

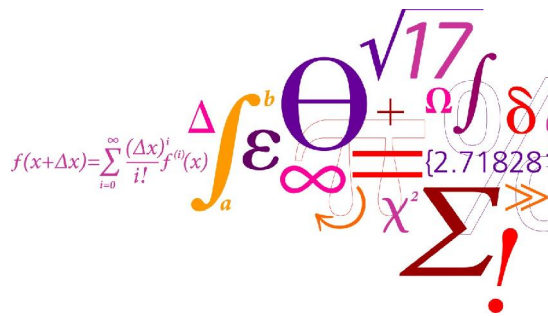


Simple Simulation Tool for Thermally Activated Building Systems

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The Problem

Today it is necessary to make a full blown building simulation to design an Embedded Radiant System.

- Possible solutions are IDA ICE 4, TRNSYS, IES VE, Energy+, ect.
- These Simulations are
 - time consuming,
 - complicated and
 - prone to errors.

⇒ We need a simple solution to effectively design embedded radiant systems

What's the Solution?

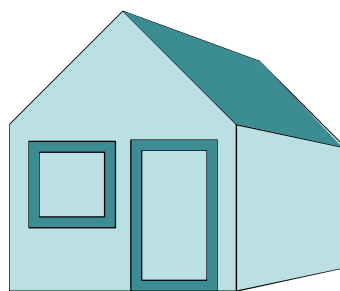
- ISO 11855 describes an iterative resistance approach to size embedded radiant systems.
- This system has been implemented in C++
- The program is called the Simple Simulation Tool (SSTe)

⇒ How dose the SSTe work?

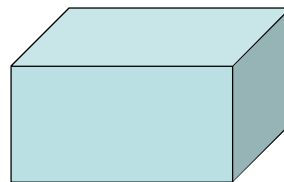


The principle of the SST

Simplification of problem



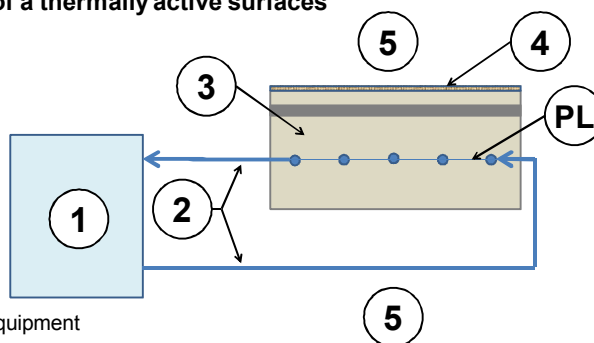
Full Building



Single Zone

The principle of the SST

Simple scheme of a thermally active surfaces



where:

PL = Pipe level

1 = Heating/Cooling equipment

2 = Hydraulic circuit

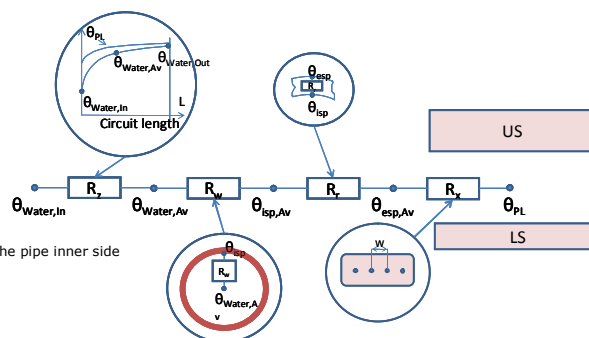
3 = Slab including core layer with pipes

4 = Possible additional resistances (floor covering or suspended ceiling)

5 = Room below and room above

The principle of the SST

General scheme of the Resistance Method



where:

L = Length of installed pipes

LS = Lower part of the slab

R_r = Pipe thickness thermal resistance

R_w = Convection thermal resistance at the pipe inner side

R_v = Pipe level thermal resistance

R_z = Water flow thermal resistance

T = Pipe spacing

US = Upper part of the slab

$\theta_{esp,Av}$ = Average temperature at the outer side of the pipe

$\theta_{sp,Av}$ = Average temperature at the inner side of the pipe

θ_{PL} = Average temperature at the pipe level

$\theta_{Water,Av}$ = Water average temperature

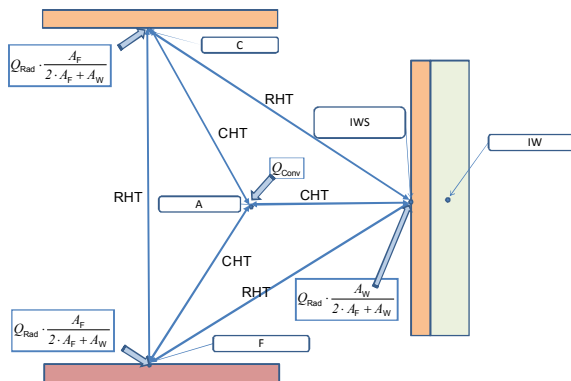
$\theta_{Water,In}$ = Water inlet temperature

$\theta_{Water,Out}$ = Water outlet temperature



The principle of the SST

Scheme of the thermal network representing the room



where:
 A = Thermal node representing the air in the room
 C = Thermal node representing the ceiling surface
 CHT = Convective heat transfer
 F = Thermal node representing the floor surface
 IW = Thermal node representing the internal walls
 IWS = Thermal node representing the internal wall surface
 RHT = Radiant heat transfer
 Q_{conv} = Total convective heat gains
 Q_{rad} = Total radiant heat gains



SSTe Interface

Overview

Project	11855-4	TRUE
Boundary	11855-4	TRUE
Circuit	11855-4	TRUE
Pipe	11855-4	TRUE
Room	11855-4	TRUE
Slab	11855-4	TRUE

Sort Libraries	Export	Run	Create Report
Save and Backup	Export and Run Project		

Boundary Data	11855-4	Unit	Circuit Data	11855-4	Unit	Slab Data	11855-4	Unit
nTimeSteps	24	[-]	pipe_spacing	0.1	[m]	nLayers	4	[-]
TimeStep	3600	[s]	area_pierc	1	[-]	ActiveLayer_depth	0.19	[m]
nSubTimeStep	500	[-]	mass_flow_mm	36	[kg/h*m2]	nDivisions	1	[-]
tolDayMax	0.0001	[-]	fluid_char_rho	1000	[kg/m3]	Thickness	0.02	[m]
tolHourMax	0.00001	[-]	fluid_c_w	4187	[J/kg.K]	ThCond	0.17	[W/(m*K)]
nHours	9	[-]	pipe_data	11855-4	Unit	SpecHeat	2300	[J/(kg*K)]
convHeatFlux	30	[W]	diameter_ext	0.02	[m]	Density	700	[kg/m3]
radHeatFlux	10	[W]	wall_thickness	0.0023	[m]	nDivisions	2	[-]
runningMode	1	[-]	thermal_cond	0.35	[W/(m.K)]	Thickness	0.07	[m]
tWater	20	[C]	Room Data	11855-4	Unit	ThCond	1.1	[W/(m*K)]
maxCoolPower	1000	[W]	FloorArea	30	[m2]	SpecHeat	850	[J/(kg*K)]
nHours	11	[-]	WallArea	48	[m2]	Density	1900	[kg/m3]
convHeatFlux	400	[W]	hAirToFloor	1.5	[W/(m2*K)]	nDivisions	3	[-]
radHeatFlux	300	[W]	hAirToCeiling	5.5	[W/(m2*K)]	Thickness	0.1	[m]
runningMode	0	[-]	hAirToWalls	2.5	[W/(m2*K)]	ThCond	1.9	[W/(m*K)]
tWater	20	[C]	FvFloorToCeiling	0.21	[-]	SpecHeat	880	[J/(kg*K)]
maxCoolPower	0	[W]	FvSlabToExtWall	0.35	[-]	Density	2000	[kg/m3]
nHours	5	[-]	FloorResistance	0.1	[(m2*K)/W]	nDivisions	3	[-]
convHeatFlux	150	[W]	CeilingResistance	0	[(m2*K)/W]	Thickness	0.1	[m]
radHeatFlux	100	[W]	WallResistance	0.05	[(m2*K)/W]	ThCond	1.9	[W/(m*K)]
runningMode	1	[-]	cWalls	25600	[J/(m2*K)]	SpecHeat	880	[J/(kg*K)]
tWater	20	[C]	Macro Report (last macro executed)			Density	2000	[kg/m3]
maxCoolPower	1000	[W]	File and Backup saved.					

Timestamp: 2013-09-17 02:41:35



SSTe Interface

Project selection

Project	11855-4	TRUE
Boundary	11855-4	TRUE
Circuit	11855-4	TRUE
Pipe	11855-4	TRUE
Room	11855-4	TRUE
Slab	11855-4	TRUE

Sort Libraries	Export	Run	Create Report
Save and Backup	Export and Run Project		

Boundary Data	11855-4	Unit	Circuit Data	11855-4	Unit	Slab Data	11855-4	Unit
nTimeSteps	24	[-]	Project	11855-4	TRUE			
tTimeStep	3600	[s]	Boundary	11855-4	TRUE			
nSubTimeStep	500	[-]	Circuit	11855-4	TRUE			
tolDayMax	0.0001	[-]	Pipe	11855-4	TRUE			
tolHourMax	0.00001	[-]	Room	11855-4	TRUE			
nHours	8	[-]	Slab	11855-4	TRUE			
convHeatFlux	30	[W]	hAirToCeiling	5.5	[W/(m ² *K)]	nDivisions	3	[-]
radHeatFlux	10	[W]	hAirToWalls	2.5	[W/(m ² *K)]	Thickness	0.1	[m]
runningMode	1	[-]	FvFloorToCeiling	0.21	[-]	ThCond	1.9	[W/(m ² *K)]
tWater	20	[C]	FvSlabToExtWall	0.35	[-]	SpecHeat	880	[J/(kg*K)]
maxCoolPower	1000	[W]	FloorResistance	0.1	[(m ² *K)/W]	Density	2000	[kg/m ³]
nHours	11	[-]	CeilingResistance	0	[(m ² *K)/W]	nDivisions	3	[-]
convHeatFlux	400	[W]	WallResistance	0.05	[(m ² *K)/W]	Thickness	0.1	[m]
radHeatFlux	300	[W]	CWalls	25600	[J/(m ² *K)]	ThCond	1.9	[W/(m ² *K)]
runningMode	0	[-]				SpecHeat	880	[J/(kg*K)]
tWater	20	[C]				Density	2000	[kg/m ³]
maxCoolPower	0	[W]						
nHours	5	[-]						
convHeatFlux	150	[W]						
radHeatFlux	100	[W]						
runningMode	1	[-]						
tWater	20	[C]						
maxCoolPower	1000	[W]						

Macro Report (last macro executed)
File and Backup saved.
Timestampe: 2013-09-17 02:41:35



SSTe Interface

Project input data

Project	11855-4	TRUE
Boundary	11855-4	TRUE
Circuit	11855-4	TRUE
Pipe	11855-4	TRUE
Room	11855-4	TRUE
Slab	11855-4	TRUE

Sort Libraries	Export	Run	Create Report
Save and Backup	Export and Run Project		

Boundary Data	11855-4	Unit	Circuit Data	11855-4	Unit	Slab Data	11855-4	Unit
nTimeSteps	24	[-]	pipe_spacing	0.1	[m]	nLayers	4	[-]
tTimeStep	3600	[s]	area_pierc	1	[m ²]	ActiveLayer_depth	0.19	[m]
nSubTimeStep	500	[-]	mass_flow_mm	36	[kg/h*m ²]	nDivisions	1	[-]
tolDayMax	0.0001	[-]	fluid_char_rho	1000	[kg/m ³]	Thickness	0.02	[m]
tolHourMax	0.00001	[-]	fluid_c_w	4187	[J/(kg.K)]	ThCond	0.17	[W/(m ² *K)]
nHours	8	[-]				SpecHeat	2300	[J/(kg*K)]
convHeatFlux	30	[W]				Density	700	[kg/m ³]
radHeatFlux	10	[W]				nDivisions	2	[-]
runningMode	1	[-]				Thickness	0.07	[m]
tWater	20	[C]				ThCond	1.1	[W/(m ² *K)]
maxCoolPower	1000	[W]				SpecHeat	850	[J/(kg*K)]
nHours	11	[-]				Density	1900	[kg/m ³]
convHeatFlux	400	[W]				nDivisions	3	[-]
radHeatFlux	300	[W]				Thickness	0.1	[m]
runningMode	0	[-]				ThCond	1.9	[W/(m ² *K)]
tWater	20	[C]				SpecHeat	880	[J/(kg*K)]
maxCoolPower	0	[W]				Density	2000	[kg/m ³]
nHours	5	[-]				nDivisions	3	[-]
convHeatFlux	150	[W]				Thickness	0.1	[m]
radHeatFlux	100	[W]				ThCond	1.9	[W/(m ² *K)]
runningMode	1	[-]				SpecHeat	880	[J/(kg*K)]
tWater	20	[C]				Density	2000	[kg/m ³]
maxCoolPower	1000	[W]						

Macro Report (last macro executed)
File and Backup saved.
Timestampe: 2013-09-17 02:41:35

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SSTe Interface

Actions

Project	11855-4	TRUE
Boundary	11855-4	TRUE
Circuit	11855-4	TRUE
Pipe	11855-4	TRUE
Room	11855-4	TRUE
Slab	11855-4	TRUE

Boundary Data	11855-4	Unit	Circuit Data	11855-4	Unit	Slab Data	11855-4	Unit
nTimeSteps	24	[]	pipe_spacing	0.1	[m]	nLayers	4	[]
tTimeStep	3600	[s]	area_pierc	1	[]	ActiveLayer_depth	0.1	[m]
nSubTimeStep	500	[]	mass_flow_mm	36	[kg/h*m2]	nDivisions	1	[]
tolDayMax	0.0001	[]	fluid_char_rho	1000	[kg/m3]	Thickness	0.02	[m]
tolHourMax	0.00001	[]	fluid_c_w	4187	[J/kg.K]			

nHours	convHeatFlux	radHeatFlux	runningMode	tWater	maxCoolPower	floorResistance	ceilingResistance	wallResistance	CWalls	Macro Report (last macro executed)	Density
5	150	100	1	20	1000	0	0.05	0.05	25600	File and Backup saved.	2000
										Timestamp: 2013-09-17 02:41:35	

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DTU

The principle of the SST

The SST Window

```

C:\Users\benbe\Dropbox\2\Dropbox\Work\SST\SSTe-v0.1.1\bin\Debug\SSTe.exe

Simulated Project: Project_Example.proj
using these Input Files:
Boundary Data: I_Files\Boundary_Example.inp
Circuit Data: I_Files\Circuit_Example.inp
Pipe Data: I_Files\Pipe_Example.inp
Room Data: I_Files\Room_Example.inp
Slab Data: I_Files\Slab_Example.inp

Simulation executed without errors!

Output written to: Project_Example.proj.out

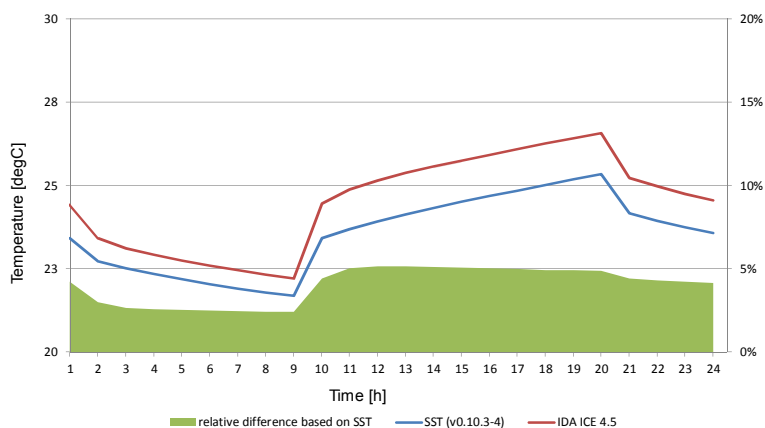
Process returned 0 (0x0) execution time : 3.994 s
Press any key to continue.
    
```

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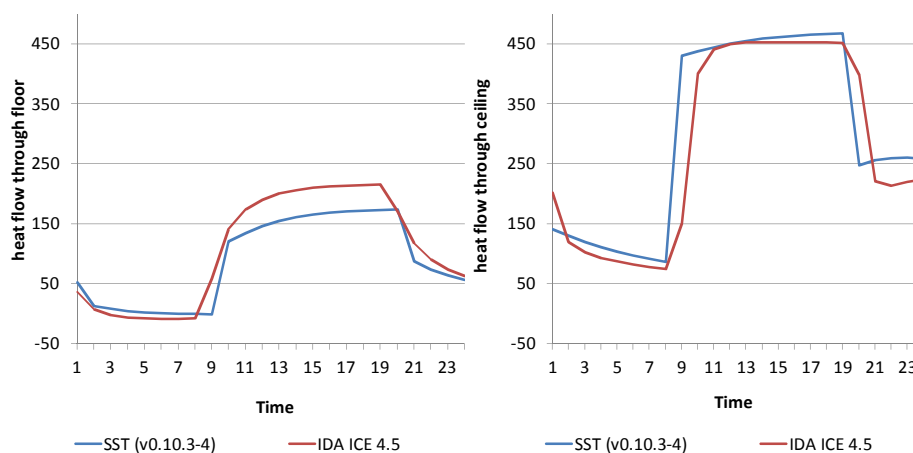
The principle of the SST

The SST Output – Operative Temperatur



The principle of the SST

The SST Output – Operative Temperatur






Conclusion

SST is a promising approach

- Fast and easy simulation
- Results are within 5% error (compared to other simulations)
- Input data library is functional
- Input data validation
- Rough system sizing is possible
- No information about humidity constraints

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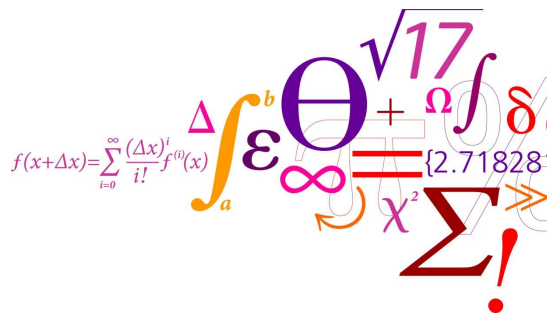
Benjamin Behrendt

Thanks for your attention!
Questions?

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What now?

- Further testing of SST
- Creating a library for the SST
- Creating simple diagrams showing the relation between some key parameters

