सत्यमेव जयते

भारत सरकार/ **Government of India**

विद्युत मंत्रालय/ **Ministry of Power**

केन्द्रीय विद्युत प्राधिकरण/ **Central Electricity Authority**

ग्रिड प्रबंधन प्रभाग/ **Grid Management Division**

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सं.: 12/एक्स/एस.टी.डी.(सी.ओ.एन.एन)/जी.एम./2023/ **दिनांक: 03.08.2023**

विषय: दिनांक 17.07.2023 (सोमवार) को अपराह्न 03:00 बजे ईवी की बैटरियों से ग्रिड की रिवर्स चार्जिंग पर दिशानिर्देश तैयार करने आवेदनों से संबंधित मुद्दों पर उप-समिति की बैठक के कार्यवृत्त।

Minutes of the Meeting of the Sub-Committee held on 17.07.2023 (Monday) at 03:00 PM to frame Guidelines on Reverse Charging of Grid from batteries of EVs.

दिनांक 17.07.2023 (सोमवार) को अपराह्न 03:00 बजे आयोजित उप-समिति की बैठक के कार्यवृत्त आपकी जानकारी एवं आवश्यक कार्यवाही हेतु संलग्न है। **यह पत्र सक्षम अधिकारी द्वारा अनुमोदित है।**

Please find enclosed the minutes of the meeting of the sub-committee held on 17th July 2023 at 03:00 AM. It is issued on approval of Competent Authority.

<u>संलग्नक:</u> यथोपरि।

चंद्र 3/8/2023

(चंद्र प्रकाश)

(मुख्य अभियन्ता)

<u>बैठक के सभी प्रतिभागियों को ई-मेल द्वारा प्रेषित</u>

Minutes of the Meeting of the Sub-Committee held on 17.07.2023 (Monday) at 03:00 PM to frame Guidelines on Reverse Charging of Grid from batteries of Electric Vehicles

As per the minutes of the 1st meeting of the committee to frame guidelines on reverse charging of grid from batteries of Electric Vehicles (EVs) held on 10.05.2023, a sub-committee was formed to analyse the various technical aspects for reverse charging of grid from EVs. Accordingly, a meeting of the sub-committee was held on 17.07.2023 (Monday) with participants from IIT Bombay, IIT Delhi, IIT Roorkee, BSES Rajdhani Power Limited (BRPL) and EVSE and EVs OEMs. The list of the participants is enclosed at **Annexure-I**.

2. Assistant Director (PSPM), CEA gave a brief presentation on the Vehicle-to-grid (V2G) services, concepts of smart charging, V2G system and architecture, technical requirements in hardware and software, challenges in V2G etc. A copy of the same is enclosed at **Annexure-II.**

3. Chief Engineer (R&D), CEA stated that the purpose of the meeting is to understand the EV reverse charging challenges from the technical aspects and the economic viability which will be used for framing guidelines by CEA.

4. Chief Engineer (GM), CEA stated that the focus should be on the technical aspects and the regulatory changes that are required for V2G in the existing CEA (Technical Standards for connectivity to the Grid) Regulations. He requested the participants to present their views on the same lines.

5. The representative of BRPL stated that most of the EVs currently plying in the country are currently two or three wheelers which have small battery sizes. Further, there is no inverter either in the vehicle or in the chargers due to which EVs cannot be used for V2G operations. Further, the electric buses have higher capacity batteries but the challenge is that they are could be available only during night time under charging mode and hence less support would be available in the grid at that time. Therefore, four wheels electric vehicles could be used to support the grid. In four wheels electric vehicles, both AC-DC and DC-AC charging is available but presently 40-50% of the cost of EVs comprises of battery cost and probably nobody would be willing to deteriorate the health of the battery by cycle aging unless suitable incentives are provided to the users of these vehicles.

It was stated that BSES have successfully demonstrated the V2G in its pilot project of 5 MW battery swapping station whereby the charging is done during off-peak hours and the grid support through the BESS is during peak hours. A report is under preparation to be submitted to DERC. Chief Engineer (GM), CEA requested the representative of BRPL to share the report with this committee as well.

6. Prof. Anil Kulkarni, IIT Bombay stated that the discussions on the V2G bear a resemblance to that of smart charging management (V1G). The IEEE Standard 1547 can be looked into although not directly related with the current discussion but some aspects can be considered while preparing broad guidelines regarding V2G, as it is related to harmonic

injection from Distributed Generators. The scope and benefits of doing only reactive power compensation in V2G mode may be relevant. e.g., reactive power support to the grid (as opposed to peak power shaving) offers the benefit of grid stabilization while having no harmful effect on battery life (as energy is not drawn from the battery since it can be supplied by an adequately-sized dc-link capacitor of the on-board charger). Apart from this charging management can be used for frequency control using vehicle as load as well as generator based on the grid requirement.

7. Prof. B.K. Panigrahi, IIT Delhi stated that the concept is at nascent stage and should be done at aggregator level rather than going for grid, as it will involve various other parameter like tariff. Apart from this, communication between vehicle-grid and short circuit study needs to be address to understand the system working.

8. The representative of TATA Power stated that majority of EVs sold in India has a battery capacity ranging from 25 kWh to 50 kWh capacity and the average running is about 40-60 km/day. Therefore, the remaining State of Charge (SoC) available after a day would be around 60-70%. In general being a slow charger, capacity of 3.3 kW or 6.6 kW for a period of 2-3 hours would be available for reverse flow to the grid. Further, it can support the grid thereby reducing the SoC by 20-30% and thereafter the battery would be required to be charge.

The representative of TATA Power further stated that at one of the battery swapping stations, high fault level test was conducted, wherein better support was provided by BESS due to on-time availability. However, this would be complicated in a power distribution system where individual EVs are getting connected-disconnected to the system as per the requirements of individual EV owners. He proposed that a society can aggregate vehicles at a common place which can be used to support the society during peak times when vehicles are at standby mode at the charging parking space in the society. The benefit of having an aggregated capacity at one connection point would help in better managing the grid stability or this concept could be used as a model to understand the implications of the reverse charging of the grid.

He also added that there are different chargers in market i.e. in AC charging, the inversion takes place inside the car and in case of Fast DC charging, the charger converts the incoming AC to DC which can be supplied directly to the EVs battery. The fast DC charging system was suggested for use in V2G as the conversion and inversion takes place on the charging station. The space in the cars can be used to fit more batteries in the car.

9. The representative of CharIn EV stated that the current infrastructure present in Indian market is not ready for bi-directional flow of current and an update in hardware as well as software is needed to support the same. The OEMs will ultimately decide V2G operations as the power output rate, pulse width and other technical aspects are in their jurisdiction. The customer should also be given the option of changing settings regarding V2G based on their itinerary.

10. Chief Engineer (GM), CEA stated that the Government of India is emphasising towards Carbon Neutrality by 2070, thereby, *interalia*, there is policy push for electrification of transportation sector as a whole. This will lead to more charging station installations in the near future, so the guidelines w.r.t V2G will help in having the technology that will support bi-directional flow of current to support future grid demands.

11. The representative of TATA Motors stated that the bi-directional technology can be embedded in the car or the charging point by the OEMs. The worldwide practice of the bi-directional technology in car can be looked upon to understand its working mechanism and to calculate the cost rise due to it.

12. Chief Engineer (GM), CEA asked the OEMs to look upon the technical aspect of the technology irrespective of the cost or incentive at this point of time as this could be looked into after the technical details have been formulated.

13. The representative of Delta Electronics stated that their team has worked on bi-directional chargers which are being sold in European markets but the Indian market is different and have to plan accordingly for Indian markets. The representative of Delta Electronics also stated that the EV battery needs to be retired from the vehicle after a certain point of time and the second life of battery can be used in the battery swapping stations rather than going for V2G. This will eliminate the need for disposing off of battery and will also support in government ESS development programme.

14. The representative of ABB stated that they have implemented V2G technology in Japan and France and will share their experience with the CEA regarding the same.

15. The representative of CITY FORUM shared the experience of European market where V2X and V1G are being explored using pilot projects. They have defined functionality requirement for V2X vehicles using AC and DC technology like minimum active power which should be allowed for this purpose. As of now, no such guidelines are being framed in European market but OEMs are pushing them to go for such solutions by inventing converters of low capacity that can be installed specifically for V2X solutions. The requirements w.r.t communication of the V2X, data exchange is also an important part to look upon while framing guidelines as there can be potential risks associated to it.

16. Member (Power System), CEA stated that the foremost challenge is safety hazard related to fire in batteries. The rate of degradation of battery as well as the temperature range of operation of battery should also be looked upon in the study as higher exchange rate of electricity could increase the temperature of battery leading to fire. During V2G, some thresholds need to be defined below which the battery shouldn't be allowed to discharge, say 20% charge shall always remain there. There shall be proper control on rate of discharge, Fire safety, voltage surge protection/transient protection, temperature control of battery, protection from battery fire. The ideal system would be to have EVs that are made for vehicle-to-home (V2H) as it would address the problem of peak demand and would also resolve the issue of metering which otherwise would persist if V2G is implemented. He further added that the charging socket configuration need also be looked upon which would support the bi-directional flow of electricity.

17. Chief Engineer (R&D), CEA thanked all the participants for their inputs. Further, the pilot project conducted by TATA Power, BRPL and ABB can be studied to understand the bi-directional flow of current. The aggregator concept as discussed can be explored more with involvement of EV fleet owners.

18. Chief Engineer (GM), CEA requested all the participants to share their inputs on the draft report discussed in the meeting at the earliest for finalisation of guidelines by CEA.

The meeting ended with thanks to the Chair.

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Annexure-I

List of participants in the meeting on 17/07/2023 at 03:00 PM

Central Electricity Authority (CEA)

1. Sh. Ashok Kumar Rajput, Member (Power System)
2. Sh. Surata Ram, Chief Engineer (Renewable Technology and Integration)
3. Sh. Chandra Prakash, Chief Engineer (Grid Management)
4. Sh. Himalaya Shubham, Deputy Director (Grid Management)
5. Sh. Sandeep Kumar, Deputy Director (Grid Management)
6. Sh. Shubhender Singh, Assistant Director (Grid Management)
7. Sh. Karan Sareen, Assistant Director (Power System Project Monitoring)
8. Sh. Dhruv Kawat, Assistant Director (Grid Management)
9. Sh. Sakil Ahmad, Assistant Director (Grid Management)
10. Sh. Shubam Kumar Singh, Assistant Director (Grid Management)

IIT Bombay

1. Sh. Anil Kulkarni

IIT Delhi

1. Sh. BK Panigrahi

IIT Roorkee

1. Sh. Bhavesh Bhalja

BSES Rajdhani Power Limited (BRPL)

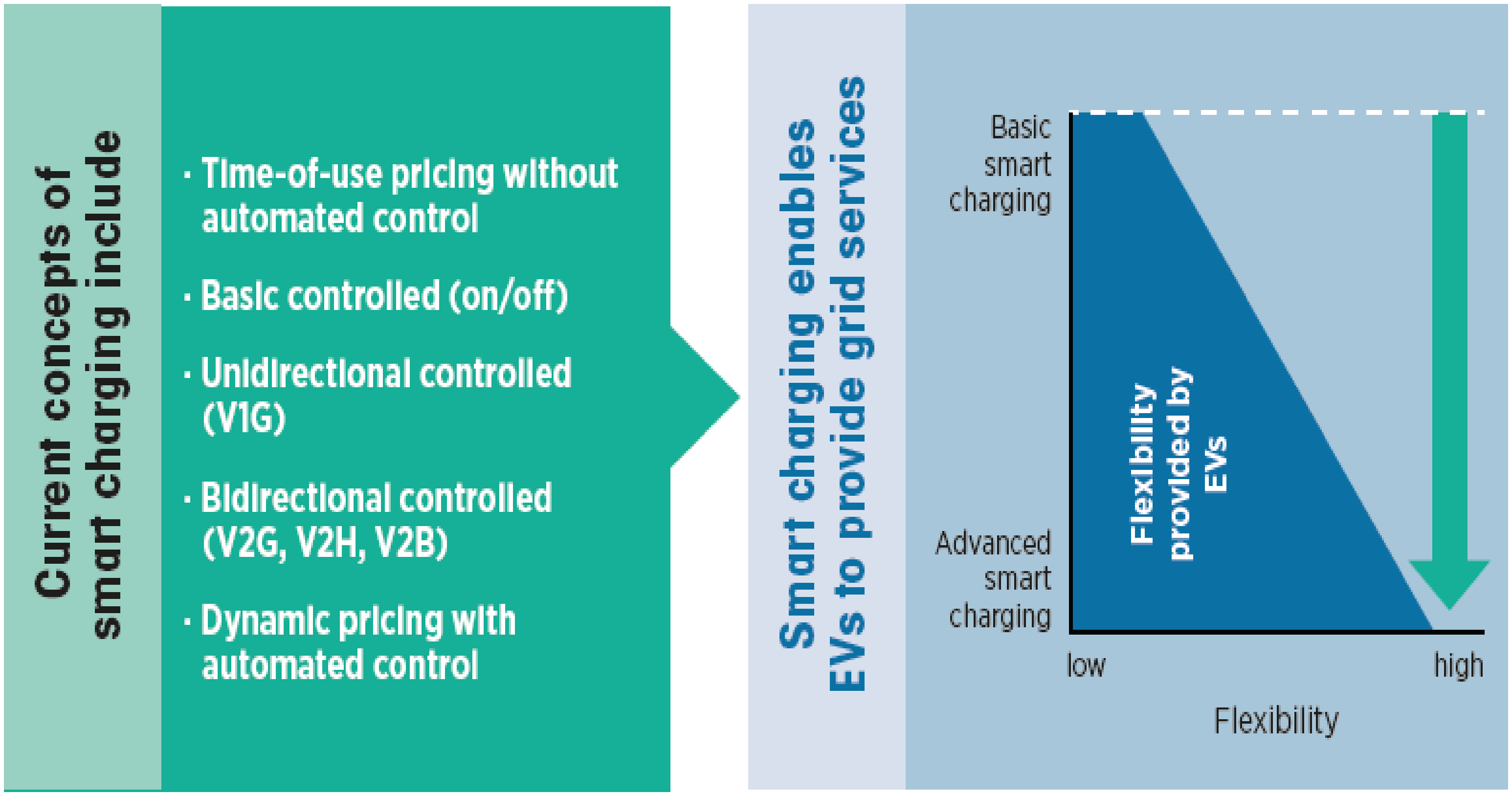
1. Sh. Pradeep Aggarwal
2. Sh. Krishna Porwal

Representatives of EVSE and EV OEMs

Electric Vehicles Utilization for Vehicle-to-Grid (V2G) Services

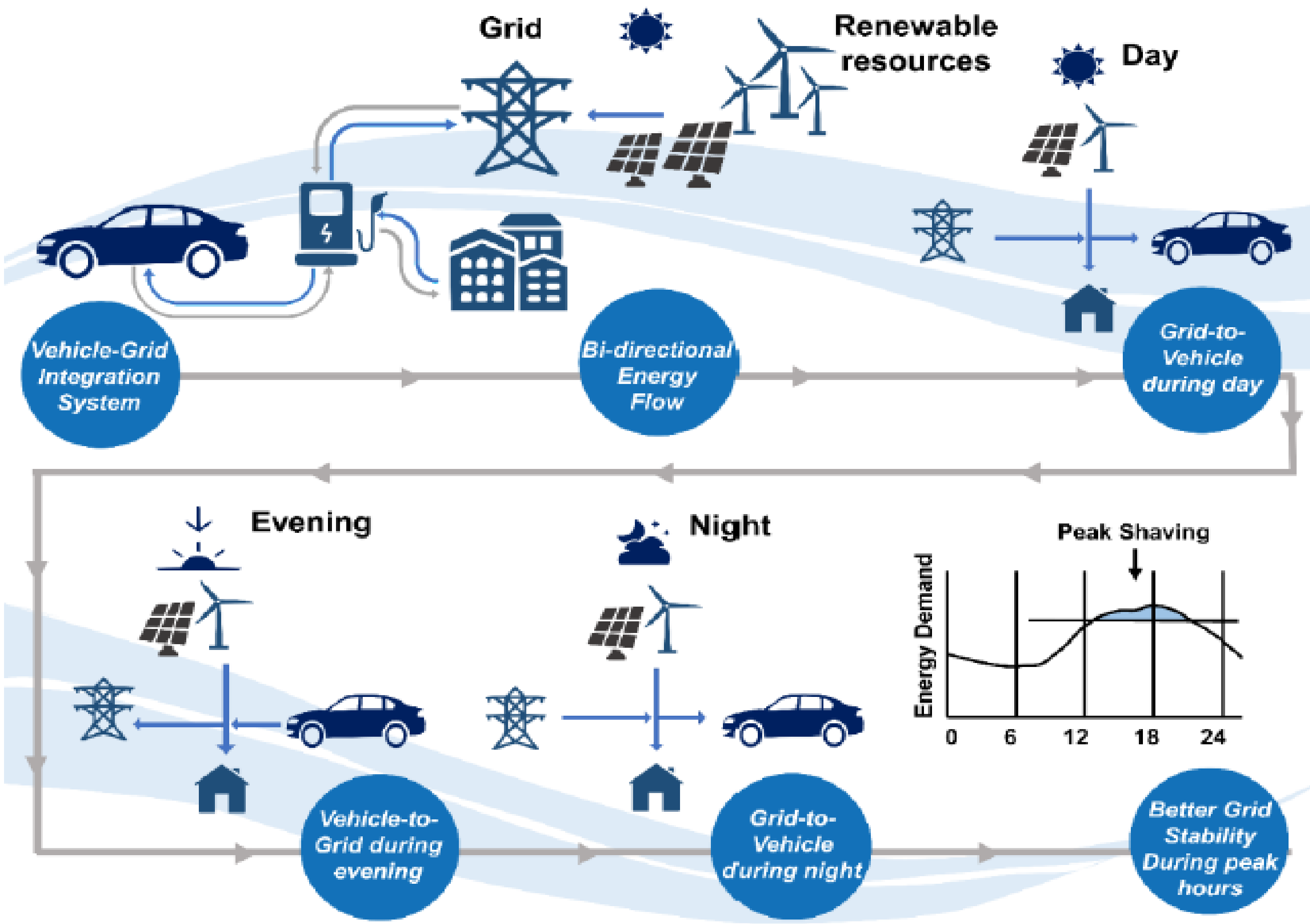
CEA

Current Concepts of Smart Charging



Cars, including EVs, typically spend about **80-90% of their lifetime parked**. These idle periods, combined with battery storage capacity, could make EVs an attractive flexibility solution for the power system.

Schematic diagram of V2G



V2G System and Infrastructure

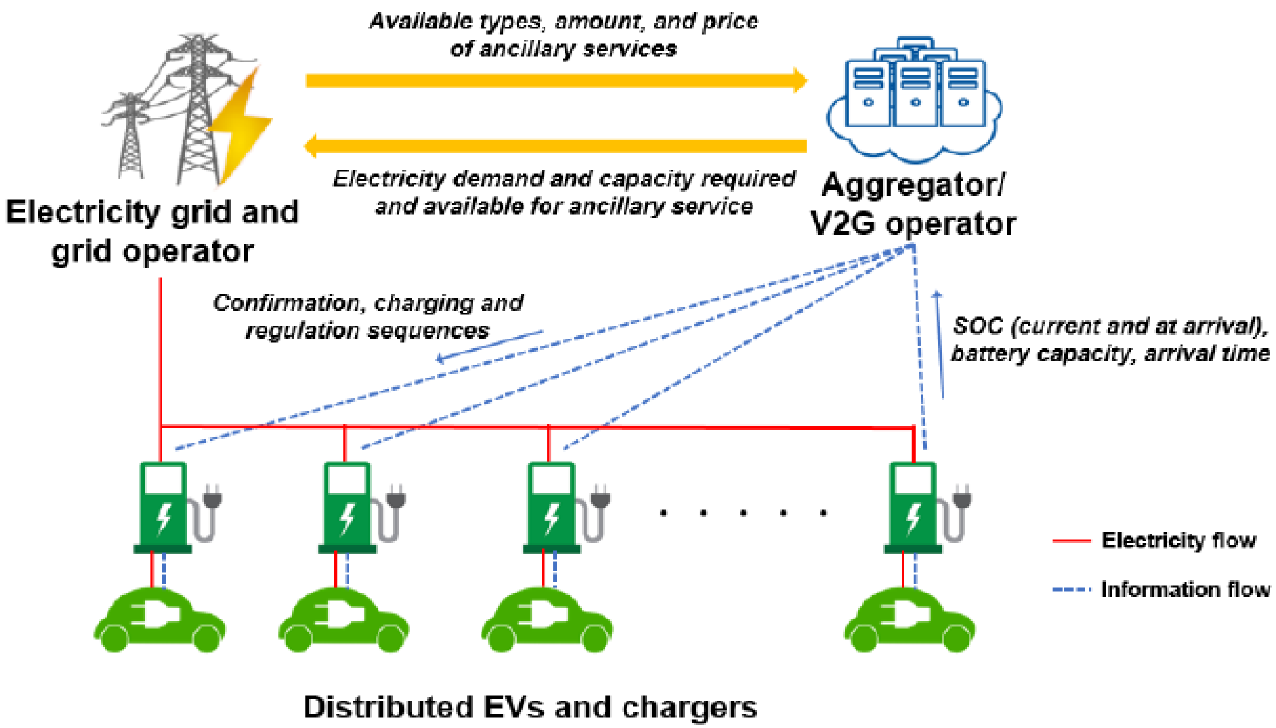
System Architecture

The system architecture associated with V2G can be classified into **centralized** and **decentralized architectures**.

In a **centralized architecture,** *the aggregator is the primary component* for handling all the charging and discharging phenomena of EVs. ***Major issue:*** *Frequency control* also becomes complicated with centralized control architecture, since controlling is difficult when different vehicles are at different states of charge, and this could often be coupled with the uncertainty of EVs at the charging stations.

In the **local/decentralized control architecture**, *the local systems*, such as office, factory, and apartment, autonomously pursue their own way to optimize the charging cost and other parameters associated with V2G. ***Major issue:*** *unpredictability factor* when a large fleet of individual vehicles chooses to vary their charging rate.

V2G System and Infrastructure (contd..)



Aggregator?

Aggregator business models may facilitate the use of EVs as a source of flexibility. At least 1-2 MW capacity must be traded to make EV power provision viable at the wholesale level. This requires the aggregation of around 500 EV cars approximately and their charging points.

V2G System and Infrastructure (contd..)

Charging System

V2G requires a bi-directional system to deliver electricity from the grid to EVs' batteries and vice versa. This bi-directional system can be facilitated using **double uni-directional** or **single bi-directional** converters. However, utilization of double uni-directional converters (chargers) means a higher total cost, heavier weight, and larger dimensions.

Fast and ultra-fast charging would be a priority for the mobility sector. However, **slow charging is better suited for V2G than are fast and ultra-fast charging.** Slow chargers are used mostly for home and office charging. With slow charging the EV battery is connected to the grid for longer periods of time, increasing the possibility of providing flexibility services to the power system. Furthermore, fast and ultra-fast charging may increase the peak demand stress on local grids.

V2G System and Infrastructure (contd..)

- ## Communication System

Communication between the grid and the EVs to transfer the data (e.g., travel, battery, EVs conditions) and decide the charging mode results in a complex communication structure.

In V2G technology, both the data and the energy flow are bi-directional amidst the vehicles, charging stations, and power networks.

ISO/IEC 15110 standard establishes the standard for EV charging station communication, while the **IEC 61850** standard establishes the standard charging station-grid communication as a result of which tariffs and charging are carried out effectively.

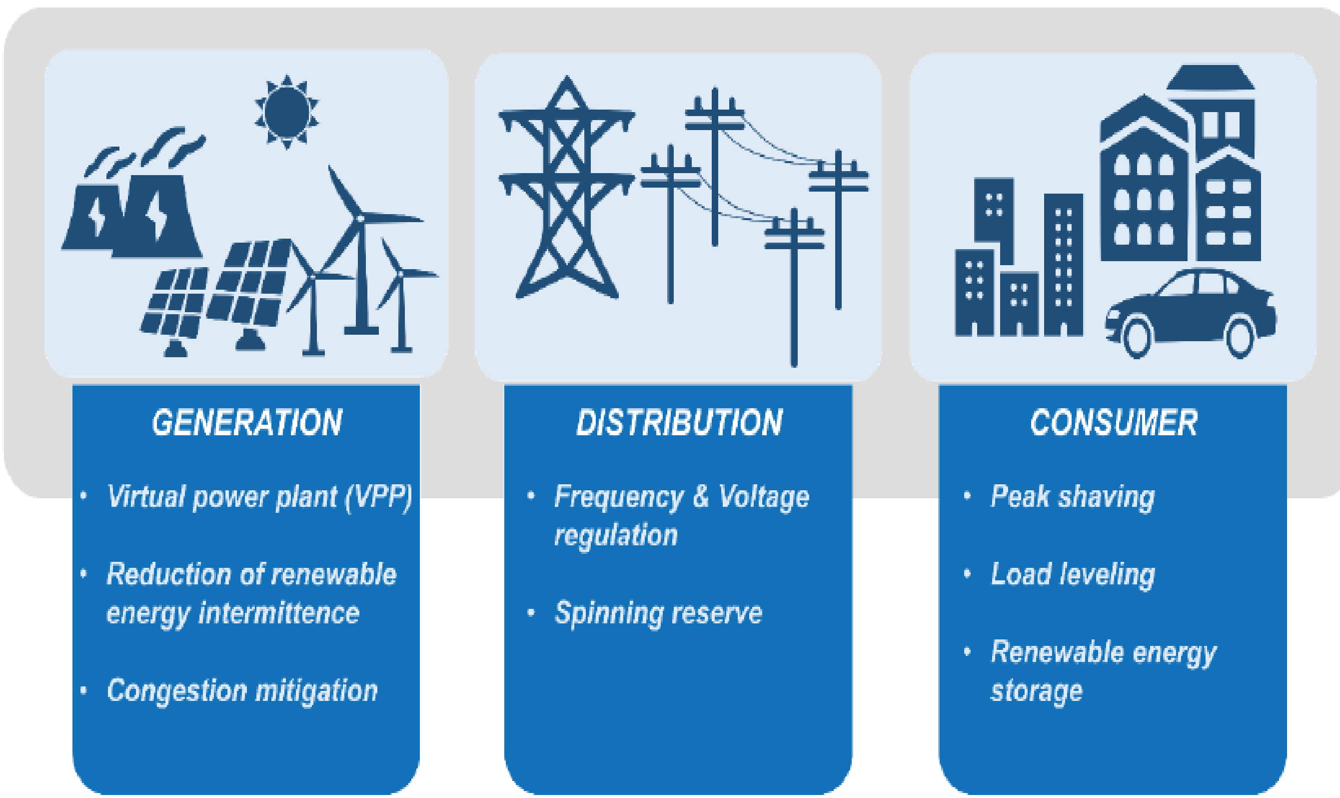
- ## System Operation and Optimization

The dynamic and unpredictable nature of EVs could increase the system complexity. This further complexity demands optimization algorithm to utilize EV mobility to achieve V2G services. Since the integration of EVs and the grid will create a complex system that will increase a large number of non-linear variables, unit commitment becomes necessary to determine the optimal dispatch schedule, and various optimization approaches are usually applied to such unit commitment problems.

V2G System and Infrastructure (contd..)

Standards	Selected Features
ISO 15118-20:2022	❖ Replacement for IEC 61851 or ISO 15118-2 ❖ Improved Charging experience; Smart charging services; Grid services; Cyber-security ❖ Bidirectional power flow for More RE uptake; Grid stability; Grid code support features
EN 50491-12	❖ Integration of EV into Energy Management Systems (EMS) ❖ Large-scale smart charging ❖ Improved interoperability
IEC 62196	Plugs, socket-outlets, vehicle couplers, and vehicle inlets—conductive charging of electric vehicles
IEC 61850-x	Communication networks and systems in substations
IEC 61439-5	Low-voltage switchgear and control gear assemblies, and assemblies for power distribution in public networks
IEC 61140	Protection against electric shock—common aspects for installation and equipment
IEC 62040	Uninterruptible power systems (UPS)
IEC 60529	Degrees of protection provided by enclosures
IEC 60364-7-722	Low voltage electrical installations, requirements for special installations, or locations—supply of EVs
ISO 6469-3	Electrically propelled road vehicles, safety specification, and protection of persons against electric shock
IEEE 2030.5	Enables utility management of the distributed energy resources such as electric vehicles through demand response, load control and time-of-day pricing
IEC 63402 (under development phase)	International version of EN 50491-12
IEC 63119 (under development phase)	Alignment with other EV-related IEC standards.

Potential services of V2G for different levels of the grid



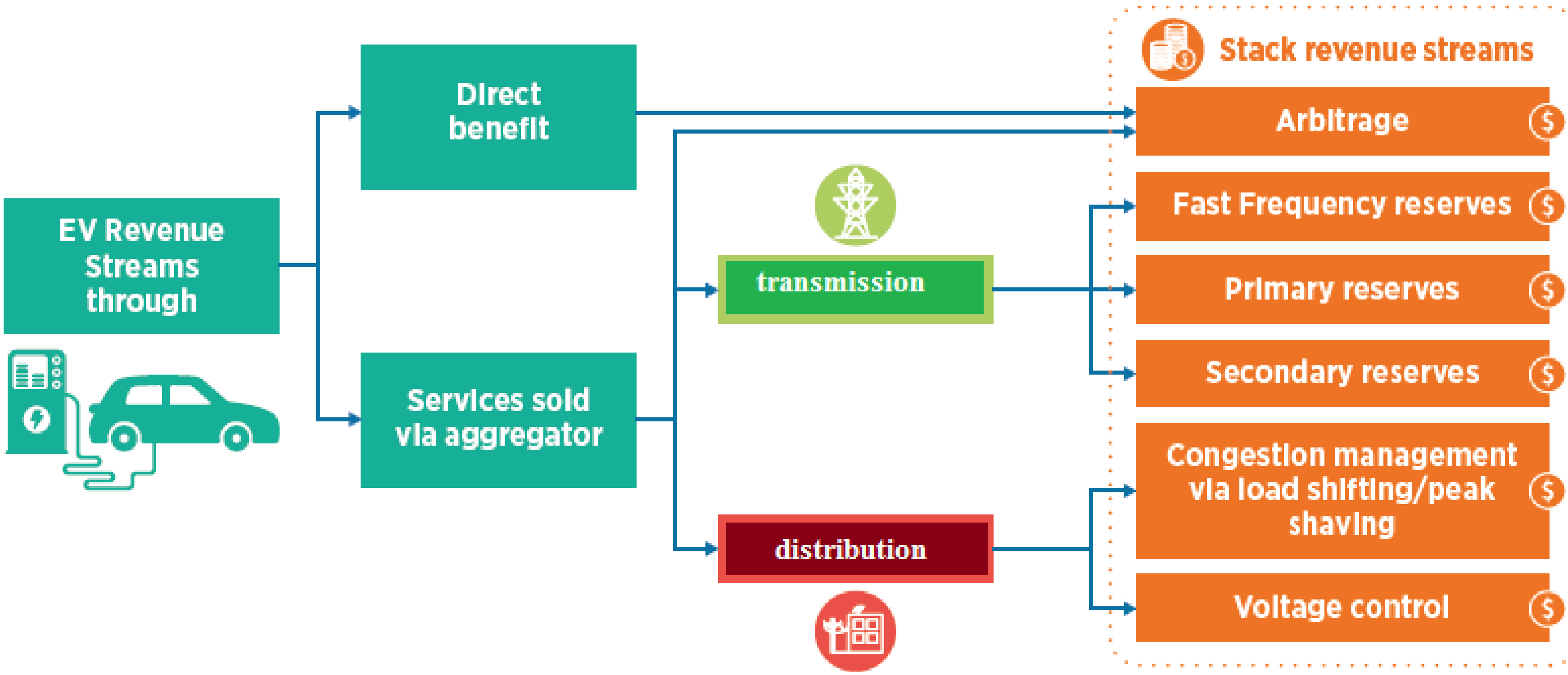
Flexibility with V2G

SYSTEM FLEXIBILITY	LOCAL FLEXIBILITY
•Peak-shaving •Frequency control (primary, secondary and tertiary reserve) •Other ancillary services (*e.g., voltage management,* emergency power during Outages)	•Voltage control •Local congestion and capacity management •Increasing the rate of Renewable Energy self-consumption •Arbitrage between locally produced electricity and electricity from the grid •Back-up power

Challenges

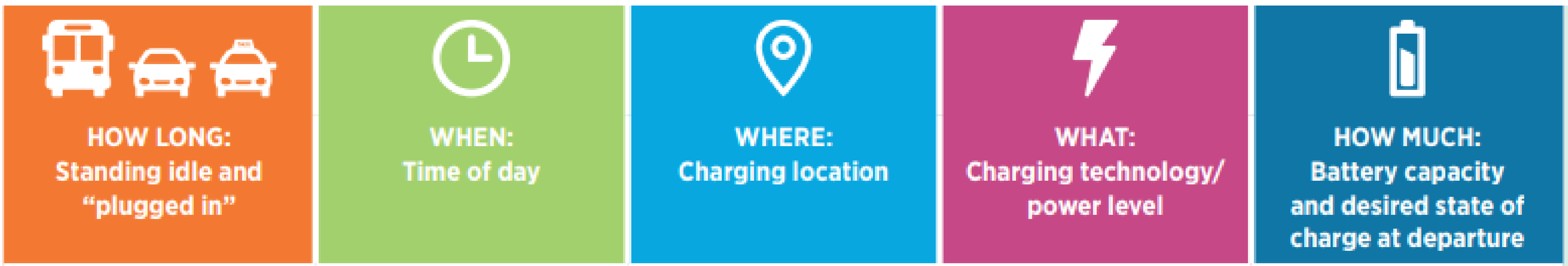
- **Profitability and competitiveness of EV flexibility**

  V2G may not materialize without the possibility to "stack revenue" from multiple revenue streams, providing flexibility at both the system and local levels.



Challenges (contd..)

➢ **Factors determining the amount of available flexibility from a single EV**



Long-duration (> 4 hours) charging provides the highest flexibility for the system.

Medium-duration (30 minutes to 2 hours) charging at shopping or leisure centres (movie theatre, gym, etc.) **or short-duration (15 minutes to 1 hour)** charging provide minimum flexibility for the system and are less suited for grid services.

Challenges (contd..)

➢ **Impact on grid infrastructure**

•**Congestion:** such as in the local distribution network prior to any EV deployment.

•**Load characteristics:** for example, the impact of uncontrolled EV charging will be higher in locations with high shares of electric heating (thus leading to higher grid reinforcement).

•**Generation assets connected at low voltage level:** for example, integration of high shares of solar PV connected at low voltage level (e.g., in Germany) could be facilitated with smart charging, whereas in locations with no or very low shares of solar PV, EVs could increase the strain on local grids.

•**Grid code limits and other regulations:** for example, national grid codes define physical constraints in terms of both voltage and frequency variations that distribution system operators have to respect, and investment in grid reinforcement if these country-specific limits are exceeded due to EV charging.

Challenges (contd..)

- **Deterioration in Life Cycle of the Batteries**

Battery degradation might be an issue with V2G technology, as the recurrent charging and discharging cycles of the battery induced by the nature of the V2G infrastructure might degrade the battery life span. This will have a huge impact on the viability of the business models that pin on the V2G technology and affect the social acceptance of the technology.

Battery degradation is primarily dependent on two factors: *calendar aging* and *cycling aging*. While the former is dependent on temperature and SOC, the latter is dependent on the depth of discharge and power throughput. Recent research shows that V2G, if used without proper management, may lead to significant battery life reduction, which will be the case when, for example, peak shaving services are used daily.

Challenges (contd..)

- **Less compatibility of Mobility-as-a-service with EV based flexibility**

Car sharing and carpooling are already changing the habits of consumers. Shifting away from vehicle ownership to shared mobility and to mobility-as-a-service (MaaS) is expected to continue progressively with digitalization. Further, the increased daily distances travelled per car will imply reduce parking time i.e. less battery capacity for grid services. Consequently, the net available flexibility in the system might decrease, especially during the daytime, for balancing solar power. The implications for the availability of EV flexibility which may decrease in a future system based on shared vehicles compared to a transport system based on individual EV ownership.

MaaS could work against VRE integration, as fewer EV batteries connect to the grid. With major mobility sector disruption, EVs might not provide as much grid flexibility.

Challenges (contd..)

- **Cyber-security**

V2G technology requires a certain level of cyber-security for seamless operation and to ensure grid safety, since the grid going digital handles massive amounts of data, making V2G a perfect target for cyber-attacks. Thus, network security and integrity with data transmission in the grid becomes essential for the seamless and safe data transfer from EVs to the grid.

- **Interaction with the vehicle owner** is key, including the **forecasting** of use in terms of schedule and driving distance.

- **Battery Capacity**

How much battery capacity can be made available for V2G depends on the vehicle's battery capacity and on drivers' needs. The battery Capacity: electric 2-3 wheelers will offer less energy flexibility than premium cars with bigger batteries. Bigger batteries helping to overcome range anxiety: there will be more EVs with larger batteries connected to the grid.

Challenges (contd..)

- **Type of Batteries required for Grid Balancing Services**

Application	**Renewable storage**	**Ancillary services**		**Back up**		
Battery acceptance	High DoD	50% SoC	Low DoD	Low C-rate	Long standby at high SoC	70% DoD
Li-ion	+	+	+	+	x	+
Lead Acid	x	+	+	+	+	+
Redox Flow	+	+	+	+	x	+

Note: DoD (Depth of discharge), SoC (State of charge), C-rate (Cycling rate)

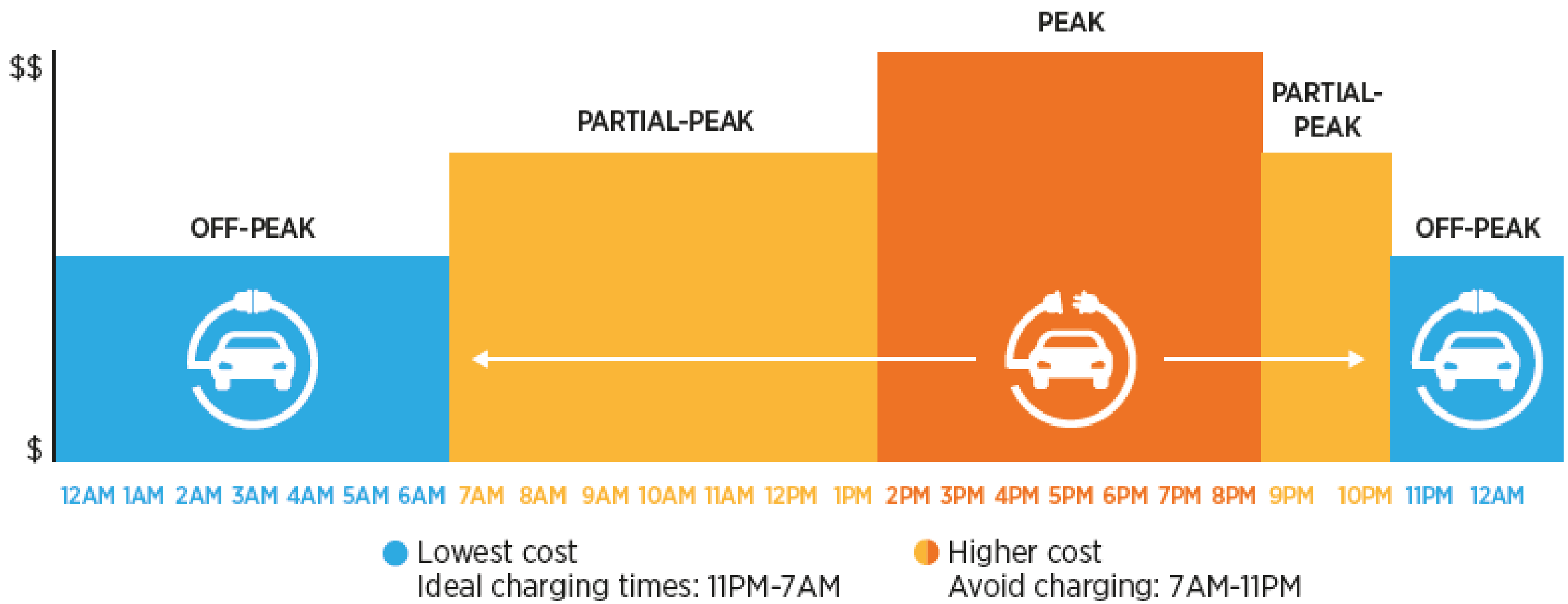
Way Forward

Technical Requirements	**Hardware:** • **Widespread adoption of EVs.** • **Public and private charging infrastructure – smart charging points.** • **Smart meters – required for supplying interval values for net consumption and net production**
	Software: • Smart charging services such as energy and power flow management systems that allow for optimal EV charging, ICT systems, intelligent charging infrastructure or advanced algorithms for local integration with distributed energy sources.
	ICT structure and development of communication protocols: • Develop common interoperable standards (both at physical and ICT layers). • Develop a uniform solution for the method of communication between charge points and the central power system, regardless of the vendor.
Regulatory Requirements	Electricity Market: • Allow EVs, through aggregators or individually, to provide services in the ancillary service market and wholesale market. • Enable revenue streams to incentivize smart charging of EVs. • Efficient price signals (such as time-of-use tariffs) or other load management schemes to incentivize smart charging. • Understand customer behavior and create awareness of the possibilities to use load management.

Way Forward (contd..)

- **Dynamic pricing plans**

Example of Time-of-Use Charging: The simplest form of incentive – time-of-use pricing – encourages consumers to move their charging from peak to off-peak periods.



Way Forward (contd..)

- **Battery Swapping**

Redundant battery storage at the stations or battery swapping with supplementary battery storage that can draw power from the grid at the most optimal time and then use it to charge EV batteries could complement grid charging. However, Standardization of battery packs, though unlikely, is also a necessary change that will need to be adopted globally for this technology to be widely accepted.

- **Second-life Storage Applications**

An alternative to recycling used EV batteries is reconditioning them and reusing them in stationary applications. Second-life battery solutions could also provide energy storage services. An EV battery needs to be replaced when the capacity declines to 70-80% that is when it is no longer sufficient for daily mileage but is still in good condition to be used as an energy storage system.

Way Forward (contd..)

Charging use case	Impacts	Possible V2G related Opportunities
Home charging	Overloading issues may be expected for distribution transformer, feeder loading etc.	Off-peak charging or reduction of variable renewable energy curtailment via load shifting depending on connection time duration and charging time.
Workplace charging	Lower probability of overloading issues due to larger capacities typical in commercial or industrial zones.	•Potential increase of consumption of solar generation due to typical daytime connection. •Flexibility potential
Public roadside charging	Overloading issues may be expected for distribution transformer, feeder loading etc. especially with higher power draws from three-phase charging.	•Potential increase of consumption of RE generation due to typical daytime connection. •Flexibility potential
En route charging (Ex: Highways etc.)	Potential high-power draw. Depending on the power and volume required, dedicated transformer or stationary storage serving as a buffer might be required.	Limited demand response flexibility due to short or non-existent surplus connection time.

Way Forward (contd..)

Charging use case	Impacts	Possible V2G related Opportunities
Depot charging	•Expected high-power draw due to larger volumes and numbers of vehicles served. •Dedicated substation might be needed, but the added cost can remain viable due to the nature of the commercial operation. •Network upgrades might encounter land use restrictions, especially if located in dense urban areas	•Fleet predictability and load management offer high potential for load shifting, variable renewable energy, curtailment reduction and bidirectional charging due to larger battery capacities and existing fleet control. •Flexibility potential might be limited to a few hours depending on the parking period and trip scheduling.
Battery swapping	•Limited overloading issues due to charging control	• 24/7 bidirectional interaction with the grid and the aggregated capacity could facilitate VRE. •Battery charging management can help reduce asset ageing.

Way Forward (contd..)

Possible Stakeholders	Typical concerns and motivations
EV users	**Concerns:** finding an available and functional charger and having enough autonomy for the next trip; privacy and security. **Motivation:** charging convenience and lower energy bills
EV manufacturer or vehicle original equipment manufacturer (OEMs)	**Concerns:** handling warranty claims; charging convenience of clients **Motivation:** sales and market share
Charge point operator (CPOs) or battery swap station operator	**Concerns:** securing grid interconnection and land acquisition; network tariffs. **Motivation:** business model to increase charge point utilization and revenue streams.
Network/system operators	**Concerns:** maintaining grid security and quality of electricity supply. **Motivation:** system/local flexibility
Electric mobility service provider (EMSP)	**Concern:** interoperability of charge points for users regarding the interface between the EV user and the CPOs, ensuring accessibility to electricity recharging. **Motivation:** business model to maximize share of subscribers

Way Forward (contd..)

- **Harnessing Synergies between EVs and Solar & Wind Power**

The incremental benefits of V2G will be particularly significant in solar-based systems as wind production profiles are more region specific. Smart charging provides greater benefits to systems high in solar PV than wind, due to the more predictable generation profile from solar.

By shifting charging to better coincide with solar PV generation, and by implementing V2G, increased shares of solar could be integrated at the system level and the local grid level, mitigating the need for investments in the distribution grid. For EV charging to complement solar, charging must shift to mid-day, which also means that charging stations must be located at workplaces and other commercial premises where EV owners park their vehicles during the day.

Way Forward (contd..)

- **Artificial Intelligence and Big data**

Smart charging through use of V2G integration technologies is a means of managing EV loads, either by customer response to price signals or by an automated response to control signals reacting to the grid or market situations, or by a combination of the two. This needs to be done while respecting the customer's needs for vehicle availability. It consists of shifting some charging cycles in time or modulating the power in function of some constraints (for example, connection capacity, user needs, real-time local energy production). Advancements in big data and artificial intelligence could facilitate and optimize the services provided by smart charging solutions.

The use of digital tools can help to improve customers' acceptance of EVs for V2G and to navigate market complexity, interacting with the grid to increase renewable energy shares. For example, a smart charging system that automatically charges EVs when energy costs are the lowest, managing recharge with intuitive sense technology.

Few Important Facts & Examples

- **EV Battery Capacity**

Type of EV	Battery Capacity (in kWh)	Charging solutions
2-wheelers & 3-wheelers	0.5-20	0.5-3.3 kW
Light-duty vehicles	10-100	Home charging (1.9 kW (low power)-7 kW (high power)); destination (workplace or leisure) charging, public charging (≤22kW); en route/highway fast charging (50-350 kW)
Light commercial vehicles	35-76	22kW
Bus	50-550	Opportunity (bus stop) charging (150 kW or more) ; depot charging (22-50 kW); Destination (school) charging (19-50 kW); En route fast charging and depot charging (50-350 kW)
Trucks	100-800	Depot (<350kW); en route/highway charging (1-3.75 MW)

Few Important Facts & Examples (Contd..)

- **Small batteries** (ranges: 30-60 kWh) & **Large batteries** (ranges: 90-200 kWh)
- **Example-1:** A 6 MW capacity would be a good order of magnitude for a highway station with 30 charging points, in the medium term. 1 litre of diesel is about 10 kWh. That means that for a car tank of 50 litres, 500 kWh is needed. If the charging time is to be equivalent to filling a tank (about five minutes), this equals about 6 MW (500*12). A charging curve does not maintain constant power: at the end of the cycle, the power decreases. Thus, a certain average power level (like 4.8 MW) requires a higher level (like 6 MW) at the beginning of the charging cycle.
- **Example-2:** For a 200 kWh battery, a charging power of 600 kW would be needed if the driver wanted to charge that quickly. With today's chemistry, a battery can charge at 3C (i.e., 20 minutes is needed to charge the battery from 0% to 100% if the same power level was kept). A 3C rate means that the discharge current will discharge the entire battery in 20 minutes.
- **Example-3:** A depot of 90 electric buses requires about 4 MW of charging power.

THANK YOU