Aviation Lights

The requirement to install aviation lights (sometimes called obstruction or hazard lights) on turbines has resulted in a need to simulate these lights in a photomontage.

The UK Civil Aviation Authority (CAA), reference 1, states that for onshore turbines there is:

…a statutory requirement to provide aviation warning lights for structures of a height of 150 meters or more. The Article 219 specification requires that medium intensity (2000 candela) steady red lights be mounted as close as possible to the top of the structure and at intermediate levels not exceeding 52 metres. Such lighting should be displayed at night and be visible from all directions.

Offshore turbines have similar requirements, reference 2.

Reference 3 from the US Clean Energy States Alliance states:

Hazard lighting is one of the most difficult visual aspects of a wind-energy project to evaluate, but it is an increasing concern. The Federal Aviation Administration (FAA) determines required hazard lighting or markings on a case-by-case basis. Usually wind turbines are required to be lit at night only (provided the turbines are white or off-white) with flashing red (L864) (white L-865 may also be used) located every ½ mile along turbine strings.

The nighttime landscape is often observed differently than the daytime landscape as there is less visible context and lights are more likely to be seen in isolation. In many landscapes where wind projects have been built or proposed, there currently is little night lighting. While red lights have less contrast than white lights in the night sky, they differ markedly from colors typically observed in the night landscape; the flashing on and off makes them particularly noticeable. Of greatest concern will be visibility from outdoor areas where night use occurs and there is an expectation of a natural landscape setting such as from natural parks or primitive camping areas.

Lighting is most intense when seen from above due to a -1° cutoff on light fixtures. Since hazard lighting only needs to be seen, not light up an entire area, it is of relatively low intensity and is less likely to affect dark skies.

In areas where there is high sensitivity to views of lights, consideration has been given to Audio Visual Warning Systems in which lights remain off but are activated by motion at a certain distance away. This type of system is more expensive to install but could help reduce concerns about wind energy projects in certain areas.

It is necessary to question whether photomontage simulation this can be done accurately enough. Reference 3 says:

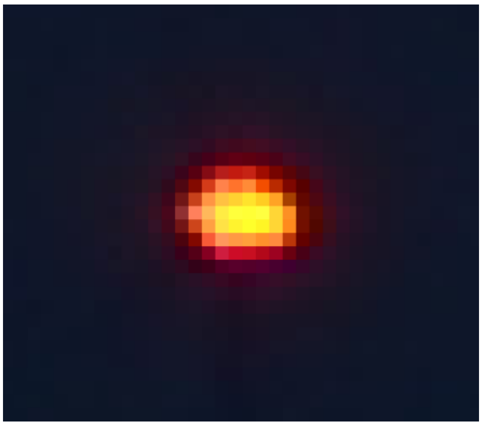
There is debate as to whether or not project lighting (FAA-required obstruction lighting) can be accurately simulated. Lighting is affected by numerous variables. Observing existing obstruction lighting is the best approach. Videography approaches are improving and combined with simulation software such as 3D Studio Max, which can compensate for variables such as refraction, reflected light, the source light, and shadows, reasonable lighting simulations can be created. Nevertheless, professionals who have created these simulations agree that they need to be adjusted using field comparisons of similar lighting situations. They will also be affected by viewing conditions such as room lighting, computer brightness settings, etc. Professionals agree that lighting simulations cannot be accurately printed as still images.

It should be recognised that simulating a photograph of aviation lights is questionable because a photograph is not necessarily accurate, particularly in brightness and colour representation. Light scattering / apparent size has to be addressed along with the brightness of the light. The latter also introduces the effect on colour representation and both will depend on the power of the light (typically 2000 candelas noted above).

Important: at present representing aviation lights in a photomontage is only indicative of the appearance of the lights. Using field comparisons will help, but caution is recommended.

Example of Brightness, Colour and Size

Frank David of Geophom has been kind enough to allow some of his photographs to be used as examples. On the right below is 25% of a photograph of a lit wind farm taken with a 50mm lens and therefore represents approximately 10° included angle. Also if the full photograph were displayed similarly it would spread across an A3 landscape page. The distance to the turbines is 13km.



On the left is a detail of one of the lights. Knowing the distance, pixel dimensions and included angle the apparent size of the light is 18m across with a core size (near to maximum intensity) of 30% to 40% of the apparent size

A very bright object cannot be represented accurately in a photograph or photomontage because of the limitations of the medium. For example, you cannot look directly at the sun but you can view it in a photograph. This is due to the limited range of the medium (screen or print) that is being used. Colour in graphics is usually represented using red, green and blue components each with a range of 0 to 255. Therefore when all are set to 255 you see the brightest white. In the example above it is a red light, but the photograph indicates that it has some other parts of the spectrum, notably green. The attenuation affects the entire spectrum so that at a distance we still see a red light with the naked eye. In the centre of the photograph the components are (255,255,23) which indicates that although the red component will be larger than the green, both have been limited to the 255 maximum value. As a result the light appears yellow in the photograph.

The representation of lights in the Photomontage module, in particular the attenuation and apparent size, will now be considered.

Attenuation

When light travels from its source, it diminishes in intensity, limiting the area that its source can illuminate. This is known as "light attenuation" or "fall-off". The attenuation of a normal, unmodified light is inverse quadratic, which is typical real world attenuation (according to inverse-square law). This rate is often too fast for virtual environments and therefore in computer simulations of lights the general formulation used for attenuation is a combination of inverse linear and inverse quadratic:

Intensity = Io / (c + a * r + b * r * r)

Where Io = Intensity at source and a, b and c are constants to be set and r is the distance. The formulation is a combination of constant, inverse linear and inverse quadratic terms.

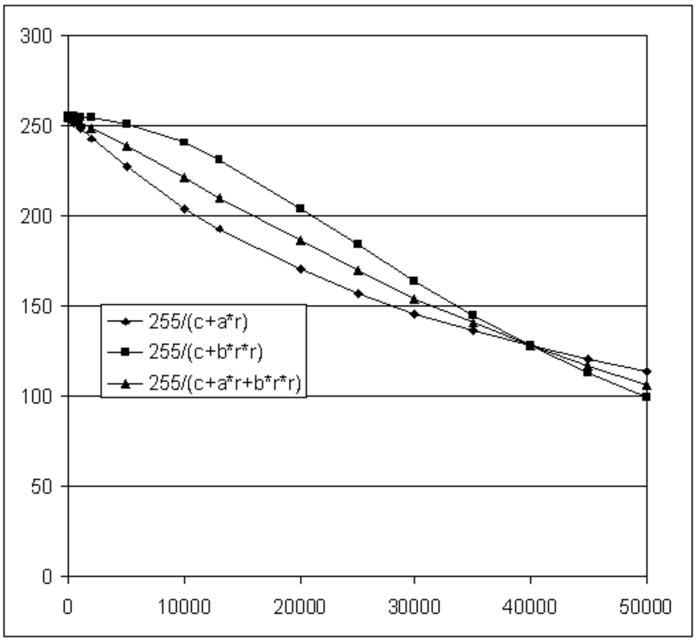
Graphics software generally prefers a and b to be set using a range or radius parameter at which the intensity is a specified fraction of the original source. This is necessary because the equation never reaches zero. The constant term c is often set to 1.

Therefore setting:
p = Ir / Io = Intensity at range / Intensity at source

If inverse linear and inverse quadratic are considered independently then:
b = ((1 / p) - c) / (range)
a = ((1 / p) - c) / (range * range)

If inverse linear and inverse quadratic are considered together and each contributes 50% of the intensity at range then:
b = ((1 / p) - c) / (2 * range)
a = ((1 / p) - c) / (2 * range * range)

The graph shows these attenuation curves starting using a constant c=1, source intensity of 255 and intensity ratio p=0.5 at a range of 40000m.

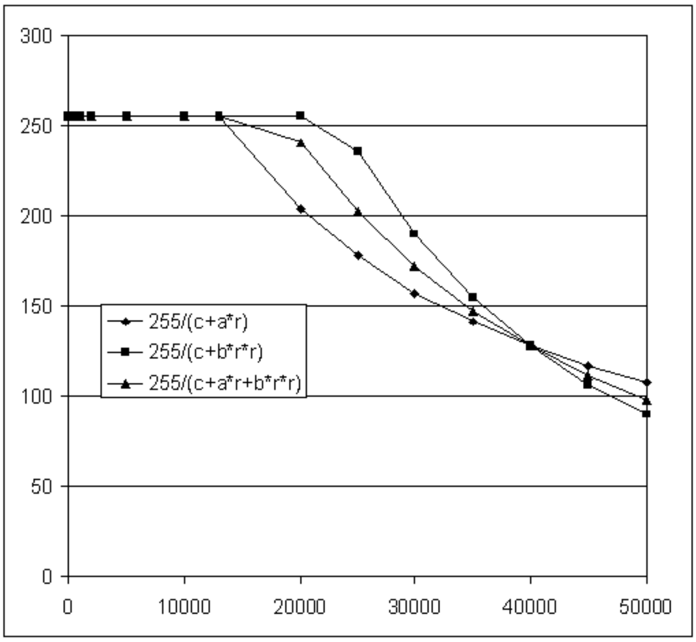


Using the same settings but setting c=0.5 the attenuation graph changes as shown.

Values larger than 255 will be attained close to the source therefore the maximum value is set to 255, giving the cut-off shown.

If you consider that it is not possible to represent a very bright light because of the limitations of the range of colours the intensity values below 20000m have been reduced.

Therefore this setting may be a better representation of the attenuation and therefore brightness at distances above 20000m.



The spreadsheet AviationLights.xls gives this formulation for attenuation allowing you to consider the effect of different settings and choose the most appropriate for your photomontage. The intensity ratio is set as a percentage, the range is in metres and the constant should be between 0 and 1. In the Photomontage module you can also choose the amount of linear and quadratic attenuation to be used.

Aviation lights often have a specified range related to their power. Though limited observations have suggested they are visible beyond the range specified. The photograph on the right is a section of photograph with lit turbines at 49km.

Apparent Size

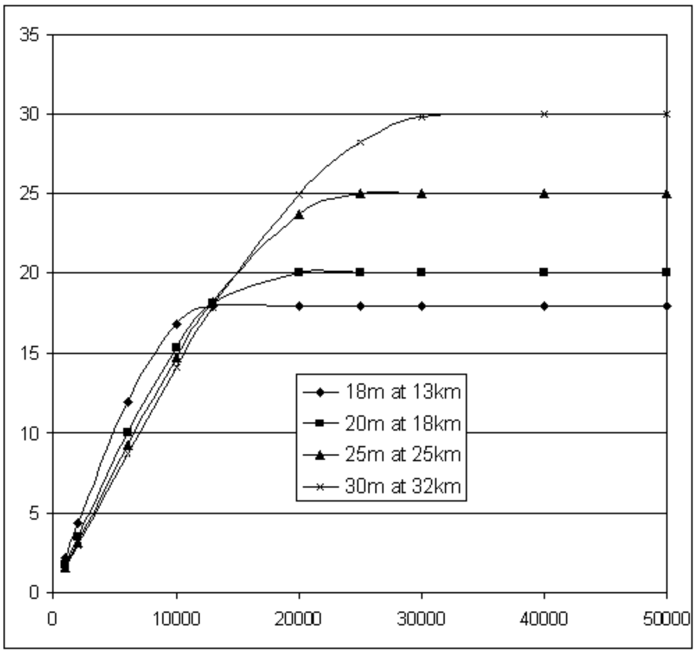
The apparent size of the light image in the first photograph is about 18m at 13km and the one above is 20m to 30m at 49km. Other photographs have shown that at 1km a size of about 2m was indicated.

These suggest a representative apparent size curve would approach the real light size close to the light with size increasing first of all rapidly and then perhaps becoming more constant beyond, say 20km.

The curves in the graph are created by a sine curve to a specified point (size, distance) and then constant beyond that.

The 18m size at 13km has been used as the target point for setting the attenuation coefficients in each of the four examples.

However, at present there is limited information to confirm any of these curves as representative. Therefore the first, a sine curve reaching a maximum of 18m at 13km and constant beyond 13km has been selected as the default in **WindFarm**.



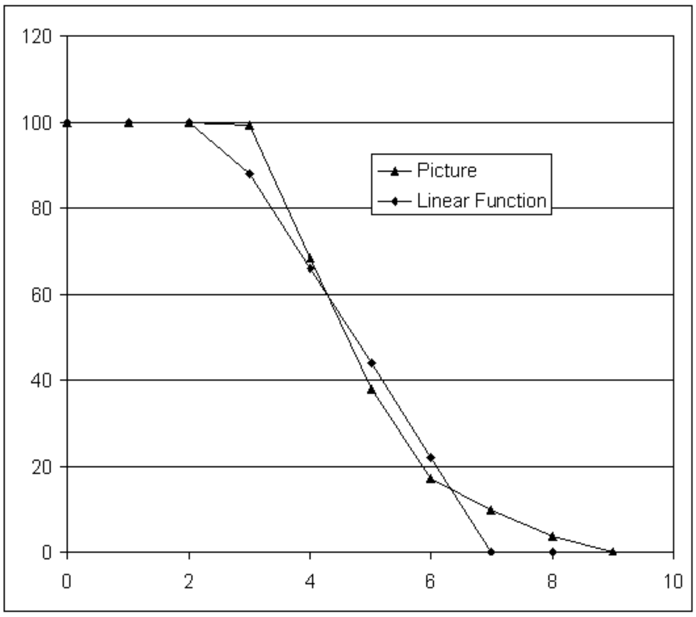
The spreadsheet AviationLights.xls gives this formulation for apparent size allowing you to consider the effect of different settings and choose the most appropriate for your photomontage.

In addition the fall off in light intensity from the core to the edge has to be represented.

The graph shows the typical fall off in light taken from the first pictures above. It displays the percentage of maximum (255) against pixels from the centre.

This has been replicated using a linear fall off to zero at 7 pixels, which is the size used to give the apparent diameter of 18m at 13km.

The core size has been set to 35% of the maximum of 7 pixels, which is 2.45 pixels.



Summary

The following topics have been covered on representing aviation lights in a photomontage:

1 Brightness, colour and size
2 Attenuation
3 Apparent size

References

1. "Lighting of En-Route Obstacles and Onshore Wind Turbines", Directorate of Airspace Policy, Civil Aviation Authority, 1 December 2010.

2. " The Lighting and Marking of Wind Turbine Generators and Meteorological Masts in United Kingdom Territorial Waters", Directorate of Airspace Policy, Civil Aviation Authority, 22 November 2012.

3. J. Vissering, M Sinclair and A Margolis, "A Visual Impact Assessment Process for Wind Energy Projects", Clean Energy States Alliance, May 2011.