



ABB HVAC WEBINARS

Requirements for electrical noise in buildings

Guidelines for developing reliable and efficient infrastructures

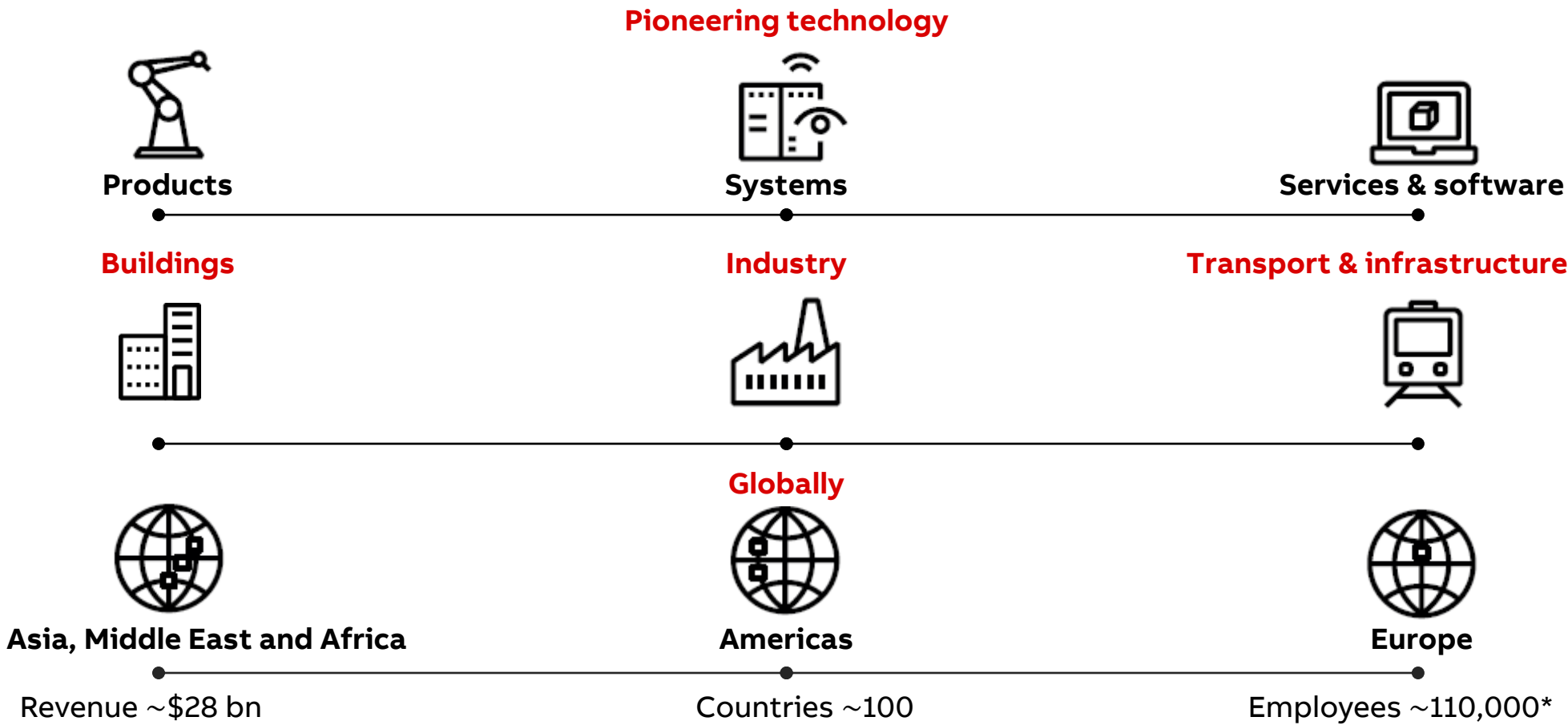
Frank Taaning Grundholm – Vice President Global HVACR Sales, ABB Motion



ABB at a glance

Facts and figures

- What Offering
- For whom Customers
- Where Geographies



Agenda

- Introduction
- EMC condensed theory
- EMC standards and regulations
- Commercial HVAC market outlook – EMC specification focus
- System EMC performance – cabling and grounding practices
- Practical examples of drive installations
- ABB product offering for HVAC – EMC specification focus
- Summary



Introduction

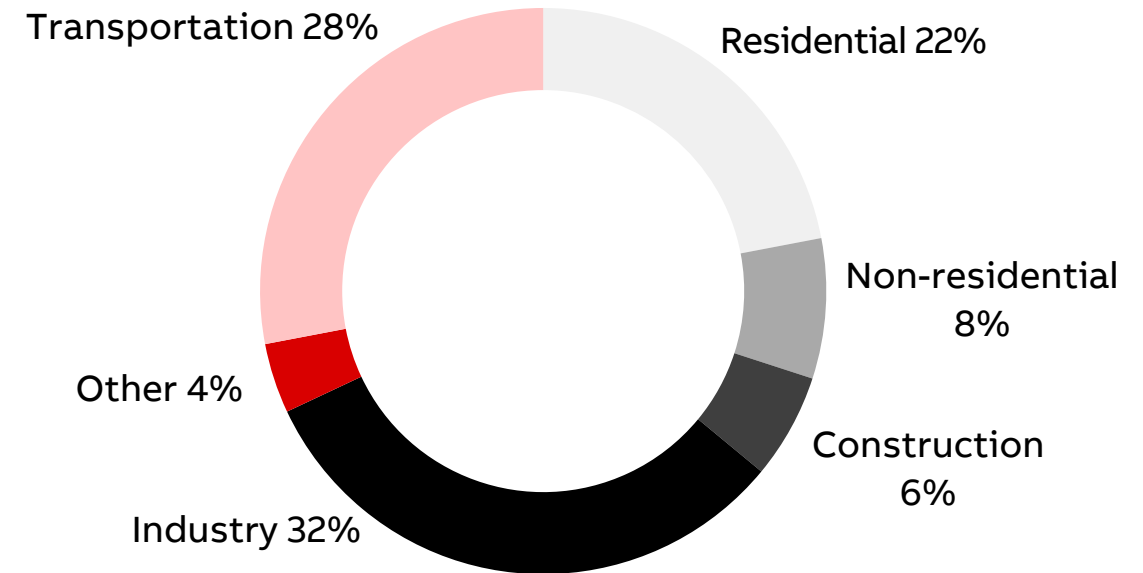
Introduction

Why do we talk about EMC or electromagnetic compatibility in HVAC?

- HVAC industry is one of the most energy consuming.
- HVAC accounts for about 40% of energy used by a building.
- Energy saving potential with VSDs in HVAC is huge since HVAC system are often oversized for peak loads¹.
- The drawback of VSDs is electromagnetic noise in the building electrical system.
- This noise in certain cases leads to malfunctioning of the equipment sharing the network with VSDs or installed nearby.
- From commercial point of view, electromagnetic emissions can contribute into the building downtime.

! The way to avoid this kind of problems is to pay attention to product/installation compliance with EMC regulations.

Global energy consumption by sector²



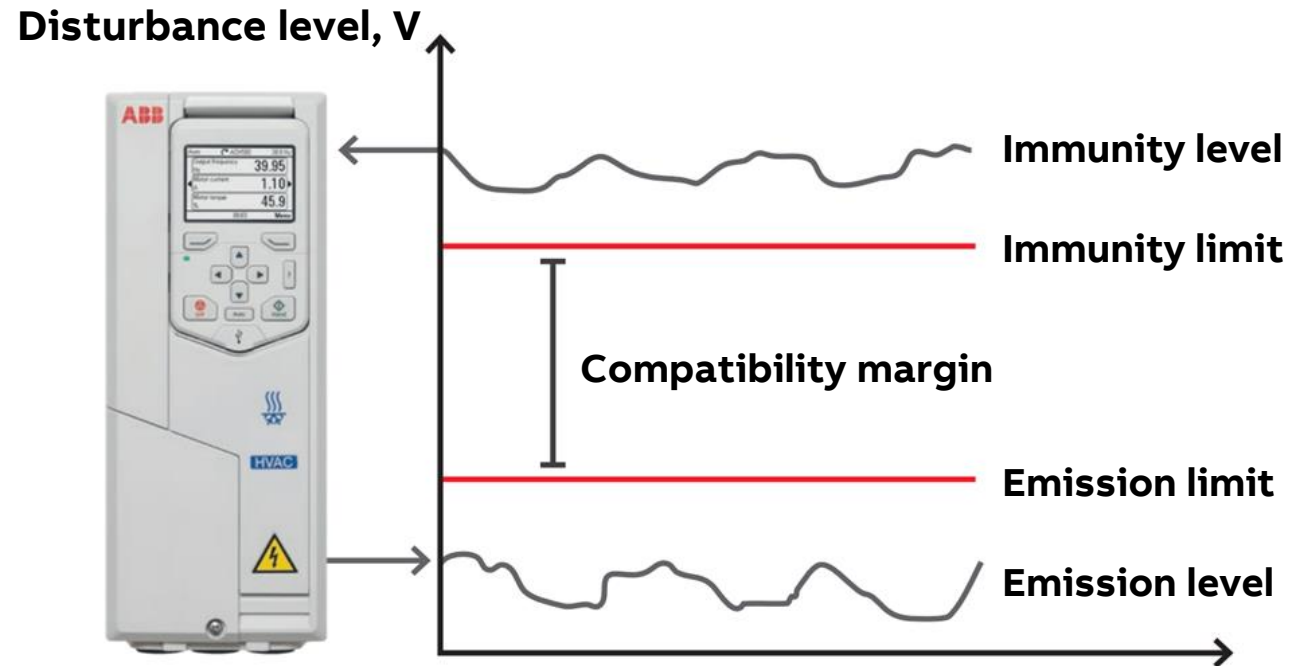


EMC theory

Brief outlook

EMC theory

What is EMC?



- EMC stands for Electromagnetic compatibility.
- EMC is the ability of an electrical/electronic equipment to operate without problems within an electromagnetic environment.
- According to EMC standards, equipment must not disturb or interfere with any other product or system within its locality.

EMC theory

Frequency bands

EMC standards have respect to electromagnetic disturbances of all types and nature:

- **Conducted low-frequency disturbances** including harmonics, voltage fluctuations, voltage dips and interruptions, voltage unbalance, power frequency variations, induced low-frequency voltages.
- **Radiated low-frequency disturbances** including continuous and transient magnetic and electric fields.
- **Conducted high-frequency disturbances** including directly coupled or induced voltages or currents, transients.
- **Radiated high-frequency disturbances** including magnetic fields, electric fields and electromagnetic fields.

Harmonics



Harmonics

- up to 3000 Hz*
- Conducted
- Low frequency disturbances

RFI related to EMC

- 150 kHz and up by EMC standard (RF starts from 9 kHz)
- Conducted (up to 30 MHz) and radiated (30 to 1 GHz)
- High frequency disturbances

EMC theory

Electromagnetic emissions and immunity

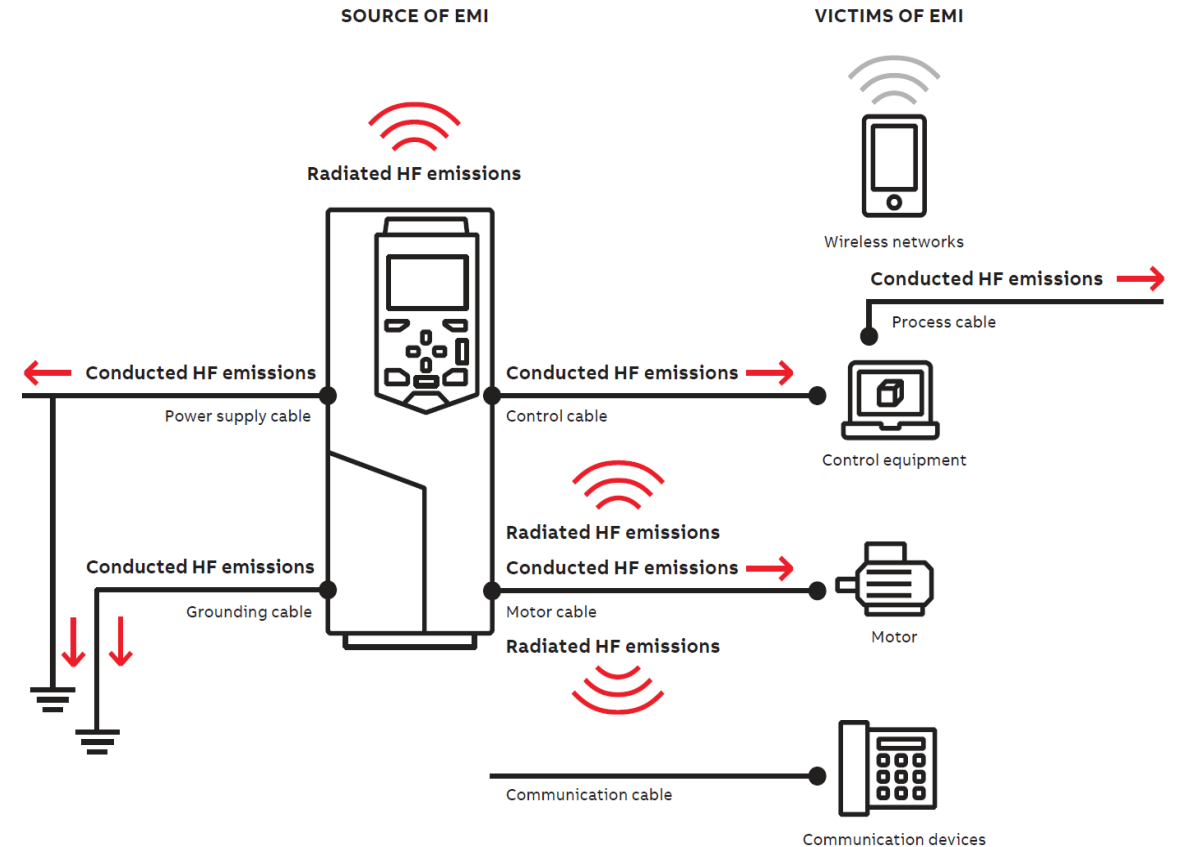
Conducted emissions from the device travel through:

- motor cable
- process control cables
- power supply cable
- earth connection

Radiated emissions from the device radiate through enclosure and motor cable

- motor cable act as antenna
- the longer the cable the bigger the antenna
- pigtails on cable screens are also antennas and to be avoided

Electrical equipment should be immune i.e. should withstand conducted and radiated emissions. Immunity requirements are higher in the industrial environment.



EMC theory

Electromagnetic disturbances in power network

Sources of electromagnetic disturbances

- The main source of electromagnetic disturbances is the fast switching of power components such as insulated gate bipolar transistors (IGBT) in modern power electronic devices including VSDs.
- A small wave of electromagnetic energy is emitted whenever electrical current in a transistor is switched on or off. The energy from switching action generates electromagnetic emissions.

Reasons of poor EMC performance

- Poor product design
- Improper cabling/wiring
- Improper grounding

Consequences for end-users

- Incorrect operation or failure of IT equipment including memory losses and switch offs: interference with data running on communication cabling leads to increased errors, higher network traffic, network overload, etc.
- Adverse effect on communication equipment – telephones, TV sets, radios, implying noisy and interrupting phone lines, TV screen disturbance, etc.

Consequences for building owners

- Costs associated with equipment life-time reduction, extra maintenance and productivity losses.
- Malfunctioning or failure of elevators, lighting and safety systems (security, fire/smoke control) can put people's security at risk especially in critical facilities like hospitals.

EMC standards and regulations

Overview of the requirements

EMC standards and regulations

EMC Directive 2014/30/EU

- The European Parliament directive on the laws of the Member States relating to electromagnetic compatibility.
- The aim – to regulate the electromagnetic compatibility of equipment, ensure the functioning of the internal market by requiring equipment to comply with an adequate level of electromagnetic compatibility.
- EMC directive is a legal requirement within EU for a CE mark. Failing to follow it can lead to legal responsibility.
- The Directive states that equipment should not disturb or be disturbed by similar (or telecom) equipment:

“The apparatus referred to...shall be so constructed that:

a) the electromagnetic disturbance it generates does not exceed a level allowing radio and telecommunications equipment and other apparatus to operate as intended;

b) the apparatus has an adequate level of intrinsic immunity to electromagnetic disturbance to operate as intended.”

- Emission vs immunity are the terms.
- Equipment failing to comply with the requirements of this Directive could not have been sold in EU area.
- CE marking according to EMC Directive is used to claim compliance.
- A Manufacturer’s Declaration of Conformity must be available (self-certification by manufacturer).

EN61800-3 product standard for Power Drive Systems is specified in Harmonized standards under EMCD 2014/30/EU for EMC.¹

EMC standards and regulations

Comparison between EMC standards

Power Drive Systems product standard EN 61800-3: 2017	Generic or product family standard for industrial, scientific and medical (ISM) equipment EN 55011: 2003	Outdated standard for drives EN 61800-3/A11 (2000)
Environment 1 (Residential area, (plug-in devices) Category C1	Class B (Residential area) Group 1+2	1 st environment, unrestricted distribution
Environment 1 or 2 (fixed professional installation, depending on the decision of the user) Category C2	Class A (Industrial area) Group 1 (Internal filter)	1 st environment, restricted distribution
Environment 2 (Industrial area) Category C3	Class A Group 2 (External filter, not applicable to drives)	2 nd environment, unrestricted distribution
Category C4 (exceeds the Class A2 limits 1000 V or 400 A)	ND	2 nd environment, restricted distribution

If there is an EMC product standard available for certain equipment, it must be used. If a product standard does NOT exist, a product family standard must be used. If a product family standard does NOT exist, a generic standard must be used.

Requirements in different standards are not same. Generally it is easier to fulfil product standards than generic since product specific characteristics are taken into consideration in product standards, and the equipment manufacturers are part of standardisation committees.

Product standards override generic standards. EMC product standard for variable speed units is EN61800-3 “Adjustable speed electrical power drive systems. Part 3: EMC requirements and specific test methods”.

EMC standards and regulations

Differences between EN61800-3 and EN61000-6-2/-3

The main differences between the product standard and generic standard are:

- EMC emission requirements are specified more specifically for the use of the product, but levels are identical.
- EMC immunity requirements are added to EN61800-3 and not completely covered by EN61000-6-2.

In 1st environment this includes:

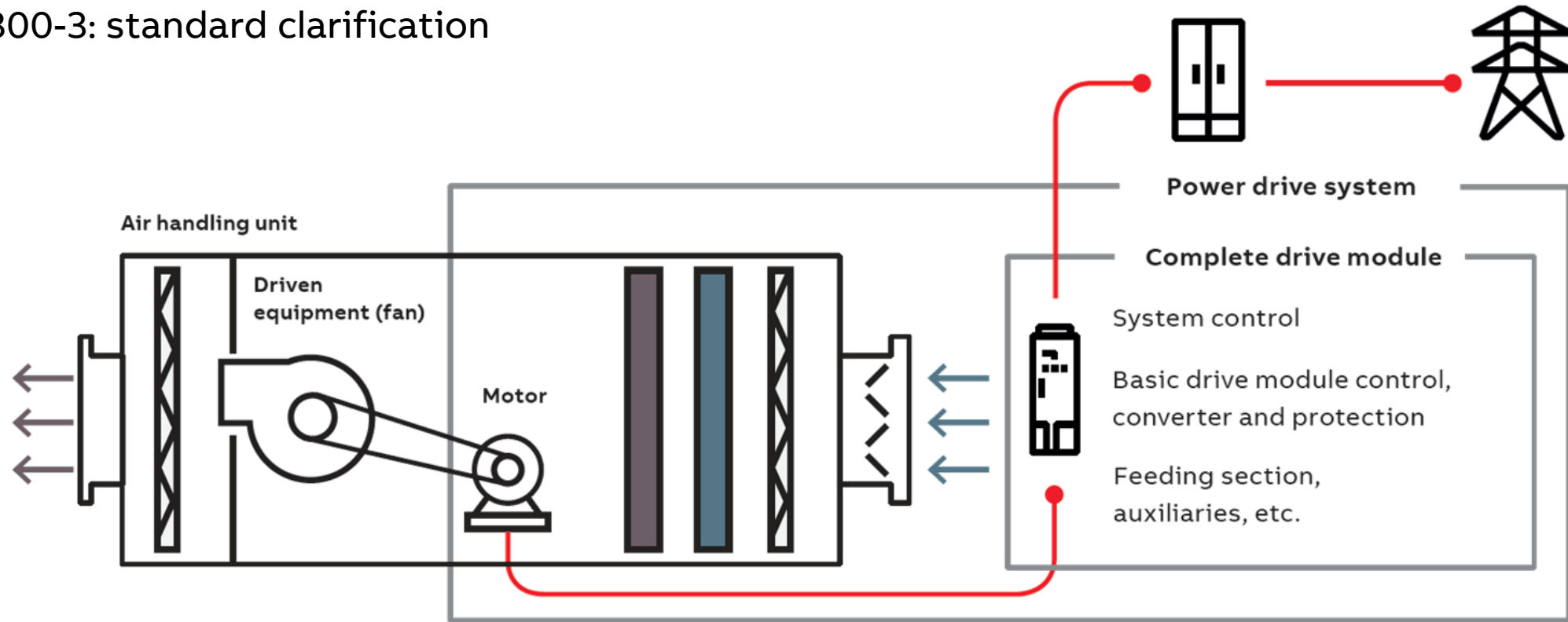
- Immunity to harmonic voltages 8% in first environment (with specific spectrum as well)
- Commutation notches N/A (2nd environment Depth 40%, total area = 250 in % degrees)
- Voltage deviations $\pm 10\%$
- Voltage unbalance 2%
- Voltage variations $\pm 2\%$
- Frequency rate of change 1%/second

Tests conducted by ABB showed failure as regards to voltage variations and 2nd environment commutation notches¹.

EMC Immunity is not fully covered by generic standard EN61000-6-2

EMC standards and regulations

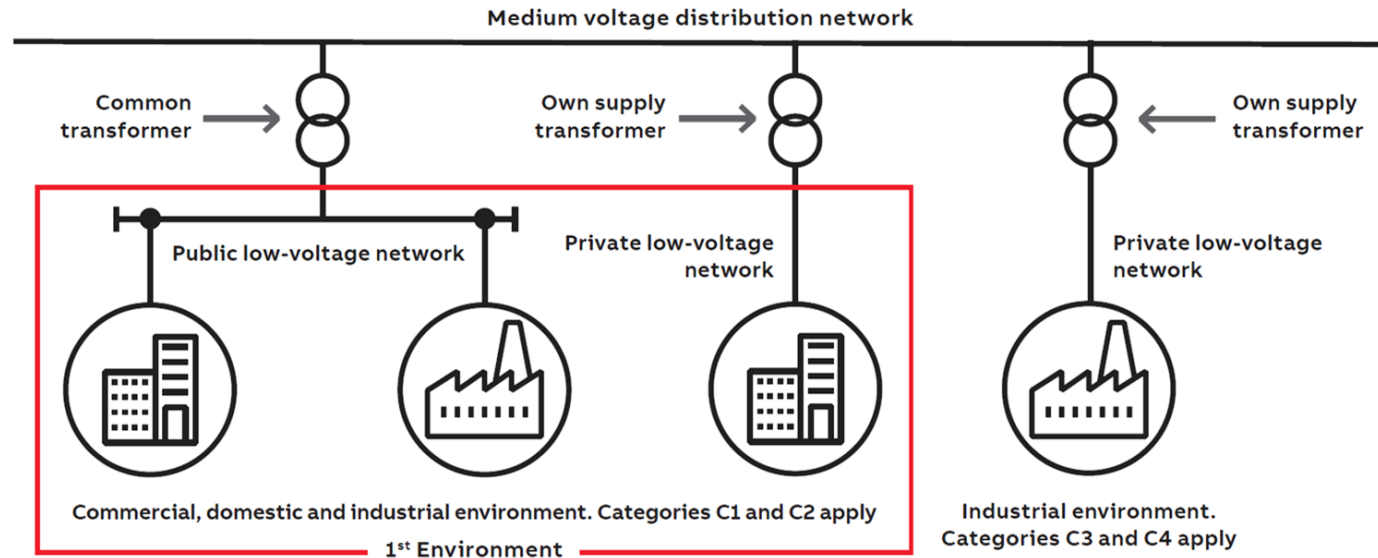
EN 61800-3: standard clarification



- EN 61800-3 applies to a complete Power Drive System (PDS). PDS incorporates a Complete Drive Module (CDM) and a Motor.
- A CDM consists of a variable speed drive (VSD), motor cabling and control interfacing – a complete system, not just a VSD.
- When one or more power drive systems are included in equipment, the standard applies to a whole package, not the PDS alone.

EMC standards and regulations

EN61800-3: EMC environments according to the standard



Drives can be connected to industrial or public power distribution networks. The environment class doesn't depend on the way a drive is connected to power supply. 1st and 2nd environments according to the EN61800-3 standard:

- **“The 1st Environment** includes domestic premises. It also includes establishments directly connected without intermediate transformer to a low-voltage power supply network which supplies buildings used for domestic purposes.”
- **“The 2nd Environment** includes all establishments other than those directly connected to a low-voltage power supply network which supplies buildings used for domestic purposes”.

EMC standards and regulations

Declaration of conformity, manufacturer's statements and CE marking

Power and productivity
for a better world™ **ABB**

EU Declaration of Conformity

We
Manufacturer: ABB Oy
Address: Hiomitie 13, 00380 Helsinki, Finland.
Phone: +358 10 22 11
declare under our sole responsibility that the following product:

Frequency converter
ACH580-01

is in conformity with the relevant requirements of European Union Directives, which have been notified in this single declaration that consists of individual Declarations of conformity, provided that the equipment is selected, installed and used according to given instructions.


The harmonised standards and other standards, which have been applied, are specified on the individual Declarations of conformity for particular EU directive.

EU Directives			
Low Voltage Directive	2014/35/EU	LVD	
EMC Directive	2014/30/EU	EMC	
Machinery Directive	2006/42/EC	MD	
RoHS Directive	2011/65/EU	RoHS	

Individual EU Declaration of Conformity:

Product	LVD	EMC	MD	RoHS
ACH580-01	3AXD10000437232	3AXD1000043729	3AXD10000437231	

Helsinki, 20 Apr 2016

Manufacturer representative: 
Tuomo Höysniemi
Vice President, ABB Oy

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- A Manufacturer's Declaration of Conformity must be available.
- It must contain the reference to EMC directive such as 2014/30/EU.
- It must contain contact details of the manufacturer and responsible person name.
- Applied standard(s) to be mentioned.
- Manufacture's statement on product EMC performance is more reliable than marketing materials.
- Marketing materials sometimes conflict with real facts regarding emissions and immunity levels both radiated and conducted.
- A CE mark on a variable speed drive verifies that the drive follows the provisions of the European Low Voltage Directive (2014/35/EU) and EMC Directive (2014/30/EU).

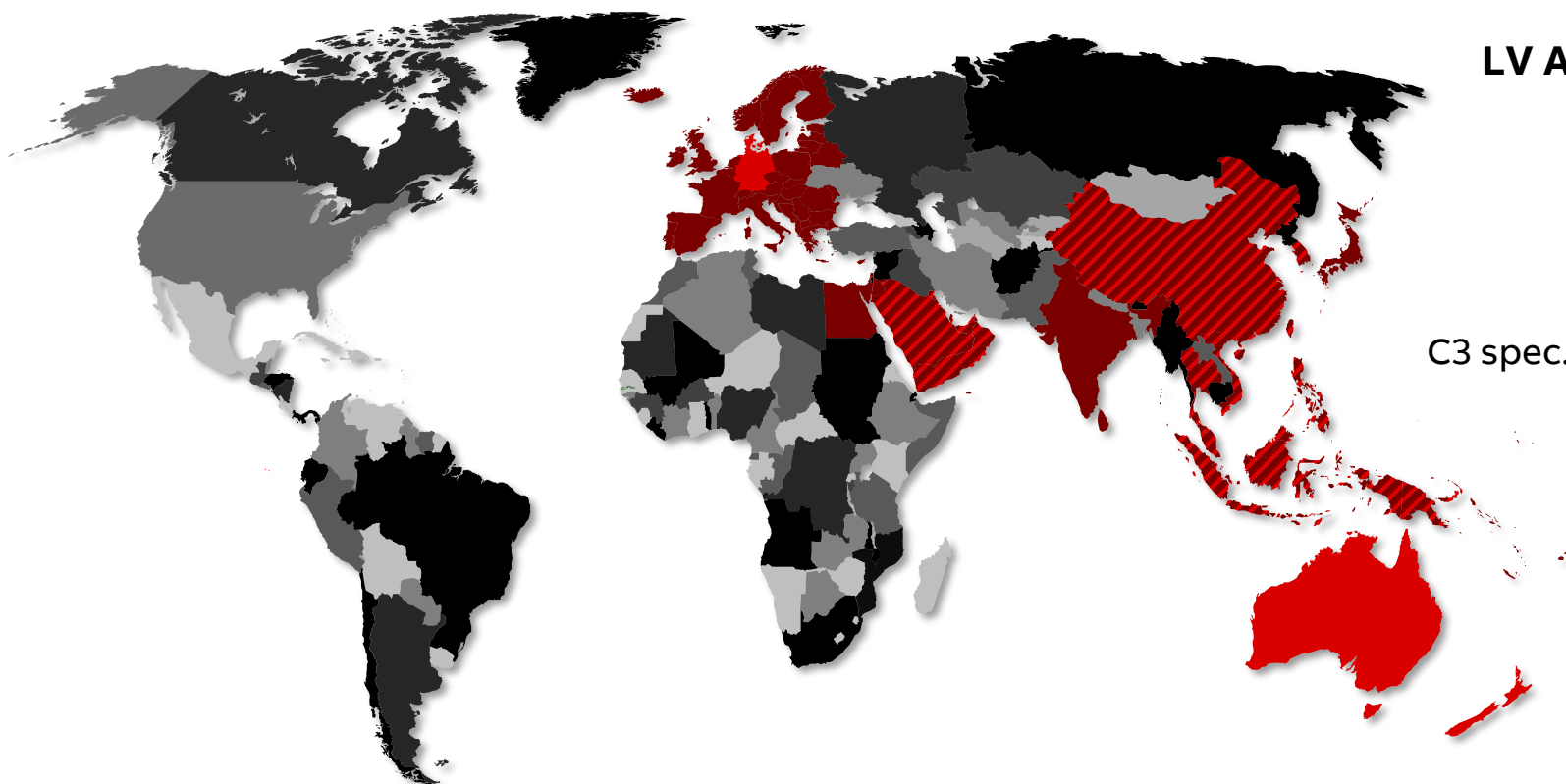


Commercial HVAC market outlook

EMC specification focus

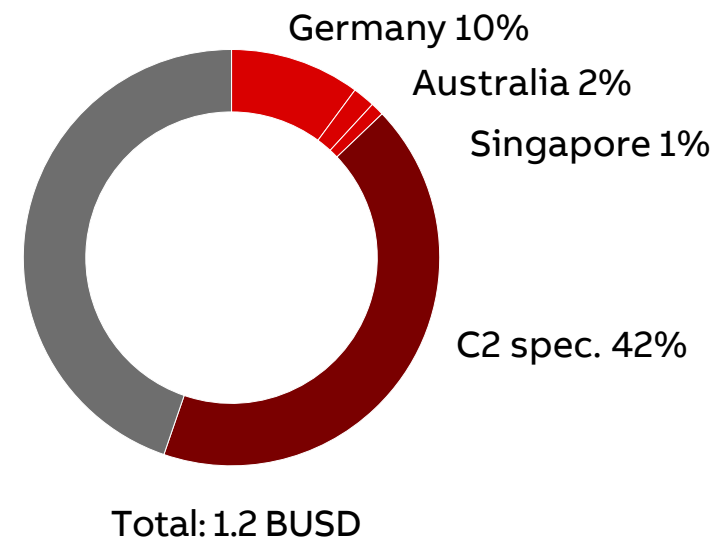
Commercial HVAC market outlook

EMC specification in regard to geography



■ C1 specification ■ C2 specification ■ C3 / No EMC specification

LV AC Drives. Commercial HVAC market¹



Commercial HVAC market outlook

Considerations on EMC specification

EMC Category C1

- Specified for drives EMC C1 is only valid for conducted emission and highly dependent on motor cable length
- C1 EMC performance of the actual installation isn't guaranteed
- Is legally only required for pluggable (movable) devices
- Should only be required in critical and sensitive areas, such as:
 - Hospitals (operating or diagnostic rooms, not inpatient rooms)
 - Airports (operating control towers, not waiting halls)
 - Telecommunication facilities
- It is a specification level driven by specific manufacturers to exclude competitors from the tenders.

EMC Category C2

- Sufficient for most HVAC application
- It is the legally required level for fixed (neither plug-in nor movable) devices installed in the 1st environment
- Increasing electromagnetic filtering beyond the necessary level will increase the leakage currents, which may lead to other problems in the installation

! Installations must always be done according to the equipment manufacturers' recommendations. If cable types, max cable length as well as distance between cables is not managed accordingly, the installation might not meet the specification.

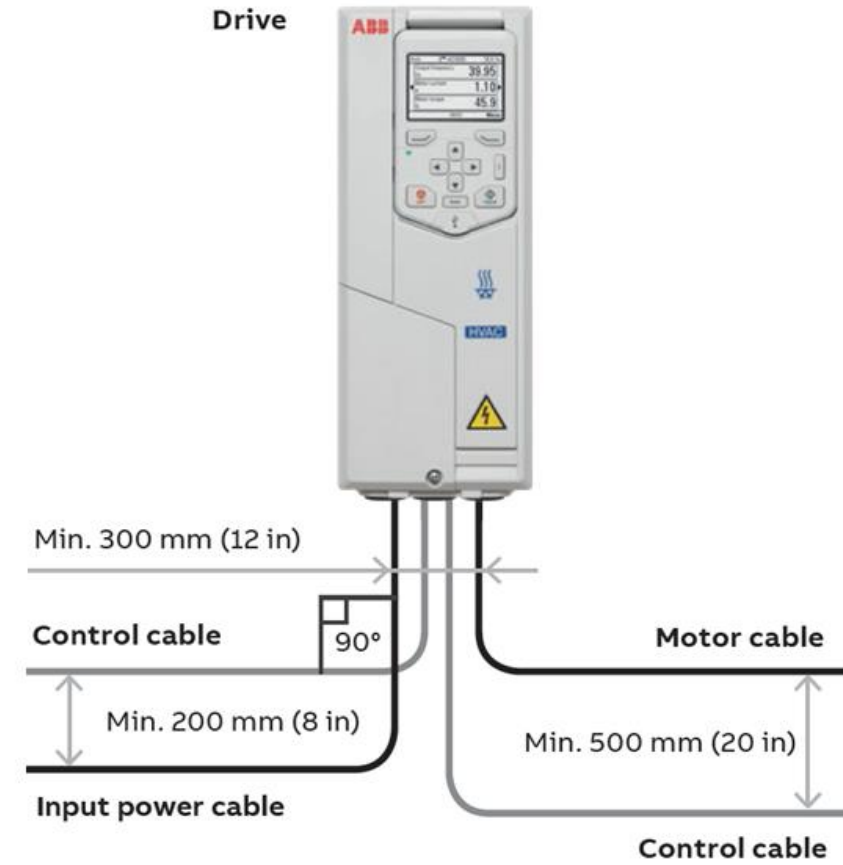
System EMC performance

Cabling and grounding practices

System EMC performance

VSD cables routing

- Route the motor cable away from other cable routes.
- Motor cables of several drives can be run in parallel next to each other but should be shielded.
- The motor cable, input power cable and control cables should be run in separate trays.
- Avoid long parallel runs of motor cables with other cables to decrease EMI caused by the rapid changes in the drive output voltage.
- Where control cables cross power cables, make sure they are arranged at an angle of 90 degrees. Do not run extra cables through the drive.
- Cable trays must have good electrical bonding to each other and to the grounding electrodes.
- Aluminum tray systems are used to improve local equalizing of potential.



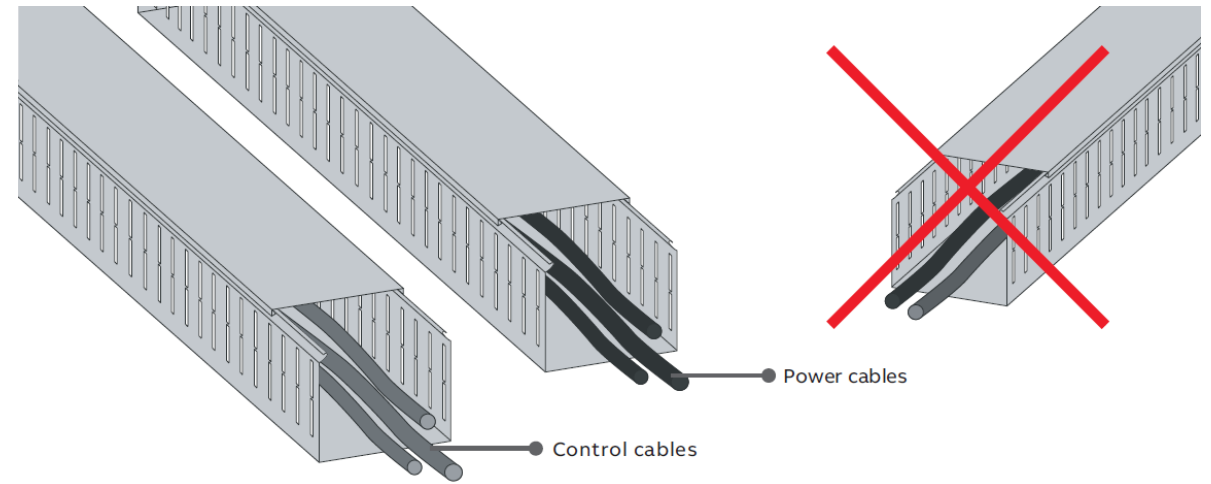
System EMC performance

VSD cables routing

Separate control cable ducts: run 24 V and 115/230/400 V control cables in separate ducts unless the 24 V cable is insulated for 115/230/400 V.

To minimize the emission level when safety switches, contactors or similar equipment is installed on the motor cable between the drive and the motor:

- In EU area install the equipment in a metal enclosure with 360-degree grounding for the shields of both the incoming and outgoing cable or connect the shields of the cables together.
- In the US install the equipment in a metal enclosure in a way that the conduit or motor cable shielding runs consistently without breaks from the drive to the motor.



System EMC performance

Power cable types

To comply with the EMC requirements of the CE mark, it is required to use one of the approved cable types.

Recommended cable types



Symmetrical shielded cable with 3-ph. conductors and a concentric copper or aluminum PE conductor as shield (the shield must meet IEC 61439-1).



Symmetrical shielded cable with 3-ph. conductors and a concentric steel or galvanized iron PE conductor as shield. A separate PE conductor is required if cable shield does not meet IEC 61439-1).



Symmetrical shielded cable with 3-ph. conductors, 1 or 3 symmetrical constructed PE conductors and shield. PE conductor must meet IEC 61439-1).

Not allowed cable types

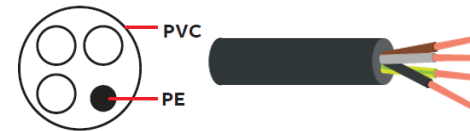


Symmetrical shielded cable with individual shields for each phase conductor is not allowed on any cable size for input or motor cabling.

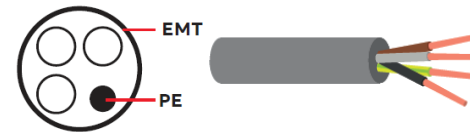
Cable types for limited use



A 4-conductor system (3-ph. conductors and protective conductor on a cable tray) is allowed for input cabling only. Not allowed for motor cabling. Not allowed in IT networks.



A 4-conductor system (3-ph. conductors and PE in a PVC conduit) is allowed for input cabling with phase conductor cross-section less than 10 mm² or motors < 30 kW. Not allowed in the USA.

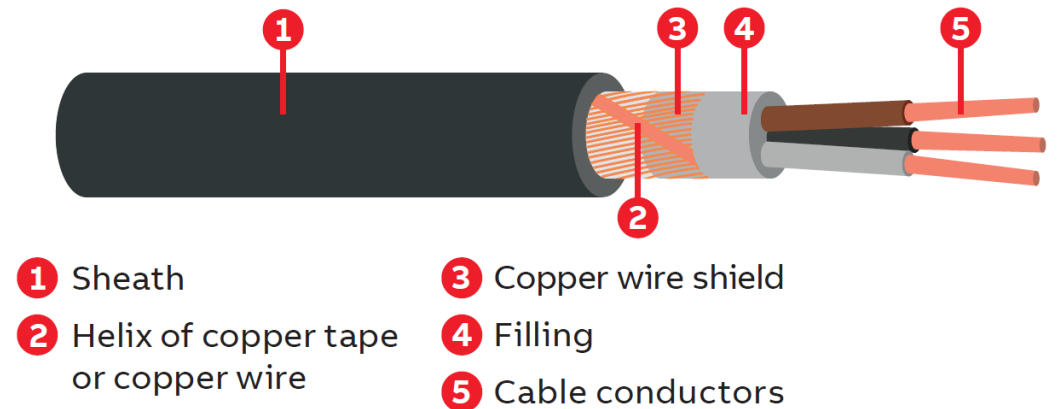


Corrugated cable or electrical metallic tubing EMT with 3-ph. conductors and a protective conductor are allowed for motor cabling with phase conductor cross-section less than 10 mm² or motors < 30 kW.

System EMC performance

Motor cable shield

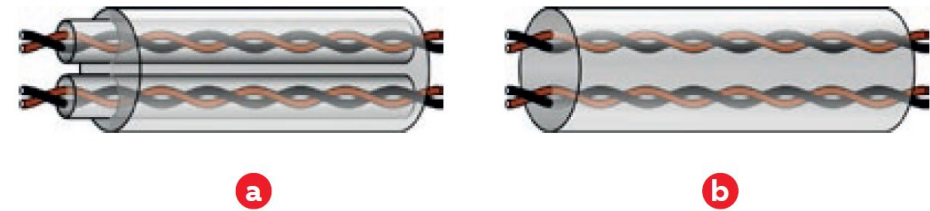
- To effectively suppress radiated and conducted radio-frequency emissions, the cable shield conductivity must be at least 1/10 of the phase conductor conductivity.
- The requirements are easily met with a copper or aluminum shield.
- The minimum requirement of the motor cable shield of the drive is shown on the right. It consists of a twisted layer of copper wires with an open helix of copper tape or copper wire.
- The braided motor cable shield is an alternative to the twisted one.
- The better and tighter the shield, the lower the emission level and bearing currents.



System EMC performance

Control cables

- All control cables must be shielded.
- Use a double-shielded twisted pair cable for analog signals. Employ one individually shielded pair for each signal. Do not use common return for different analog signals.
- A double-shielded (a) cable is the best alternative for low-voltage digital signals but single-shielded (b) twisted pair cable is also acceptable.
- Run analog and digital signals in separate, shielded cables. Do not mix 24 V AC/DC and 115/230/400 V AC signals in the same cable.
- Relay-controlled signals not exceeding 48 V, can be run in the same cables as digital input signals. The relay-controlled signals should be run as twisted pairs.



a – double-shielded control cable

b – single-shielded control cable

System EMC performance

Grounding practices

System type	Main application	Human safety	Property safety	EMC performance
TT	Domestic installations and similar, small industries with low voltage power supply	Good Residual current circuit breakers required	Good Medium fault current 10 -100 A	Good Risk of overvoltages Equipotential problems Need to manage devices with high leakage currents
TN-S	Industries and big installations with medium voltage power supply	Good Continuity of the PE conductor must be ensured	Poor High fault current similar to single-phase fault current	Very good Few equipotential problems Need to manage devices with high leakage currents High fault currents (transients)
TN-C				Poor (should never be used) Circulation of disturbed currents in exposed conductive parts (high radiated emissions) High fault currents (transients)
IT	Chemical and petrochemical industries, i.e. plants for which service Continuity is fundamental	Good Continuity of the PE conductor must be ensured	Good Low current for the 1st fault (μA -2 A) and high current (values typical for TN or TT systems) for the 2nd fault	Poor (should be avoided) Risk of overvoltages Common-mode filters must handle phase-to-phase voltages Residual current circuit breakers subject to tripping if common mode capacitors are present

Consider that a VSD with a properly chosen EMC filter is not able to solve the electromagnetic interference problem within the electrical system if the system has wrong design and grounding in particular. A VSD with C2 filter installed in a properly designed electrical system can perform better from EMC point of view than a VSD with C1 filter in a system designed against IEC standards.

The system grounding should ensure not only safety of life and property, but EMC compliance as well. European standards EN 50174-2 and EN 50310 recommend the TN-S system which causes the fewest EMC problems for IT equipment.

System EMC performance

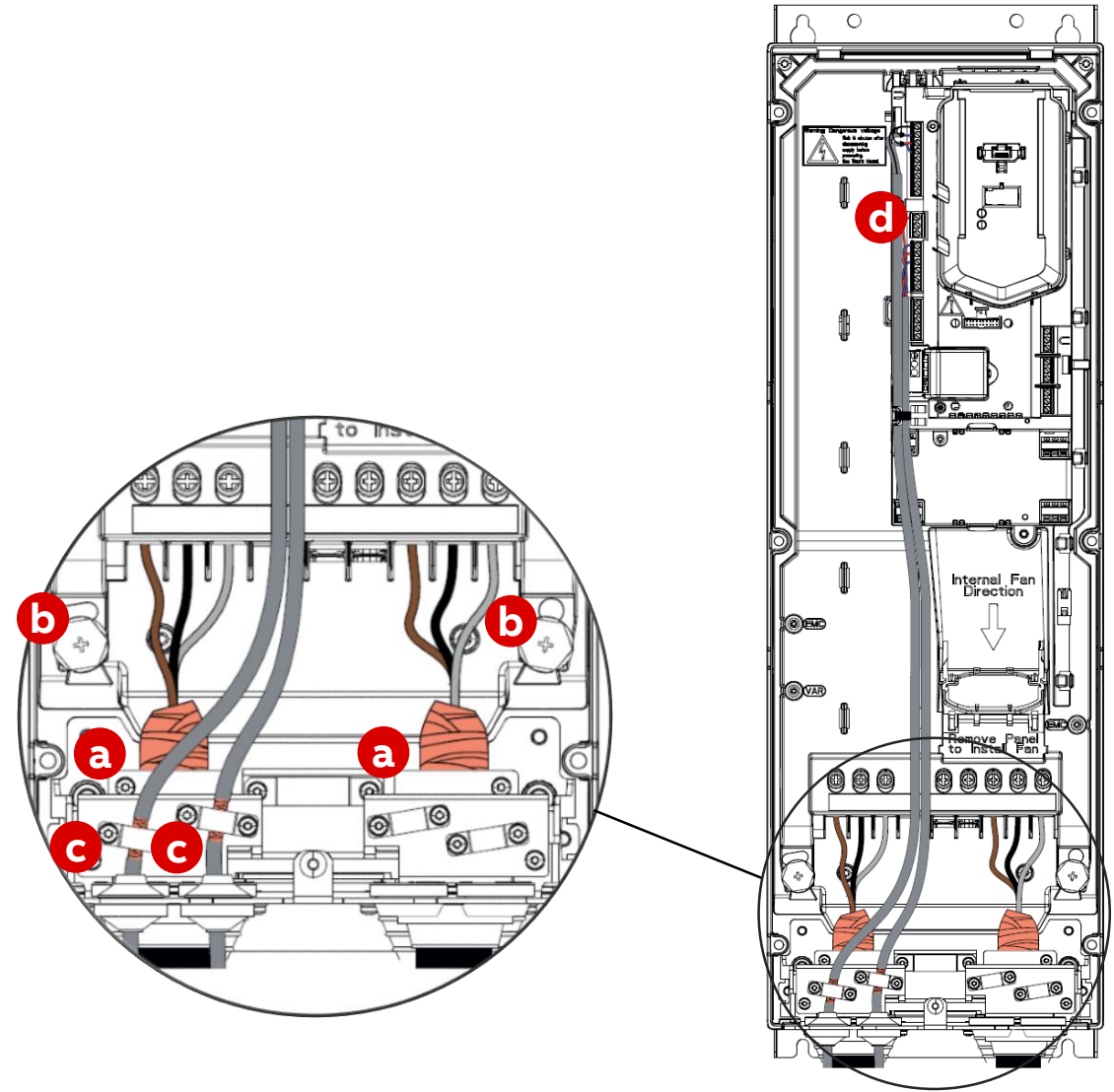
Equipotential grounding in buildings

- A grounding system secures EMC compliance by avoiding differences in potential and providing path for noise in the system to ground.
- Stray currents are always present in a grounding system. Ground loops are also inevitable.
- When a magnetic field (e.g. lightning) affects a site, differences in potential are created in the loops formed by conductors and the currents flowing in the grounding system.
- As long as the currents flow in the grounding system and not in the electronic circuits, they do not cause damage.
- When grounding systems are not equipotential, HF stray currents flow wherever they can, including control wires. This leads to disturbing, damaging or even destroying the connected equipment.
- In a building, various grounding systems must be interconnected to ensure equipotential. The grounding system must be as meshed as possible. If the grounding system is equipotential, the differences in potential between communicating devices will be low and a large number of EMC problems will disappear.
- If equipotential conditions between buildings cannot be achieved, it is highly recommended to use optical fiber for communication links and galvanic insulators for communication systems.

System EMC performance

VFD wiring and grounding

- Motor and mains cables to be grounded 360°. EMC cable glands are an optimal solution. Metal cable clamps with full cable shield contact are also sufficient (a).
- For cables with a PE conductor as a shield, grounding happens on metal clamps (a). A motor cable shield to be grounded at the motor end as well. Unshielded cable parts to be kept as short as possible.
- For cables with a separate PE conductor, ground the drive connecting the PE conductor to the grounding terminals (b).
- Terminate and ground drive control cables to cut noise in the control circuit. A control cable shield to be 360° grounded via the grounding clamp (c). Connect control cable shields and grounding wires to a grounding terminal at the drive side.
- Keep the cables unstripped as close to the control board terminals as possible (d). Signal wire pairs to be kept twisted as close to the terminals as possible. Twisting the wire with its return wire reduces inductive coupling disturbances.



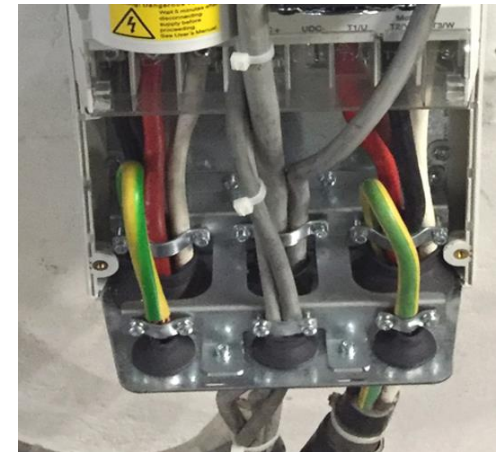
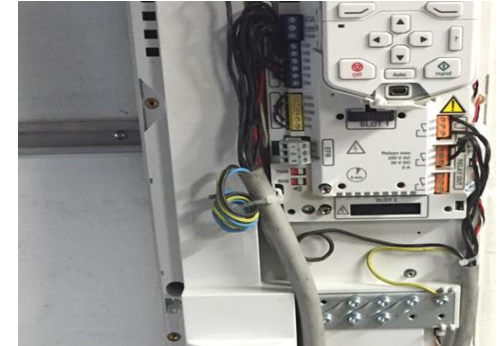
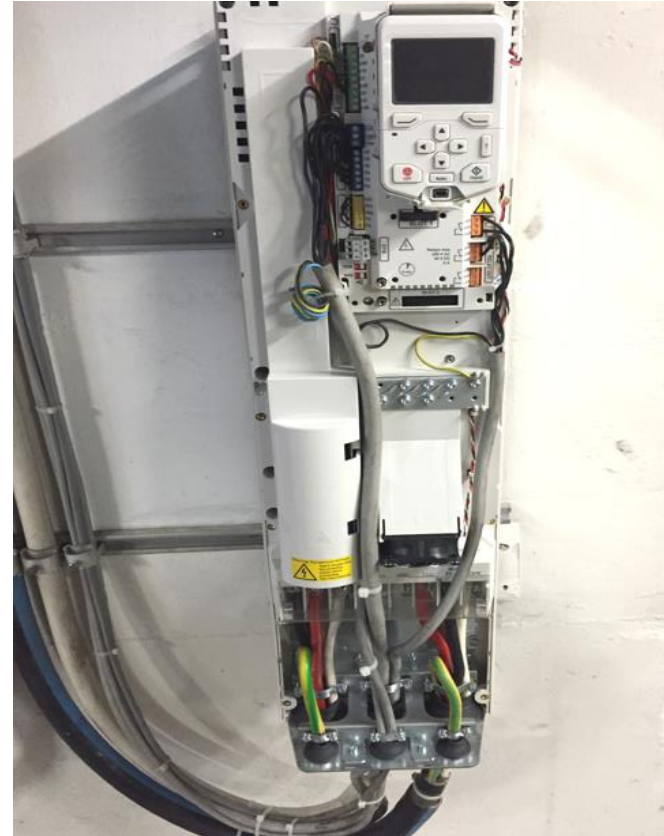
Installation EMC compliance

Real life examples

Installation EMC compliance

Real life cases

- Usage of unshielded control cables
- Usage of unshielded motor cables
- No distance between mains, motor and controls cables (all run in the same cable tray)



Installation EMC compliance

Real life cases

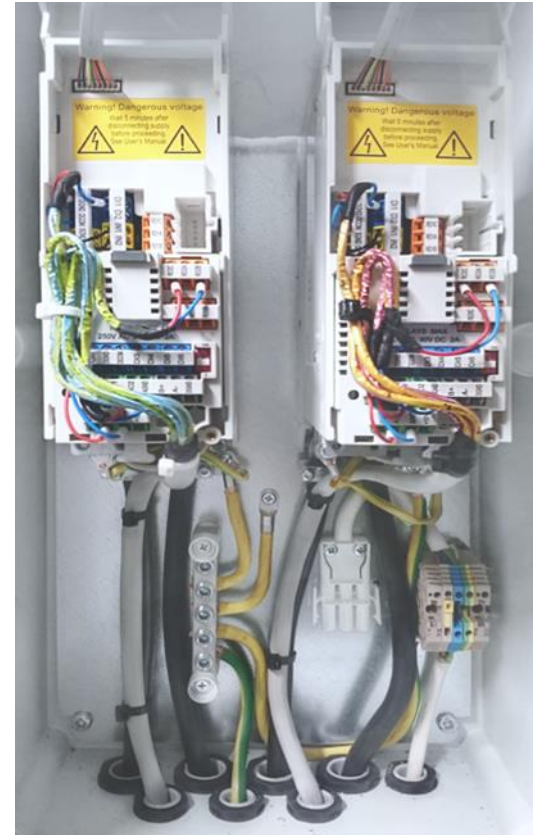
- Improper way of routing motor cables, power cables and control cables: the installation looks neat, but the required clearance between power, motor and control cables isn't maintained



Installation EMC compliance

Real life cases

- Use of shielded control wires
- Proper grounding
- Motor cable shield is not grounded
- No clearance between motor and control cables



Installation EMC compliance

Real life cases

- Use of shielded motor cables
- Proper 360-degree clamp grounding of motor and control cable shields
- Remark: some of the control cables are not grounded since they are daisy-chained and grounded at the end of chain



Installation EMC compliance

North American practices

- In North American practice, electrical conduits are used to protect and route electrical cables in a building.
- Conduits can be made of metal, plastic, fiber or fired clay. Most conduits are rigid, but flexible conduits are also used.
- Steel conduits have been used since early 1900s. Steel is the most effective shield for 60 Hz electromagnetic field – reduces it by 95%. Aluminum conduit reduces such field by 5%. Nonmetallic materials are equal to conductors installed in free air.
- Steel conduits also provide a good electrical path to ground.
- These are some of the reasons EMC-related problems are not so common in e.g. the USA.

Picture: the cables go to the same conduit making mains, motor and control cables running unscreened in parallel.



ABB product offering for HVAC

EMC specification focus

ABB HVAC Drives offering

EMC categories

ACH480-04



- Complete HVAC functionality in a compact package
- Cabinet optimized
- IP20, UL Type 1
- 0.75 – 22 kW

C2

ACH580-01/04/07

- Complete specification drive
- Effortless installation and operation
- Different variants available:



IP21 and IP55
Wall-mounted 0.75-250 kW
Modules 250-500 kW
Cabinets 75-500 kW
By-pass
Main switch

C2 up to 250 kW, above – C3

ACH580-31/34



- Premium drive for demanding facilities
- Ultra low harmonic (< 3%)
- Different variants:
Wall-mounted 4-110 kW
Modules 132-355 kW

C2/C3 depending on power

ACH580-01+E223



- ACH580-01 functionality with improved EMC performance
- Wall-mounted 0.75-55 kW
- IP55

C1 conducted



Summary

Summary

Requirements for electrical noise in buildings



Specify EMC based on the actual need

Specify right level of EMC compliance based on the actual need of the installation. C2 is sufficient for most of the commercial installations.



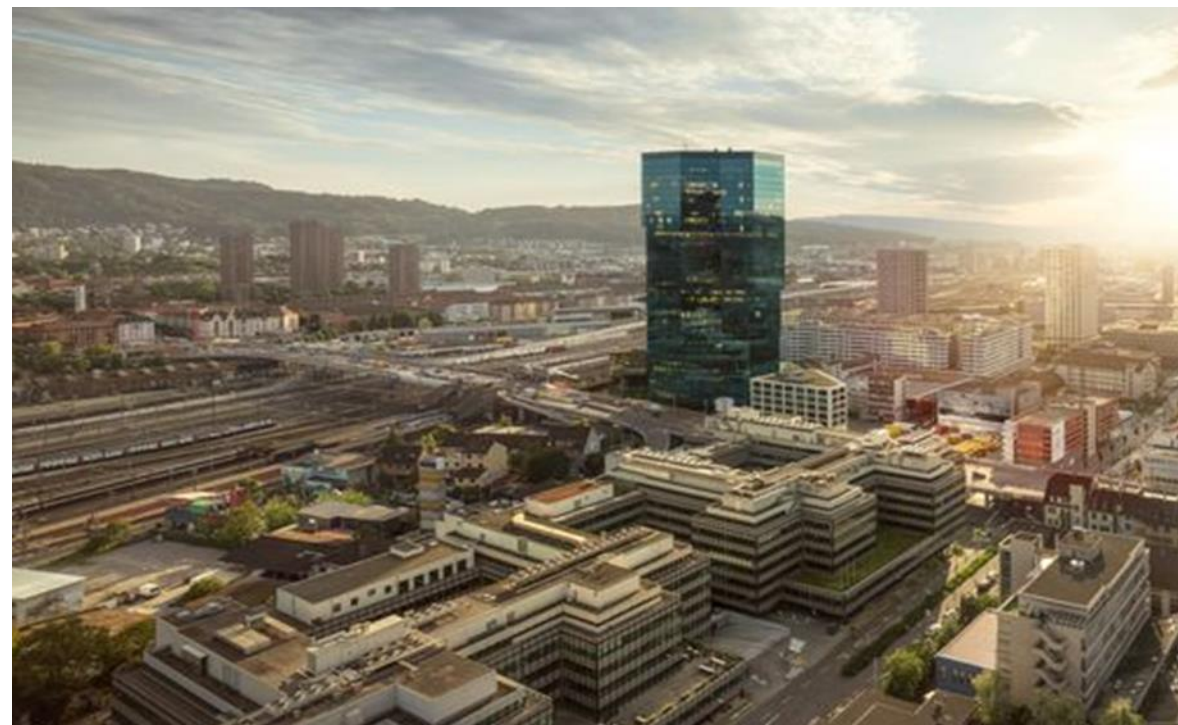
Cabling is critical to EMC performance

Improper cabling negatively affects EMC performance of a power drive system. Good EMC filter doesn't always guarantee good installation EMC performance.



Save costs with EMC correct installation

Following the manufacturer's guidelines and paying attention to EMC correct installation saves lots of time and costs of troubleshooting and downtime.



It's not only a drive's EMC performance, but the whole installation correctness that defines PDS EMC performance.

EMC: sources of information

ABB database

- ABB technical guide No. 3 “EMC compliant installation and configuration for a power drive system”
<http://search.abb.com/library/Download.aspx?DocumentID=3AFE61348280&LanguageCode=en&DocumentPartId=1&Action=Launch>
- ABB technical guide No. 2 “EU Council Directives and adjustable speed electrical power drive systems”
<http://search.abb.com/library/Download.aspx?DocumentID=3AFE61253980&LanguageCode=en&DocumentPartId=1&Action=Launch>
- ABB application guide “Radio frequency interference in HVAC applications”
<http://search.abb.com/library/Download.aspx?DocumentID=3AUA0000222151&LanguageCode=en&DocumentPartId=&Action=Launch>
- ABB drives hardware manuals include important information concerning EMC. There are e.g. cabling requirements stating approved cable design and routing recommendations

ABB