June 2020

SAFETY FUNCTION - CONNECTOR INTERLOCK DETECTION FOR CHARGING CONNECTORS WITH INTEGRATED POWER ELECTRONICS FOR ELECTRIC VEHICLES

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Technical task:
The following invention increases safety during the charging process of an electric vehicle.

Initial situation:
Current electric vehicles (BEVs) have a combo charging socket for charging the high-voltage storage unit. This enables charging with direct current DC as well as alternating current AC. For the combo charging socket there is a corresponding counterpart - the charging cable (see Figure 1).

Figure 1: Combo charging plug

With current charging systems or charging columns, the plug fulfils only two requirements:

1. it establishes the connection between the cable and the plug contact
2. it serves as a handling element for the customer/user

As a result, the interior of the connector contains only the assembly and connection technology.

To avoid electric arcs caused by pulling under load, the charging plug must be locked before charging begins and during the charging process. This is done differently depending on the charging standard and country of use. Figure 2 shows an overview of the standardised DC charging plugs with different implementations of the plug-interlock.

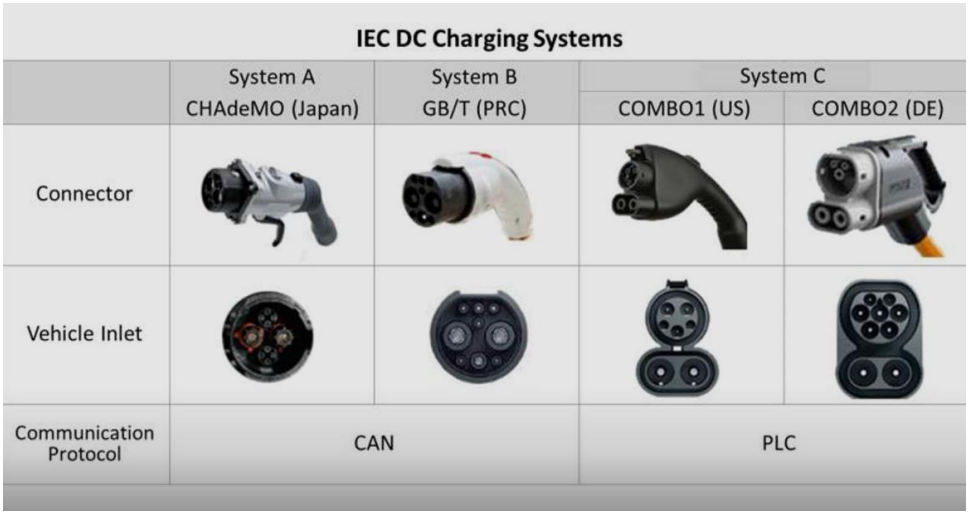

Figure 2: Overview DC charging connectors CHAdeMO, GB/T, CCS Type1, CCS Type2

a. CHAdeMO - Japan
This DC charging plug has a mechanical lock which locks mechanically when the charging plug is inserted into the charging socket. In order to remove the charging plug again, the latched lock must be mechanically released. This process is monitored by the charging station and charging is stopped immediately.

→ Mechanical locking mechanism in the plug
→ Connector Interlock must be implemented and detected by charging connector

b. GB/T standard - China
This DC charging plug has a mechanical lock which locks mechanically when the charging plug is inserted into the charging socket. In order to remove the charging plug again, the latched lock must be mechanically released. This process is monitored by the charging station and charging is stopped immediately.
→ Locking mechanism is controlled by the vehicle
→ Connector Interlock must be implemented and detected by charging connector

c. CCS vehicle charging plug type 1 - North America
This DC charging plug has a mechanical locking device which locks mechanically when the charging plug is inserted into the charging socket (lever lock). To remove the charging plug again, the locked lock (lever) must be mechanically released.
This process is monitored by the charging column and charging is stopped immediately.
→ Locking mechanism is controlled by the vehicle
→ Connector Interlock must be implemented and detected by charging connector

d. CCS vehicle charging plug type 2 - Europe
An electromechanical actuator locks the vehicle charging plug in the vehicle during the charging process. The actuator pin is designed to withstand maximum pull-out forces.
→ Locking mechanism is controlled by the vehicle
→ Connector Interlock must be implemented and detected by charging connector

Figure 3 shows all DC charging plugs used worldwide with the corresponding charging socket on the vehicle including their locking mechanisms. These must be complied with or implemented for each standard in accordance with the prescribed standards.

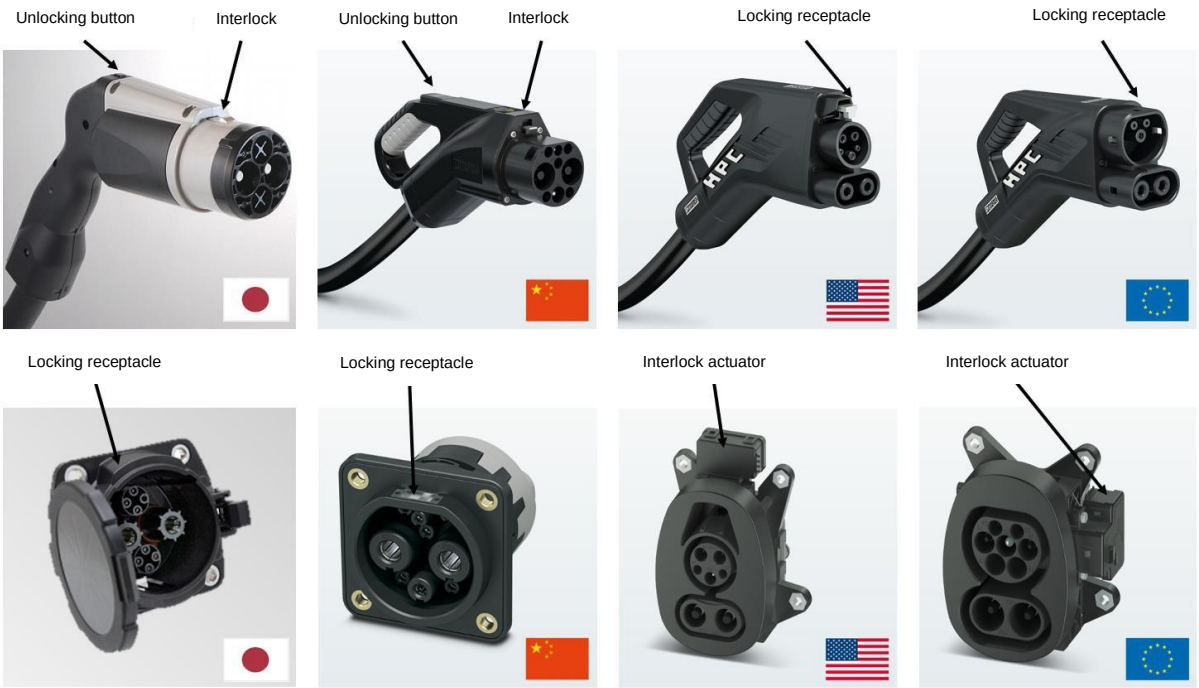

Figure 3: Overview DC charging plugs + plug interlocks

To enable AC charging of future electric vehicles (BEV) and hybrid vehicles without an onboard charger, the charging electronics are to be integrated into the charging plug (see Figure 4, for example Combo 2).

Figure 4: Charging plug with integrated power electronics

To implement the charging functionality directly in the plug of the DC charging cable, the following circuit parts must be integrated. Figure 5 shows the current implementation of the integration of power electronics including control logic in the charging connector.

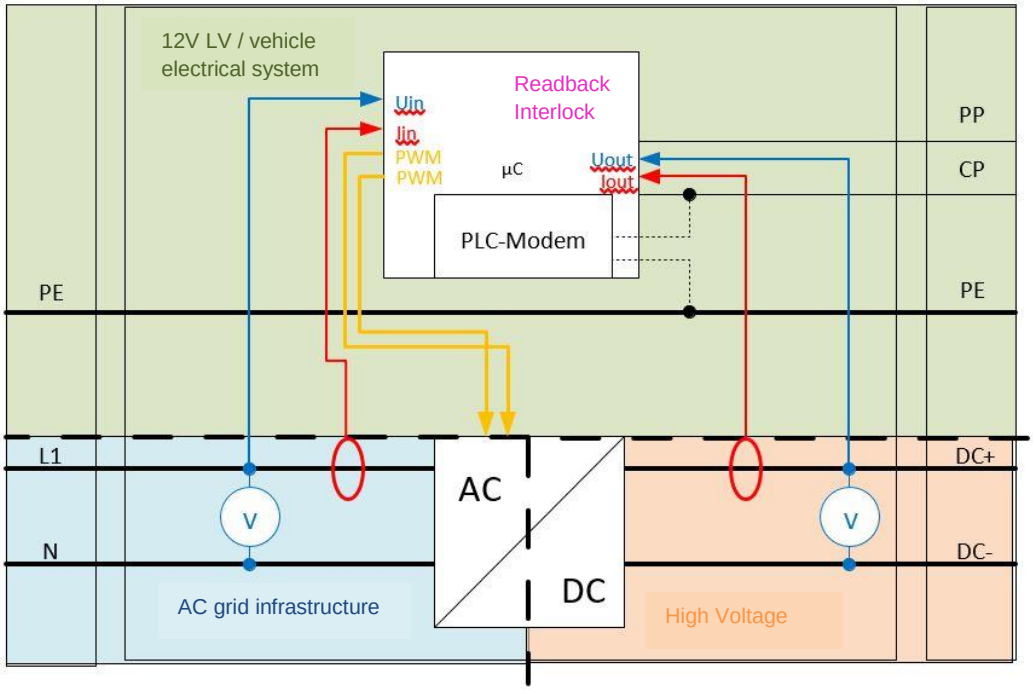

Figure 5: Block Diagram Power Plug Charger / Plug Power Supply

By integrating the power electronics (AC/DC converter) into the charging plug, the plug can be used in Connection with the infrastructure-side mains voltage capable of generating a high-voltage (400800Vdc). The power electronics integrated in the charging cable pose two major hazards, which must be prevented from the point of view of operational safety by means of appropriate protective equipment. A potential danger can occur especially if the customer first connects the cable to the mains infrastructure before the DC plug is plugged into the vehicle. Here it must be ensured that energy conversion is not started until the charging plug is also plugged into the vehicle. The touch protection as well as the insulation could be damaged by handling the cable etc. In addition, the clearance and creepage distances could be shortened by soiling the DC plug and the contacts. Without an appropriate protective device, an electrical hazard to the user/customer cannot be excluded. A further potential danger is the pulling of the charging plug under load (current flow). If the plug is pulled under load, the high DC voltages can lead to arcing between the charging plug and the charging socket. Without an appropriate protective device, an electrical hazard to the user/customer cannot be excluded even in this case.
Currently, there is no read-back of the plug interlock or interlock actuator for power electronics integrated in the charging plug.

Solution:
The invention disclosure includes a hardware as well as software conversion which reads back the connector lock and recognizes the state "locked or unlocked". Depending on the country variant or the charging standard, a mechanical locking device is also integrated into the charging plug. The plug-interlock detection is implemented in the control electronics of the electronics integrated in the charging plug. For example, an "interlock" can be provided for this purpose, which reads back the locking mechanism. Power conversion/power transmission is only started after the charging plug has been securely locked. Thus, safe operation of the plug-in power supply unit is always guaranteed by reading back the interlock. Power conversion/power transfer when the charging plug is not inserted is therefore impossible in normal use. Furthermore, "pulling the plug" under load during power transfer/charging is also impossible. This means that no arcing and no danger for the customer can occur.

Advantages:
- function enables the distribution of a charging cable with integrated power electronics in the DC connector
- Safe condition for the customer is always ensured:
  - no generation of a HV voltage when the plug is not plugged in (avoidance of an electric shock for user/customer)
  - no plug can be pulled under load (during charging) (avoid electric shock due to an arc between plug and charging socket)
- No power consumption of the charging cable when the plug is plugged in on the infrastructure side
- Compliance with all prescribed standards
- Differentiation from the competition

Possible application:
Figure 6 shows a possible implementation of the integration into the charging plug as well as the basic elements of the power and control electronics. As can be seen in the figure, the plug-in power supply unit has three different voltage potentials internally. The control electronics as well as the detection of the plug interlock are at 12V LV potential. Thus a safe state can always be set by the µC. Only after the "interlock" is closed by plugging in the charging plug (shown in pink) the µC will start the control of the power electronics and start the charging process.

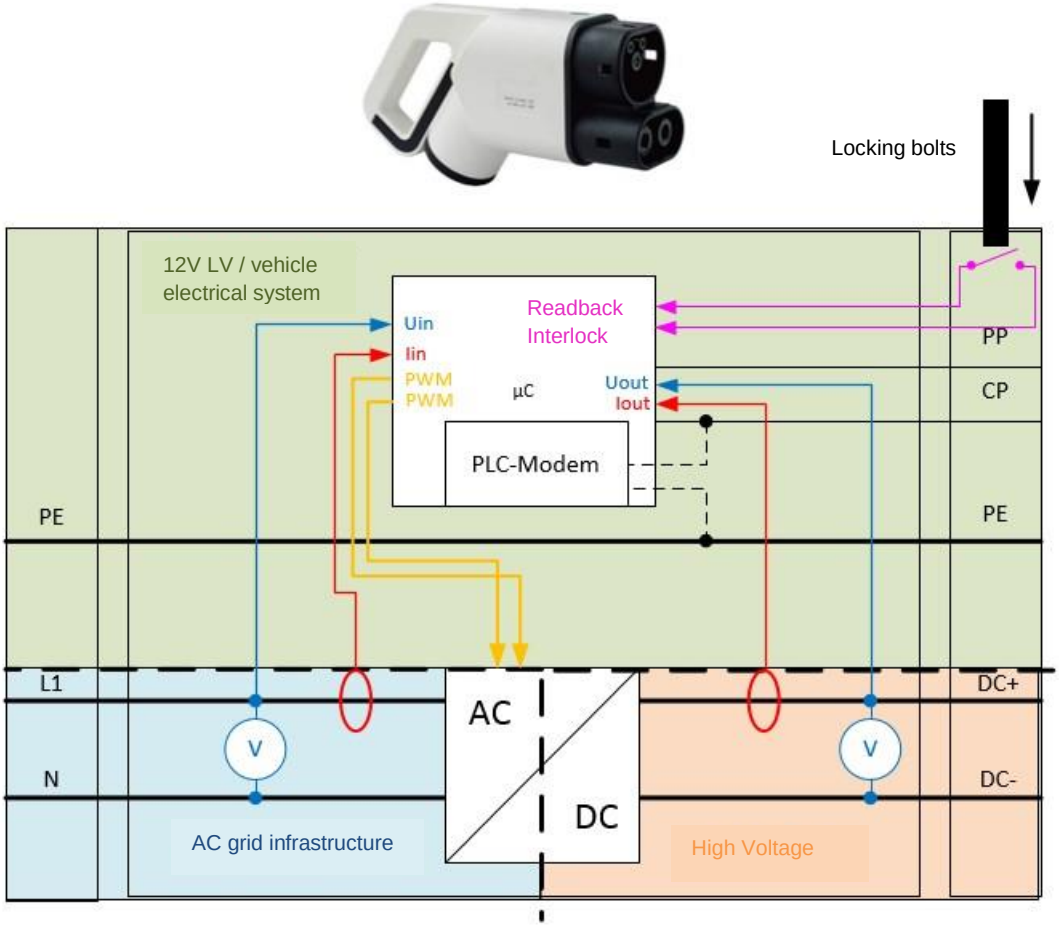

Figure 6: Read-back interlock CCS2