Codes and Standards Support for Vehicle Electrification

2011 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review

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Sponsored by Lee Slezak

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Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Project Overview

Timeline

- Support of PHEV-Grid related standards started in 2007
- SAE J2907 Motor Rating Standards initiated in 2007

Budget

- FY2010- $300k
- FY2011- $400k

Barriers

- Establishing consensus between competing approaches to intelligently manage vehicle charge and communication
- Interoperability of vehicle-grid communication and hardware connections is a necessity for effective infrastructure deployment
- Low cost, secure, validated technology and communication standards are required coincident with PHEV/EV market introductions

Partners

- Utilities (DTE Energy, Southern Cal. Edison, Communications technology vendors)
- EVSE suppliers (Clipper Creek, Coulomb, SPX, Leviton, Ecotality, G.E. Schneider)
- Vehicle OEMS (Ford, GM, Chrysler, BMW)
- National Labs (INL, PNNL, ORNL)

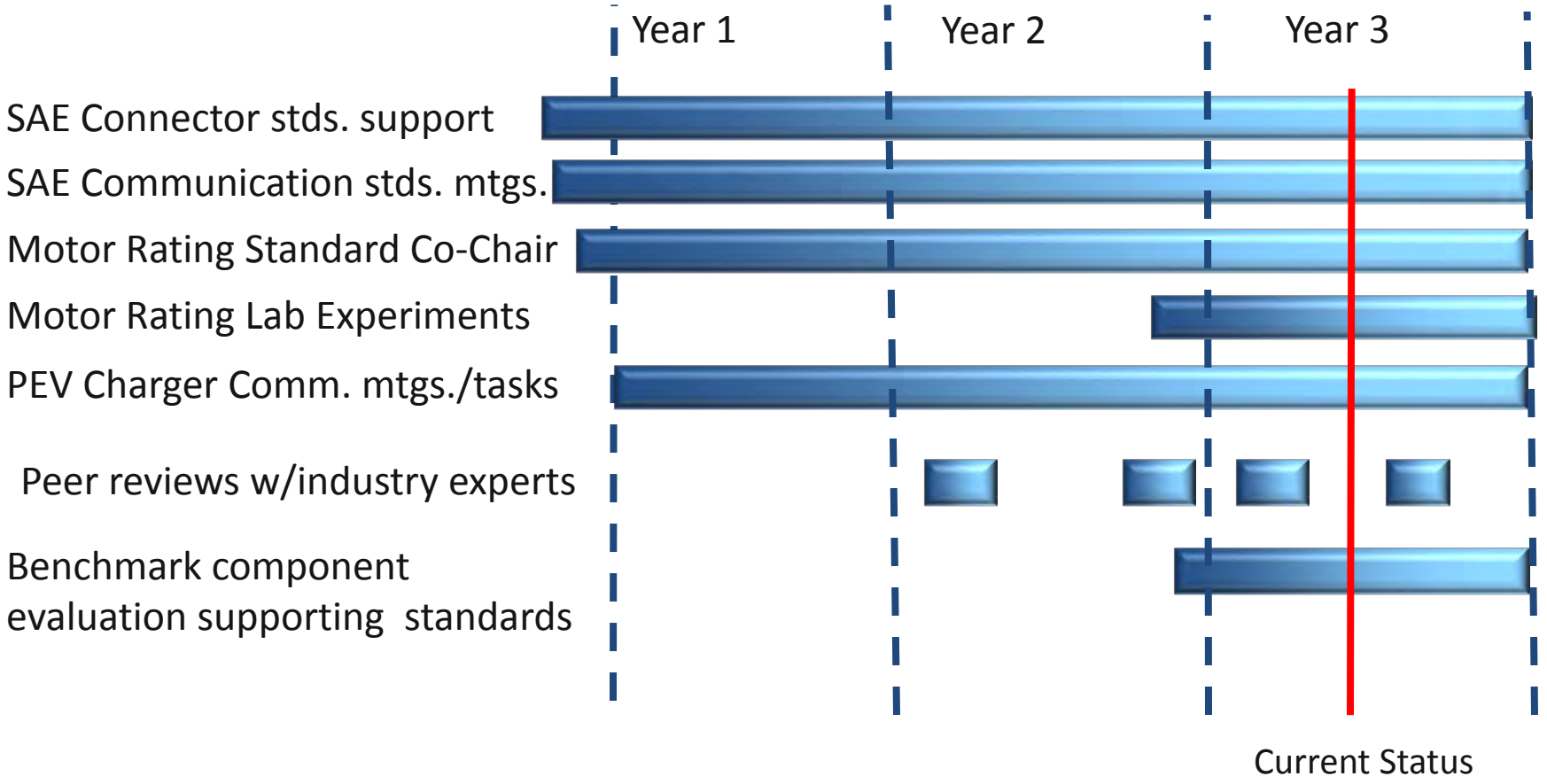
Objectives

- Address codes and standards requirements to enable wide-spread adoption of electric-drive transportation
- Encourage harmonized worldwide standards approach
- Validate adopted performance targets in a systems context

  Examples:

  - Power electronics and energy storage technology
  - Electric motor ratings standards activity
  - Energy storage system communications technology validation
- Support standards to improve grid connectivity of electric vehicle charging infrastructure via lower cost, secure, universalized wired and wireless communications technologies

Milestones


Year 1
Year 2
Year 3
SAE Connector stds. support
SAE Communication stds. mtgs.
Motor Rating Standard Co-Chair
Motor Rating Lab Experiments
PEV Charger Comm. mtgs./tasks
Peer reviews w/industry experts
Benchmark component evaluation supporting standards
Current Status

Approach – Provide Technical Support to SAE Codes and Standards

- **Address codes and standards requirements to enable wide-spread adoption of electric-drive transportation with Smart Grid Interoperability**.
  - Engage with suppliers, academia, automotive industry, and government officials to continuously assess state-of-the art
  - Provide technically sound guidance to SAE Standards committees
  - Participate with the Institute of Electrical Engineers (IEEE) and the National Fire Protection Agency (NFPA) on electrical wiring standards for charger wiring and installation requirements
  - Participate on the National Institute for Standards and Technology (NIST) in determining Smart Grid standards setting effort for the electrical utility network
  - Evaluate and validate hardware and communication protocol proposals
  - Encourage consistency with international harmonization

Approach – Support SAE PEV/EVSE Related Standards

http://www.sae.org/servlets/product?PROD_TYP=STD&HIER_CD=TEVHYB&WIP_SW=YES&ORDERBY=DOCNUM

- **J1772** SAE Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler *(J1772-DC under development)*
- **J2836** Use Cases for Communication between Plug-in Vehicles and ..
  - **J2836/1** The Utility Grid
  - **J2836/2** The Supply Equipment (EVSE)
  - **J2836/3** The Utility Grid for Reverse Power Flow
  - **J2836/4** For Diagnostic Communication for Plug-in Vehicles
  - **J2836/5** Their customers.
- **J2847** Communication between Plug-in Vehicles and …
  - **J2847/1** The Utility Grid
  - **J2847/2** The Supply Equipment (EVSE)
  - **J2847/3** The Utility Grid for Reverse Power Flow
  - **J2847/4** For Diagnostic Communication for Plug-in Vehicles
  - **J2847/5** Their customers.
- **J2931** Electric Vehicle Supply Equipment (EVSE) Communication Model
- **J2894** Power Quality Requirements for Plug-in Vehicle Chargers
  - Part 1: Requirements
  - Part 2: Test Methods

Approach – EVSE Related Standards

- **SAE 2894 Vehicle Battery Charger Power Quality and Efficiency Test Methods**
  - Use benchmark in-vehicle charger performance data, validation and iteration of sub-parts for component level testing on a load bank

Approach - SAE J2847 Communication Nomenclature Focus on Four Communication Nodes

- **Electric Vehicle Supply Equipment (EVSE)** {branch circuit coupled to PEV, off board}
- **End-Use-Measurement-Device (EUMD)** {revenue-grade submeter, PEV energy} *The physical form, location and ownership of the EUMD may be unique for different applications.*
- **PEV/Energy Management System (EMS)** Vehicle and devices use of smart loads
- **Home Area Network (HAN)/Utility** Network in user's home that connects a person's digital devices, from multiple computers and their peripheral devices to telephones, VCRs, televisions, video games, home security systems, "smart" appliances wired into the network.
- **Human Machine Interface (HMI)** HAN application characteristics that provide local user input and/or output. These are based constrained and based on the data type.

Approach – Support SAE Electric Motor Codes/Standards Activities

- **J2908 Power rating method for hybrid-electric and battery electric vehicle propulsion.**
  Scope: Test method and conditions for rating performance of complete hybrid-electric and battery electric vehicle propulsion systems reflecting thermal and battery capabilities and limitations.
  Rationale: Promote uniform testing method and harmonize global markets. At present there are no unambiguous standards for rating hybrid-electric and battery electric propulsion systems.

- **J2907 Power rating method for automotive electric propulsion motor and power electronics sub-system** (T. Bohn- chair)
  Scope: Test method and conditions for rating performance of electric propulsion motors as used in hybrid electric and battery electric vehicles.
  Rationale: Promote uniform testing method and harmonize global markets. At present there are no unambiguous standards for rating propulsion motors.

Approach - SAE Codes and Standards

- **SAE J2907** Electric motor ratings standards lack consensus based definitions of usage cycles, impulse, peak/transient, steady state.
  - Benchmark representative sample motors use to create draft usage cycle definitions.
  - Benchmark impact on rating as a function of motor cooling methods used in cycle definitions.
  - Utilize vehicle test results to determine in-vehicle peak demand.

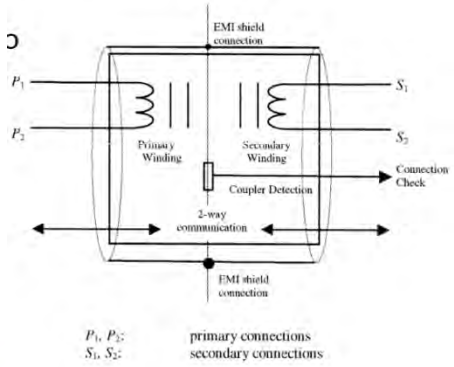
Example motor ratings- motor on left is 50kW, on right is 60kW but smaller

Proximity loss measurement and extrapolation for high speed/higher frequency motors as a function of winding materials and methods

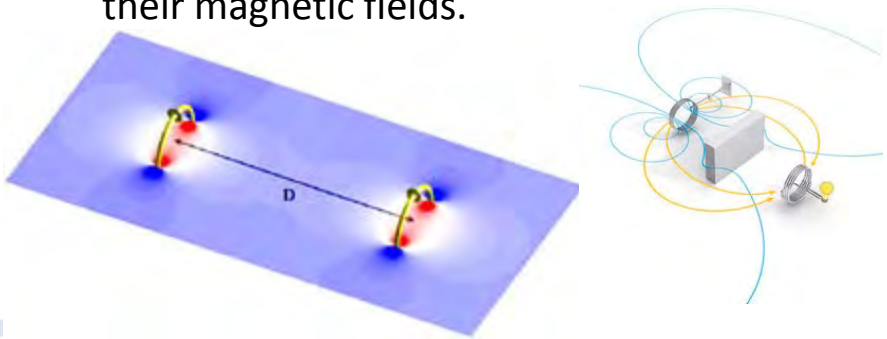
Technical Accomplishment - New SAE J2954 Committee Assessing Technology for Wireless Charging

- Automotive OEMs had great interest in potential of wireless EV charging, but there were no baseline standards. Collecting knowledge on state of the art is needed.
- DKE/European groups (IEC/ISO) working on requirements, need harmonization with US/SAE.
- New SAE Standard created as a technical information reference (TIR)- SAE J2954.
- Knowledgeable technical experts recruited as committee members (now 60+).
- Requirements pooled from existing products and future performance goals.

Inductive charging: Electromagnetic field used to transfer energy between two objects in close proximity.

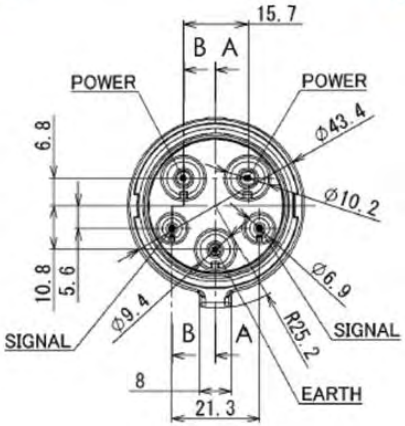


Magnetic Resonance: Based on coupling when two objects exchange energy oscillating magnetic fields. Two idealized resonant magnetic coils, shown in yellow. The blue and red color bands illustrate their magnetic fields.

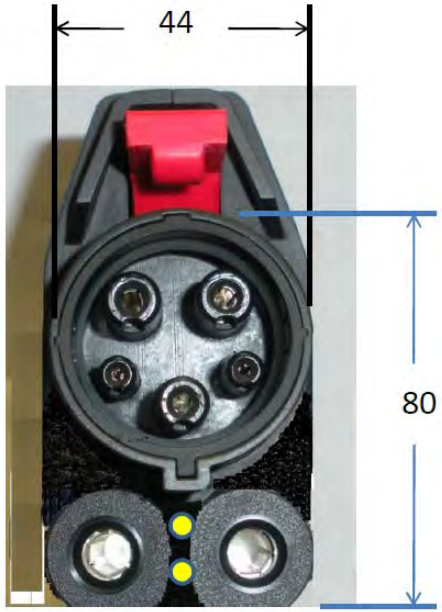


Technical Accomplishment – J1772 DC Coupler Development Continues

- SAE J1772 AC Coupler approved January 2010



- SAE J1772 DC Coupler design in process with synergy to AC coupler (allowing AC and DC coupler interface compatibility)
- Impact on mechanical design based on delays in DC message standard validation- extra pins, cascaded reqs.



Preliminary Specifications		
Voltage	600 VDC	
Current, DC	200 A	
Contacts	DC Power	8.0 mm diameter
	Ground	2.8 mm diameter
	Signal	1.5 mm diameter
Cable Sizes	DC Power (2)	AWG 1/0 (50 mm²)
	Ground (1)	AWG 6 (15 mm²)
	Signal (4)	AWG 18 (0.75 mm²)
Ingress Protection		IPX5
Weight Estimate, including 7.5m cable & mechanical assist		10.75 Kg (23.7 Lbs.)
Insertion / Extraction Force With Mechanical Assist		< 60 N

Accomplishment – Disseminate Information Charging Levels - Convenience to Fast Charge

SAE J1772 Level 1 AC 120vac, 20 branch, 15A continuous

- Carried in vehicle, uses onboard charger at less than maximum capability (typically 3kW to 7kW onboard)

Example of 120vac 15A Convenience Charger

SAE J1772 Level 2 AC 240vac, up to 100A branch, 80A continuous- 19.2kW

- Typical US installation uses a 40A branch, 30A continuous
- Uses include commercial fleets, public charging stations and residential charging stations for use with vehicle onboard charger

Example of GM Volt / Voltec™ home charging system

Charging Levels- Convenience to Fast Charge

- **SAE J1772 Level 2 DC (draft)** Up to 600vdc/~300A- 50kW+ fed by 480vac 3 phase
- **OFF BOARD CHARGING** - (expect smaller units in the future for level 1 DC- 80A)
- Approximately $20 minimum fee, 20 minute limit (at 50kW=50/3=12.6kWhr-> $1.20 of electricity at $0.10/kWhr; including service fee $20/12.6kWhr=$1.59/kWhr)

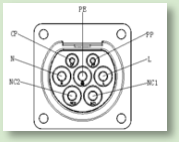
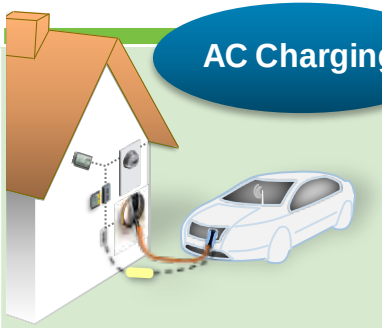
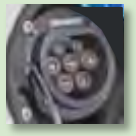
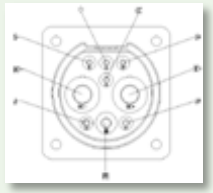
Above units use the JEVS105-1993 (JARI) DC coupler

Accomplishments – Progress Toward Harmonization

- The SAE and IEC have been successful in harmonizing key features of the AC charging connector (low - to medium-power charging in residential and commercial applications), specifically:
- SAE J1772™ and IEC 62196-2 Type 1 are *common connectors.*
- SAE J1772™ and IEC 62196-2 Types 1, 2 and 3 have *common control signals*, allowing on-board charge control modules and software to be common between Europe and North America
  - Significant because charge couplers (i.e., primarily plastic plugs and receptacles) are inexpensive compared to development and validation of control modules and software.
- SAE and ISO/IEC are working to harmonize the DC charging connector for 'fast charge' as well, basically using the Type 1 or Type 2 'core' and adding DC contacts. Progress has been made here as well - *the DC contact location, other physical features and control signals are common*.

Accomplishments – Progress Toward Common Connectors between US, EU, China and Japan

Global Differences in Connectivity

		US	EU		CHINA	JAPAN
AC Charging	Single-Phase (1Ø)	 SAE J1772™	 IEC 62196-2 Type 1	*SAE and IEC AC standards have common control signals*	 Type 2	 SAE J1772™ *
	Single- or Three-Phase (1Ø or 3Ø)		 IEC 62196-2 Type 2  IEC 62196-2 Type 3		*China charge couplers (not standard yet) have unique control signals and overall physical shape*	*Japan CHADEMO standard has unique control signals and overall physical shape*
DC Charging 		 SAE J1772™ 'Hybrid'	 IEC 62196-2 Type 2 'Hybrid'	*SAE and IEC working toward harmonization of DC 'Hybrid' charge couplers*	 Mode 3	 JEVS G105-1993 (CHADEMO)

* SAE J1772™ AC connector has also been adopted by Korea and Australia

Summary – Status of Harmonization on J1772 Charging Station Connectors

- **AC charging in the EU and US are harmonized sufficiently**.
  - EU is working to reduce the number of connector types, which will reduce complexity
- **DC charge couplers (for fast charge) have harmonization potential**, i.e., to reduce the number of connectors and harmonize controls.
- **Differences in design and communication remain in Asia**, in particular China, but SAE and ISO/IEC continue to work toward harmonization.
  - China uses a modified version of the European AC charge coupler and has their own version(s) of a DC charge coupler; resulting in unique physical features and control signals
- **The Japanese standard includes the SAE J1772™ AC charge coupler**, but the CHADEMO DC standard has unique physical features and control signals.

Collaborations

- SAE J2907 Motor Ratings
  - ORNL
  - Vehicle OEMS : GM, Ford, Chrysler, Toyota, Nissan, John Deere, Tesla, Fisker
  - Motor manufacturers: Remy, G.E., Bosch, Azure Dynamics, Magna, etc.
- SAE J2894 Charger Efficiency/Quality
  - Charger manufacturers: Delta-Q, Magna, Azure Dynamics)
  - Utilities: PGE, SCE
- Codes and Standard: IEEE, NFPA, SAE, UL, NEC, Industry, Academia, Suppliers, Utilities, National Labs, et.al.

Activities for Next Fiscal Year

- Continue to investigate limitations and propose solutions for harmonized vehicle-grid communications technologies with emphasis on interoperability between countries as well as regions (utility districts)
  - Guide standards development for technology neutral sound outcome

- Validate performance targets in a systems context
  - Power electronics and energy storage technology
  - Electric motor ratings standards
  - Expand benchmarking hardware experiments to support validation of methods used to determine electric motor rating standards, with emphasis on cooling methods and their impact.
  - Energy storage system communications technology

Summary

- Participated in SAE and other standards organizations to provide technical direction:
  - Kept informed of technology changes and new stakeholder engagement
  - Disseminated information to DOE and other affected parties
- Provided support and leadership for codes and standards required to enable wide-spread adoption of electric-drive transportation
- Guided grid connectivity technology between electric vehicles while charging
- Evaluated proposals for lower cost, secure utility infrastructure for universalized wired and wireless communications technologies
- Validated electric drivetrain components in a systems context for establishing performance targets