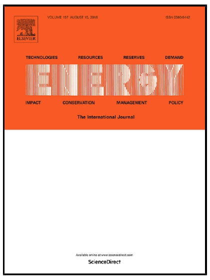

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The Thermodynamic and Economic Characteristics of the Modern Combined Cycle Power Plant with Gas Turbine Steam Cooling

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Abstract

This paper presents a methodology to clearly identify energy benefits (in terms of power and efficiency) resulting from the use heat from gas turbine steam cooling and heat from cooling air. These potential benefits are evaluated in terms of the characteristics of combined cycle power plants in a wide range of pressure ratios $\beta = 10 \div 100$. Calculations were made for four variants (optimistic and conservative), differing in terms of the performance characteristics of the compressor and turbine isentropic efficiency as a function of β and the permissible temperature of the expander blades in the gas turbine. The steam part of the power plant in question is composed of a classical steam cycle with a triple-pressure subcritical heat recovery steam generator (HRSG) with reheating, to which gases from a gas turbine are fed at a constant temperature of 630°C. The power plant also has an additional steam cycle utilizing the heat from cooling the air from the intercooler of the air compressor. The impact of using steam cooling on the electrical efficiency of the gas turbine as well as the entire power plant is presented. This was compared to classical open-air cooling, achieving a gas turbine electrical efficiency seven percentage points higher for high pressure ratios. Using steam and air heat, the combined cycle power plant achieves a net electrical efficiency of more than 65% for $\beta \geq 95$. This paper presents the calculation algorithm of the break-even cost of electricity $C_{\mathrm{el}}^{\mathrm{b\text{-}e}}$ (at the NPV = 0) and the cost of the components as a function of the pressure ratio β. In addition, the efficiency and power degradation of the power plant over time is presented. The lowest cost $C_{\mathrm{el}}^{\mathrm{b\text{-}e}}$ = 64.85 €/MWh (at the fuel price 8.179 €/GJ) was obtained for the compression ratio $\beta = 31$. But, the range of compression ratios for which this is close to the optimum is wide and is within the range of $\beta = 18 \div 53$. Sensitivity analysis of the break-even cost of