



SURFACE VEHICLE RECOMMENDED PRACTICE

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Power Quality Requirements for Plug-in Electric Vehicle Chargers

RATIONALE

As the market for Plug-in Electrified Vehicles (PEVs) continues to expand, the demand on the electric grid is expected to broaden. As a result, the expectations of charging equipment, both to and from the grid, has become more demanding. This revision is updated to reflect current and future market expansion of electrified vehicle charging. Minimum requirements of power supplied to charging equipment and charger behavior are provided

FOREWORD

Designers and the vehicle manufactures that implement PEV battery chargers must understand the characteristics of the AC service to which the equipment will be connected if they are to develop products that are sufficiently robust, reliable, and cost effective to satisfy the needs of the PEV owner. The charger designer and vehicle manufacturer must also understand that the battery charger can have a significant impact on the quality of the AC service to which it is connected.

The information presented in this recommended practice may be used by charger power supply designers, managers of charger development programs, and an electric utility.

NOTE: This SAE Recommended Practice is intended as a standard practice and is subject to change to keep pace with experience and technical advances.

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1. SCOPE

The intent of this document is to develop a recommended practice for PEV chargers, whether onboard or off-board the vehicle, that will enable equipment manufacturers, vehicle manufacturers, electric utilities, and others to make reasonable design decisions regarding power quality. The three main purposes are as follows:

1. To identify those parameters of a PEV battery charger that must be controlled in order to preserve the quality of the AC service.
2. To identify those characteristics of the AC service that may significantly impact the performance of the charger.
3. To identify values for power quality, susceptibility, and power control parameters that are based on current U.S. and international standards. These values should be technically feasible and cost effective to implement into PEV battery chargers.

SAE J2894/2 will describe the test methods for the parameters/requirements in this document.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1772 SAE Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler

SAE J2836/1 Use Cases for Communication Between Plug-in Vehicles and the Utility Grid

SAE J2847/1 Communication for Smart Charging of Plug-in Electric Vehicles Using Smart Energy Profile 2.0

SAE J2894/2 Power Quality Test Procedures for Plug-in Electric Vehicle Chargers

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

ANSI C62.41 Recommended Practice for Surge Voltages in Lower-Voltage AC Power Circuits

ANSI C62.45 Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits

ANSI C84.1 Electric Power Systems and Equipment - Voltage Ratings (60 Hz)

2.1.3 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 60146-1-1 Semiconductor converters - General requirements and line commutated converters - Part 1-1: Specification of basic requirements

IEC 60555-2 Disturbances in supply systems caused by household appliances and similar electrical equipment - Part 2: Harmonics

IEC 60555-3	Disturbances in supply systems caused by household appliances and similar electrical equipment - Part 3: Voltage fluctuations
IEC 60718	Electrical equipment for the supply of energy to battery-powered road vehicles
IEC 61000-3-2	Electromagnetic compatibility (EMC) - Part 3-2: Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)
IEC 61000-3-4	Electromagnetic compatibility (EMC) - Part 3-4: Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A
IEC 61000-4-5	Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test
IEC 61851	Electric Vehicle Conductive Charging System

2.1.4 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE 519	Harmonic Specifications
IEEE 1159	Recommended Practice for Monitoring Electric Power Quality
IEEE 1547	Standard for Interconnecting Distributed Resources with Electric Power Systems

2.1.5 UL Publications

Available from UL, 333 Pfingsten Road, Northbrook, IL 60062-2096, Tel: 847-272-8800, www.ul.com.

UL 1741	Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources
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2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1715	Hybrid Electric Vehicle (HEV) and Electric Vehicle (EV) Terminology
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2.2.2 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE 2030.1.1	Technical Specifications of a DC Charger for Use with Electric Vehicles
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3. DEFINITIONS

3.1 AC LEVEL 1 CHARGING

A method that allows a plug-in electric vehicle (battery electric vehicle [BEV] or plug-in hybrid electric vehicle [PHEV]) to be connected to the most common grounded electrical receptacles (NEMA 5-15R and NEMA 5-20R). The vehicle shall be fitted with an onboard charger capable of accepting energy from the existing single phase alternating current (AC) supply network. The maximum power supplied for AC Level 1 charging shall conform to the values in Table 1 of SAE J1772. A cord and plug EVSE with a NEMA 5-15P plug may be used with a NEMA 5-20R receptacle. A cord and plug EVSE with a NEMA 5-20P plug is not compatible with a NEMA 5-15R receptacle.

3.2 AC LEVEL 2 CHARGING

A method that uses dedicated AC BEV or PHEV supply equipment in either private or public locations. The vehicle shall be fitted with an onboard charger capable of accepting energy from single phase AC electric vehicle supply equipment. The maximum power supplied for AC Level 2 charging shall conform to the values in Table 1 of SAE J1772.

3.3 CHARGER

An electrical device that converts alternating current energy to regulated direct current for replenishing the energy of an energy storage device (i.e., battery) and may also provide energy for operating other vehicle electrical systems. A charger can be on board or off board the vehicle.

3.4 CHARGER - ISOLATED

A charger that incorporates galvanic isolation between the AC line and the charger DC output.

3.5 CHARGER - NON-ISOLATED

A charger that provides no galvanic isolation between the AC line and the charger DC output.

3.6 CHARGER - INDUCTIVELY COUPLED

A charger where galvanic isolation is provided by the charge coupling, which is composed of two components: the vehicle inlet and the coupler. The charge coupling is actually a take-apart transformer, with the coupler comprising the transformer primary and the vehicle inlet housing the transformer secondary.

3.7 ONBOARD CHARGER

A charger located on the vehicle for the purpose of delivering DC energy to the PEV's energy storage device. Typically requires an AC input from an external EVSE.

3.8 OFF-BOARD CHARGER

A charger located externally to the vehicle for the purpose of delivering DC energy to the PEV's energy storage device. Typically requires an AC input from the site's electrical infrastructure.

3.9 PLUG-IN ELECTRIC VEHICLE (PEV)

An electric vehicle that can be recharged with an off-board source of electricity; it includes both battery electric vehicles (BEV) and plug-in hybrid vehicles (PHEV).

3.10 DC CHARGING

A method that uses a dedicated off-board direct current (DC) BEV or PHEV supply equipment to provide energy from an appropriate off-board charger to the BEV or PHEV in either private or public locations.

3.11 ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)

The conductors, including the ungrounded, grounded, and equipment-grounding conductors, the electric vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatuses installed specifically for the purpose of delivering energy from the premises wiring to the electric vehicle. Charging cords with NEMA 5-15P and NEMA 5-20P attachment plugs are considered EVSEs.

3.12 FREQUENCY VARIATION

The normal range of variation of the AC line frequency.

3.13 MOMENTARY OUTAGE

A complete loss of AC line voltage for 12 cycles (200 ms) or more.

3.14 VOLTAGE RANGE

The normal range of variability of the AC line voltage. Voltage range is generally expressed as a “percent of nominal” of the nominal value of line voltage and varies regionally.

3.15 VOLTAGE SAG

A reduction in the AC line voltage below the normal range of variability, typically of relatively short duration of 30 to 120 cycles (500 to 2000 ms).

3.16 VOLTAGE SURGE (TRANSIENT)

A temporary increase in the AC line voltage far beyond the normal range of variability that is evidenced by a sharp brief discontinuity of the waveform, typically of very short duration (sub-cycle).

3.17 VOLTAGE SWELL

A temporary increase in the AC line voltage of more than 10% of the normal range of variability at the power frequency, typically of relatively short duration of half a cycle to a few seconds (8 to 5000 ms).

4. CHARGER POWER QUALITY PARAMETERS

4.1 Displacement Power Factor

Displacement power factor is defined as the ratio of real power in watts to apparent power in volt-amperes and is expressed by the following formula:

$$\text{Total Power Factor} = \text{Real Power (kW)} / \text{Apparent Power (kVA)}$$

If voltage distortion is negligible, displacement power factor is equal to the product of displacement power factor and distortion power factor. Displacement power factor, which is the ratio of real power to apparent power at the fundamental frequency (50/60 Hz), is a measure of the phase shift that occurs between line voltage and line current when the AC line is loaded with a linear load having reactive characteristics, such as an AC motor. The line current is sinusoidal in shape but either leads or lags the line voltage in phase (see Figure 1).

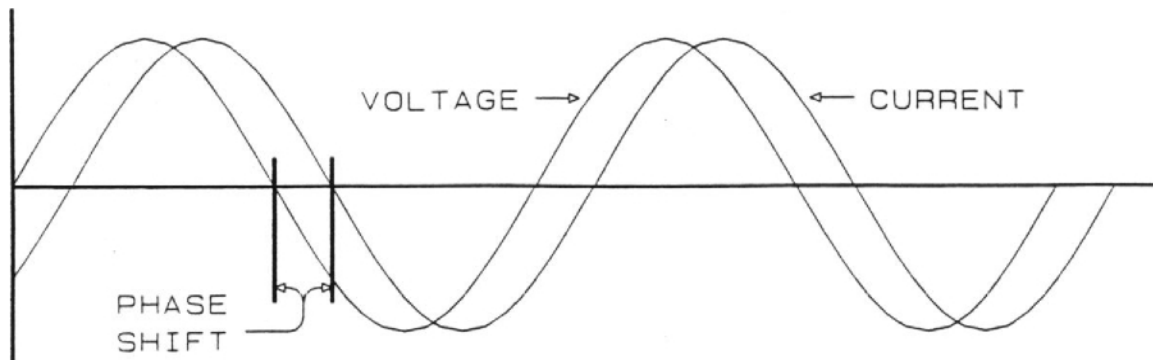


Figure 1 - AC line voltage/line current phase relationship

Current distortion is the ratio of fundamental current to total Root Mean Square (RMS) current. The line current distortion is normally the result of non-linear loading of the AC line. Most switching power supplies, except those that incorporate active power factor correction, use full wave bridge rectifiers with capacitive input filters to perform AC to DC conversion from the line (see Figure 2). The rectified AC peak charges the input capacitor to produce a DC voltage nearly equal to the peak line voltage. Because the capacitor is peak charged, the diodes in the bridge rectifier are reverse biased for most of the AC sine wave, forward biasing only near the peak of the line voltage where $V(\text{line})$ exceeds $V(\text{cap}) + 2 \times V(\text{diode})$. The resulting currents are highly distorted from the ideal sine wave and contain harmonics of the fundamental line frequency.

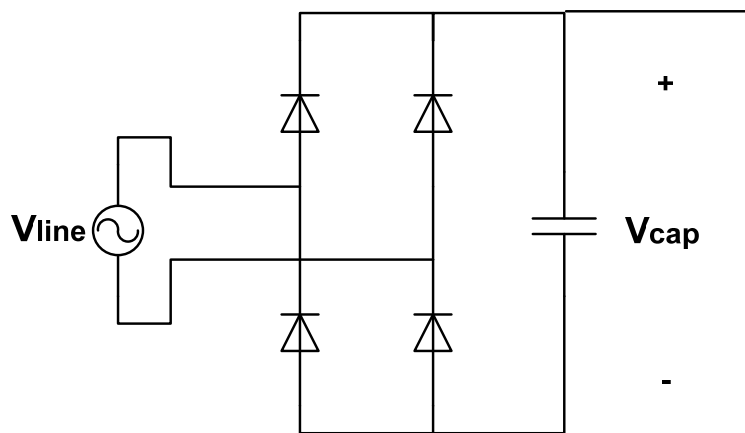


Figure 2 - Typical input circuit

Maintaining a high input power factor is important for two reasons:

- Maintaining a high-power factor minimizes reactive line current and harmonic currents of the fundamental line frequency. Because available power is limited by available line current, which is in turn limited by the circuit breaker protecting the line, minimizing reactive and harmonic currents maximizes the line current that is actually available for true power delivery.
- Minimizing reactive and harmonic currents minimizes heating of the AC service conductors for a specified delivered power. This permits optimal utilization of infrastructure and may eliminate the need to perform a service upgrade when EV battery chargers are installed.

The recommended minimum values for total power factor are defined in Table 1. These values are specified for operation at the full rated output power of the charger and do not apply to the power factor when the charger, in conjunction with the utility grid management system, actively controls its reactive power on the AC side based on signals from the electrical grid, a premises energy management system, or other power management systems outside of the vehicle or EVSE.