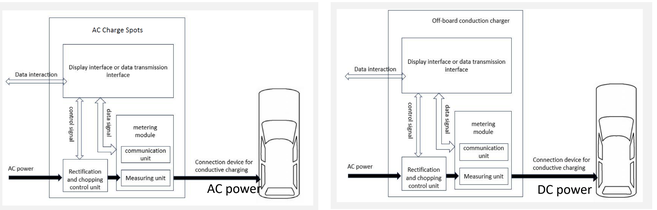
Development of Electric Vehicle Supply Equipment (EVSE) Metrology and Regulation Technology in China

Hongtao Huang, Lei Wang, Haiming Shao
National Institute of Metrology, China
hht@nim.ac.cn

Electric Vehicle Supply Equipment (EVSE)



AC Charging Spot　　DC Charging Spot

National Standards and Regulations

For EVSE

GB/T 28569-2012	Electric Energy Metering for Electric Vehicle AC Charging Spot
GB/T 29318-2012	Electric Energy Metering for Electric Vehicle Off-board Charger
JJG 1148-2018	AC Charging Spot for Electric Vehicles
JJG 1149-2018	Off-board Charger for Electric Vehicles
JJG 1148-2022	AC Charging Spot for Electric Vehicles (for Trial Implementation)
JJG 1149-2022	Off-board Charger for Electric Vehicles (for Trial Implementation)

For Calibrators

JJG 1192-2023	Calibrator of Off-board Chargers for Electric Vehicles
JJG 1193-2023	Calibrator of AC Charging Pile for Electric Vehicles



Verification in Accordance with JJG 1148 and JJG 1149

Accuracy Class and Extension of BMPE

Accuracy Class	
1	2
BMPE	
±1.0%	±2.0%

Accuracy Class	
1	2
Average Temperature Coefficient (%/K)	
0.05	0.10

- For special ambient temperatures（-20℃ ≤ *T*<-10℃ or +40℃< *T*≤+50℃）considering the influence of ambient temperature changes, the BMPE is corrected by the value e.
- The ambient temperature should be measured outside the range of 0.5 m from the charging equipment.

- e =C×|⊿T|

where,

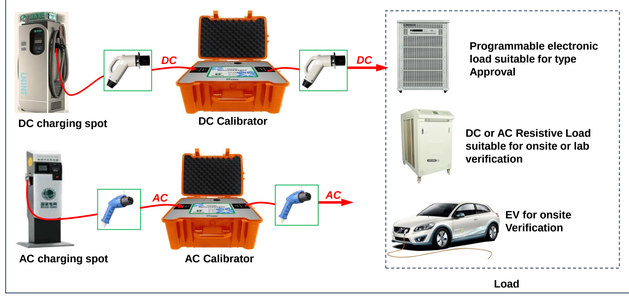
- C - average temperature coefficient, %/K;
- ⊿T -deviation value of ambient temperature, for high temperatures, it is the difference between the current ambient temperature and +40°C; for low temperatures, it is the difference between the current ambient temperature and -10°C.

Verification Items

Verification Items	Initial Verification	Subsequent Verification	In-Use Inspection
Visual Inspection	+	+	+
Operational Error	+	+	-
Time Error	+	+	-

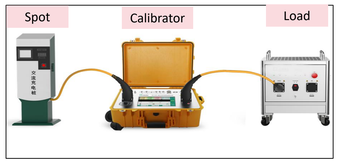
Note: "+" indicates compulsory, and "-" indicates optional.

EVSE, Calibrators, Loads



Commonly Used Onsite Verification Solution

Calibrator + Resistive Load



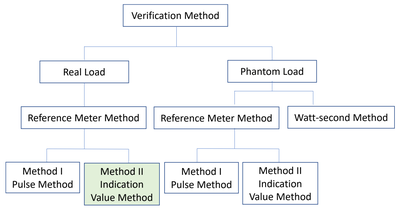


Verification Item 1 – Visual Inspection

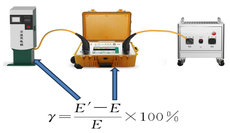
Checking

- Whether the marks on the nameplate are complete;
- Whether there is any obvious damage;
- Whether there are measures to prevent data input or operation by unauthorized persons;
- Whether the number of display digits complies with the regulations;
- Whether the basic functions are normal.

Verification Items 2 – Operational Error



Real Load – Reference Meter Method – Method II



$$\gamma = \frac{E' - E}{E} \times 100\,\%$$

Get two errors, γ_1 and γ_2, take the average value as the final result.

On required minimum value of E'

The ratio of the last digit (or the resolution) of the display of the charging equipment under verification to the accumulated energy should not exceed 1/5 of the BMPE.

Example

- The accuracy class is 2, the BMPE is ±2.0%.
- The display format of the DUT is XXXXX.DD kWh. The last digit is 0.01 kWh.
- Thus we need $\frac{0.01}{E'} \le 2.0\%/5$
 Therefore, $E' \ge 2.5$ kWh.

Verification Item 3 – Time Error

The time difference of DUT's clock and the reference clock in Beijing Time

$$\Delta T = |T - T_0|$$

T_0——Displayed time of the reference clock, XX h XX min XX s;

T—— Displayed time of the DUT, XX h XX min XX s.

For the charging spots with multi-tariffs, the error should not exceed 5 s during the initial verification. During subsequent verifications, it should not exceed 3 min.

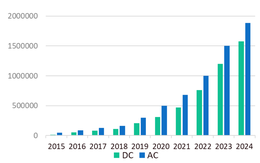
Verification Period

- The verification period is generally not more than 3 years.
- The period of the charging equipment with online monitoring of metrological performance or anti-cheating features, the verification period can be appropriately extended.

Challenges and Novel Methods

Challenges

- Up to the end of 2024, the public EVSE in China is growing to 3.46 millions，including 1.575 million DC, and 1.85 million AC。
- The expected amount by the end of 2030 is 9 millions.
- Annual growth rate: 26%



Two Challenges

(1) Cost

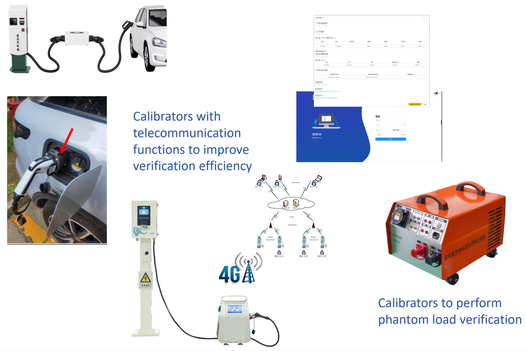
Time:
1) Net time of verifying of one charging spot:（20~40) min
2) Much time for transportation to charging stations.

Labor:
1) Calibrators and loads are heavy to move.
2) Usually, two persons as a group to do on-site verification.

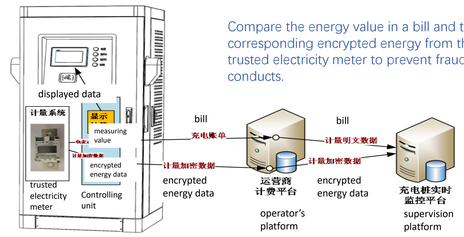
Fund:
A large amount of funds are needed for verifying the huge amount of EVSE.

(2) Lack of durative supervision

Novel Calibrators

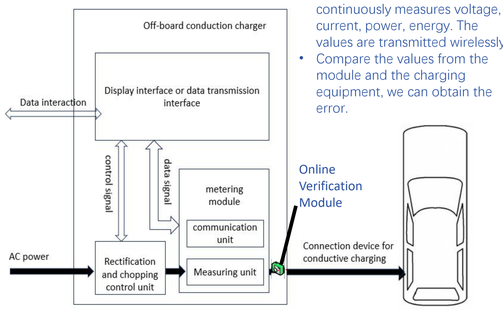


Encrypted Energy Data Comparison



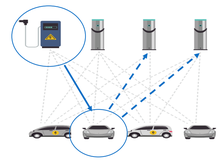
Compare the energy value in a bill and the corresponding encrypted energy from the inner trusted electricity meter to prevent fraudulent conducts.

Online Verification Module



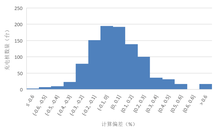
- An online verification module is installed inside. The module continuously measures voltage, current, power, energy. The values are transmitted wirelessly.
- Compare the values from the module and the charging equipment, we can obtain the error.

EV-EVSE Interaction (Data-driven)



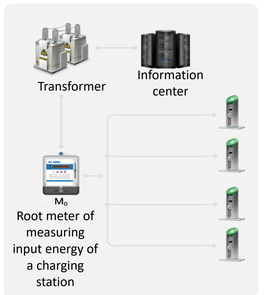
- Various EVs are charged in various charging equipment.
- EVs behave as transfer standards.
- The BMS (Battery Management System) in an EV's battery records voltage and current.
- By comparison of the charging results of one EV in two charging equipment, we indirectly compare the two equipment.

$$\begin{cases} \varepsilon_1 - \varepsilon_2 = \Delta_2^1, \ u(\Delta_2^1) \\ \varepsilon_1 - \varepsilon_2 = \Delta_2^{1'}, \ u(\Delta_2^{1'}) \\ \vdots \\ \varepsilon_j - \varepsilon_k = \Delta_k^j, \ u(\Delta_k^j) \\ \varepsilon_j - \varepsilon_k = \Delta_k^{j'}, \ u(\Delta_k^{j'}) \end{cases}$$



Energy Conservation Based Method (Data-driven)

- Based on the energy conservation law, a system of linear equations are established, with the errors of charging spots as the unknows in the equations.
- By solving the equations, we obtain the errors.



Input Energy to a Charging Station

Output Energy from all EVSE + Loss

$$T(i) = \sum_{j=1}^{N} M_j(i)(1-\gamma_j) + L_0 + L(i)$$

$$\begin{cases} M_1(1)(1-\gamma_1)+M_2(1)(1-\gamma_2)+\ldots+M_n(1)(1-\gamma_n)+L_0+L(1)=T(1) \\ M_1(2)(1-\gamma_1)+M_2(2)(1-\gamma_2)+\ldots+M_n(2)(1-\gamma_n)+L_0+L(2)=T(2) \\ M_1(3)(1-\gamma_1)+M_2(3)(1-\gamma_2)+\ldots+M_n(3)(1-\gamma_n)+L_0+L(3)=T(3) \\ \ldots \\ M_1(m)(1-\gamma_1)+M_2(m)(1-\gamma_2)+\ldots+M_n(m)(1-\gamma_n)+L_0+L(m)=T(m) \end{cases}$$

Overall Supervision System

Data-driven Remote Error Evaluation

Energy Conservation Based Method　　EV-EVSE Interaction

+

Verification

Statistical Verification　　Online Verification Module

On-site Automatic Verification

- The data-driven method is the key part, while verification is the supplemental to it.
- Integrating the data-driven method, statistical verification and other verification method, it is expected that cost of supervising public charging equipment becomes 40% to 50% of the cost of traditional verification.