Smart Integration of Large-Scale Electric Vehicle Storage into the Grid: Challenges and Opportunities

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by

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Introduction

Transportation sector

• 2nd largest source of CO₂ emissions
• Contributes to 20% of global GHG
• 70% energy is utilized for road transport
• 61% emissions comes from the passenger or personal mobility related vehicles
• In India – it consumes 16.9% of total energy, and road transport accounts for around 80% of GHG emissions

Government of India's Target

• GOI has announced an ambitious target of 100% Electric Car country by 2030
• Scheme – FAME India and NEMMP
• 15 million EV by 2020 + 6-7 million EVs per year is projected thereon
• 27 million EVs on road by the end of 2022
• Assumption – Half of them would be electric cars, further equally divided into PHEVs and BEVs i.e. 6.75 million each of BEVs and PHEVs
• BEV capacity – 21.78 kWh, and PHEV capacity – 9.5 kWh
• Total battery storage capacity: 211 GW – 66% of total installed capacity of 315 GW of India as of Feb. 2017 and 120% of MNRE’s target of 175 GW renewable capacity by 2022.
• PGCIL, the CTU, is also considering developing an EV charging business and setting up charging infrastructure to help the national grid.
Introduction

Techno-Economic Aspects Covered in this Paper

• Electric vehicle (EV) charging functionality
• EV and electric utility integration: Key components in V2G system interconnection
• V2G opportunities through EV battery storage
• Utility / Government / Regulator’s concerns
• Relevant mobility attributes in EV storage system modelling
**The Electric Vehicle**

### EV Types

- Hybrid Electric Vehicles (HEVs)
- Plug-in Hybrid Electric Vehicles (PHEVs)
  - Series PHEVs
  - Parallel PHEVs
- All Electric Vehicles (BEVs)
- Fuel cell Electric Vehicles (FCEVs)

### Battery Technology

- Li-ion battery
  - High energy density
  - Lifetime
  - Number of charge discharge cycles

### Why Transportation Electrification?

- Sustainable environment
  - 28% of worldwide energy consumption
  - 2nd largest source of CO₂ emission - 20% of global GHGs
  - Continuously growing travel demand for personal vehicles
- EV benefits
  - High fuel economy, low operating cost
  - High performance
  - Low emissions
  - Energy security
  - Flexible fueling

### Barriers in EV Adoption

- High EV cost
- Long charging time
- Costly charging infrastructure

- Charging facility availability
- Range anxiety
- Battery Energy Density
The Electric Vehicle

Best Electric Cars

<table>
<thead>
<tr>
<th>Car Model</th>
<th>Capacity (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nissan LEAF</td>
<td>24</td>
</tr>
<tr>
<td>Fiat 500e</td>
<td>24</td>
</tr>
<tr>
<td>Volkswagon e-Golf</td>
<td>24</td>
</tr>
<tr>
<td>Ford Focus Electric</td>
<td>23</td>
</tr>
<tr>
<td>BMW i3</td>
<td>22</td>
</tr>
<tr>
<td>Smart Electric Drive</td>
<td>17</td>
</tr>
<tr>
<td>Chevrolet Spark EV</td>
<td>19</td>
</tr>
<tr>
<td>Tesla Model S</td>
<td>40, 60, 70, 85, 90</td>
</tr>
</tbody>
</table>

Top EV Charging Networks

- CHARGEPOINT
- BLINK NETWORK
- SEMACONNECT
- SHOREPOWER CONNECT
- GE WATTSTATIONS
- TESLA SUPERCHARGERS
## Electric Vehicle Charging Functionality

<table>
<thead>
<tr>
<th>Charging Type</th>
<th>Voltage level</th>
<th>Current Level</th>
<th>Power Level</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Level 1</td>
<td>120 V</td>
<td>12-16 A</td>
<td>1.2-2.5 kW</td>
<td>1-Φ</td>
</tr>
<tr>
<td>AC Level 2</td>
<td>208-240 V</td>
<td>12-80 A</td>
<td>2.5-19.2 kW</td>
<td>1-Φ</td>
</tr>
<tr>
<td>DC Level 1, 2 and 3</td>
<td>200-600 V</td>
<td>≤ 80-400 A</td>
<td>≤ 19.2 - ≤ 240 kW</td>
<td>DC</td>
</tr>
<tr>
<td>Middle Rate DCFC (DC Level 2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHAdeMO</td>
<td></td>
<td>Up to 50 kW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SAE Combo / CCS</td>
<td></td>
<td>Range rating: up to 100 kW</td>
<td></td>
</tr>
<tr>
<td>High Rate DCFC (DC Level 3)</td>
<td></td>
<td></td>
<td>Up to 150 kW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BYD Tesla Superchargers</td>
<td></td>
<td>Range rating: up to 200 kW</td>
<td></td>
</tr>
</tbody>
</table>
To utilize electric vehicles as a RESOURCE – load / generation for grid services.
Collaborative Vehicle–Utility Interface: Key Components in V2G System Interconnections

Vehicle Aggregator (A proposed entity)
- To control and provide interface of large pool of EVs (capacity in MWs range) to the operator
- Individual communication of EVs with the operator will be impractical
- A few kW appears merely a noise at the power system level

Electric Vehicle Supply Equipment (EVSE)
- Encompasses metering and bidirectional communication interface
- Grid connection for power transfers

Communication / Control Infrastructure
- Enables the needed monitoring
- Flow of control/command signals to interact with individual EVs as well as system operator
- For the provision of billing information and payments for the services

Battery Management System (BMS)
- Assimilation of sensors, communication, computation, and control hardware which takes into account the SOC and SOH of the battery pack to determine the charge and discharge power to/from it.
V2G Opportunities: Grid Point of View

Charging / Discharging control to provide grid services
- Regulated charge/discharge: V2G - Peak power support
- Demand response
- Spinning, supplemental and replacement reserve

Power system frequency regulation to the TSO
- Charging - G2V - Regulation down
- Discharging - V2G - Regulation up

Load levelling/ Valley filling / Peak shaving
- Rides out the load fluctuations
- Reduced energy and reserve requirements, and maintenance and operation cost
- Dispatch for a flat load is far less complex than for a fluctuating load

Integration / storage of intermittent renewable energy sources
- Can compensate variability of electric supply
- Integrate more renewable energy sources - Target toward reducing carbon footprint

Congestion management, voltage profile improvement, and loss reduction
- DER at receiving end, reducing I and VD with peak shaving / valley filling.

Mitigation of power quality problems, Q compensation
- P–Q control in bidirectional switching cell converters of EV chargers

EV as Storage
## Utility/Regulator’s Perspective: Managing the Smart Charging

### Operational and planning resources for infrastructure
- Distribution capacity (Transformers, substations, feeders, protective devices etc.)
- Transmission and generation capacity addition

### Control of the grid
- Peak EV load imposed
- Load levelling
- Peak shaving/valley filling
- Geographical uncertainty: EV clustering

### New grid features - dedicated metering
- Tariff system like TOU rate system
- Intelligent meters to segregate transportation consumption from others
- Location monitoring to track and bill the exact customers

### Third party charging network / stations
- Regulatory challenges to enter into the market
- How utilities will be paid for the power consumed by third party owned/operated charging stations

### Role of utilities over management of charging stations
- Utilities role in EV marketplace
- Business models for installation and governing of charging stations

### - Barriers in EV adoption
- Economic viability
- High cost, **charging point availability (ease + speed)**, charging time, range anxiety, costly charging infrastructure
- Economic benefits of V2G and willingness to participate
Mobility Attributes in EV Storage Modelling

- EV types and their equilibrium
- Trips, their types and driven mileages
- Arrival/departure times and travel/parking duration
- Charging/discharging process
- Charging/discharging power levels
Conclusion

- **Creation of charging/discharging facility business structure**
  - Market environment to facilitate smart G2V/V2G operations for grid services

- **Set up of aggregation system to control large fleet of EVs**
  - Enabling control and interfacing of rapidly controllable MWs of storage

- **Establishment of control/communication infrastructure**
  - Monitoring of system and flow of control/command signals, information and payments

- **Assessment of grid level impacts of EVs**
  - Peak load impacts and distribution system loading due to clustering of EVs
  - Impact charging/discharging power, charging/discharging process considering vehicle’s heterogeneity

- **Economic benefits and feasibility justification**
  - Engaging customers in demand response program – reduced rate for EV charging
  - Interactions with customers notifying energy savings information and GHG reductions
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I look forward to receiving your valuable comments and suggestions

Thank You

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