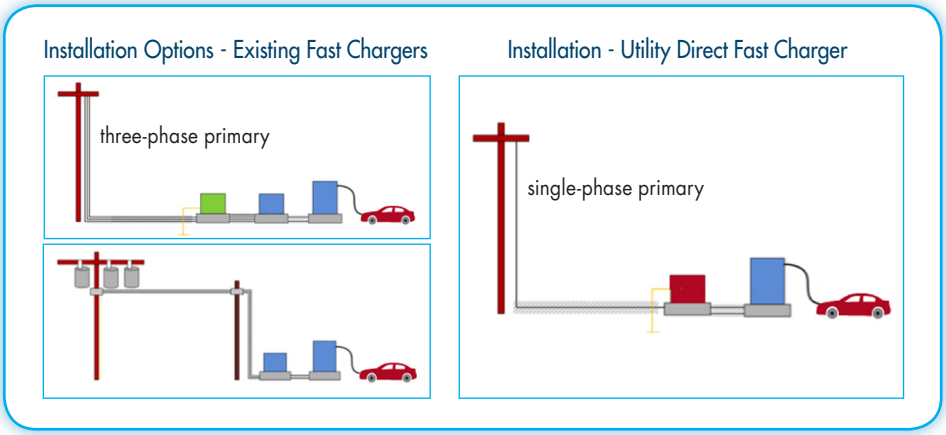
EPRI ELECTRIC POWER RESEARCH INSTITUTE

TECHNOLOGY PIPELINE

Prospectus on High-Value Strategic Innovations

SOLID-STATE TRANSFORMER: UTILITY DIRECT FAST CHARGING OF ELECTRIC VEHICLE BATTERIES



As a multifunctional solid-state transformer designed for medium-voltage service, the utility direct fast charger promises significant reductions in infrastructure and space requirements relative to current fast-charging technologies, as well as the potential to serve as a distribution system asset.

EXECUTIVE TAKE-AWAY

- Enable point-to-point charging and increase customer acceptance of battery electric vehicles
- Reduce infrastructure installation and service costs by at least one-third and create new utility assets
- Improve charging efficiency by at least 5% and deliver smart grid functionalities

THE TECHNOLOGY

Commercial plug-in electric vehicles (PEVs) have enough battery capacity to meet the typical driver's daily needs, but the hours required for battery charging present barriers to market acceptance. Direct current (DC) fast-charging technologies expand the daily range and applicability of PEVs by reducing charging times from multiple hours to well under an hour. Today's state-of-the-art fast chargers are inhibited by the need for a dedicated three-phase alternating current (AC) transformer and other components to step down medium-voltage service to appropriate levels and to meet applicable safety codes.

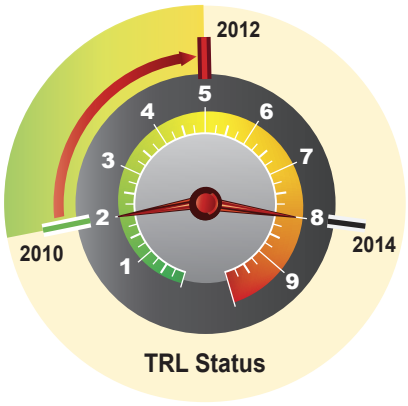
The utility direct fast charger (UDFC) is based on intelligent, solid-state transformer technology suitable for direct interconnection with the utility distribution system. It is capable of recharging PEV batteries in minutes with simplified grid integration, reduced installation costs, and significant operational benefits.

THE VALUE

The UDFC's simple design and compact footprint could deliver fast charging without extensive interconnection requirements and at operational efficiency exceeding that of today's best systems by about 5%. These features are expected to allow economical installation of charging stations tied directly to the medium-voltage (4 to 15 kV) distribution system in urban environments, parking structures, and buildings. They also would help extend fast-charging infrastructure and thus the practical daily driving range of current and future vehicles, as well as lower energy use per charge and PEV ownership costs.

The UDFC's abilities to precisely control two-way energy flows and DC and AC output voltages could position it as a distribution asset capable of managing power quality and real-time supply and demand. Deployed to replace existing transformers, it could provide fast charging and dispatch vehicle batteries as storage resources for smart grid operation.

ADDRESSING THE CHALLENGES



MILESTONES

- ☑ Develop IUT concepts and initiate developmental research on advanced materials, device components, and packaging
- ☑ Conduct laboratory, modeling, and optimization studies on switch, diode, and device designs
- ☑ Build UDFC prototype to establish proof of concept at distribution system voltages
- □ Refine device design and packaging based on laboratory optimization studies
- □ Integrate charging, communications, and other hardware and software
- □ Produce and validate field-ready UDFC units for demonstration in diverse settings

TECHNOLOGY READINESS LEVEL (TRL)

1. Exploratory Research
2. Concepts Formulated
3. Proof of Concept Validated
4. Subsystem Validated
5. System Validated
6. Early Demonstration
7. Demonstration
8. Early Commercial Deployment
9. Commercialization

EPRI'S ROLE

For decades, EPRI has served as a focal point of collaborative work by the automotive and utility industries. Since 2003, EPRI has been leading development of a new family of solid-state power electronics devices based on intelligent universal transformer (IUT) designs incorporating next-generation silicon carbide semiconductors. In 2010, these two lines of work came together when the UDFC was conceived as an IUT to overcome the limitations of today's fast-charging technologies.

Design development at successively higher voltages led to 2012 tests at EPRI's Knoxville laboratory demonstrating a 2.4-kV, 45-kVA prototype's interoperability with a medium-voltage grid and commercial PEV battery management system. Relying on a single solid-state interface, it showed an overall system efficiency of 96 to 97%, whereas existing fast-charger designs result in losses of about 10%. Moving from copper- and iron-based technology to semiconductor wafers and integrated circuits improves charging performance while reducing weight from above 1000 lbs to about 100 lbs and lowering installation costs by at least one-third and upwards of 50% depending on site-specific circumstances.

TAPPING THE PIPELINE: A CALL TO ACTION

Updates on the UDFC and other IUT innovations are provided on www.epri.com and through the advisory structures of the Technology Innovation Program and Power Delivery & Utilization Sector. EPRI seeks utilities, building owners, and others to host additional demonstration projects.

NEXT STEPS

For the 2.4-kV, 45-kVA UDFC, laboratory testing to optimize device design is continuing, and an integrated charging connector and communications interface is being built to industry standards. In addition, a prototype IUT capable of handling an input of 8 kV is being built to support direct vehicle-charging application on 15-kV distribution circuits. After utility-ready, production-grade units undergo validation and acceptance testing, they will be deployed for field demonstration within the service territories of Southern Company, TVA, and Northeast Utilities. Cost, performance, and reliability data will inform commercialization activities by device manufacturers, as well as utility planning.

DELIVERY PLAN

EPRI's Technology Innovation Program has transitioned the UDFC from TRL-2 to TRL-5, in the form of a 2.4-kV, 45-kVA IUT. Field demonstration and commercialization are proceeding through the Electric Transportation (18) and Distribution Systems (180) programs in conjunction with utilities and manufacturers of solid-state, high-power control devices. Early commercial application is expected in 2014.

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