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Pacific Northwest National Laboratory
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GridLAB-D Technical Support Document: Commercial Module Version 1.0

DP Chassin

May 2008

Prepared for the U.S. Department of Energy
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Acronyms and Abbreviations

ODE	ordinary differential equation
ETP	equivalent thermal parameters
UA	thermal conductance (surface area x thermal conductivity)

Contents

1.0 Introduction

The Commercial Module implements commercial building models. Version 1.0 of this module only supports single-zone office buildings. Support for additional commercial buildings types is planned, including multi-zone office, schools, stores, and refrigerated warehouses.

2.0 Single-Zone Office Building

The Commercial Module uses a simple Equivalent Thermal Parameters (ETP) model (Taylor and Pratt 1988) with first-order ordinary differential equations (ODEs):

$$T_i' = \frac{1}{c_a}\left[T_m h_m - T_i(UA - h_m) + \Sigma Q_x + T_o UA\right] \tag{2.1}$$

$$T_m' = \frac{h_m}{c_m}\left[T_i - T_m\right] \tag{2.2}$$

where
T_i = the temperature of the air inside the building
T_i' = $\frac{d}{dt}T_i$
T_m = the temperature of the mass inside the building (for example, furniture, inside walls)
T_m' = $\frac{d}{dt}T_m$
T_o = the ambient temperature outside air
UA = the UA of the building envelope
h_m = the UA of the mass of the furniture, inside walls, etc.
c_m = the heat capacity of the mass of the furniture inside the walls, etc.
c_a = the heat capacity of the air inside the building
Q_i = the heat rate from internal heat gains of the building (for example, plugs, lights, people)
Q_h = the heat rate from heating, ventilating, and air conditioning unit
Q_s = the heat rate from the sun (solar heating through windows, etc.)

The general first order ODEs (C_1-C_5 defined by inspection above) is

$$T_i' = T_i C_1 + T_m C_2 + C_3 \quad T_m' = T_i C_4 + T_m C_5 \tag{2.3}$$

The general form of the second-order ODE is

$$p_4 = p_1 T''_i + p_2 T_i' + p_3 T_i \tag{2.4}$$

The solutions to second-order ODE for indoor and mass temperatures are

$$T_i(t) = K_1 e^{r_1 t} + K_1 e^{r_2 t} + \frac{p_4}{p_3} \tag{2.5}$$

$$T_m(t) = \frac{T_i'(t) - C_1 T_i(t) - C_3}{C_2} \tag{2.6}$$

where:

$$r_1, r_2 = roots(p_1, p_2, p_3)$$
$$K_1 = \frac{r_2 T_{i,0} - r_2 \frac{p_4}{p_3} - T_{i,0}'}{r_2 - r_1}$$
$$K_2 = \frac{T_{i,0} - r_1 K_1}{r_2}$$

$p_1 = \frac{1}{C_2}$
$p_2 = -\frac{C_3}{C_2} - \frac{C_1}{C_2}$
$p_3 = C_5 \frac{C_1}{C_2} - C_4$
$p_4 = -C_5 \frac{C_3}{C_2}$
t = the elapsed time
$T_i(t)$ = the temperature of the air inside the building at time t
T_o = $T_i(t = 0)$, for example, the initial temperature of the air inside the building
T_o' = $T_i'(t = 0)$, for example, the initial temperature gradient of the air inside the building

3.0 References

Taylor, ZT and RG Pratt. 1988 "The effects of model simplifications on equivalent thermal parameters calculated from hourly building performance data." In *Proc. 1988 ACEEE Summer Study on Energy Efficiency in Buildings,* pp. 10.268-10.285.