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Optimized monthly-fixed thermostat-setting scheme for maximum energy-savings and thermal comfort in air-conditioned spaces

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Abstract

The present study deals with energy conservation in buildings via reduction of cooling-and-heating transmission loads through walls by optimizing the indoor air-temperature settings. Maximum energy-saving and thermal-comfort are obtained for both yearly- and monthly-fixed thermostat settings. The transmission loads are calculated under the climatic conditions of Riyadh by using a dynamic heat-transfer model based on the finite-volume implicit procedure, which has been validated previously. The study utilizes a basic thermal-comfort chart where indoor air temperatures are selected inside the summer and winter comfort-zones, as a function of relative humidity, in a manner to provide the highest comfort-level while maximizing energy savings. The yearly-fixed thermostat settings range between 21.6 °C and 24.1 °C (70.9 °F and 75.4 °F), and those for the optimized monthly-fixed settings range between 20.1 °C and 26.2 °C (68.2 °F and 79.1 °F). For the yearly-fixed thermostat settings, the results show that about a 10% reduction in yearly cooling transmission load can be achieved per 1 °C increase in thermostat setting. Despite a corresponding increase of about 14% in yearly heating transmission load, a net saving in the yearly total energy cost of about 4% can still be affected per 1 °C increase in thermostat setting within the comfort zone. However, much bigger savings are achieved by utilizing an optimized monthly-fixed thermostat setting scheme developed in this study. Savings in energy cost between 26.8% and 33.6% compared with the yearly-fixed settings are obtained depending on the value of yearly-fixed setting. The corresponding reductions in peak loads compared with the yearly-fixed settings range between 13.5% and 25.6% in summer, and between 15.1% and 31.9% in winter depending on the yearly-fixed setting. These percentage savings in energy cost and reductions in peak loads are conservative since the yearly-fixed settings are themselves selected for high annual energy-savings while maintaining a high level of thermal comfort throughout the year.

Keywords: Thermostat settings; Energy conservation; Thermal comfort; Heat transmission

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Nomenclature

C_e	yearly cost of electric energy
c	specific heat (J/kg K)
c_e	charge of electricity ($/kWh)
DBT	dry-bulb temperature
E	yearly electric-energy consumption
HWHCB	heavyweight hollow concrete-block
h	heat-transfer coefficient (W/m^2 K)
I_s	solar radiation flux (W/m^2)
i	nodal point in finite-volume grid
k	thermal conductivity (W/m K)
MRT	mean radiant-temperature
N	number of layers in wall
p_c	coefficient of performance of vapour-compression system
p_f	performance factor of heat pump
Q	heat-transmission load (kWh/m^2 year) or (kWh/m^2 day)
q	heat flux (W/m^2)
q_{peak}	peak heat-transmission load (W/m^2)
RH	relative humidity
T	temperature (°C or K)
T_{eff}	effective indoor-air temperature (°C or °F)
$T_{f,i}$	indoor-air temperature (°C or °F)
$T_{f,o}$	outdoor-air temperature (°C or °F)
t	time (s)
x	coordinate direction normal to wall (m)

Greek letters

α	thermal diffusivity (m^2/s)
ε	surface emissivity
λ	solar absorptivity
ρ	density (kg/m^3)
σ	Stefan–Boltzmann constant (W/m^2 K^4)
ϕ	relative humidity or phase-shift angle (rad)

Subscripts

c	convection, or cooling
f	fluid (ambient)
g	ground
h	heating
i	inside
j	layer number in wall
N	outer layer in wall
o	outside
r	radiation
0	initial
1	inner layer in wall