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Thermal integration of trigeneration systems

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Abstract

Trigeneration can be considered as a special case of the application of cogeneration systems where a fraction of the shaft work or residual heat is used for running a refrigeration system. This work focuses on trigeneration schemes where a gas turbine is used as a prime mover for power production and cooling is generated by a typical compression–refrigeration system. In most applications, a gas turbine will meet either the process power requirements or the heating needs, but it is unlikely that both would be satisfied simultaneously in the most efficient manner. The selection of the gas turbine that minimizes the heat losses to the ambient while supplying the required power can be readily accomplished by superimposing the turbine exhaust gas temperature profile to the process streams profile in a T vs enthalpy curve. This is because the maximum overall efficiency depends on the process heat and power demands and on the shape of the heat demand profile of the process. The use of the thermodynamic model helps to simulate the main components of the system and permits a fast and interactive way to design the optimum trigeneration scheme using the performance data of commercial gas turbines.

Keywords: Trigeneration; Thermal integration; Pinch analysis; Gas turbines; Cogeneration

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Nomenclature

C_p	heat capacity at constant pressure
C_v	heat capacity at constant volume
COP	coeficient of performance
F	fuel consumption
H	enthalpy
$H_{v'1}$	adiabatic compressor outlet stream enthalpy
H_{v2}	compressor inlet stream enthalpy
K	C_p/C_v
mC_p	heat capacity mass flow rate
m_R	refrigerant mass flow rate
P	pressure
Q_{amb}	heat loss to surroundings
Q_C	condenser heat duty
$Q_{c\,min}$	minimum process cooling needs
Q_E	evaporator heat duty
Q_{excess}	heat in excess from turbine
$Q_{h\,av}$	heat available in hot gases
$Q_{h\,min}$	minimum process heat needs
Q_{SK}	heat delivered to sink of heat engine
Q_{SR}	heat available from source of heat engine
r_c	air compression ratio
r_T	turbine inlet/outlet pressure ratio
T	temperature
T_1	compressor air inlet temperature
T_3	turbine gases inlet temperature
T_4	turbine gases outlet temperature
T_{4s}	adiabatic turbine gases outlet temperature
T_E	refrigerant evaporating temperature
T_C	refrigerant condensing temperature
T_{SK}	heat engine sink temperature
T_{SR}	heat engine source temperature
W_{ad}	adiabatic compression work
W_e	process power needs
$W_{e\,av}$	power available for the process
$W_{e\,exc}$	power produced in excess
W_{eR}	refrigeration power consumption
W_{eT}	turbine power production
W_g	exhaust gases mass flow rate
W_n	specific net power from turbine
ΔH	enthalpy change or heat duty