Thermal: Apache Profiles
Version: All

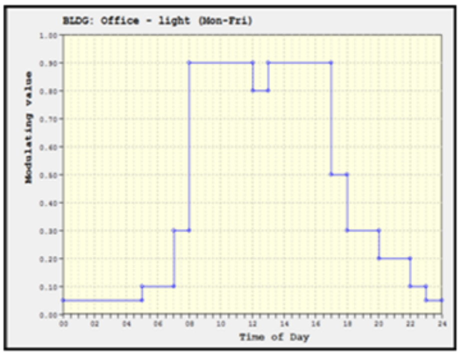
Daylight Dimming in IES <Virtual Environment>

For spaces with daylight dimming, a dimming profile is applied to the lighting controls in the internal gains dialog. Lighting gains to the space and lighting power consumption are reduced when adequate daylight levels are available or, in the case of continuous dimming, as daylight levels increase. Daylight levels are determined by a sensor in each space.

Daylighting analysis should be used first to optimize architectural elements and glazing selections to provide design daylighting levels (*e.g.,* 50 foot-candles on the work plane). When this is complete or there are alternative scenarios defined for testing with respect to energy savings, etc., images from the daylight analysis are used to determine appropriate sensor locations. Typically, sensors are first added for default locations at a user-defined work-plane height in each space and then manually adjusted in the plan view as needed.

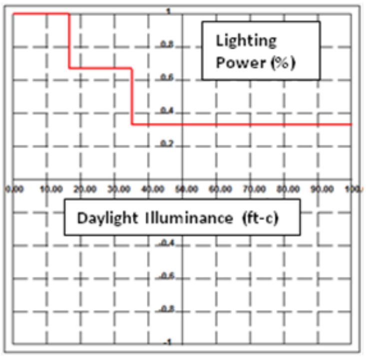
The sensors are used first to record illuminance readings for three standard-sky conditions in RadianceIES. The same sensors then provide daylighting illuminance values at each simulation time step based upon the previously recorded levels for the three standard sky conditions, the solar position at each simulation time step, and hourly solar radiation values from simulation weather file.

Daylight Dimming Formula Profiles



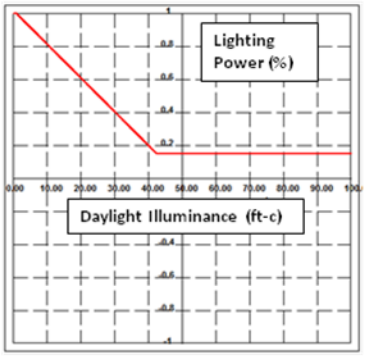
No Dimming

- Building schedules are modelled using default schedules from **ASHRAE 90.1** User's Manual, Table G-I – Office Occupancy



Step Dimming

- 3-Lamp Fixtures
- Last "step" does NOT turn off
- % of lighting controlled is determined per zone from initial **Radiance** sims



Continuous Dimming

- Ballast allows lighting to be reduced down to 15% energy consumption
- % of lighting controlled is determined per zone from initial **Radiance** sims

Step Dimming Profile:

> *if(e1>33, 0.38, if(e1>16.5, 0.71, 1.0)*
> *if(e1> [2/3 illuminance target], [fraction of gain at 1/3 lighting level], if(e1> [1/3 illuminance target], [fraction of gain at 2/3 lighting level], 1.0)*

The stepped dimming example above would be suitable for 2-lamp fixtures controlled to sequentially turn off one or two lamps per fixture, but never the third lamp. It modulates the lighting gain as a function of the illuminance on the working plane, e1, at each simulation time step. The value of the profile is constant at 1.0 up to 16.5 fc, drops to 0.71 for illuminance all values greater than 16.5 on up to 33, and then drops to 0.38 for all illuminance values greater than 33 at (which is 2/3 of the 50-fc work-plane illuminance target assumed to be made up by either electric lighting along or some combination of electric lighting and daylight).
The "fraction of gain" value represents the fraction of the power consumption and lighting gain for a particular room that is not subject to daylight control or that will remain when the lights are stepped down to the minimum light output (during

hours when the lighting schedule is ON). Note that the dimming profile will modulate the lighting gain indicated for a space in addition to any modulation provided by the lighting schedule profile and any diversity factor that has been included in the lighting gain dialog.

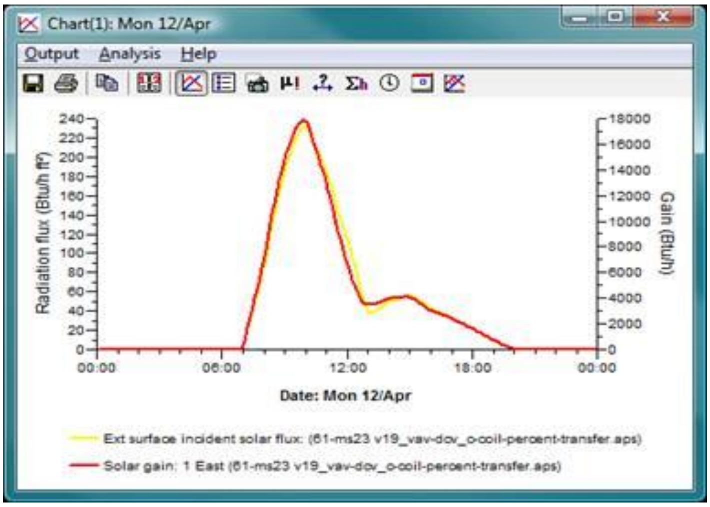
Proportional (continuous) Dimming Profile:

ramp(e1,5,1.0,50,0.2)
ramp (e1, [min daylight to begin dimming], [fraction of gain at max lighting level], [work-plane illuminance target ×(1-minimum electric lighting fc or lux level at the work plane)], [fraction of gain at minimum lighting level])

The continuous dimming example above would be suitable for dimming control of lighting gain as a function of available daylight. It modulates the lighting gain as a function of the illuminance on the working plane, e1, at each simulation time step. The value of the profile is constant at 1.0 up to 5 fc, falls from 1.0 at 5 fc illuminance to 0.2 at illuminance 50 fc, thereafter remaining constant at this value.
Again, the "fraction of gain" value represents the fraction of the power consumption and lighting gain for a particular room that is not subject to daylight control or that will remain when the lights are dimmed to the minimum light output (during hours when the lighting schedule is ON). Note that the dimming profile will modulate the lighting gain indicated for a space in addition to any modulation provided by the lighting schedule profile and any diversity factor that has been included in the lighting gain dialog.

The illuminance *e1* must be computed for three standard sky conditions using the sensors facility in RadianceIES. During the simulation run, the standard-sky values are used in conjunction with the changing sun position and hourly solar radiation values in the simulation weather file to determine the daylighting levels at each time step.
To account for operable blinds that respond to solar gain in the room, two such profiles (one for the daylighting levels with blinds open and one with blinds closed) are coupled by an IF statement using the "*sol*" variable. To coordinate properly with the operable interior shades/blinds in the Glazed Constructions dialog, however, the threshold of the *sol* variable for switching from one dimming formula to the other needs to be specific to each significant zone-by-zone variation in glazing area and orientation so that the space solar gain value that triggers lowering the blind will correspond to a similar level of incident radiation on the glazing (Btu/h-ft^2 or W/m^2), which is what will trigger the blinds in the thermal model for control of solar gain.

The example of the required formula below is followed by a graph of the values used to determine the *sol* threshold should be for each space to match a given value for incident radiation. In this case, I've started with an assumption that, because it is associated with if(sol>3600,ramp(e1*[transmittance],5,1, [illuminance target*(1-min turndown)], [power output at min turndown]), ramp (e1,5,1, [illuminance target*(1- min turndown)], [power output at min turndown]))



It may further be desirable to set up the formula so that the blind responds to both solar gain and excessive daylighting.

This requires a second IF statement to determine which formula to use as a function of a user-defined threshold for excessive daylighting (*e.g.,* 150 fc). However, blinds controllable according to incident radiation for control of solar gain in the thermal simulation are not able to respond to daylighting levels, as this constitutes a circular reference, and thus will be assumed to remain open until incident radiation exceeds the set value, which may or may not correspond to the chosen threshold for excessive daylighting levels. Some degree of coordination is already afforded just by using solar gain as the trigger, given that excessive daylighting will tend to be a function of direct-beam solar radiation entering the space.
A seasonal variation in the formula profiles for daylight dimming and operable solar-control shades may be used to allow for desirable solar gain in the winter. If the upper limit for excessive daylighting is also used, this would normally remain consistent throughout the year—i.e., the seasonal variation would differ only with respect to the threshold of solar gain assumed to trigger the blinds, and not the threshold of daylight level.

Daylight illuminance sensor values in RadianceIES and ApSim as reported in Vista Results

It is important that users understand that while the illuminance sensor values reported in RadianceIES are a precursor to values used at the time of simulation, they are not the actual values used at that time. The actual values used in simulation are reported in Vista Results via the variable "Daylight illuminance 1" for each room containing a daylight sensor and to which a formula profile containing the variable "e1" was assigned.
RadianceIES calculates illuminance values for a standard (CIE) overcast sky and a set of clear skies for hourly sun positions. Hourly sensor values are reported for each of the three sky types.

- The three sky types for which sensor values are reported in RadianceIES are as follows:
  - CIE Overcast = normalized overcast sky, representing a standard cloudy day
  - Circum solar = normalized direct-beam solar radiation per sun position only
  - Diffuse = normalized solar radiation for a clear sky omitting just the direct-beam component.
- The sky types are a function only of overcast vs. clear sky and solar position (altitude and azimuth) in the case of the clear sky models. Thus location is reflected in the Radiance sensor values only with respect to geographic latitude and longitude. The results as reported within Radiance thus exclude any location-dependent *atmospheric* influences associated with the typical haziness, air moisture content, air pollutants, height relative to sea level, etc.
- Each of the sky models has a set of values associated with the solar position, and thus the hour of the day.
- The second and third of these three models together provide the conditions for a clear sky for each sun position according to the month and hour of the day. There is thus one of each circum-solar (direct) and diffuse clear-sky for each solar position modeled.
- The luminous efficacy (ratio of illuminance in the visible light spectrum to the total solar radiation) differs according to the sky type and sun position.
- Because they are based upon normalized sky conditions, the sensor values as reported within Radiance do not reflect weather conditions for any time or date in the simulation weather file. This is accounted for by ApacheSim at the time of the simulation run and reported in Vista Results via the room variable "Daylight illuminance 1".

At simulation time, ApacheSim mixes an appropriate fraction of the clear and overcast sky types to match the weather conditions at each hour of the simulation. It is at this stage that the luminous efficacy and other differences between sky types are accounted for within a single illuminance value for each user-define illuminance sensor—*e.g.,* at the work plane in each room.
This involves applying luminous efficacies for the appropriate mix of sky types to the weather file solar variables (solar radiation in W/m^2) to generate illuminance values (lux or ft-cd), from which multipliers are obtained scaling the contributions of the standard overcast and clear skies. The multipliers are then applied to the internal sensor illuminance values calculated by Radiance for the standard skies to derive the internal sensor illuminance values for the hour in question.

- The hourly solar radiation in the weather file indicates the overall radiation available at the particular location in a particular hour on a particular date.
- The mix of sky types determines the efficacy of this radiation in terms of visible light as a fraction of the total solar radiation. The sky model used for each simulation time step combines the one standard overcast sky and two clear skies with different sun positions.

- The hourly sensor values from RadianceIES determine how much of the light available in the visible wavelength of the solar spectrum reaches the sensor location via the building fenestration.
- Sensor values are calculated for each hour that the initial inputs were recorded in RadianceIES. If the simulation time step is less than hour, the result for the additional time steps are interpolated in terms of the sensor values between those returned for the analysis at the two adjacent hourly data points.
- The modulation of sensor values according to the hourly solar radiation values in the weather file to accounts for the variation in day of the month as this differs from the solar day for each month that was run in RadianceIES.