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

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Outline

- Introduction
- The Electric Vehicle
- Electric Vehicle Charging Functionality
- Vehicle-Utility Interface: Key Components in V2G System Interconnections
- V2G Opportunities: Grid Point of View
- Utility / Regulator's Perspective: Managing the Smart Charging
- Mobility Attributes in EV Storage Modelling
- Conclusion

Introduction

Transportation sector

- 2^{nd} largest source of CO_2 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

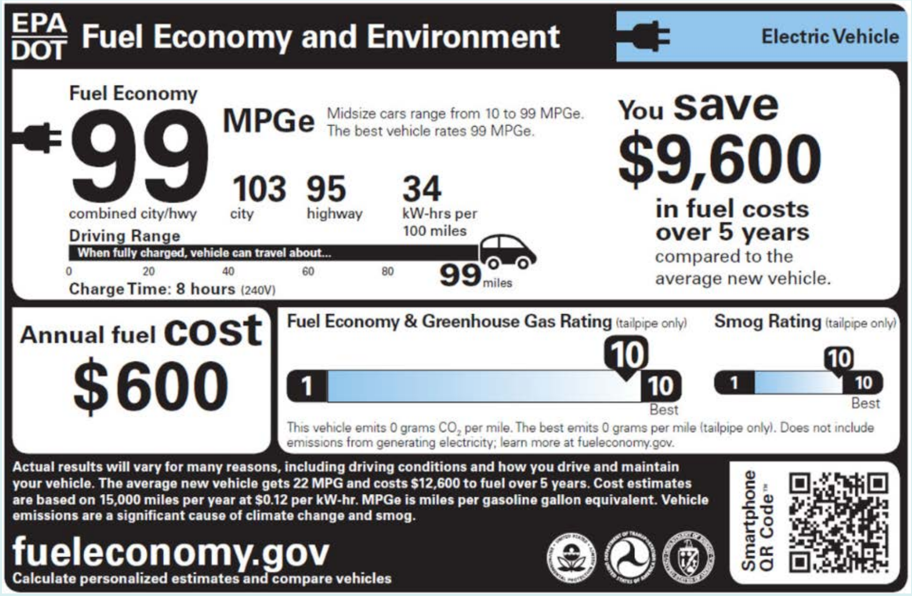
Why Transportation Electrification?

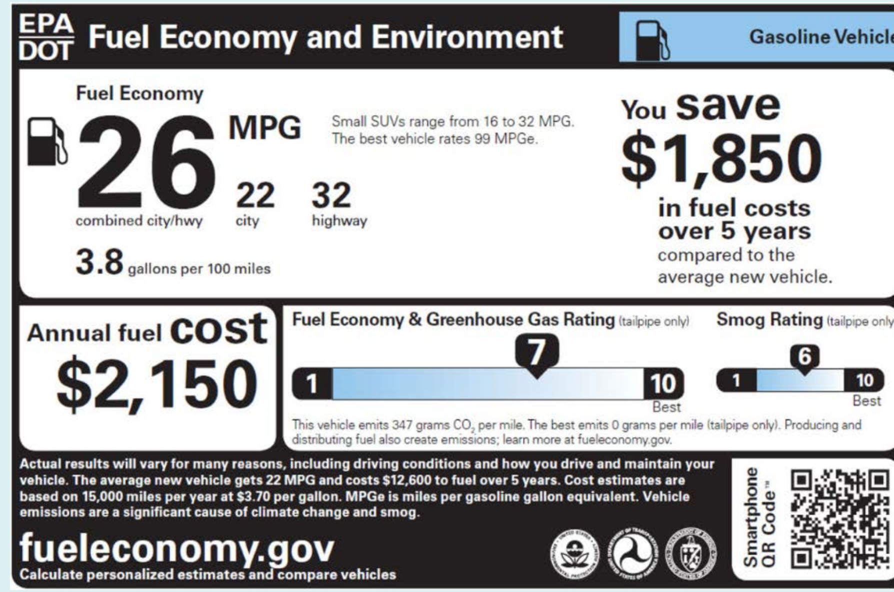
- Sustainable environment
  - 28% of worldwide energy consumption
  - 2nd largest source of CO_2 emission
  - 20% of global GHGs
  - Continuously growing travel demand for personal vehicles
- EV benefits
  - High fuel economy, low operating cost
  - Flexible fueling
  - High performance
  - Low emissions
  - Energy security

Barriers in EV Adoption

- High EV cost
- Long charging time
- Costly charging infrastructure
- Charging facility availability
- Range anxiety
- Battery Energy Density

The Electric Vehicle

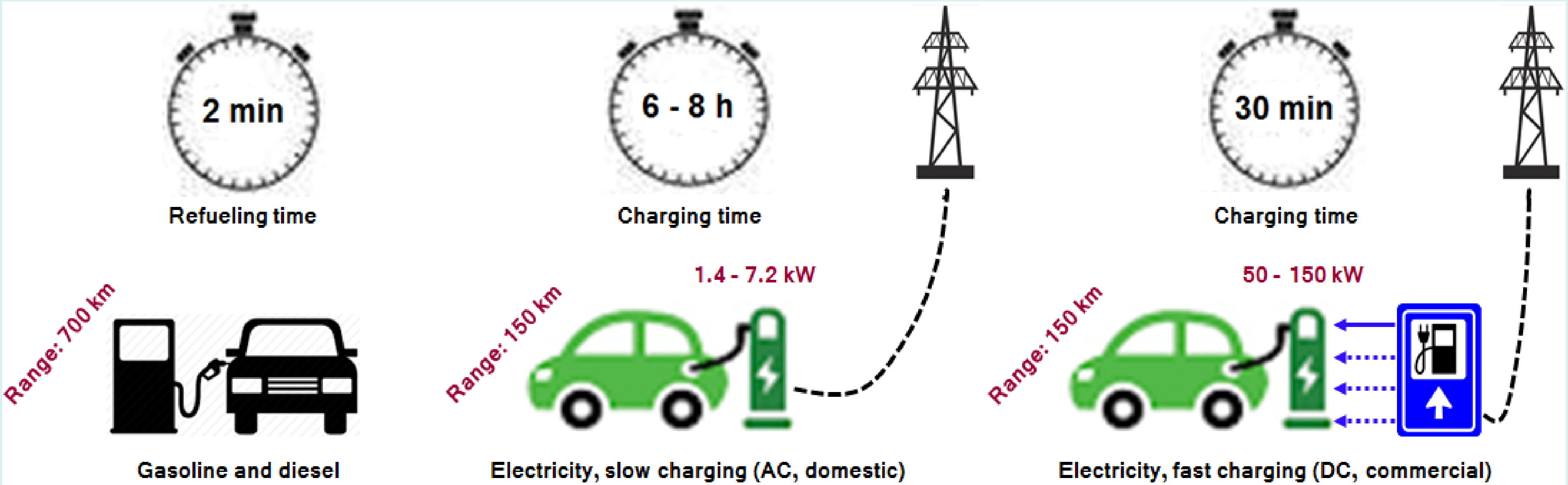




Best Electric Cars	Capacity (kWh)
Nissan LEAF	24
Fiat 500e	24
Volkswagon e-Golf	24
Ford Focus Electric	23
BMW i3	22
Smart Electric Drive	17
Chevrolet Spark EV	19
Tesla Model S	40, 60, 70, 85, 90

Top EV Charging Networks
CHARGEPOINT
BLINK NETWORK
SEMACONNECT
SHOREPOWER CONNECT
GE WATTSTATIONS
TESLA SUPERCHARGERS

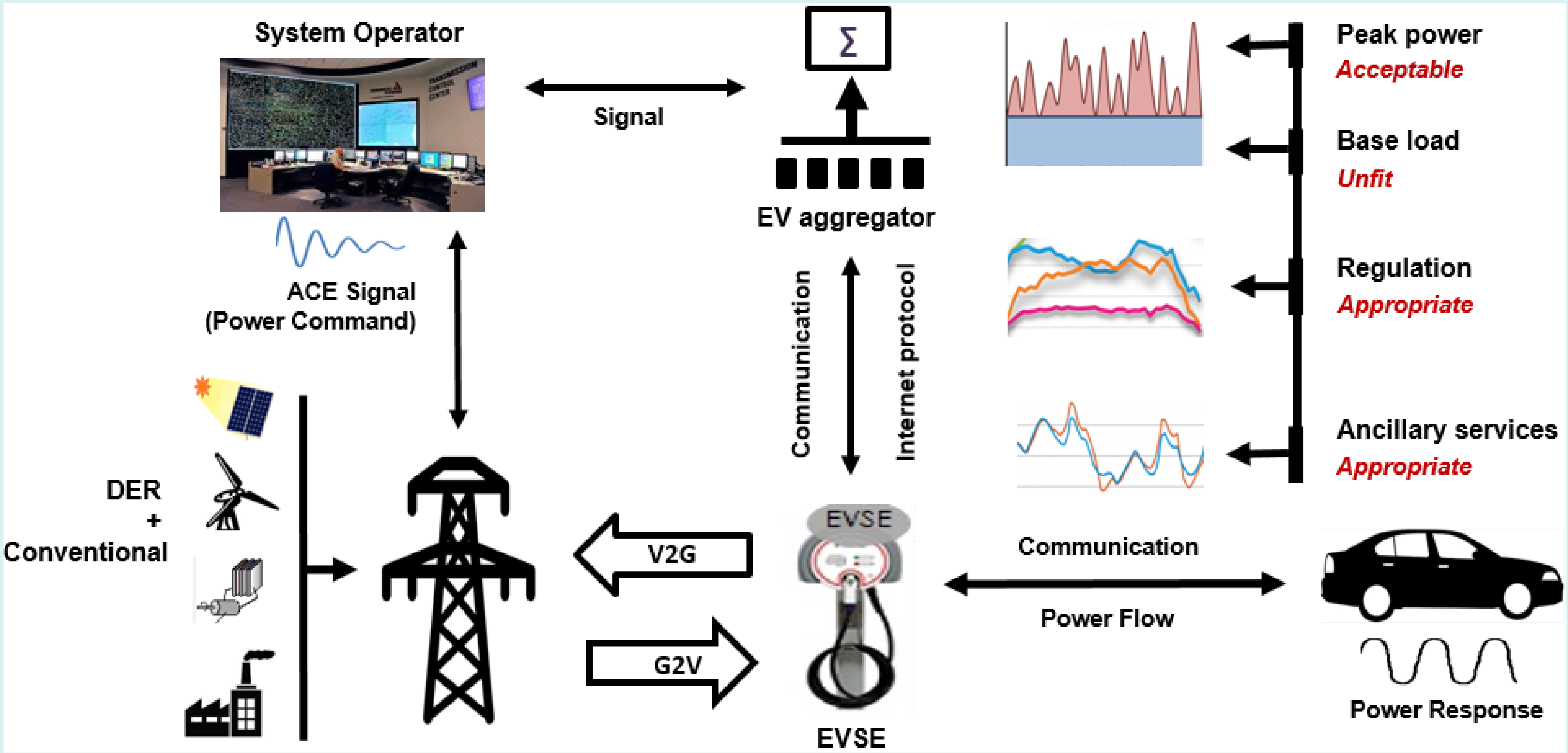
Electric Vehicle Charging Functionality



Charging Type	Voltage level	Current Level	Power Level	Phase
AC Level 1	120 V	12-16 A	1.2-2.5 kW	1-Φ
AC Level 2	208-240 V	12-80 A	2.5-19.2 kW	1-Φ
DC Level 1, 2 and 3	200-600 V	≤ 80-400 A	≤ 19.2 - ≤ 240 kW	DC
Middle Rate DCFC (DC Level 2)	**CHAdeMO SAE Combo / CCS**		**Up to 50 kW Range rating: up to 100 kW**	
High Rate DCFC (DC Level 3)	**BYD Tesla Superchargers**		**Up to 150 kW Range rating: up to 200 kW**	

Collaborative Vehicle–Utility Interface: Key Components in V2G System Interconnections

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

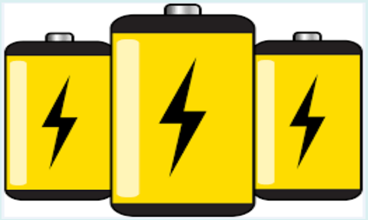
- Enables the needed monitoring
- Flow of control/command signals to interact with individual EVs as well as system operator
- For the provision of billing information and payments for the services

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

EV as STORAGE



Charging / Discharging control to provide grid services

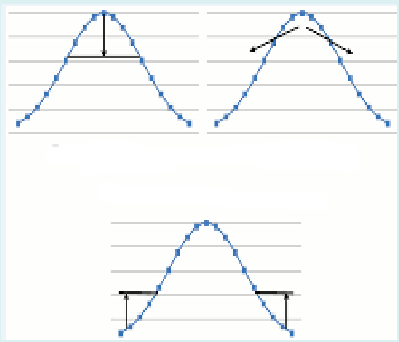
- Regulated charge/discharge: V2G - Peak power support
- Demand response
- Spinning, supplemental and replacement reserve

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

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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