

DC Fast Chargers

Electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV) are recognized as the future of the automotive industry. In the coming decade the transition to EVs and PHEVs will reduce our national dependence on foreign sources of oil, improve the health of our citizens and environment, and create a new clean energy economy. Furthermore these new vehicles will offer better performance with lower fuel and maintenance costs.

The main limitation to accelerating adoption of these new vehicles has been their initial cost, primarily due to the cost of lithium ion battery systems. Battery technologies are predicted to improve both in cost, performance and lifetimes (# cycles). However another less publicized technology will also play a critical role in the adoption rate of EVs and PHEVs in the next few years. This is the technology for DC fast chargers.

The first large scale study on consumer behavior with electric vehicles began by TEPCO (Tokyo Electric Power Company) in the 1990s. A key result of this study indicates that consumers will use electric vehicles for many more vehicle miles if a network of high speed DC chargers is available in heavily used urban areas. This allows drivers to rapidly recharge their vehicles, and reduces range anxiety of running out of (electric) fuel.

EV and PHEV owners will typically install low power 2–7kW (level 1 or 2) chargers at their homes and will charge their vehicles at night during periods of low electricity demand. These relatively low power chargers require 4–8 hours to charge an EV and are limited by the residential 120/240 single-phase electrical infrastructure. This is adequate for normal vehicle operation and is

desirable by electrical utilities to create demand during relatively low night time usage hours.

Level 1 and 2 chargers can be installed as public networks in the urban environments, but their slow charge times make them attractive only at the driver's place of employment where the vehicle will be parked for many continuous hours.

High power level 3 DC chargers use commercial 3-phase power lines (480V AC) and can charge vehicles more than 10 times faster than the level 1 and 2 chargers. The DC chargers range from 30kW to 100kW and charge vehicles in 15 to 60 minutes. If these high power DC chargers are located at retail stores or restaurants, the charging cycle can be accomplished conveniently while the driver is engaged in non-charging activities. The availability of high power DC chargers in the urban environment will significantly accelerate both the number of EVs sold and the number of miles driven per vehicle.

Bidirectional DC Charger/Inverter

High power DC chargers are advanced power conversion systems. It is desirable to enable bidirectional high power DC charging systems to improve grid stability and provide value-added Vehicle-to-Grid (V2G) functions. Such V2G functions can help pay for electric vehicle and DC charger infrastructure costs.

VAR Compensation A bidirectional DC charger can provide reactive power compensation to the distribution network, enhancing grid stability and reducing electrical costs for commercial electric customers. Under loads distribution lines often exhibit a lagging power factor

($PF < 1$) which reduces distribution grid efficiency and increases electrical loads. Additionally utilities often charge commercial customers substantial rate adders for low power factors (if $PF < 0.85$).

During VAR compensation the bidirectional charger shifts the phase of the current with respect to the line voltage. VAR compensation provides leading power factor ($PF > 1$) so that a unity power factor ($PF = 1$) is maintained. VAR compensation can reduce commercial electrical costs by both improving efficiency and by eliminating rate adders. These systems can provide VAR compensation even when a vehicle and battery is not connected to the charger. Large capacitor banks are normally used for this function, but these only can be switched-in with large increments under utility control. VAR compensation using bidirectional EV DC chargers can occur continuously and autonomously by measuring and compensating for the power factor.

When an EV is connected to the level 3 charger, the addition of the battery to the system can enable full 4-quadrant distribution grid support.

Utility Ancillary Services Depending on the regulations in the local utility market there may already be an open market mechanism for V2G ancillary services in regulation and reserve reduction. This can provide incremental revenue to the EV charger/vehicle owner, who can provide these ancillary services at lower cost than conventional fossil fuel generation. The primary challenges here are not technical, but regulatory and providing necessary real time control signals to the EV charger/vehicle owner.

IPC Bidirectional DC Charger/Inverter

Ideal Power Converters' (IPC) patented current-modulation topology enables a low cost bidirectional

DC charger/inverter. IPC has already developed and delivered evaluation samples of this product to NREL (National Renewable Energy Lab).

The IPC bidirectional DC charger/inverter is dramatically smaller, lighter weight, and lower cost than conventional DC chargers. IPC initial 30kW EV charger/inverter weighs only 94lbs, about one-tenth the size and weight of conventional 30–50kW chargers without bidirectional capability. Due to the small size and weight the IPC inverter can ship UPS ground and mount on a wall which reduces shipping and installation costs by up to 90%. This also enables the unit to be mounted outside conveniently near the EV parking without giving up valuable parking or exterior space.



**IPC 30kW 480V AC Bidirectional
Electric Vehicle Charger mounts
outdoors on a wall next to EV parking.**

	IPC	Conventional EV DC Charger
Input AC Volts	480V 3-phase	480V 3-phase
Output Power	30kW	30–50kW
Output DC Volts	100–800	100–550
Output Amps	60	60–120
Efficiency	96.5–97%	>92%
Power Factor	>99%	>95%
Weight	94lbs	500–660lbs
Operating Temp	-25 – +50°C	0 – +40°C
Relative Humidity	0–100%	20–80%
Mounting	Wall mount outdoor	Concrete pad (+500lbs concrete)
Bidirectional	YES	No

The IPC charger is also more efficient, and is based on the same power converter platform as its breakthrough PV inverter, simplifying UL1741 certification.

The IPC bidirectional charger is not yet CHAdeMO compliant, but it supports the necessary isolation without a transformer. It also can support the SAE emerging DC charging standard. A CAN controller interface is required and can be easily be added to its proven power converter platform.

Single Stage 3-port Bidirectional Charger

A bidirectional high power DC charging infrastructure will improve convenience and use of electric vehicles. Charging vehicles during peak summer afternoon hours can be problematic for business and utilities for several reasons.

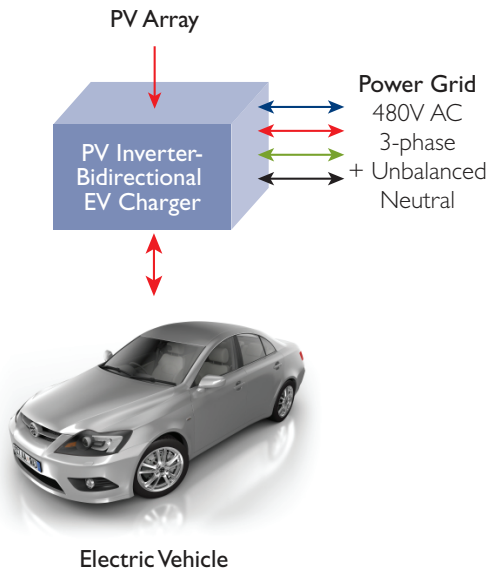
- 1) Commercial business accounts have high demand charges, and high power charging during these periods can substantially increase the commercial customer electricity costs for the entire monthly billing period.
- 2) Utilities will need to restrict high power charging during peak periods when it may contribute to brown out conditions. Utility controlled disablement of high power DC chargers may be necessary.
- 3) On smaller distribution feeders high power line capacity may not be available, particularly during peak periods.

A solution to all of these issues is to combine DC charging with PV generation or stationary energy storage. IPC will address this need with a new single stage 3-port bidirectional DC charger that can be used with either stationary batteries or PV arrays.

	IPC PV Inverter & Bidirectional EV Charger	Conventional PV Inverter & EV Charger
Converter Efficiency		
PV to grid	97%	95%
PV to EV battery	97%	88% (95% inverter x 92% charger)
EV to grid	97%	Not supported
Installation and Capabilities		
Converter Weight (30kW)	120lbs	1200lbs (PV inverter) 500lbs (EV charger)
Mounting	outside wall mount by EV parking	concrete pads (+1000lbs concrete) inside conditioned room
Microgrid capabilities	Yes	Not supported

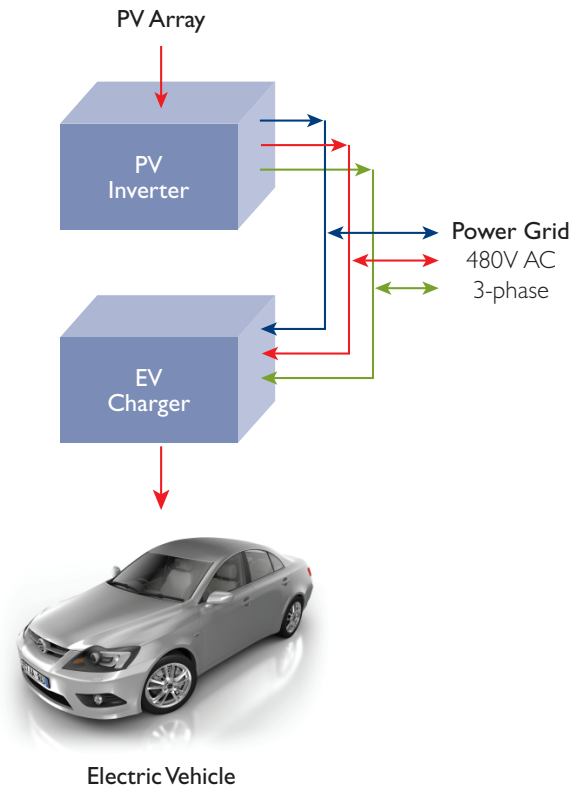
Combined PV Inverter- Bidirectional EV Charger

- 1 inverter system—lower cost & more efficient
- Operates during grid & communications faults
- Microgrid and unbalanced loads capability



Conventional PV Inverter & EV Charger

- Separate PV inverter and EV charger
- Grid-Tied, requires active grid
- Requires balanced loads



This solution has several additional benefits over conventional systems with two separate charger/inverter systems.

The power conversion efficiency from the PV array or stationary battery to the EV battery is 97% compared to about 88% from two separate conventional inverter systems. The weight and cost of the IPC 3-port system is only modestly more than the cost of one individual PV inverter or battery charger and much less than the cost of two separate systems.

Another approach is to use three power converter systems. This would include one AC-DC charger, and

two DC-DC converters—one for the EV and one for the stationary battery. This three converter approach still requires two conversion steps with lower system efficiency and higher costs than the single stage 3-port bidirectional charger.

The IPC solution is a single lightweight unit that can charge EVs during power grid and communications grid faults. During power grid faults the system can also support microgrid capabilities. With grid disconnect controls and energy storage from either a stationary battery or electric vehicle, this system can act as a short term power system for a building during a power grid failure.