UNICOLL

Simulation program for collector with automatic controller

The program UNICOLL can be used for the optional simulation of glazed or unglazed collectors. Next to the computation method for collectors this program contains a rule algorithm for mass flow. Mass flow or collector outlet temperature can be entered as time dependent input. If the collector outlet temperature is given as an input the corresponding mass flow rate is calculated by the controller within a certain defined range. In case that the requested outlet temperature cannot be reached, mass flow rate is set to 0. Once reached the maximum mass flow rate, the collector outlet temperature can even reach higher values than requested.
Useful collector heat is calculated according to eq. (1).

$$
\begin{aligned}
\dot{Q}_{nutz} / A_K = F' \Big\{ & \tau_G^{\ *} \alpha_A^{\ *} \cdot E_{glob,K} - \tau_G^{\ *} \alpha_A^{\ *} b_0 \left[E_{dir}((1/\cos\Theta) - 1) + E_{dfu}((1/\cos\Theta_e) - 1) \right] \\
& - k_0(w_{Wi})(\vartheta_{fl,m} - \vartheta_{am}) - k_1(\vartheta_{fl,m} - \vartheta_{am})^2 \\
& - \varepsilon_A^{\ *} \cdot \sigma \cdot \left[\varphi_{sky}(T_{fl,m}^{\ 4} - T_{sky}^{\ 4}) + \varphi_{Geb}\, \varepsilon_{Geb}^{\ *}(T_{fl,m}^{\ 4} - T_{Geb}^{\ 4}) + \varphi_B\, \varepsilon_B^{\ *}(T_{fl,m}^{\ 4} - T_B^{\ 4}) \right] \Big\} \\
& - (C_K / A_K)(d\vartheta_{fl,m} / dt)
\end{aligned}
\qquad (1)
$$

The equation takes into consideration the reduction of incoming solar radiation due to the optical properties of the glazing by the Boes-coefficient b_0 as well as heat losses dependent on the wind velocity integrated as follows:

$$k_0(w_{Wi}) = k_0^{\ *} + k_1^{\ *} \cdot w_{Wi} \qquad (2)$$

The coefficient k_1 is the second order heat loss coefficient.

The third part in eq. (1) calculates heat transfer due to long wave radiation exchange between the collector and the environment. The hemisphere seen by the collector plane is therefore divided in three parts: the sky (black body with temperature T_{sky}), environmental buildings or obstacles seen by the collector (temperature T_{Geb}, emission coefficient $\varepsilon_{Geb}^{\ *}$) and the surrounding ground seen by the collector (temperature T_B, emission coefficient $\varepsilon_B^{\ *}$). The coefficients φ_{sky}, φ_{Geb} and φ_B define the referring share.

The last term describes the transient behaviour due to collector heat capacity C_K including heat transfer fluid.

Thus an equation with 9 coefficients describes the thermal behaviour. These coefficients have to be set in the component description:

$$\begin{aligned}\dot{Q}_{nutz} / A_K = {} & a_1 \cdot E_{glob,K} - a_2\left[E_{dir}((1/\cos\Theta) - 1) + E_{dfu}((1/\cos\Theta_e) - 1)\right] \\ & - a_3(\vartheta_{fl,m} - \vartheta_{am}) - a_4 w_{Wi}(\vartheta_{fl,m} - \vartheta_{am}) - a_5(\vartheta_{fl,m} - \vartheta_{am})^2 \\ & - a_6(T_{fl,m}{}^4 - T_{sky}{}^4) - a_7(T_{fl,m}{}^4 - T_{Geb}{}^4) - a_8(T_{fl,m}{}^4 - T_B{}^4) \\ & - a_9(d\vartheta_{fl,m}/dt)\end{aligned} \tag{3}$$

<u>Nomenclature:</u>

A_K	Collector area	m²
b_0	Boes-coefficient	-
C	Heat capacity	kJ/K
E_{dfu}	Diffuse radiation	kJ/hm²
E_{dir}	Direct radiation	kJ/hm²
$E_{glob,K}$	Global radiation on collector surface	kJ/hm²
F’	Efficiency factor	-
k_0	1 order heat loss coefficient (see eqn(2))	kJ/(hm²K)
k_1	2 order heat loss coefficient	kJ/(hm²K²)
k_0^*	wind independent 1 order heat loss coefficient	kJ/(hm²K)
k_1^*	wind dependent 1 order heat loss coefficient	kJ/(m³K)
$\dot{Q}_{nutz}$	Useful heat flux of collector	kJ/h
T	Absolute temperature	K
t	Time	h
w_{Wi}	Wind velocity	m/h
α^*	Absorptivity	-
ε^*	Emissivity	-
φ	View factor	-
τ_G^*	Transmissivity of glass cover	-
θ	Angle between diffuse radiation and surface normal	°
θ_e	Angle between direct radiation and surface normal	°
$\vartheta_{fl,m}$	Mean fluid temperature	°C
ϑ_{am}	Ambient temperature	°C
σ	Stephan-Boltzmann-constant	

Parameter	variable	discription	unit
1	COLAR	collector area	[m²]
2	IOPTCT	control options	[-]

IOPTCT = 1: Mass flow rate as input

IOPTCT = 2: Collector outlet temperature as input, mass flow rate controlled

Coefficients of collector equation (3)

qcol =

+ a1 * eglob
- a2 * (edir*((1/cos(tetadr))-1) + (edfu*cdfu))
- a3 * tetaam
- a4 * tetaam * wwind
- a5 * (tetaam**2)
- a6 * ((tkelfl**4) - ((tgrd+273.15)**4))
- a7 * ((tkelfl**4) - ((tbui+273.15)**4))
- a8 * ((tkelfl**4) - ((tsky+273.15)**4))
- a9 * (tflm - tflma) / Step

3	A1	$= F' \times \tau_G^* \times \alpha_A^*$	[1]
4	A2	$= F' \times \tau_G^* \times \alpha_A^* \times b_0$	[1]
5	A3	$= F' \times k_0^*$	[kJ/(hm²K)]
6	A4	$= F' \times k_1^*$	[kJ/(m³K)]
7	A5	$= F' \times k_1$	[kJ/(hm²K²)]
8	A6	$= F' \times \varepsilon_A^* \times \sigma \times \varphi_{grd}$	[kJ/(hm²K⁴)]
9	A7	$= F' \times \varepsilon_A^* \times \sigma \times \varphi_{bui}$	[kJ/(hm²K⁴)]
10	A8	$= F' \times \varepsilon_A^* \times \sigma \times \varphi_{sky}$	[kJ/(hm²K⁴)]
11	A9	$= F' \times C_k/A_k$	[kJ/m²K]
12	TETADF	Angle of incidence between diffuse radiation and surface normal	[°]
13	CPFL	specific heat capacity of the collector fluid	[kJ/kgK]

Additional parameters with regulation option 2:

14	MCOLMI	minimum collector mass flow rate	[kg/h]
15	MCOLMA	maximum collector mass flow rate	[kg/h]

Input	variable	discription	unit
1	TINC	Collector inlet temperature	[°C]
2	MCOL	Collector mass flow rate (IOPTCT = 1)	[kg/h]
	TOUC	Collector outlet temperature (IOPTCT = 2)	[°C]
3	TAMB	Ambient temperature	[°C]
4	WWIND	Wind velocity	[m/h]
5	EGLOB	global irradiance on collector surface	[kJ/hm²]
6	EDFU	diffuse radiation on collector surface	[kJ/hm²]
7	TETADR	Angle of incidence between direct ssolar radiation and surface normal	[°]
8	TGRD	Ground temperature	[°C]
9	TBUI	Building wall temperature	[°C]
10	TSKY	Sky temperature	[°C]
11	FSHAD	Exposure to direct radiation (= 1 for no shading)	[-]

Output	variable	description	unit
1	TOUC	Collector outlet temperature	[°C]
(if fluid flow stops, the outlet temperature is calculated for a fictive mass flow rate of 5 kg/h·m2 of collector area.)			
2	MCOL	collector mass flow rate	[kg/h]
3	QCOL	Useful energy gain of the collector	[kJ/hm²]
4	COLEFF	Collector efficiency	[-]
5	TOUMAX	maximum collector outlet temperature during the simulation	[°C]