ExteriorSurfaceNode

$$C_{esn}\frac{dT_{esn}}{dt}=\dot{Q}_{in}-\dot{Q}_{out}$$

$$C_{esn}\frac{dT_{esn}}{dt}=\frac{T_{ext}-T_{esn}}{R_{ext,esn}}-\frac{T_{esn}-T_{bmn}}{R_{esn,bmn}}$$

$$\frac{T_{esn,k-2}-4T_{esn,k-1}+3T_{esn}}{2\Delta t}=\frac{T_{ext}-T_{esn}}{R_{ext,esn}C_{esn}}-\frac{T_{esn}-T_{bmn}}{R_{esn,bmn}C_{esn}}$$

$$T_{esn,k-2}-4T_{esn,k-1}+3T_{esn}=\frac{2\Delta t}{R_{ext,esn}C_{esn}}T_{ext}-\left(\frac{2\Delta t}{R_{ext,esn}C_{esn}}+\frac{2\Delta t}{R_{esn,bmn}C_{esn}}\right)T_{esn}+\frac{2\Delta t}{R_{esn,bmn}C_{esn}}T_{bmn}$$

$$-\left(3+\frac{2\Delta t}{R_{ext,esn}C_{esn}}+\frac{2\Delta t}{R_{esn,bmn}C_{esn}}\right)T_{esn}+\frac{2\Delta t}{R_{esn,bmn}C_{esn}}T_{bmn}=T_{esn,k-2}-4T_{esn,k-1}-\frac{2\Delta t}{R_{ext,esn}C_{esn}}T_{ext}$$

BuildingMassNode

$$C_{bmn1}\frac{dT_{bmn1}}{dt}=\frac{T_{esn}-T_{bmn1}}{R_{esn,bmn1}}-\frac{T_{bmn1}-T_{bmn2}}{R_{bmn1,bmn2}}$$

$$\frac{T_{bmn1,k-2}-4T_{bmn1,k-1}+3T_{bmn1}}{2\Delta t}=\frac{T_{esn}-T_{bmn1}}{R_{esn,bmn1}C_{bmn1}}-\frac{T_{bmn1}-T_{bmn2}}{R_{bmn1,bmn2}C_{bmn1}}$$

$$T_{bmn1,k-2}-4T_{bmn1,k-1}+3T_{bmn1}=\frac{2\Delta t}{R_{esn,bmn1}C_{bmn1}}T_{esn}-\left(\frac{2\Delta t}{R_{esn,bmn1}C_{bmn1}}+\frac{2\Delta t}{R_{bmn1,bmn2}C_{bmn1}}\right)T_{bmn1}+\frac{2\Delta t}{R_{bmn1,bmn2}C_{bmn1}}T_{bmn2}$$

$$\frac{2\Delta t}{R_{esn,bmn1}C_{bmn1}}T_{esn}-\left(3+\frac{2\Delta t}{R_{esn,bmn1}C_{bmn1}}+\frac{2\Delta t}{R_{bmn1,bmn2}C_{bmn1}}\right)T_{bmn1}+\frac{2\Delta t}{R_{bmn1,bmn2}C_{bmn1}}T_{bmn2}=T_{bmn1,k-2}-4T_{bmn1,k-1}$$

InteriorSurfaceNode

$$\frac{T_{bmn}-T_{isn}}{R_{bmn,isn}}-\dot{Q}_{conv}-\dot{Q}_{rad}=0$$

$$\dot{Q}_{rad}=F_{rad}\left(\dot{Q}_{conv}+\dot{Q}_{rad}\right)$$

$$\Rightarrow\left(1-F_{rad}\right)\dot{Q}_{rad}=F_{rad}\dot{Q}_{conv}$$

$$\Rightarrow\dot{Q}_{rad}=\frac{F_{rad}}{1-F_{rad}}\dot{Q}_{conv}$$

$$\frac{T_{bmn}-T_{isn}}{R_{bmn,isn}}-\dot{Q}_{conv}-\frac{F_{rad}}{1-F_{rad}}\dot{Q}_{conv}=0$$

$$\frac{T_{bmn}-T_{isn}}{R_{bmn,isn}}-\left(1+\frac{F_{rad}}{1-F_{rad}}\right)\dot{Q}_{conv}=0$$

$$\frac{T_{bmn}-T_{isn}}{R_{bmn,isn}}-\frac{1}{1-F_{rad}}\cdot\frac{T_{isn}-T_{zan}}{R_{isn,zan}}=0$$

$$\frac{1}{R_{bmn,isn}}T_{bmn}-\left(\frac{1}{R_{bmn,isn}}+\frac{1}{\left(1-F_{rad}\right)R_{isn,zan}}\right)T_{isn}+\frac{1}{\left(1-F_{rad}\right)R_{isn,zan}}T_{zan}=0$$

ZoneAirNode

$$\frac{T_{isn1}-T_{zan}}{R_{isn1,zan}}+\frac{T_{isn2}-T_{zan}}{R_{isn2,zan}}+\frac{T_{tsn}-T_{zan}}{R_{tsn,zan}}+\sum\dot{Q}_{conv}=\dot{Q}_{sys}$$

$$\sum\dot{Q}_{conv}=\left(1-F_{rad,wnd}\right)UA_{wnd}\left(T_{ext}-T_{zan}\right)$$
$$+\left(1-F_{rad,edr}\right)UA_{edr}\left(T_{sa}-T_{zan}\right)$$
$$+\left(1-F_{rad,ibe}\right)UA_{ibe}\left(T_{adj}-T_{zan}\right)$$
$$+\dot{Q}_{sol,cv}+\dot{Q}_{ihg,cv}$$

$$\sum\dot{Q}_{conv}=$$
$$\left(1-F_{rad,wnd}\right)UA_{wnd}T_{ext}$$
$$+\left(1-F_{rad,edr}\right)UA_{edr}T_{sa}$$
$$+\left(1-F_{rad,ibe}\right)UA_{ibe}T_{adj}$$
$$-\begin{pmatrix}\left(1-F_{rad,wnd}\right)UA_{wnd}\\+\left(1-F_{rad,edr}\right)UA_{edr}\\+\left(1-F_{rad,ibe}\right)UA_{ibe}\end{pmatrix}T_{zan}$$
$$+\dot{Q}_{sol,cv}+\dot{Q}_{ihg,cv}$$

$$\frac{1}{R_{isn1,zan}}T_{isn1}+\frac{1}{R_{isn2,zan}}T_{isn2}+\frac{1}{R_{tsn,zan}}T_{tsn}$$
$$-\left(\frac{1}{R_{isn1,zan}}+\frac{1}{R_{isn2,zan}}+\frac{1}{R_{tsn,zan}}+UA_{wnd}+UA_{edr}+UA_{ibe}\right)T_{zan}$$
$$=\dot{Q}_{sys}-UA_{wnd}T_{ext}-UA_{edr}T_{sa}-UA_{ibe}T_{adj}-\dot{Q}_{sol,cv}-\dot{Q}_{ihg,cv}$$

ThermalStorageNode

$$C_{tsn}\frac{dT_{tsn}}{dt}=\dot{Q}_{rad,isn1}+\dot{Q}_{rad,isn2}+\sum\dot{Q}_{rad,oth}-\frac{T_{tsn}-T_{zan}}{R_{tsn,zan}}$$

$$T_{tsn,k-2}-4T_{tsn,k-1}+3T_{tsn}=\frac{2\Delta t}{C_{tsn}}\left[\dot{Q}_{rad,isn1}+\dot{Q}_{rad,isn2}+\sum\dot{Q}_{rad,oth}-\frac{T_{tsn}-T_{zan}}{R_{tsn,zan}}\right]$$

$$\dot{Q}_{rad,isn1}=\frac{F_{rad,isn1}}{1-F_{rad,isn1}}\cdot\frac{T_{isn1}-T_{zan}}{R_{isn1,zan}}$$

$$\dot{Q}_{rad,isn2}=\frac{F_{rad,isn2}}{1-F_{rad,isn2}}\cdot\frac{T_{isn2}-T_{zan}}{R_{isn2,zan}}$$

$$\sum\dot{Q}_{rad,oth}=\dot{Q}_{sol,rd}+\dot{Q}_{ihg,rd}+\dot{Q}_{wnd,rd}+\dot{Q}_{edr,rd}+\dot{Q}_{ibe,rd}$$

$$\sum\dot{Q}_{rad,oth}=\dot{Q}_{sol,rd}+\dot{Q}_{ihg,rd}+F_{rad,wnd}\dot{Q}_{cond,wnd}+F_{rad,edr}\dot{Q}_{cond,edr}+F_{rad,ibe}\dot{Q}_{cond,ibe}$$

$$\sum\dot{Q}_{rad,oth}=\dot{Q}_{sol,rd}+\dot{Q}_{ihg,rd}+F_{rad,wnd}UA_{wnd}\left(T_{ext}-T_{zan}\right)+F_{rad,edr}UA_{edr}\left(T_{sa}-T_{zan}\right)+F_{rad,ibe}UA_{ibe}\left(T_{adj}-T_{zan}\right)$$

$$T_{tsn,k-2}-4T_{tsn,k-1}+3T_{tsn}=\frac{2\Delta t}{C_{tsn}}\left[\frac{F_{rad,isn1}}{1-F_{rad,isn1}}\cdot\frac{T_{isn1}-T_{zan}}{R_{isn1,zan}}+\frac{F_{rad,isn2}}{1-F_{rad,isn2}}\cdot\frac{T_{isn2}-T_{zan}}{R_{isn2,zan}}\right.$$

$$\left.+\dot{Q}_{sol,rd}+\dot{Q}_{ihg,rd}+F_{rad,wnd}UA_{wnd}\left(T_{ext}-T_{zan}\right)+F_{rad,edr}UA_{edr}\left(T_{sa}-T_{zan}\right)+F_{rad,ibe}UA_{ibe}\left(T_{adj}-T_{zan}\right)\right.$$

$$\left.-\frac{T_{tsn}}{R_{tsn,zan}}+\frac{T_{zan}}{R_{tsn,zan}}\right]$$

$$\frac{2\Delta t \cdot F_{rad,isn1}}{C_{tsn}\left(1-F_{rad,isn1}\right)R_{isn1,zan}}T_{isn1}-\frac{2\Delta t \cdot F_{rad,isn1}}{C_{tsn}\left(1-F_{rad,isn1}\right)R_{isn1,zan}}T_{zan}$$
$$+\frac{2\Delta t \cdot F_{rad,isn2}}{C_{tsn}\left(1-F_{rad,isn2}\right)R_{isn2,zan}}T_{isn2}-\frac{2\Delta t \cdot F_{rad,isn2}}{C_{tsn}\left(1-F_{rad,isn2}\right)R_{isn2,zan}}T_{zan}$$
$$+\frac{2\Delta t}{C_{tsn}}F_{rad,wnd}UA_{wnd}T_{ext}-\frac{2\Delta t}{C_{tsn}}F_{rad,wnd}UA_{wnd}T_{zan}$$
$$+\frac{2\Delta t}{C_{tsn}}F_{rad,edr}UA_{edr}T_{sa}-\frac{2\Delta t}{C_{tsn}}F_{rad,edr}UA_{edr}T_{zan}$$
$$+\frac{2\Delta t}{C_{tsn}}F_{rad,ibe}UA_{ibe}T_{adj}-\frac{2\Delta t}{C_{tsn}}F_{rad,ibe}UA_{ibe}T_{zan}$$
$$+\frac{2\Delta t}{C_{tsn}}\dot{Q}_{sol,rd}+\frac{2\Delta t}{C_{tsn}}\dot{Q}_{ihg,rd}$$
$$-\frac{2\Delta t T_{tsn}}{R_{tsn,zan}C_{tsn}}+\frac{2\Delta t T_{zan}}{R_{tsn,zan}C_{tsn}}-3T_{tsn}=T_{tsn,k-2}-4T_{tsn,k-1}$$

$$\frac{2\Delta t \cdot F_{rad,isn1}}{C_{tsn}\left(1-F_{rad,isn1}\right)R_{isn1,zan}}T_{isn1}+\frac{2\Delta t \cdot F_{rad,isn2}}{C_{tsn}\left(1-F_{rad,isn2}\right)R_{isn2,zan}}T_{isn2}$$
$$-\left(\frac{2\Delta t}{R_{tsn,zan}C_{tsn}}+3\right)T_{tsn}$$
$$-\left(\begin{array}{l}\dfrac{2\Delta t \cdot F_{rad,isn1}}{C_{tsn}\left(1-F_{rad,isn1}\right)R_{isn1,zan}}+\dfrac{2\Delta t \cdot F_{rad,isn2}}{C_{tsn}\left(1-F_{rad,isn2}\right)R_{isn2,zan}} \\ +\dfrac{2\Delta t}{C_{tsn}}F_{rad,wnd}UA_{wnd}+\dfrac{2\Delta t}{C_{tsn}}F_{rad,edr}UA_{edr}+\dfrac{2\Delta t}{C_{tsn}}F_{rad,ibe}UA_{ibe} \\ -\dfrac{2\Delta t}{R_{tsn,zan}C_{tsn}}\end{array}\right)T_{zan}$$
$$=\left(\begin{array}{l}T_{tsn,k-2}-4T_{tsn,k-1} \\ -\dfrac{2\Delta t}{C_{tsn}}F_{rad,wnd}UA_{wnd}T_{ext}-\dfrac{2\Delta t}{C_{tsn}}F_{rad,edr}UA_{edr}T_{sa}-\dfrac{2\Delta t}{C_{tsn}}F_{rad,ibe}UA_{ibe}T_{adj} \\ -\dfrac{2\Delta t}{C_{tsn}}\dot{Q}_{sol,rd}-\dfrac{2\Delta t}{C_{tsn}}\dot{Q}_{ihg,rd}\end{array}\right)$$