

# Recommendation of Charging Interface Initiative e.V.

Recommendation for multiple DC inlets on EVs with CCS or MCS

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# 1. Introduction

With the increasing adoption of electric vehicles (EVs) and the demand for faster charging solutions, the possibility of integrating multiple inlets into an EV has been analyzed. The goal of this document is to present the findings of the MCS working group and outline the considerations for standardization committees, including IEC 62196-3, IEC 61851-23-3, IEC 63379, ISO 5474 and SAE J3271.

As the EV industry grows, manufacturers and infrastructure providers are continuously looking for ways to enhance the charging experience. One possible solution is the use of multiple charging inlets on a single vehicle, which could potentially allow for higher charging power, redundancy, and improved compatibility to different charging networks. However, this approach introduces several technical and safety challenges that must be carefully addressed to ensure compatibility, safety, and regulatory compliance.

IEC 61851-23:2023 annex FF already covers requirements for EVSEs with multiple output vehicle connectors.

The integration of multiple inlets raises questions regarding electrical isolation, charging coordination, and power management. It is crucial to ensure that simultaneous use of multiple charging connections on one vehicle does not cause safety hazards or system failures. Furthermore, charging stations and vehicle communication protocols need to be aligned to prevent conflicts and ensure seamless operation for all users, avoiding proprietary solutions and incompatible equipment. Addressing these concerns requires a collaborative effort between standardization bodies, industry stakeholders, and technology developers.

This document provides an overview of the current state of multi-connector charging, identifies key technical considerations, and outlines proposed guidelines for standardization. The goal is to establish a guideline of work needed in standards groups to allow for safe and efficient multi-inlet charging while maintaining compatibility with existing charging infrastructure and emerging technologies.

## 2. Current Status and Industry Developments

The electric vehicle industry is experiencing rapid transformation, with manufacturers actively developing new solutions to optimize charging performance. Among these advancements, multiple charging inlets have emerged as a potential game-changer, allowing vehicles to access different charging sources and infrastructures. Many automotive, marine, and mining equipment companies have created or proposed multi-inlet solutions to accelerate charging speeds and improve vehicle uptime while utilizing existing charging equipment. These developments are particularly significant for commercial fleets, where downtime can significantly impact operational efficiency.

Several heavy-duty and industrial applications have already implemented multi-inlet solutions. In mining and construction, vehicles requiring high-power charging solutions have demonstrated the feasibility of this approach. In regions with diverse charging standards, equipping EVs with multiple inlets with different standards enhances compatibility and ensures access to a wider range of charging stations. Furthermore, as battery technology evolves, vehicle architectures may increasingly support configurations that optimize power distribution and energy management through multiple inlets.

The adoption of multiple inlets, however, can present significant challenges. Existing charging infrastructure has not been designed to recognize or regulate simultaneous charging from multiple sources, raising concerns about safety and system integrity. The lack of standardized protocols complicates integration and requires harmonization across manufacturers, charging station operators, and grid regulators. Additionally, the presence of multiple Isolation Monitoring Devices (IMDs) on the same system may lead to potential interference, affecting the reliability of safety mechanisms.

Despite these challenges, the industry recognizes the potential benefits of multi-connector charging, and various stakeholders are working toward solutions. Continued collaboration between vehicle manufacturers, charging infrastructure providers, and regulatory bodies will be critical in shaping the future of this technology. By addressing technical barriers and developing appropriate safety standards, multi-inlet charging can become a viable solution for improving charging flexibility, reducing downtime, and enhancing the overall EV ecosystem.

### 3. Key Technical Considerations

Adding multiple charging inlets to electric vehicles introduces complex technical challenges. This chapter highlights the most critical aspects—such as safety signaling, isolation monitoring, current distribution, and compatibility with existing infrastructure—that must be addressed to ensure reliable and safe operation of multi-inlet systems. These considerations form the basis for future standardization efforts.

1. **Simultaneous Charging:** While multiple inlets on the vehicle exist, there are technical and safety constraints that need to be considered during simultaneous charging from different sources.
2. **Vehicle charging systems using different charging standards** are not considered in the context of this document. Differences in short-circuit requirements, Protective Earth (PE) diameters, sequencing, etc. make this overly complicated for the sake of this overview.
3. **Insulation monitoring:** The presence of multiple Isolation Monitoring Devices (IMDs) on the same DC bus may cause interference and unreliable measurements. This is critical to system safety and is a key aspect of EV charging safety.
4. **Y-Capacitance:** All Y-capacitances on systems connected to the same DC bus will be combined. Depending on the system the limits on Y-capacitance may be exceeded if you combine multiple EVSEs.
5. **Short circuit and current limitations:** Current from different inlets must be managed carefully to prevent overload or failure of electrical components.
6. **Multiple DC conductor pairs in one connector and/or multiple connectors:** Some connectors have multiple pins for DC charging. Sometimes if not all pairs are used, unused pins may be accessible, and these must not become hazardous-live. When using multiple connectors, these may or may not be close to each other, and the charge cables may or may not have significant differences in lengths and impedance.
7. **Voltage imbalance between systems:** It's assumed that best practices are followed to ensure that appropriate component sizing is done to prevent imbalance due to circuit resistance. It's also expected that voltage control devices such as power electronics have appropriate hardware and software control mechanisms to ensure the target voltages for the system are provided appropriately. However, for some scenarios it is inherently impossible to avoid voltage imbalance, and some configurations are easier to manage this imbalance compared to others.
8. **Safety Signaling:** Charging standards have basic signaling used to indicate different operating modes between equipment. When multiple connectors are used, safety signaling with multiple connectors must be defined in the relevant standards. Safety on one system should not influence the safety of other systems.
9. **Sequence of connection:** The sequence in which the connectors are inserted and removed should not pose a safety hazard.
10. **Loss of one of the PE may not be detected.** If a single PE is sufficient to ensure safety, this may not be an issue. Care needs to be taken if different systems are involved. It may not be possible to detect loss of PE in a single charge cable when the other charge cable is connected and grounded; however, the vehicle remains safely grounded by the one charging cable and if that fails both EVSEs will detect loss of ground connection.

11. **High level communications:** While different charging standards have different physical and software layers that handle different types of high-level communications, it's clear that none of the existing standards have identified how to manage this with multiple inlets connected. This is important for establishing items such as maximum current-limits, voltage-limits, and much more complex items that most standards can support.
12. **Diagnostics:** Similar to high level communications, diagnostics information that has been created to date has not considered multiple connectors used for a single EV, and this will have a significant impact on the value of diagnostic information for these use cases. By making diagnostic information relevant to the use case, future EV reliability and uptime can be continuously improved.
13. **Site power distribution:** Initially, it may seem that multiple EVSEs allow for the sum of their independent power limits. However, site power available is independent from individual EVSE power summed together. It is important to ensure that the individual EVSEs are managed as a combined system if the use case expects balanced performance from independent EVSEs while charging with multiple inlets on a single EV.
14. **(Galvanic) Separation between EVSE outputs:** It is required to have separation between outputs of a single EVSE, or multiple EVSEs. See IEC 61851-23:2023 cl 8.105.1: Multiple side Bs shall be separated from each other by basic insulation a, f (8.105.1). This also means that you cannot have a shared DC+ or DC-. In case this is not observed, circulating currents could occur and possible resonance could occur leading to an uncontrolled situation. It would not be possible to guarantee adherence to IEC 61851-23:2023,cl 6.3.1.111 Overload protection for parallel conductors (conditional function). This is required in case multiple DC outputs are combined, also within a single connector.
15. **EVSEs with different PE potentials:** Differences in PE potential can cause large circulating currents through the PE conductors to the vehicle. Careful consideration must be given that all EVSE's involved are bonded to the same PE to prevent this. This would involve installation guidelines as, for instance, IEC 60364-7-722 or NFPA70, cl 625.
16. **Fault handling:** Fault handling is important to define clearly to provide predictable system behaviors. If one of the charging/communication sessions fails, is it allowed to have other sessions continue? Under what conditions can a charging/communication session restart?
17. **EVSE outputs not in series:** Under no circumstances should the EVSE outputs be used in series. The working voltages the EVSEs have been designed for the maximum output voltage of the EVSE. If multiple outputs are used in series, the designed working voltage will be exceeded.
18. **Backwards compatibility:** EVSE's that are designed/installed today have no means to detect if the vehicle uses multiple inlets and/or if there are any safety implications.
19. **Bi-directional:** Bi-directional power transfer is not considered in this document.

## 4. Use Cases

A variety of use cases were considered that included multiple independent chargers, multiple independent battery systems, and multiple connectors. For this document, the following premises are considered for the variety of use cases in scope:

- The focus is considering when all circuits are being used simultaneously.
- This document does not address vehicles that have multiple inlets, but only one vehicle inlet can be used at a time. This is considered equivalent to the normal use case (Use Case A).
- No proprietary solutions are considered, only those which can be supported by the present international charging standards.
- When EVs have multiple battery systems that can be electrically isolated, it is assumed that this isolation is maintained during parallel charging with multiple charge connectors.
- No mixing of different standards is considered (for example, one CCS connector and one MCS connector) for simultaneous use of multiple connectors in this overview. All cases consider the charge connectors to be from the same standard (for example, 2 MCS connectors).
- In case of bi-directional energy transfer use cases, this document does not consider use cases where the multiple connectors handle energy transfer in different directions.
- Use cases should not be mixed, and it is up to the reader to extrapolate to more

The visual below summarizes different multi-connector charger and vehicle configurations that have been considered.

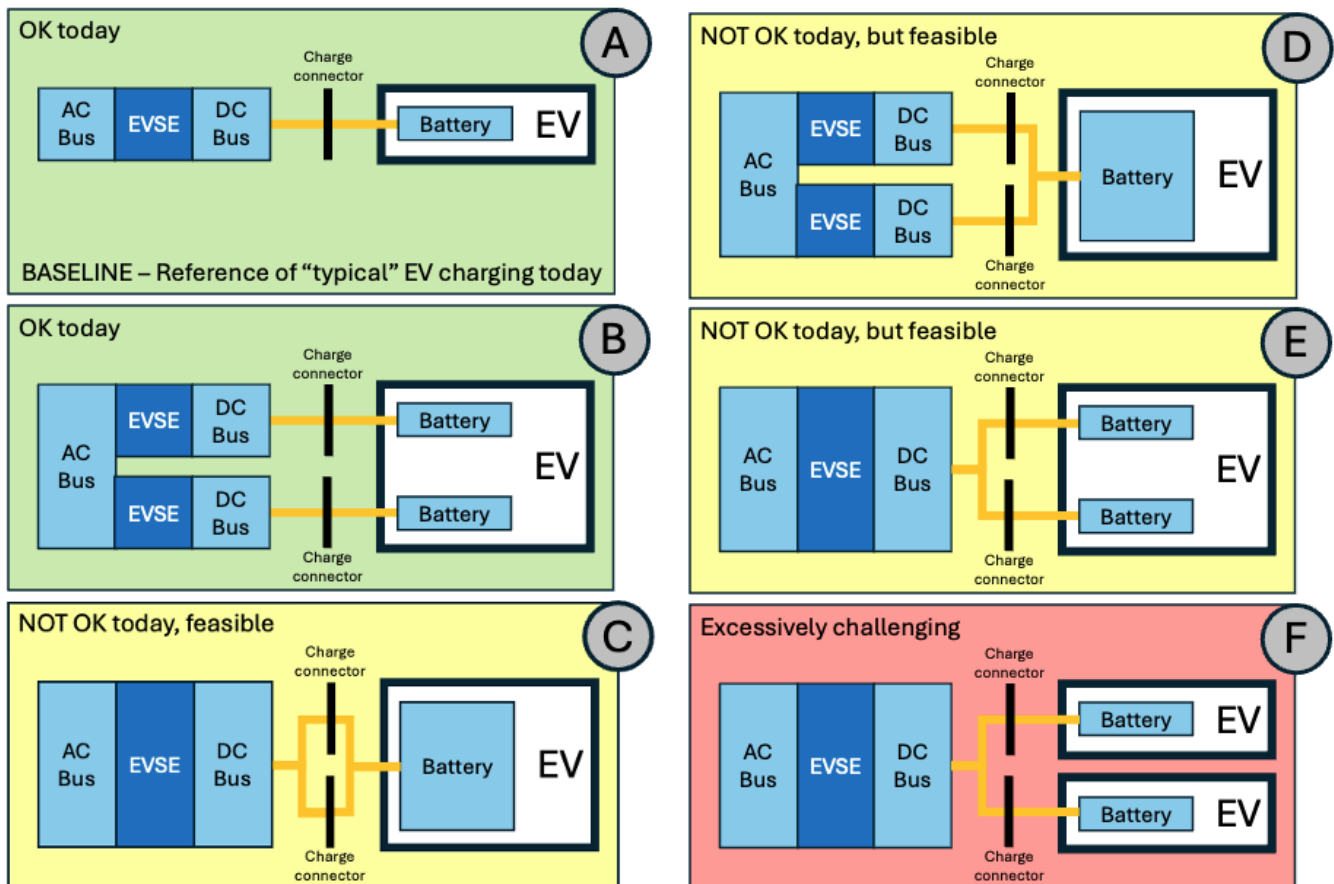


Figure 1 Different use cases of charging equipment configurations

These visuals are simplified to focus on the most important aspects of multiple connectors for this whitepaper.

✔ Ok today     
 ? Slightly challenging     
 ! Very challenging     
 ✘ Excessively challenging

| Safety Critical Features |   |                    |               |                   |                  |              |                  |             |
|--------------------------|---|--------------------|---------------|-------------------|------------------|--------------|------------------|-------------|
| ID                       | Short Description                                 | Insulation monitor | Short circuit | Voltage imbalance | Safety Signaling | P.E. Monitor | High Level Comms | Diagnostics |
| <b>A</b>                 | 1 charger<br>1 Connector<br>1 EV<br>1 battery     | ✔                  | ✔             | ✔                 | ✔                | ✔            | ✔                | ✔           |
| <b>B</b>                 | 2 chargers<br>2 connectors<br>1 EV<br>2 batteries | ✔                  | ✔             | ✔                 | ✔                | ✔            | ✔                | ✔           |
| <b>C</b>                 | 1 charger<br>2 connectors<br>1 EV<br>1 battery    | ✔                  | !             | ✔                 | ?                | ?            | ?                | ?           |
| <b>D</b>                 | 2 chargers<br>2 connectors<br>1 EV<br>1 battery   | ?                  | !             | ✔                 | ?                | ?            | ?                | ?           |
| <b>E</b>                 | 1 charger<br>2 connectors<br>1 EV<br>2 batteries  | ?                  | !             | !                 | ?                | ?            | ?                | ?           |
| <b>F</b>                 | 1 charger<br>2 connectors<br>2 EVs<br>2 batteries | ✘                  | !             | ✘                 | ?                | ✘            | ✘                | ✘           |

Figure 2 Evaluation of different charging configuration regarding safety aspects

## Use Case A

Use Case A – Baseline of a “typical” EV charging today.

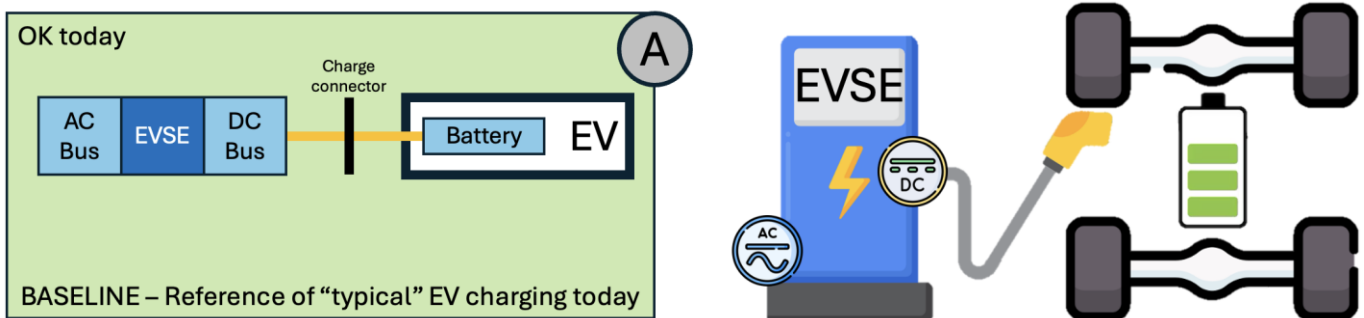


Figure 3 Use Case A

This is the normal case in which a single vehicle connector is used to charge a single battery system in a single vehicle. Every use case has to take into account all the (safety) requirements defined for this use case and have the same or an equivalent level of safety.

## Use Case B

Use Case B – 2 (or more) chargers, 2 (or more) connectors, 1 EV, 2 (or more) battery systems

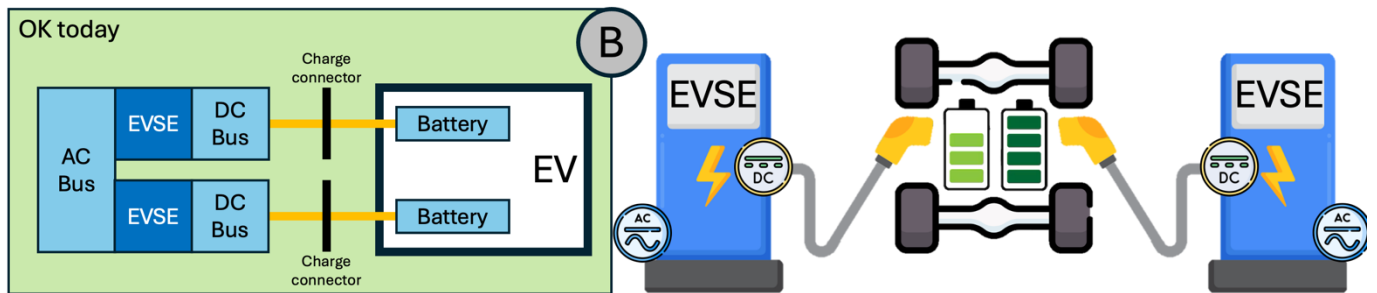


Figure 4 Use Case B

In this case, during charging, the vehicle is almost the equivalent of 2 (or more) separate EVs charged at the same time. The batteries and systems associated with charging are separated by at least simple separation. The EVSEs are not any different from an EVSE charging a single battery system.

The following concerns should be considered:

- The EVSEs are bonded to the same earthing system (PE) and therefore a loss of PE on one of the couplers will not be detected.
- Due to the shared PE, currents could start circulating between EVSEs, causing interference.
- Even though the systems are separated in the EV, it is still possible that the IMDs may interfere with each other through measurement systems in the EV. Careful consideration should be given to these high-impedance paths between the systems.
- If the battery packs are combined after a charge session, the EV has to take care of small differences between the packs.

## Use Case C

Use Case C – 1 charger, 2 (or more) connectors, 1 EV, 1 battery system

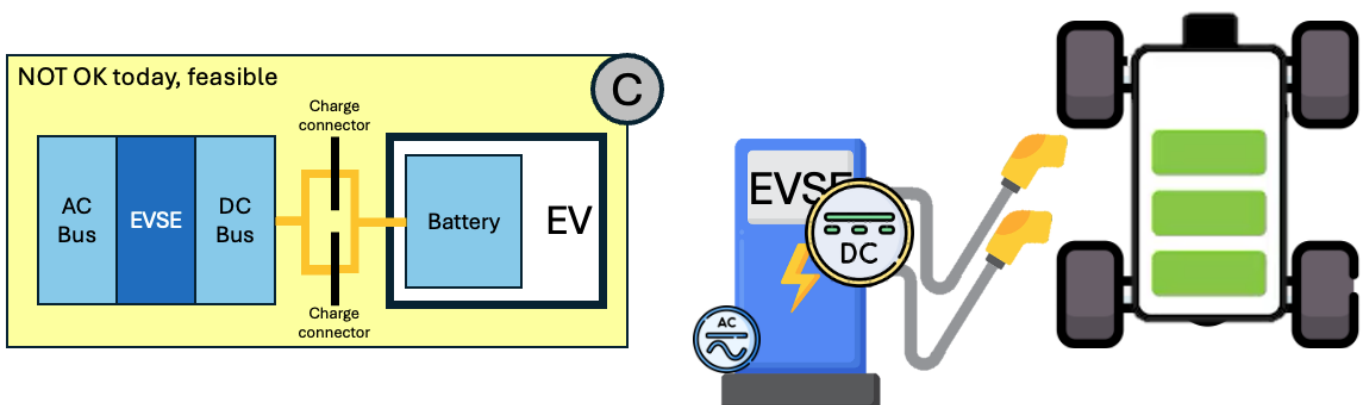


Figure 5 Use Case C

This use case is more challenging than use case A and B. It assumes a single output of the EVSE that is split over multiple connectors going into a single battery system.

The following concerns should be considered:

- With this configuration, if the impedances of the pathways are not the same, the current will not evenly distribute between the pairs.
  - This can evolve over time as contacts age differently
  - This can happen after maintenance with newer components that are aged differently
  - This can happen with different lengths of cable if the inlets are not in the same position or the lengths of cable from the vehicle inlet to the battery are different
  - This can happen if connections are not torqued or crimped the same
  - This can happen if one coupler has been vandalized or damaged and is still in operation
- Even if currents distribute relatively evenly, if one of the pathways become disabled during charging, the second one will take all the current. Such a fault should be detected and result in a quick reduction of the charge current to meet the requirements of a single connection.
- When adding a second pathway during charging, more inrushes may occur than expected. It is better to ramp down the current before adding or removing inlets to the charging process, as traditional pre-charge is not really possible while the system is in normal operation.
- The EVSE connections are bonded to the same earthing system (PE) and therefore a loss of PE on one of the couplers will not be detected.
- There is only 1 IMD active in the EVSE, so no coordination is needed

## Use Case D

Use Case D – 2 (or more) chargers, 2 (or more) connectors, 1 EV, 1 battery system

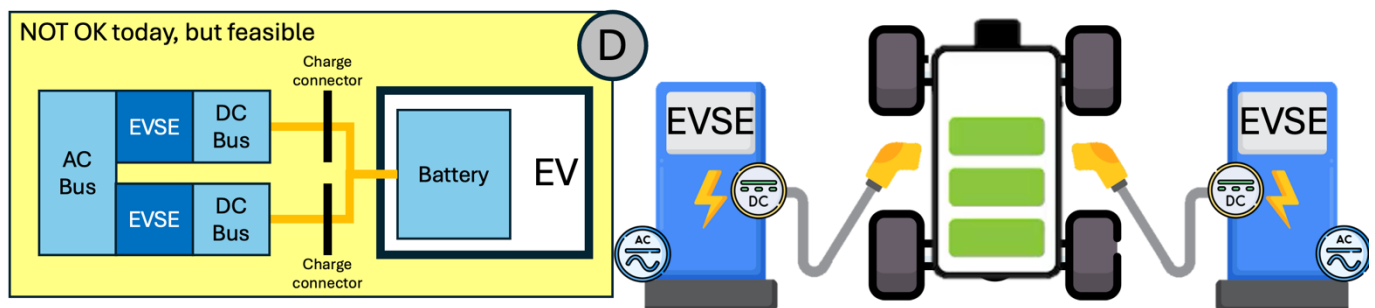


Figure 6 Use Case D

For case D, the distribution of the current and inrushes from EVSE can be controlled for each inlet. Therefore, a lot of the difficulties with case C can be resolved. However, there are aspects that need special attention:

- There may be multiple IMDs on the EVSE side. Coordination of the IMDs is needed to ensure only 1 is active at a time.
- The EVSEs are bonded to the same earthing system (PE) and therefore a loss of PE on one of the couplers will not be detected.
- Due to the shared PE, currents could start circulating between EVSEs, causing interference
- The Y-capacitances of the EVSEs would add up and could exceed allowable limits specified in the system when using parallel connected equipment. For example, in CCS, the EVSEs are allowed up to 1uF and the EV up to 4uF, but in this configuration it is possible to have up a total of 6uF instead of 5uF. This can interfere with the IMD performance and could exceed energy limitation, increasing the risk of a harmful electric shock.

- Short-circuit current adds up with parallel connected equipment, thereby exceeding the maximum current as specified by the system if components were designed for normal "Use Case A" limits.

Short-circuit example with Use Case D:

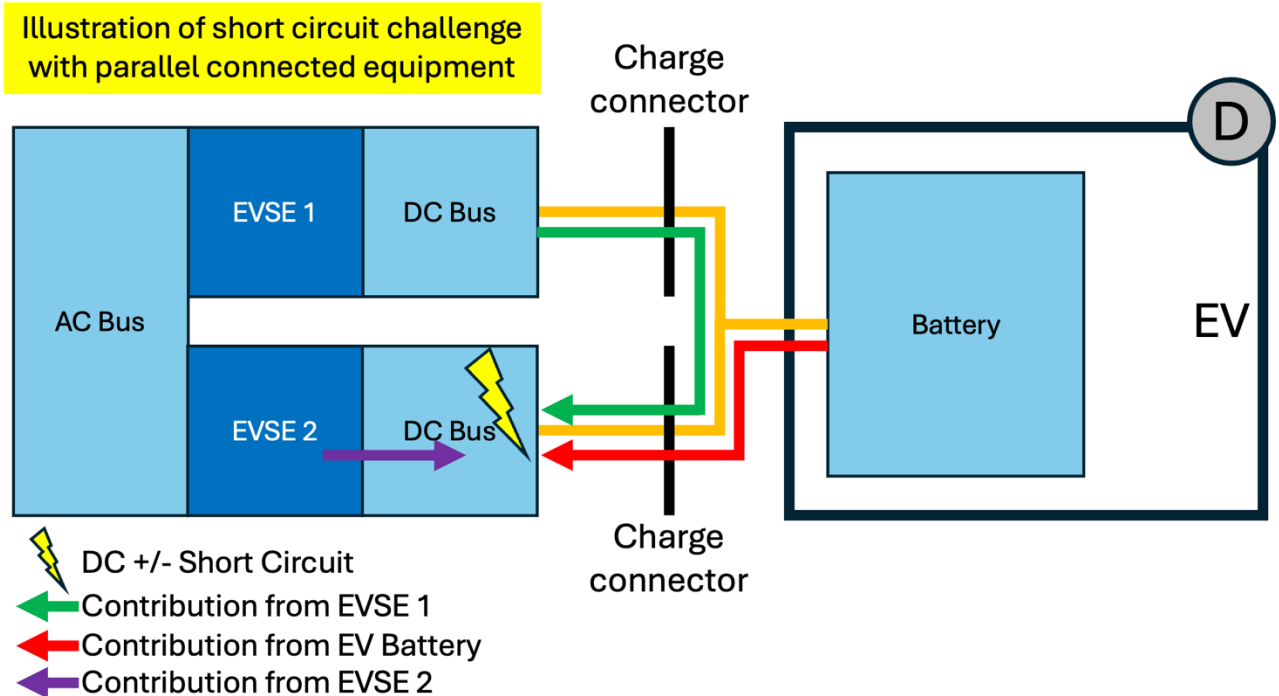


Figure 7 Short circuit example with Use Case D

In this example, if we assume the CCS charging system, EVSE1 may contribute 10kA to the short-circuit in EVSE2, and the battery may contribute 30kA. The total of 40kA would exceed the limitations of the EV as specified in ISO 5474-3:2022, cl 6.3.2.3.2 and most likely the maximum  $I^2T$  of 5 000 000 would also be exceeded. This could cause an explosion in EVSE2 with more energy than it was designed for, perhaps causing an injury or fire.

## Use Case E

Use Case E – 1 charger, 2 (or more) connectors, 1 EV, 2 (or more) battery systems

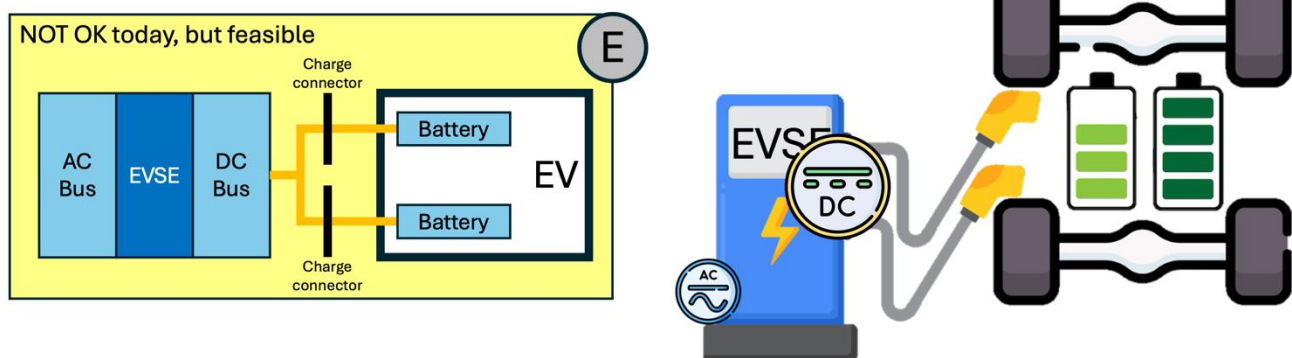


Figure 8 Use Case E

- There may be multiple IMDs in the EV. Coordination of the IMDs is needed to ensure only 1 is active at a time.
- The EVSEs are bonded to the same earthing system (PE) and therefore a loss of PE on one of the couplers will not be detected.
- Due to the shared PE, currents could start circulating between EVSEs, causing interference
- The Y-capacitances of the EV batteries would add up and could exceed allowable limits specified in the system when using parallel connected equipment. For example, in CCS, the EVSEs are allowed up to 1uF and the EV up to 4uF, but in this configuration it is possible to have up a total of 9uF instead of 5uF. This can interfere with the IMD and could exceed energy limitation, increasing the risk of a harmful electric shock.
- The battery voltage may not be the same at the beginning of the charging process. The EV must employ a strategy where only batteries that have exactly the same voltages are combined before and during the charging process.
- Short-circuit current may add up, thereby exceeding the maximum current as specified by the system. This case is similar to D but reversed.

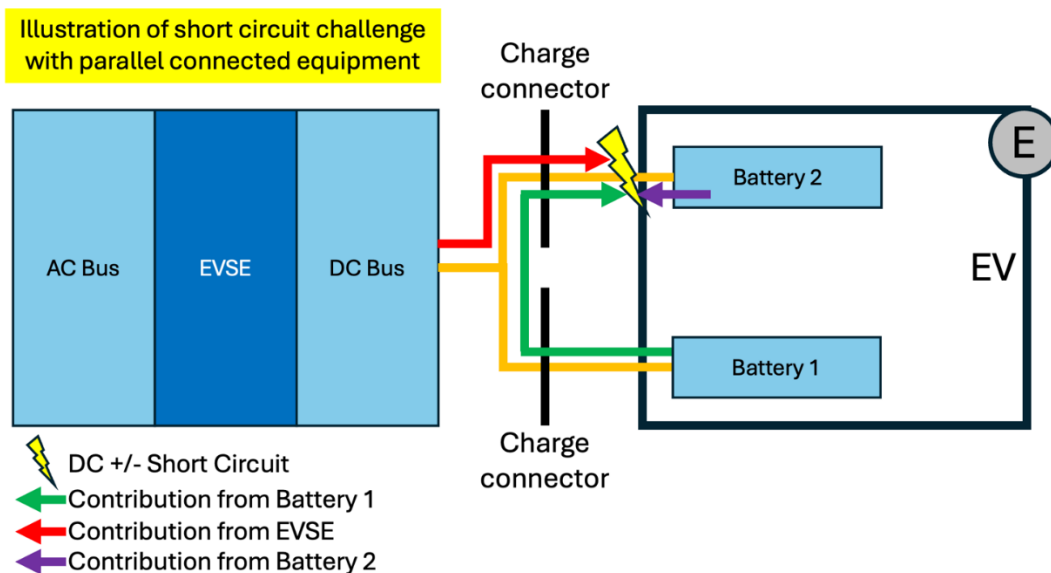


Figure 8 Short circuit example with Use Case E

In this example, if we assume the CCS charging system, EVSE may contribute 10kA to the short-circuit in, and the EV Battery 1 may contribute 30kA. The total of 40kA would exceed the limitations of 10 kA for the EVSE as specified in IEC 61851-23:2023, cl 13.101 and most likely the maximum I<sup>2</sup>T of 1 000 000 would also be exceeded. This could cause an explosion in the EV for Battery 2 circuit with more energy than it was designed for, perhaps causing an injury or fire.

## Use Case F

Use Case F – 1 charger, 2 (or more) connectors, 2 (or more) EVs, 2 (or more) battery systems

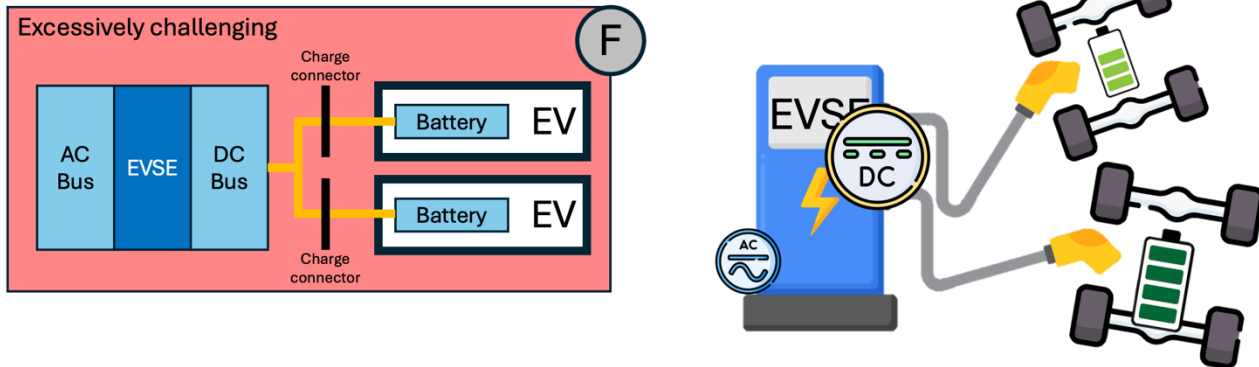


Figure 9 Use Case F

This use case is significantly more challenging than the others presented. It assumes a single output of the EVSE that is split over multiple connectors being used with more than one vehicle.

The following concerns should be considered:

- With this configuration, the different vehicles being used simultaneously with uncontrolled software versions, circuit protection strategies, power distribution sizing, etc. resulting in nearly infinite combination of variables. These all would effect safety critical behaviors for items such as shutdown timing and short circuit reactions that are fundamental to the robust implementation of safe charging standards.
- Vehicles or EVSEs would require very complicated systems to allow mismatch in charger voltage compared to vehicle system target voltage to compensate for the expected variety of vehicle voltages. This would drive up system complexity resulting in significant weight, packaging space, and costs for equipment either in the vehicle or in the EVSE, even without galvanic isolation in the DC-DC conversion. With galvanic isolation, this impact becomes unreasonable with today's technologies.
- While it is reasonable for a vehicle with multiple batteries to coordinate complex safety information within its own systems, for multiple vehicles to coordinate that same level (or more) of complex information required and to define all potential signals for safety and control that should be standardized across the industry is considered to be unmanageable.
- Testing all variables and combinations for conformity would become an incredible burden that likely no private organization would endeavor, and no public organization could justify for such a rare use case.

There are further technical complications, but based on these most significant challenges, this use case is considered excessively challenging with little benefit to justify the effort to solve these issues in a standardized format. In cases like this where a large power supply is available and multiple vehicles need charged, the standards world has already defined how the EVSE should be prepared (refer to IEC 61851-23:2023 annex FF).

## 5. Proposed Guidelines for Standardization

The following proposals don't cover all technical considerations that may be relevant for all standards groups and all use cases. However, the following are some of the most important changes that would be needed for the standards bodies that work on multi-connector systems.

### 5.1. Active Inlet Coordination

Vehicles equipped with multiple charging inlets should ensure that the vehicle only allows one inlet to be active during charging (similar to Use Case A) unless the galvanic isolation concept on both EV and EVSE is established by the standard with the appropriate use cases. In order to prevent potential electrical hazard, both EV and EVSE must communicate and coordinate to ensure that no inlets are active unless they are appropriately connected in the manner coordinated by the standard.

If the vehicle has multiple battery packs that are electrically isolated, multiple inlets may be used simultaneously with isolated EVSEs, as in Use Case B.

### 5.2. Isolation Monitoring Management

Standardized methods must be developed to manage isolation monitoring and ensure no interference occurs between multiple IMDs. This includes defining protocols for the coordination of IMDs to avoid false readings and ensure accurate monitoring of electrical isolation.

For most charging systems, the EVSE is responsible for monitoring the isolation during charging. When an EV has more than one EVSE connected, or an EVSE has more than one EV connected, there needs to be a control mechanism to prevent the classic implementation of each EVSE monitoring the isolation during charging. There are 3 options:

#### A. Direct Charger-to-Charger Communication

Chargers communicate directly with each other to decide which IMD should remain active. When a second charger connects, it sends a request to the first charger to determine whether it should disable its IMD. If the first charger disconnects, the second charger automatically reactivates its IMD.

#### B. Vehicle selects IMD

One charger (primary) keeps its IMD active, while the second charger (secondary) disables its IMD. The vehicle informs the chargers which IMD should remain active before charging starts. If the charger with the active IMD is stopped, the vehicle will enable the IMD on one of the other chargers.

#### C. Using a Single IMD in the Vehicle

During charging the vehicle itself could use its IMD for monitoring the system. This would mean chargers no longer need to handle isolation monitoring actively, avoiding IMD conflicts entirely. (an isolation monitor in the EVSE is still required during the cable-check phase)

**IMD Coordination:** Each charging systems has its own requirements for isolation monitoring. The technical committees must decide what is the preferred method for a specific combination of systems or between inlets of the same system. The IMD operation must also be defined regarding when equipment should return to default state and when it should be managed according to the IMD coordination.

If there is a message that can enable and disable the IMD of the EVSE during charging, the vehicle can choose which EVSE will perform the monitoring of the system, or even to disable the IMDs of all EVSEs and rely on its own IMD. There is a risk that none of the IMDs are enabled, but the EVSEs are not able to determine this. The vehicle is responsible for the coordination of the IMDs. The risk of not having an active IMD in the system during charging is not a tolerable risk and needs mitigation measures.

There are no facilities in ISO 15118, SAE J2836/3 or IEC 61851-24, to disable the IMD of the EVSE, this would need to be added.

**Disabled IMD:** In order not to interfere with the IMD function of the activated IMD, the disabled IMD not only has to disable its injected measurement signal, but the resistance to ground of the disabled IMD could cause availability issues or even effect the active IMD. Disabled IMDs must not cause any interference even if a plurality of inlets/chargers are being used resulting in a plurality of IMDs in the system during charging.

### 5.3. Y-Capacitance

Y-capacitance is a critical aspect of human safety that is necessary in charging systems to ensure touch safety where people might be exposed to hazardous levels of energy. Charging standards to date have defined maximum levels of Y-capacitance for the complete system, with contributions at the EV and EVSE accounted for. The defined safety limits remain the same for people, and connecting more equipment (designed with previous charging standards) to the same connected system (such as Case D) would result in a hazardous level of Y-capacitance. For this reason, if charging systems are created specifically to allow multiple pieces of equipment to be connected together (such as Case D), the allowable Y-capacitance for each device must be lower than traditional systems used in the past (such as Case A).

### 5.4. Compliance Testing Requirements

Standardization should address compliance testing requirements to validate vehicle and Electric Vehicle Supply Equipment (EVSE) interactions. This includes developing test procedures to verify that vehicles with multiple inlets can safely and effectively interact with existing and future charging infrastructure.

### 5.5. Backward compatibility

EVSEs that are designed/installed today have no means to detect if the vehicle uses multiple inlets and/or if there are any safety implications.

If the vehicle would allow the use of multiple EVSEs charging at the same time, there is no responsibility to the EVSE to detect this and stop charging. The EVSE cannot determine if the EV has properly considered all the safety implications.

If the EVSE has proprietary protocol/function, it shall be ensured that a “normal” EV will be charged fully compliant to the standard, or not at all. Similarly, if an EV uses a proprietary protocol/function, it shall be ensured that a “normal” EVSE will charge fully compliant to the standard, or not at all.

It is recommended that the standards include some requirements to indicate these responsibilities.

## 5.6. Short Circuit Requirements

For each inlet, the requirements for short-circuit must be maintained.

Consideration has to be taken on how short-circuit currents add up, as a fault in one EVSE can be supplied from multiple EVSEs and the vehicle combined. Standards that are being revised to allow parallel equipment connection should establish a maximum limit to the quantity of equipment that can be connected in parallel and contributions allowed from each piece of equipment in order to ensure that the system stays within the accepted limits for short circuit current and energy.

The following examples help to illustrate how the parallel use of multiple connectors creates a higher short circuit fault than systems without parallel connectors.

Example with Use Case D:

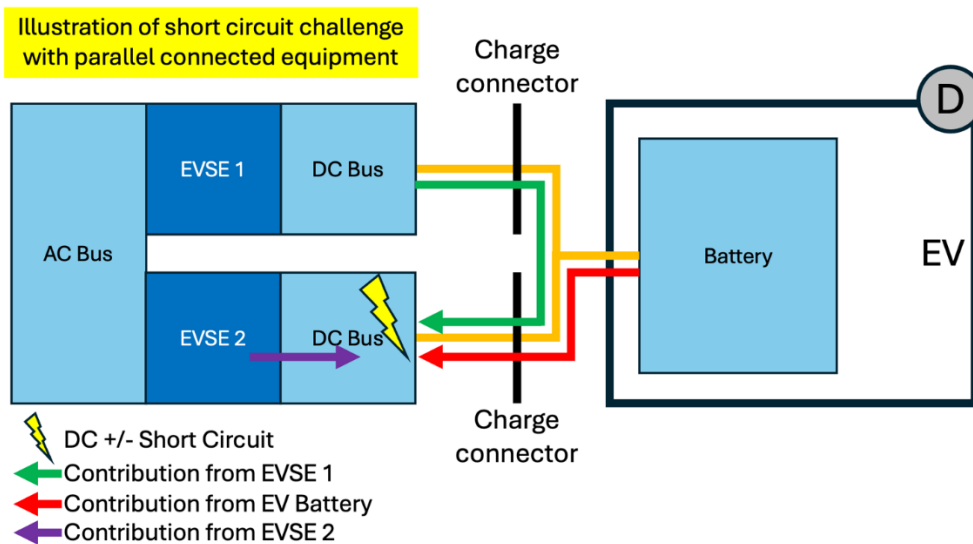


Figure 10 Short circuit example with Use Case D

Example with Use Case E:

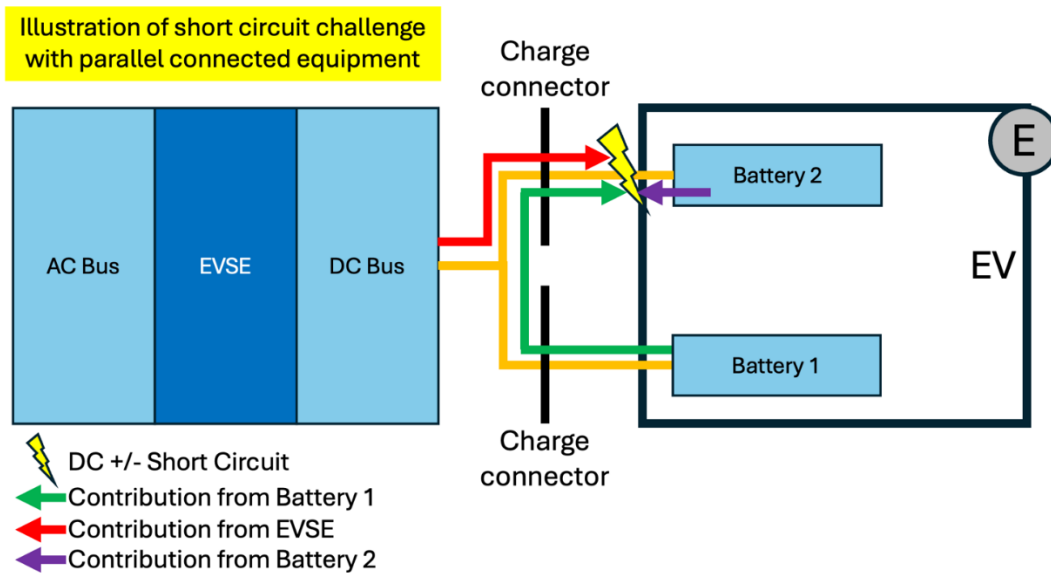


Figure 11 Short circuit example with Use Case E

## 6. Next steps

Further analysis is required to define specific test cases and compliance measures for vehicles with multiple inlets. This involves conducting detailed evaluations of scenarios such as short circuits, current summation, and isolation monitoring to ensure all safety aspects are thoroughly addressed. Engaging with standardization committees, including IEC 62196-3, IEC 61851-23, IEC 61851-23-3, IEC 63379 and ISO 5474, is essential to incorporate these considerations into future editions of the standards. Industry collaboration is also crucial, bringing together vehicle manufacturers, charging infrastructure providers, and regulatory bodies to explore safe implementation pathways for multi-inlet charging configurations. This collaboration ensures that all stakeholders are aligned on safety, efficiency, and compatibility standards.

Developing standardized protocols for managing isolation monitoring with multiple IMDs is a key step. These protocols must define communication methods to prevent interference and ensure accurate insulation resistance measurements, which are critical for detecting potential electrical faults. Implementing robust short circuit protection mechanisms, such as fuses and circuit breakers, is also necessary to quickly disconnect power in the event of a short circuit, preventing damage to the vehicle's electrical system and ensuring user safety. Comprehensive compliance testing procedures must be developed to validate the safe operation of vehicles with multiple inlets, covering interactions with existing and future charging infrastructure to ensure that vehicles meet all safety and performance standards.

Investigating the feasibility of allowing safe simultaneous charging from multiple inlets is another important step. This requires rigorous testing and validation to ensure that the vehicle's electrical system can manage multiple power sources without risk of failure or safety hazards. Implementing dynamic load management strategies will optimize charging efficiency and safety, involving real-time monitoring and adjustment of charging power based on the vehicle's state of charge, battery health, and the capacity of the charging station. Designing user interfaces that clearly indicate the status of each charging inlet and provide guidance on safe and efficient charging practices is essential for educating users and preventing misuse.

## 7. Conclusion

The introduction of multiple charging inlets in electric vehicles presents a significant opportunity to enhance charging performance and reduce downtime, particularly for commercial fleets, heavy-duty equipment, and emergency response vehicles. However, this advancement also brings forth a range of technical and safety challenges that must be meticulously addressed to ensure the safe and reliable operation of multi-inlet charging systems.

One of the primary considerations is the management of electrical safety, particularly in preventing short circuits and ensuring accurate isolation monitoring. The presence of multiple IMDs requires standardized protocols to avoid interference and ensure reliable measurements. Additionally, robust short circuit protection mechanisms, such as fuses and circuit breakers, are essential to quickly disconnect power in the event of a fault, thereby protecting the vehicle's electrical system and ensuring user safety.

The development of compliance testing procedures is crucial to validate the interactions between vehicles with multiple inlets and the existing and future charging infrastructure. These procedures must cover various scenarios, including current summation effects and the potential for simultaneous charging, to ensure that all safety and performance standards are met.

User education and interface design play a vital role in the successful implementation of multi-inlet charging systems. Clear and intuitive user interfaces that indicate the status of each charging inlet and provide guidance on safe charging practices will help prevent misuse and enhance the overall user experience. Environmental and durability testing is also necessary to ensure that multiple inlets can withstand various operating conditions, including exposure to weather and physical wear.

In conclusion, while the integration of multiple charging inlets in electric vehicles offers promising benefits, it requires a comprehensive approach to address the associated technical and safety challenges. By following the proposed guidelines and engaging in industry collaboration, the standardization committees can develop robust standards that ensure the safe and efficient implementation of multi-inlet charging systems. This will pave the way for a more flexible and reliable charging infrastructure, ultimately supporting the broader adoption of electric vehicles and contributing to a sustainable future.

## 8. Reference

This document was created by the focus group FG Charging Connection and within the Subgroup of MCS of the CharIN association. The MCS Subgroup focuses on the development, evaluation, and standardization of the Megawatt Charging System for heavy-duty vehicles and industrial applications. Its purpose is to provide technical recommendations, coordinate industry feedback, and ensure alignment with international standardization efforts such as ISO, IEC, and SAE.

### Document Status:

This position paper represents the consensus reached within the MCS subgroup as of July 2025. It is intended to support ongoing standardization efforts and facilitate stakeholder discussions.

### Referenced Standards:

- IEC 61851-23
- ISO 15118
- IEC 63379
- ISO 5474
- SAE J3271
- IEC 61851-24
- IEC 62196-3
- IEC 61851-23-3
- SAE J3400
- SAE J1772

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