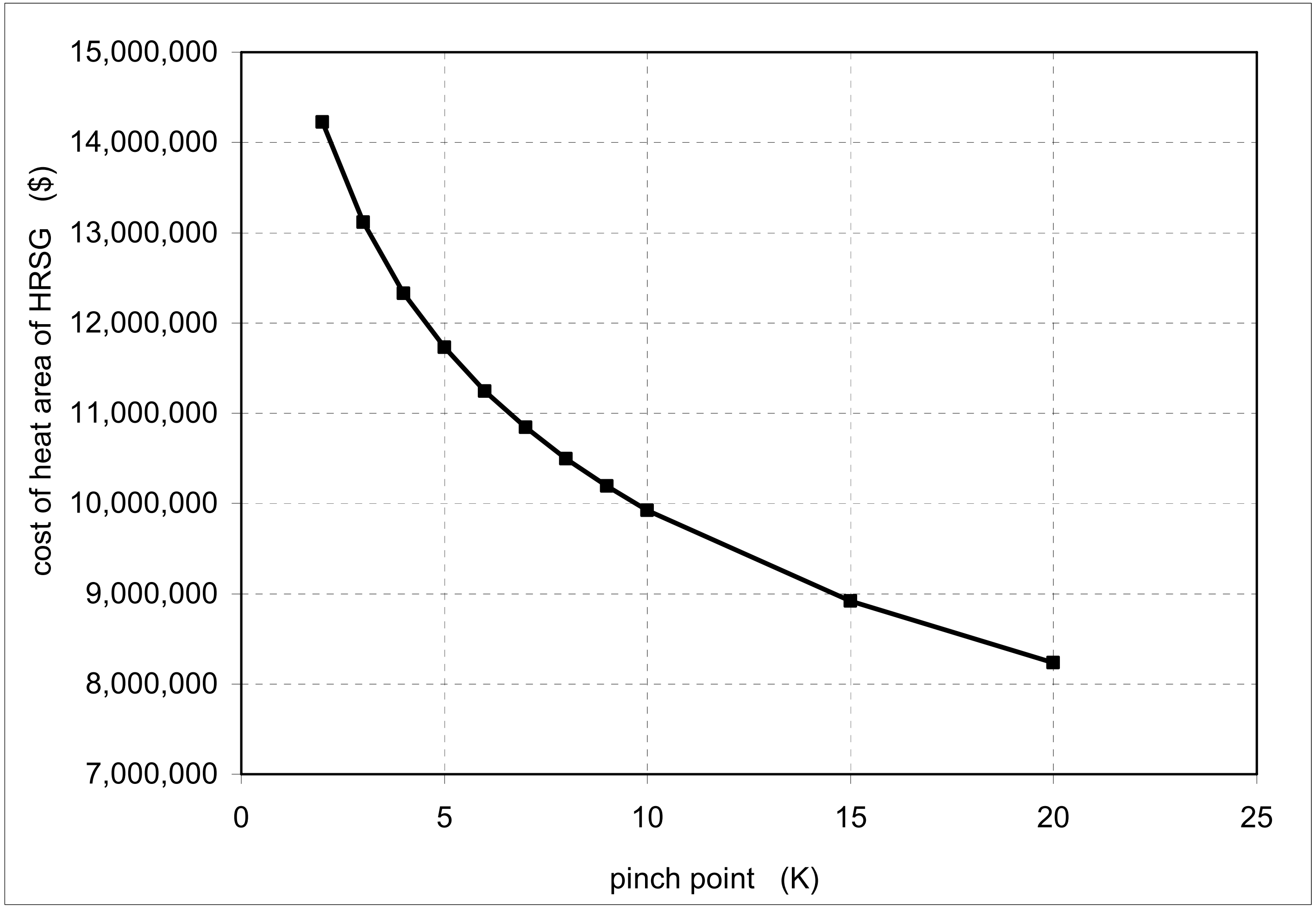
$$K = K_I + K_{HRSG}$$

$$= k_I . H . I + \frac{1}{D} \sum_e k_e A_e + \sum_V k_V A_V + \sum_{sh} k_{sh} A_{sh}$$

The **heat exchange surface** is:

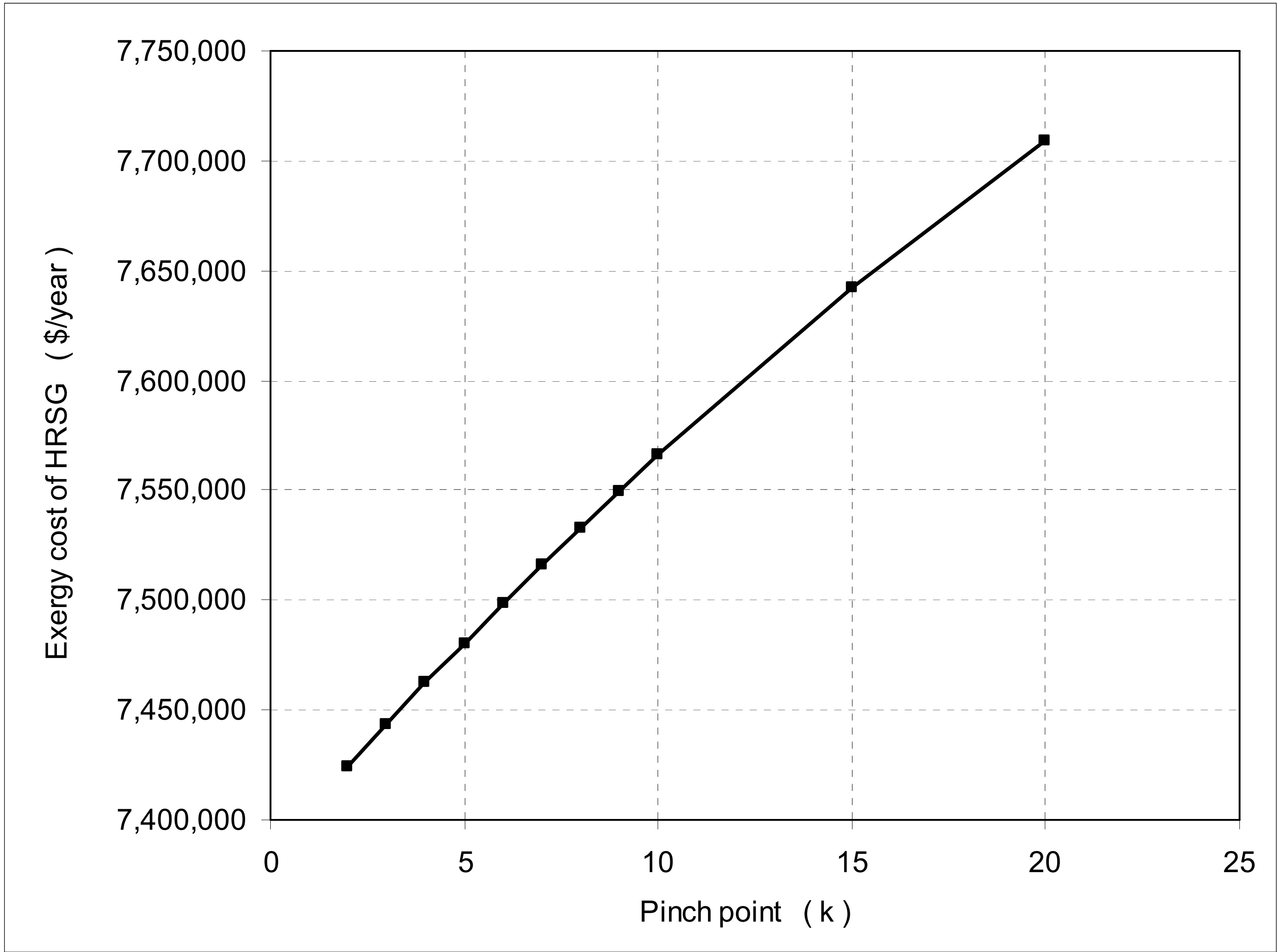
$$A_i = \frac{Q_i}{U_{m,i} . \Delta T_{m,i}}$$

Results and Discussion - Cost of heat area



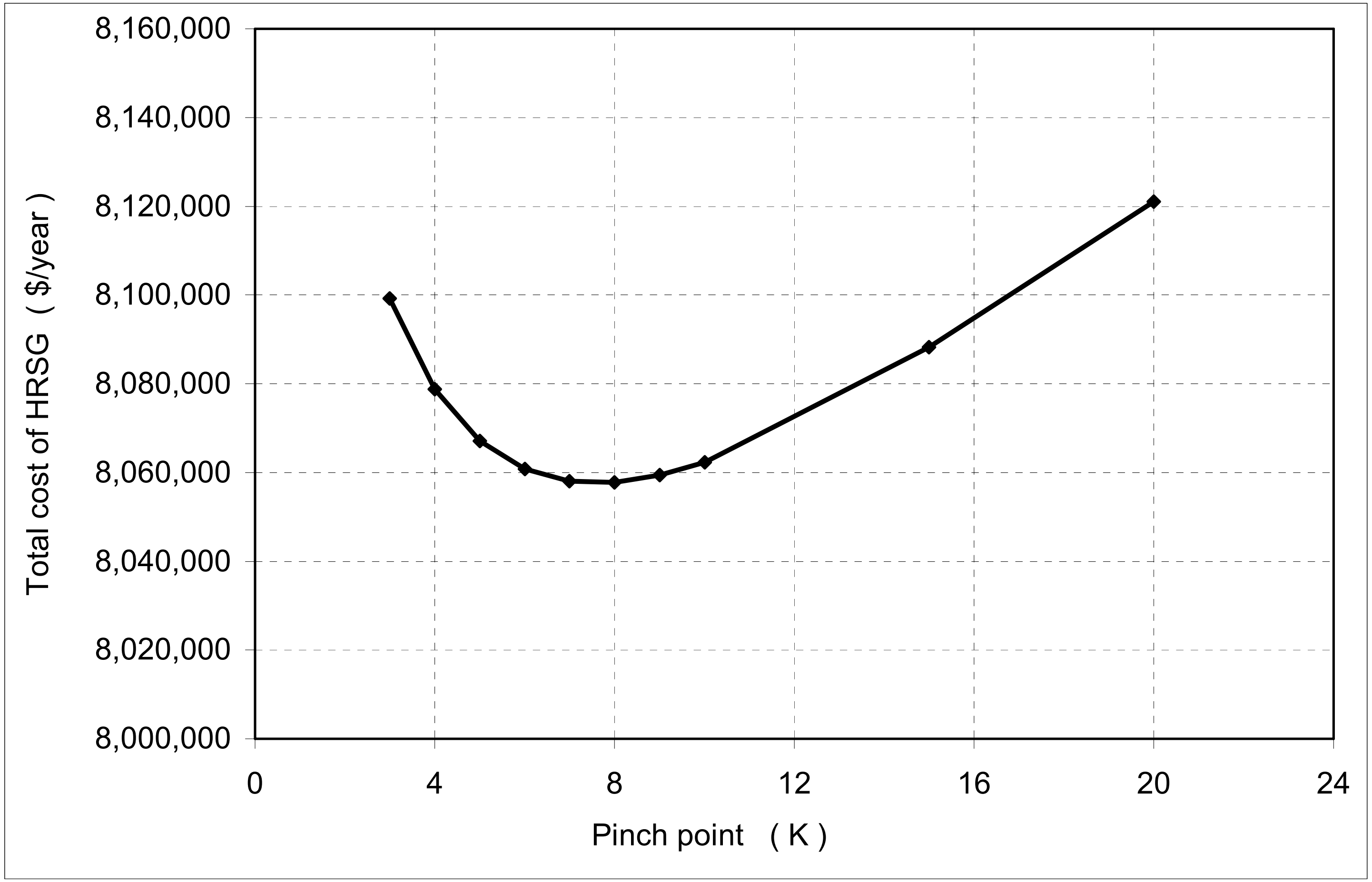
The **cost of heat area** of HRSG decreases with increasing **P.P**

Results and Discussion - Exergy loss cost



The relation between **exergy loss cost** of HRSG and **P.P** is very close to linear.

Results and Discussion - Total cost of HRSG



The **total cost of HRSG** decreases with increasing the **P.P** until pinch point **8 K** and than increases with increasing the **P.P**.

Conclusions

- The thermodynamic optimization was carried out by means of the minimization of exergy losses due to the temperature difference between the hot (gas) and the cold stream (steam).
- The exergy loss decreases almost linearly by reduction of the P.P.
- The thermoeconomic optimization was performed by analyzing the total cost of HRSG (the sum of the costs related to the exergy losses plus the costs of HRSG components).
- The variation of values for the pinch-points in the range between 3 and 20 K has shown that the optimal value is at **8 K**.

Optimization of parameters for heat recovery steam generator (HRSG) in combined cycle power plants

Muammer Alus, Milan V. Petrovic

University of Belgrade - Faculty of Mechanical Engineering
Laboratory of Thermal Turbomachinery