



Research Paper

Investigation of climatic effect on energy performance of trigeneration in building application



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HIGHLIGHTS

- Extent of energy merit of trigeneration depended on waste heat utilization.
- Associated to electrical efficiency of prime mover and building loads due to climatic effect.
- Trigeneration application was favorable in continental and tropical climates.
- Temperate climate might result in low energy merit for trigeneration.
- Energy saving potential of trigeneration was not guaranteed in certain occasions.

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ABSTRACT

Trigeneration is commonly considered as one of the energy-efficient solutions, since the heat recovered from electricity generation can be adopted to produce both heating and cooling for building use. It is generally accepted that the trigeneration system should outperform the conventional separate provisions of cooling, heating and power. However, energy efficiency of the prime mover of trigeneration would be diminished in part-load conditions, which are mainly determined by the changing climatic situations. In this regard, it is not sufficient to consider the energy performance of trigeneration based on the design point. Therefore, this study attempts to conduct year-round evaluation of trigeneration systems subject to climatic effect. Four cities with close longitude but different latitudes were involved, which had different heating-to-cooling ratios in building loads due to climatic conditions. A set of energy performance indicators were applied to thoroughly appraise the trigeneration systems against the conventional provisions. It was found that the extent of energy merit of trigeneration depended on the utilization degree of waste heat, which was associated to the electrical efficiency of prime mover and the building loads caused by climatic effect. While the year-round fuel energy utilization ranged from 61.9 to 83.8%, the respective primary energy reduction only varied from 0.4 to 7.5%. Energy saving potential of trigeneration might not be guaranteed in certain occasions in a year.

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1. Introduction

Global warming due to CO₂ emissions has been the most controversial debate nowadays. There are possible environmental impacts on ambient air conditions [1–4] and fresh water supply [5–10]. The majority of worldwide CO₂ emissions come from the power plants. Hence, the quest for more effective power generation systems is one main direction of energy researches. Trigeneration system primarily produces electricity, meanwhile, it utilizes the waste heat captured from the prime mover to offer space cooling and heating. The recovered heat is used to energize a

thermally-driven cooling equipment to provide air-conditioning. Due to utilization of waste heat, trigeneration is considered more energy-efficient than the classical power plants, and the system efficiency can be 60–80% [11,12]. Actually, the effectiveness of trigeneration would be affected by the loading ratio in building applications. Al-Sulaiman et al. [13] reviewed that it was common to use the electric-to-heating ratio to characterize different prime movers of trigeneration. Marques et al. [14] conducted thermodynamic analysis of trigeneration systems by taking into account both the electric-to-heating and electric-to-cooling ratios for buildings. Ebrahimi and Keshavarz [15] studied the prime mover sizing and operational mode for micro-trigeneration, it was found that they should be determined according to the climatic features. Hajabdollahi et al. [16] considered suitable operational strategy for

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