Perspective solutions of SmartGrid and Vehicle-to-grid connectivity problems

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Abstract
The paper presents the overview of electrical vehicle charging standards, SmartGrid and Vehicle-to-grid conceptions, shows the difficult points and the perspective visions of electrical vehicle infrastructure development. The aim of this paper is to describe problems of connection of electrical powered vehicles to main electrical grid and to give a solution defined for these problems.

Keywords
Page set-up, SmartGrid, EV, V2G, V2G+

Introduction
Within the last years gasoline prices have increased and vehicle manufacturing companies were trying to find alternative variants how to power the vehicles. Vehicle owners are searching for cheap and comfortable arrangement. From many variants like an ethanol fuel based or biogas models we can allocate an electrical powered vehicles (EV-s). Evolution of electrical vehicles is very rapid. Main factors are development potential and future perspectives of this kind of transport power-train.

Nowadays we have three types of electro-powered cars: hybrids, plug-in electrical and fuel-cell powered vehicles [1].

Various “green” organizations favour to a CO2 reductions, probably, only in US and Denmark governments not only sets “green” transport as a priority, but also takes part in a technical development of charging infrastructure [2].

Smart Grid is a form of electricity network with digital data transfer technology. A smart grid includes an intelligent monitoring system that keeps track of all electricity flowing in the system. The idea of a smart grid is to use digital technology in order to introduce more intelligence in control for delivering electric energy from suppliers to consumers. This means, by consolidating data from different sources (e.g. generators, renewable energy production, consumers and network operators and electrical vehicles) demand and supply are matched favourably for network security and sustainability [3]. Standard for electric vehicles is compilation, when the battery is installed only for taking electrical power from power grid with goal to give it forward to electrical motor, like it is shown on Figure 1. The combustion engine can be added in hybrid electrical vehicle version with the goal to charge batteries in series hybrid or give a part of torque to drive wheels parallel hybrid. Or both of these operations in series-parallel hybrid.

Fig. 1. Electrical vehicle modular power scheme with parallel hybrid mode

Principle of operation is quite simple: energy, saved in battery, regulates power flow by electronic power converter to traction motors, all processes are controlled by vehicle main computer system. It seems to be rather simple and reliable system, but there are some serious issues, which may hinder the development this type of vehicles.

Problems
Main problem is existence of different connectivity vehicle charging standards.

Currently we have defined for a three most common power levels of vehicle charging stations. Around 1998 the California Air Resources Board classified levels of charging power that have been codified in title 13 of the California Code of Regulations, the U.S. 1999 National Electrical Code section 625 and SAE International standards [4].

1 SAE J1772 is an North American standard supported by the Society of Automotive Engineers based on Yazaki plug, and corresponds to Level I AC energy to the vehicle's on-board charger; from the most common U.S. grounded household receptacle, commonly referred to as a 120 volt outlet with maximal power of 16.8 kW transfer available, supported by vehicle producers Chevrolet, Coda and Nissan [4]
2 IEC 62196 is an international standard for set of electrical connectors and charging modes for electric vehicles and is maintained by the International Electrotechnical Commission, based on Mennekes plug corresponds to Level II AC energy to the vehicle’s on-board charger; 208...240 volt, single phase [5]. The maximum continuous current specified is 32 Amperes with a branch circuit breaker rated at 40 amps. Maximum continuous input power is specified as 7.68 kW and supported by vehicle producers Daimler and RWB [6].

3 JARI high-voltage CHAdeMO (the trade name of a quick charging method for battery electric vehicles via a special electrical connector). It is proposed as a global industry standard by an association of the same name-plug based, developed by Tokyo Electric Power Company and corresponds to Level III DC energy from an off-board charger. There is no minimum energy requirement but the maximum current specified is 400 A and 240 kW continuous power can be supplied. Supplies with high voltages (300...600 V DC) and high currents (100 s of amperes/ampere) and supported by vehicle producers Mitsubishi, Nissan and Subaru [7].

It seems that at least three systems will be developed in parallel because of range of their supporters like a Ford, GM and Toyota. In addition to car producers some electrical companies like a Legrand, Schneider Electric and Scame develop their own charging systems and standards [8]. Variety of standards seriously disturbs overall development of the vehicle charging system. This problem is also caused an infrastructure non-availability. It is hard to develop one infrastructure for different types of plugs, voltages and currents. Various governments donate power infrastructure projects, however, fully developed charging power stations exist only in some countries like a US, Germany and Japan [9]. Another serious problem is appearance of self-discharge of battery. It is consists in the fact that battery can not save energy for a days [10]. This problem is especially serious in North countries with cold climate, like a Canada, Russia and Scandinavian region. In addition to faster self-discharge caused by cold, vehicle heating system consumes a lot of electricity. This problem is solvable, but it can take years to develop batteries with low losses and special economy heaters. However, connectivity problems can be solved by alternative way.

Vehicle-to-grid conception

Vehicle-to-grid, or V2G, is an a system in which plug-in electric vehicles, such as electric cars (EVs) and plug-in hybrids (PHEVs), communicate with the power grid to sell demand response services by either delivering electricity into the grid or by throttling their charging rate [11]. The main idea of vehicle-to-grid system is to connect electrical vehicle and an electrical grid together using two-way power connection and data connections. In this way vehicle can not only consumes power from grid, but also send energy back to the local utility power system. During peak demand periods, when the cost of electricity can be high, vehicle can be used as a source of electrical power. Energy is demanded also during blackouts, as an emergency backup supply. Here the batteries in the vehicles serve as a distributed storage system to buffer energy. These vehicles can then be recharged during off-peak hours at cheaper rates while helping to absorb excess energy, generated at night time [12]. To request an order for needed power, vehicle owner and grid operator should sign a contract. The contract is special document also the legal side of the issue to provide data from vehicles to grid operator and contrary. Technically for charging and energy trading special two-way energy meters and charging stations with data changing are also needed.

In this way vehicle owner can earn money for just being connected his own car into grid. Vehicles, connected to grid, offer the opportunity to sell electricity stored in their batteries back to the power grid thus assisting utilities to operate more efficiently in the management of their demand peaks. Principle scheme of V2G concept is shown at Figure 2.

![Fig. 2. V2G principle scheme](image)

In case of electrical vehicle two-way connection between vehicle and power grid estimates, main driving resource is electricity. In hybrid mode gasoline fuel additionally needed, hybrid is able to get and give electricity to grid. In fuel cell mode electricity can be only given to the power grid. V2G concept is comparable with Smart Grid with new partner like a vehicle. The new partner is an energy producer and energy consumer depending on the grid mode [13]. Additionally the GPS module can be used in V2G concept to position the vehicle and to determine the closest place of serve. However, V2G concept has some drawbacks, most serious is fact, that vehicles are not stationary energy devices, they move around the world. In many countries in each region is his own grid operator, in this way it is hard to fix the contracts with every operator in every region. Dependence on grid operator can be serious problem in mobility era. As a solution it is possible to use an integrated system named V2G+ with a number of grid operators and a lot of vehicle owners...
with optimised database and global positioning using GPS/Galileo/Glonass modules or GPRS or GSM positioning is proposed. V2G+ conception is shown at Figure 3. Every interested grid operator and vehicle owner involved in the system V2G+ could get needed info. For grid operator there are potential of summary electrical power on region, information about quantity of vehicles in region to calculate powers available, quantity of charging stations and difference between demand and proposal.

![Fig. 3. V2G+ conception GPS positioning mode shown](image)

For vehicle owner necessary data are displacement of charging stations and energy prices at the moment. In this proposed solution power demand will be more predictable, and forecast schedule designed by grid operator helps to smooth out the peak jumps of power demand. In the electricity market, price may vary depending on time or on demands. Battery charging and electricity selling to grid should be organised according to real time price rate. When power demand is higher, the price is higher too and that fact should stimulate and motivate car owners to be active and take a part in the market place [14]. Online text message information to a vehicle main computer or additional modular display about regional power demand and energy price can be sent providing GSM or RDS (Radio Data System, communications protocol standard for embedding small amounts of digital information in conventional FM radio broadcasts [15] invitation to sell saved electricity can be shown at vehicle info display).

V2G+ solution will be popular only, if it is comfortable or and profitable for users/players/members. Maximal comfort will be available only with full automation of processes and clear data exchanges. In this way every member of this global vision of situation.

Main parameters grid operators need to know are quantity of vehicles in a given region, parameters of each type of vehicle, number of active participants at the moment and summary potential of power available to transfer from vehicles to grid and conversely. Cause of every type of vehicle has his own parameter values, typical values should be specified. Typical charging parameters are specified in standards.

Vehicles can be a part of V2G+ and be a capacitors of electrical energy. This form of cooperation between electrical vehicle owners and grid operators can save grid operators from buying and installing expensive energy equipment. A universal Control pilot, a communication line used to coordinate charging level and another important data between vehicle and the charger station, should be developed and integrated on plugs. Control Pilot functions should be:

- Supply equipment detects plug-in electric vehicle
- Supply equipment indicates to PEV readiness to supply energy
- Determines electrical vehicle ventilation requirements
- Supply equipment current capacity provided to electrical vehicle. [16]

Serial electrical vehicles should be changed as low as possible to be competitive with other rivals and be interesting for buyers. Best way is to make rearrangement by a modular scheme, small additional universal module should be installed and integrated with vehicle main computer system. Module software should be certified by vehicle manufacturers. This module can be named a V2G+ module and will consist of control block, additional active GPS transmitter available to send and receive data from satellite or GSM/GPRS transmitter depending on region and networking prices, radio transmitter for getting info from grid operators via cheaper radio channel and connection buses with main vehicle computer system. The main advantage of V2G+ to the V2G system is conception of mobility.
Controller gets main signal from driver and regulates power regulator operations. Feedback connections give to controller information about battery, motor and transmission operating to optimise system processing. The minimum degree of battery charge level required. Degree should be programmed in car SmartModule and this data should be open for grid operator to avoid full discharge of battery element to prevent damages of battery and possible troubles to car owners. Preferable is to charge battery when price of electricity is low, for example at night, for reason to sell electricity when electricity price is higher, for example in a day on purpose to earn money on a difference between price rates.

**Conclusion**

In this paper is shown a new vision of future intelligent connections between electrical vehicle and electrical grid, named as a V2G+ system. Conception of V2G+ system needs a technical support and infrastructure supply by interested companies and regional governments. Majority of the problems preventing a development of electrical vehicles and charging infrastructure are solvable in medium term. V2G+ conception defines one possible way to develop charging technology of electrical vehicles. Standards developmental should be evolving in locksteps.

**References**

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