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Review article

Closed-cycle gas turbine for power generation: A state-of-the-art review

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HIGHLIGHTS

- Closed-cycle gas turbine applicable to a wide range of heat sources.
- Working fluids include air, nitrogen, supercritical CO_2 and helium.
- Review of important R&D programmes and operated plants.
- Heat exchangers are significant driver in the capital cost and technical viability.
- Demonstration plant essential before commercial deployment.

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ABSTRACT

In the last few years, there has been considerable interest in closed-cycle gas turbine power plants due to the important contribution it can make to meeting worldwide energy demands. Closed-cycle gas turbine has the potential to serve as power conversion system for a wide range of energy sources such as fossil fuel, concentrated solar power, nuclear, biomass and waste heat. However, there is a need to provide an update on the development of closed-cycle gas turbine with a view to identifying the challenges and the opportunities for future commercialisation. This paper is a review of the research activities and studies carried out worldwide so far on closed-cycle gas turbine. The historical development in chronological order was presented first, followed by a review of some fundamental features such as heat sources, working fluids, heat exchangers and cycle layouts/configurations. Important research programmes and experimental/pilot plants as well as previous commercially operated plants were also reviewed. Moreover, various studies based on modelling and simulation of closed-cycle gas turbine were reviewed, in addition to the operation and control strategies. Based on the review studies, the challenges ahead and potential future breakthroughs were highlighted in different aspects such as heat source technologies, power conversion system and demonstration plant.

Contents

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1. Introduction

1.1. Background and motivations

Closed-cycle gas turbine power plant has the potential to complement the conventional coal-fired power plant and internal combustion (open cycle) gas turbine (GT) power plants. Early popularity of the closed-cycle GT in the 1950s to the 1970s was over shadowed by the more matured open cycle GT, which gives higher efficiency due to its higher firing temperature. However in the recent past, there has been a revival of interests in the study of closed-cycle GT as an alternative or as an additional power conversion system (PCS).

Contributing to the renewed interest are the enormous achievement in the areas of high temperature small modular reactors (SMRs), the development of next generation nuclear reactors by Generation IV consortium and the improvement of solar receivers. While these new promising heat sources share the common features of moving to higher operating temperatures, the conventional power conversion systems (PCSs) cannot be adapted to exploit some of these higher temperatures. Hence, the door is open for the closed-cycle GT to be more competitive and will have billions of US dollars of commercial market. A previous drawback of the closed-cycle GT has been the lack of suitable heat source since light water reactors (LWRs) could not meet the high temperature requirement necessary for the cycle to be competitive. Similarly, the closed cycle GT was not well suited for conventional fossil-fired heat sources [1,2].

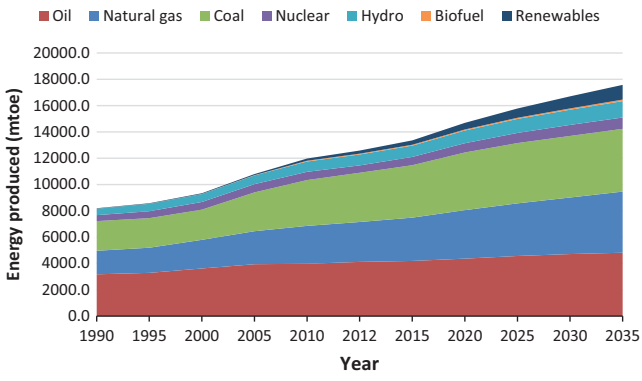

Fig. 1. Global energy production by fuel [18].