**More Daylighting Control Sensors/  
Integrate DElight**

**Jason Glazer, GARD Analytics**

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**Justification for New Feature**

EnergyPlus has daylighting modeling capabilities allowing users to control interior lighting as a function of the daylit conditions in the space but with some significant limitations. For example, Appendix C of the ASHRAE 90.1-2013 Standards implies the use of three or more daylighting sensors, which EnergyPlus cannot currently handle. This current modeling limitation has the potential to limit EnergyPlus’ usability in some daylighting-centric applications.

In addition, the current Daylighting:Controls object and Daylighting:DElight:Controls are very similar could be combined and would reduce complexity for implementing daylighting by interfaces.

**E-mail and Conference Call Conclusions**

After significant discussion, the overall conclusion is that many additional changes to the handling of daylighting in EnergyPlus are desired and that a second phase of work to address those issues should be considered. The specific other recommended changes are shown in the Overview section.

**Overview**

The current Daylighting:Controls object allows only two sensors (currently called “reference points”). The code also reflects computations done on the first or second daylighting reference point. The revised object simply rearranges the fields into two objects Daylighting:Controls and Daylighting:ReferencePoint and allow for as many reference points as desired by referencing them in extensible fields of Daylighting:Controls.

The specific objects called Daylighting:DELight:Controls and Daylighting:DELight:ReferencePoint will be removed and combined into the Daylighting:Controls and Daylighting: ReferencePoint objects. The DElight objects provide as many reference points as the user enters but unfortunately do not support some other aspects of measures related to daylighting such as dynamic shading (such as electrochromic glazing and blind control), it does not calculate glare or prompt shading to occur, or the presence of exterior shading such as overhangs and fins. To switch between the “classic” and “DElight” option in the Daylighting:Controls object a new field will be added called “Daylighting Method” with options of “SplitFlux” and “DElight.” As part of this change the object called Daylighting:DELight:ComplexFenestration will be renamed to Daylighting:ComplexFenestration but no other changes. No algorithmic changes will be made to the DElight daylighting model, only the GetInput routines will be changed.

In addition, the Lighting Control Type field is changing from number 1, 2, and 3 to "Continuous", "Stepped", and "ContinuousOff" options.

After an initial NFP was provided to a small review team, it was clear that many different changes in EnergyPlus related to daylighting were desired as shown in the following list. We recommend that these suggestions be considered during a broader Phase 2 task related to daylighting.

* Associate one or more individual Lights objects with each Daylighting:Controls object
* Allow multiple Daylighting:Controls objects per zone
* Separate the daylighting zones from thermal zones since they do not always align (i.e. allow the control of daylighting in one thermal zone be based on reference point in another thermal zone)
* Allow a single reference point to be used by multiple Daylighting:Controls objects
* Enhance DElight to support dynamic shading, electrochomic glazing, blind controls, glare, exterior shading
* Continue to allow a fraction of the lights controlled be specified (in current work and in phase 2)
* Continue to allow the entire zones lights be controlled by default (in current work and phase 2)
* Ensure that OpenStudio approach of lights in spaces and spaces in thermal zones be supported including allowing controls to reference a list of lights
* Support many individual light fixtures (luminaires) each with dedicated daylighting sensors and controls including the ability to specify their location in a grid pattern
* Specify glare based controls to be based on one or more reference points perhaps using a new separate object such as GlareControl (use maximum value to control shading)
* Specify the order that shades respond to glare
* Allow multiple angles for glare calculation
* Remove the Fraction Replaceable field in the Lights object and replace with Fraction Controlled which can be any value not just 0 or 1.
* Separate glare related controls to a separate Glare:Control object
* Add orientation to each sensor point so that they can be put on walls and ceilings
* Allow sensors to be on exterior wall or roof for open-loop control
* Allow sensors to include spatial sensitivity map
* Continue to supported lumped lighting such as 1.2 W/ft as specified in codes and standards
* Add more sophisticated output metrics related to daylighting and glare
* Add more sophisticated algorithms beyond split-flux such as ray-tracing

Given this long list of desired enhancements related to daylighting, we recommend that the work be broken into two or more phases. This first phase will focus on the original scope of work of providing more daylighting control sensors (reference points) as well as removing combining the input objects for the “classic” and DElight daylighting. It will make no additional changes that might make transition to future changes more confusing to users. The second phase which has not currently been funded would address more comprehensive changes based on selected items from the list above.

**Approach**

Some of the input fields for the Daylighting:Controls object will be moved to a new object called Daylighting:ReferencePoint which the remaining fields of Daylighting:Controls will be rearranged. The code will be changed to handle any number of reference points for each zone. Only a single Daylighting:Controls object will be allowed per zone just as it is currently. The Daylighting:DElight:Controls, Daylighting:DElight:ReferencePoint objects will be merged into the Daylighting:Controls and Daylighitng:ReferencePoint objects. The Daylighting:DELight:ComplexFenestration will be renamed to Daylighting:ComplexFenestration. No algorithmic changes will be made to the DElight daylighting model, only the GetInput routines will be changed.

**Testing/Validation/Data Sources**

No differences are expected for transitioned files that currently have one or two reference points. For tests cases with additional reference points, they will be compared for reasonableness.

**IDD Changes**

Current objects:

Daylighting:Controls,

A1 , \field Zone Name

N1 , \field Total Daylighting Reference Points

N2 , \field X-Coordinate of First Reference Point

N3 , \field Y-Coordinate of First Reference Point

N4 , \field Z-Coordinate of First Reference Point

N5 , \field X-Coordinate of Second Reference Point

N6 , \field Y-Coordinate of Second Reference Point

N7 , \field Z-Coordinate of Second Reference Point

N8 , \field Fraction of Zone Controlled by First Reference Point

N9 , \field Fraction of Zone Controlled by Second Reference Point

N10, \field Illuminance Setpoint at First Reference Point

N11, \field Illuminance Setpoint at Second Reference Point

N12, \field Lighting Control Type

\note 1=continuous,2=stepped,3=continuous/off

N13, \field Glare Calculation Azimuth Angle of View Direction Clockwise from Zone y-Axis

N14, \field Maximum Allowable Discomfort Glare Index

N15, \field Minimum Input Power Fraction for Continuous Dimming Control

N16, \field Minimum Light Output Fraction for Continuous Dimming Control

N17, \field Number of Stepped Control Steps

N18, \field Probability Lighting will be Reset When Needed in Manual Stepped Control

A2 ; \field Availability Schedule Name

Daylighting:DELight:Controls,

A1 , \field Name

A2 , \field Zone Name

N1 , \field Lighting Control Type

\note 1=continuous,2=stepped,3=continuous/off

N2 , \field Minimum Input Power Fraction for Continuous Dimming Control

N3 , \field Minimum Light Output Fraction for Continuous Dimming Control

N4 , \field Number of Stepped Control Steps

N5 , \field Probability Lighting will be Reset When Needed in Manual Stepped Control

N6; \field Gridding Resolution

Daylighting:DELight:ReferencePoint,

A1 , \field Name

A2 , \field DElight Name

N1 , \field X-coordinate of Reference Point

N2, \field Y-coordinate of Reference Point

N3, \field Z-coordinate of Reference Point

N4 , \field Fraction of Zone Controlled by Reference Point

N5; \field Illuminance Setpoint at Reference Point

Daylighting:DELight:ComplexFenestration,

A1, \field Name

A2, \field Complex Fenestration Type

A3, \field Building Surface Name

A4, \field Window Name

N1; \field Fenestration Rotation

Output:IlluminanceMap,

A1 , \field Name

A2 , \field Zone Name

N1 , \field Z height

N2 , \field X Minimum Coordinate

N3 , \field X Maximum Coordinate

N4 , \field Number of X Grid Points

N5 , \field Y Minimum Coordinate

N6 , \field Y Maximum Coordinate

N7 ; \field Number of Y Grid Points

In the revised objects, the fields are rearranged. The reference point related fields are moved to a new object. The Total Daylighting Reference Points field is eliminated. The Lighting Control Type field is made into a choice field rather than using numbers 1, 2 and 3. The DElight objects are merged into the Daylighting objects.

Revised Objects for Phase 1

Daylighting:Controls,

A1 , \field Name

A2 , \field Zone Name

A3 , \field Daylighting Method (choice: SplitFlux, DElight)

A4 , \field Availability Schedule Name

A5, \field Lighting Control Type (choice: Continuous, Stepped, ContinuousOff)

N1, \field Minimum Input Power Fraction for Continuous Dimming Control

N2, \field Minimum Light Output Fraction for Continuous Dimming Control

N3, \field Number of Stepped Control Steps

N4, \field Probability Lighting will be Reset When Needed in Manual Stepped Control

A6, \field Glare Calculation Daylighting Reference Point Name

N5, \field Glare Calculation Azimuth Angle of View Direction Clockwise from Zone y-Axis

N6, \field Maximum Allowable Discomfort Glare Index

N7, \field Delight Gridding Resolution   
 \begin-extensible

A7, \field Daylighting Reference Point Name <within same zone or (if possible) other zones)

N8, \field Fraction Controlled by Reference Point

N9; \field Illuminance Setpoint at Reference Point

Daylighting:ReferencePoint,

A1 , \field Name

A2 , \field Zone Name

N1 , \field X-coordinate of Reference Point

N2, \field Y-coordinate of Reference Point

N3; \field Z-coordinate of Reference Point

Daylighting:DElight:ComplexFenestration, <unchanged>

A1, \field Name

A2, \field Complex Fenestration Type

A3, \field Building Surface Name

A4, \field Window Name

N1; \field Fenestration Rotation

Output:IlluminanceMap, <unchanged>

A1 , \field Name

A2 , \field Zone Name

N1 , \field Z height

N2 , \field X Minimum Coordinate

N3 , \field X Maximum Coordinate

N4 , \field Number of X Grid Points

N5 , \field Y Minimum Coordinate

N6 , \field Y Maximum Coordinate

N7 ; \field Number of Y Grid Points

A warning would be issued if Daylighting:DElight:ComplexFenestration is present but the the DElight method is not used.

The IOref documentation would be revised to combine the classic and DElight daylighting descriptions.

Preliminary Plan for Phase 2

Phase 2 is not yet funded but this preliminary plan is included to show compatibility with phase 1. Further refinements are anticipated.

Daylighting:Control, <multiple objects allowed per zone>

A1, \field Name

A2, \field Zone Name, ZoneList Name, Lights Name, or LightsList Name

A3 , \field Daylighting Method (choice: SplitFlux, DElight)

A4, \field Daylighting Reference Point Name

A5, \field Availability Schedule Name

N1, \field Illuminance Setpoint at Reference Point

N2, \field Fraction Controlled by Reference Point

A6, \field Lighting Control Type (choice: Continuous, Stepped, ContinuousOff)

N1, \field Minimum Input Power Fraction for Continuous Dimming Control

N2, \field Minimum Light Output Fraction for Continuous Dimming Control

N3, \field Number of Stepped Control Steps

N4, \field Probability Lighting will be Reset When Needed in Manual Stepped Control

N5; \field DELight Gridding Resolution

Glare:Control,

A1 , \field Name

A2 , \field Availability Schedule Name

N1, \field DELight Gridding Resolution

\begin-extensible

A3, \field Daylighting Reference Point Name

N2, \field Glare Calculation Azimuth Angle of View Direction Clockwise from Zone y-Axis

N3, \field Number of Glare Angles

N4; \field Maximum Allowable Discomfort Glare Index

Daylighting:ReferencePoint,

A1 , \field Name

A2 , \field Zone Name

N1 , \field X-coordinate of Reference Point

N2, \field Y-coordinate of Reference Point

N3, \field Z-coordinate of Reference Point

N4 , \field Psi rotation around X-axis

N5, \field Theta rotation around Y-axis

N6, \field Phi rotation around Z-axis

A3; \field Spatial Sensitivity Matrix

LightsList,

A1, \field Name

\begin-extensible

A2; \field Lights Name

Daylighting:DElight:ComplexFenestration, <unchanged>

A1, \field Name

A2, \field Complex Fenestration Type

A3, \field Building Surface Name

A4, \field Window Name

N1; \field Fenestration Rotation

Output:IlluminanceMap, <unchanged>

A1 , \field Name

A2 , \field Zone Name

N1 , \field Z height

N2 , \field X Minimum Coordinate

N3 , \field X Maximum Coordinate

N4 , \field Number of X Grid Points

N5 , \field Y Minimum Coordinate

N6 , \field Y Maximum Coordinate

N7 ; \field Number of Y Grid Points

For more information about the Spatial Sensitivity Maxtrix field, see the following:

<http://www.lrc.rpi.edu/programs/NLPIP/tutorials/photosensors/spatial.asp>

While many other much more extensive changes were considered, it would make more sense to make those changes as part of a larger phase 2 project.

**Outputs Description**

The current output variables that reference a specific reference point number will be changed to reference a named reference point. No other changes are anticipated.

**Engineering Reference**

No changes will be made to algorithms described but editorial changes to places where specific objects are mentioned may be required.

**Example File and Transition Changes**

Over two dozen example files will be changed that use the Daylighting:Controls and Daylighting:DELight:Controls object. This will be done using the Transition program. No results changes are expected because no algorithmic changes are planned. Since the new DaylightingCalculation object applies to the entire file, any test files that contain both Daylighting:Controls and Daylighting:DELight:Controls will have to be separated into two files.