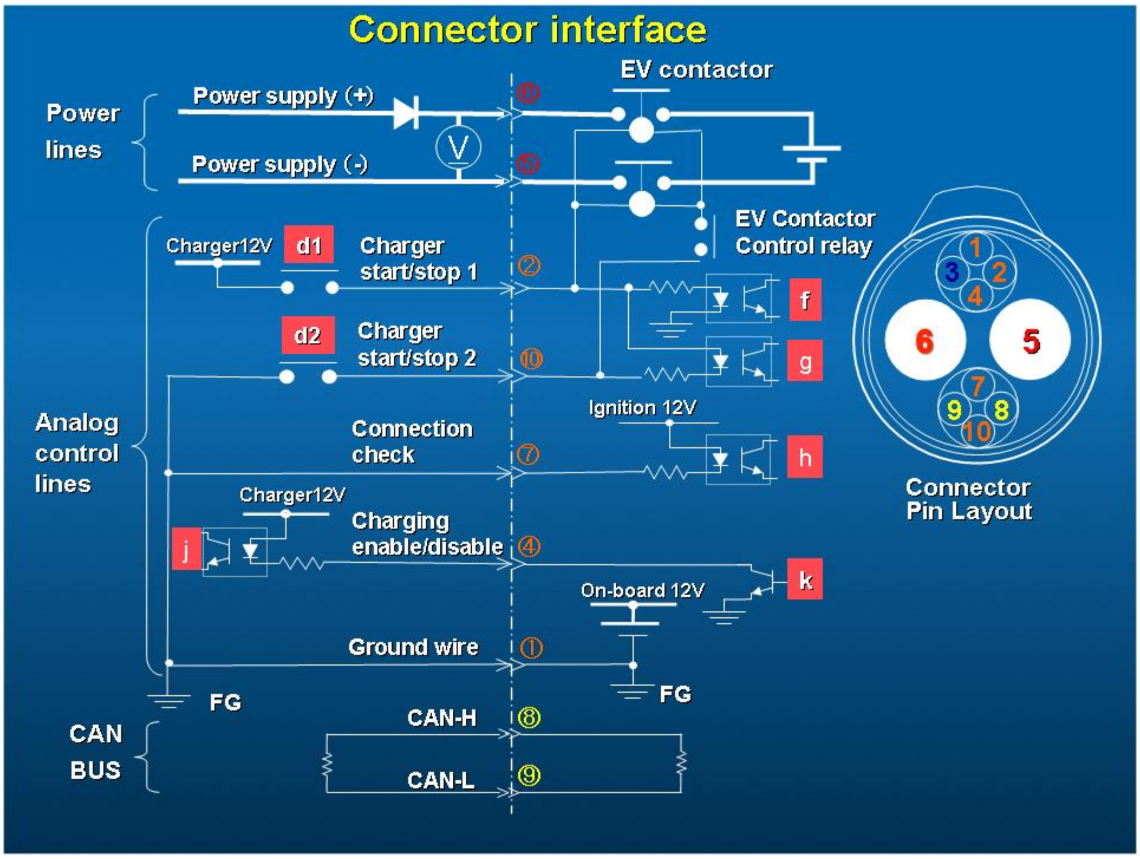


The CHAdeMO quick charger uses an analog signal transmission and a digital communication via CAN. This diverse and redundant design ensures its safe operation.

In the design of the DC connector, in addition to having enough safety margin such as an insulation distance, between the power pins, four analog signal pins, two CAN digital signal pins and one ground pin which are implemented so that the control signals can be transferred properly between the vehicle and the charger.

A transformer separates power grid and battery system. This design prevents accidental high voltage penetration from power grid to batter system.

Power factor corrector keeps power grid transportation efficiency. AC filter is installed to remove negative impact of higher harmonic distortion. In the DC output lines, LC filter is equipped to smooth ripple noises, which may degrade a lithium battery.

While charging process goes on, earth leakage detector is watching ground fault incident in a battery side circuit as well as charger side circuit. This equipment makes it possible to be ground wire diameter thinner than normal protection base ground wire. Generally, thin ground wire seems poor from safety point of view because it can’t bypass high current in case of ground fault accident. But in fact, it achieves higher safety level compare to protection base thick ground wire for current bypass.

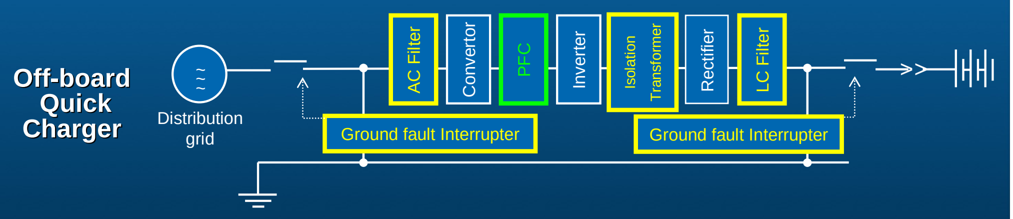
That because, protection ground wire has to be kept sound condition throughout its long lifetime to bypass huge current in case of ground fault accident, but it is not sure because of poor installation or aging degradation.

In the case of protection by earth leakage detector in CHAdeMO quick charger, ground wire disconnection is detected directly though analog signal function, and then charging process is immediately shut down. This is a typical case that the entire charging system design increases safety level.

Safety elements in off-board quick charger

Element	Objectives
AC Filter	Remove higher harmonics distortion to protect distribution grid.
Power Fraction Corrector	Improve conversion efficiency.
Isolation Transformer	Separate battery circuit from grid for operator protection.
LC filter	Reduce ripple noise from output current to protect battery system.
Ground Fault Interrupter	Rapid response GFI to protect operator from electric shock.

Safety function   Performance improvement



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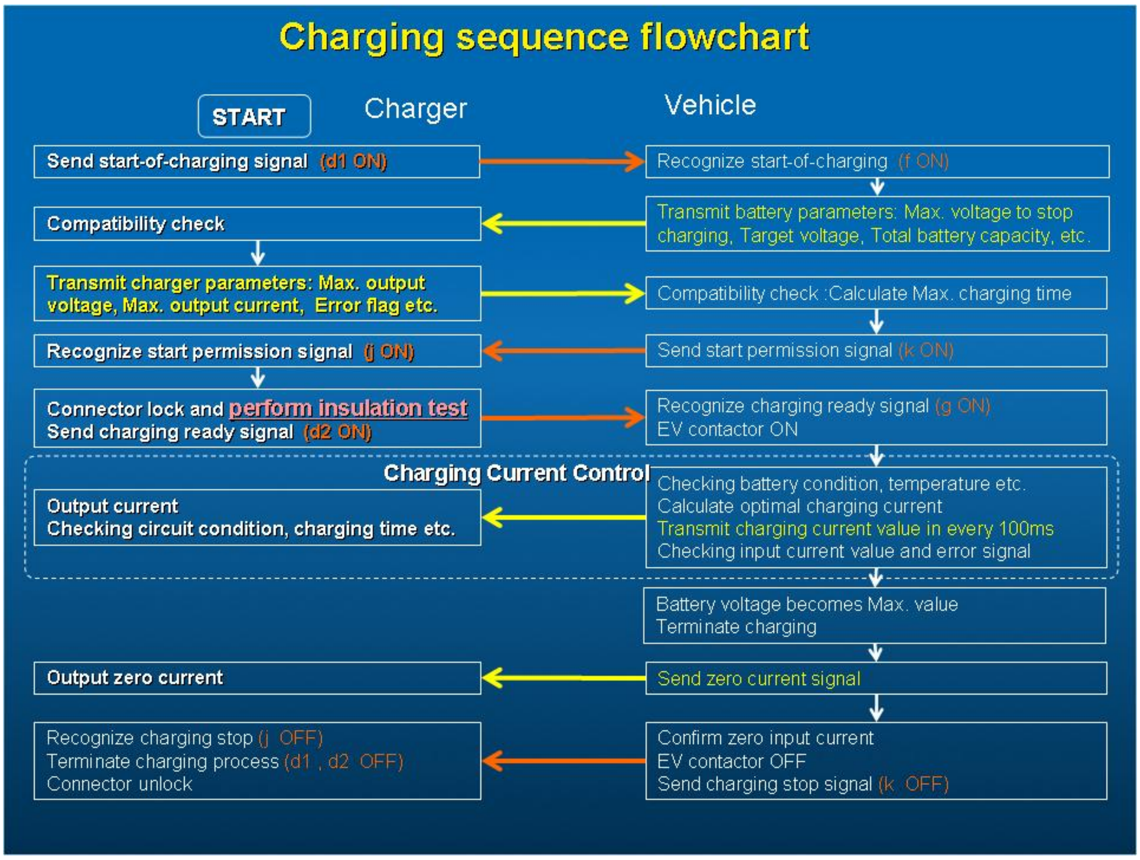

(1) Preparation for charging

The charger closes the ‘d1’relay, and then 12V control voltage is supplied from the charger to a vehicle through analog pin No.2 and excites the photo-coupler ‘f’. At that juncture, the vehicle recognizes that the charging operation has begun, and responds by transmitting a parameter such as the voltage limit, maximum current and capacity of its battery system to the charger via the CAN bus. After the charger receives this information and confirms that it can charge the vehicle, the charger transmits its maximum output voltage and maximum output current to the vehicle via the CAN bus.

The vehicle checks its compatibility with the charger based on transmitted data. If it does not find any problems, it sends the permission signal to start charging by conducting the transistor ‘k’ through analog pin No.4.

Upon receiving this, the charger recognizes that the vehicle has given it permission to begin charging. After the connecter is locked, it applies a short-term voltage load to its exit circuit and conducts a test on the circuit including the connecter interface to confirm there are no abnormalities such as a short circuit or ground fault.

Conducting an insulation test before each charging is an effective means to prevent accidents such as short circuit due to aging degradation or the abuse of connecter cables.

When the insulation test is completed, by closing the ‘d2’relay, the charger lets the vehicle know that preparations for charging have been completed through the analog pin No.10. The vehicle recognizes this via the photo-coupler ‘g’, and finally charging is commenced.

This is the preparation process for charging, and actually only takes a few seconds.

It is technically possible to design a charger to transmit all information that passes through via the CAN. However, the combination of analog communication to digital transmission improves the safety level as follows.

1) It prevents the erroneous start of charging due to malfunctions in the digital control system.
2) It can be confirmed that both control systems in the vehicle and the charger are operating correctly at each step of the operation.
3) When the analog signal is lost, the charging operation will be shut down immediately. As the result, shutdowns can be achieved faster than transmitting a digital signal.

An important feature of this design is the fail-safe function.

(2) Start of power supply

After the aforementioned procedures, the charging controlled by the vehicle starts.

The vehicle closes the EV contactor set on the entrance of its battery system.

After this, the vehicle calculates the current level based on the battery performance an d circumstances, which can be charged and sends the value to the charger every 0.1 se cond through the CAN bus.

The charger supplies an electric current that meets the value from the vehicle via constant current control.

Throughout the whole charging process, the vehicle is monitoring its battery condition and the current value being supplied. When an abnormality is detected, the supply of the current can be shut down in the following four ways.

1) Send a zero value of output current to the charger through the CAN bus
2) Send an error signal to the charger through the CAN bus
3) Turn off the transistor ‘k’ which sends a NO CHARGE analog signal to the charger
4) Open the EV contactor and the block input current

The charger monitors its condition while charging. It monitors the current, voltage and temperature in each subcircuit, and when any value exceeds the limitations, the charger stops charging and sends an error signal to the vehicle via the CAN bus.

The charger can stop charging in the following four ways.

1) Block the convertor’s gate signal

2) Block the inverter’s gate signal
3) Open the contactor on output lines
4) Open the breaker on input lines

In these ways, the charger has a multiple and diverse safety design that can stop charging in various ways.

(3) End of Charging

Charging process is terminated as followed. First, the vehicle sends zero current signals though CAN bus, and then charger stops its output. After confirmation of zero current on inlet lines of vehicle, EV opens contactor and sends prohibit signal to a charger by cutting transistor ‘k’, and the charger confirms that its output current is zero and open relay ‘d1’ and ‘d2’.

A role of relay ‘d2’ is to supply 12V control power from the charger to solenoid of EV contactor. Opening and closing of EV contactor is decided by EV electric control system and performed by EV contactor control relay. However, since power of solenoid of EV contactor is designed to be supplied from the charger, EV contactor cannot be failure closed by single failure of EV electric control system.

Because solenoid power cannot be supplied when connector is decouple, probability of failure close of EV contactor is very small and this design ensures to prevent inadvertent high voltage load on the socket pins.