HOW AUTOSAR FUELS INTELLIGENT EV SMART CHARGING

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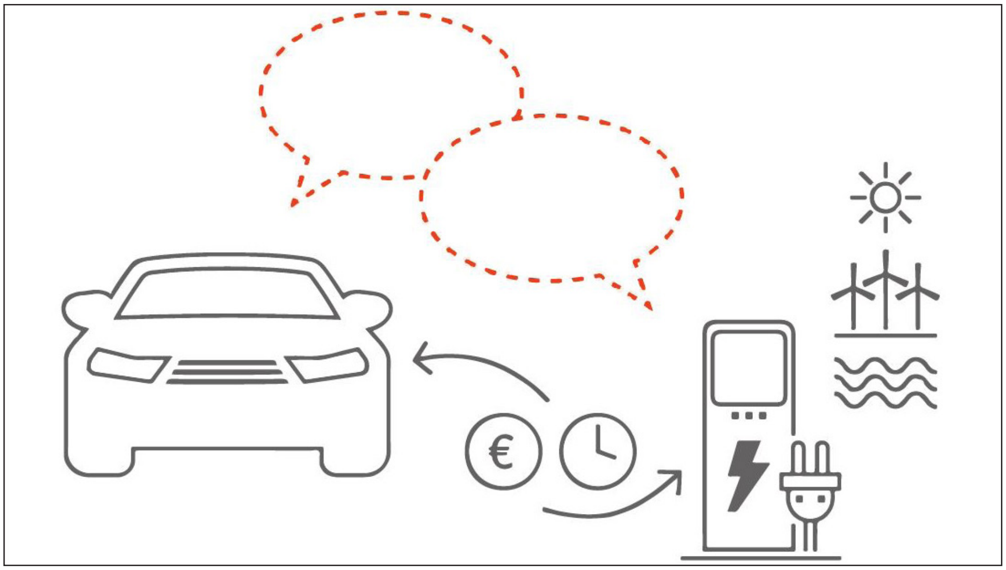
INTRODUCTION

Up until now, charging an electric vehicle (EV) at a private residence has been a rather straight-forward process. The user/driver plugs the vehicle in during the evening hours and waits until the next morning for a complete charge. While these recharges occurred primarily at home, we are now seeing more charging stations at the workplace. Today, we are also seeing more public recharging stations across the city landscape. While charging an EV at home was a rather simple process, the process at a public recharging station can be quite complicated, requiring the swiping of an authentication card and other steps to begin the recharging process.

To make matters worse, different public charging station providers often require different cards to begin the process.

But the world is quickly changing. We are at a point now where charging an EV should be as simple as recharging a mobile phone. While recharging a smart phone has made progress over the years – why hasn't EV charging made similar inroads?

Telemotive Intelligent Charging (TIC) is a new approach that modernizes EV charging. TIC utilizes Power Line Communication (PLC), which acts as a type of "transceiver" linking to Internet-based services that allow authentication, payments, and other services. It should be noted that with TIC, the charging cable *itself* transmits



data, thus establishing real communication between the vehicle and charging station. This type of approach opens up new possibilities for the user/driver experience where requests can be fulfilled quickly, conveniently, safely, and in the most intelligent way possible.

TIC implements according to the ISO 15118 and DIN 70121 standards. The implementation follows the Motor Industry Software Reliability Association (MISRA) guidelines. The entire package is then integrated with AUTOSAR.

In addition to discussing TIC and its many attributes, this paper will also discuss the integration of TIC into the Mentor® Volcano™ VSTAR AUTOSAR stack. The integration of these two technologies provides the critical software infrastructure needed to help OEMs and third-party suppliers create Electronic Control Units (ECUs) that will help usher in a new era in intelligent EV charging.

SMART CHARGING

What does *smart charging* actually mean? One can think of optimized charging in respect to time, cost, and sustainable energy resources. Using these parameters ensures maximum battery capacity at a certain departure time. Fluctuation of energy prices can also be a considered. An example of intelligent charging can be seen in Figure 1. In this depiction, the user interface (UI) shows when the projected solar energy will provide enough power for charging a vehicle as it relates to the departure time. TIC is a technology that goes beyond what is indicated in Figure 1. Also, TIC does not require a RFID card or smartphone authentication; instead, secure communications and payment transactions are taken care of automatically.

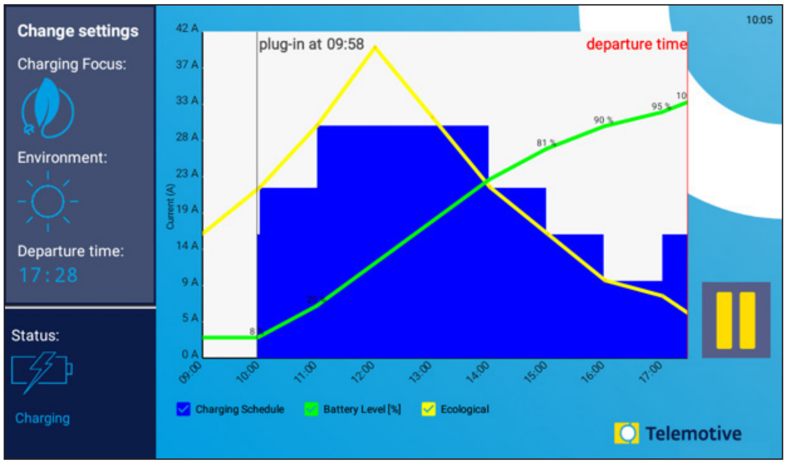


Figure 1: *A user can see when there is enough solar energy available for charging a vehicle.*

And what happens if an influence factor such as cost, weather, or an energy load spike occurs while the user/driver is not in control of the charging process? TIC is the answer for these variables as well. It takes into consideration dynamic renegotiation of a charging schedule when environmental or user conditions change unexpectedly.

So why stop there? The ISO 15118 protocol is capable of third-party specific services that can be defined by OEMs or Tier One suppliers in the future. Think about ...Internet access over the charging table. …Updates to the car software or certificates. …Or even media streaming while waiting for the battery to be full.

VEHICLE-TO-GRID COMMUNICATION

No question, a great deal of technology is involved in Telemotive Intelligent Charging. Figure 2 (following page) provides an overview of the ISO 15118 protocols.

First, it's important to realize that ISO 15118 is divided into three separate parts (ISO 15118-1, -2, and -3). The first document (ISO 15118-1) defines the use cases around public and private charging infrastructure scenarios. Here, specific use cases will be defined by charging infrastructure vendors and vehicle manufacturers. A few of the current use case/interface examples in place today are mentioned later in this paper.

The second document (ISO 15118-2) defines the core product of Telemotive Intelligent Charging. In this area, the communication protocol works like a communication stack, expanding over ISO-OSI layers three to seven. Here, you will see well-known protocols such as TCP/IP version six, User Datagram Protocol (UDP), and even the Transport Layer Security (TLS) protocol. However, notice the new protocols designed specifically around smart charging. For example, this stack consists of a transport protocol known as Vehicle-to-Grid Transport

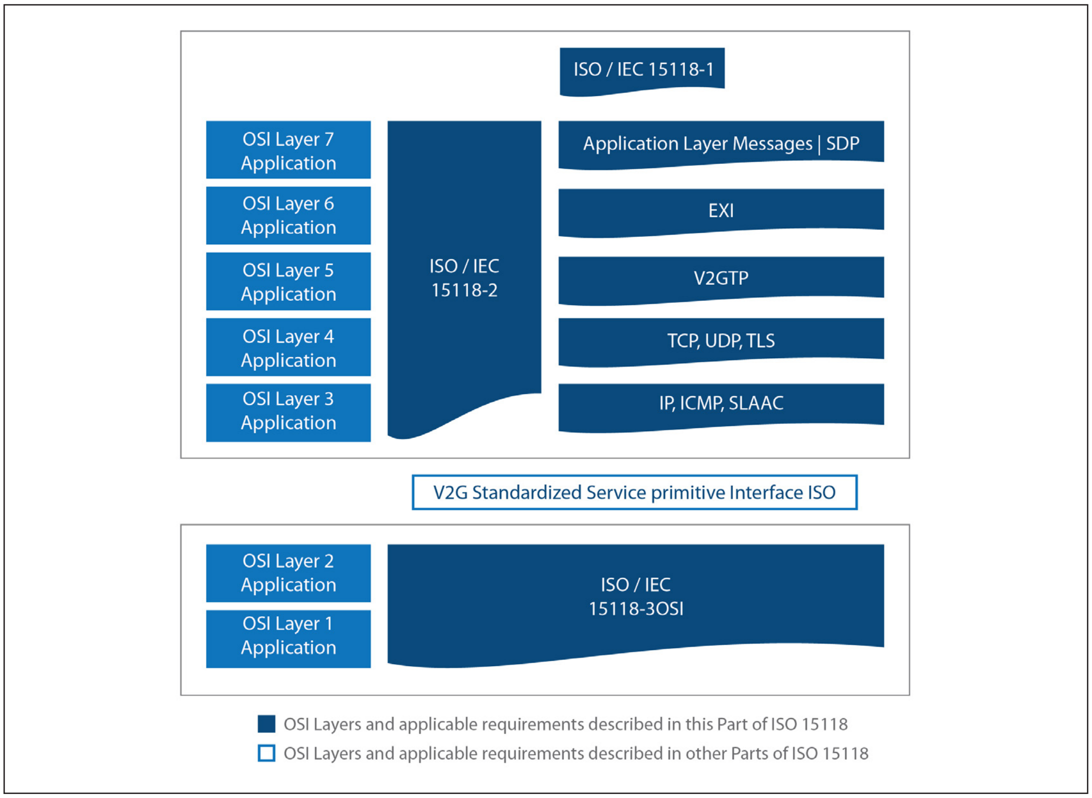


Figure 2: *Vehicle-to-grid communication (V2G) is based on the ISO/IEC 15118 standard, which can be broken down into three sub-categories.*

Protocol, or V2GTP. There's also a very intelligent compression algorithm called Efficient XML Interchange, or EXI, for shrinking communication data size down to about four percent of the original XML data size.

On top of that, there are 17 different message types, the so-called application layer messages, which were defined to enable a charging process specific to a user/driver's unique needs.

On the bottom of the ISO-OSI layers, the document ISO 15118-3 defines the physical connection. It's in this area where Power Line Communication, or Green PHY comes into play. The Telemotive Intelligent Charging solution discussed in this paper utilizes the Mentor AUTOSAR offering which has already integrated PLC into its basic software (BSW) package.

A CLOSER LOOK AT THE COMMUNICATIONS PROCESS

Let's look in greater detail at how this communication works (Figure 3, on following page). First, before energy can be transferred, the charging station and the vehicle must negotiate to ensure both partners speak the same language (standards such as ISO 15118 or DIN 70121).

If the standard is shared, a high-level communication link will be established. In this stage, the user/driver can define whether to use encrypted and safe communication over known standards including TLS, and therefore, different certificates will be validated and exchanged. By doing this, the user/driver will know that the communication will take place in a safe environment. The user/driver can also opt-in for any services the charging station might provide. Most of these services will be defined over the coming years by various OEMs and third-party vendors. Current services include updating security certificates or even smart charging itself.

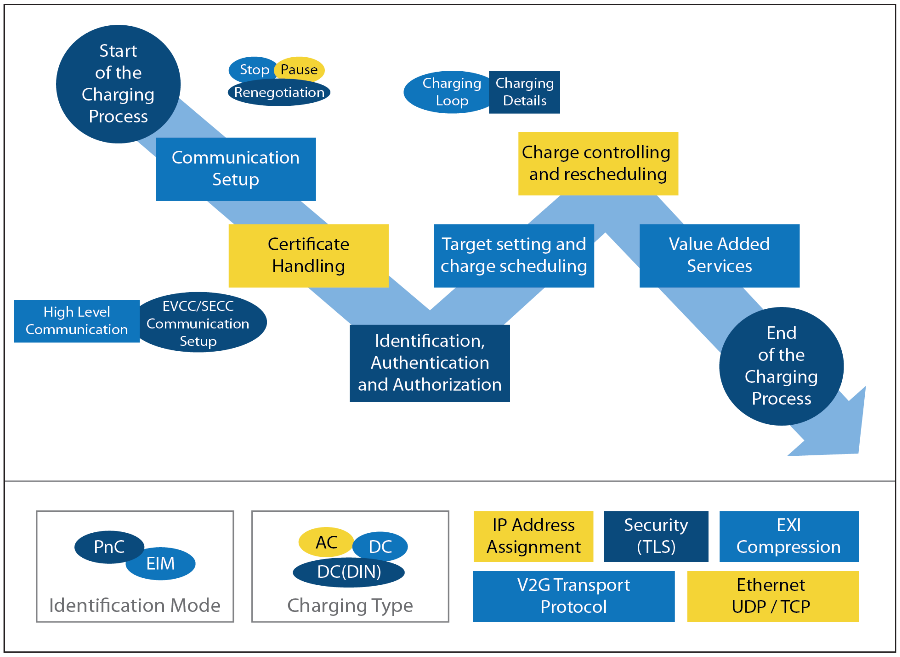


Figure 3: *Communication between vehicle and charging station.*

The user/driver can authenticate automatically using stored information inside the vehicle. After the authentication step has been completed, the initial communication and the charge scheduling will begin. Here, the car provides incentives like departure time or intended state of charge at the charging station. Based on the charging environment, the charging station will suggest different charging schedules that fulfill the incentives given by the user/driver. The software is able to adapt to these schedules, and soon after some negotiating between the charging station and the car, charging begins on an agreed-upon schedule.

This is what intelligent automotive recharging is all about. The user/driver does not have to be inside the vehicle, or standing near the charging station in order for recharging to commence. All of this can be done automatically and quite quickly. During the charging cycle, a variety of information can be exchanged; examples include metering data, state of charge, and so on. At any point during the recharging, the user or the system can influence the charging process. For example, what if the car notices that at the given departure time, 100 percent state of charge will not be reached? In this type of situation, the charging station will automatically renegotiate a charging schedule with a new target.

ISO 15118-2 STACK FOR AUTOSAR

The Telemotive Intelligent Charging solution discussed in this paper has been developed by MAGNA Telemotive GmbH. In partnership with Mentor using Mentor's Volcano VSTAR AUTOSAR stack, a high-quality, state-of-the art EV charging solution has been developed, compliant to Automotive SPICE and MISRA. Achieving very high test coverage, as well as complex continuous integration, the EV charging solution discussed in this paper provides high adaptability and the flexibility the industry needs to elevate the game in the public smart charging market.

AUTOSAR - A BRIEF BACKGROUND

AUTomotive Open System Architecture, or AUTOSAR, is the software foundation of the application of a modern Electronic Control Unit (ECU). The standard was created with a high reusability of the application in mind. AUTOSAR introduces several layers of abstraction with standardized interfaces and Application Programming Interfaces (APIs), as seen in Figure 4. One of its layers is the microcontroller abstraction layer which includes all necessary drivers for the internal peripherals of a microcontroller.

The higher layers are target-independent basic software. These provide several rudimentary functionality and systems services for the ECU, such as scheduling of the software via an operation system. The basic software is divided into several functional clusters such as memory services, diagnostics, or communication services, which in turn, gives the software components access to the vehicle communication bus. With that concept, the effort to integrate software on different hardware platforms is minimized.

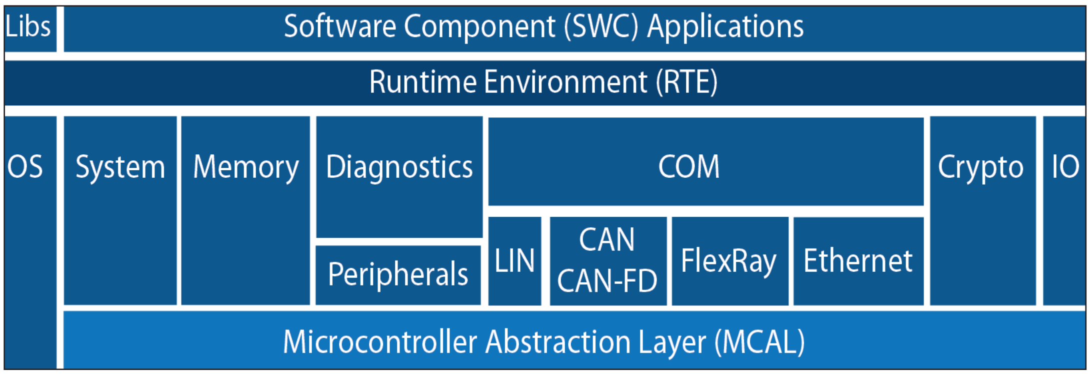


Figure 4: *AUTOSAR basic software.*

In AUTOSAR, the smallest software unit is called a software component, which can be allocated in the ECU. The communication needs of the software component are defined by its ports, whereas the communication itself is defined by its interfaces and data types. Compatible interfaces allow the connection between different software components. At that point, the software component is described on the virtual functional bus level, where the allocation to different ECUs is possible. As a result, the Real-Time Environment (RTE) can generate the communication between software components according to their allocation. The communication channel is either created internally, or on the vehicle bus, according to the allocation.

Now we can go deeper into how smart charging from Telemotive could be realized on the basis of the Mentor AUTOSAR basic software. These ECU applications can be implemented as software components or as complex device drivers. They can be executed on the top of the RTE. The basic software resides below the RTE. Connections to other software components on other ECUs are directly generated from the RTE. It makes direct use of the VSTAR communication stack functions.

THE INTEGRATION BETWEEN TELEMOTIVE INTELLIGENT CHARGING (TIC) AND AUTOSAR

When looking specifically at the use case example of TIC and AUTOSAR integration, Ethernet is utilized for the communication of the charging station over a special powerline communication hardware. The software acts according to inputs from the vehicle network, or the driver over the Ethernet and Controller Area Network (CAN). Service software components are providing interfaces towards the application. For example, the non-volatile memory manager provides the means of controlling data stored in flash. This is used by the certificate handler to handle certificates. Due to the fact that the powerline communication protocol is not defined in AUTOSAR, it is implemented as a complex device driver. This complex device driver is utilizing the communication and crypto modules to establish a secured and authentic TCP/IP connection with the charging station.

To find errors during development or operation, it is a good practice to use the diagnostic lock and trace modules from the diagnostic stack. From the same stack, the storage of diagnostic trouble codes or implementing diagnostic services are possible. At the end, the whole system is scheduled by an OSEK-based AUTOSAR operating system (OS). (OSEK is a standards body that provides a certain set of specifications for an embedded operating system.) This can achieve functional safety requirements up to ASIL D.

With a holistic solution for powerline communication and AUTOSAR, the question arises on how to integrate both?

The following steps focus on how to achieve a fully functional ECU. The ECU integration itself starts within board bring-up. That involves the initialization of the microcontroller and all drivers for internal and external devices. The main part of the configuration is related to the Microcontroller Abstraction Layer (MCAL) modules. This includes the configuration of the MCU, CAN, and the Ethernet driver modules (Figure 5.)

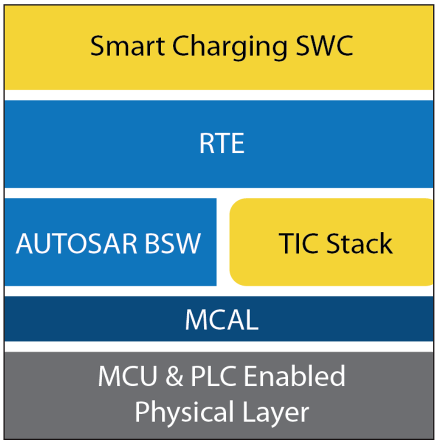


Figure 5: *Integration of PLC into Volcano VSTAR.*

In parallel, the application and software component design around the already existing Telemotive intelligent Charging functionality can take place. Therefore, the developer creates the necessary components in the software component design view in Volcano Vehicle Systems Builder™ (VSB). The basic software configuration, including the TIC module, can be done in the ECU configuration view of VSB. Here, the creation of the OS tasks that are executing the functions of the application, and setting their priorities, is an important step. Each module has its own set of configuration parameters. Because of the large set of values defined by AUTOSAR, the tool is assisting with an ECU configuration generator. This is automatically setting configuration values according to the ECU extract's input.

After the design of the application and the configuration of the basic software according to the application needs, it is time to look into the RTE. The runnable-to-task mapping in the RTE influences the task activation of the system. After setting other mandatory parameters, the source code of the RTE along with all VSTAR basic software, can be generated. With the VSTAR build system or custom build environment, that output will form the final executable. The integration steps at the Tier One or third-party site to reach an end product for the customer are minimal. This includes the import of the ECU extract and adapting the project to the required communication. The integration of the ECU-specific software components from the Tier One, and the configuration of the additional basic software needs are often quite similar. With the combined experience and product offering, the customer gains the benefit of an "out-of-the-box" working smart charging-enabled ECU, which is based on a reference hardware. With that, it is a pre-integrated, pre-configured, intelligent charging application, which is tested and mature.

The AUTOSAR approach makes it future proven, easily extendable, and reusable.

CURRENT AUTOSAR INTERFACES

The following user interfaces are the direct result of integration between TIC and AUTOSAR:

• Charging Schedule Controller

Does exactly what the name indicates. The controller compares the actual charging process against what was previously negotiated. If the agreed-upon goal will not be reached, the controller will renegotiate a new charging schedule. Also, every user input is taken into account. For example, if the user wants to stop the charging process, this component will do the rest.

- Certificate Handler

Validates security features. This includes validation as well as updates for existing certificates.

- Charging Schedule Optimizer

Perhaps one of the more intelligent components. Any user and charging station input will be transferred in an optimized charging schedule. There is a lot of room for interesting ideas and innovation in this area. One idea is to integrate learning algorithms, so if a customer does not provide a departure time, the car will decide on its own based on what it has learned from the driver's previous patterns.

- EV Input

A lot of data from the EV will be used for this algorithm, and the EV input component will connect that data with the software stack to ramp up the view on the product.

CONCLUSION

The need for reliable and production-proven software for electrical vehicles is increasing by the day. Also, the manner in which these vehicles are charged needs to evolve as the automotive technology advances. Public charging stations for the modern EV must be updated to include a more convenient, faster, and safer means of recharging – with no exceptions.

As discussed in this paper, the Telemotive Intelligent Charging solution, along with the integration of AUTOSAR at the ECU level, offers the user/driver an error-free communication between charging station and vehicle via the actual charging cable, thus establishing real communication between the vehicle and charging station. With very little effort, OEMs and third-party vendors can now offer a useful, intelligent, and sustainable technology to their customers for safe, convenient, and intelligent EV recharging – no matter what road the user/driver may take.

For a webinar on this subject, please visit "AUTOSAR-based Power Line Comminication (PLC) for Intelligent Charging ECUs." You can also visit the Volcano Automotive website.

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Florian Köttner is the group leader for Agile Project Management at Magna Telemotive. Florian has close to six years product-owner experience in E-Mobility Projects. Today, Florian is the product owner of Telemotive Intelligent Charging (TIC) and domain expert in AUTOSAR software development & intelligent charging related topics such as ISO 15118, and public & private charging infrastructure.

Dirk Vogel is a system architect for AUTOSAR and Basic Software at Mentor, a Siemens Business. Dirk has six years of experience working with leading OEMs and Tier Ones. During this time, he has gained a deep knowledge and understanding in ECU test and validation, virtual validation concepts for AUTOSAR ECUs, and AUTOSAR serial production projects among various OEMs.

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