

e-Mobility the next frontier for Automotive Industry

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Abstract—This paper provides an overview on the introduction of electric vehicles (EV) and discusses how electric mobility will influence the developments in automotive industry by integrating the EVs into the Internet of Energy (IoE) and Smart grid infrastructure by providing novel business models and requiring new semiconductor devices and modules. In this context the EVs are evolving from mere transportation mediums to advanced mobile connectivity ecosystem platforms.

Keywords—electric vehicle; Internet of Energy; in-vehicle communication; telematics; connected vehicle

I. INTRODUCTION

The deployment of electric vehicles (EVs) will introduce a number of changes in the automotive industry where information and communication technologies are at the core of the change from traditional mobility as we know it to mobility as a service. This can bring a new ownership structure, where end users do not need to own a vehicle to drive one, while the revenue and cost structure appears in mobility services: end users pay a subscription fee that includes all ancillary costs such as insurance, maintenance, and charging, while the service company bears all of the upstream and downstream risks.

In the future the source of innovative value creation is in the connection of vehicle to the electricity grid. The connection of vehicles to the grid enables smarter energy demand management, as well as new opportunities to store electricity in EV batteries or use them as energy regulation service providers for the Distribution System Operator (DSO). Enabling the exchange of information between the electricity network, the telecommunications network, vehicles, and consumers, information and communication technology driven models will improve the efficiency of electricity use and electric mobility.

In this context, combining the power network with the distributed data network into an Internet of Energy (IoE) concept makes it easy for people to sell the excess power generated from decentralized energy power plants (i.e. photovoltaic, wind, etc.). Such a infrastructure will strengthen the grid to handle a more granular demand and eventually lead to significant increase of renewables in national energy mixes. The architecture of Internet of Energy is inherently intelligent,

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(cross) layered, distributed, standardized, networked, asynchronous, asymmetrical, and with a multitude of distributed storage units and designed to support the “prosumer” concept, a natural evolution of the energy consumer role with increased consumption awareness and innovative production capabilities. Distributed energy means that the power network/grid comes increasingly close to the “peer to peer” transfer mode, many vendors, multi standards, global competition and world scale flexibility. This will give the ability for electric vehicles, residential buildings, consumers, etc. to buy energy from power grids when needed and sell it back when they have excess in self generation.

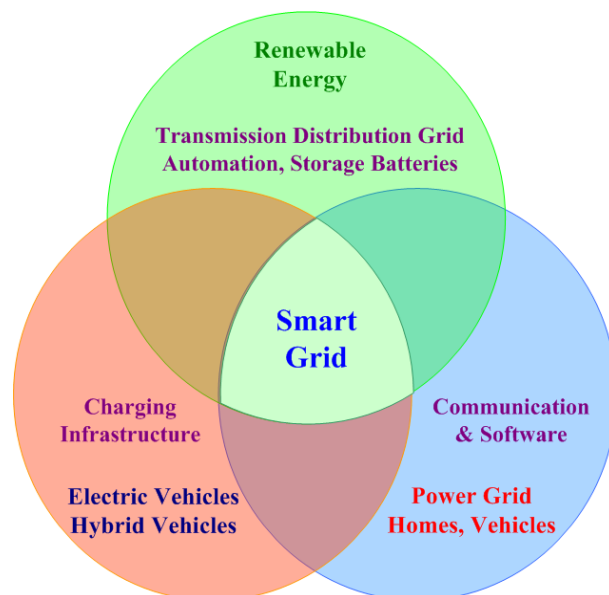


Fig. 1 Smart Grid elements

The information management within the IoE is defined as the ability to control the on-site equipment, the information tools and operational intelligence the system provides. Smart e-meters will automate data collection from/to user/utility. With technology and capabilities to implement advanced meters based on power line communication for example, the information usage throughout the stakeholders will rise new opportunities for both the end users and the market.

All the above have to be complemented by a close examination of power hardware performance under the rugged working conditions of a Smart Grid. The elements that are intersecting for Smart Grid integration with electric mobility applications are illustrated in Fig. 1.

A real time monitoring will be essential for both the consumer control of the process on the basis of the real-time energy price, and for the DSO/Energy Supplier to restrict or permit to a specified device the access to the power network on the basis of the grid's local and overall state

During a fast charge, in the timeframe of few minutes an electric vehicle can pull as much power as an entire home consumes during the whole day at full load and this need to be managed, in particular when concurrent activities are occurring.

This new concept will accommodate greater levels of demand side management; generation and storage resources on the distribution system; generation closer to the loads; and possible greater flexibility for islanding and micro grids; and considerably higher levels of intermittent generation, especially on the transmission system.

These changes will require changes to the power system capabilities, and will have a significant impact on the EVs and the "real time" connectivity between the EVs and the infrastructure/Smart Grid in order to monitor and control the reliable operation of the power system in a most economical fashion and provide an optimal energy management solution to individual EV.

Investment in electric vehicle infrastructure is a priority. With companies seeking to invest in infrastructure that will provide economic growth, it is clear that special infrastructure for electric vehicles will stimulate growth from the private sector. Electric vehicle market segment is positioned for growth for vehicles used for local driving.

In this context intelligent energy management systems will use the information available in-vehicle and on the infrastructure through connection to the Internet to optimize the energy management of the vehicle and make proper decisions about energy consumption. In this way intelligent energy management systems can help to use the energy efficiently depending on the context situation and enables vehicle drivers to plan their trips, manage their battery pack and under specific circumstances, inject electricity from their EVs to power the grid, contributing to a smarter distribution of power and better support of decentralized energy power plants through dedicated counter-peaks the renewable fluctuations and the provisioning of ancillary service and frequency regulation and reducing their cost of ownership of the vehicle.

II. ELECTRIC VEHICLES

EVs are expected to play an important role in the smart grid (SG) and IoE concept. Electric-drive vehicles (EDVs) include battery electric vehicles, fuel cell electric vehicles and hybrid electric vehicles [2].

EDVs incorporate batteries which are capable of storing a significant amount of energy. Summing up all the possible

electrical energy stored in the expected amount of EVs in near future, one finds that it is possible with a constructive bidirectional interaction between the EVs and the upcoming smart grid.

Many new EVs are now entering the automotive market, and a large increase of EVs on the roads is anticipated in the coming years. As sales numbers rise, so do the competition between the EV producers. This in turn results in new innovative developments, e.g. in control systems, technologies, devices and products.

The idea of a bidirectional connection between the EVs and the grid is not new. A "two-way, computer-controlled connection to the electric grid" is suggested in [3]. In this way they claim it would be possible that the grid both provides power to and receives power from the EVs.

Power transferred from the vehicle into the grid is commonly named "Vehicle-to-Grid" power (V2G) [2]. In addition to be a power resource for the grid during demanding periods, the EDV fleet can act as storage for large-scale wind power [4] and other intermittent energy sources, e.g. solar and wave. Higher grid flexibility and control has to be implanted as these large-scale variable energy sources enter the market and connect to the existing grid.

The EV charging system has the following functions:

- To push electricity into the batteries as fast as the batteries will allow
- To monitor the batteries and avoid damaging them during the charging process

The charging systems monitor battery voltage, current flow and battery temperature to minimize charging time. The charger controls the current flow and sends as much current as is required or available without raising battery temperature over the defined temperature limit.

The typical EV charging process is illustrated in Fig. 2.

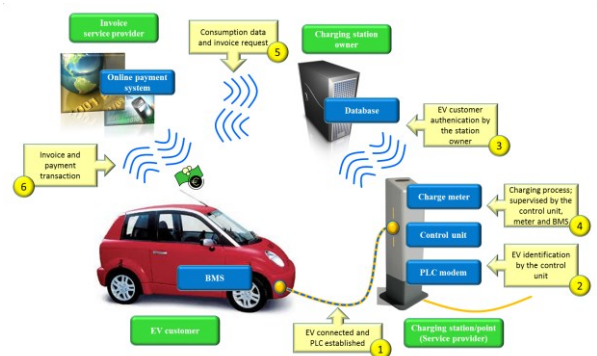


Fig. 2 Electric vehicles charging process

III. ELECTRIC VEHICLES, RENEWABLE ENERGY, AND THE INTERNET OF ENERGY

The Internet of Energy (IoE) concept enables the creation of electric mobility ecosystems where the electric utilities will need to provide incentives to consumers for shifting loads (the vehicle charging is one of them) during off-peak hours.

Electric vehicles constitute a new category of loads with considerable load management ability. Electric vehicles recharging in peak load periods may cause challenges for the energy suppliers, by increasing the need for power production capacity in the system.

If however, recharging is displaced to the low load periods or periods of low electricity prices, e.g. via recharging in the night period, a considerable electricity demand increase to serve a fleet of electric vehicles may be covered from the existing supply system.

The charging method of electric vehicles will depend on where EV customers want to charge their vehicles and the charging process that takes place between electric vehicles and charge spots has to be coordinated, taking electricity grid and electricity generation capacities into account.

By appropriate system integration, the electric vehicles can contribute considerable flexibility to the system, due to its load management ability, which increases the overall system capability as to integrate fluctuating energy sources such as solar panels and wind power.

Residential buildings are expected to be the predominant charging location in the future. Charging points (and smart plugs) are expected to be installed over time to support potential EV buyers and users who do not have a residential garage.

Work, apartment building, and public charging options are important for commuters, which will favour to have reasonable charging options at work, and/or live in a community with strong commitment to (and investment in) public charging.

Challenges for EV infrastructure can be summarised in the following:

- Anticipate consumers' needs and behavior towards infrastructure with a limited EV market.
- Develop advanced billing systems allowing communication between the vehicles and charging stations.
- Attain standardization from OEMs on battery and charging modes to optimize infrastructure.
- Obtain funding or support from government to develop infrastructure.
- Ensure that electric energy supply will come from renewable sources to keep EVs a sustainable solution.
- Expand logistics of infrastructure from cities to highways to rural areas as EV autonomy increases.

Large scale diffusion of electric mobility is unfeasible without dedicated infrastructure since the development of a charging infrastructure, both public and private and integrated with the electric distribution network, guarantees:

- European/national wide balanced development.
- Compliance with the standards.

- Rise of a competitive market to exchange energy and services.
- Investment optimization.
- Integrated development with the modern smart grids.

The Internet of Energy concept is illustrated in Fig. 4.

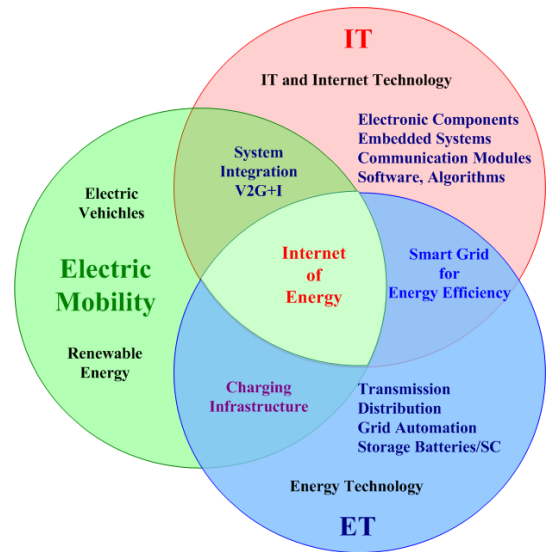


Fig. 4 Internet of Energy (IoE) concept

There are two reference models used for managing the infrastructure:

- Infrastructure managed by distributor (DSO) that provides:
 - Recharging points as part of the LV/MV Grid.
 - EV as independent consumption unit identified everywhere to bill.
 - Energy supply in a competitive market according to a multi-vendor approach.
 - Dedicated contract for each EV-POD for home charging eventually combined with multi-vendor on public charging.
 - Coordinated grid infrastructure development and impacts optimization.
 - Neutral infrastructure deployed according to universal access principle: locations of charging points are decided on a profit-free basis.
 - Identification, authentication and billing performed through DSO infrastructure on behalf of different Service Providers.
 - Rates and access regulated by Authority.
- Infrastructure managed by service provider (SP)
 - Gasoline station-alike business model.

- Public recharge: after-meter infrastructure owned by Service Provider, recharge service.
- Infrastructure Planning and development on local basis (agreements between SP/Local entities).
- Technical solutions defined according to current technical standards.
- Identification, authentication and billing performed by only one Service Provider, who also has invested on charging infrastructure.

The DSO Business Model natively integrates the Smart Grid features as the IT infrastructure managing the charging points is closely linked to the DSO legacy systems. Therefore such a model for charging infrastructure deployment would guarantee a quicker Time To Market for value added services related to Smart Grid integration of EVs, e.g. smart charging or “green” charging. The implementation of a smart charging infrastructure at a wider scale is imperative to allow the market success of the electric mobility and to overall reduce costs of technology adoption, increase efficiency, increase consumer awareness, and allowing the network operators to supervise the local and overall load management.

The Internet of Energy converts the traditional power system into a network/grid that is largely automated, applying greater intelligence to operate, monitor and, heal itself when needed. By being Internet of Energy concept is a wider definition of Smart Grids, it includes a proactive role of DSO in deploying the needed field devices in the LV/MV grid to increase its observability.

This require the integration and interfacing between the power network represented by the grid and the data network represented by the Internet focusing on transmission, substation and distribution control, metering, substation monitoring and diagnostics and location information systems into seamless and coherent Internet of Energy implementation.

In this context developing and promoting a sustainable EV recharging infrastructure results in the following:

- Economic savings as the most important target to be achieved to attract clients to use EVs. In this case, subsidies to charging infrastructure and EVs purchase

in the rollout phase of electric mobility might speed up the technology adoption, as recently demonstrated by Norwegian EV market (in September 2012 the EV sales were 5.2% of total car sales).

- Commercial breakthrough only possible if actively supported by Market Players.
- Charging infrastructure widely distributed and adapted to clients’ needs.
- DSO model that provide both large infrastructure and high savings for clients.
- SP model that provide only selected services.
- DSO able to support the integration of the EVs in the Smart Grid, enabling Smart Grid services.
- Additional services provided via dedicated ICT platforms.

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