FRAUNHOFER INSTITUTE FOR EMBEDDED SYSTEMS
AND COMMUNICATION TECHNOLOGIES ESK

TRANSITIONING CHARGING STATIONS TO SMART GRID NODES – A COMPARISON OF CURRENT COMMUNICATION STANDARDS

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EXECUTIVE SUMMARY

The process of charging an electric car should involve more than just plugging a cable into an outlet. Charging needs to be convenient and cost-effective for the driver, as well as manageable and efficient for the energy provider, especially to ensure the stability of the electricity network given the growth of renewable energy sources. This goal is achievable only with an intelligent charging infrastructure, or one that is integrated in the power grid from a communications standpoint.

Before electromobility can become established, e-vehicles, drivers, energy suppliers, grid operators and to some extent other parties such as billing service providers, must be able to interact with one another. Charging stations should be usable regardless of the manufacturer or location, reservable while travelling and be able to automatically carry out the charging process in accordance with pre-defined user settings. To reduce the load on the electricity network, energy providers need real-time information about the local short- and medium-term energy demand. They also need the ability to manage the charging process when required. For this reason, several factors play a key role in selecting the communication technology. Apart from the basic security aspects, this includes interoperability, the ability to exchange an extensive amount of data in a secure manner before, during and after charging, and efficient integration into the overall system, taking into account the costs and ease of use. This is something that only a uniform charging infrastructure with communication technology based on international standards can provide. Fraunhofer ESK researchers examined the potential standards and produced a white paper that summarizes the most important characteristics of a sustainable charging infrastructure.

Using this detailed technology evaluation as a foundation, and by relying on ISO/IEC 15118 for the vehicle-to-charging station communication and IEC TR 61850-90-8 for the charging station-to-smart grid communication, Fraunhofer ESK designed an intelligent charging infrastructure that can be seamlessly integrated into the smart grid. The concept is outlined in the following white paper.

ELECTRIC VEHICLES – NETWORKED INSTEAD OF MERELY CONNECTED TO THE NETWORK

Electromobility starts to roll – at least from a planning standpoint

In August 2009, the German government introduced a national electromobility development plan that stipulated the goal of having 1 million electric vehicles on the road in Germany by 2020. Various market development scenarios, including one that was included in a study published by the National Electromobility Platform (NPE), an advisory committee of the German government, no longer view these figures as realistic. To reach these goals, there should have been around 100,000 electric vehicles on the road by 2014. As of January 1, 2104, the number of registered e-vehicles was actually 12,156.

Nevertheless, even if the actual figures are less than expected, the number of e-vehicles will no doubt continue to increase. With government and the research community aware of this trend, early studies regarding the technical challenges of the charging infrastructure and its impact on the energy supply have already been carried out.

One of the first results of these analyses was a statement by the NPE, which was created in 2010, that under certain conditions the growth in electromobility could place an additional load on the country's electricity networks. This is especially true when, as is currently customary, charging primarily takes place at home and with the help of a simple and cost-effective infrastructure. In other words, by using normal power outlets. Another study that examined the Salzburg smart grid model region substantiated the assumption that electromobility places an additional load on specific network segments [2]. The initial premise was that the still relatively expensive e-vehicles would be driven primarily by well-off car owners in the commuter belts of larger cities, most of whom would drive home and plug their cars into their power outlets for charging during roughly the same period of time. Depending on the available charging infrastructure, the maximum charging capacity ranges between 3.7 kW for power outlets and 43.5 kW for fast charging stations. This equates to a charging current of 16 to 63 amps. Single-family dwellings are rated at 50 amps, while multi-family dwellings with 10 units have an overall rating of 80 amps. If unregulated, even a few simultaneously charging e-vehicles have the potential to overload single network connections or individual network segments.

To avoid this situation, the industry must take immediate steps to develop active management concepts for e-vehicle charging and factor them in when planning future smart grids, especially given the fact that the required network build-out, including the management of smart applications, represents a long-term and costly undertaking for grid operators.

Electromobility and renewable energy

Apart from electromobility, the government is also pushing for an increase in the percentage of energy generated by renewable sources. The issue is that the storage of energy from renewable sources such as wind and solar in low- and medium-voltage networks is volatile. During periods of low network capacity, if too many e-vehicles recharge at the same time without being regulated, this further increases the risk of overloaded grids. Furthermore, since these power generation facilities require considerable space, they are usually built in rural, infrastructure-deficient regions with marginal network build-out, which further exacerbates the situation.

For this reason, the capability to manage the charging infrastructure and adapt it to the capacity of the grid is essential in order to minimize the load on the network. Ideally, the charging process should also be coordinated through the network operator who can balance the supply and demand from a control center. Generally speaking, flexible charging processes adapted to the energy supply should not be an issue since private vehicles remain parked for 23 hours a day on average. This of course assumes that the mobility wishes of the vehicle user are taken into consideration. Users could also profit from flexibly managed charging processes by taking advantage of lower rates during periods of high network capacity for instance.

COMMUNICATIONS TECHNOLOGY FOR A UNIFORM CHARGING CONCEPT

As stated in § 1 of the German Energy Act (EnWG), a modern energy supply based increasingly on renewable energy sources must be secure, economically successful and environmentally-sustainable. Furthermore, in the spirit of a maintaining a secure energy supply, § 11 of the EnWG obligates energy supply providers to ensure that their electricity networks are secure, reliable and efficient. In this respect, § 14a of the EnWG permits network operators to regulate interruptible consumption systems such as heat pumps and off-peak heat storage units for the purpose of relieving the load on the grid at the low voltage network level. In effect, this allows the network operator to delay the consumption of electricity in order to ease the load on the network.

This paragraph defines charging stations for e-vehicles as interruptible consumption devices as well. That means the network operator can intentionally suspend the charging process in order to relieve the network, in so far as this has no adverse effect on the end user and supplier according to the legislation. To specifically accomplish this through a comprehensive expansion of the charging infrastructure, each charging station has to be connected to a communication network and be remote controllable.

The special challenge here is reconciling the interests and obligations of the network operators with the drivers' desire for individualized mobility.

In order to manage the charging process, network operators not only have to know that a specific vehicle is connected to the charging station, where the charging station is located within the distribution network and how many additional charging stations are available within the network segment. They also need to know how much energy is required for the charging process, what the charging status of the vehicle is and how far the vehicle has to be driven. Finally, network operators must know if the user has authorized an interruption of the charging process.

This comprehensive exchange of information requires the use of intelligent charging stations.

In this context, intelligent refers to the communications-based integration of the charging station in the overall system. Depending on the application scenario, e-vehicles, drivers, energy providers, network operators and to some extent other parties such as billing service providers must be able to interact [2].

Communication between all participants is what makes it possible to successfully integrate e-vehicles in the overall system, thus leading to an automated charging process. This approach also provides the opportunity to implement a wide range of value-add services such as variable charging rate structures, which significantly increase driver convenience. That means drivers can charge their vehicles at any available station regardless of the location, charging station operator or energy provider. Drivers merely have to connect to a charging station and individually configure the process in accordance with their own needs. That might involve fast charging or - depending on the situation, the timeframe and distance of the next journey - configuring the system to only charge during off-peak periods, which leads to lower electricity rates. The charging process then begins automatically, including user authentication and all of the background information required for billing and settlement with the driver's energy provider.

This process first requires a uniform charging cable connector. The so-called Type 2 plug is well-established in Europe [3]. The interface specification is based on the IEC 62196-2 standard and the Type 2 plug is a three-phase connector specified in the VDE-AR-E 2623-2-2 standard.

A manageable and efficient charging concept also requires a uniform communication infrastructure between the e-vehicle, charging station and network operator, which requires integration of the following interfaces:

- Vehicle – charging station
- Charging station – smart grid backend system

The charging station forms the central communication node between the e-vehicle and the network operator. The following section outlines several approaches for these communication links with a view toward the development of an integrated concept.

COMMUNICATION BETWEEN THE VEHICLE AND CHARGING STATION

Data exchange between the e-vehicle and the charging station can be carried out using various communication standards. There are currently several proprietary solutions, industry consortium developments and international standards created by independent committees in use. The key criteria for a suitable communication infrastructure include:

- comprehensive, bi-directional exchange of information between these instances, uncoupled from the actual process before, during and after charging
- interoperability of the charging stations, which are integrated in the remaining infrastructure of the network operator independent of the manufacturer

This allows e-vehicles to be charged anywhere within the implemented infrastructure. Since the proprietary solutions cannot satisfy the requirements of a universally-available charging infrastructure, they will not be covered any further in this paper. Following is a discussion of the standards that, according to the current status, will most likely be deployed in the development of a uniform charging infrastructure.

IEC 61851-1 – Safe and needs-based charging

The IEC (International Electrotechnical Commission) 61851-1 standard [4] describes the fundamental monitoring functions required for the safe and needs-based charging of e-vehicles. Because of its relevance to safety, nearly all e-vehicles available around the world support the 61851-1 standard, which outlines four charging modes that differ based on the type of connector, maximum charging current and communication technology (see table 1).

Table 1: Charging modes supported by the safety-relevant IEC 61851-1communication standard [4].

	Connector	Max. charging current	Communication technology
Mode 1	Earthed outlet	16 A, 3-phase	Not planned; charging device is integrated in the vehicle
Mode 2	Earthed outlet	32 A, 3-phase	Control and protection functions integrated in the cable or wall outlet, charging device integrated in the vehicle
Mode 3	Charging station with special AC charging connector	63 A, 3-phase	Communication device, FI-switch, overcurrent protection, interrupt, specific charging outlet
Mode 4	Charging station with special AC charging connector	Fast charging using DC power	Charging station contains the charging device and control and monitoring functions for the charging process

The primary purpose of the communication protocol within the standard is implementation of the multilevel safety concept. This includes an immobilizer that is activated whenever the charging cable is connected, in addition to electrical protection for Mode 2 and 3 that prevents voltage from being applied if the connector is not fully plugged in. Both functions utilize two reciprocally-redundant circuits that check if the connector is properly plugged into the vehicle and the charging station. Furthermore, Mode 2 and 3 will feature component protection that provides information to the vehicle such as the charging station capacity or the maximum voltage of the charging cable.

Communication is carried out using pulse width modulation (PWM) and a control pilot wire in the charging cable. It is designed to merely signal two independent variables:

- Vehicle status (connection to the charging station)
- Maximum charging voltage (PWM duty cycle)

Plans are in place to expand the communication functionality through other standards. The technique relies on pulse width modulation or the PWM duty cycle. With pulse width modulation, the change between two values serves as the basis for the modulation. The simplest method could be an ON/OFF signal that can be utilized to modulate a rectangular wave. The PWM duty cycle, which involves determining the proportion of on-time to a defined regular period of time, can also be used to transmit information. A well-known example is the transmission of Morse code.

Significance for future charging infrastructures

Creating a uniform charging infrastructure for all e-vehicles will require more than the communication capabilities of the IEC 61851-1 standard. It is nevertheless an important element given its relevance to the operational safety of the system, which is evidenced by how wide the standard has already been propagated. The upward compatibility to further standards will ensure that IEC 61851-1 continues to play a key role in regulated e-vehicle charging systems in the future and provides the means to expand the standard's communication capabilities.

CHAdeMO – Proprietary fast charging system

The CHAdeMO standard (Charge de Move) [5] was initially developed by the Japanese companies TEPCO, Nissan, Mitsubishi and Fuji Heavy Industries (Subaru). Toyota joined later as the fifth member of the group. CHAdeMO is based on the CAN vehicle diagnostics standard (ISO 11898) and is meanwhile in incorporated in ISO/IEC 61851-23 [6] and ISO/IEC 61851-24 [7] as the standard for DC-based charging. It is used primarily for fast charging (80 percent within 15 to 30 minutes) vehicles without integrated charging units and uses a proprietary plug from TEPCO.

With roughly 4,200 fast charging stations, CHAdeMO enjoys worldwide use, although half of the stations are in Japan. In Europe, CHAdeMO-supported stations are found mainly in Great Britain and the Benelux countries, with some installations spread across the German-speaking region. This standard is supported by e-vehicle models such as the Nissan LEAF, Mitsubishi i-MiEV, Peugeot iON and Citroen C-ZERO.

In this standard, the primary purpose of the communication between the e-vehicle and charging station is to prevent damage to the vehicle battery since CHAdeMO uses a high to very high charging power of up to 62 kW (max. 125 A, max. 500 V). Data transmission between the e-vehicle and charging station is CAN-based using signal/communication pins parallel to the two pins that are required for the DC charging process. The system transmits various information such as the charging status of the battery, the actual voltage, the maximum allowed charging current and the battery temperature. Management of the charging process is performed by the vehicle's battery management system. The charging station automatically configures the settings required for the vehicle, such as the charging current.

Significance for future charging infrastructures

The CHAdeMO standard also supports applications such as price-based charging and thus the goal of integrating e-vehicles into the smart grid to some extent. The downside is that the scope of the information that can be transmitted is limited.

The real issue for its long-term suitability however is the lack of compatibility with connectors other than the TEPCO plug, an issue that prevents this standard from satisfying the key interoperability criteria. Since the Type 2 plug is already well-established in Europe, it's unlikely that CHAdeMO will enjoy wide acceptance.

Added to that is the fact that direct current charging stations are relatively expensive and thus are installed and operated on a sporadic basis. A charging infrastructure with *adequate coverage cannot be implemented using only fast charging stations. The upside to the CHAdeMO standard is that it is already used on a relatively wide basis and supported by several popular e-vehicle models. It's conceivable that future fast charging stations will be equipped with two different systems to ensure that vehicle models which support CHAdeMO can be charged as well.*

ISO/IEC 15118 – Comprehensive data transmission and integration

ISO/IEC 15118 is the most recent of the communication standards under consideration for the vehicle-to-grid interface. The eight-part standard extensively describes various charging options ranging from „normal" AC charging, delayed and fast charging to the possibility of wireless charging processes. Part 1 [8] of the international standard, which was published in 2013, covers basic terminology definitions, requirements and application scenarios. Part 2 [9] contains the network and application layer protocol specifications while Part 3 [10] describes the bit transmission and security layers. Parts 2 and 3 were first published in 2014. The remaining sections of the standard, which are currently under development and unavailable for publication, relate to the creation of conformance tests for verifying the correct implementation of ISO/IEC 15118-2 and -3 (Parts 4 and 5). They also cover the design of wireless processes using techniques such as inductive charging (Parts 6-8).

While ISO/IEC 15118 largely relies on the older IEC 61851-1 standard for operational safety, built-in functionality allows it to safeguard the charging process on its own. This downward compatibility ensures that 1st generation e-vehicles will be able to utilize charging stations with ISO/IEC 15118. This standard is compatible with Type 2 (IEC 62196-2) and Type 3 (IEC 62196-3) connectors.

In ISO/IEC 15118, communication is used for much more than operational safety and exchanging system information such as control and switch commands. This standard can be used to exchange extensive data between the vehicle and charging station before, during and after charging. Apart from the battery charging status and the maximum allowed values for voltage and current, this also includes transmitting information that can be used for automatic vehicle identification, energy prices, planned duration of the charging process or billing details. TLS encryption as specified in the standard allows secure data transmission.

Communication is implemented via the control pilot wire in the charging cable. Coexistent to the PWM signal of the IEC 61851-1, the ISO/IEC 15118 also uses a powerline connection in line with the energy-saving HomePlug Green PHY standard [11].

Significance for future charging infrastructures

The ISO/IEC 15118 series of standards permits comprehensive interaction between network operators, drivers and vehicles in order to structure the charging process. As a result, it satisfies the requirements mentioned at the beginning of this paper for the successful integration of e-vehicles in the entire system. Charging station manufacturers and operators, as well as automobile manufacturers, can offer their customers added convenience and a wide selection of services such as off-peak charging at lower rates. By adapting to supply and demand and giving network operators the opportunity to regulate e-vehicle charging in response to impending overloads, the grid can be proactively relieved.

With its comprehensive communication and control options, development through an independent international standards committee and compatibility with older IEC 61851-based systems in use around the world, as well as with connector systems deployed in Europe, ISO/IEC 15118 is an ideal candidate for the vehicle-to-charging station interface. Because it supports different modes of operation, as well as wireless charging systems, ISO/IEC 15118 simplifies the build-out of a sufficiently-large charging infrastructure, even as the number of e-vehicles continues to grow.

Given that the European Automobile Manufacturer's Association (ACEA) and the Union of the Electricity Industry (EURELECTRIC) recommend ISO/IEC 15118 as the standard for electromobility [3] [11], various national committees and R&D projects involving automobile manufacturers are now concentrating on the use of this standard. Although ISO/IEC 15118 is a relatively new standard that is not supported by currently available e-vehicle models or charging stations at this point, there is a high probability that it will eventually establish itself as the standard communication interface for e-vehicle charging stations in Europe.

Standard	IEC 61851-1	CHAdeMO ISO/IEC 61851-23 ISO/IEC 61851-24	ISO/IEC 15118
Committee/ Association	ISO/IEC	Industry consortium: TEPCO, Nissan, Mitsubishi, Fuji Heavy Industries, Toyota Later: ISO/IEC (design stage)	ISO/IEC
Charging modus	AC up to 3.7 kW using only IEC 61851 for communication Higher charging power and DC (fast) charging. Additional communication capabilities possible via other standards	DC (fast charging) up to 62.5 kW	AC, DC (fast charging) up to 63 kW
Connector (Germany)	IEC 62196 Type 2, as well as Combo 2 for fast charging	Proprietary design, incompatible with other connectors	IEC 62196 Type 2, as well as Combo 2 for fast charging
Safety and control aspects	Simple monitoring function checks cable connection, activates immobilizer, etc.	Transmits safety-relevant information such as current charging status and maximum allowed charging current	Based on IEC 61851-1 with additional functions; TLS data encryption
Amount of control information	Low	Low to medium	High
Transmission method	Pulse width modulation (PWM)	CAN	Powerline (HomePlug Green PHY)
Protocol compatibility	Upward compatible with ISO/IEC 15118	Not compatible with ISO/IEC 15118	Downward compatible with IEC 61851-1; compatible with different parts of ISO/IEC 15118
Propagation	Worldwide. Supported by nearly all e-vehicles due to its impact on charging safety	Primarily in Asia. Supported by vehicle models such as: Nissan LEAF, Mitsubishi i-MiEV, Peugeot iON, Citroen C-ZERO	Europe. Not currently supported by any commercially-available vehicle models, but recommended by German and European automobile manufacturer associations [3].

Table 2: Overview of the various charging station-to-vehicle interface standards.

COMMUNICATION BETWEEN THE CHARGING STATION AND THE SMART GRID BACKEND SYSTEM

In many of today's electromobility applications, communication between the charging station and the smart grid backend is largely limited to authenticating the user and approving the charging process. Regulating the charging process based on the capacity of the grid, which is essential to ensuring the seamless integration of the charging stations into the grid, has not been implemented at this point. Today, network operators are already required to communicate with and manage a wide variety of power generation sources such as biogas and solar facilities, in addition to private and industrial users on the low voltage side of the grid, an environment that will only intensify in the future. According to §14a of the German Energy Act, regulating the charging stations is simply one application scenario. To date, communication has been solved with proprietary protocols for the most part. From an economic and technical complexity standpoint however, it makes sense for network operators to rely on already-established communication solutions and reduce the number of different communication solutions for the various application scenarios to a minimum [12].

This is exactly the goal of the Network Technology/Operation Forum within the German Association for Electrical, Electronic & Information Technologies (VDE). Under the framework of the Smart Metering System 2020 project, this group is promoting the use of a communication gateway for regulating the grid load and energy sources. With this in mind, the focus is on two specific protocols for the interface between the charging stations and the smart grid backend: the Open Charge Point Protocol (OCPP) and IEC TR 61850-90-8.

Open Charge Point Protocol (OCPP) – Open-source, licence-free, established

The Open Charge Point Protocol (OCPP) [14] was developed by the Open Charge Alliance, a global consortium of public and private enterprises. OCPP is utilized across Europe primarily for authenticating/authorizing e-vehicles for use with public charging stations.

The OCPP communication protocol is used to monitor and administer the charging process and to transfer the billing and settlement data to the service provider. The system transmits first and foremost metering and other energy- and transaction-related data, including information that allows drivers to reserve charging stations via the central management system. The protocol can also be used to transmit firmware updates and remote control or maintenance commands (restart, charging cable lock/unlock). Dynamic billing rates, as well as information required for adapting the charging capacity to the grid situation, can also be transmitted. The protocol supports 25 different operations, 10 generated by the charging station and 15 generated by a control center in the grid.

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OCPP is a manufacturer-independent, license-free protocol based on the Simple Object Access Protocol (SOAP). Data transfer is carried out with HTTP.

Significance for future charging infrastructures

The OCPP protocol is already well-established in Europe and integrated in numerous charging stations. Because it's license-free, OCPP is a cost-effective solution for the charging station-to-smart grid interface. The open approach furthermore offers the opportunity to adapt the protocol to the individual needs of the grid operator.

The one clear disadvantage to OCPP is the fact that it is limited to this one interface. Charging station management is thus isolated from the remaining network management functions. That eliminates the possibility to implement a uniform control system for other smart devices and forces grid operators to rely on additional protocols for other applications if they use OCPP.

IEC TR 61850-90-8 – Grid-wide network management

IEC TR 61850-90-8 [15] is a technical report based on IEC 61850, an internationally-standardized communication protocol for managing substations in medium and high voltage networks. Because it is a technical report, this standards extension does not feature any normative character.

The underlying IEC 61850 norm [16] is an internationally-established, energy and telemetry technology for automating substations. It sets itself apart through an object-oriented approach that makes it possible to represent transformers as node models for instance.

Extensions to the IEC 61850 standard are being implemented in a variety of developments as far down as smart devices operating at the low voltage network level. This includes communication for monitoring and controlling wind power facilities (IEC 61400-25) and hydroelectric stations (IEC 61850-7-410), as well as communication systems for distributed energy sources (IEC 61850-7-420). The object models required for the integration of the charging infrastructure into the smart grid are currently being incorporated into the IEC TR 61850-90-8 technical report. This allows the charging stations to be represented and integrated in the overall grid model as similar object types. To identify individual objects, a hierarchal, clear text name is utilized in IEC 61850 in order to create a self-documenting system.

To expand the existing object models for electromobility, several new logical nodes are being defined in the IEC 61850-90-8 technical report. These nodes describe information for controlling and monitoring the charging stations, the charging connection and the connected e-vehicle. The technical report also defines an extension of the ZCAB class for electromobility charging cables. In line with the reusability approach anchored in IEC 61850, the object models can simply rely on existing classes such as the meter-based MMTR logical node.

Significance for future charging infrastructures

At the moment, IEC TR 61850-90-8 has no practical application since it is still in the design stage. The potential is enormous however. On the one hand, representing the charging station as a logical node model allows the system to remotely read-out and regulate the power consumption of the vehicle. Integration of the charging infrastructure into the smart grid is thus flexible and simple.

The IEC 61850 extensions furthermore offer the opportunity to communicate with all smart devices in the network - and not just the charging stations - using a single standard. Energy management is much simpler as a result. Although the standard itself is very extensive, well-developed libraries exist which can be used as a foundation to lower the technical and financial barriers to entry. It's anticipated that the increasing deployment of the standard in low and medium voltage networks will lead to further market growth and drive down the costs associated with its implementation.

The bottom line is that new applications such as electromobility can be uniformly integrated into the power grid and the information and communication infrastructure of the network operator. That makes IEC TR 61850-90-8 an ideal standard for communication between the charging infrastructure and upstream IT systems/backends.

Standard	IEC TR 61850-90-8	OCPP Open Charge Point Protocol
Description	IEC 61850 object models for electromobility	For standardizing the charging station backend interface
Committee/Association	Independent, international standards committee (IEC)	Global consortium of public and private enterprises
Functional scope	Transmission of vehicle charging control parameters. Also suitable for on-site regulation and monitoring of the charging station.	Limited to 25 different operations: 10 from the charging station and 15 from the grid control center.
Technology	IP-based (TLS-encrypted) data transmission, MMS-based (Manufacturing Message Specification) messaging	SOAP-based, HTTP
Uniform integration into the network operator's control system?	Yes. Other systems such as decentralized cogeneration units can be regulated and monitored as well with IEC 61850.	No
Propagation	IEC 61850: worldwide use in the energy industry (control technology interface, substation automation) IEC 61850-90-8: still under development	Europe. Relatively extensive utilization in current charging stations

Table 3: Overview of the key charging station-to-smart grid communication interface standards.

CHARGING INFRASTRUCTURE IN THE REAL WORLD – THE FRAUNHOFER ESK SOLUTION

Integration of the e-vehicle charging infrastructure into the electricity provider distribution networks is a vital aspect of transforming the existing network into a smart grid that features the capability to regulate the transport, distribution and consumption of energy even at the low voltage network level [17].

Whether it's network operators, energy suppliers or vehicle operators, all parties profit equally from this development. The prerequisite for making this work is the seamless integration of all participants into a uniform communication infrastructure that supports the electricity network.

An essential foundation of this infrastructure is on-going communication between the e-vehicle, charging station and the network operator's control center. As part of the Smart Vehicle-to-Grid Interface project [18] that is being funded through the European Union's Seventh Framework Program (FP7), Fraunhofer ESK researchers specified the vehicle, charging station and backend system interfaces and implemented them in a demonstrator. After completing a detailed technology evaluation, ISO/IEC 15118 was selected for the exchange of information between the charging station and e-vehicle, and an initial version of IEC TR 61850-90-8 for the charging station-to-backend system communication. Researchers then specified the requirements of the communication interface, implemented both standards and demonstrated the practicality of the intelligent charging infrastructure solution in mid 2014. ESK engineers have meanwhile developed a proprietary implementation that can be deployed in charging stations. The continuous communication ensures a charging infrastructure with better safety and provides the foundation for the creation of future applications such as time-delayed charging, individual and/or dynamic billing and automatic user authentication at the charging station.

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