WHITE PAPER

# ADDRESSING THE KEY CHALLENGES IN THE DEVELOPMENT OF EV CHARGING SYSTEMS

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**Antje Schütz**, Senior Marketing Manager IoT Security

**Jean-Marc Darchy**, EMEA Regional Marketing Manager (RMM)

**Marc Gebert**, Senior Director IoT & Cloud Business Development

**Denis Noel**, Head of Marketing — Smart Product Authentication & IoT Security

**Fabrice Punch**, Marketing Director NFC Infrastructure

**Mark Swinburn**, Smart Appliance Vertical Manager

With the shift towards eMobility comes the need for an energy system that can effectively replace the fleets of fossil-fuel service stations drivers currently rely on. These trends require balancing EV charging to conventional service areas, converting older areas to electric-only and building new charging areas. According to market and consumer data provider Statista, China had more than 800,000 publicly accessible charging outlets in 2020, accounting for more than 60 percent of installations worldwide. The US has approximately 100,000 charging outlets, and Europe (including Turkey) around 295,800. Yet the dilemma of supply versus demand continues to amount to fewer public charging points than needed being installed.

Delivering power to EV charging stations will become a matter of national importance and will form part of a country's critical infrastructure. As such, it needs to be much more than simply a power socket in a driveway. With more EVs on the road, more energy is needed. This implies the need for improved grid management systems, more efficient chargers and the integration of home energy management.

There is now a great demand for smart charging at home and work. Today there are more than 200 OEMs engaged in this market across EMEA with smart wall boxes. These companies are mostly motivated by government-funded projects. Greater availability also means faster charge time, which necessitates the move from AC to DC chargers. Automotive OEMs supply AC cable chargers at the time of purchasing the EV, which has the AC/DC converter, also called an onboard charger, built inside the car. In comparison, DC chargers convert the AC to DC within the charger, making charge time faster. So far, high-power DC charger network deployments are primarily associated with specific automotive brands and, as such, tend to be closed systems.

On top of this, there is the safety of operations to consider. Suppose a battery is replaced in the EV. In such a case, the authentication of the battery is crucial to the charger. Battery authentication is also key for public chargers that have to charge any car. At the same time, battery technologies and chemistries will evolve, which will undoubtedly require different charging profiles that will also require battery authentication.

Another important challenge to consider is the monetization of charging stations. In the future, charging will be integrated into other services. Much like the fuel stations today that have a convenience store attached, EV charging stations will offer additional goods and services. This "charge as a service" offering will require the chargers to connect to the cloud to access credentials and collect user data. Here, data protection and secure connections are essential.

Today, charge roaming is expected, which will enable users to charge anywhere and get one bill or integrate a point-of-sale (POS) terminal in the charger. Here, there is the overall user experience to consider. This means secure connectivity with the EV; for example, getting remote notification of the charging status. This will also improve charge management and automated but secure billing.

## SECURITY IS KEY

Incorporating secure elements designed to support compliance with industry standards like ISO 15118 or calibration laws (e.g., German Eichrecht), is crucial. NXP's latest EdgeLock® SE05x family of embedded security solutions, for example, ensures the entire value chain can be secure and resilient against cyberattacks, while the point of connection will still be safe and universally easy to use. Adding an electric vehicle to an average household could represent between a 5- and 10-fold increase in demand from the domestic supply on the grid, so load balancing becomes much more important. This demands a more granular approach that can be achieved using smart meters based on pre-certified devices, like NXP's MKM35xx family of precision metrology MCUs.

To avoid unauthorized access, the use of secure protocols to unlock the EV charging station via credentials, such as a physical smartcard or smartphone, is about to be standardized. The MIFARE® DESFire® EV3 secure smartcard solution, for example, fulfills the security requirements for EV charging. It also enables other smart city applications, such as bike-sharing, parking, tolling systems and public transport.

These are only some of the associated industry challenges, but they rely on two important features: the conversion of electrical energy and its controlled and secure application. All of these aspects are enabled almost exclusively by semiconductor-based solutions.

## CONTACTLESS CONNECTIVITY

Near Field Communication (NFC) technology enables users to easily identify themselves and pay securely at the EV charging stations, getting access to the requested services. Users can use a card based on the NXP MIFARE DESFire solution or directly via their phone. Tapping the card or device toward the NFC reader embedded in the EV charging station, whose location is indicated by an NFC symbol, initiates secure authentication and releases payment credentials.

The high-performance PN5190 NFC reader from NXP is the most flexible way to add NFC in an EV charging station and is compliant with the EMV Contactless Interface Specification v3.0 (EMVCo 3.0) for payment systems. When EMV payment is not a requirement, the new PN7160 NFC controller enables integration with fewer components in applications running an operating system like Linux or Android, reducing Bill of Material (BoM) size and cost.

## FROM LOW-POWER TO HIGH-POWER EV CHARGING

Today, the majority of charge points deliver AC, often this is single-phase but access to 3-phase AC charge points is increasing. This type of charge point relies on the vehicle's onboard charger (OBC) to rectify and boost the supply to as much as 800 V DC to charge the vehicle's battery. The battery management system (BMS) will often be a separate but connected system.

There is a small yet growing number of high-voltage DC charge points now available, and the expectation is for this balance to change over time, with much greater access to DC charging in the future. This is important: depending on the charge point and the vehicle's own system requirements, DC charge points can deliver much higher levels of power than an AC charge point and therefore reduce the charge time. In general, DC charging is referred to as either rapid or ultra-rapid, depending on the amount of power delivered.

Starting with the residential single-phase AC (slow) charger, the power delivered is around 3 kW to 7 kW, while a 3-phase (fast) system would increase this to around 22 kW. Moving to DC, the output starts at around 50 kW (rapid) and can reach 350 kW (ultra-rapid).

This also highlights the need for accurate and secure metrology, using application-specific solutions like NXP's MKM35Zxx family of pre-certified metering devices to ensure the consumer only pays for the energy they use. This demands the use of simple and secure user authentication, ideally through a "zero-touch" technology like NFC. This is enabled by products such as NXP's PN5190 NFC reader, used in conjunction with the SE05x family of embedded secure elements. The EdgeLock SE05x can securely store the keys and credentials, both for the user authentication as well as for the authentication to the cloud. The charging station, or EVSE (Electric Vehicle Sourcing Equipment), will also need to communicate to the grid to facilitate load balancing, as explained below.

## THE EV CHARGING SOLUTION

At a system level, the EVSE needs to include an external communication feature that is compatible with all systems used in various geographical regions. This could include ISM and cellular technologies, implemented using a product like NXP's IW620 dual-band solution that combines Wi-Fi® and Bluetooth® in the same device, or the OL2385 RF transceiver designed for sub-GHz protocols such as Sigfox. These could be combined with devices like the LPC55S69, which is ideal for implementing NBIoT as well as wired communications such as PLC. This is closely linked to the SE05x-based security functional block, which will provide authentication with end-to-end cryptography to exchange sensitive information such as billing data and OTA updates. It will also manage the exchange of data between the vehicle's OBC all the way to the backend servers.

The charge point plays a central role in the charging process of an electric vehicle. It connects the vehicle with the electricity supply. But it is no longer only about a dump provisioning on two or three levels of power. If you would like to do it smart, you need communication, and there are two paths to consider.

The first is Vehicle to ChargePoint, which is based on the ISO15118 communications standard and enables EVs to be charged in a smart manner. It takes care of the authorization, and starts and stops the charging process or exchanges data about demand and availability with charging profiles and tariff tables.

The second path to achieving a smart charging solution is Charge Point and Central Charge Management. Here, the OCPP (Open Charge Point Protocol) supports the management of charge points, thereby influencing charging processes from a central location. The user defines the charging schedules, showing max power over time, start or stop transactions, handles the authorization and metering as the basis for billing and even supports charge point reservations.

Historically, these two standards have been developed independently. However, in the meantime, the groups are working on harmonization and synchronization. Nevertheless, in today's world, you still need to align and translate the communication with the vehicle and central charge management inside the charge point.

The controller board will use both the security and external communications blocks to manage the main functions and services, such as high-level communications as well as running the protocols stacks used in the EVSE applications. This includes the ISO 15118 standard defined for V2G (vehicle to grid) communications and may also include the OCPP. Drawing on NXP's broad range and scalable device families of both microcontroller and application processor platforms can achieve the ultimate combination of performance versus cost. The choices available from NXP cover the complete performance spectrum from MIMX8xx MPU application processors to the MIMXRT11xx family based on Arm® Cortex®-M7 real-time MCU cores, through the latest LPC55x series of Cortex-M33 based MCUs.

As shown in Figure 1, the final major block deals with metrology. Based on NXP's MKM35Zxx family, this functional block provides the accurate measurement of energy as it flows into (or out of) the vehicle. It will also provide some low-level communications to the vehicle, as well as critical safety features such as monitoring the temperature of the charging station's connector. It may also include some form of contactless communications, such as NFC-based on the PN5190 reader; manufacturers may use these during installation, commissioning and maintenance, as well as to support cashless payment.

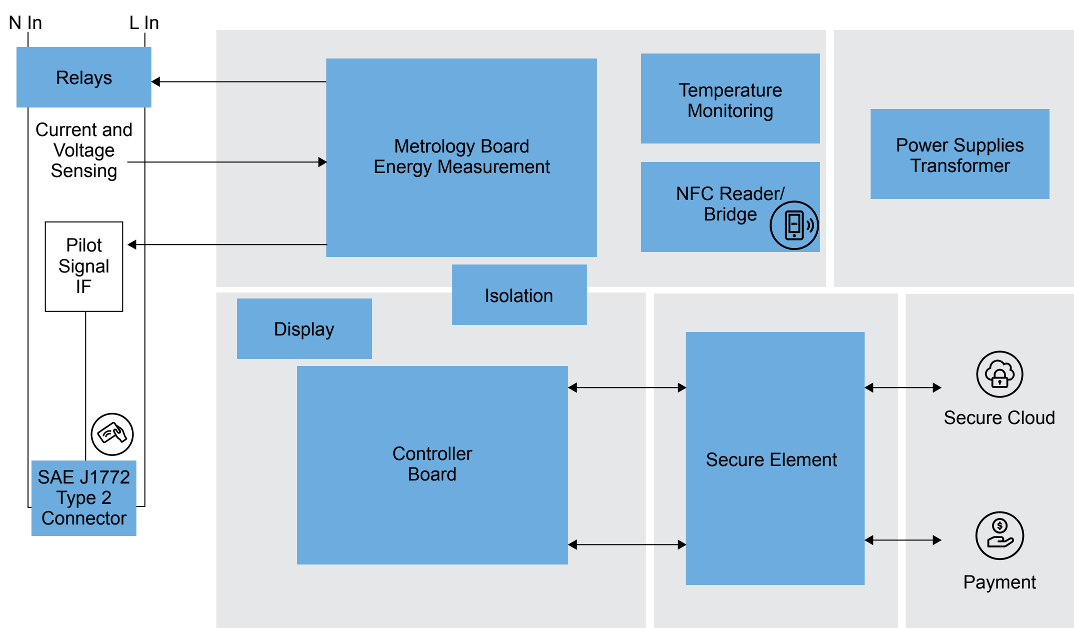


**Figure 1: The system-level view of an EVSE (Electric Vehicle Sourcing Equipment)**

The industry is now imposing high levels of accuracy for metrology units. As an example, a difference in accuracy between 0.25% and 3% could account for 550 kWh over one year for a single charging station. In a network of 20,000 charging stations, that would equate to 11 MWh of electricity cost over one year.

## ENABLING 3-PHASE AC CHARGING

With over more than 95% of the installed base, AC charging is by far the more dominant technology in use today. Of course, the AC that is fed into the vehicle still needs to be converted to DC to charge the battery, and that conversion needs to take place either inside the vehicle using an OBC or inside the charge station.

In either scenario, the AC will be rectified using a PFC stage (power factor correction). The requirement here is to convert the AC to DC in the most efficient way possible to maximize the available energy. The efficiency of conversion stages can vary based on the way the digital signals used to control the high- and low-side power switches are generated. In a high-power PFC stage that takes a 3-phase input, the efficiency will also be dependent on how each phase is controlled; this is invariably implemented using a PWM (phase width modulation) signal for each phase.

One approach to developing the control circuit for the PFC is to use an integrated solution that is dedicated to the function. These devices will be almost mechanical in nature, generating PWM signals with mark/space ratios that are largely pre-determined. In addition, the relative position of each of the three PWM signals may also be fixed. This offers very little flexibility and configurability for tuning the control circuit based on the switching technology being used.

For example, IGBT power transistors are still the most widely used, but they are being displaced by new solutions based on SiC technology (silicon carbide). SiC transistors have a very different switching profile than IGBTs, which makes them more efficient. This efficiency gain can result in faster charging or a longer range.

To accommodate the variation in power transistor technology that now exists in eMobility applications, NXP recommends using a DSC (digital signal controller) in the control circuit rather than a dedicated, fixed-function integrated solution. As a DSC is programmable, it offers a lot more flexibility in the shape and relative position of the PWM signals. In addition to its programmability, the MC56F83xxx and MC56F81xx families of DSCs from NXP feature an Event Generator module (EVTG). This has been designed specifically to provide configurability with repeatability in how the PWM signal for each AC phase is managed.

While the EVTG is implemented through PWM signals generated by a software algorithm, the resolution with which the signal's timing can be modified is extremely granular; each signal can be adjusted in steps of 312 ps. In an AC/DC conversion stage based on PWM signals, it is extremely important to ensure the high-side and low-side power switching devices are not both on simultaneously, as this would represent a short-circuit between the live and neutral lines. The difference between these two active periods is called the "dead time;" its length depends on the profile of the switching transistors being used. In power conversion designs, the objective is to reduce the dead time to the shortest but safest time possible to maximize conversion efficiency.

Thanks to the EVTG contained within the NXP MC56F83xx and MC56F81xx families, it is now possible to control the dead time between PWM signals with a resolution of 312 ps steps. This level of control means each design can be tuned to achieve the highest possible efficiency, while also being configured to drive either IGBT, SiC or GaN power switching technologies. This resolution is achieved using a combination of software-defined PWM signals and hardwired gating logic that is used to generate the dead time in a repeatable and deterministic way, with a resolution of 312 ps. No fixed-function solution is able to provide this combination of flexibility and precise configurability.

### INTELLIGENT CHARGING STATIONS

Intelligent wall boxes and charging stations are usually connected to cloud to realize use cases such as time of use tariffs, end-user consumption profiling and EVSE log and billing. These use cases address the different needs of the various stakeholders, such as the grid operator, charge point operator, OEM, energy supplier or the end-user. The distributed control between the charging station and the cloud requires a wired or wireless connection for sensitive control and payment data between authenticated devices, advanced cloud services and on-the-go users. This is achieved by using either an authenticated, secure and robust IP-based communication with Wi-Fi 6 and Zigbee® and other wireless technologies or via Ethernet. To provision the charging station to the cloud (cloud onboarding), a simple provisioning and ownership process is required, while maintaining high security and confidence about connection to an authentic device. NXP supports a zero-touch onboarding process to major cloud partners through its EdgeLock SE05x secure element and EdgeLock 2GO service.

### ACHIEVING HIGH-LEVEL SECURITY

The Common Criteria EAL5+ certified EdgeLock SE05x secure element securely stores the credentials used to establish a TLS connection with the cloud service provider. It also authenticates sensitive user data, like the consumption profiles and user tariffs as well as payment data. The EdgeLock 2GO service complements the solution enabling secure management of credentials.

Intelligent charging stations are often combined with smart metering solutions; for example, households producing their own electricity from photovoltaic modules or households above a certain energy consumption requiring a smart meter gateway (as mandated, e.g., in Germany). Due to the amount of sensitive data handled, smart meter gateways also have strong security requirements, and in many regions, a secure element is mandated. Combining different entry points of the power supply therefore requires intelligent management of the input and output of the power supply, the connection of the photovoltaic module, the loading of the vehicle and the connection to the network. It also increases the amount and complexity of the data handled, adding focus on the requirements on security and secure authentication to the network and of the user and data.

### SMART EV CHARGING CARDS

The contactless smartcard solution is based on NXP's MIFARE DESFire, which integrates smart city services on one card. It allows customers to pay easily, quickly and securely at the charging station. Services such as transport ticketing, parking, tolling, car sharing and park & ride can also be integrated onto the EV charging card, bringing convenience to the car owner. This solution leverages the large MIFARE contactless ecosystem NXP has built in more than 750 smart cities worldwide. MIFARE is a flexible platform that can be enabled on mobile and wearables seamlessly, allowing the installation to meet the future requirements of EV charging retailers.

### LOCAL STORAGE FOR EV CHARGING

As charging stations migrate from single-phase AC to ultra-rapid DC, the underlying consequence will be an increase in the amount of power that goes into the charging station before it can then be fed into the e-vehicle. This presents several challenges, firstly ensuring the grid can sustain the demand for high-power (350 kW or more) outputs, but also in terms of billing.

Looking at the challenge of billing first, it relates to the contract that energy suppliers have in place with the owner or operator of the charging station. This is much like any service level agreement that restricts a consumer to a maximum amount of a utility; it could be electricity, internet bandwidth or even cellular airtime. Once the pre-agreed amount of that utility is used, further usage will likely be subject to a much larger tariff.

This relates to the technical challenge of delivering enough power during peak demand. Both issues are being addressed through local storage, using batteries and NXP's tried and tested BMS. When the battery is fully charged, it can deliver its capacity to the e-vehicle first before then drawing energy from the grid. When no e-vehicles are using the charging station, it can use that downtime to recharge the local battery storage at a slower rate, therefore helping to smooth out peaks in demand on the wider grid. This local balancing is managed by the central Battery Management Unit (BMU) based on NXP's FS32K1xx family, which is specifically designed for safety and reliability applications.

The local battery storage would be configured to match the output required, typically between 400 V and 1000 V. The trend, as with the e-vehicles themselves, is for the battery voltage to move upwards. This is quickly becoming popular with ultra-rapid DC charging stations around the world, often in collaboration with arrays of solar cells that are used to provide a renewable source of energy for recharging the storage batteries. The same concept could be used with other types of renewable energy, or in collaboration with e-vehicles that could sell back some of the energy stored in their onboard batteries.

### BATTERY AUTHENTICATION

To enable public chargers to charge any EV, even one that has had a replacement battery, battery authentication is crucial to ensure safety of operations. NXP's EdgeLock SE05x embedded secure elements and A500x family will enable battery-to-charger and charger-to-battery authentication. In addition, as battery technologies and chemistries evolve, new charging profiles will emerge. When used in combination with NTAG5, a secure, standard-based link from the charger to the cloud, this provides a future-proof way to address new charging profiles.

### POINT OF SALE SOLUTIONS

With the monetization of charging stations, other services will be offered, such as the ability to buy food products, a lottery ticket, a cup of coffee or another last-minute purchase. This POS offering will require the chargers to connect to the cloud to access credentials and collect user data. Here, data protection and secure connections are essential. NXP's POS solutions, which combine NFC readers and MCUs with UWB TRX and SE05x secure elements, provide robust and secure solutions to address these requirements.

### AUTONOMOUS VEHICLE CHARGING SOLUTIONS

Another requirement becoming visible is how charge stations will accommodate autonomous vehicles. While this is still an emerging need, the industry is already starting to consider how to address it.

With autonomous vehicles, the objective would be to have them guide themselves to a charging station with enough accuracy to connect without the need for a human operator or (expensive) robot assistant to provide that "last cm" connection.

One way of achieving this would be to use a highly accurate localization wireless technology, such as UWB (ultra-wideband). Adding NXP's SR150 and SR040 UWB devices complemented by the EdgeLock Secure Element would enable an autonomous vehicle, such as a taxi or delivery truck, to steer itself into exactly the right position. The same technology is already being explored with autonomous mobile robots and drones.

## CONCLUSION

Electric vehicles are becoming more common, and most nations are now considering supporting that transformation. It requires them to develop wide networks of charging stations that are both safe and secure.

NXP has a long history of delivering both highly efficient power conversion and highly secure data transactions and device authentication. In EV charging, these two domains come together in an entirely new way. With a growing number of evaluation kits and reference designs, covering most of the functional requirements of AC and DC EV charging stations, NXP is well placed to provide the technical insights that manufacturers and service providers need to take EV charging to the global marketplace. Smart home wall chargers will also become part of the mix for which NXP is working on solutions, including SE051H security for Smart Home equipment.

## HOW TO REACH US

**Home Page:** www.nxp.com
**Web Support:** www.nxp.com/support

**USA/Europe or Locations Not Listed:**
NXP Semiconductors USA, Inc.
Technical Information Center, EL516
2100 East Elliot Road
Tempe, Arizona 85284
+1-800-521-6274 or +1-480-768-2130
www.nxp.com/support

**Europe, Middle East, and Africa:**
NXP Semiconductors Germany GmbH
Technical Information Center
Schatzbogen 7
81829 Muenchen, Germany
+44 1296 380 456 (English)
+46 8 52200080 (English)
+49 89 92103 559 (German)
+33 1 69 35 48 48 (French)
www.nxp.com/support

**Japan:**
NXP Japan Ltd.
Yebisu Garden Place Tower 24F,
4-20-3, Ebisu, Shibuya-ku,
Tokyo 150-6024, Japan
0120 950 032 (Domestic Toll Free)
www.nxp.com/jp/support/

**Asia/Pacific:**
NXP Semiconductors Hong Kong Ltd.
Technical Information Center
2 Dai King Street
Tai Po Industrial Estate
Tai Po, N.T., Hong Kong
+800 2666 8080
support.asia@nxp.com

**www.nxp.com**



Document Number: EVCHARGINGWP REV 0