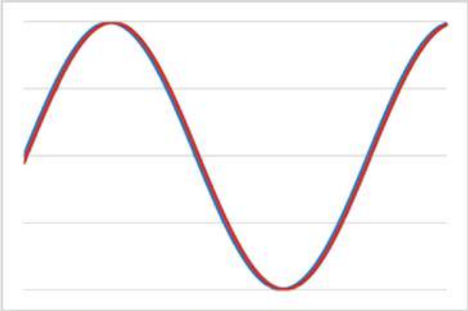
LUNERA BALLASTLED TECHNOLOGY

Total Harmonic Distortion and BallastLED Lamp

LUNERA®

What is THD?

Total Harmonic Distortion (THD) is the distortion in the current waveform caused by non-linear electrical loads (fig. 1). Prior to the 1960s, there were very few non-linear loads, however with the advent of switching electronic power supplies, arc furnaces and other contemporary devices quantifying and managing THD is critical to the design and operation of a modern electrical system.



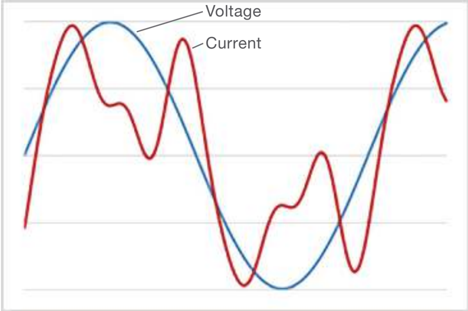


Fig. 1 Voltage and power for a linear electrical load and one with high THD

THD is measured as a % distortion of the current waveform using the formula below; however the higher frequency distortion components are more impactful thus a detailed analysis is necessary to understand the impact of THD to the building and grid level power system.

$$THD\ \% = 100\% * \frac{\sqrt{{I_2}^2 + {I_3}^2 + {I_4}^2 + {I_5}^2 \ldots + {I_n}^2}}{{I_1}^2}$$

Fig. 2 THD is calculated as the root mean squared (RMS) of the harmonic components of the current divided by the fundamental current

What are the impacts of THD to an electrical system?

There are two primary impacts of THD to an electrical system:

1. Increased heating transformers used in the system resulting in derating; IEEE defines the k-factor as a way to quantify this impact

2. Increased neutral wire current when 3 phase power is wired in a wye configurations due to triplen of addition odd numbered harmonics (3, 5, 7, etc.)

K FACTOR CALCULATION AND MEASUREMENT FOR BALLASTLED LAMPS

The k factor is a weighted calculation of the harmonics of a waveform that takes into account the more severe impact of the higher frequency components. The k factor is calculated as:

$$K\ Factor = \sum(I_h{}^2)h^2 \text{ where } \sum\left(I_h{}^2\right) = 1$$

Practically for a 400W Metal Halide Ballast at 120V driving (4) lamp types with the performance outlined below:

	400W New Metal Halide Lamp	400W EOL Metal Halide Lamp	Lunera MH LED 400W	
Volts	120	120	120	V
Amps	4.081	4.074	3.246	A
THD	10.2	12.4	23.8	%
Power Factor	0.95	0.96	0.6	PF
Volt-Amps	491	492	393	VA
Watts	465	471	235	W

The harmonic content of each lamp is listed below and the k-factor for each configuration is calculated:

Current Harmonics	400W New Metal Halide Lamp	400W EOL Metal Halide Lamp	Lunera MH LED 400W	
1	4.069	4.059	3.152	A
3	0.320	0.453	0.763	A
5	0.233	0.182	0.105	A
7	0.109	0.133	0.042	A
9	0.016	0.045	0.015	A
Normalized ih2 Current				
1	0.995	0.992	0.971	
3	0.078	0.111	0.235	
5	0.057	0.044	0.032	
7	0.027	0.033	0.013	
9	0.004	0.011	0.005	
Ih2*h2				
1	0.990	0.985	0.943	
3	0.055	0.110	0.498	
5	0.081	0.049	0.026	
7	0.035	0.052	0.008	
9	0.001	0.010	0.002	
k Factor (sum ih2*h2)	1.162	1.206	1.477	

ANSI defines a derating curve for transformers as a function of k Factor (ANSI C57.110)

K FACTOR CALCULATION AND MEASUREMENT FOR BALLASTLED LAMPS - CONTINUED

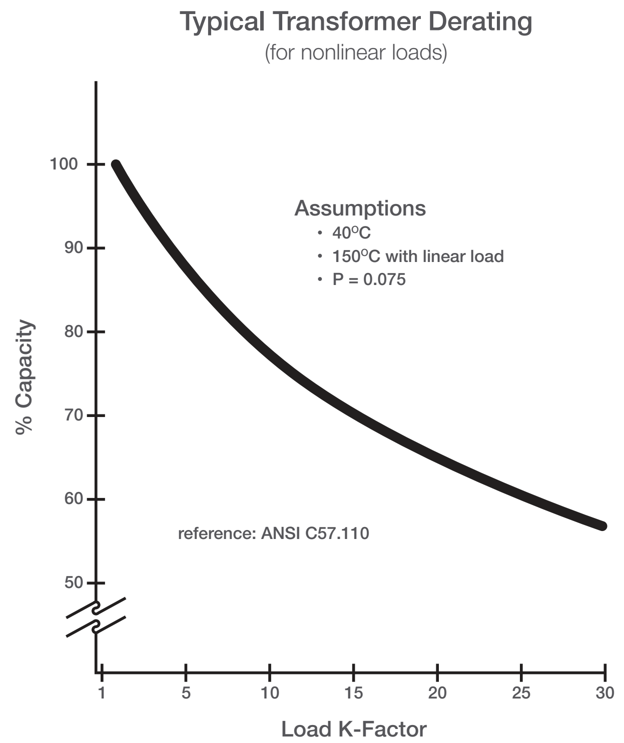


Fig. 3 ANSI C57.110 transformer derating as a function of k factor. For k factors below 2, the derating is <4%.

	400W New Metal Halide Lamp	400W EOL Metal Halide Lamp	Lunera MH LED 400W	
Volts	120.1	120.2	120	V
Amps	4.081	4.074	3.246	A
THD	10.2	12.4	23.8	%
Power Factor	0.95	0.96	0.6	PF
Volt-Amps	491	492	393	VA
Watts	465	471	235	W
k factor	1.162	1.206	1.477	
Derating	1%	2%	3%	
Derated VA	495.96	502.04	405.15	VA

Conclusion is that the increased k factor, results in an immaterial derating of the transformer, which is more than overcome by the reduction in the volt-amp (VA) requirement of the Lunera MH HID LED Gen 2 lamps.

Although the THD of the Lunera MH HID LED Gen 2 lamp is >20%, it does not appear to present an issue due to transformer heating for a circuit originally designed for metal halide lamps.

INCREASED NEUTRAL WIRE CURRENT FOR TRIPLEN HARMONICS

When buildings are wired in Wye configuration (fig. 4), fundamental and even numbered harmonics (1, 2, 4, 6, 8, etc.) are carried only in the phase lines and cancel each other out in the neutral line. However, off numbered harmonics (3, 5, 7, 9, etc.) do not cancel each other out and thus the harmonic from each of the 3 phases is additive and can result in high neutral currents.

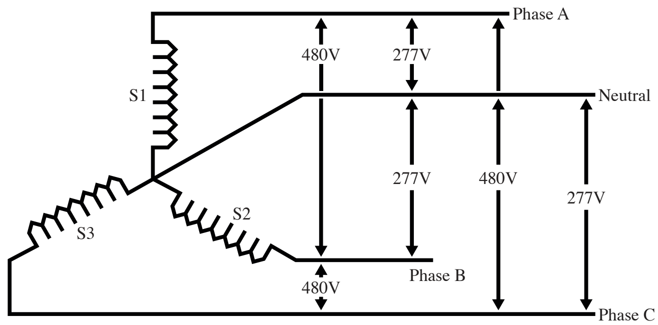


Fig. 4 480V 3 Phase input wired in a Wye diagram resulting in 277V inputs. Typically metal Halide ballasts are driven at 480V (delta configuration with no neutral) or 277V (Wye configuration using a Neutral). Neutral wire current is thus only a concern in the 277V case.

The Triplen Neutral wire current in the wye configuration case can be calculated by adding together the harmonic currents of the odd numbered harmonics and multiplying by (3) for the 3 phases.

Off Harmonic #	400W Fresh Metal Halide Lamp	400W EOL Metal Halide Lamp	Lunera MH LED 400W	Units
3	0.96	1.359	2.289	A
5	0.699	0.546	0.315	A
7	0.327	0.399	0.126	A
9	0.048	0.135	0.045	A
Total Triplen Neutral Wire Current	2.034	2.439	2.775	A
Phase Wire Current	4.081	4.074	3.246	A
Ratio of Neutral Current to Phase Current	50%	60%	68%	

The NEC code requirement for neutral wire sizing is that it must be at least as large as the phase wiring – in this case the maximum neutral wire current in only 79% of the phase current. Thus there is sufficient headroom.

A typical 480V 3 phase drop is used to power an entire building; this calculation also assumes that 100% of the Wye configuration power is used to driving metal halide lighting alone; a more typical number would be 30% thus providing an additional safety margin of 3.3x.

Conclusions

A BallastLED retrofit of a magnetic ballasted product such as a 400W Metal Halide lamp does raise concerns around total harmonic discharge (THD) as it related to transformer derating and triplen neutral wire currents. However, a detailed analysis indicates that the reduction in magnetic volt-amps (VA) is more than sufficient to offset the impact of a slight increase to THD.