Requirements for an interface between a plug-in vehicle and an energy system

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Abstract-- **In this paper, requirements for an interface between a plug-in vehicle and an energy management system are discussed. A case where there is a service provider aggregating large amount of small resources was considered. Requirements were set for electrical and ICT interfaces and some related standardization work was briefly presented. Four different types of interfaces were presented: passive load (type 1), dynamic load (type 2), V2G (vehicle-to-grid – type 3) and V2H (vehicle-to-home – type 4).**

Index Terms--**Plug-in hybrid electric vehicle, electric vehicle, interface, power system, electricity network, ICT**

I. Introduction

Transportation has a very important function in today's society. Globally, the energy production of transportation systems is highly dependent on oil, and there are strong expectations that the price of oil as well as its volatility will increase in the future. The transportation sector is also a significant consumer of energy and a significant source of greenhouse gases and of other emissions [1]. Today's climate and energy policies push increasingly towards a diversification of transportation fuels, an improvement in energy efficiency and a decrease in emissions. The use of electrical energy for plug-in hybrid electric vehicles (PHEV) and electric vehicles (EV) offers the potential to partly fulfill these challenging requirements. Emission reductions and the amount of primary energy conservation due to plug-in vehicles are, however, highly dependent on the energy system.

There are some barriers related to high penetration of plug-in vehicles (PHEV and EV). The most important barrier is the battery technology. Batteries suitable for transportation appliances are very expensive at the moment, but the technology is continuously evolving and prices are expected to go down [2]. Secondly, a lack of adequate charging infrastructure is a major barrier. A massive installation of charging infrastructure would probably be fairly expensive especially in densely populated areas.

Vehicle battery chargers affect the power system. Plug-in vehicles are not very big loads when considering the amount of energy absorbed. For example, there are about 2.5 million registered passenger vehicles in Finland today. If all of them were full EVs, their total energy need would be roughly about 10 % of the total electricity consumption of Finland. Plug-in vehicles can however cause challenges when considering instantaneous power. A great penetration level of plug-in vehicles can increase dramatically the peak powers of different parts of an electricity distribution network [3].

A plug-in vehicle can include different kinds of functionalities other than being simply passive electrical loads [4]. They could be used smartly to mitigate their harmful impacts on the network (i.e. to avoid high cost grid investments) and to make electricity market operation more effective [4]. In the beginning of the market penetration process only the mandatory functionalities will probably be used, but when the penetration level increases, other functionalities and services might become economically attractive. Although plug-in vehicles are mostly discussed in this paper, it is very important to remember that they are only one of the many resources that could be used to provide different services.

In the context of power systems, plug-in vehicles can be used as controllable loads or as dischargeable energy storages. Efficient and cost effective energy storage capacity would offer many advantages and possibilities which are analyzed for example in [5]. Storages could be discharged to public distribution networks (Vehicle-to-grid – V2G) or to small isolated network islands such as single households (Vehicle-to-home – V2H). V2G and V2H functionalities are very interesting because of their ability to store relatively large amounts of electrical energy. In addition the cost of the storage itself can be viewed as fairly low because it comes as an ancillary service on top of the driving purposes. Storage and discharging of batteries however bring some new challenges. Additional charging-discharging cycles pose additional stress to batteries and decrease their cyclic lifetime causing additional costs for vehicle owners. As the cyclic lifetime of batteries lengthens and the prices go down, this issue will become less important. Also the users have to accept that the state-of-charge of the batteries of their vehicles can decrease while they are connected to the electricity

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network. These challenges will have to be tackled with relevant customer incentives.

This paper discusses the requirements for the interface between the “energy management system” and a plug-in vehicle. Energy management system refers to a unity including all the systems and parties related to power system and electricity markets.

II. Services offered by plug-in vehicle fleet and other small resources

Figure 1 illustrates services and functionalities a plug-in vehicle fleet could offer to different parties in the future. In the figure, the links between different parties are represented along with the relevant services and processes. The charging spots are connected to a party called service provider (SP) who has an essential role in the system. The service provider aggregates a large number of vehicles and possibly other types of resources and offers services to different parties. Other common terms for service provider could be virtual power plant (VPP) or aggregator. For different parties it is necessary to allow the aggregation of small resources and treat the aggregated resources as a single, larger, unit. The connection between the charging point and the SP can range in complexity from a very simple situation to an “interactive customer gateway” [6] allowing interactions and communication in real-time.

Energy companies could use the aggregated resource for demand response (DR) based on electricity price or for balancing purposes. This means that the customers modify their energy consumption based on the electricity price [7] or on other signals. In the Nordic electricity market energy companies are responsible for two different balances: production balance and consumption balance. Using the aggregated resource an energy company could adjust its realized consumption and production in order to improve its balance positions. The difference between balance management and other DR functions is that balance management tries to change the real consumption closer to a value bought from the electricity market, and some other DR functions are used to modify the energy amounts that have to be bought from or sold on the market. Plug-in vehicles can be charged in many physical locations. There are many possible market mechanisms [4] offering the vehicle users different levels of freedom to choose the electricity product when charging in public charging spots. Information flows between different parties are needed and they could be managed by SP.

The service provider could also make bids directly on the day-ahead and intra-day markets in the power exchange (NordPool in the Nordic countries). In addition to these markets, the TSOs administrate separate balance power markets. In fig. 1 all of these markets are lumped under the term “power exchange”.

As mentioned earlier, distribution networks may experience dramatic load changes due to plug-in vehicle charging. A SP could offer network management services to manage these changes, and these services could be treated as an alternative for network reinforcements. Different services provided by vehicles acting as loads are described in [4]. The range of services becomes wider if the batteries can also be discharged into the grid. If the services are based on communication, the DSO can monitors the state of the network (cf. fig. 1) using distribution management system (DMS) and advanced metering infrastructure (AMI) and send information to the vehicle chargers and other resources. Vehicle chargers could also be used to improve power quality in a local distribution network by for example mitigating voltage dips, harmonics and asymmetry. In some market mechanisms presented in [4], SP could offer services for balance settlement process.

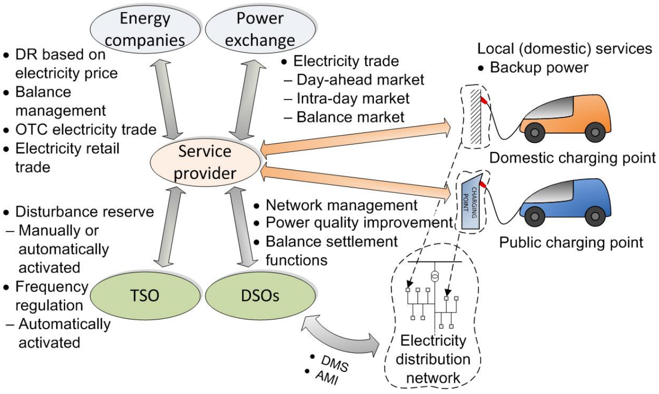

Fig. 1. Services and functionalities which plug-in vehicle fleet could offer for different parties

Plug-in vehicles can be used to provide different reserve services for the TSO. Making the charging dependent on local frequency measurement would be an easy way to realize automatically activating disturbance or frequency regulation reserves [8]. Such reserves could also be offered using many other types of loads [9;10]. Vehicles could also provide manually activated disturbance reserve which could be offered directly to the TSO.

An individual vehicle can also be used to provide some local services, such as backup power, at the charging site. During an electricity distribution outage the batteries of the vehicles could be used as energy storages to feed a small network island in a network, such as a single household. This is discussed in more detail in chapter III.D.

III. Interface requirements

An interface between an energy management system and a vehicle can be divided into two parts: an electrical interface and an ICT interface. The electrical interface links the vehicle to the physical power system. The ICT interface links the vehicle to the information systems which is needed to realize different services. One essential part of the ICT interface is the communication between the vehicles and the different parties of fig. 1. In this paper, the requirements for communication are discussed from an operational point of view so that a network operator could design and define the communication system with satisfying characteristics.

A charger can be physically connected to an electricity network in two ways: through conductive and inductive coupling. In this paper conductive coupling is mostly covered. Inductive coupling, however, includes some features which could make it preferable for some special applications.

Different kinds of services set different requirements for an interface. Thus, in this paper the interfaces are divided into four different types: types 1, 2, 3 and 4. For each type, the electrical and ICT requirements are presented. The impacts of each interface types' functionalities on the power system and electricity market are also discussed. The presented interface type division is of course only an option, and it does not cover all the possible solutions. Different interfaces do not necessarily have to include all the functionalities which interface types make possible.

A. Type 1 interface: "passive load"

The type 1 interface, called passive load interface, is the simplest one. It presents only a simple and safe connection to an electricity network in order to draw electrical energy from the grid. Type 1 interface includes no vehicle specific measurement of electrical energy or any control possibilities by any parties presented in chapter 2. In this concept, when public charging spots are used to charge the vehicle, billing is not based on the amount of electrical energy drawn from the grid, but the billing can be included for example in a parking payment as a constant or parking time dependent payment.

Functional requirements of the type 1 interface

The electricity connection needs the regular electrical safety requirements for equipment designed for indoor or outdoor (depending on the location of the charging spot) usage. The physical connection to the electricity network can take the form of a "regular" one-phase or three-phase socket. In Finland there is a long history of using pre-heaters for the vehicle engines in outdoor environments in winter time, and there have been very little problems with electrical safety issues. If a high power three-phase charger is used, methods of local load coordination [4] can be applied for this type of interface to manage the peak power of a network connection.

Type 1 interface and standardization

An exhaustive list of the standards related to this type 1 interface is not given in this paper, but only a brief overview of some relevant issues. Related standards include rules for the design of the inlets, outlets, connecting cables as well as the insulation level (IP class), the required grounding system, residual current devices etc.

In Finland, electrical installations on a low-voltage network should be made according to the standard SFS 6000, based on the IEC and CENELEC 60364-series. The rules for working on low-voltage installations are given by regulations in Finland. The regulations are considered to be fulfilled if the Finnish standard SFS 6002 is complied with [11].

The relevant Finnish laws and regulations are the following:

- Electrical safety act (410/1996, 634/1999, 893/2001, 913/2002, 220/2004)
- Electrical safety decree (498/1996, 323/2004)
- Decision/statute of the Ministry of Trade and Industry on electrical works (516/1996, 1194/1999, 28/2003, 1253/2003)
- Decision/statute of the Ministry of Trade and Industry on commissioning and use of electrical installations (517/1996, 30/2003, 335/2004)
- Decision of the Ministry of Trade and Industry on safety of electrical installations (1193/1999)

The Technical Committee IEC/TC69 dealing with 'Electric road vehicles and electric industrial trucks' has published the standard IEC 61851 [12] about electric vehicle conductive charging systems. It is currently being taken into account by SESKO, the Electrotechnical Standardization body in Finland, in order to form a Finnish standard [13]. Some add-ons (parts 21 and 22) have also been published regarding the specific measures for the vehicle charging systems and the AC charging stations. Their content is however very similar to part 1, and they just mostly complement it. The content of the standard covers the electrical and mechanical aspects of the connection between a vehicle and the grid. It thus includes issues such as protection against electric shocks (direct, indirect, capacitor discharge…), specific inlets and connectors' ratings, IP class, permissible temperatures and environmental conditions, and specifications for the charging cables. It also considers three different types of connections depending on where the charging cable is attached: to the car, to the charging point or if it can be disconnected from both sides.It is now assumed by SESKO that the existing outlets used for car heating will need to be replaced by new installations, although they could remain mounted on the same pole [13].

In addition to this standard, the IEC/TC69 is also working on charging installations based on inductive charging. That standard is not finalized yet, but it is announced to be based on the IEC 61980. However, some inductive charging installations do exist such as Magne Charge WM7200. In addition to the standards for conductive charging, inductive installations should be equipped with other protections such as overheating protections for the charger, detectors preventing the charging if the receiving battery is not adapted (for example if the vehicle requires ventilation for inductive charging which is not provided by the charger) or a protection against over-voltage faults at the battery level.

There are currently some existing outdoor conductive charging installations in Finland [13]. They follow the principles and use the same technologies as those encountered in building electrification.

Their characteristics are listed here:

- Nominal voltage: 400/230V
- Nominal current: 3x16A or 50A
- Thermal overcurrent rating: 10kA
- 1-phase outputs, 230V, 3,6kW
- 3-phase output, 400V, 10,8kW
- Residual current protection: 30mA
- Over current protection: 16A
- IP class 34
- Lock on the casing

B. Type 2 interface: "dynamic load"

The second interface type is called a dynamic load interface. In addition to the functionalities and requirements of the passive load interface, the dynamic load interface includes a few additional features. One of these is a vehicle specific energy measurement, which is used for billing purposes. In such market mechanisms where the charged energy is bought from the same retailer as the one from which the user buys the domestic electrical energy [4], payment of the charging in public charging spots could be added to the user's regular electricity bill. The dynamic load interface makes possible the use of the charger as a controllable load using communication or based on local logic or intelligence. In addition, monitoring of the state of the loads could be needed depending on the service. The use of a charger for frequency regulation or disturbance reserve capacity based on local frequency measurement is also supported by this interface. Local power quality improvement, such as harmonics or voltage asymmetry mitigation, could also be possible

Functional requirements of the type 2 interface

This interface type includes some additional requirements for the electrical interface when compared to the passive load interface. Vehicle specific energy measurement equipment should be included in the vehicle or in the charging spot. Frequency measurement and related technology for realization of frequency dependency is needed. For local power quality improvements, the charger should present relevant design and characteristics.

The dynamic load interface sets some requirements for the ICT interface. Communication is needed to send control signals, such as price data or direct instructions, to the chargers unless the control is based on local intelligence/logic. In some cases there could be a need to send information from the vehicles to the service provider in order to monitor the state of the distributed resources and assess the available resources. Many communication requirements can be set for the ICT interface. They can be quantified by investigating the needs of the different services.

If the energy meter is in the vehicle, it should be possible to read the meter remotely when the payment of electricity is carried out in a public charging spot. This communication should be very reliable and it should have such characteristics, that the user experience is of good quality.

One possible service is the participation in a regulating power market. In today's Nordic electricity market the activation time between the order and the full volume delivery must be less than 15 minutes [14].

Another electricity market related service is balance management. For balance management the differences between scheduled and realized production and between estimated and realized consumption in a certain time interval are minimized within certain boundary conditions. The requirements set for the communication regarding this service are dependent on the moment when the short-term estimations of production and consumption are carried out. Estimations can be carried out before the time interval or during the time interval. In the first case, the time requirement for control actions depends on the time between the finalization of the estimation and the beginning of the time interval under manipulation. In the latter case, the control actions should be performed as soon as possible.. Thus, if the estimation is conducted during a one-hour time interval, the control actions must have the ability to be realized within some minutes.

Another possible service is the manually activated disturbance reserve. Today in the Finnish power system, manually activated fast disturbance reserves must have the ability to be activated within 15 minutes [15]. It can be considered as the time response requirement for a load decrease of a plug-in vehicle fleet.

A type 2 interface vehicle fleet can also participate in the management of the electricity distribution network. The aim is to use lines and transformers nearer to their economic-physical limits. The services include avoiding the excessive overloading of network components. In the case of overloading time response requirements depend on the component under overload and weather conditions such as outdoor temperature. Depending on the system, the over-current protection of the network may or may not be set to trip because of overload. If overload situations are covered in the protection system, the electricity network management service should operate before the protection system. This type of service is based on state estimations of the network and may require a high level of coordination in order to operate extensively in different network states. This type of service can however be realized for different degrees of scale. One must not manage the whole distribution network but a part of it: for instance a single problematic medium voltage feeder can also be the target of this service.

Another possible service is frequency dependent reserve. The Finnish TSO's grid code requires that the frequency controlled normal operation reserves have to be activated within two to three minutes after an appropriate frequency change. On the other hand, 50 % of a frequency controlled disturbance reserve's capacity has to be activated within 5 seconds and 100 % has to be activated within 30 seconds in the case of a sudden 0.5 Hz frequency drop. [16]

In addition to these services communication can also be needed for many other services which include modest requirements for the time response of the communication system.

Many of these services can have a need to monitor the state of the vehicles. For some services it is important to have an accurate enough estimate concerning for example total power (MW) of controllable chargers. The level of monitoring need is the main attribute defining the requirements for the communication system.

Table 1 sums up the time response requirements for communication and control equipment for different services in the Finnish power system and presents information concerning the location of the measurement and control equipment needed in different services. Time ranges refer to the permitted delay between the time when the need is detected and the time when the control action is taken. "L" (local) in the table means that measurement or control equipment is located near the resource and "R" (remote) corresponds to remote location.

TABLE I
APPROXIMATE TIME RESPONSE REQUIREMENTS AND LOCATION OF MEASUREMENT EQUIPMENT AND CONTROL INTELLIGENCE FOR DIFFERENT SERVICES

Service	Time range	Measur.	Control
Power quality improvement	Some µs…some ms	L	L
Distribution network power flow management	Some min…some h	L /R	L/R
Frequency controlled disturbance reserve	5…30 s	L	L
Frequency controlled normal operation reserve	2…3 min	L	L
Balance management	5 min...1 h	–	R
Monitoring of reserves	Some minutes… 1 h	L	L/R
Balancing power market (realized bid)	15 min	–	R
Fast disturbance reserve	15 min	–	R
Intra-day market (Elbas market)	1 hour	–	R
Day-ahead market (Elspot market)	10…34 h	–	R

The amounts of data which should be transferred for the different services are not large. Data can comprise simple on/off type commands, starting and stopping times of some event, some simple numerical data such as electricity prices of different periods of time etc.

Type 2 interface and standardization

The first new requirement for this type of an interface is a specific metering infrastructure for the vehicle. This infrastructure can be located inside the vehicle or inside the charging points.

The meters will most likely have to follow the existing regulations and standards as for household consumption meters. There are European and national regulations and standards detailing the precision required by the meters as well as for data protection and transmission. The EU Measurement Instrument Directive (MID) [Directive 2004/22/EC] for example provides the legal requirements to ensure that trade based on measurements is accurate, reliable and fair.

Often the owner of the charging point is not the owner of the vehicle. There could then be a need for two different metering systems. The first would be at the connection point to the network. The DSO would use it to bill the owner of the charging point. The second would be used by the owner of the charging point to bill the vehicle user. There could be an additional meter inside the car. The system could be greatly simplified if a secure and reliable communication system was installed. In any case, it is important that the EV user pays for his charging and that the owner of the charging point pays for the electricity consumed, each of them paying once and only once.

New meters will most likely be "smart-meters" that can be read remotely. For the interface with the network in Finland, the electricity market decree 65/2009 [17] details the way that the DSOs should implement their smart-meter roll-out as well as minimum requirements for them (such as an hourly measurement and a daily meter reading).

In cases where the meter is installed inside the vehicle, they will have to comply with standards and regulations about on-board electric equipments for EV (under work standard IEC 61981), but also the reading of the meter may not need to be daily (the vehicle may be unable to transmit the information on a daily basis, e.g. in the case of a travel in another country) and the transmission of the information to the DSO would offer complications. If this solution is to be considered, a specific regulation should be drawn up in order to make it possible.

The communication standards between the meter and the electricity actors are the object of the report [18]. The meters, or the data concentrators should have a Wide Area communication Network (WAN) access such as a GSM/GPRS modem, an xDSL-modem or a satellite phone modem. If concentrators are used, the communication with the meter is made using some 'last kilometer' communication such as PLC, short range radio communication or some other local communication system. In the case of a specific EV measurement at the charging point, it would be likely that a concentrator is used. If the measurement is made onboard, either the meter communicates directly with the company responsible for the metering, or it should be able to communicate with the concentrators wherever the charging takes place.

In Europe, the series of standards IEC 62056 "Electricity metering – Data exchange for meter reading, tariff and load control", also called DLMS (Device Language Message Specification) are widely used for meter communication and cover most major aspects.

With this type of interface, the vehicle's load (the charger) can be used as a controllable load based on signals received or on local control. The electricity market decree 66/2009 states that the metered hourly data should be used in balance settlement by 2014. It is therefore very likely that electricity retailers and/or network operators will submit electric vehicles to hourly metering and possibly to direct control signals or to price or price and volume signals. The exchange of these signals should follow the same standards as those used for metering with the additional constraint that the communication system must be fast enough for the vehicle's charger to react to the signals.

The possibilities based on local measurements are not currently being studied much because frequency and disturbance regulations are reserved for producers and large consumers. However, they could be introduced through the SP or if the TSO policies change. In a smart-grid context, with increased levels of interactivity between the network and the distributed resources and with a higher penetration of renewable energies, they would become of vital importance.

This type of interface would require a fast enough measurement system and probably some other elements such as can be found in the existing contracts between Fingrid and frequency control service providers [19]. They include such information as what types of disturbances the service should react to, how fast it should respond and prices for the utilization of the service.

The metering infrastructure should also in this case be faster in order to assess the provision of the frequency or disturbance control action. In other words the metering data should show if the service has been provided according to the contract. Currently, Fingrid requires "real time" measurement for its services. Collecting the data and sending it to the service buyer can however be done at a lower frequency (every hour or day for example).

Another aspect of the vehicle specific metering to be considered is data security. This is especially true when the meter is attached to the vehicle. Data security needs different sets of standards depending on the communication technologies and protocols used [18].

C. Type 3 interface: "V2G"

Type 3 interface includes the vehicle-to-grid capability in addition to the functionalities of type 2.

Functional requirements of the type 3 interface

To operate in V2G mode, some additional features are necessary in the electrical interface. The most important additional feature is the bidirectional converter of the charger with appropriate protection equipment such as over current, over voltage and under voltage protections. Loss-of-mains (LOM) protection is also needed in the electrical interface. If a part of a network in which a vehicle operates in V2G mode is disconnected from the public distribution network due to for example an earth fault, the vehicle should also stop feeding energy to the grid for safety reasons. There are many different types of LOM protection methods. Some of them are discussed and extensively overviewed for example in [20]. Also, safety issues during network repair and maintenance should be ensured to avoid the sudden start of V2G operation during such work. This could be carried out by designing the converters to be unable to operate in dead network or by using a remotely controllable switch that could be opened before network repair and maintenance work. Also, energy meters should be able to handle two-way energy flows. Interface of type 2 included a functionality of power quality improvement. This could be enhanced in V2G interface, because feeding real power back in a network offers new possibilities such as mitigating voltage dips.

V2G does not set very many new requirements for the ICT interface. The requirements of type 2 are valid when applied to V2G operation. Concerning the monitoring of resources, in V2G operation it is necessary to monitor the total amount of battery energy storage capacity (MWh), which could be used for V2G purposes. This requires that the information concerning the state of charge of the batteries should have the ability to be transferred from the battery controller equipment to the service provider.

Type 3 interface and standardization

A good basis for this type of interface in Finland would be to comply with the network guideline YA9:09 [21] from the Finnish energy industries. The recommendation is based on the European standard EN 50438: "Requirements for the connection of micro generators in parallel with public low-voltage distribution networks". The YA9:09 includes recommendations about:

- The disconnection of the generator (according to the standards SFS 6002 and SFS 6000)
- EMC requirements:
  - o The standard EN 61000-3-15 is in preparation: Electromagnetic compatibility (EMC) Limits – Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network
  - o Existing standards that can be applied to micro-generation:
    - – Interference immunity: EN 61000-6-1
    - – Electromagnetic emissions: EN 61000-6-3
    - – Harmonic current emissions: EN 61000-3-2
    - – Voltage fluctuation and flicker: EN 61000-3-3
- Quality of electricity: the quality of the voltage at the connection point must comply with the standard SFS-EN 50160 "Voltage characteristics of electricity supplied by public distribution systems"
- Network connection and tripping in case of network fault situation (including limits in voltage deviation requiring a disconnection, Loss of mains situations and resynchronization after a disconnection)
- Short-circuit current limitations to be fed into the network

Another related standardization work is standard draft ISO/IEC CD 15118-1 "Road Vehicles – Vehicle to grid communication interface – Part 1: General information and use-case definition".

D. Type 4 interface: "V2H"

The fourth interface type is called the V2H (Vehicle-to-home) interface. In addition to the functionalities of type 3, V2H interface has an ability to feed energy to a single household. This would offer the possibility to use the vehicle as a domestic back-up power. The V2H interface does not necessarily include all the functionalities of the V2G interface and thus all the same requirements do not necessarily have to be set for it. In addition to the requirements of the V2G interface or part of them, the V2H operation sets some new interface requirements.

Functional requirements of the type 4 interface

Type 4 interface includes some important new requirements. One requirement is a switch, which is used to disconnect the household (or another small network island) from the public distribution network (see fig. 2). This isolation has to be made, because a V2H capable vehicle has very limited power and energy capacities and thus cannot feed other households or customers connected in the public distribution network. It is also preferable that the connection to the electricity network is three-phased (see fig. 2). Otherwise it would be necessary to select the loads to be fed during an outage, and those should be connected to a certain phase. Some load reduction of non-critical loads may be necessary to ensure that the power capability of the converter, the line and the energy capability of the battery are sufficient. This requires some special equipment including some sort of a relay or home automation able to disconnect these loads. Assuming that the vehicle works as the only power source (unless there is some sort of small scale power production such as solar panels) during V2H operation, the feeding equipment has to include all necessary control and protection functions very similar to the ones found in conventional power plants. This comprises voltage control, big enough short circuit current capacity, short circuit protection etc. However, fulfillment of all the power quality requirements defined by standards is not necessarily mandatory. The switching equipment has to include a battery back-up or other type of back-up power to realize the necessary switching and communication actions during an outage.

V2H operation brings some new requirements for ICT interface. In addition to the relevant requirements of type 3, there is a requirement for an automatic operation of the isolation switch during an outage and automatic control of the converter. The transfer into back-up power mode could be made with a short interruption or voltage dip, or totally seamlessly. The transfer to V2H mode after an outage and returning on the basic mode (electricity transfer from distribution network) after the outage is carried out as follows.

1. When an outage is detected in the network, the isolation switch has to be opened automatically.
2. After the isolation, necessary load reductions have to be made.
3. "Start back-up power operation" command has to be sent to the converter of the vehicle. Converter starts to feed the loads.
4. When the end of the outage is detected, a "stop back-up power operation" command has to be sent to the vehicle converter.
5. The isolation switch has to be closed.
6. Loads which were disconnected have to be reconnected to the network.

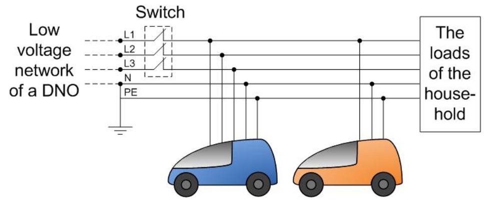

Fig. 2. Realization of the vehicle-to-home service.

Type 4 interface and standardization

The Finnish guideline YA9:09 (ET 2009) states: "If a consumer wants to use a micro-generator as reserve power in parallel with the network it is of utmost importance that the installation may under no circumstances concurrently feed both the network and the isolated network" and that it requires a separate switch and additional devices.

This situation brings up new requirements that are not included in current standards. One is that the local system must keep a balance between production and consumption on the islanded network. For that purpose, some loads must be turned off or down in order to not exceed the battery capacity (for example sauna, water heaters, space heaters…). In the case where the vehicle is connected to a single phase, only the loads connected to that same phase can be fed. Another point is that the power quality on the local network does not need to fulfill the normal power delivery standards. However, some limitations should be put in place and the control capabilities of the converter must be able to respect them. Also, safety standards must still be fulfilled. That includes a possibility to disconnect the vehicle from the local network in situations of faults or of repairs. The short-circuit protection must also work during V2H operation.

IV. Conclusions

A cost effective but still flexible and dynamic system is the target of the plug-in vehicle infrastructure development. In this report requirements for an interface between a plug-in vehicle and an energy management system were discussed. A case where there is a service provider aggregating large amounts of small resources was considered. Requirements were set for electrical and ICT interfaces and some related standardization work was briefly presented.

In this report, many different types of services were discussed. However, these services were not discussed from an economical point-of-view. In this context, economical factors should be analyzed from the vehicle users', service provider's and different power system and electricity market related actors' point-of-views. It is very important that vehicle users have a reasonable economic incentive to participate in different service markets with their vehicles and other energy resources. Also, the service provider must have reasonable revenue possibilities for its operation. Different actors cooperating with the service provider, such as energy companies and network companies, must also have reasonable economical incentives to apply the services. For energy companies such incentives could be formed by means of more efficient electricity trade and for a distribution network company such incentive could be peak load reduction and avoidance of some network reinforcements.

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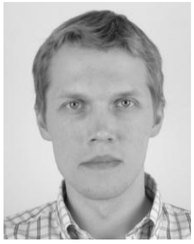
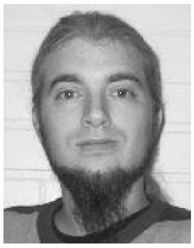
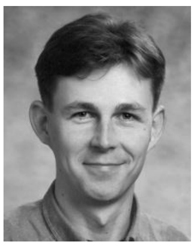
VI. Biographies



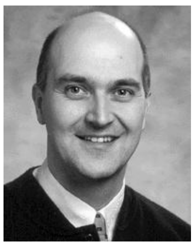
A. Rautiainen received his M.Sc degree from Tampere University of Technology in 2008. He is now working as a researcher towards doctoral degree at Tampere University of Technology. His main interest focuses on the effects of plug-in vehicles to electric power systems, ancillary service possibilities of plug-in vehicles and smart load control.



C. Evens received M.Sc. degrees in Electrical Engineering from the Helsinki University of Technology and from the University of Liège in 2007. He has since been working for VTT, Technical Research Center of Finland. His work focuses on demand response, the aggregator concept and the future interactions between electricity actors.



S. Repo received his M.Sc. and Dr.Tech. degrees in Electrical Engineering from Tampere University of Technology in 1996 and 2001 respectively. At the present he is a University Lecturer at the Department of Electrical Energy Engineering of Tampere University of Technology. His main interest is the management of active distribution network including distributed energy resources.



P. Järventausta received his M.Sc. and Licensiate of Technology degrees in Electrical Engineering from Tampere University of Technology in 1990 and 1992 respectively. He received the Dr.Tech. degree in Electrical Engineering from Lappeenranta University of Technology in 1995. At present he is a professor at the Department of Electrical Energy Engineering of Tampere University of Technology. The main interest focuses on the electricity distribution and electricity market.