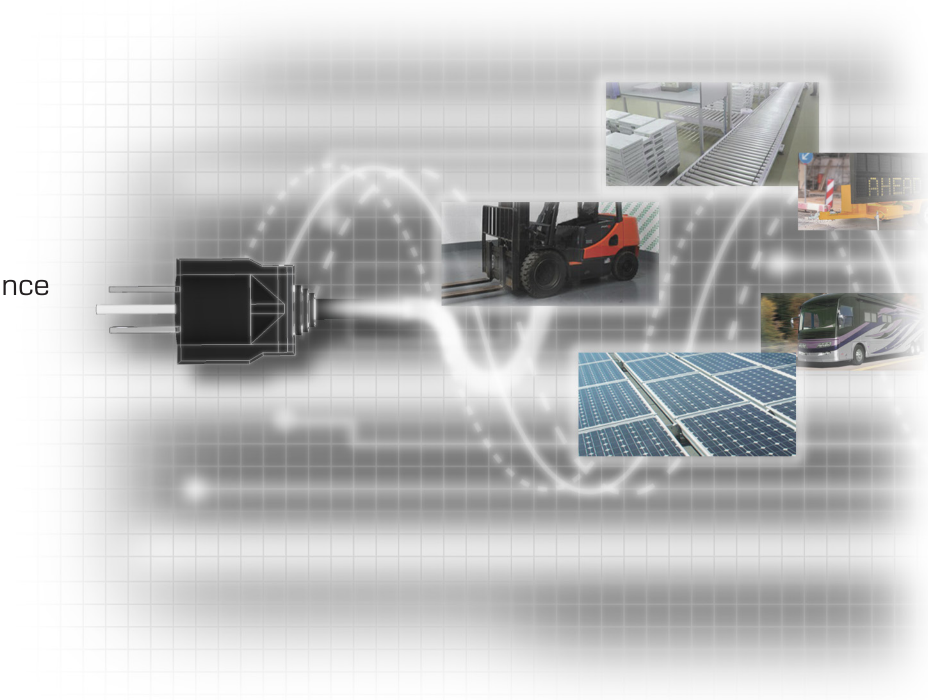
Power Factor Correction in Battery Chargers

Improving PF Performance and Compliance by using Battery Chargers with Built-in Power Factor Correction



Content Highlights

- What is Power Factor?
- PF Standards in AC/DC Applications
- CEC Performance Standards
- Automatic Power Factor Correction in Battery Chargers

Efficient power consumption continues to be a focus throughout the commercial and industrial sectors. In a quest for continuing improved energy efficiency, power factor (PF) is becoming a growing focus for ensuring optimal power consumption. Simply put, power factor is a measurement expressing how much power is used versus how much is wasted. A higher power factor indicates better overall utilization of the energy used (For a detailed definition of PF, refer to the sidebar on page 2). Power factor has long been a target for improved energy efficiency in sectors where inductive motors are used. Utilities impose requirements, penalties, and surcharges on these types of major power consumers that use power inefficiently to provide incentive to improve. While efficiency standards continue to be adopted in industrial motor applications, one of the challenges utilities face is the meteoric rise of battery-operated, mobile equipment and portable electronics. Their demand for power combined with the inefficient way they consume power – and the impact this has on utilities – is now under scrutiny and a target for new efficiency standards at international, national, and state levels, led by the state of California.

Correcting for low PF is critical for industrial environments where the needs for improved AC use, mobile equipment reliability, and regulatory compliance are high. Available technologies including power factor correction built in to battery chargers and charge controllers automatically correct poor PF to 0.90 to immediately improve use of AC line power, increase power capability, and comply with California's new energy efficiency standards.

The High Cost of Low Power Factor

Utilities produce and distribute power to meet the demand for real power, so power production is increased to compensate for the loss between apparent power and real power (see **Figures 1** and **2** for decriptions of real and apparent power). Energy losses attributed to poor PF are enormous. The California

What is Power Factor?

Power factor (PF) is the ratio of power used, or real power, to the total power supplied, or apparent power, and is expressed as a value ranging from 0 to 1, where 1 represents a 100% PF. Non-linear loads interact with the linear current from the AC outlet, introducing time lags and distortions that cause some of current to flow in and out of the load without being used as working power. The result is that not all the AC line power is used by the devices on the circuit.

PF is a desirable 1.0 and is in unity when a load draws current that is exactly synchronized with voltage and without distortion so that 100% of the apparent power can be used as real power. This is typical of a resistive load, such as a light bulb.

But most loads have inductive or capacitive elements that introduce distortion and phase shifts between current and voltage that prevent a device from using all of the apparent power. If 70% of apparent power is used as real power, the PF is 0.7, with 30% of the apparent power lost as non-working, reactive power that does not produce watts. The lower the PF, the more inefficient the device, and the more power is wasted as reactive power.

Energy Commission (CEC) estimates that one-third of the energy produced by a power plant is lost due to poor PF.

Poor PF also has a significant impact on distribution. The unused, reactive power (see Fig. 2) flows back into the distribution system, using capacity and limiting distribution capacity for active power.

With improvements in PF, utilities can generate less power while improving distribution capacity, and still meet customer power demand. The scope and magnitude of these benefits to utilities are key drivers of minimum PF standards, but end-users also benefit with lower utility bills and increased capacity of their internal electrical system while still satisfying their power needs.

Traditional Minimum PF Standards in Industry

PF performance has largely been in the domain of industry, especially where large inductive motors are used. Not only do industrial motors have relatively high power consumption, but their inductive elements introduce phase shifts that reduce their PF in the range of 0.4 to 0.7. This combination of high power use and low efficiency has made these industrial applications early targets for improved PF from both the utility and the end-user.

Today, most utilities meter and charge residential customers for real power only. Due to their high power use and lower PF (and the significant energy loss and reduced distribution capacity this represents), utilities typically charge industrial and commercial customers for both real power and for the power they wasted.

Approaches to this vary by region, but many utilities set a minimum average monthly PF of 0.95, calculated by metering both real power and reactive power. Utilities then charge penalties or surcharges for noncompliance. Industry users have an incentive to meet the PF standard and adopt PF correction methods such as capacitor technologies to reduce or eliminate these penalties and other operating costs caused by poor PF.

The Next Step: PF Standards in AC/DC Applications

From smart phones to medical instruments to mobile communication networks, the use of battery-operated, mobile devices and equipment has skyrocketed along with their share of overall power consumption. Battery-operated device manufacturers have focused design and engineering resources on extending device operating time between charges but not yet on improving efficiency in the AC/DC process itself.

Figures 1 and 2:

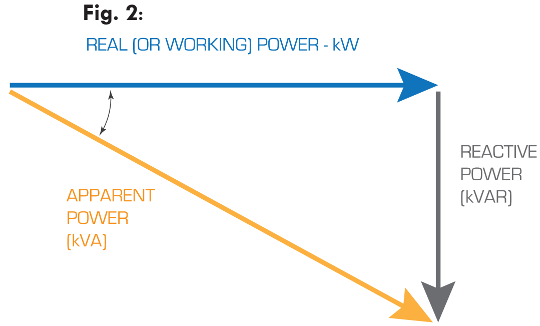
PF Formula and the Power Triangle

Power Factor is calculated by dividing the real power by the apparent power. Optimal PF, or 100% PF, would be a result of 1.0

Fig. 1:

$$\text{POWER FACTOR} = \frac{\text{REAL POWER}}{\text{APPARENT POWER}}$$

Fig. 2:



The Power Triangle illustrates the relationship between real and reactive Power.
REAL POWER (measured in kilowatts) is the power that is actually used in doing the work, such as creating heat, light, etc.
REACTIVE POWER (measured in kilovolt-amperes-reactive) isn't used as 'real' power but is spent sustaining the electromagnetic field. The more reactive power that is being used results in an increase in apparent power.

When the larger apparent power is factored into the PF formula, the result is a decreased PF.

The CEC estimates that two-thirds of the 8,000 gigawatt hours of electricity used by battery chargers in California is wasted by inefficiency. Thus, battery chargers have become a target for efficiency improvements through regulation and performance specifications in California. It is important to note that California has been an early adopter of energy and environmental regulation, and commercial and industrial policies established in California tend to be accepted throughout the remaining United States as standard practices. In the U.S., the Department of Energy and EPA's EnergyStar program are reviewing battery charger efficiency and PF standards. Internationally, the International Electrotechnical Commission has adopted standards directly related to PF.

California's PF Standards for Battery Charging Systems

The CEC has adopted requirements of 0.90 PF to improve efficiency in large battery charger systems aimed at non-consumer electronics and in small battery systems aimed at consumer and non-consumer electronics. California estimates it will save 150 GWh to 575 GWh per year by regulating PF in battery charger systems. In addition to PF, these standards cap maintenance-mode power and no battery-mode power, and the total amount of energy allowed in a charge cycle. (See Figure 3 for a summary of new battery charging system energy efficiency requirements).

Since large battery chargers spend much of their time in charge mode, improvements are required in power conversion efficiency and PF. For small battery chargers, the standards focus on improving efficiency in charge return Factor and in the more common maintenance mode.

Automatic Power Factor Correction in Battery Chargers

Power factor correction (PFC) technologies built in to battery chargers automatically correct PF to 0.90. IOTA's **DLS-UI-27-40** features built-in capacitive technology to efficiently use more of the AC line potential. There are direct

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See the sidebar on Page 4 to find more information on the DLS-UI-27-40 model and IOTA's experience with other industrial PFC designs.

LARGE BATTERY CHARGER SYSTEMS (rated input power >2kW and not used for golf carts)	
Performance Parameters	Standards
Charge Return Factor (CRF): 100%, 80% depth of discharge	CRF ≤ 1.10
Charge Return Factor (CRF): 40% depth of discharge	CRF ≤ 1.15
Power Conversion Efficiency	≥ 89%
Power Factor	≥ 0.90
Maintenance Mode Power (E_b = battery capacity of test battery)	≤ 10 + 0.0012E_b W
No Battery Mode Power	≤ 10 W
SMALL BATTERY CHARGER SYSTEMS (for golf carts or rated input power <2kW*)	
Maximum 24-hour charge and maintenance energy (Wh) (E_b = capacity of all batteries in ports and N = number of charger ports)	16 x N
For E_b > 2.5 Wh and ≤ 100Wh:	12 x N=1.6E_b
For E_b > 100 Wh and ≤ 1000Wh:	22 x N=1.5E_b
For E_b > 1000 Wh	36.4 x N=1.486E_b
Maintenance Mode Power and No Battery Mode Power (W)	The sum of the maintenance mode power and no mode power must be less than or equal to:1 x N+0.0021xE_b W

Figure 3:

Summary of California Energy Commission Appliance Efficiency Regulations 1602(w)

This table summarizes the California Energy Commissions performance requirements for large (>2kW) and small (<2kW) battery charger systems. The CEC does provide exemptions for some product applications, such as use for electric motor vehicles, certain medical devices, and exit signs. Refer to the complete CEC regulations for additional information.

benefits to the utility through reduced power demand and more distribution capacity.

The direct benefits to end-users of automatic PFC include:

- Reduction of reactive current
- Use of more line power to reduce charge times
- Lower utility bills by using line power more efficiently
- Improved internal distribution capacity

Power Factor Correction Trend: Up

The benefits of improved power factor performance are gaining momentum through consumer, commercial, and industrial sectors. Correcting low power factor can save industry and end-users money by reducing energy costs and surcharges, and creates more efficient generation and delivery systems. California, which sets benchmarks in energy and environmental standards, has set a requirement for 0.90 PF in large battery charger systems.

As demand and proliferation of battery-operated devices grows, battery chargers that automatically correct for low power factor will be key in making these devices more energy-efficient and complying with new regulations. IOTA's PFC-equipped power supplies and battery chargers will enable industry users to utilize the full potential of AC line power and increase power capability.

PFC Design Experience

IOTA has proven experience in developing specialized PFC equipment for industrial customers with unique application requirements. Idle-mitigation for large trucks is one such application that enabled the efficient use of equipment inside truck cabs without the need for a running engine. The DLS-UI-27-40 represents IOTA's first commercially-available PFC solution, offering >90% utility consumption, the capability to utilize 40A output from a typical 15A circuit, and universal input of 120-240V for 27VDC 40 amp applications. You can find the complete specifications at www.iotaengineering.com.

About IOTA Engineering

IOTA is a privately held, family-owned company that has worked continuously in the electronic R & D field, designing and manufacturing innovative products for the lighting and electronics industries since 1968. Initially focused on the development of low voltage solid state ballasts, IOTA has expanded to include emergency battery packs for contemporary lighting designs, DC inverter ballasts, and AC/DC power converters and battery chargers. The company is a leader in developing technology for smart chargers for specialty applications and configurable smart chargers to meet unique customer specifications. IOTA is continually expanding its development of state-of-the-art electronics that keep pace with customer needs and industry demands. From the circuit board design to the completed unit, IOTA designs and develops products that maintain superior performance, and is dedicated to providing the highest levels in customer satisfaction, quality and innovation in the industry.

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