NEW MARKET OPENING UP FOR ELECTRIC VEHICLE CHARGER MAINTENANCE

The market for electric vehicles (EV) in Australia is still in its infancy with an estimated national fleet of 4,000+ vehicles, not counting hybrids. However, the number of electric vehicles will swell over the next five years or so, as will charger stations which currently number approximately 200. Commercial buildings in central business districts are being equipped with chargers, so the market for the maintenance of electric vehicle supply equipment (EVSE) will expand. However, unlike conventional battery chargers, those for EV are more complicated as they are used by the public in the same way as a petrol or diesel bowser and therefore have to be safe as well as effective.

Charging systems
There are two basic charging systems: AC output and DC output, the latter providing a fast charge. EV has its own internal charger circuit providing AC to DC conversion. The AC section for many EV can be bypassed to allow direct DC charging. Because of the power restrictions for low AC voltage (220 to 240 volts), AC charging is slow and suited to overnight charging. DC charging requires a voltage in excess of the vehicle’s battery bank, typically more than 400 volts. At present, there is no one standard for fast chargers making life complicated.

There are four widely used protocols and standards for EV fast chargers; SAE Combo, CHAdeMO, Tesla Supercharger and China GB/T. Generally, an EV model is designed to accept one standard only. In some cases, adapters can be used to take advantage of another type of fast charger. However, each standard defines communication protocols in addition to the physical design of the plugs.

CHAdeMO is the trade name of a Japanese initiative for a quick charging method delivering up to 70 kW of high-voltage (up to 500 Volts DC) direct current via a special electrical connector. It is proposed as a global industry standard and is specified by the JEVS (Japan Electric Vehicle Standard). The connector includes two large pins for DC power, plus other pins to carry CAN Bus (controller area network) connections between the car and charging stations. CHAdeMO experienced rapid adoption in Japan, with around 5,000 stations deployed in 2017.

The SAE Combined Charging Solution (i.e., SAE Combo, or CCS), which is a standard J1772 plug with two additional DC fast charging ports. The upper part of the plug is the J1772 plug used in the U.S., and the lower part has the two DC power pins. CCS supports slow and fast charging with a single port and uses power line communication (PLC), which is part of the smart grid protocols supported by regulations in Europe. CCS is used by Audi, BMW, Daimler, Ford, General Motors, Porsche, and Volkswagen. The Tesla DC Supercharging network provides the fastest broadly available charging speeds, up to 600 kilometers range in an hour with 120 kW charging rate.

China GB/T standard was developed by ABB to be compatible with a Chinese fast charging standard and uses a connector of same physical shape as a widely-used in Europe, with CAN control protocol instead of PLC.

Fast chargers are expensive and therefore not suitable for private use. There are fast AC chargers, but these require three-phase power, something the average home is not equipped with. Manufacturers of EV generally limit the power capacity of on-board chargers to limit cost. One idea is to use the already available traction electronics onboard the vehicle used to drive the electric motor. In this way, the traction electronics are reused for charging purposes.

Charger technologies
Single and three-phase equipment is in use. The single-phase equipment has a top limit of 2 kW and is only suitable for residential overnight charging. Three-phase chargers can have a rating of 20 kW or higher in the case of commercial systems. The four charging methods are as follows:

- In Mode 1, the vehicle is charged with a single-phase power
- supply with a maximum current of 16 A without a pilot signal.
- In Mode 2, the charging operation uses a single-phase to

![Figure 1: Showing the essence of the ‘handshake’ circuit.](image-url)
• three-phase power supply with a maximum current of 32 A and a pilot signal.
• In Mode 3, charging takes place with a single-phase to three-phase power supply with a maximum current of 63 A and a pilot signal provided by the charging station.
• Mode 4 describes DC charging with up to 400 V/125 A.

While the Mode 1 charging operation does not involve communication between the vehicle and the charging infrastructure, charging in Modes 2, 3, and 4 always involves low-level communication based on pulse width modulation (PWM) via the Control Pilot (CP) connection. If the vehicle and charging station support high-level communication, the corresponding signal is modulated by PWM power line communication (PLC), and this is only possible in Modes 3 and 4 as described by IEC/ISO 15118 [3].

Mode 3 AC charging
Mode 3 AC charging is popularly employed, and a brief description is given here based on fig 1, showing the essence of the ‘handshake’ circuit to establish a safe connection between the EV and EVSE. Not shown is a separate resistor network in which the charger plug closes a switch altering the DC voltage for an EV onboard operational amplifier indicating the charger plug is properly inserted in the vehicle receptacle.

The vehicle is shown to the right of the CP and protective earth (PE). The EVSE transmits a PWM signal with a frequency of 1 kHz and a voltage of 12 V into the EV charge controller. The EV driver to pin CP connects to a diode and two resistors: 2.74 kΩ and 1.3 kΩ. When the charger plug is enabled, a current loop PWM signal CP-PE is established by a 2.74 kΩ resistor, resulting in a decrease in the voltage at CP to ±9, ±12 volts. The charging procedure is initiated by the switch S2 in the vehicle closing (establishing an effective resistance of 880 ohm) thus providing an effective voltage at CP of ±6 V, ±12 volts. For EV charging requiring ventilated conditions, a 330 ohm resistor changes the voltage to ±3, ±12 volts. The EVSE is now ready to charge by varying the duty cycle of the 1 kHz signal.

Testing the functionality of EVSE
An inline tester is employed with one connection being made to the EVSE and the other to the vehicle or a simulation circuit. The tester should indicate whether the vehicle (or simulated circuit) is connected, whether the diode (refer to the above figure) is functioning, and whether the EVSE residual current device (RCD) is in an operational state by testing trip time. Additionally, the AC input (single or three-phase) should be indicated by showing active lines and, in the case of three-phase, the phase rotation. The testing procedure is not complicated and should be scheduled on a practicable time interval.

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