How Does Charging Impact the Electrical Infrastructure

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EPRI
APEC
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Auto Industry Investing $ Billions In New PEVs
6 PEVs Arrived In 2014 and More On The Way

<table>
<thead>
<tr>
<th>Make</th>
<th>Model</th>
<th>Type</th>
<th>Body Style</th>
<th>Battery (kWh)</th>
<th>AER (miles)</th>
<th>Launch</th>
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<tbody>
<tr>
<td>BMW</td>
<td>i3</td>
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Auto Industry Investing $ Billions In New PEVs
15+ Models Are On The Way

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Macro Level View

- The US has about 300M automobiles – one each per head
- 0.1% today are PEVs – about 280,000, growing at 40% year over year
- California has over 100,000 PEVs – that is 100MW load on average, 300MW peak (about 2 power plants)
- California also required to have 1.5M PEVs by 2023 – in 9 short years – raising the peak power 15-fold – 1.5GW on average, 4.5GW on peak - that is 8-10 new power plants just to sustain EV charging
- California has projected capacity to deliver 70GW in 2016, whereas average load is 36.4GW, meaning about half of the capacity is idle and it has worsened since 2007

Systematic PEV integration with the grid enables delivery cost reduction by spreading more GWh over the same GW capacity
Cumulative PEV Sales In USA Exceed 297k (1/31/2015)

The chart shows the cumulative sales of electric vehicles (PEVs) in the USA from December 2010 to December 2014. The data includes sales from various manufacturers:

- **Nissan**
- **GM**
- **Tesla**
- **Toyota**
- **Ford**
- **Other**
- **BMW**
- **PHEV/EREV**
- **BEV**

Sales are indicated by different colored lines, with Nissan leading in sales. The x-axis represents the months from December 2010 to December 2014, and the y-axis represents the total sales in thousands.
Technology Landscape
Plug-in Electric Vehicle Charging Overview

- There are three kinds of electric vehicle charging on the market:
  - **AC Level 1**
    - 120V wall outlet or hard-wired 120V supply
    - Uses J1772 connector (or Tesla connector)
    - 1.44 kW
    - Comes with PEV
  - **AC Level 2**
    - 240V wall box, plug-in or hard-wired
    - Uses J1772 connector (or Tesla connector)
    - Most current models are 3.3 kW, 6.6 kW, or 10 kW
    - Goes up to 19.2 kW (Tesla)
  - **DC Level 2 AKA “Fast Charging”**
    - Commercial only
    - 3 phase
    - 25 kW to 100 kW
    - May use CHAdeMO, SAE Combo, or Tesla connector
Technology Landscape
Electric Vehicle Supply Equipment

- Safely provides electricity to plug-in electric vehicles
- Often called a “charger”
- Connector
  - J1772 (Level 1 and Level 2)
  - CHAdeMO or SAE Combo or Tesla (DC)
- Vary in size and style by:
  - Application
  - Location
  - Functionality (smart or dumb)

**AC Level 1**
120V at up to 16A
~3 to 5 miles of range per hour of charging

**AC Level 2**
208/240V at up to 80A
~10 to 20 miles of range per hour of charging

**DC Level 2**
500V at up to 200A
~80% re-charge in 20 to 30 minutes
Technology Landscape
Multiple Options For DC Fast Charge Connectors

SAE Combo
(USA and Europe)

CHAdeMO
(Japan)

Tesla
Power versus Time

DC “FAST” CHARGING
Up to 100+ kW

AC Level 2 CHARGING
Up to 19.2 kW

Wireless CHARGING

AC Level 1 CHARGING
Up to 2 kW
Capacity is Set by the Current Rating of the Weakest Link

The National Electric Code Views EVSE as Continuous Loads
Infrastructure - Many Challenges Remain

Residential
- Multi-unit and tenant dwellings
- Relatively high initial costs
- High adoption of Level 1 at very low cost

Workplace
- Potential has grown—see as driver of adoption
- High installation costs, scaling issues

Public Charging
- Clustering – need to build out networks
- Long-term sustainability of infrastructure
- Underestimated difficulties of locating infrastructure

Public
Workplace
Residential
Key Industry Challenges and Outlook

- **Role of utility industry**
  - Public charging, including workplace
  - Customer support
    - Understanding purchase motivators
  - Grid impact and cost/benefit analysis

- **Utility – automotive collaboration**
  - Mutual/shared customer
  - Smart charging
    - Cost/benefit analysis, proof of concept, etc.

- **Plug-in Vehicles (PEVs)**
  - Strong sales, but many concentrated in a few geographic areas
  - Expanding beyond city vehicles
  - Strong halo presence of Tesla
EPRI Has Worked On Electric Transportation For Nearly Two Decades

Research on key ET industry challenges including role of the utility, charging infrastructure, data collection / analysis, utility-automotive collaboration and market transformation

- Vehicle demonstration, data collection, and analytics
- Infrastructure systems designs, costs, & economics
- DC charging research — medium voltage fast charging
- Smart charging programs
- Utility PEV readiness support
- Service territory-specific PEV sales tracking and load forecasting
- Hub of collaboration between utilities and automakers
- Assessment of consumer expectations
- PEVs and distributed resources
- EV energy management circuit breaker

Support introduction and market success of transportation electrification
Emerging Load Management Landscape

Utility Cloud

Back Office Systems

MDMS

Concentrator

OpenADR

Providers

Aggregators
EVSP Network Operators
Telematics Providers
Internet Service Providers
Home Security Companies
Off-the-Shelf, DIY (IRIS, Staples....)

SEP2 or other

Public Internet

Telematics
Distribution Infrastructure Upgrade Cost Sensitivity to Charge Rate for a Homogeneous PEV mix
PEV Location Determination Using Smart Meter Data

Household 04 With PEV, Week Starting: Sunday, May 15, 2011

Source: Orcor

15 minute raw signal 3.7kW PEV charging
Sensitivity of Different PEV Charge Levels on Example 25KVA Distribution Transformer Loading
Increasingly High Charge Rates Create Disproportionate Grid Impacts – 3 CA Distribution Circuits

<table>
<thead>
<tr>
<th>Charge Rate</th>
<th>Count of Transformers at Risk (% of Transformers at Risk)</th>
<th>Circuit EE</th>
<th>Circuit U</th>
<th>Circuit V</th>
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<td>3.3</td>
<td></td>
<td>5 (2%)</td>
<td>7 (2%)</td>
<td>37 (23%)</td>
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<tr>
<td>6.6</td>
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<td>62 (22%)</td>
<td>88 (30%)</td>
<td>103 (64%)</td>
</tr>
<tr>
<td>9.6</td>
<td></td>
<td>192 (67%)</td>
<td>132 (45%)</td>
<td>136 (84%)</td>
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<tr>
<td>19.2</td>
<td></td>
<td>285 (100%)</td>
<td>229 (78%)</td>
<td>155 (96%)</td>
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<tr>
<td>Total Xfmrs</td>
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<td>286</td>
<td>292</td>
<td>161</td>
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9.6 kW → 45 – 84% of Transformers Potentially at Risk

19.2 kW → 78 – 100% of Transformers Potentially at Risk
Load Management Programs - Principal Approaches Within the Utility Industry

Minimal Intervention – Lack of customer involvement

- On/Off control
- Similar to A/C programs

Smart EVSE – Lack of customer involvement

- Utilities like it - allows utility to control fixed endpoint
- Network vendors like it – enables them to be aggregators
- Not so popular with consumers or OEMs

Smart Charging – Enables Customer Preferences

- Direct, low-cost, open standards-based, utility to PEV path
- Complemented by automotive telematics

Customer-focused load curtailment of PEV charging enables environmentally responsible and increased PEV mobility
Smart Charging has biggest impact near-term in asset upgrade cost containment – if done right

Challenge – how to tie distribution system stress with smart charging that responds to bulk level pricing and DR

1. Increasing PEV penetration...

2. Drives up charging demand, which can be managed to...

3. Contain the asset upgrade costs...

4. Requiring robust, secure, scalable smart charging through AMI, HAN...

5. And/or third-party telematics systems based PEV connectivity
Open Vehicle-Grid Integration Platform

- Joint utility and automotive industry effort – Determine a common interface architecture
- Single unified control interface to PEVs from OEM manufacturers
- Path to production for on-vehicle technology that is Customer-Centric
- Open and extensible standards based – OpenADR 2.0b and SEP2
- Communications through the Cloud and/or AMI/HAN
What Does the Future Hold

- Smart Grid-Enabled PEVs
- Unified Platforms for Grid Services encompassing
  - PEVs
  - Storage
  - Renewables
  - Flexible Loads
- Utility Programs that Incentivize asset utilization improvement - ‘Nega’Watts vs. MegaWatts
- Diversity of Communication Methods that are interoperable, secure, scalable and extensible
- Lowered total cost of ownership for PEVs, simplified managed charging and grid integration systems
- Happy customers and ratepayers!
Together ... Shaping the Future of Electricity

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