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Identification of Design Criteria for District Cooling Distribution Network with Ice Thermal Energy Storage System

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Abstract

Two (2) distribution network models of district cooling system with ice thermal energy storage system are presented in which the theoretical system pressure drop, system flow rate and flow rate requirements in each energy transfer station were determined. The hydraulic calculation and system simulation of distribution networks with and without secondary lines are evaluated based on system temperature difference set-point of 11°C. Variable primary flow pumping system arrangement was used to improve energy usage and to eliminate the need for a distribution pump in the network. The system of nonlinear equations was solved using multivariable Newton-Raphson method. The linearized equations revealed that coefficient matrices formed between the two networks were different from each other which suggested that different decomposition algorithms must be used to properly determine the solution vectors. Optimization technique such as exhaustive search method was adopted to identify the piping network design criteria that could yield minimum overall cost.

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Keywords: District Cooling System, Ice Thermal Energy Storage System, Distribution Network Design Criteria, Multivariable Newton-Raphson Method, Exhaustive Search Method

1. Introduction

One of the largest contributors of electrical peak demand is to provide air conditioning of commercial buildings during summer daytime hours for comfort cooling. Other electrical loads include lighting,

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computers and operating equipment which allow additional electrical demand during peak hours. To mitigate the increasing electrical costs, an ice thermal energy storage (Ice TES) system is needed which shifts electrical load during nighttime or off-peak periods. Such austerity measure significantly reduces energy and demand charges during summer and lower total energy usage as well. With the presence of ice thermal energy storage system, solid ice produces at night when the building electrical loads are at a minimum. Ice is stored in tanks to provide cooling and air conditioning requirement during daytime.

Although it requires higher overall costs for district cooling plants with Ice TES, it can reduce the initial investment costs of distribution network due to an increasing temperature difference set-point of 11°C. Allowable temperature difference of district cooling plant with Ice TES system is around 13.3°C [4]. Nevertheless, it decreases the chilled water system flow rate requirement along the network by less than 18.2% as compared with district cooling plant without Ice TES system. As the distribution network is often the most expensive portion and requires large initial investment cost of the district cooling system, careful design is needed to optimize its use. It follows that appropriate piping design criteria would be needed to properly identify the minimum overall cost of construction and maintenance of distribution network.

2. Materials and Methods

Two (2) distribution network models with variable primary flow pumping arrangement were used as the basis for fluid flow analysis. As required for plant design and chilled-water system operation, both networks have a temperature difference set-point of 11°C. To compare the piping network design criteria of two distribution network models, the schematic diagrams DNModel-01_12 and DNModel-03_12 were used as shown in Fig 1(a) and Fig 1(b), respectively. Figure 1(b) shows the presence of secondary lines in the network. In both cases, twelve (12) energy transfer stations in each network were used with total pipe length of 5.2 km. Table 1 shows the pipe length details installed in the two (2) distribution network models.

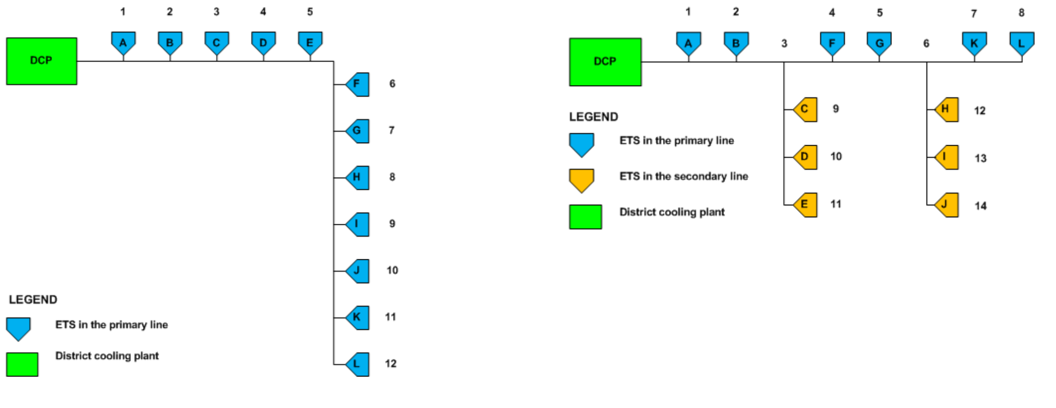

Fig. 1. Schematic diagrams of piping networks namely; (a) DNModel-01_12 and (b) DNModel-03_12