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Energy and Exergy analysis of diesel engine powered trigeneration systems

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Abstract

This article presents the thermodynamic analysis of diesel engine powered trigeneration system considering the actual engine data of 200 kVA engine systems. Trigeneration systems considered for analysis comprises of a diesel engine integrated with absorption chillers. For better thermodynamic performance of a trigeneration system for cooling applications, absorption chillers integrated with engine systems should accept the heat energy at almost the same temperature at which it is available. With this consideration two trigeneration systems are examined. System one uses low grade heat energy recovered from engine jacket water with single effect chiller and high grade heat energy of exhaust gases in double effect chiller. System two combines recovered energy for use in a single chiller. Analysis of such trigeneration configurations cannot be based on first law analysis alone. This paper through an energy and exergy analysis of a trigeneration system under cooling mode, recommends the use of a trigeneration system with two chillers over a trigeneration system with single chiller. Operating the trigeneration system near the rated capacity of engines improves its energetic as well as exergetic performance. Though the initial cost of a trigeneration system with two chillers is more than the one with single chiller, life cycle costing analysis reveals the former is attractive even on economic basis.

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1. Introduction

Trigeneration with reciprocating engines as prime movers involve recovery of energy rejected from engines and using this energy to satisfy cooling and heating demand of a given load. Energy recovered from exhaust gases is

Nomenclature

C_p	specific heat of water [kJ/kg K]
C_{pg}	specific heat of engine exhaust gases [kJ/kg K]
CRF	capital recovery factor
COP	coefficient of performance
DEC	double effect chiller
DG	diesel generator
d	discount rate
e	specific exergy [kJ/kg]
EJ	diesel engine jacket
EHRU	Exhaust heat recovery unit
E_F	Exergy of fuel
E_P	Exergy of product
E_q	Exergy associated with heat transfer
E_D	Exergy destroyed
HE_1	Heat exchanger for heat transfer from engine jacket water to water input of desorber
m_g	mass flow rate of exhaust gases of the engine [kg/s]
m_a	mass flow rate of air consumed by the engine [kg/s]
m_f	fuel consumption rate of engine [kg/s]
m_h	mass flow rate of hot water entering the desorber of single effect chiller [kg/s]
m_w	mass flow rate of engine jacket water [kg/s]
m_c	mass flow rate of chilled water from single effect chiller[kg/s]
m_c'	mass flow rate of chilled water from double effect chiller[kg/s]
P	Pump
P_c	Cooling load in TR
P_e	electrical power output
SEC	single effect chiller
S	specific entropy in kJ/kg K
T	temperature of the fluid in K
T_0	dead state temperature in K
TR	tons of refrigeration
y^*	exergy destruction in component with respect to exergy input
y	exergy destruction in component with respect to total exergy destruction in system
η_e	exergetic efficiency

commonly harnessed using suitably designed heat exchangers [2,3]. Absorption chillers come in different configurations and types which affects its performance [4]. Systems approach in analyzing trigeneration systems has been used in many studies indicating the desirability of trigeneration [5]. Trigeneration systems are required to satisfy the variable power demand or variable thermal demand depending on the load curve and the mode of operation of diesel generator [6]. Diesel generators operating in electricity demand following mode would operate at part loads at times. Part load behavior of engines would result in corresponding reduction in output of absorption chillers.

Integrating absorption chillers with diesel engine generators requires a thorough understanding of both quantity as well as quality of energy recoverable from the engine. The energy balance of diesel generators is investigated thoroughly by many researchers. It is known that the exhaust gas quantity as well as its temperature varies