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Design and Performance Analysis of the Distributed Generation System Based on a Diesel Engine and Compressed Air Energy Storage

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Abstract

The distributed generation system coupled with the energy storage system could perform a 'peak shaving' function for maintaining a required power output. As a result it decreased the core engine power rating and increased integrated system's efficiency. In this study a hybrid power generation system integrated with a Compressed Air Energy Storage (DE-CAES) system was proposed. To carry out a technical analysis the design flow chart was designed and process models were developed. The simulation results were also validated by the experiment. The results revealed that integrated system's efficiency and fuel saving ratio could be increased by 6.5% and 14.4%, respectively.

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Key words: Distributed generation; DE only; Hybrid DE-CAES system; Fuel saving

1. Introduction

Distributed generation (CCHP - combined cooling, heating and power) is being extensively developed with respect to its merits such as high efficiency, low Greenhouse Gas (GHG) emissions and reliability which is more suitable for remote areas than conventional generation plants [1, 2]. A typical distributed generation, as shown in Figure 1 is composed of a diesel engine (DE), an absorption chiller and the waste heat recovery system. Basically, daily demand loads are fluctuated stochastically. Thus the power output from the core engine has to be adjusted to adapt these changes, resulting in an efficiency reduction during the partial rating power period [3,4]. Considering as an effective solution to deal with this problem [5, 6] energy storage could play an important role in "peak shaving" [7]. As one of energy storage technologies, Compressed Air Energy Storage (CAES) can store excessive shaft power through compressed air, and recover the waste heat from the process during the off peak time. During the peak period stored energy is released to generate power, heat and cool. As downgraded the core engine power size, the system integrated with CAES keeps the engine working stably with high efficiency and reduces the fuel consumption [8].

Energy storage is an emerging technology which is attracting much attention from both academic and industrial communities [7, 9]. The CAES technology along with the thermal energy storage technology are considered as the most promising and affordable alternative. Many researchers have been engagingwith the

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electricity "peak shaving", large scale renewable power generation and distributed generation in order to improve the energy efficiency and decrease the GHG emissions [5, 7, 10]. Although the DE integrated with energy storage has been studied numerically, the modelling of the system components are not accurate enough to reveal the system's characteristics, and the dynamic characteristics of the CAES system are not considered.

In this study, the CAES technology is integrated into a diesel engine based distributed generation system. Both DE and CAES systems are modelled and simulated. The CAES modelling is based on the research of a 1.5MW CAES system in Institute of Engineering Thermophysics (IET), Chinese Academy of Sciences. The hybrid system's performance is also compared with the experimental results

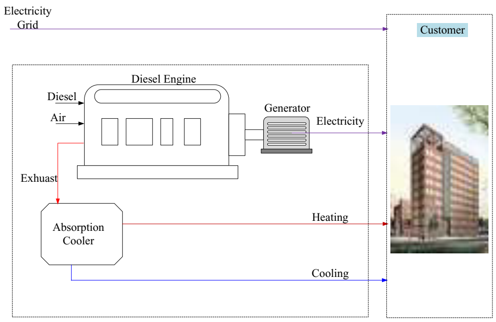

Fig. 1. A typical DG system

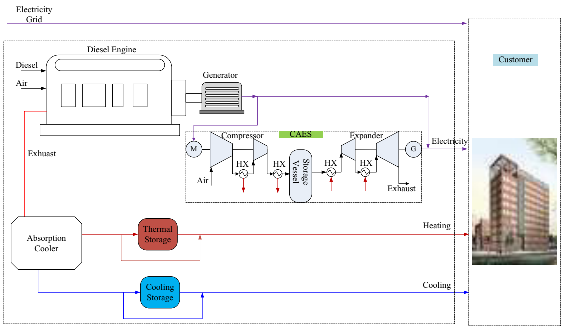

Fig. 2 A DE-CAES generation system

2. System description

The proposed system is illustrated in figure 2. The DE, fueled by diesel to generate power is designed to work at its rated power. The excessive electricity is stored by the CAES system via compressed air during off-peak time. Recovered waste heat (exhaust, coolant water) is stored and then used to heat up the air temperature of the expander in the CAES system during its energy releasing process. Meanwhile stored heat is split to an absorption chiller for generating cooling energy. The rest thermal energy is supplied to customers for hot water or space heating. The cooling and thermal energy storage systems as shown in figure 2 are used to store the abundant cooling and heat of the hybrid system for later use. As a result, it will not be necessary to equip the DE to a community according to the maximum power demand.

The CAES system is composed of a compression unit, heat exchangers, thermal energy storage, compressed air vessel, expanders, motor and generator. The compression unit which consists of 5-stage compressors delivers an air pressure around 10MPa with equal pressure ratio of each stage. The heat produced by compressors is also recovered and stored. The expansion unit which is composed of of 4-stage expanders is operated at 7MPa with an equal pressure ratio for each stage. The inlet air of each stage is heated up by the DE flue gas before expansion.

3. Methodology

3.1. Design flow of the DE-CAES system

The design flow chart of distributed generation integrated with energy storage systems is illustrated in figure 3. the fluctuated load from users is introduced and its initial basic load is calculated with respect to energy storage and energy release processes. Initial energy storage power and energy release power profiles are first calculated based on their models constructed. Energy balance and stored air pressure are compared. If the difference between stored air pressure and release pressure is negative as shown in figure 3, the initial base load is increased by a small step. As result the energy storage and releasing profiles will be re-