Design and Optimization of Distributed Belowground LNG Storage System for End-users

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ABSTRACT

To generalize the application of natural gas without involving large-scale infrastructure construction, the distributed belowground storage of LNG (DBS) is proposed for providing LNG supply to areas without gas grid. The analysis of system workability and cost are conducted via three-dimensional (3D) thermal-mechanical models and analytical model, the optimal model of which is obtained via Genetic Algorithm (GA). The overall cost is the optimization target of GA, with the structural workability and thermal requirement taken as constraints. It is found that the configuration of DBS system affects both the thermal-mechanical behaviors and the overall cost.

KEY WORDS: LNG; Belowground storage; Multiphysics analysis; Structural optimization; Genetic Algorithm (GA).

INTRODUCTION

Natural gas is known as the cleanest fossil fuel and contribute to more than 95% of electricity generated in Singapore (Ali et al. 2017). It is also thought that utilization in some areas without gas grid is promising and can highly reduce environmental burden (Kumar et al. 2011). The conventional concept of centralized supply chain (see Fig. 1) may provide a solution to the utilization of LNG in highly urbanized area, which, however, requires large investment and great effort into infrastructure upgrade and the associated level of complexity and risk are high (Ölz et al. 2007). If LNG is to be distributed through pipelines, they will be laid underground, just like almost all electric power cables, telecommunication cables, water pipes, and so on (Bobylev 2009). Therefore, emergency occurring at certain location could lead to inestimable consequence to surrounding residents. Therefore, to generalize the application of natural gas without introducing large scale construction, the concept of distributed belowground storage of LNG (DBS) is proposed, which can provide LNG supply to nearby areas. DBS will be constructed in areas safe and convenient enough to regional LNG supply. Meanwhile, according to experiences from the distributed energy supply system for power generation, the fuel utilization efficiency exceeds 80% with greatly reduced pollutant emissions (CIMC-ENRIC 2014).

Hence, this DBS concept could not only increase the efficiency of energy utilization and reduce energy dissipation, but also increase the level of system safety. Nevertheless, the focus of the present work is on the interaction between DBS system and the ambient environments, which involves serval aspects, such as system insulation (configuration of tank container and underground cavern), system workability (thermomechanical behaviors of concrete wall, ambient soil, and tank containers), system cost (container tank, soil/rock excavation, soil

Fig. 1 Schematic diagram of natural gas value chain (Ishwaran et al. 2017)