HOW TO REAP THE BENEFITS OF SMART EV CHARGING SAFELY AND EFFICIENTLY

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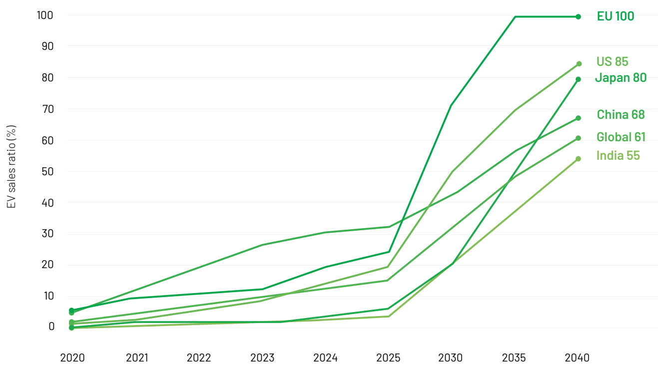
Given the activities of the multi-government Electric Vehicles Initiative (EVI)[i] and efforts by individual countries to move to electric vehicles (EVs) from fossil fuel types, continued growth of the EV market is inevitable.

This is creating an escalating demand for EV charging capacity, which raises the question:[ii]



"How do we accommodate this huge extra demand on the grid, while providing EV charging infrastructures which are safe, efficient, and cost-effective for their users?"

The answer lies in smart grids, and, by extension, smart EV charging infrastructures. Implemented correctly, smart EV chargers can not only help to mitigate grid loading, but also create energy management and saving opportunities that were not otherwise available to their users. Additionally, advances in the field of electromobility are mainly linked to the development of battery technology and power electronics for charging, discharging and driving electric motors.

This article looks at how smart EV charging infrastructures can be deployed to deliver these benefits; we start with a brief review of smart grid concepts and technology to provide context. This covers the concept of bidirectional power, which is fundamental to smart grids, yet confusing to many users and even engineers.

Then we introduce smart EV charging infrastructures as components of a smart grid.

Next, we highlight the many benefits of smart EV charging infrastructures, including the emerging Vehicle to Home (V2H), Vehicle to Grid (V2G) and Vehicle to Vehicle (V2V) technologies. Then we take a deeper dive into the underlying power delivery architectures and options available for building them. In particular, we discuss the IEC 61851 standard, on which these options are based.

However, to be safe, efficient, and compliant with relevant legislation, smart EV charging infrastructures must not only be well designed but also tested and proven to behave as expected, even when subjected to events like grid disturbances.

Accordingly, we finish by looking at some examples of test platforms used for R&D, validation, and End of Line applications. These include grid emulators to emulate grid behaviour, as well as EV simulators, or electronic loads, to replicate on-board EV charger and battery behaviour. This discussion covers the benefits of using instruments which are both regenerative and bidirectional.

THE RISE OF SMART GRID

Oskar von Miller & Marcel Deprez

1882 saw the first successful attempt to transmit electricity over long distances using overhead wires, when German engineer Oskar von Miller and his French colleague Marcel Deprez successfully transmitted 2.5 kilowatts of electricity 57km along a telegraph line[iii] It transmitted a 200V current from a steam engine-powered generator to power an electric motor for an artificial waterfall.

The next century

In the century and more since then, although power transmission lines developed massively in terms of reliability, capacity, and distances covered, the model remained the same: a central monolithic source (More likely a nuclear power station than a steam generator) feeding downstream loads.

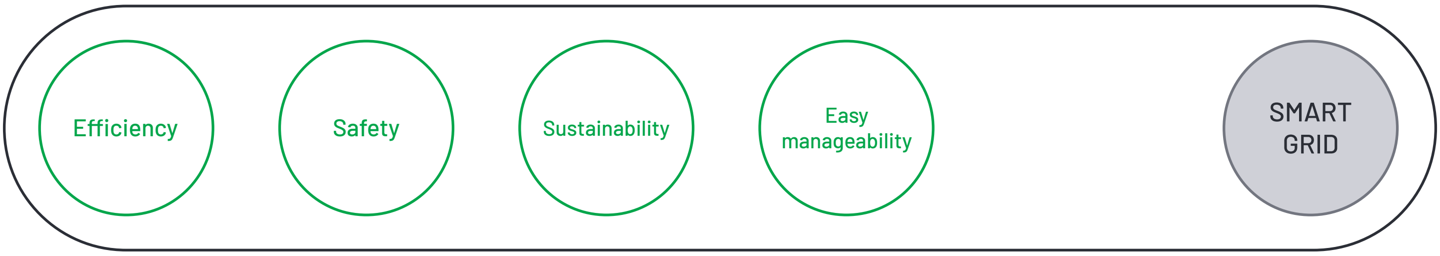
Digitisation

However, this is becoming insufficient to meet modern electricity demands. Digitisation is transforming our lives, but it also brings a proliferation of IoT-based electricity-consuming devices, from EVs and smart homes to Industry 4.0-based manufacturing. Yet digitisation, and the transition towards renewable energy add up to the smart grid – an IoT infrastructure with two-way communications and power components that are remotely monitored and controlled by the utility operator, and, as appropriate, by users.

Digital control allows connection of downstream renewable energy sources, such as homes with solar panels. Such homes can be grid loads, or energy sources if they feed power back into the grid.
This improves flexibility and security, and can critically lighten the load on utility power stations. However downstream electricity sources can put utility service personnel at risk, so these sources must use grid tied inverters to prevent this risk. Such inverters must include algorithms to disconnect the device when the grid fails. This functionality must be tested under the anti-island standards.

HOW SMART GRID TECHNOLOGY ENABLES THE BENEFITS OF SMART EV CHARGING

For EV drivers, the vast majority of whom charge at home[iv], charging their vehicle efficiently is a top priority. Safety, sustainability, and easy manageability are also important considerations.



Investing in a smart EV charging infrastructure can help drivers achieve these objectives. Smart EV charging is associated with the Smart Grid, and shares some characteristics; in particular, relying on Internet communications for monitoring and control, and, increasingly, supporting bidirectional power flow.

When a vehicle is smart charging, the charger is communicating with the car, the EV charging infrastructure, and the utility company through data connections. Information such as charging time and speed is sent via WiFi or Bluetooth to a centralised cloud-based management system.

The received data is analysed and visualised in real-time by the software behind the platform. It can then be used to make automatic decisions about how and when EVs are charged. It also provides the charging operator (typically an individual with a charger at their home or a business owner with multiple charging stations) with insights into their energy usage, so that they can optimise their charging schedule.

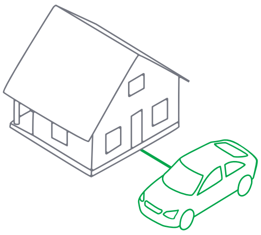
They can reduce costs by charging when electricity prices are lowest, and avoid blackouts and circuit overloads, by using techniques such as dynamic load balancing, load shifting, and peak shaving. Smart charging also allows EVs to be charged from renewable energy, if available, to top up grid power.

Additionally, smart charging allows utility companies to define certain limits for energy consumption, to avoid overloading the grid.

Another emerging benefit of smart EV charging is V2X bi-directional charging technologies, which cover V2H, VRG and V2V.

To support V2X, smart EV charging circuit designs and control systems must be able to support bi-directional power flow.

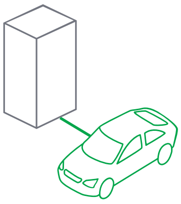
VEHICLE TO HOME



V2H

This allows energy stored in the EV battery to act as a power source for the home.

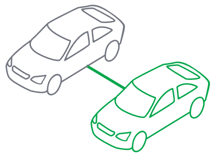
VEHICLE TO GRID



V2G

This feeds EV battery energy back into the grid, to help boost grid capacity at times of peak demand. An OVO V2G trial is currently under way[v].

VEHICLE TO VEHICLE



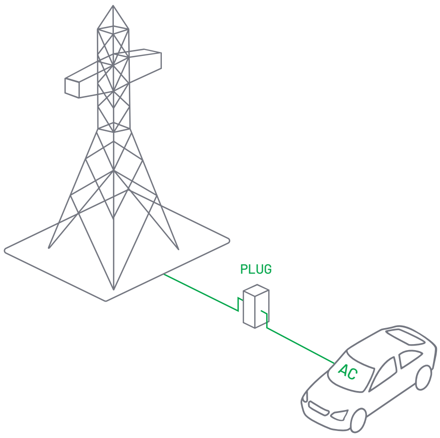
V2V

One vehicle can be used to charge another vehicle, especially in an emergency situation.

PRACTICAL IMPLEMENTATION AND IEC 61851

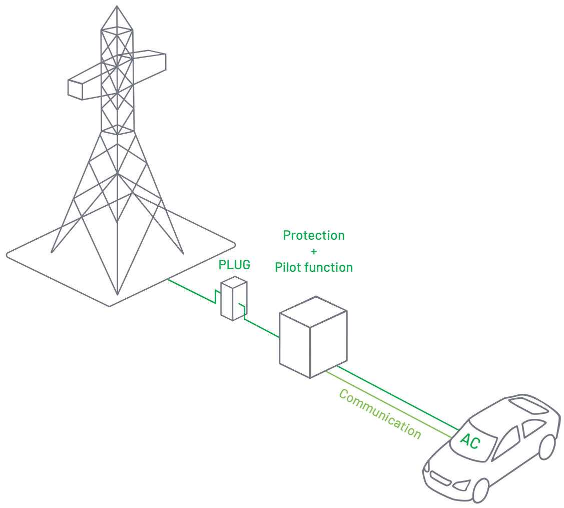
International standards such as IEC 61851 are being developed to answer the needs of the EV market[vi]. Global EV uptake depends on well-established international standards that can address the safety, reliability, and interoperability issues of this market. Below, we review the IEC 61851 standard's four charging modes (mode 1,2,3, and 4).

EV CHARGING MODE 1 - SLOW CHARGE AC



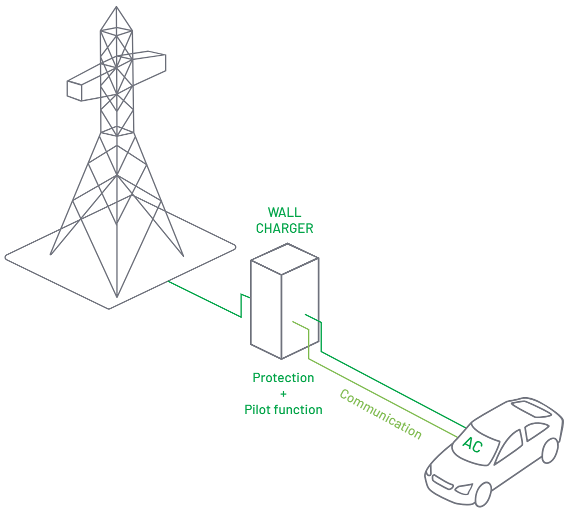
With this mode, the EV is directly connected to a household socket. The maximum current of this mode is 16A and its voltage should not exceed 250V with a single-phase system and 480V for three-phase networks.
Mode 1, as shown in Figure 1, is the simplest possible charging mode and does not support any communication between the EV and the charge point. This charging mode is prohibited or restricted in many countries.

EV CHARGING MODE 2 - SLOW CHARGE AC



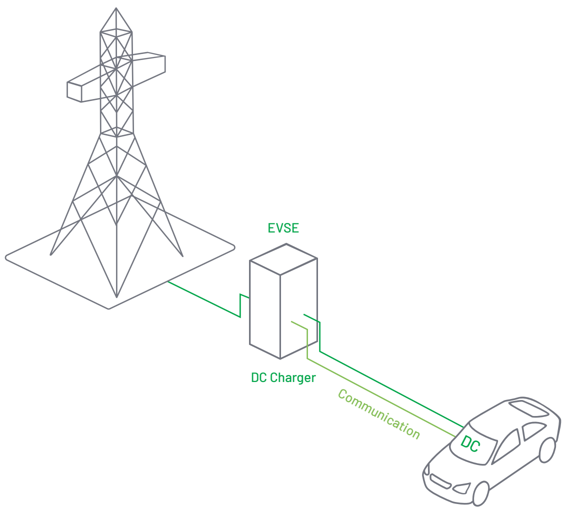
Socket outlets and plugs designed for household use may not always be compliant with electrical standards, and might not be able to tolerate continuous current draw at the maximum rated value.
Accordingly, connecting an EV to the socket-outlet for a long time with no control and safety functions can increase the risk of electric shock. Charging mode 2 was developed to solve this problem by using a special type of charging cable equipped with an in-cable control and protection device (IC-CPD) - see Figure 2.
The IC-CPD performs the required control and safety functions. The maximum current of this mode is 32A and its maximum voltage should not exceed 250V single-phase or 480V three-phase. Mode 2 can be used with both household and industrial sockets.
The safety functions of this mode can detect and monitor the protective earth connection. The mode also supports over-current and over-temperature protection and safety functions. Additionally, the electric vehicle supply equipment (EVSE) can perform functional switching as it detects connection to the EV and analyses its charging power demand.

EV CHARGING MODE 3 - SEMI-FAST CHARGING AC



This mode integrates protection and pilot functions into the dedicated wall charger EVSE as shown in Figure 3. Several control and protection functions are employed to guarantee public safety. These include verifying the protective earth connection and the connection between the EVSE and the EV.
This charging mode operates with either a 250V single-phase or 480V 3-phase network, typically supporting EV charging currents up to 32A single-phase or 63A three-phase. It also supports an operational mode compatible with mode 2.

EV CHARGING MODE 4 - FAST CHARGING DC

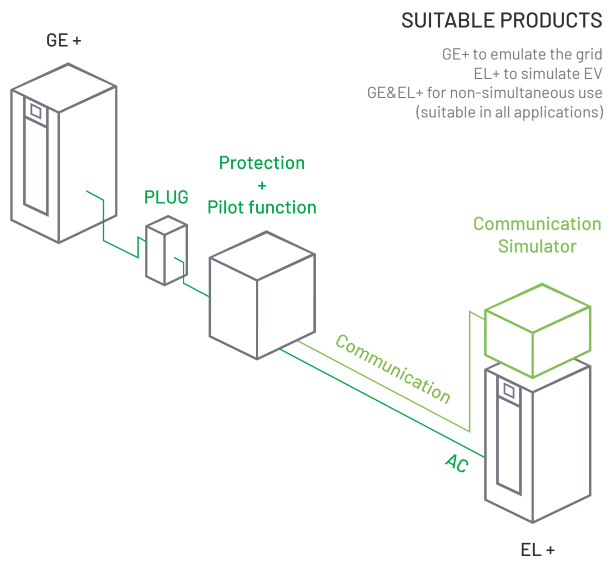


This is the only charging mode that incorporates an off-board charger with integrated monitoring, protection and pilot functions, and a DC output, as Figure 4 shows. The DC current bypasses the on-board charger, being delivered directly to the battery. This mode can provide 600V DC with a maximum current of 400A . The high power level involved in this mode mandates a higher level of communication and stricter safety features.

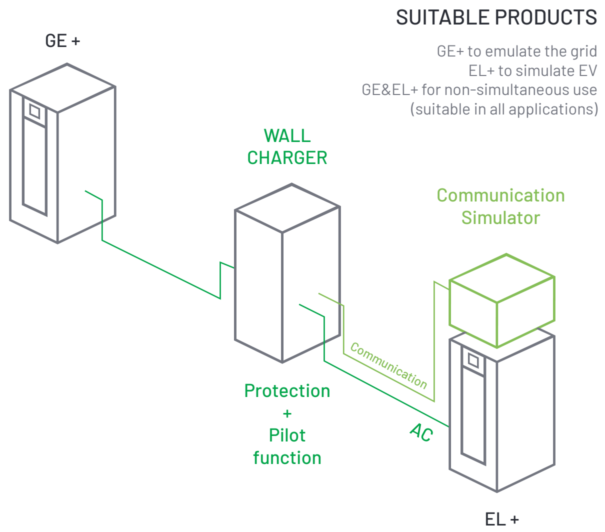
TEST SOLUTIONS: It is essential that the EVSE equipment is performing to specification to ensure optimised operation, energy efficiency, and safety. Cinergia has deep expertise in providing R&D, Validation, and End of Line testing solutions. After extensive experience gained from applying our technology to many e-mobility projects, we have developed a set of instruments and test platforms for all types of EVSE equipment as well as on board chargers and batteries. On board charger testing also extends to V2G and V2H test platforms.

Below, we look at the EVSE test platforms that we offer, and then at the instruments used to build these platforms.
The following figures show the platform configurations for the various charging modes:

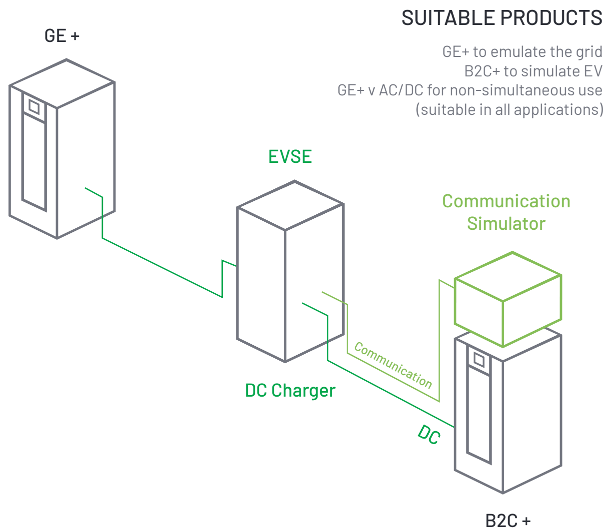
EVSE MODE 2 TEST PLATFORM FOR TYPE 2 CHARGING CABLES



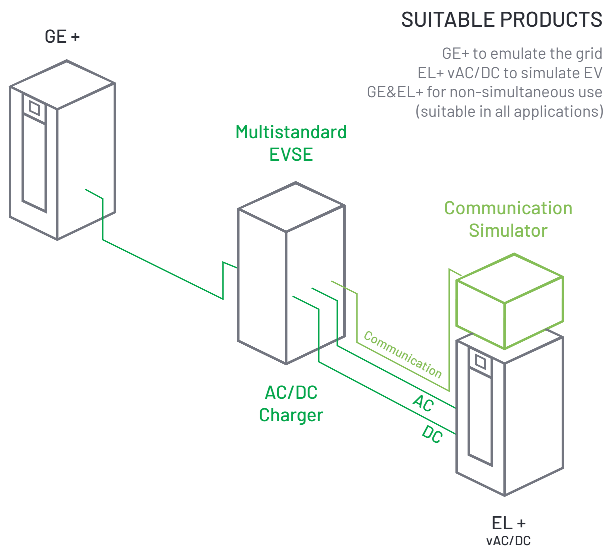
EVSE MODE 3 TEST PLATFORM FOR WALL CHARGERS



EVSE MODE 4 TEST PLATFORM FOR DC CHARGERS



MULTISTANDARD EVSE



TEST INSTRUMENTS: These Figures show that the test platforms can be built using various combinations of three instruments: GE+ vAC ePlus Regenerative AC Grid Emulator, EL+ vAC ePlus Regenerative AC Electronic Load, and B2C+ ePlus Regenerative DC Converter.

Alternatively, the GE&EL+ integrated product package can be used for non-simultaneous testing applications.

GE+ VAC EPLUS REGENERATIVE AC GRID EMULATOR

The GE+ vAC ePlus Regenerative AC Grid Emulator is a Four Quadrant (4Q) programmable AC Voltage Source designed to create both stable and distorted AC grids, now including predefined IEC testing software. With an attractive price, this grid emulator is ideal for performing AC testing on the AC grid side of the on board charger (OBC) and Types 2, 3 and 4 EVSE. It is extensively used in the fields of Renewable Energy Sources, Smart Grids, EV and EVSE and, in general, grid connected devices.

EL+ VAC EPLUS REGENERATIVE AC ELECTRONIC LOAD

The EL+ vAC ePlus Regenerative AC Electronic Load is a 4Q programmable AC Current Source designed to emulate the electrical behaviour of passive and active devices connected to the grid. This cost-effective solution is specially suitable for testing the AC output side of EVSE Type 2 and 3 as well as AC sources/inverters, UPS and other electrical AC voltage generators. Its Regenerative Hardware allows a reduction in the total power and energy needed for the test.

B2C+ EPLUS REGENERATIVE DC CONVERTER

The B2C+ ePlus Regenerative DC Converter is CINERGIA's solution for Regenerative and Bidirectional DC Test Platforms. Thanks to its unique flexibility, it is used to test OBCs and Type 4 DC outputs and is suitable for multiple applications: Renewable Energy Sources, Energy Storage Systems, Battery Testing and Characterisation, Electrical Vehicles, EV Charging Infrastructures, Traction Converters and Avionics.

GE&EL+ PRODUCT FAMILY

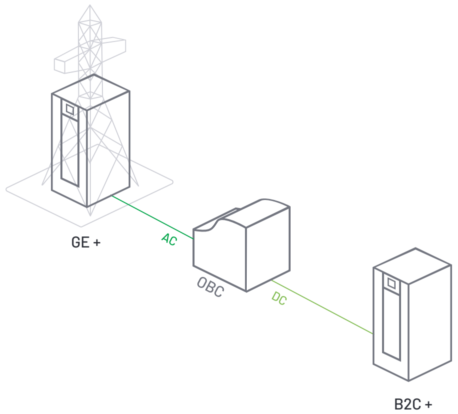
The GE&EL+ product family aggregates Grid Simulators, Electronic Loads and Bidirectional DC Converters into one product.

All of these products have bi-directional topology, which allows them to be regenerative. This reduces both the consumed energy during the tests and the power required from the electrical installation.

This technology allows Cinergia to work in both directions; as power generators or as consumers for realising all types of tests.

VEHICLE TO GRID (V2G) AND VEHICLE TO HOME (V2H) APPLICATIONS

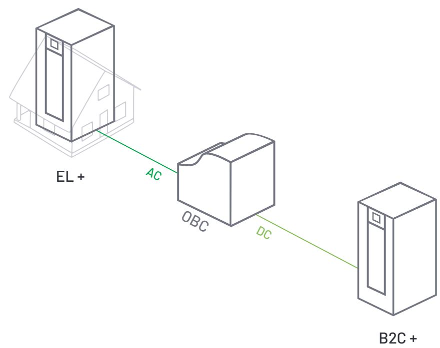
Vehicle to Grid and Vehicle to Home solutions are next generation systems envisioned to convert the electrical vehicle into an active agent of the electrical grid. These systems can reduce power consumption (becoming a controllable load) or supply energy from the EV battery into the grid to provide ancillary services in high-demand scenarios. New revolutionary developments go even further in using the EV battery as the energy resource of an islanded grid. Figures 9 and 10 show test platforms for such configurations.



TEST PLATFORM FOR EV ON BOARD CHARGER (OBC) IN V2G SYSTEM

SUITABLE PRODUCTS

GE+ to emulate grid
B2C+ to simulate Battery
GE+ vAC/DC for non-simultaneous use
(suitable in all applications)



TEST PLATFORM FOR OBC IN VEHICLE TO INSULATED GRID

SUITABLE PRODUCTS

EL+ to emulate grid or loads
B2C+ to simulate Battery
EL+ vAC/DC for non-simultaneous use
(suitable in all applications)

CONCLUSION

Smart EV charging infrastructures can protect their owners from electric overload problems, while reducing energy costs. Collectively, they can also reduce the load on the grid, or even contribute power - increasing its resilience to peak loading. Overall, they contribute to our drive for carbon neutrality.

These benefits can be realised in practice with safety, reliability, and efficiency through using appropriate test procedures and instrumentation.

Regenerative
Power Electronic
Solutions

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