Convenient Charging of Electric Vehicles

Smart Charging with MICROSAR IP Enables Flexible Charging Processes and Easy Payment

Compared to conventionally powered vehicles, electric vehicles (EVs) have significantly shorter driving ranges due to the low energy density of their batteries. For EVs to experience a successful market launch, it is important to have a charging infrastructure in place that is widely accessible and easy to use. It is equally as important to have a standardized charging process. This article describes Smart Charging and its standardization in the ISO 15118 standard. With Smart Charging, in addition to a power connection, the vehicle also establishes a communication channel with the charging station. Today, Vector is already providing a first implementation based on its MICROSAR IP communication stack.

International Standardization and its Distribution

Widespread establishment of a charging infrastructure can only be properly achieved if all aspects of the charging process are standardized across manufacturers. The connector and cable as well as the charging communication must be standardized for all EVs and charging stations. In Europe, charging communication is described in the framework of ISO 15118. In the USA, this is being done in SAE (Figure 1). In Japan, there is already the CHAdeMO standard and a charging station network of over 250 stations. According to the "National Development Plan for Electromobility" by the German federal government, Germany should become the lead market for electromobility. This plan calls for one million EVs to be on the roads of Germany by 2020.

Today, charging of EVs generally takes place at home. Just a few charging stations are available in public areas – as part of model studies. Since vehicles are parked frequently, e.g. while shopping or at work, they can be charged during these times. In the future, a broadly based and standardized infrastructure will be built up for this purpose. It has to offer a standardized mechanism for charging the batteries, and it must also support a method for easy payment. To enable convenient payment, debiting of the small amounts should be conveniently handled by automated electronic billing.
Providing the Energy
Charging of EVs can cause a severe load of local electrical distribution networks. Today’s electrical grids require some time to react to such load changes. If several charging EVs draw high power simultaneously in one location, e.g. in a parking garage, this could lead to a local grid overload and outage. Until now, no consideration has been given to the total power requirement for charging EVs on the electrical grid. As soon as the driver plugs in the vehicle’s charging cable, charging begins at the maximum possible current, and this adds a certain amount of load to the grid. This might appear to be similar to the model of fueling up at a normal fuel station, where energy is always in stock and is easy to obtain in the form of gasoline. But the situation with electrical energy differs fundamentally. It cannot be stored as simple as gasoline and be drawn from storage. Nonetheless, by introducing an intelligent electrical grid (Smart Grid) and by using intelligent charging, it is possible to avoid overload and grid failure. In a Smart Grid, data is exchanged about power requirements, and the electrical grid can be optimized accordingly.

The power needed for a charging operation lies between 3 kW and 20 kW, or even over 100 kW, depending on the available power connection and charging profile. By comparison, a typical citizen in Germany uses an average of 3–5 kWh of daily electrical energy, depending on household size. To operate the grid so that it is more stable, the energy provider needs time to supply the charging energy. One way to obtain this time is to delay the start of the charging operation by several tens of seconds.

Charging Method for DC or AC Power
In charging the batteries, two different procedures can be distinguished. First, the battery can be charged with alternating current, which is available in the electrical grid as single-phase or three-phase AC. Nearly any electrical outlet may be used for charging here. However, the charger must be installed in the vehicle, which means additional weight. In the second variant, the battery is charged with DC electricity. In this case, the charger is located outside of the vehicle, in the charging station, and it generates the DC voltage for charging the batteries. In this case, the weight of the charger does not matter, but costs are higher for such a DC charging station. Since these two charging processes each have their advantages and disadvantages, they are used in parallel.

Communication between Vehicle, Charging Station and Energy Provider
If the vehicle only has to communicate with the charging station for charging, the choice of transmission medium and protocol would be quite flexible. However, the charging station and vehicle also need to communicate with various servers on the Internet (Figure 2). Therefore, it makes sense to use the conventional protocols of IP-based networks. Since requirements call for just using the cable for the charging current – and no auxiliary lines for communication – communication is implemented directly via the charging cable (Figure 3). PLC technology (Power Line Communication) is available for this purpose. In this system, the data stream is modulated onto the power line. This system is more familiar under the names Homeplug AV and IP-over-powerline in the consumer products field; they offer a simple way to set up private computer networks via a building’s power lines. In the vehicle’s charge control module, a TCP/IP stack is used for communication. It provides socket communication over IP (Internet Protocol) for TCP (Transmission Control Protocol) or UDP (User Datagram Protocol). Overlaid on this protocol are several applications and protocols such as:
> DNS (Domain Name System) for name resolution
> TLS (Transport Layer Security) for encrypting the data on the transport level

<table>
<thead>
<tr>
<th>ISO/OSI Layer</th>
<th>Europe</th>
<th>USA</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Application</td>
<td>ISO/IEC 15118 Part 1</td>
<td>SAE J2836</td>
<td>General information and use case definition</td>
</tr>
<tr>
<td>7 Application</td>
<td>ISO/IEC 15118 Part 2</td>
<td>SAE J2847</td>
<td>Technical protocol description and Open Systems Interconnections (OSI) layer requirements</td>
</tr>
<tr>
<td>6 Presentation</td>
<td>ISO/IEC 15118 Part 3</td>
<td>SAE J2931</td>
<td>Wired physical and data link layer requirements</td>
</tr>
</tbody>
</table>

Figure 1: Charging communication is defined in ISO and SAE standards.
> V2GTP (Vehicle To Grid Transport Protocol), a new protocol for connection monitoring and data transfer

Furthermore, a module is needed that contains the Smart Charging functionalities from ISO 15118. For this purpose, Vector has developed its own standard module: SCC (Smart Charge Communication.) It establishes the connection to the charging station and exchanges parameters on the charging process over the connection. The module can be adapted to the requirements of specific carmakers and suppliers by its many different configuration options. Currently, data transmission over the Internet is generally still performed using the IPv4 protocol. To circumvent the growing scarcity of addresses on the Internet, ISO requires that vehicles and charging stations support IPv6. Overall, a system is created in the vehicle that is very complex and resource-intensive, but it is also very powerful. Vector already offers an implementation based on the MICROSAR IP stack (Figure 4); it was specially optimized for use in motor vehicles and conforms to the AUTOSAR standard. In addition to the TCP/IP stack, the charger requires a CAN stack to connect to the existing vehicle network. Communication with energy management and the user terminal are implemented via the CAN stack (Figure 5).

**Procedure for a Charging Operation**

On current EVs, the charging process is simple: the user simply plugs a connector into the charging station, and the charging process starts right away. In Smart Charging per ISO 15118, the charging process is more complex. After plugging in the charging cable, the vehicle first establishes a connection with the charging station via PLC for communication. Then the vehicle obtains an IP address over DHCP, after which the SCC module queries the IP address of the charging station via a broadcast message (ChargePoint-Discovery). Now the vehicle establishes a TCP connection and, overlaid on this, a TLS connection over which both the
Convenient Charging of Electric Vehicles

During this process, the vehicle and charging station regularly exchange status information and electrical meter readings, and the vehicle acknowledges the reception of energy. During charging, the vehicle may be placed in a quiescent state to reduce its own energy consumption. It periodically wakes up from this state to execute a status update. The charging itself continues without stop. When charging is finished, the charging station shuts off the electrical power and unlocks the plug connection. The last acknowledged meter reading is transmitted to the energy provider over the Internet for billing.

Paying by Micropayment

As described at the beginning of this article, EVs have a short range due to the limited energy storage capacity of the batteries. To be equipped for unplanned or longer drives despite this limitation, efforts are made to charge the batteries as often as possible and/or in a short period of time. For example, full charging of a typical 20 kWh battery will cost between 3 and 10 Euros, depending on the different rates. Often the amount is significantly less than this, because the battery is seldom entirely depleted and does not need a complete charge. So, a simple payment system is needed that avoids the need to make small individual payments for several short charging operations.

In principle, there are a number of different possibilities for paying for the electrical charges: cash payment, payment by card and PIN or an automated billing method. This might be based on electronic authentication and a suitable billing contract with an energy provider – similar to a contract for a mobile telephone. The latter makes the most sense for the small and unequal sums. As a side benefit, this also reduces the risk of vandalism to charging stations in public spaces, because the charging station only requires a plug outlet and a small display.

Figure 4: The MICROSAR IP Stack from Vector contains modules to communicate over the Internet Protocol

Charging station and the vehicle are authenticated by certificates. Data such as service information, rate tables and charging profiles is exchanged and selected over this encrypted connection, and payment modalities are set. Now the cable is physically locked, so that it cannot be pulled during the charging process – as to prevent theft of the electrical power. Finally, the charging station switches the power on, which starts the actual charging process. During this process, the vehicle and charging station regularly exchange status information and electrical meter readings, and the vehicle acknowledges the reception of energy. During charging, the vehicle may be placed in a quiescent state to reduce its own energy consumption. It periodically wakes up from this state to execute a status update. The charging itself continues without stop. When charging is finished, the charging station shuts off the electrical power and unlocks the plug connection. The last acknowledged meter reading is transmitted to the energy provider over the Internet for billing.

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Figure 5: In addition to the IP stack, the charge control module also required a CAN stack to communicate with the control panel.
The price for charging an EV cannot be given as a lump sum; price tables are communicated to the vehicle to calculate the price. The combination of the price table, the charging profile and the available power at the charging station yields a number of variants for pricing and charging duration. The selected variant is based on pre-configuration in the vehicle, so that charging can be started automatically.

**Outlook**
Certain aspects of intelligent charging of electric vehicles may still seem like a dream. However, the foundations are already being laid today, e.g. in the framework of ISO 15118. Release of the ISO 15118 standard is scheduled for mid-2012, with the goal of further expanding its range of application.
Extensions of the AUTOSAR-based basic software are also in planning or discussion. Vector is working on advanced developments as an active participant in ISO and AUTOSAR standardization committees to ensure that it can offer production-ready customer solutions in a timely manner.

Translation of a German publication in Elektronik automotive, 07/2011

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