APPLICATION NOTE

Switching & Protection for Level 3 DC Fast Chargers

Electric Vehicle Supply Equipment (UL)

Are you involved in designing an EV charger as an original equipment manufacturer or contract manufacturer?
ABB Applications provide a jumping-off point able to simplify and reduce design time and complexity thanks to application “bundles” and reference designs.

What is an EV Charger?
At its simplest, an EV charger is a gate for supplying power to an electric vehicle. There are many types of chargers, ranging from onboard Level 2, to dedicated Level 2 (external) and even Level 3 [DC] fast chargers. In the case of DC charging, AC is converted to DC via a three-phase rectifier and accompanying power electronics. Size and cost vary, depending on the type of charger, rated power and charging time. While there are many varieties (commercial versus residential, for example), the most common EV chargers today are dedicated Level 2 for destination charging (take longer to charge) and Level 3 DC fast-chargers for when you’re on the go!

Why you need Switching & Protection solutions
Modern DC “fast” chargers require significant power (>50 kW), so there are accompanying risks related to circuit and user protection. Users must be protected from electric shock, burns and arc flash. Circuits also require protection:

- Overcurrent protection for devices and conductors (fuses and breakers)
- Disconnecting means for safe shutdown and servicing
- Circuit isolation and control (electrical switching)
- Ground fault protection (for shock, fire and damage prevention)
- Surge protection to prevent damage to switching devices and electronics

Main benefits

Smarter protection
Select from a comprehensive range of low voltage components to ensure interoperability and compliance in your next design.

Reduce Design Time
Speed up your process and reduce total design time by using ABB’s application bundles and reference materials for faster component searches and overall engineering time.

Safety
Choose from stringently tested, globally-compliant product lines for all your protection needs:

- Overcurrent protection
- Surge protection
- Disconnecting means
- Switching / interrupting devices
- Control
- Monitoring
- Communications.

Smarter metering and monitoring
Your system design can be enhanced with embedded monitoring and controls able to determine everything, from electrical parameters and conditions, to product wear. These signals are optionally made available through specific ABB Ability-enabled devices, such as molded case circuit breakers.

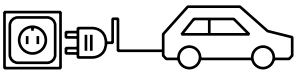
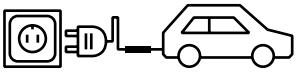
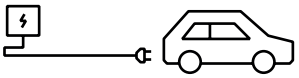
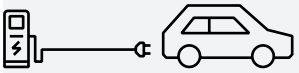
Level 3 DC Fast Chargers for Electric Vehicles

EV chargers come in a variety of sizes, power and voltage levels, which determine the time it takes to fully charge an electric vehicle.

Level 3 chargers
Level 3 (L3) DC "fast chargers" use direct current for impressively fast charging as compared to Level 2 AC chargers. Their sizes range from 50kW to 350kW (typical), where more than 150-180kW is loosely considered ultra-fast or high power.
The Level 3 DC fast charger is often provided in convenient locations for when users are "on the go." The most plausible settings are retail shops, last-mile delivery charging depots, dedicated charging centers (typically, fuelling stations) and along travel routes where users are likely to need a quick "top up" before proceeding on. The priority here is quick turnaround, to get vehicles back on the road.

The L3 charger is essentially a power gate with a rectifier, inclusive of safety systems, plus some accompanying communications to negotiate the charging cycle with the vehicle. Beyond the communication protocol between the charger and the vehicle, L3 chargers are primarily power electronics equipment dedicated to switching and circuit protection.
Most DC fast chargers are three-phase 480Y/277V, with output power ranging from 90-350 kW and up to 1000V (DC, max). The upstream AC breakers range accordingly from 150-600A.
The charging mode described in this application note is called "Mode 4" in the IEC literature. Such installations are the highest rated EV charging solutions (see table on right).

	Level 3
Charging type	DC "fast" charging
Voltage / Current (AC)	480V / 150-600A
Power	>50kW; 50-350 kW (typical)
Voltage / Current (DC)	1000V / 60-400A
Application	Retail, commercial, fleet
Charging time	15-60 minutes
Range per hour	90-300 miles

	**Mode 1:** AC-Charging, up to 16 A 250V AC single-phase/ 480V AC three-phase
	**Mode 2:** AC-Charging, up to 32 A 250V AC single-phase/ 480V AC three-phase
	**Mode 3:** AC-Charging, up to 32 A single-phase or three-phase
	**Mode 4:** DC-Charging, up to 400 A and up to 950V DC

Level 3 DC Fast Chargers for Electric Vehicles

From slow to fast charging

Power level

120 VAC	208-240 VAC	480 VAC	
			
AC Charging – Hours		**DC Charging - Minutes**	
AC "Level 1" Charging ~1 kW 8-16A	**AC "Level 2" Charging 243-19 kW** 16-80A	**DC Fast Charging 24-50-180 KW** 40-125-200 A	**DC High power 175-350 / 450 kW** 200-500 / 600 A
Residential and workplace charging (Destination) When a car, truck or bus is parked all day or overnight		**Public / highway / buses and trucks (On the Go)** When a recharge is required very quickly / large battery vehicles	
Time to charge: 8-48 hours	4-20 hours	15-60 minutes	5-15 minutes
Range per hour: 3-5 miles	15-80 miles	90-300 miles	300-600 miles

Level 3 DC Fast Chargers for Electric Vehicles

Fundamentals, main components & functionalities

Personnel Protection Systems

DC Level 3 chargers are generally listed to UL 2202 for EV use. The standard introduces required subsystems (personnel protection systems) that safeguard users and service personnel against the risk of electric shock. Two system architectures are available:

- Grounded DC systems in which a leg of the DC circuit is bonded to ground, or
- Isolated (ungrounded) DC systems, where the DC conductors are isolated to ground, with no possible connection to earth via the vehicle or any exposed components.

Grounded systems provide certain benefits as they are typically galvanically isolated from the AC supply. This can limit fault current by means of a high frequency transformer. However, protecting the DC circuit from earth currents poses challenges, since large DC residual current devices require highly sensitive, expensive and bulky magnetics that are largely impractical for high current DC circuits. All in all, a grounded system may cost more and still poses the risk of earth current flowing after a single fault. Conversely, isolated or ungrounded systems do not use DC residual current devices to detect earth current leakage. Instead, they measure isolation or insulation resistance by means of an insulation monitor and interrupter (IMI or IM/I).

The IM/I passes a trivial amount of current to ground through its sensing network and calculates the resistance for both DC conductors as follows: $R_{iso} = V_{dc} / I_{sense}$. This is a reasonably low-cost method of fault detection that is both safe and reliable. Further, since the DC circuit conductors are both ungrounded, a single fault to ground will not cause current to flow—the system is robust to single-point failures and inherently safer.

UL 2202 requires a personnel protection system for DC EV chargers to protect users against electric shock. The systems are described in UL 2231-1 («what») and UL 2231-2 («how»). We have considered the choice of architecture for an isolated system for a DC fast charger. The requirements for personnel protection in an isolated system are described in UL 2231-1 Section 6.2 Isolated Circuits and Table 3 (please reference all applicable codes and standards).

The most practical implementation is to use option #2, or basic insulation plus an isolation monitor/interrupter with self-check feature, as the device continuously monitors the insulation system (at least once an hour and throughout charging) and ceases operation when a fault is detected.

NOTE: ABB does not currently offer components that have been evaluated to meet the requirements of UL 2231-1 and UL 2231-2.

Protection System Requirements (150-1000 VDC; <1000VDC between any two conductors). Pick One (*):

Option	Insulation Type	Requirements
1	Basic Insulation	Ground monitor/interrupter (GM/I) + isolation monitor/interrupter (IM/I)
		OR
2	Basic Insulation	Isolation monitor/interrupter with self-check (IM/I/SC)
		OR
3	Double Insulation	Isolation monitor/interrupter (IM/I)
		OR
4	Reinforced Insulation	Isolation monitor/interrupter (IM/I)

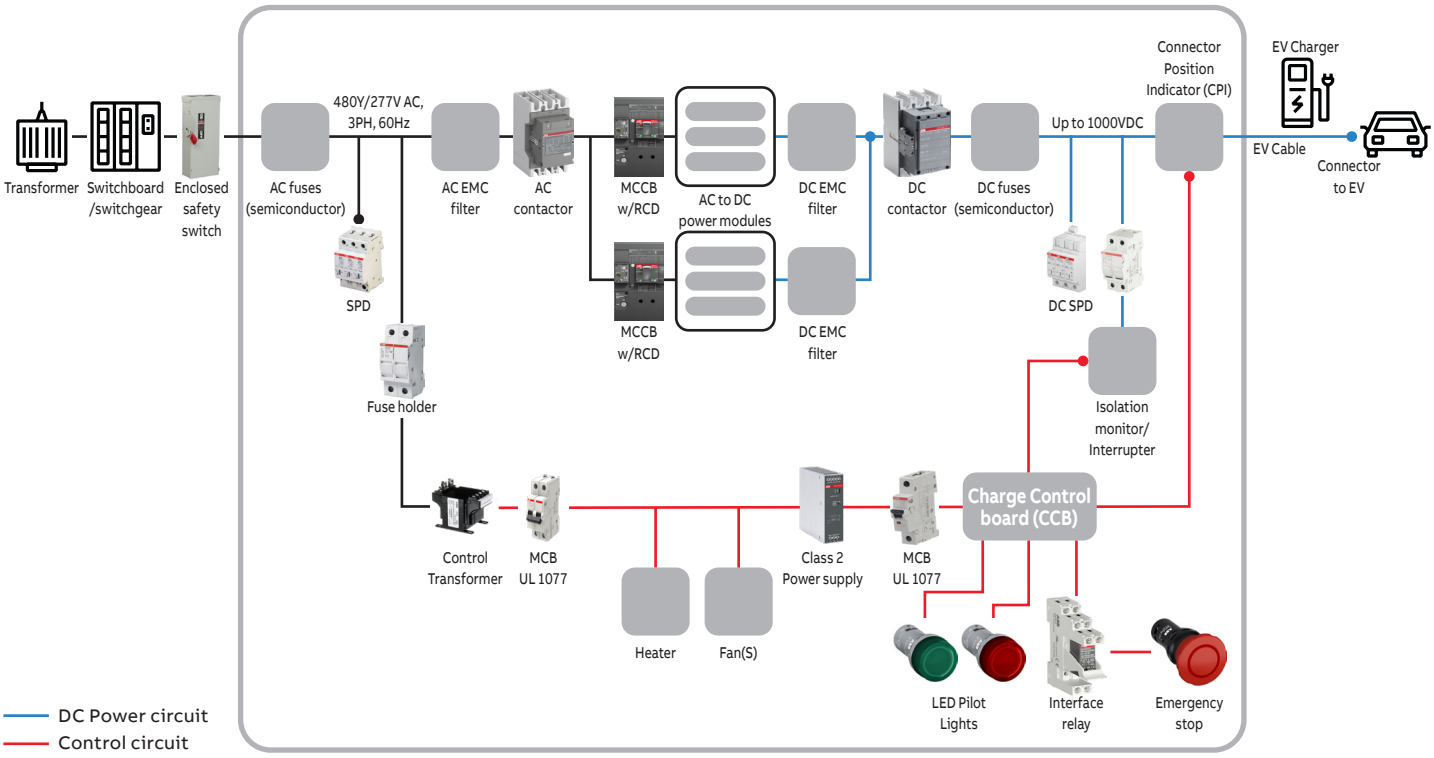
*) Requirements excerpted from UL 2231-1 Table 3

Level 3 DC Fast Chargers for Electric Vehicles

Charging sequence

This is the typical **charging sequence**:

- User plugs charger cable into vehicle
- Vehicle «handshake» with charger (communications)
- Ground continuity and insulation resistance safety checks (where applicable)
- Power contactor closes
- Charging: EV on-board charge controller begins switching, power circuits are conducting
- Once sufficient charge has been added, or user halts the charge sequence, the charge controller stops switching and the charger's isolation contactor opens.
- If, at any point, there is a short circuit (improper connection), ground fault (failure of insulation system) or interruption of the ground connection (ground continuity), the charger's respective protective devices may open so as to isolate the fault to protect the user and prevent damage to any downstream equipment.
- The charger circuit may also be manually isolated using an external enclosed disconnect or safety switch.



Main components			
AF Series AC Contactor	Tmax XT Molded Case Circuit Breaker (MCCB)	ST200M UL 1077 Supplementary Protector (MCB)	F202 Series Residual Current Devices (RCD)
CM-IWN Insulation Resistance Monitor	CP.C and CP.E Power Supplies	E90 Series Fuseholders	OVR Series Surge Protective Devices

Primary Functional Requirements

- Negotiating charging sequence with the vehicle (charger-vehicle communication)
- Overcurrent Protection of charging circuit
- Electrical isolation of charging circuit
- Earth leakage / ground fault detection and interruption
- Limiting potential differences between the EV and ground while charging
- [Generally] safety & testing in accordance with UL 2202 DC Charging Equipment for Electric Vehicles.

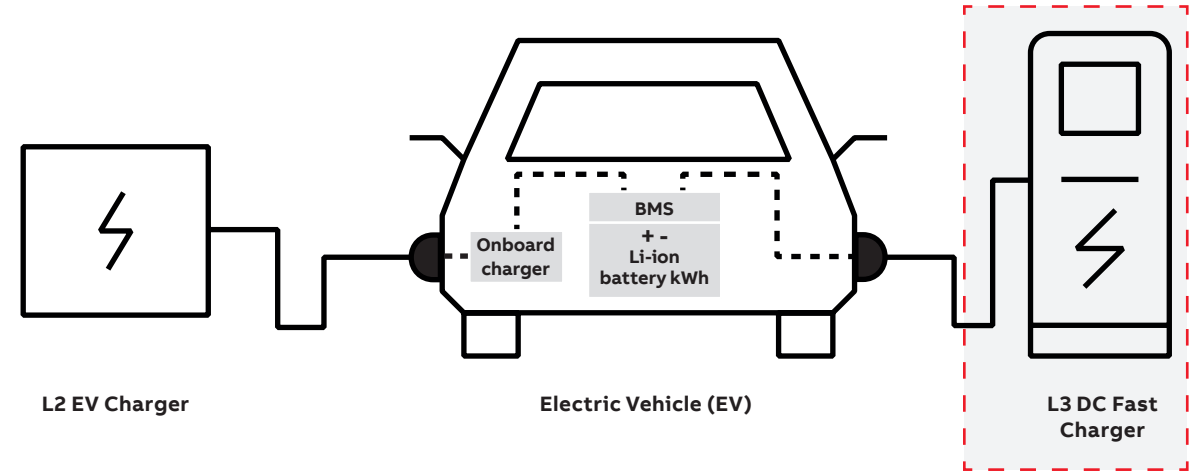
Secondary Optional Requirements

- Surge Protection to protect against voltage spikes, such as those from switching or lightning
- Monitoring: for collecting data on charge process, history and overall system health
  - Voltage, current, power or temperature monitoring
  - Communication: to communicate parameters to an HMI, point-of-sale or centralized monitoring system
- Charge management and scheduling (if not done elsewhere, could be done within the charger)
- Remotely-operated: need for remote control (such as via cloud-based services or consumer-facing apps).

Switching & Protection for Level 3 DC Fast Electric Vehicle Chargers

Discover our Switching & Protection solutions for easy L3 charger configuration considering a fixed unit rated for 180kW

EV Charging Block Diagram

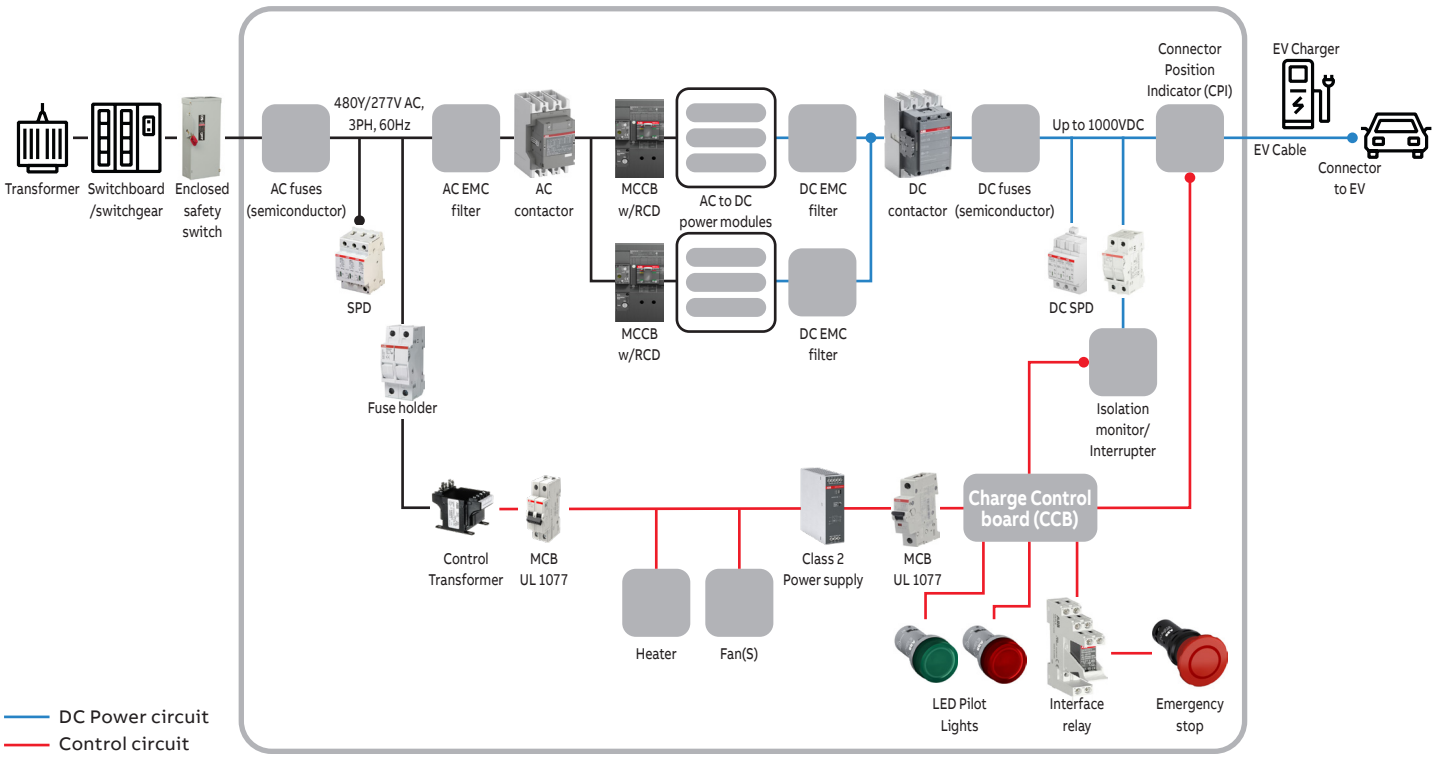


Specifications of electrical quantities for a 180kW charger

L3 EV Charger Data – DC Fast Charger		
Rated power	[kW,ac]	180
Rated AC voltage	[V,ac]	480Y/277V
Rated current	[A,ac]	217
Prospective AC short circuit current	[kA]	65
Overcurrent protective device rating	[A,ac]	300
Maximum output voltage rating	[V,dc]	1000
Maximum output current rating	[A,dc]	200

ABB’s offering (UL) - Example of DC Fast Charger Use

L3 DC Fast Charger Single-Line Diagram



Charger Components

Charger Components (Switching & Protection)	Charger Components
AC Circuit • AC ultra-fast acting semiconductor fuses (non-ABB) • AF series AF205 AC contactor for supply circuit isolation • Tmax XT series molded case circuit breaker(s) equipped with residual current detector for equipment protection • ABB OVR series surge protective device (SPD).	**On each charger power circuit** • SU200M (UL 489 MCCB) or ST200M (UL 1077 supplementary protector) for local overcurrent protection and circuit disconnection • F202 series residual current devices for ground fault detection and interruption (property protection) • ESB installation contactor for charging circuit control; may be tested and included as part of a CCID for UL 2231 requirements
Control Circuits • E90 fuseholder + Type CC fuses • F202 series residual current devices for ground fault detection and interruption (supplemental protection) • 9T58 open core machine tool / control power transformer • ST200M UL 1077 Supplementary Protector • CP	**Additional Components** • Surge Protective Device (SPD) • (External) enclosed rotary disconnect • Aux contact, shunt trip, emergency stop, pilot devices
Additional Components • 400A [External] enclosed safety switch • Aux contact, shunt trip, emergency stop, pilot devices	

Bill of materials

Reference Design Parameters

Level 3 EV charger
DC Fast Charging
480Y/277V Three-Phase Source
300A overcurrent protection / 180 kW

Description	Purpose	Product ID	(US product code)	Total quantity
CTR,3P,192A,100-250VAC/DC	AC contactor	1SFL527002R1300	AF205-30-00-13	1
XT4H 250 E.TCH LSI 150 3p UL	AC OCPD+RCD	1SDX037151R1	XT4HU3150PFF000XXX	2
OVR SPD 3P+N 40KA 320V P TS 3RD ED	AC SPD	2CTB802346R2500	OVR T2 3N 40-320 P TS U	1
E90 CC 2P W/BFI	AC Fuseholder	2CSM299922R1801	E92/30SCC	1
RCD F200 2P 16A 10MA	RCD	2CSF202101R0160	F202A-16/0.01	0
1C,0.5kVA,240x480-120,80C,C&C,TB,IP	Control Transformer	N/A	9T58K0050	1
MCB ST200M 2P C 5A UL1077	MCB (1077)	2CDS272334R0054	ST202M-C5	1
SPD,OVR,PV,40KA,T2,1000VDC,PLG,AUX CONT	DC SPD	2CTB802401R1000	OVR PV T2 40-1000 P TS	1
PV FUSE HOLDER, 2P, 32A	DC Fuse holder	2CSM204703R1801	E92/32PV	1
DC.CTR,DC1-600A,100-250VAC/DC,1/	DC Contactor	1SFL597025R7011	GAF460-10-11-70	1
CP-C.1 24/10.0 POWER SUPPLY	Class 2 Power Supply	1SVR360663R1001	CP-C.1 24/10.0	1
MCB ST200M 1P C 4A UL1077	MCB (1077)	2CDS271334R0044	ST201M-C4	1
CR-M024DC2L PLUGGABLE INTERFACE REL	Interface Relay	1SVR405611R1100	CR-M024DC2L	1
STANDARD SOCKET CR-M2SS	Interface Relay Body	1SVR405651R1000	CR-M2SS	1
40MM PU-REL RED, 2 NC	Pilot Devices	1SFA619551R1051	CE4P-10R-02	1
PILOT LIGHT CL2 GREEN 24V AC/DC	Pilot Devices	1SFA619403R5022	CL2-502G	1
PILOT LIGHT CL2 RED 24V AC/DC	Pilot Devices	1SFA619403R5021	CL2-502R	1
400A 3P HD N3R 600V NONFUSE	External Safety Switch	N/A	THN3365R	1

APPLICATION FINDER

We've made it simpler for you to set up your project!
Click here to find the reference architecture that best fits your needs and download the Bill of Materials.

Product offering

SU200M MCB:

WEB PAGE

CATALOG

ST200M Suppl. Protector:

WEB PAGE

CATALOG

ESB Contactors:

WEB PAGE

CATALOG

F200 Series RCD / RCCB:

WEB PAGE

CATALOG

AF Contactors:

WEB PAGE

CATALOG

Definite Purpose Contactors:

WEB PAGE

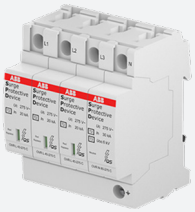
CATALOG

Enclosed Disconnects:

WEB PAGE

CATALOG

OVR Series Type 2 SPD:



WEB PAGE

CATALOG

Glossary of Terms

Symbol	Name	Description
CPI	Connector Position Indicator	The Connector Position Indicator is a feature or component that helps in identifying the correct position of the charging connector when it is connected to the electric vehicle. It is designed to ensure proper alignment and connection so as to prevent damage or errors during the charging process.
CCB	Charger Circuit Board	The Charger Circuit Board is the internal electronic board within the charger that is responsible for controlling the charging process. It includes various components and circuits that ensure proper voltage conversion, current regulation and communication between the charger and the vehicle. The CCB plays a crucial role in managing the charging operation and coordinating the interaction between charger and electric vehicle.
CCS	Combined Charging System	The CCS (Combined Charging System) is a fast-charging protocol for EVs. The CCS connector, also known as CCS Type 2 or CCS Combo 2, combines AC and DC charging capabilities. It has a Type 2 connector for AC charging and two additional DC pins for fast DC charging. The CCS protocol is widely used in Europe and North America for its compatibility and faster charging times.
CU	Central Unit	The Central Unit is a component or module within the charger's internal hardware that serves as the main control unit or brain of the charging system. It is responsible for managing and coordinating various functions such as power distribution, communication with the vehicle, monitoring charging parameters and ensuring safe and efficient charging operations. The Central Unit plays a vital role in controlling the charger's overall operation and facilitating communication between the charger and the electric vehicle.
GM/I	Ground Monitor and Interrupter	The Ground Monitor Interrupter is used in grounded DC charging systems to ensure a continuous bond to ground between the EV and the supply equipment. In the event of an open circuit or high-resistance ground, the GM/I will de-energize the charging circuit and put the EV and charging cable into a safe state.
IMI, IM/I	Insulation Monitoring Interrupter	The Insulation Monitoring Interrupter is a feature in some charging systems that monitors the insulation resistance between the electric vehicle and the charger. It helps in detecting any faults or insulation breakdowns that could pose a safety risk during the charging process. The IMI provides a means for the charger to monitor and report the insulation status, thereby ensuring safe and reliable charging operations.

To discover more

APPLICATION FINDER

Find the reference architecture tailored to your needs and speed up your project thanks to our new Application Finder Tool!

CONTACT US

Do you have a similar project and are searching for the right Application configuration?
Contact us and talk to our experts!

RATE US

Your opinion matters! Let us know if you found the document useful and how can we improve!

ABB S.p.A.
Electrification Business Area
Smart Power Division
5, Via Pescaria
I-24123 Bergamo - Italy
Phone: +39 035 395.111

new.abb.com/low-voltage

9AKK108468A7157 - 2023.10