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Equipment arrangement planning of a fuel cell energy network optimized for cost minimization

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Abstract

The systems configuration and operation plan of a fuel cell energy network using the micro-grid of the power using a solid polymer membrane-type fuel cell and the hot-water piping network to which exhaust heat is conveyed are considered. In this study, a computer program that optimizes the equipment arrangement of each building linked to a fuel cell network and the path of the hot-water piping network for supplying the exhaust heat of fuel cells and reformers to each house under the cost minimization objective was developed. As a result of analyzing the fuel cell network constructed in four to nine houses using the energy demand pattern of the average house of Sapporo, which is a cold, snow-covered city, compared with the system that is not optimized, it clearly showed lower equipment and installation costs. As a result of using and analyzing the energy demand pattern of the house in Sapporo, and outside temperature data in February, there will be 18%–25% cost reduction by optimization. Having optimized and planned the path of hot-water piping and arrangement of equipment so that the heat release of a hot-water piping network decreases is a reason for the cost reduction result. Furthermore, by this study, the capacity of a heat storage tank, and the arrangement planning of boilers and each capacity, and the quantity of flow of the hot-water circulating pump were investigated, and the operation plan of each piece of equipment was considered.

Keywords: Fuel cell; Energy network; Micro-grid; Energy planning

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Nomenclature

D_c	outside diameter of the heat insulating material, m
D_i	inside diameter of the hot-water piping, m
D_o	outside diameter of the hot-water piping, m
E	electricity, W
F	objective function
g	acceleration of gravity, m/s^2
g_c	weight of facility cost
g_d	weight of operation cost
g_y	weight of facility installation cost
H	heat, W
H_w	heat release of hot-water piping, W
h_w	heat transfer coefficient inside hot-water piping, $W/m^2\,K$
h_∞	heat transfer coefficient between heat insulation material and the open air, $W/m^2\,K$
J_c	unit cost of equipment capacity, US dollars/W
J_{cl}	unit cost of hot-water piping, US dollars/m
J_f	installation unit cost of equipment, US dollars/set
J_s	unit cost of fuel, US dollars/J
K	coefficient of overall heat transmission, $W/m^2\,K$
k_p	heat conductivity of piping material, W/m K
k_c	heat conductivity of heat insulation material, W/m K
l_{xy}	length of hot-water piping between, S_x and S_y, m
N	number of set
N_{bd}	number of buildings linked to a network
P	power, W
Q	quantity of heat, W
q_w	volume flow rate, m^3/s
S_x	number of buildings ($x = 1, 2, \ldots, \mathrm{bd}$)
T	temperature
t	sampling time
Δt	sampling interval, s
U	capacity of facility
W_p	water head of hot-water circulation pump, m
Y_c	equipment cost, US dollars
Y_d	operation cost, US dollars
Y_f	equipment installation cost, $

Greek letter

ρ	density of water, kg/m^3