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Modeling, numerical optimization, and irreversibility reduction of a dual-pressure reheat combined-cycle

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Abstract

Optimizing the gas-turbine combined-cycle is an important method for improving its efficiency. In this paper, a dual-pressure reheat combined-cycle was modeled and optimized for 80 cases. Constraints were set on the minimum temperature-difference for pinch points (PP_m), superheat approach temperature-difference, steam-turbine inlet temperature and pressure, stack temperature, and dryness fraction at the steam-turbine's outlet. The dual-pressure reheat combined-cycle was optimized using two different methods; the direct search and the variable metric. A technique to reduce the irreversibility of the steam generator of the combined cycle was introduced. The optimized and the reduced-irreversibility dual-pressure reheat combined-cycles were compared with the regularly-designed dual-pressure reheat combined-cycle, which is the typical design for a commercial combined-cycle. The effects of varying the inlet temperature of the gas turbine (TIT) and PP_m on the performance of all cycles were presented and discussed. The results indicated that the optimized combined-cycle is up to 1% higher in efficiency than the reduced-irreversibility combined-cycle, which is 2–2.5% higher in efficiency than the regularly-designed combined-cycle when compared for the same values of TIT and PP_m. The advantages of the optimized and reduced-irreversibility combined-cycles were manifested when compared with the most efficient commercially-available combined cycle at the same value of TIT.

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Nomenclature

CC	combustion chamber
D	steam drum
h	enthalpy (kJ/kg)
$\bar{h}$	enthalpy per kmole
LHV	lower heating value (kJ/kg)
M	molecular weight (kg/kmole)
$\dot{m}$	mass-flow rate (kg/s)
P	pressure (Pa)
PP	pinch-point temperature-difference (K)
r	pressure ratio (dimensionless)
SW	specific work [kJ/kg]
T	temperature (K or °C)
TIT	gas-turbine's inlet-temperature (K)
TOT	gas-turbine's outlet-temperature (K)
X	steam dryness-fraction (dimensionless)
y	mole fraction
α	reheat pressure ratio
η	efficiency (dimensionless)
δT	temperature difference (K)
γ	principal specific-heats ratio (dimensionless)

Subscripts

a	air
c	cooling
ccycle	combined cycle
com	compressor
f	fuel
g	gas
gcycle	gas cycle
i	point number i, or component number i
m	minimum
s	steam
sD_1	dry steam for drum 1
$seDi$	evaporation for steam of drum number i
sta	stack
stih	steam at the inlet of the high-pressure turbine