Application Note

Electric Vehicle Charging Systems

EMC Requirements and Compliance

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Applicable Standards: IEC 61851-21-2, SAE J2954, ISO 15118

1. Introduction to EV Charging EMC

Electric vehicle (EV) charging systems present unique EMC challenges due to high-power electronics, power line communication (PLC), and interaction with the electrical grid. Charging equipment must comply with both grid connection standards and automotive EMC requirements while ensuring safe, reliable operation.

This application note addresses EMC requirements for EV charging equipment including AC Level 1/2 chargers, DC fast chargers, and wireless charging systems. Understanding these requirements is essential for manufacturers of EV supply equipment (EVSE) and automotive charging systems.

1.1 Charging System Classifications

EV charging systems are classified by power level and charging method. Each category has specific EMC requirements based on power levels, operating frequencies, and installation environment.

Type	Power Level	Voltage	Typical Use
AC Level 1	1.4-1.9 kW	120V AC	Residential
AC Level 2	3.3-19.2 kW	208-240V AC	Residential/Commercial
DC Fast Charge	50-350 kW	200-1000V DC	Public charging
Wireless (WPT)	3.7-22 kW	85 kHz	Residential/Fleet

2. EMC Standards for EV Charging

Multiple EMC standards apply to EV charging equipment depending on charging method, power level, and geographic market. Understanding applicable standards is essential for compliance.

2.1 IEC 61851-21-2: AC and DC Charging EMC

IEC 61851-21-2 specifies EMC requirements for EV conductive charging systems. This standard addresses both emissions and immunity with special consideration for power line communication and grid interaction.

Key Requirements:

- Conducted emissions: 9 kHz - 30 MHz per CISPR 11 Group 1 limits
- Radiated emissions: 30 MHz - 6 GHz, Class B limits for residential
- Harmonic current injection: IEC 61000-3-2 (up to 16A per phase)
- Voltage fluctuations and flicker: IEC 61000-3-3
- Immunity: IEC 61000-4 series tests (ESD, RF, EFT, Surge)

2.2 SAE J2954: Wireless Charging EMC

SAE J2954 addresses wireless power transfer (WPT) systems operating at 85 kHz. Unique EMC challenges include magnetic field emissions, foreign object detection, and coil misalignment effects.

WPT-Specific Requirements:

- Magnetic field emissions: 9 kHz - 30 MHz (coupling to nearby cables)
- Electric field emissions: >30 MHz from power electronics
- Immunity during foreign object detection and alignment
- Human exposure limits: ICNIRP guidelines compliance

3. Conducted Emissions Testing

Conducted emissions from EV charging equipment can affect the electrical grid and other devices. Testing uses LISNs or Artificial Mains Networks with consideration for high charging currents.

3.1 AC Charging Conducted Emissions

AC charging equipment (Level 1/2) tested with standard 50 μH LISNs for single-phase or specialized high-current LISNs for three-phase installations. Measurements capture switching noise from onboard or external AC-DC converters.

Test Configuration:

- **LISN:** 50 μH + 50Ω, 16A or higher current rating
    - Com-Power LI-550C LISN - 100 kHz to 108 MHz, CISPR 25 and CISPR 16-1-2 compliant, 50A AC / 35A DC rating
    - Com-Power Three-Phase LISN Series - Current ratings from 16A to 100A, CISPR 16-1-2/ANSI C63.4 compliant
- **Frequency range:** 150 kHz - 30 MHz
- **Detector:** Quasi-peak and average per CISPR 16-1-1
    - Com-Power Spectrum Analyzers - CISPR-compliant with appropriate detectors
- **Load:** Resistive load bank or actual EV for realistic charging current
- **Transient Protection:**
    - Com-Power LIT-930A Transient Limiter - protects analyzer during conducted emissions testing with LISN

3.2 DC Fast Charging Conducted Emissions

DC fast chargers with 50-350 kW power levels require specialized test setups. High charging currents (up to 500A) and three-phase AC input complicate LISN selection and test configuration.

High-Current Test Requirements:

- **Three-Phase LISNs for DC Fast Chargers:**
    - Com-Power 3P Series Three-Phase LISNs - available in 16A, 32A, 63A, and 100A current ratings
    - 12 separate models of four-conductor, 50Ω, 50 μH networks
    - Designed for MIL-STD-461, CISPR 16-1-2, and ANSI C63.4
- **Current Monitoring:**
    - Com-Power Current Monitor Probes - for measuring high-current emissions
- **Testing Services:**
    - Compatible Electronics EV Charging EMC Testing - comprehensive testing for EV charging equipment

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4. Radiated Emissions and Immunity

Radiated emissions from charging cables, power electronics, and wireless charging coils must comply with limits. Immunity testing ensures reliable operation in electromagnetically noisy environments.

4.1 Radiated Emissions Testing

Radiated emissions tested in semi-anechoic chamber or OATS. Charging cable acts as antenna requiring representative cable routing. Wireless charging systems need special consideration for near-field magnetic emissions.

Test Setup:

- **Test distance:** 3m or 10m depending on installation classification
- **Frequency range:** 30 MHz - 6 GHz (1 GHz for Class B residential)
- **Antennas for Radiated Emissions:**
    - **30-300 MHz (Biconical):**
        - Com-Power AB-900A Biconical Antenna - 25-300 MHz, FCC, CISPR, EN, automotive standards compliant
        - Com-Power ABF-900A Biconical Antenna - 25-300 MHz for emissions testing
    - **200 MHz - 2 GHz (Log Periodic):**
        - Com-Power AL-100 Log Periodic Antenna - 300 MHz to 1 GHz
        - Com-Power ALC-100 Compact Log Periodic Antenna - 300 MHz to 1 GHz, compact design
    - **1-18 GHz (Horn):**
        - Com-Power AH-118 Double Ridge Horn Antenna - wideband horn antenna
        - Com-Power AH-840 Horn Antenna - 18-40 GHz
        - Com-Power AHA-118 Active Horn Antenna - integrated preamplifier for enhanced sensitivity
    - **Broadband/Hybrid Solutions (reduces antenna switching time):**
        - Com-Power AC-220 Combilog Antenna - 20 MHz to 2 GHz, reduces testing time by up to 30%
        - Com-Power ACL-6000 Combilog Antenna - 30 MHz to 6 GHz (receive), 80 MHz to 6 GHz (transmit), covers full test range with one antenna
- **Preamplifiers:**
    - Com-Power Preamplifier Line - for low-level emissions measurement
- **Cable routing:** Worst-case geometry representing actual installation
- **Operating modes:** All charging states including standby, charging, communication
- **Near-Field Probes for Debugging:**
    - Com-Power PS-400 Near Field Probe Set - for EMI source identification
    - Com-Power PS-500 Near Field Probe Set - includes contact tip probe for direct measurement

Testing Services:

- Compatible Electronics EMC Testing Services - seven semi-anechoic chambers for radiated emissions testing
- Compatible Electronics Pre-Compliance Testing - cost-effective pre-compliance scans before formal certification

4.2 Power Line Communication (PLC) Considerations

ISO 15118 and other PLC protocols are used for vehicle-charger communication. PLC frequencies (typically 1-30 MHz) overlap with the conducted emissions measurement range, requiring careful test planning and signal exclusion.

PLC Testing Challenges:

- **Frequency Overlap:** PLC signals (1-30 MHz) coincide with the conducted emissions frequency range (150 kHz - 30 MHz)
- **Signal Exclusion:** Test procedures must exclude or account for intentional PLC signals during emissions testing
- **Communication Protocol Validation:** Ensure PLC signals themselves meet EMC requirements

Test Equipment for PLC Analysis:

- **Spectrum Analyzers:**
  - Com-Power Spectrum Analyzer Products - for identifying and characterizing PLC signals
- **Current Probes for PLC Measurement:**
  - Com-Power CLCE-452 Current Probe - 9 kHz to 400 MHz, suitable for PLC frequency range
  - Com-Power CLCE-1032 Current Probe - 9 kHz to 1 GHz for broadband analysis

Best Practices for PLC EMC Testing:

1. **Baseline Measurements:** Measure emissions with PLC disabled to establish baseline
2. **PLC Signal Characterization:** Document PLC signal levels and bandwidth separately
3. **Margin Analysis:** Ensure adequate margin between PLC signals and emission limits
4. **Interoperability Testing:** Verify PLC communication functions correctly in presence of EMI
5. **Filter Design:** Implement filters that allow PLC signals while suppressing switching noise

Testing Services and Consultation:

- Compatible Electronics Wireless Device Testing - includes PLC and communication protocol testing
- Compatible Electronics Technical Consultation - expert guidance on complex EMC scenarios including PLC integration

Additional Resources for EV Charging EMC Testing

Complete Pre-Compliance Systems:

- Com-Power PC-114 Pre-Compliance Test System - 9 kHz to 1 GHz, includes spectrum analyzer, antennas, LISN
- Com-Power PC-114H Pre-Compliance Test System - extended frequency range with 3.2 GHz spectrum analyzer

Antenna Systems:

- Com-Power Complete Antenna Line - 9 kHz to 40 GHz coverage for all EV charging test requirements

LISNs and Artificial Networks:

- Com-Power LISN Product Line - single-phase, three-phase, and high-current options

Testing and Certification Services:

- Compatible Electronics EMI/EMC Compliance Testing - ISO/IEC 17025 accredited laboratory
- Compatible Electronics Medical Device Testing - radiated emissions, radiated immunity, ESD testing services
- Compatible Electronics Learning Center - EMC standards and testing information

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Key Standards for EV Charging EMC

- **IEC 61851-21-2:** Electric vehicle conductive charging system – EMC requirements for off-board charging systems
- **SAE J2954:** Wireless Power Transfer for Light-Duty Plug-In/Electric Vehicles
- **ISO 15118:** Vehicle-to-grid communication interface
- **CISPR 11:** Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics
- **EN 55011/CISPR 11:** Limits and methods of measurement for industrial equipment

Compatible Electronics can provide guidance on applicable standards and testing requirements for your specific EV charging application.

5. Design Guidelines

EV charging system EMC design must address high-power electronics, grid harmonics, cable emissions, and safety requirements. Proactive design prevents costly test failures and redesign.

5.1 Power Electronics Design

EMI Mitigation Techniques:

- Implement active power factor correction (PFC) with EMI filters
- Use soft-switching topologies (LLC, resonant converters)
- Add common-mode and differential-mode input filtering
- Minimize high di/dt and dv/dt switching transients
- Shield and filter DC output to the vehicle

5.2 Cable and Connector Design

Charging cables carry high currents, generating significant common-mode currents. Proper shielding, ferrite cores, and filtered connectors are essential for emissions control.

Cable Design Best Practices:

- Use shielded cables with 360-degree shield termination
- Add ferrite cores at both ends of the charging cable
- Implement filtered connector designs
- Minimize cable length while meeting operational requirements

6. Conclusion

EV charging systems present unique EMC challenges combining automotive, grid interface, and high-power electronics requirements. Successful compliance requires understanding applicable standards, proper test methodologies, and proactive EMC design.

Key Recommendations:

1. Understand charging type-specific EMC standards (AC, DC, wireless)
2. Address grid harmonics and power quality requirements
3. Design robust EMI filtering for power electronics
4. Implement proper cable shielding and ferrite suppression
5. Conduct pre-compliance testing with realistic loads

7. References

6. IEC 61851-21-2: Electric vehicle conductive charging system - EMC requirements
7. SAE J2954: Wireless Power Transfer for Light-Duty Plug-In/Electric Vehicles
8. ISO 15118: Road vehicles - Vehicle to grid communication interface
9. IEC 61000-3-2: Harmonic current emissions limits

For EV charging EMC test equipment and support,
contact Com-Power Corporation
www.com-power.com