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Energy storage systems for refrigerated warehouses

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Abstract

To reduce the peak load, dynamic electricity price schemes have been widely used. Refrigerated warehouses consume a large amount of energy, most of which happens during the daytime due to the higher ambient temperature. This work evaluated the potential benefits of integrating energy storage in the refrigerated warehouses. Two types of energy storage systems have been considered, including a cold energy storage system and an electrical energy storage system. A dynamic model has been developed in TRNSYS to study the performance of those two energy storage systems and assess the benefits.

Results show that using the cold energy storage to shift power consumption from daytime to nighttime can increase the energy efficiency of the refrigeration system. However, as the electrical energy storage system can shift more power consumption, it can achieve a large cost saving. Compared to the reference system without energy storage, the introductions of a cold energy storage system and an electrical energy storage system can reduce the operational cost by 10 and 53.7% respectively.

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Keywords: refrigerated warehouse; peak load shifting; cold energy storage system; electrical energy storage system; dynamic simulation; TRNSYS

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1. Introduction

With the improvement of the living standard, more and more refrigerated warehouses have been built, resulting in a fast increase of the electricity consumption, which accounts for approximately 16% of the electricity consumption of the food industry [1]. Naturally, refrigerated warehouses consume much more electricity in the daytime, during which the peak electricity consumption appears, than in the evening as the ambient temperature is higher [2 ,3]. The dynamic electricity price has been a tendency to balance the grid loads. As a result, the electricity price is higher at the peak load. Consequently, if the electricity consumption can be shifted from the peak time to valley time, or from daytime to evening, the operational cost can be reduced. Therefore, energy storage systems, which can shift energy consumption and save costs, have attracted more and more attentions [4-7].

For refrigerated warehouses, two types of energy storage systems can be selected: the cold energy storage system and the electrical energy storage system. Cold energy storage systems have been widely used in buildings. According to Zeng et al. [8], by applying a refrigerated warehouse located in Hunan, the energy consumption and cost can be reduced by 19.2% and 26.6%, respectively. Besides, with the development of battery technologies, electrical energy storage systems become more and more popular. Particularly, when a lot of depleted batteries become available as a result of the rapid development of electrical vehicles, the capital cost of electricity energy storage can largely decrease [9-11]. However, there have been few studies regarding comparing these two energy storage systems for the application in refrigerated warehouses.

The objective of this paper is to compare the performance and benefits of the cold energy storage and electrical energy storage when being applied to a refrigerated warehouse. By doing dynamic simulations, the warehouse indoor temperatures, electricity consumption and operational cost for the two energy storage systems will be evaluated for the warmest period (Jun.-Sep.). The results intend to provide suggestions and guidelines when choosing energy storage technologies for refrigerated warehouses.

2. Model

2.1. Introduction of the refrigerated warehouse and the TRNSYS model

A refrigerated warehouse located in Beijing, China, is chosen as a case study, which volume is 3189m^3 (40.5m×17.5m×4.5m). Polyurethane with 0.1m thickness is used as insulation material for the walls, ground, and roof, which thermal conductivity and the heat transfer coefficient are 0.031W/(m·°C) and 0.31 W/(m^2·°C), respectively. This refrigerated warehouse is used to store fresh food at 0-4°C. In order to simulate the energy demand of the refrigerated warehouse, a model has been developed in TRNSYS. The schematic diagram is shown in Fig.1.

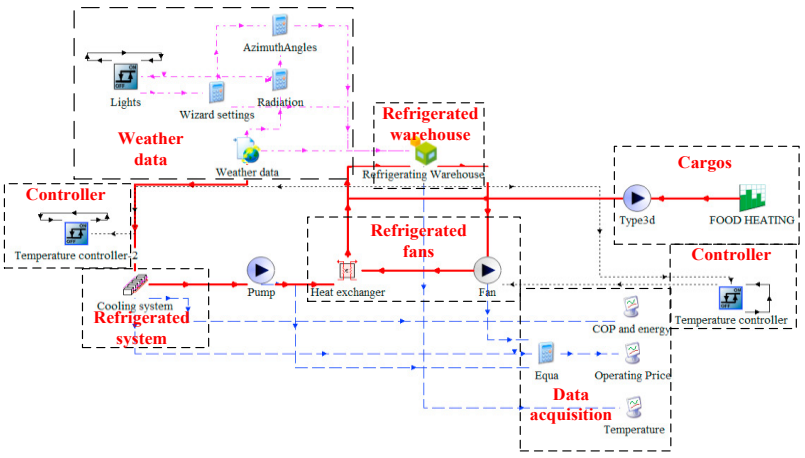

Fig.1 The TRNSYS model of refrigerated system.