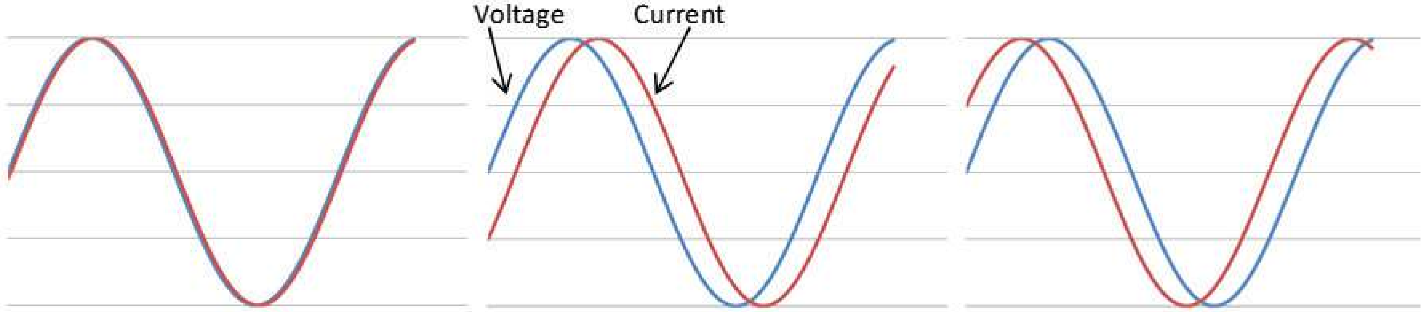
LUNERA BALLASTLED TECHNOLOGY AND POWER FACTOR

LUNERA®

Replacing metal halide lamps in magnetic ballast-driven fixtures with the Lunera MH HID LED Gen 2, a LED plug-and-play replacement, causes the ballast to have a leading (capacitive) power factor. In most large facilities, this leading power factor can used to offset other lagging (inductive) devices such as motors and pumps resulting in an improvement of the building's overall power architecture and financial savings to the user.

What is Power Factor (PF)

Power factor (PF) is a measurement of the alignment of the voltage and current waveforms in an AC system, a number from 1.0 (perfect aligned) to 0.0 (90° out of phase). What causes voltage and current to be misaligned are reactive loads which can either be lagging (inductive – such as motors, pumps and most power converters) or leading (capacitive), as opposed to resistive loads.

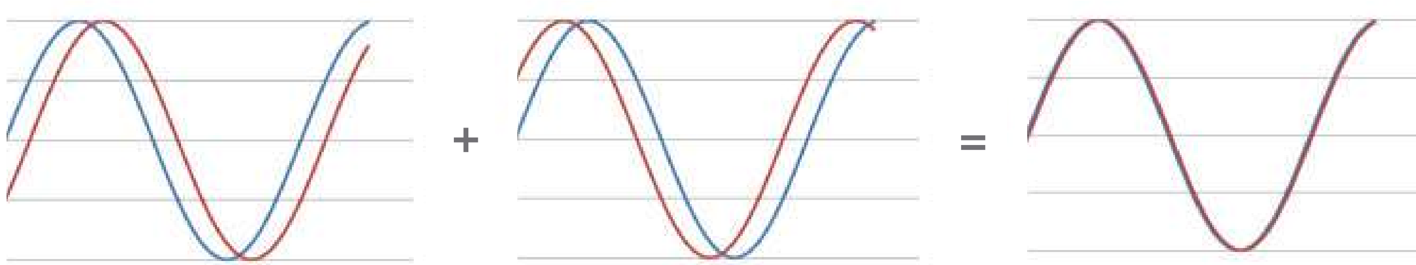


Neutral (Resistive) Load
Voltage and Current Aligned PF=1.0

Lagging (Inductive) Load
Current Lags Voltage PF < 1.0

Leading (Capacitive) Load
Current Leads Voltage PF < 1.0

Fig. 1 Power factor for a neutral (resistive) load vs. lagging (inductive) or leading (capacitive) loads. Loads seen in buildings are typically a combination of resistive and inductive loads driven by electric motors, magnetic ballasts and mixed plug loads.



Lagging (Inductive) Load

Leading (Capacitive) Load

Neutral (Resistive) Load

Fig. 2 When lagging and leading loads are added together, they have the helpful effect of canceling each other out as can be seen in Fig. 2. For example a 10A load with a lagging 0.6PF and a 10A load with a leading 0.7PF when added together create a combined load of 13A with a lagging PF of 0.99.

Watts are a measure of the power delivered to a device. In an AC system it is:
Watts = Voltage (V rms) × Current (A rms) × Power factor
As opposed to Volt-Amps (VA) – which is simply a measure of Voltage x Current
Voltage-Amps = Voltage (V rms) × Current (A rms)

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Why do Utilities Care about Power Factor?

Utilities charge for watts consumed; however their infrastructure of switching yards, transformers and distribution lines must be sized to the amount of current delivered. The effect of power factor on current can be quite dramatic:

- 10kW load driven at 277V with a PF of 0.95 draws a current of 38A
- 10kW load driven at 277V with a PF of 0.65 draws a current of 56A (46% more)

As we saw earlier, lagging loads can be compensated by adding leading loads to them, or practically by applying capacitors; this is typically done at key stages in the distribution process such as the switching yard in order to compensate the lagging load and minimize the distribution losses and infrastructure requirements as shown in fig. 3.

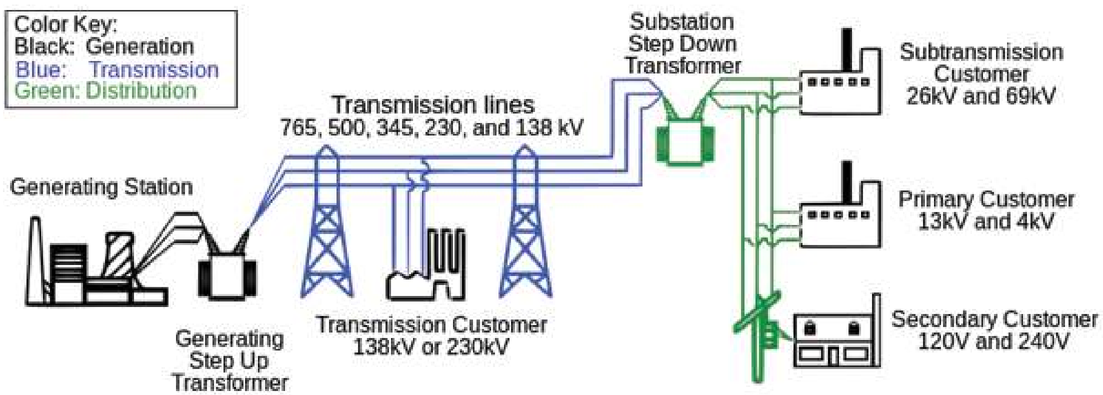

Fig. 3 Utilities use large adjustable capacitor banks at various stages in the electrical distribution grid in order to compensate for lagging (inductive) loads and minimize the distribution losses and infrastructure requirements of supporting lagging loads.

Fig. 4 Compensating capacitors perform power factor compensation at a utility switching yard.

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Magnetic Ballasts, Compensation and Power Factor

Arc lamps, such as fluorescent and HID lamps, require a high voltage to initially strike them. But once operating, they require a stable current flow in order to maintain the arc and light output. Magnetic ballasts use large magnetics (inductors) to accomplish this stable current flow. However, inductors have the downside of delivering a low power factor load so compensating capacitors are embedded in the ballast to compensate the load. The capacitor is sized to the delivered lamp load as shown in Fig. 5.

Constant Wattage Autotransformer (CWA) Ballast

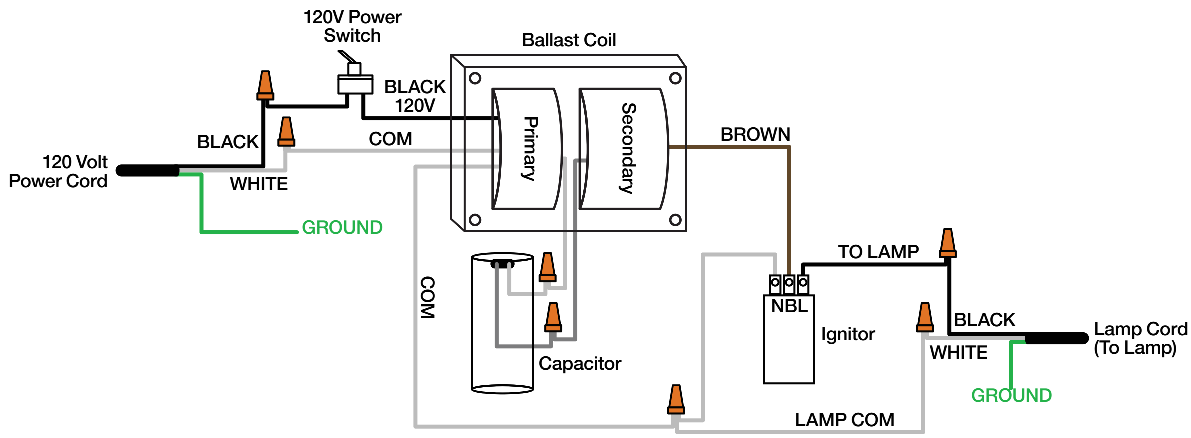

Fig. 5 Simplified magnetic ballast architecture with compensating capacitor. An inductor is used to limit power and control current to the lamp while a capacitor is used to compensate for the lagging (inductive) load and generate a high power factor. The capacitor is sized to the relative load of the lamp.

BallastLED Lamps and Magnetic Ballasts

When a legacy arc lamp, driven by a magnetic ballast, is replaced with a Lunera BallastLED lamp which consumes 50% to 90% less power, the resulting ballast is now over-compensated for the reduced load it is driving. Simply put, after installing the Lunera BallastLED lamp, the capacitor installed in the ballast is larger than what is needed to compensate for the lagging power factor of the inductors in the ballast. This causes the ballast to have a leading (capacitive) power factor.

In most large facilities this leading power factor can used to offset other lagging (inductive) devices such as motors and pumps resulting in an improvement of the building's overall power architecture and financial savings to the user.

The following case studies explore the scenario of replacing a 400W metal halide lamp with a MH HID LED lamp.

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Case Study #1

Replacing a 400W Metal Halide Lamp with a MH HID LED LAMP

The Lunera MH HID LED Gen 2 lamp consumes 162W and delivers the same mean lumens as the 400W metal halide lamp it replaces. However, as the ballast is over-compensated, the load presented to the circuit is more complex.

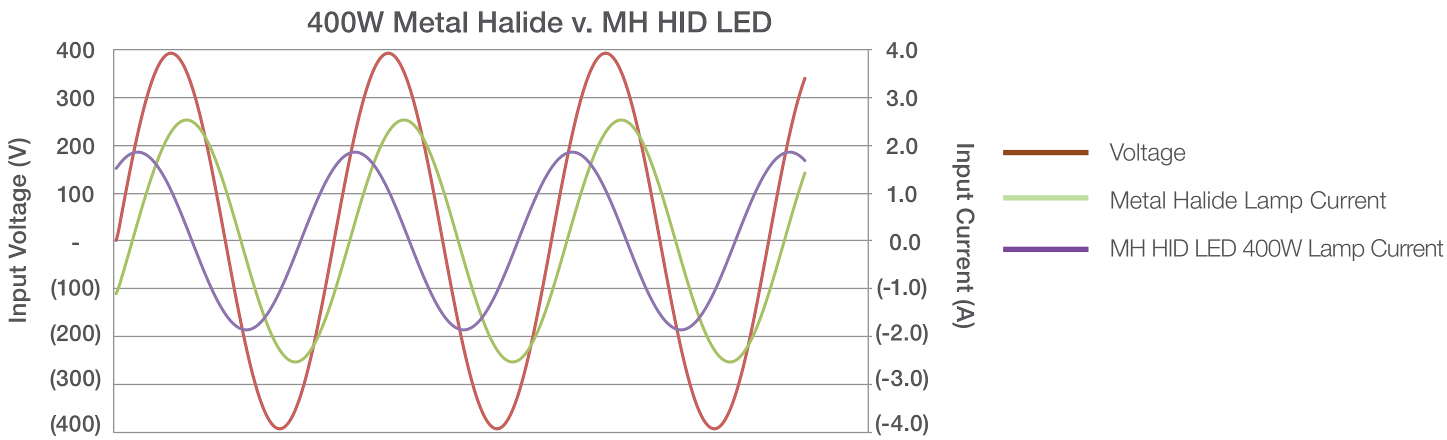

Fig. 6 Input Volt-Amps of Metal Halide v. Lunera MH HID LED Gen 2.

The MH HID LED Lamp creates a substantial reduction in both consumed power (watts) as well as volt-amps (VA). However, even more valuable, it creates a leading power factor load that can be used to offset other lagging power factor loads in the facility.

For example, California utility company, PG&E, charges large customers (over 400kW) adjusts their kW rate based on the power factor of their load:

- A 0.06% premium is added for each point that a customer's power factor (PF) falls below 0.85
- A 0.06% discount is applied for each point that a customer's power factor (PF) rises above 0.85

	400W HID	MH HID LED
Lamp Power (W)	400	156
Ballast Power (W)	45	45
Total Power (W)	445	201
Current Phase Angle (Degrees)	26	(55)
Ballast (VA)	494	353
Input Voltage (V rms)	277	277
Input Current (A rms)	1.78	1.27
Power Savings		**-55%**
VA Reduction		**-29%**

Tbl. 1 Power Savings and VA Reduction of the MH HID LED Lamps.

Learn more at: http://bit.ly/PGEDocs

Case Study #2

Building-Level Retrofit Implications of Replacing Metal Halide Lamps with the Lunera MH HID LED Gen 2

Assumptions

- 100,000 sq. ft. building lit with 400W Metal Halide (MH) lamps on a 20'x20' spacing
- Building is operated 4,370 hours per year
- Lighting represents 35% of building electrical load; HVAC represents 35% of the building electrical load, and plug loads represent the remaining 30%
- Metal halide lamps and HVAC have a lagging power factor of 0.9; plug loads have a lagging power factor of 0.7

Comparing Metal Halide and MH HID LED Lamp Solutions in the Building

	BEFORE the MH HID LED Lamp Retrofit			AFTER the MH HID LED Lamp Retrofit		
	W/sq. ft.	Total Power	Total Load	W/sq. ft.	Total Power	Total Load
Lighting	1.10	111kW	123kVA (lagging 0.90 PF)	0.50	52kW	91kVA (leading 0.57 PF)
HVAC	1.20	139kW	155kVA (lagging 0.90 PF)	1.20	139kW	133kVA (lagging 0.90 PF)
Plug Load	1.00	100kW	142kVA (lagging 0.70 PF)	1.00	100kW	142kVA (lagging 0.70 PF)
Aggregate	**3.5**	**350kW**	**415kVA (lagging 0.84 PF)**	**2.70**	**291kW**	**305kVA (lagging 0.95 PF)**

Tbl. 2 Comparing the building's power envelope before and after a MH HID LED Lamp retrofit.

	BEFORE the MH HID LED Lamp Retrofit	AFTER the MH HID LED Lamp Retrofit
Energy Consumed	1.53M kWh	1.27M kWh
Base Rate Charge	$230,155	$190,078
PF Surcharge	+$924 (PF of 0.84 is below 0.85)	-$11,198 (PF of 0.95 is above 0.85)
Electric Bill	**$231,079**	**$178,880 (22.6% savings)**

Tbl. 3 Comparing the building's cost of energy before and after a MH HID LED Lamp retrofit using a PG&E PF calculation at a nominal rate of $0.15/kWh adjusted for power factor.

Bottom Line

Lighting power was reduced by 54%, including the ballast load from the HID fixtures. Total power was reduced by 18%. However total VA was reduced by 28% as the leading current going into the lighting fixtures **now compensates for the lagging current inside the building**.

The result is a substantial improvement in the load presented to the utility, and a reduction in building load (VA) that is nearly twice as large as the power (watts) reduction enabled by the lamps.

Conclusion

Retrofitting from legacy HID lamps to Lunera's BallastLED technology provides a building owner not only 50-90% energy savings and substantial maintenance savings, but also unlocks value in the magnetic ballasts to provide capacitive compensation for inductive loads in the building. These cost saving pillars justify the investment in your HID LED lamp retrofit:

- Energy Savings of 50-90%
- Up to a 5x extension in maintenance cycles for lamp replacement
- Improvement in light levels and light quality
- Building Level power factor Improvement of up to 11 basis points
- Potential for substantial rebates from your utility partner