Enabling Fast Charging – Introduction and Overview

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The pursuit of U.S. energy security and independence has taken many different forms throughout the many production and consumption sectors. For consumer transportation, a greater reliance on powertrain electrification has gained traction due to the inherent efficiencies of these platforms, particularly through the use of electric motors and batteries. Vehicle electrification can be generalized into three primary categories, hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs); the latter two, PHEV and BEV, are often referred to as plug-in electric vehicles (PEVs).

Plug-in electric vehicles use electricity from domestic sources, can produce significantly fewer emissions, and save American drivers a significant amount in fuel costs. The half million PEVs currently on U.S. roadways are expected to reduce U.S. dependence on imported oil by 5 billion gallons and save $2 billion in fuel costs over their useful life. Although sales of PEVs have been increasing every year, this sector constitutes less than 1% of total new vehicle sales in the U.S. annually. Providing BEVs at a cost, and with similar range and refueling experience to internal combustion engine vehicles (ICEVs) would increase wider BEV adoption. Studies have shown [1] that in areas where drivers have access to 50 kW or 120 kW chargers, such as California and Washington, the utility of PEVs increases. This means electric vehicle miles traveled (eVMT) has increased, resulting in lower vehicle emissions and imported oil consumption. Currently refueling time with a commonly available 50 kW fast charge is 3-6 times longer than gasoline refueling, depending on starting state-of-charge. Higher charging rates can reduce the fueling time by a factor of 2-4. However, there are several barriers to implementing higher rate charging that need to be addressed.

Current PEVs employ lithium-ion batteries, given their attributes for high energy or power density, which are both ideal characteristics for vehicle electrification. An energy-dense cell, or single electrochemical device, maximizes the amount of energy stored based on the weight and volume of the device. Similarly, a power-dense cell maximizes power across the weight and volume of the battery. To date, PHEVs have relied on the use of high power density cells in order to supplement the output of a downsized engine while improving efficiency and maintaining comparable performance to that of the traditional ICEV. Conversely, BEVs utilize a lithium-ion cell with high energy density to facilitate longer driving ranges. The larger size of a BEV battery pack size results in appropriate power to drive the vehicle, per customer expectations, while maximizing driving range. Because the PHEV has an engine to provide the necessary range, energy for electric range is less important. Furthermore, there is less of a business case to fast charge a PHEV given it gains the bulk of its range via refueling its gasoline or diesel fuel tank, thus these vehicles have little to no barrier for consumers to overcome from a convenience or experience standpoint.

A larger battery, however, requires more energy from the electric grid, which increases the time a vehicle needs to reach full charge. The time to charge depends on the battery chemistry and the rate at which the charger, or electric vehicle supply equipment (EVSE), can push energy into the onboard vehicle battery. EVSE have several categories which define the power delivery to the PEV. Included in this issue are more in-depth discussions of what obstacles currently face charging at up to the 400-kW rate, which will be referred to as extreme fast charging (XFC), and how XFC can be used to reduce BEV refueling time in addition to the barriers associated with implementing the technology.

XFC stands to reduce the electric vehicle refueling time to an experience a consumer can relate to their gasoline or diesel powered vehicle; ideally taking less than ten minutes to replenish approximately 200 miles of driving range. However, having charging powers of up to 400 kW is not a trivial task. It requires cooperation and coordination across many technology sectors and stakeholders, some not previously engaged in past charging network installations. The overall goal of BEV research is to provide consumers with options that can serve all or nearly all of their needs without sacrificing customs and conveniences users have become accustomed to with their ICEVs. These customs include, as example, refueling time, abundance of refueling station locations, ease of station operation, and user interface experience. To accomplish XFC, the battery technology onboard the vehicle must have not only be able to accommodate the electrochemical and thermal demands of XFC, but the battery pack and on-board electronics capable of handling the high charging power.

The Department of Energy Vehicle Technologies Office (VTO) assigned a team of researchers from three national labs to work with various industry stakeholders including automakers, battery suppliers, charging equipment developers, and electric utilities to assess the feasibility of high rate charging up to 350 kW). This report identifies gaps that exist for implementing XFC from the perspective of battery, vehicle, infrastructure, and economic feasibility and is presented here as a set of independent articles. Research, development, and deployment (RD&D) activities to address these gaps are proposed in this report for the Vehicle Technologies Office and other industry stakeholders to consider.

Argonne National Laboratory (ANL), Idaho National Laboratory (INL), and National Renewable Energy Laboratory (NREL), with guidance from VTO, initiated this study to understand the technical, cost, infrastructure, and implementation barriers associated with high rate charging up to 350 kW. ANL, INL, and NREL worked collaboratively to identify gaps in implementation of XFC technologies from perspective battery, vehicle, infrastructure and economics. ANL led the battery area; NREL, the vehicle area; INL, the infrastructure area; and another group at ANL, the economic feasibility area. From these areas, the four articles included in this Special Issue focus on the Battery Technology Considerations, Battery Cell and Pack Design and Thermal Considerations, Infrastructure and Economic Considerations and Vehicle Design Considerations.

Through many discussions with experts and industry representatives in each area, technology gaps along with technologies ready to support charging up to 350kW were identified. These are discussed in the four articles in this Special Issue of Journal of Power Sources. RD&D needs for implementation of XFC technologies in each area were also proposed. The later report summary section will outline these findings. It should be noted that VTO, ANL, INL, and NREL held a Stakeholder Meeting on Opportunities and Barriers for XFC at NREL on September 21-22, 2016 to obtain input from other government agencies, automakers, battery suppliers, charging equipment developers, electric utilities and others. The information gathered through these discussions was critical in helping the team to identify gaps and RD&D needs for XFC technologies.

XFC implementation stands to significantly increase the adoption of PEVs, which in turn will provide significant reduction in imported oil, vehicle emissions, and fuel costs for American consumers while enhancing U.S. energy security. However, this requires progress in making batteries, power electronics and motors, vehicle and grid integration, charging infrastructure, and economic and business models.

References

1. Lutsey, N.., S. Searle, S. Chambliss, and A. Bandivadekar, “Assessment of Leading Electric Vehicle Promotion activities in United States Cities, International Council for Clean Transportation, July 2015.