

System-Level Safety in DC EV Chargers: The Role of Insulation Monitoring

Safe DC charging depends on several protection functions working together. Insulation monitoring, protective earthing, power switching, voltage and current supervision, temperature monitoring and charger control each address different operating conditions and potential faults.

Introduction

An insulation monitoring device (IMD) provides essential information about the condition of an unearthed DC circuit. However, detecting an insulation fault is only part of the protection process. The charger must interpret the indication, take the appropriate action and verify that the required response has occurred.

This application note explains how insulation monitoring fits into the wider DC charger safety architecture, with reference to the Broyce Control IMD100 and IMD125.

Why safety must be considered at system level

A DC charger combines power conversion equipment, high-voltage switching, charging cables, connectors and control electronics. Once connected, the vehicle also becomes part of the electrical system involved in power transfer.

Potential faults can arise in several places. Moisture or contamination may reduce insulation resistance, a damaged connector may overheat, or a contactor may fail to open when instructed. Each condition requires a suitable means of detection and a defined response.

The effectiveness of the protection depends on the complete chain:

Detect the condition → determine the response → act → verify the result.

A fault indication alone does not remove the hazard. Equally, issuing a shutdown command does not prove that power transfer has stopped or that the output voltage has fallen to an acceptable level.

The role of insulation monitoring

In an unearthed DC system, the live conductors are not intentionally connected directly to earth. An IMD monitors insulation resistance between the live circuit and protective earth, helping identify deterioration that could otherwise remain undetected.

A first insulation fault may produce insufficient fault current to operate an overcurrent protective device. This makes insulation monitoring particularly relevant to unearthed DC charging circuits. The charger's required response must follow the applicable charging-system requirements; continued operation should not be assumed simply because the first fault current is limited.

The IMD100 provides insulation monitoring for unearthed DC systems operating at up to 1000VDC, while the IMD125 extends this capability to 1250VDC. Both provide adjustable insulation resistance thresholds, allowing the monitoring function to be configured for the application.

The IMD supplies information about insulation condition. The surrounding protection system determines how that information prevents charging, initiates shutdown or supports maintenance.

Complementary protection functions

Different protection functions address different hazards. The following table illustrates their contribution to a DC charger's overall safety architecture. Their implementation depends on the charger design and applicable requirements.

Protection function	Contribution to the system
Insulation monitoring	Detects reduced insulation resistance between an unearthed DC circuit and protective earth.
Protective earthing and continuity supervision	Provides protective bonding and, where required, checks that the protective-earth connection is intact.
Residual-current protection	Addresses residual-current hazards in the relevant part of the installation, with device selection matched to the earthing arrangement and possible current waveforms.
Overcurrent protection	Addresses overloads and short circuits through suitably coordinated protective devices.
Voltage and current supervision	Checks that electrical conditions remain within permitted operating limits.
Temperature monitoring	Identifies overheating in components such as power modules, cables and connectors.
DC contactors and power-converter control	Provide the means to stop power transfer and disconnect the output according to the designed shutdown sequence.
Control logic and diagnostics	Coordinate operating permissions, fault responses and restart conditions.

An IMD and a residual-current device perform different functions. Insulation monitoring assesses resistance to earth in the monitored unearthed circuit; residual-current protection responds to current imbalance. Their positions and roles must be established from the charger's electrical architecture.

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Protection throughout the charging cycle

Before power transfer

Before enabling charging, the controller should establish that the required operating conditions are satisfied. Depending on the charging system, this may include connection checks, protective-earth supervision, insulation checks, communication checks and confirmation of switching-device status.
The IMD's connection point matters. Open contactors may separate the circuit into sections, so a satisfactory insulation measurement on one section does not automatically confirm the condition of every cable, connector or vehicle circuit.

During power transfer

During charging, the system supervises insulation condition alongside other relevant parameters, including voltage, current, temperature and communication status.
Changes in the connected circuit can affect insulation measurements. System capacitance, electrical interference and the connection of additional equipment must therefore be considered when assessing measurement behaviour and response time.

During shutdown

When a condition requires charging to stop, the charger must execute its defined shutdown sequence. This may involve disabling the power converter, operating DC contactors and controlling the discharge of stored energy.
Opening a contactor does not, by itself, prove that the output is safe. The design must account for contactor failure, remaining stored energy and any other source that could maintain voltage.

Example: an insulation fault during charging

Consider a charger in which moisture enters a charging connector and reduces insulation resistance to protective earth.
An illustrative response is:
1. Detect: The IMD identifies that insulation resistance has crossed the configured fault threshold.
2. Recognise: The protection logic receives the fault indication and determines that power transfer must stop.
3. Act: The charger executes its shutdown sequence using the power converter and switching devices.
4. Verify: Appropriate feedback and voltage measurements confirm the required response.
5. Control restart: Charging remains inhibited until the defined recovery conditions are satisfied.

The exact sequence and timing depend on the charger architecture and applicable requirements.
This example shows why insulation monitoring must be integrated into a complete protection strategy. Detection must lead to an effective response, and the system must recognise when that response has failed.

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Integrating the IMD100 and IMD125

The IMD100 and IMD125 provide relay outputs and communication facilities that can be incorporated into charger monitoring and control. The IMD100 provides isolated Modbus RTU communication. The IMD125 offers isolated Modbus RTU or CAN bus communication options. These interfaces can support access to insulation measurements and device status, while relay outputs provide additional signals for the surrounding control architecture.

Integration should consider:

- **Monitoring coverage:** Which parts of the DC circuit are connected to the IMD in each operating state?
- **Thresholds:** Are the configured values appropriate for the charger voltage, application and applicable requirements?
- **Response time:** Can the complete system respond within the required time under the expected capacitance and operating conditions?
- **Fault signalling:** How are insulation faults, device faults and unavailable measurements handled?
- **Supply and communication failures:** What happens if the IMD loses power or the controller stops receiving valid information?
- **Switching feedback:** How does the charger confirm that shutdown has occurred?
- **Multiple monitoring devices:** Could another active IMD on the connected circuit interfere with measurement?

Factory settings provide a starting configuration. They must be reviewed as part of the charger design rather than treated as universal acceptance limits.

Fail-safe behaviour and system validation

A robust protection design considers failures within the protection system itself. Loss of an auxiliary supply, a disconnected monitoring lead, a stalled controller or a failed contactor can affect the charger's ability to detect or respond to a hazardous condition. The design should define how these failures are recognised and what operating state follows. A healthy insulation reading also needs to be valid, sufficiently recent and representative of the circuit being assessed. Missing or outdated data should not automatically be interpreted as permission to charge.

Validation should test the complete response chain. Introducing a representative insulation fault should demonstrate that the charger detects it, takes the required action and verifies the outcome. Tests should also address relevant failure conditions, including loss of monitoring information and failure of a switching device to respond.

Recording fault information can support diagnosis and maintenance, helping distinguish an insulation problem from a communication, supply or switching fault.

Standards and compliance context

Different standards address different parts of the protection architecture.
IEC 61557-8 addresses insulation monitoring devices for IT systems. IEC 61851-23 addresses DC electric vehicle supply equipment, while IEC 61851-24 addresses digital communication used to control DC power transfer.

For North American applications, relevant standards include UL 2202 for DC charging equipment and UL 2231-1 / UL 2231-2 for personnel protection systems used in electric vehicle supply circuits.
The applicable standards, editions and national requirements depend on the charging system and intended market. Component compliance supports the design process, but the completed charger must be assessed as an integrated system.

Conclusion

System-level safety in a DC charger depends on coordinated detection, control, switching and verification. Insulation monitoring provides a vital indication of the condition of an unearthed DC circuit, while complementary protection functions address other hazards and enable the charger to respond appropriately.

The IMD100, for systems up to 1000VDC, and IMD125, for systems up to 1250VDC, provide insulation monitoring that can be incorporated into this wider architecture. Their contribution is most effective when monitoring coverage, thresholds, response times and fault behaviour are considered alongside the charger's complete shutdown and restart strategy.

Detecting a fault is essential. Ensuring the charger responds correctly completes the protection process.