Rittal – Das System.

Schneller – besser – überall.

Electromagnetic compatibility for the control and power distribution systems of machinery and equipment

White Paper

August 2020

Author: Hartmut Lohrey, Dipl.-Ing. (Univ.)

SCHALTSCHRÄNKE STROMVERTEILUNG KLIMATISIERUNG IT-INFRASTRUKTUR SOFTWARE & SERVICE

FRIEDHELM LOH GROUP

Regardless of whether the activities are performed in a private or a professional environment: Nowadays there are hardly any tasks that be carried out without electrical equipment.
The electrical technology must not only function perfectly and so be safe and free of interference. In addition, it must not influence any other devices during operation or cause any inadmissible mains feedback. The planners, constructors and operators of the systems and the manufacturers of the components must conduct this sometimes-complex task reliably. This White Paper provides an overview of the fundamentals and standards; it also outlines the basic principles and requirements, as well as the approaches to solutions.

Table of contents

Executive summary

Electromagnetic compatibility is tremendously relevant as one aspect of the trouble-free operation of the electrical equipment of machinery, production plants and energy distribution systems.

As well as the task of safeguarding the electrical control technology and power distribution from environmental influences and protecting users from the dangers of electric current, enclosures also make a significant contribution to undisturbed operation thanks to the shielding effect of their metallic housings and potential equalisation measures.

You will learn more about the basic requirements, connections and solutions in this White Paper.

Hartmut Lohrey,
Head of Marketing Training / Support at Rittal

Author

Dipl.-Ing. (Univ.) Hartmut Lohrey

Dipl.-Ing. (Univ.) Hartmut Lohrey has worked in the Marketing department at Rittal in Herborn since 1988. In 1995/96 he was the manager of the Key Account Sales Department for IT enclosures, then Enclosure Technology specialist in Marketing. Since July 2001, he has overseen the Marketing Training/Support department and of technical customer consulting and product training.

He has also taken part in numerous national and international standardisation committees and he represents Rittal in the German Association for EMC technology (DEMVT).

Introduction

Nowadays, electrical devices are a constant feature in the entire private and professional worlds. Daily life in economically advanced countries would barely be conceivable without these systems of active electronic devices, connected to each other directly or via network components.

The protection of the devices to ensure the undisturbed operation the entire system with a high level of availability, as well as the protection of the user against the dangers of the electrical energy in the event of a fault are of the utmost importance in any application. Any possible hazards in either of these fields can be counteracted with suitable protective measures.

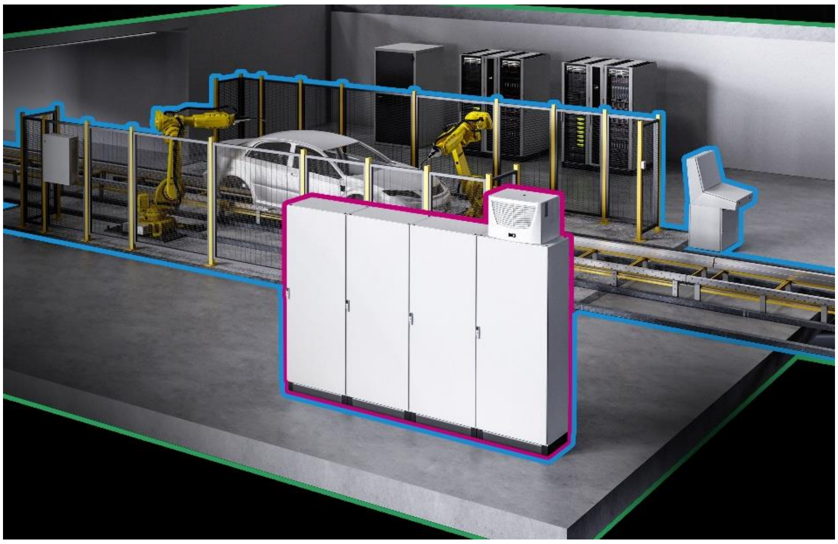


Figure 1
Production area with enclosures for electrical equipment

In most cases, the structure of modern electrical systems consists of the control system, energy distribution and the IT network.

The devices used for controlled power distribution and for exchanging and processing information are housed in enclosures that are designed to provide multiple protection:

This means protection against

- Unallowed access to the device
- Dust and moisture
- Electromagnetic interference
- Contact with dangerous voltage in the event of a fault

This White Paper focuses on measures against electromagnetic interference in and on enclosures for process-related machines and systems, as well as power distribution systems.

Measures against electromagnetic interference in and on enclosures for process-related machines and systems, as well as power distribution systems.

1. The fundamentals

> The high packing density of the electronic components, greater signal processing speeds and lower signal levels are making technology increasingly sensitive.

1.1 The threat

Increasing attention is now being paid to electromagnetic compatibility when selecting housings and enclosures.

Errors frequently occur in complex systems, which can be attributed to electromagnetic interference because of the high packing densities in instrumentation and control electronics, ever higher signal processing speeds and the ever-lower signal levels of the electronic circuits used.

Here are two examples:

- Failure of the control system of a press when a mobile radio device is transmitting
- Error message from a BUS system when a cooling device is switched on

there are numerous international standards and regulations that define limit values for interference emissions and criteria for interference immunity to protect material and personnel from the effects of electromagnetic interference. Compliance with these standards is documented by appropriate identifications on the devices or systems.

The (protective) aim of these standards and regulations is summarised under the designation “electromagnetic compatibility.”

1.2 Sources of interference

In the enclosure or its environment, electromagnetic influences and disturbance variables may be generated by internal sources of interference (artificial, i.e. technically induced) or external sources of interference (natural, such as lightning or electrostatic discharges, as well as by artificial sources, i.e. technically induced).

Lightning discharges

As has been shown in studies by property insurers, the damage caused by lightning-induced overvoltage surges is far more significant even than the destruction caused by direct strikes.

The lightning strike's intensity depends on the distance from its point of impact. We can distinguish between direct, close and remote impact.

In the event of a direct or close strike, the magnetic field of the leakage current (lightning path, partial current paths via the earthing system) induces overvoltages in conductor loops and/or generates them via the earthing resistance (= increase in the earth potential).

In the event of a remote impact, travelling waves of overvoltage are generated by direct strikes in high-voltage overhead lines or by the influence of cloud-to-cloud lightning strikes that propagate along the overhead lines.

Besides these overvoltages, every lightning strike also generates an electromagnetic pulse, a transient electromagnetic field (LEMP - lightning electro-magnetic pulse, with a frequency spectrum in the kHz to MHz range. This LEMP can generate disruptive or even destructive voltages in signal circuits.

Electrostatic discharges

Electrostatic charges may arise when solid substances come into contact and rub against one another.
On surfaces with good conductivity, they are quickly discharged again. In contrast, they may reside for a long time on less conductive surfaces. These charges in non-conductors - as leakage currents - may impair or even destroy electronic components with electrostatic voltages when they touch conductive parts.

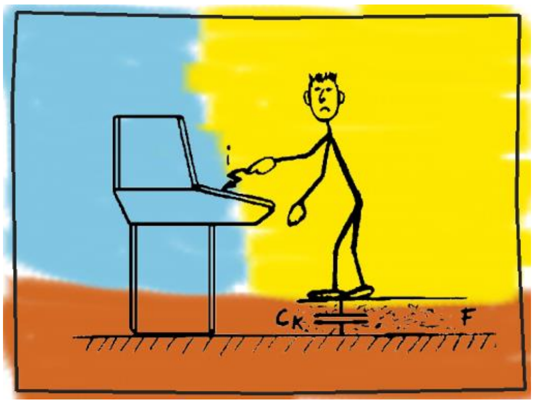


Figure2 Electrostatic charging / discharging

Electrostatic discharges from people onto control components and device housings are particularly significant. The voltages that occur in such cases may be as high as 15000 V, with discharge currents of up to 5 A and with current rise rates of up to 5 kA/μs.

There is a greater risk of malfunctions or damage where there are poorly conductive floor coverings and low air humidity.

Electromagnetic interference sources represent both internal and external threats

Technical sources of interference

Where technically induced interference sources are involved, we must make a distinction between the effects of electromagnetic variables created and used for operational purposes (such as radio transmitters, radar, etc.), and electromagnetic variables occurring in the context of operations or in the event of a fault and which are not deliberately generated (e. g. spark discharges on switch terminals or the magnetic fields generated by high currents, etc.).

Electromagnetic processes in devices and systems may cause periodic continuous interference at frequencies ranging from a few Hz to approx. 100 GHz, e. g.:

- Current converters,
- Switchable power supplies,
- Induction heating systems,
- Radar systems.

or emit randomly occurring interferences (pulses), such as:

- Switching of inductances (transformers, chokes or electric motors)
- Switching power electronic devices on or off
- The ignition processes of arc welding systems
- Contact bouncing on switch terminals

Due to the sources of interference with the highest risk in low-voltage networks (mechanical switching of inductances), then the following interference phenomena may occur in the worst case:

- Switch-off overvoltage at the point of origin, up to 10 kV
- Voltage rise rate, up to 100 V/ns
- Overvoltage rise time, 1 ns to 1 µs
- Rate of voltage decrease for pulses, 2 to 5 kV/ns
- Pulse duration from 100 ns to 1 ms
- Interference voltage values caused on network or data lines, up to 3 kV

The disturbance variables caused by internal or external sources of interference may be voltages, currents, or electrical, magnetic or electromagnetic fields that can either occur continuously, periodically or randomly as pulses.

In both cases, there are narrow-band (frequency spectrum 0 to a few 100 kHz) or broad-band manifestations (a few 10 kHz to a few 100 MHz).

For variables occurring in the form of pulses, the respective frequency spectra can be determined using appropriate calculation methods (Fourier transformation).

1.3 Types of influence

The disturbance variables can affect devices and systems via several coupling mechanisms:

Disturbance variables can affect devices and systems via several different coupling mechanisms:

Conducted influences

- Galvanic coupling
- Capacitive coupling
- Inductive coupling
- Wave interference

Field-bound influences

- Field-bound interference (low-frequency)
- Radiation interference (high-frequency)

Thermal (temperature) switch	30 to 300 kHz
Switching arcs	20 to 200 MHz
Motors	10 to 400 kHz
Switchable power supplies	100 kHz to 30 MHz
Power electronics switching devices	100 kHz to 300 MHz
Relays	10 kHz to 200 MHz

Table 1: Frequency spectra of field-bound disturbance variables

2. EMC tasks

Manufacturers must ensure that their products are designed and manufactured based on EMC requirements and that they conform to standards.

2.1 Tasks of the manufacturers of electrical engineering components, devices and systems

When designing and manufacturing their products, manufacturers must ensure that attention is given to EMC. Moreover, they provide conformity with the standards and thus compliance with the safety objectives set out in the EU’s EMC directive.

2.2 Legal situation and standardisation

The “Council Directive of 3 May 1989 on the harmonisation of the laws of the member states on electromagnetic compatibility, 89/336/EEC” (current version: 2014/30/EU) created a basic document for the EU member states in which EMC is defined as a safety objective for electrical and electronic devices.

This directive has been transposed into national law by corresponding legislation in the member states, so that it is binding throughout the EU.

In Germany, the EMC law regulates the conditions for the market launch, exhibition and operation of devices that can cause electromagnetic interference or whose operation may be impaired by this interference.

The harmonised European regulations are used to assess the compliance of devices with directives.

The standards for EMC have a three-part structure:

Basic standards define the fundamental requirements, as well as the measuring instruments and methods, while generic standards define the requirements for products in specific electromagnetic environments.

The main areas identified are:

- Residential areas, business and commercial areas and small businesses
- Industrial environments

For these areas, specific standards exist in relation to interference emissions

Finally, **product families and product standards** define the special, product-typical measuring arrangements and the operating conditions during measurement, as well as defined interference immunity requirements.

In principle, given this standard hierarchy, the product standard must initially be applied. If there is no corresponding standard for a device or system, then the generic standard shall be binding. The current EMC standards can be found in the Official Journal of the European Union (EU).

The compliance of a device or system with the protection requirements of the EMC directive must be documented by the CE mark.

2.3EMC measures

The EMC directive mentioned above also calls on the device manufacturer to carry out a risk analysis, based on which the necessary measures to achieve the safety objectives can be defined.

The EMC-compliant design considers all the measures for preventing or reducing interference emissions and for achieving a defined interference immunity for the operation of a device or system in a specific environment.

It is possible to distinguish the following EMC measures:

- Filtering and overvoltage protection against conducted influences
- Shielding against field-bound influences

Moreover, EMC-compliant installation in the enclosure plays an important role, with a focus on component placement, cable routing, earthing and potential equalisation in machines and systems, as well as in building technology.

3. Solutions

3.1 Enclosure, requirements and possibilities; enclosure shielding as a contribution to EMC

The contribution of the enclosure to safeguarding EMC is defined by the following objectives:

- Reducing unwanted radiation to avoid disturbances to the environment and to avoid the unlawful reception of security-relevant data
- Reducing radiation from the environment to protect the installed system through a defined shielding effect
- Support for internal EMC measures

The enclosure made of sheet steel offers the user the best possible conditions for implementing controls for machines and systems with good EMC properties in relation to field-related influences.

A restriction does exist for low-frequency magnetic (H) fields, where a good shielding effect can only be achieved by using a suitable material that has specific material properties (high relative permeability µR), such as “Mumetal.” This is of great practical importance, for example, in medical devices like EEGs or ECGs.

Shielding attenuation measurements are carried out as per IEC 61000-5-7 or IEC TS 61587-3 to assess the shielding properties of basic (empty) enclosures. These measurements allow a qualitative statement to be made.

Quantitative statements can only be determined by checking the finished enclosure, including the components installed in it, during operation. This is necessary, for example, to document compliance with specific limit values from the respectively applicable regulations, e. g. radio interference suppression of information technology equipment (ITE) under EN 55022.

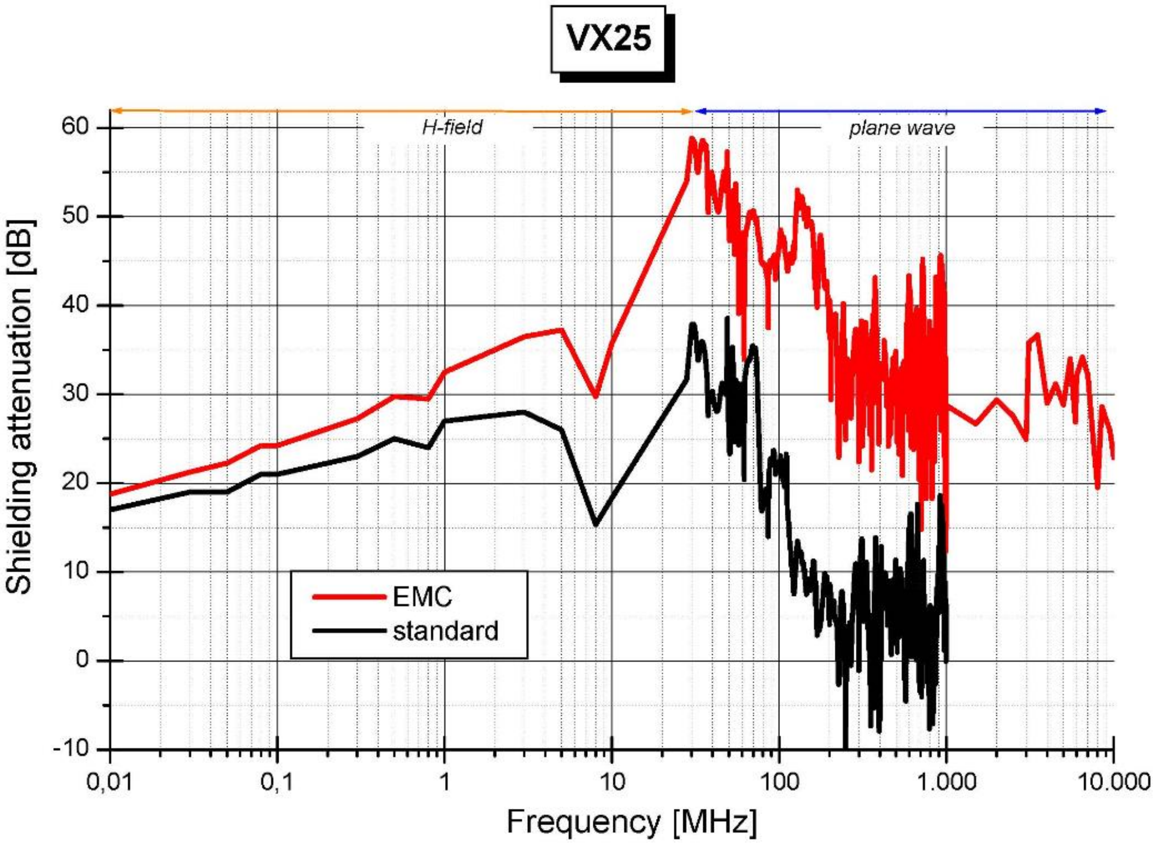
The aim of optimum RF shielding is to achieve the best possible slot-free conductive connection of all the outer surfaces of the enclosure to each other to dissipate the high-frequency currents generated by impinging electromagnetic fields.

Removable walls, doors that open and cut-outs for fitted elements must be considered. With sheet steel enclosures, corrosion protection must not be neglected either.

Every metal enclosure already offers good primary shielding in a broad frequency range. It attenuates electromagnetic fields, although often not enough to meet the requirements in high-frequency ranges (see the attenuation diagram, Fig. 3). Often, on removable or openable parts, only one potential equalisation connection exists.

For large enclosures, better shielding attenuation can be achieved by using cost-effective measures to create multiple conductive connections between all the enclosure parts, for instance, using direct contacts in the Rittal VX25 enclosure system.

High shielding attenuation levels in the frequency range up to 1 GHz can be achieved via special seals that conductively connect the blank metallic inner surfaces of doors and removable side panels, as well as roof and gland plates to the conductive sealing edges of the enclosure body or frame, mostly without using slots. The higher the frequencies that arise, the more critical the openings in the enclosure become. For this reason, several points also need to be observed when machining the enclosures, such as the use of special gaskets for the devices/components installed as well as the use of cable glands or filter connectors.



Explanations:

The *RF attenuation (dB),* abbreviated as ***a*** (dB), gives the ratio between the field in the surroundings - electric (E), magnetic (H) or electromagnetic (plane wave) - and the field inside the enclosure, on a logarithmic scale.

a = 20 log E0/E1 or a = 20 log H0/H1

with index 0 for the unattenuated values and index 1 for the shielded values

Figure 3 Attenuation diagram

- Conductive gasket between the enclosure and the removable panels
- Shielded windows to be kept as small as possible.
- Potential equalisation via suitable rails
- Climate control openings with RF filters
- Mains filter/overvoltage protection, contacted over a large area at the point of entry
- Unshielded signal lines leading through filter bushings connected to the enclosure's point of entry
- Shielded cables via EMC cable glands
- Possibly an enclosure within an enclosure

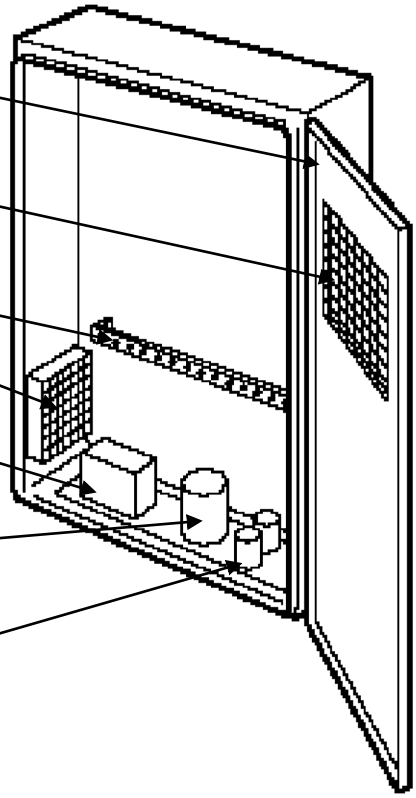


Figure 4 EMC-compliant design (high shielding effect) and assembly of an enclosure

For a detailed consideration of which solution to choose, we need to know the requirements for the enclosure regarding the type of field (electric field, magnetic field or electromagnetic field), the frequency range (e. g. from 100 MHz - 1000 MHz) and the shielding effect required (Attenuation "a") and other mechanical requirements (e. g. cut-outs for climate control, viewing windows, etc.), see Fig. 4.

3.2 Accessories

As already mentioned above, cable entries and cut-outs for operating and display elements and/or climate control components for enclosures with high shielding attenuation values must also be included in the shielding. In the simplest case, suitable shielded parts are used, whose conductive connection to the enclosure is already established during the installation phase. Otherwise, design solutions must be developed, depending on the requirements.

Otherwise, design solutions must be developed, depending on the requirements.

Viewing windows and doors

Devices and system parts that contain display elements can be arranged behind shielded panes. Here, it is to be recommended to keep the necessary visible area as small as possible.

Climate control components

When installing climate control components, appropriate screen grids, the openings needed for ventilation with shielding against electromagnetic fields can be provided by perforated sheets or honeycomb-structured inserts.

Cable entry

Suitable shielded or EMC screw connections are available for inserting shielded cables in RF-shielded enclosures that provide an all-round contact between the cable shield and the enclosure's conductive outer surface without breaking the braided screen.

Even if no improved shielding effect is needed, the potential equalisation of the cable shield at the cable entry point can be enabled when using shielded cables, for instance, when using frequency converters.

The insertion of unshielded cables can be performed in an EMC-compliant way by using filter bushings and filter connectors, which are offered in a wide range of voltages and performances.

3.3 Interior installation and EMC-compliant installation

Placement of components, potential equalisation and correct cable routing ensure EMC-compliant interior installation.

EMC-compliant interior installation is guaranteed by the spatial separation/placement of the components, potential equalisation and cable routing.

Spatial separation is preferably implemented by placement based on an EMC zone model, in which the components are divided into the functional groups of feed/mains connection, control and communication technology, sensor technology and power electronics, and are accordingly structured. The principle of placing power and signal processing are placed as far apart from each other as possible must be observed.

The also applies to the cabling; in other words, the spatial separation of the power cables and the signal-carrying cables is desirable. These two categories of cable should not be routed in parallel without adequate cable shielding or shielding provided by cable ducts.

The potential equalisation needs to be made possible with as low an impedance as possible through short, large-area connections and tight meshing.

It is not always necessary to shield the whole enclosure. Frequently, a more cost-effective solution to the EMC requirements can be realised by shielding system parts in subracks of the 482.6 mm (19-inch) mounting system or with shielded small enclosures within the larger enclosure.

In addition, the large-area, low-inductance potential equalisation is supported within the enclosure to achieve EMC, for example by suitable potential equalisation rails, potential equalisation strips, terminals and bare metal mounting plates.

4. Summary

In most industrial enclosure applications, EMC can be achieved by adhering to a few fundamental principles during assembly and installation and with the shielding effect that is normally already present in metal enclosures. The use of frequency converters does not represent a different situation.

However, special sensitivity is desirable in relation to the requirements if there are any indications of strong fields of interference at the installation site, for example from spark erosion machines, high-frequency welding systems, or from the application itself, for instance radar or satellite communication, etc. In such cases, an RF-shielded enclosure must be urgently planned as an additional EMC measure.

Optimisation of the EMC is only possible with a combination of every possible measure and aid such as a choice of enclosure, installation rules as well as filters and surge protection. In such cases, an EMC analysis of the planned application is crucial.

> Optimisation of the EMC is only possible with a combination of measures, a choice of enclosure, installation rules, as well as filters and surge protection.

Directory of figures, tables and sources

Directory of figures

Directory of tables

Directory of sources

Ref. 1 Rittal Whitepaper: “Rittal TS IT network and server enclosures”, Link: http://www.rittal.com/imf/none/5_1962/Rittal_Whitepaper_TS_IT_5_1962

Ref. 2 Rittal TS IT Installation and Operating Instructions, Link: http://www.rittal.com/imf/none/5_619/Rittal_TS_IT_Montage-_und_Bedienungsanleitung_Assembly_an_5_619

Glossary

AC: Alternating Current

DC: Direct Current

EMC: Electromagnetic Compatibility

IT: Information Technology or also the (*isolé terre*) type of earthing: direct earthing of the body of a piece of equipment, a system of energy distribution

FO: Fibre-optics

PE: Protective Earth (cable)

PEN: Protective Earth Neutral - combined protective conductor and (floating) neutral conductor

MESH-BN: Meshed Bonding Network (meshed potential equalisation system)

NSHV: Low-voltage switchgear distributor

RCD: Residual Current Device (residual current circuit breaker)

TN-C: A type of earthing (*terre* - *neutre* = earth - neutral): *combined* protective conductor and neutral conductor, a system of energy distribution

TN-S: A type of earthing (*terre* - *neutre* = earth - neutral): *separate* protective conductor and neutral conductor, a system of energy distribution

TT: A type of earthing (*terre* - *terre* = earth -earth): direct earthing of a current source point and the body of the equipment, a system of energy distribution

Rittal – Das System.

Schneller – besser – überall.

- Enclosures
- Power distribution
- Climate control
- IT infrastructure
- Software & Services

You can find the contact details of all
Rittal companies throughout the world here.

www.rittal.com/contact

8.2020

RITTAL GmbH & Co. KG
Auf dem Stützelberg · 35726 Herborn · Germany
Phone +49 (0)2772 505-0 · Fax +49 (0)2772 505-2319
E-mail: info@rittal.de · www.rittal.com

SCHALTSCHRÄNKE STROMVERTEILUNG KLIMATISIERUNG IT-INFRASTRUKTUR SOFTWARE & SERVICE

FRIEDHELM LOH GROUP