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A numerical comparison of control strategies applied to an existing ice storage system

Vincent Lemort *

University of Liège – Thermodynamics Laboratory, Campus du Sart-Tilman B49, P33 B-4000 Liège, Belgium

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Abstract

While ice storage systems are designed according to a defined strategy for warm day loads, it is interesting to consider other conventional control strategies for mid-season day loads. Three different charging–discharging control strategies are applied to an existing cooling plant and compared in terms of operating costs and energy consumption. A cooling plant model is built. A time stage equal to 15 min is considered to simulate numerically a whole charging–discharging process and compare the different control strategies. These simulations take into account existing technical constraints and set points. EES software is used. The operating costs of the cooling plant are evaluated by taking into account both the energy and the demand cost rate. It is shown that an ice storage system can allow savings of operating costs. However, they can increase energy consumption.

Keywords: Ice storage; Cooling plant; Energy savings; Control strategies

1. Introduction

Ice storage is a process which allows the spatial and temporal dissociation of production and consumption of cooling energy. Cooling energy is produced at night, stored under ice state in storage tanks. In the day, melting ice gives back the cooling energy. Ice storage allows reduction of the size of both chillers and surrounding devices (cooling towers, transformers, etc) because the plant is not designed on maximal load anymore. Ice storage allows savings of operating costs since it takes advantage of cheaper electricity rates during off-peak hours. Finally, ice storage can temporarily ensure the cooling production in the event of a breakdown of the chillers.

An ice storage system allows operating cost savings. However, while it is important to realize energy savings, ice storage systems can increase energy consumption.

* Tel.: +32 43664824; fax: +32 43664812.
E-mail address: Vincent.Lemort@ulg.ac.be.

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Nomenclature

AU	heat transfer coefficient (kW/K)
c	specific heat (kJ/kg K)
CCAP	nominal chiller capacity (kW)
D	demand cost rate (EUR/kW)
e	thickness (m)
E	energy cost rate (EUR/kWh)
f_{sto}	fraction of load met by the ice storage system (%)
h	convective heat transfer coefficient (kW/m^2 K)
h	specific enthalpy (kJ/kg)
H	height (m)
$\dot{H}$	enthalpy flow rate (kW)
J	utility cost associated with the billing period (EUR)
k	thermal conductivity (kW/m K)
L_F	latent heat of fusion of ice (kJ/kg)
$\dot{M}$	mass flow rate (kg/s)
N	number of time stages over the billing period
N_{nod}	number of nodules in 1 m^3 of the tank
NTU	number of thermal units (–)
Nu	Nusselt number (–)
P	average power consumption of the cooling plant (kW)
Pr	Prandtl number (–)
$\hat{\dot{Q}}$	forecast of the building cooling load (kW)
$\hat{Q}_{int}$	forecast of the total integrated building cooling requirement until the end of on-peak period (kWh)
R	thermal resistance (K/kW)
Re	Reynold's number (–)
r_i	inner radius of nodule (m)
S	surface (m^2)
SCAP	storage capacity (kWh)
SVF	sliding valve factor (–)
T	temperature (K)
$\dot{U}$	rate of increase of internal energy (kW)
$\dot{W}$	power (kW)
x	state of charge of the ice storage tanks (%)
$\dot{x}$	charge rate of the ice storage tanks (%/s)
x^*	ratio of ice volume to inside volume of the nodule (–)

Greek letters

α	fraction of the electromechanical losses proportional to the compressor internal power (-)
ε	efficiency (–)
ΔP	pressure difference (Pa)
Δt_{on}	time remaining in the on-peak period (h)
$\Delta\tau$	time stage interval in simulation (h)
Λ	coefficient in demand charge calculation