

TECHNICAL SPECIFICATION



**Recommendations for small renewable energy and hybrid systems for rural electrification –
Part 5: Protection against electrical hazards**



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**Recommendations for small renewable energy and hybrid systems for rural electrification –
Part 5: Protection against electrical hazards**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RECOMMENDATIONS FOR SMALL RENEWABLE ENERGY
AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –****Part 5: Protection against electrical hazards**

FOREWORD

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 62257-5, which is a technical specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This document is based on IEC/PAS 62111(1997); it cancels and replaces the relevant parts of IEC/PAS 62111.

This technical specification is to be used in conjunction with IEC 62257 series.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
82/370/DTS	82/390/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

IEC 62257 consists of the following parts, under the general title *Recommendations for small renewable energy and hybrid systems for rural electrification*:

- Part 1: General introduction to rural electrification
- Part 2: From requirements to a range of electrification systems
- Part 3: Project development and management
- Part 4: System selection and design
- Part 5: Protection against electrical hazards
- Part 6: Acceptance, operation, maintenance and replacement
- Part 7: Technical specifications: generators ¹
- Part 8: Technical specifications: batteries and converters ¹
- Part 9: Technical specifications: integrated systems ¹
- Part 10: Technical specifications: energy manager ¹
- Part 11: Technical specifications: considerations for grid connection ¹
- Part 12: Appliances ¹
- Part 13: Other topics ¹

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard ²,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual edition of this publication may be issued at a later date.

IMPORTANT – The “colour inside” logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

¹ Under consideration.

² This text is standard IEC text but it is not the intention of IEC technical committee 82 to convert this into an IEC standard. This might be done by another body at a later date, if needed.

INTRODUCTION

The IEC 62257 series of documents intends to provide to different players involved in rural electrification projects (such as project implementers, project contractors, project supervisors, installers, etc.) documents for the setting up of renewable energy and hybrid systems with a.c. nominal voltage below 500 V, d.c. nominal voltage below 750 V and nominal power below 100 kVA.

These documents are recommendations:

- to choose the right system for the right place,
- to design the system,
- to operate and maintain the system.

These documents are focused only on rural electrification concentrating on but not specific to developing countries. They should not be considered as all inclusive to rural electrification. The documents try to promote the use of renewable energies in rural electrification; they do not deal with clean mechanisms developments at this time (CO₂ emission, carbon credit, etc.). Further developments in this field could be introduced in future steps.

This consistent set of documents is best considered as a whole with different parts corresponding to items for safety, sustainability of systems and at the lowest life cycle cost as possible. One of the main objectives is to provide the minimum sufficient requirements, relevant to the field of application that is: small renewable energy and hybrid off-grid systems.

The purpose of this part of IEC 62257 is to specify the general requirements for the protection of persons and equipment against electrical hazards to be applied in decentralized rural electrification systems.

RECOMMENDATIONS FOR SMALL RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 5: Protection against electrical hazards

1 Scope

Decentralized Rural Electrification Systems (DRES) are designed to supply electric power for sites which are not connected to a large interconnected system, or a national grid, in order to meet basic needs.

The majority of these sites are:

- isolated dwellings,
- village houses,
- community services (public lighting, pumping, health centers, places of worship or cultural activities, administrative buildings, etc.),
- economic activities (workshops, micro-industry, etc.).

The DRE systems fall into three categories:

- process electrification systems (for example for pumping),
- individual electrification systems (IES) for single users,
- collective electrification systems (CES) for multiple users.

Process or individual electrification systems exclusively consist of two subsystems:

- an electric energy generation subsystem,
- the user's electrical installation.

Collective electrification systems, however, consist of 3 subsystems:

- an electric energy generation subsystem,
- a distribution subsystem, also called micro-grid,
- user's electrical installations including interface equipment between the installations and the micro-grid.

The purpose of this document is to specify the general requirements for the protection of persons and equipment against electrical hazards to be applied in decentralised rural electrification systems. Requirements dealing with protection against electric shock are based on basic rules from IEC 61140 and IEC 60364.

These general requirements are to be applied to all the identified categories of DRES. Application to each subsystem of a DRES is dealt within a specific section of IEC 62257-9.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-826, *International Electrotechnical Vocabulary (IEV) – Part 826: Electrical installations*

IEC 60364 (all parts), *Electrical installations of buildings*

IEC 61024-1:1990, *Protection of structures against lightning – Part 1: General principles*

IEC 61140:1997, *Protection against electric shock – Common aspects for installation and equipment*

IEC 62257-1, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 1: General introduction to rural electrification*

IEC 62257-2, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 2: From requirements to a range of electrification systems*

IEC 62257-3, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 3: Project development and management*

IEC 62257-4, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 4: System selection and design*

IEC 62257-5, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 5: Safety rules*

IEC 62257-6, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 6: Acceptance, operation, maintenance and replacement*

IEC 62257-7, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 7: Technical specifications: generators*³

IEC 62257-8, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 8: Technical specifications: batteries and converters*³

IEC 62257-9, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 9: Technical specifications: integrated systems*³

IEC 62257-10, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 10: Technical specifications: energy manager*³

IEC 62257-11, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 11: Technical specifications: considerations for grid connection*³

IEC 62257-12, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 12: Appliances*³

IEC 62257-13, *Recommendations for small renewable energy and hybrid systems for rural electrification – Part 13: Other topics*³

IEC 62305-2:2005, *Protection against lightning – Part 2: Risk management*

³ Under consideration.

3 Terms and definitions

For the purpose of this part of IEC 62257, the following terms and definitions apply.

3.1

DRES

decentralized rural electrification system

3.2

REN

renewable energy

3.3

micro-grid

subsystem of a DRES intended for power distribution

NOTE The prefix «micro» being intended to express the low level of transmitting capacity, usually less than 50 kVA.

3.4

micro-powerplant

subsystem of a DRES intended for power generation. The prefix «micro» being intended to express the low power level generated (from a few kVA to a few tens of kVA)

3.5

SPD

Surge Protection Device

4 Classification of decentralised rural electrification systems

DRES are classified into six different types. See Table 1.

Table 1 – Typology of decentralized electrification systems

Type of generator	Classification of associated systems	
	Individual	Collective
REN only, hybrid or not no storage	T _{1.I}	T _{1.C}
REN only, hybrid or not storage	T _{2.I}	T _{2.C}
REN, hybrid or not plus Genset no storage	T _{3.I}	T _{3.C}
REN, hybrid or not plus Genset storage	T _{4.I}	T _{4.C}
Genset only no storage	T _{5.I}	T _{5.C}
Genset only storage	T _{6.I}	T _{6.C}
Notation principle: T _{i.I} = individual system, type i; T _{j.C} = collective system, type j. "Storage" = storage of energy produced by one of the generator of the system and which can be reconverted.		

Architecture and characteristics of the different electrification system types are developed in Clause 6 of IEC 62257-2.

5 Protection against electric shock

5.1 General

Basic rules for protection against electric shock are given in IEC 61140 and IEC 60364-4-41. Information is also available in Annex A.

5.2 Requirements on the d.c. side of a DRES

The principles for the design and erection of a d.c. electrical circuit are similar to those for an a.c. circuit. The main differences concern short-circuit current calculation and the selection of the protective devices.

Protection by extra-low voltage (SELV and PELV systems) or protection by double or reinforced insulation should preferably be adopted on the d.c. side of DRES.

NOTE Protection by automatic disconnection of supply on the d.c. side requires special measures which are under consideration.

Simple separation, at least, should be provided between the a.c. side and the d.c. side unless the inverter is not able, by construction, to feed d.c. fault current into the a.c. installation.

Earthing of one of the live conductors of the d.c. side is permitted, if there is at least simple separation between the d.c. side and the a.c. side.

5.3 Requirements on the a.c. side of a DRES

5.3.1 General

Protection by use of automatic disconnection of supply should preferably be adopted on the a.c. side of a DRES. For each circuit, maximum disconnecting times given in IEC 60364-4-41 should apply.

TN-S system should preferably be used for user's installations, TN-S or TN-C system being preferably used for the micro-grid.

TT system is acceptable. IT system is normally not used for DRES and has hence not been dealt with in this specification.

A residual current protective device, with a rated operating residual current not exceeding 30 mA, should be provided as additional protection for each installation or for a group of installations.

5.3.2 TT system

Basic protection is provided by basic insulation of live parts or by barriers or enclosures. Fault protection is provided by residual current devices regarding the resistance value of the earth electrode to which the PE conductor is connected. The fault current should be high enough to activate the differential current device. The rated operating residual current $I_{\Delta n}$ of the device should fulfil the formula:

$$I_{\Delta n} \leq \frac{U_L}{R_A} \quad \text{with} \quad U_L = 50 \text{ V}$$

where U_L is the conventional maximum voltage and R_A is the earthing resistance.

This formula results in the values shown in Table 2.

Table 2 – Rated operating residual current of the protective device depending on the value of the earthing resistance

R_A Ω	$I_{\Delta n}$ A
$R_A \leq 50$	1
$50 < R_A \leq 100$	0,5
$100 < R_A \leq 167$	0,3
$167 < R_A \leq 300$	0,1
$300 < R_A \leq 500$	0,03

5.3.3 TN system

Basic protection is provided by basic insulation of live parts or by barriers or enclosures. Fault protection is provided by devices protecting against over-currents.

Additional information is given in Annexes A and B.

6 Protection against overcurrent

6.1 General

Protective devices should be provided to break any over-current flowing in the circuit conductors before such a current could cause a danger due to thermal and mechanical effects or a temperature rise detrimental to insulation, joints, termination (see IEC 60364-4-43).

6.2 Protection against overload currents

The operating characteristics of a device protecting a cable against overload current should satisfy the two following conditions:

$$I_b \leq I_n \leq I_z$$

$$I_2 \leq 1,45 \times I_z$$

where

- I_b is the current for which the circuit is designed;
- I_z is the continuous current-carrying capacity of the cable;
- I_n is the nominal current of the protective device;
- I_2 is the current ensuring effective operation in the conventional time of the protective device.

6.3 Protection against short-circuits

For cables and isolated conductors, each short-circuit protective device should meet both of the following conditions:

- The breaking capacity should not be less than the prospective short-circuit current at the place of its installation, except where another protective device having the necessary breaking capacity and coordinated characteristics is installed upstream.

- All current caused by a short-circuit occurring at any point of the circuit should be interrupted in a time not exceeding that which brings the conductors to the admissible limit temperature. For short-circuits of duration up to 5 s, the time t , in which a given short-circuit current will raise the conductors from the highest admissible temperature in normal duty to the limit temperature can, as an approximation, be calculated from the formula:

$$\sqrt{t} = k \times S/I$$

where

t is the duration in s;

S is the cross-sectional area, in square millimetres;

I is the effective short-circuit current, in amperes, expressed as r.m.s. value;

k is a factor taking account of the resistivity, temperature coefficient and heat capacity of the conductor material, and the appropriate initial and final temperatures.

7 Protection against risk of fire

Where there is a risk of personal injury or property damage due to fire caused by an earth fault in the system, a residual current protective device should be provided at least at the entry to the user's installation. Its rated operating residual current should be ≤ 300 mA. Such a device should switch all live conductors.

8 Protection against effects of lightning

8.1 Principle

Information about the effects of lightning on electrical supply systems is given in Annex D.

Decision for lightning protective provision (lightning rod, surge protective devices, ...) should be based on risk assessment, taking account of the lightning frequency statistics, the characteristics and position of the structures, the length of the overhead lines, if any, the cost and the requested availability of the equipment.

Examples of risk assessment methods appropriate for lightning protection can be found in the draft IEC 60364-4-44:2001, Clause 443 and IEC 62305-2:2005.

8.2 Provisions for lightning protection of DRES

8.2.1 Protection against overvoltages

Where protection against overvoltages (for example due to indirect lightning) is required, an SPD(s) should be installed both at the distribution board of the micro-power plant, and at the entry point of the user's installations or associated with each socket-outlet.

Installation of SPD should comply with IEC 60364-5-53, Clause 534.

To minimize voltages induced by lightning, the area of all wiring loops should be as small as possible.

8.2.2 Protection against direct lightning

Where protection against direct lightning is required, the following provisions apply:

- In case of wind powered generation, the lightning rod should be installed at the summit of the mast.

- Where PV generation coexists with wind-powered generation, protection against direct lightning is generally achieved by placing the panels inside the pick-up zone of the wind-powered generator mast.
- Where PV generation is alone, the panels can be protected by installing a protective wire above the PV panel with an appropriate pick-up area.
- Protection should be completed by the installation of SPDs between conductors and between conductors and earth, with appropriate characteristics (see IEC 60364-5-53, Clause 534).

Determination of the pick up area of a rod or wire should be achieved according to IEC 61024-1.

9 Selection and erection of electrical equipment

9.1 General

All equipment should be selected according to the rules of IEC 60364-5-53.

9.2 Operational conditions and external influences

Every item of equipment should be selected and erected in compliance with the appropriate standards.

Equipment should be suitable for the nominal voltage (r.m.s. value for a.c.) of the circuit concerned and for the overvoltages which could occur.

Equipment should be selected for the design current (r.m.s. value for a.c.) which it has to carry in normal service.

Equipment on the d.c. side should be suitable for direct voltage and direct current.

Equipment should also be capable of carrying the currents likely to flow in abnormal conditions for such periods of time as are determined by the characteristics of the protective devices.

If frequency has an influence on the characteristics of equipment, the rated frequency of the equipment should correspond to the frequency and frequency variations which could occur in the circuit concerned.

The electrical equipment should withstand the expected external influences such as wind, ice formation, temperature and solar radiation, etc. If a piece of equipment does not have, by construction, the necessary qualities corresponding to the location in which it is installed, appropriate additional protection should be provided, forming part of the installation.

Electrical equipment should be selected and erected so that it does not produce, in normal service, any interference with the other equipment in the system. The causes of interference include:

- power factor,
- inrush current,
- phase unbalance (three-phase systems),
- harmonics.

9.3 Wiring system

The minimum cross-sectional area of protective conductors should be determined according IEC 60364-5-54.

The minimum cross sectional area of conductors should be determined according to:

- The current-carrying capacity of conductors taking account of external influences and of the methods of installation. See tables in IEC 60364-5-52.
- The acceptable voltage drop in conductors. Voltage value should comply with the following limits at the terminals of any user's electrical equipment:

$$230 V_{a.c.} \pm 10 \%$$

NOTE A wider range of voltage variation (up to 20 %) may be accepted regarding the agreed target for power quality (see IEC 62257-2).

$$12/24 V_{d.c.} \left(\begin{smallmatrix} +20 \\ -15 \end{smallmatrix} \right) \%$$

9.4 Isolation and switching

9.4.1 Isolation

The purpose of isolation is to separate a circuit or equipment unit from the rest of the system in order to guarantee the safety of persons who may have to work on, to maintain or repair it.

Every circuit should be capable of being isolated.

In TN-C systems, the PEN conductor should not be interrupted (broken, switched or disconnected). In TN-S systems, the neutral conductor need not be interrupted.

Suitable means (padlocking, location within lockable enclosure, etc.) should be provided to prevent any equipment from being unintentionally energised.

The isolating distance between open contacts should be visible or clearly and reliably indicated.

9.4.2 Over-current protective devices

9.4.2.1 General

Fuses (gG type) or circuit-breakers with appropriate range of instantaneous tripping should be used.

The range of instantaneous tripping for a circuit-breaker should be selected according to the prospective short-circuit current.

Over-current protective devices should be preferably of a type ensuring protection against both overload and short-circuit currents and capable of acting as isolating switch in the open position.

Special attention should be paid to over-current protective devices installed in series, to ensure that an appropriate coordination is achieved. Selectivity between protective devices in series should preferably be total.

9.4.2.2 AC over-current protective devices

The number of protected poles depends on the neutral earthing distribution system and on the cross-sectional area the neutral conductor, in accordance with Table 3.

NOTE A protected pole is a pole provided with an over-current release.

Table 3 – Number of protected poles with regard to the characteristics of the distribution system

Neutral earthing distribution system	Conductors	Cross-sectional area of the neutral conductor	Protected poles	Conditions
TT or TN-S	3 ph		3 ph	
	3 ph + N	$S_N = S_{ph}$	3 ph or 3 ph + N	
	ph + N	$S_N = S_{ph}$	ph or ph + N	
	3 ph + N	$S_N < S_{ph}$	3 ph	1 + 2 + 3 + 4
	3 ph + N	$S_N < S_{ph}$	3 ph + N	1 + 2 + 3
TN-C	3 ph + PEN	$S_N = S_{ph}$	3 ph	
	3 ph + PEN	$S_N < S_{ph}$	3 ph	1 + 2 + 3 + 4
	ph + PEN	$S_N = S_{ph}$	ph	
Conditions: 1: The cross-sectional area of the conductors is $>16 \text{ mm}^2 \text{ Cu}$ or $>25 \text{ mm}^2 \text{ Al}$. 2: The power consumed between phases and neutral is $<10 \%$ of the total power transmitted by the mains. 3: The maximum current expected to flow in the neutral conductor is less than its permissible current. 4: The neutral conductor is protected against short-circuits by the steps taken to protect the phase conductors.				

9.4.2.3 DC over-current protective devices

For the selection of d.c. overcurrent protective devices, it is recommended to be assisted by the manufacturer after having determined and transmitted the characteristics of the circuit (short-circuit current, rated current, time constant).

NOTE For calculation of the short-circuit current in case of a battery whose internal resistance is not known, the following formula may be used:

$$I_k = 10 \times C$$

C in A/h.

For calculation of the short-circuit current at the terminals of a d.c. generator, the following formula may be used:

$$I_k = 1,1 \times U_n / R_i$$

R_i is the internal resistance of the generator.

For calculation of the short-circuit current at any point of the installation, the following formula may be used:

$$I_k = 1,1 \times U_n / (R_i + 2R_L)$$

R_L is the line resistance.

And in case of the presence of a d.c. motor, the value of I_k , here above is increased by the value of $6I_N$ of the motor.

9.4.3 Residual Current protective Devices (RCD)

Residual current devices should be so selected, and the electric circuits so subdivided that any earth-leakage current which may be expected to occur during normal operation of the connected load(s) will be unlikely to cause unnecessary tripping of the device.

NOTE Residual current protective devices may operate at any value of residual current in excess of 50 % of the rated operating current.

Residual current protective devices in d.c. systems should be specially designed for detection of d.c. residual currents, and to break circuit currents under normal conditions and fault conditions.

For the systems concerned, RCDs installed upstream surge protective devices should be of type S, in order to allow service continuity.

9.5 Surge protective devices

The selection and erection of SPDs should comply with IEC 60364-5-53, Clause 534.

The following are the leading parameters needed to select SPDs (see also Annex 3):

UP = protection level for nominal current (for example 2,5 kV, 1,5 kV).

UC = continuous service voltage to be chosen on the basis of mains nominal voltage.

I_{nominal} (8/20 wave) = nominal discharge current. Standard values: 20 kA, 10 kA, 5 kA, etc.

Use of SPDs in presence of harmonics (e.g. where non sine-wave inverters are used) is problematic. Due to harmonics, the ageing of varistors is accelerated. The solution consists in installing SPDs including internal spark-gaps in series with the varistor (SiC or ZnO).

9.6 Earthing arrangement, protective conductors and protective bonding conductors

9.6.1 Earth electrodes

9.6.1.1 General

Materials and dimensions of the earth electrodes should be selected to withstand corrosion and to have mechanical strength.

When selecting type and embedded depth of earth electrode, consideration should be given to local conditions so that soil drying and freezing will be unlikely to increase the earth resistance of the earth electrode to such a value that would impair the protective measures against electric shock.

9.6.1.2 Earth electrodes for the supply system

Examples of earth electrodes which may be used are:

- underground structural network embedded in foundations (foundation earthing),
- rods or pipes,
- tapes or wires,
- metal sheaths and other metal coverings of cables according to local conditions or requirements,
- plates.

Where possible, a foundation earthing should be preferred.

Common minimum sizes for earth electrodes of commonly used material can be found in IEC 60364-5-54.

9.6.1.3 Earth termination (electrode) of a lightning protection system

In order to disperse the lightning current into the earth without causing dangerous overvoltages, the shape and the dimensions of the earth termination system of an LPS are more important than the value of the resistance of the earth electrode (characteristic applicable for d.c. or low frequency phenomena).

The earth termination system should be composed of:

- either conductors of the same nature and same cross-section as the down-conductors (in general, 30 mm × 2 mm copper strip) laid out in the form of a large crow's foot: 3 conductors 7 m to 8 m long buried horizontally at a depth of at least 0,60 m,

- or a set of 3 vertical rods 2 m in length connected together and set out at the apexes of an equilateral triangle with sides measuring about 2 m.

The earth termination system of the LPS should be bonded to the earthing arrangement with short connexions.

9.6.1.4 Application to the protection of an ENR power system

The wind-powered generator and/or the frame of the PV panels should be earthed by a crow's foot earth electrode with the lowest possible resistance (a $10\ \Omega$ at 50 Hz is frequently adopted). This earth electrode should be bonded, with short connexions, to the earthing arrangement of the technical rooms housing the other equipment of the installation.

9.6.2 Protective bonding conductors

Where protective equipotential bonding conductors are installed, they should be parallel to and in close contact as possible with d.c. cables and a.c. cables and accessories (IEC 60364-7-712).

10 Verification

See IEC 62257-6.

11 Operation and maintenance

See IEC 62257-6.

Annex A (informative)

Protection against electric shock in electrical installations (for complete information, see IEC 61140 and IEC 60364-4-41)

A.1 Terms and definitions

For the purposes of this Annex, the following terms and definitions, taken from IEC 60050-195, apply.

A.1.1

protection against electric shock

provision of measures reducing the risk of electric shock

A.1.2

basic protection

protection against electric shock under fault-free conditions

A.1.3

fault protection

protection against electric shock under single-fault conditions

A.1.4

direct contact

electric contact of persons or animals with live parts

A.1.5

indirect contact

electric contact of persons or animals with exposed-conductive-parts which have become live under fault conditions

A.1.6

hazardous-live-part

live part which, under certain conditions, can give a harmful electric shock

A.2 Protection against electric shock

The fundamental rule of protection against electric shock, according to IEC 61140, is that hazardous-live-parts should not be accessible and accessible conductive parts should not be hazardous live either under normal conditions or under single fault conditions.

According to IEC 61140, protection under normal conditions is provided by basic protective provisions and protection under single fault conditions is provided by fault protective provisions. Alternatively, protection against electric shock is provided by an enhanced protective provision which provides protection under normal conditions and under single fault conditions.

NOTE Formerly, protection under normal conditions was referred to as protection against direct contact and protection under single-fault conditions was referred to as protection against indirect contact.

Consequently, a protective measure is:

- an appropriate combination of a basic protective provision and an independent fault protective provision, or
- an enhanced protective provision which provides both basic protection and fault protection.

In each part of an installation, one or more protective measures should be applied. Except otherwise specified, the following protective measures are permitted:

- automatic disconnection of supply,
- double or reinforced insulation,
- electrical separation for the supply of one item of current using equipment,
- extra-low voltage.

The following protective measures

- use of obstacles,
- placing out of reach,

should only be used under the control of skilled or instructed persons.

The following protective measures

- non-conducting location,
- earth-free local equipotential bonding,
- electrical separation for the supply of more than one item of current using equipment,

may be applied only when the installation is under the control of skilled or instructed persons so that unauthorized changes cannot be made.

A.3 Automatic disconnection of supply

A.3.1 General

Automatic disconnection of supply is a protective measure in which:

- basic protection is provided by basic insulation of live parts or by barriers or enclosures, and
- fault protection is provided by automatic disconnection of supply.

NOTE 1 Where specified, additional protection is provided by a residual current protective device with rated residual operating current not exceeding 30 mA.

A protective device should automatically disconnect the supply to the circuit or equipment in the event of a fault of negligible impedance between a live part and an exposed-conductive-part or a protective conductor in the circuit or equipment within the time required.

The maximum disconnection time is given in IEC 60364-4-41.

If automatic disconnection cannot be achieved in the time required as appropriate, supplementary protective equipotential bonding should be provided.

In a.c. systems, additional protection by means of a residual current protective device with rated residual operating current not exceeding 30 mA should be provided for:

- socket-outlets with a rated current not exceeding 20 A, under the supervision of ordinary persons and

NOTE 2 This additional protection may be in the socket-outlets (SRCD) or the circuit supplying the socket-outlet.

NOTE 3 For example, domestic dwellings are normally under the supervision of ordinary persons.

- the final circuits for portable and Class I current-using equipment, with a current rating not exceeding 32 A, for use outdoors where the equipment is connected other than through a socket-outlet.

A.3.2 In TN systems

The characteristics of protective devices and the circuit impedances should fulfil the following requirement:

$$Z_s \times I_a \leq U_0$$

Z_s is the impedance in ohms of the fault loop comprising the source, the live conductor up to the point of the fault and the protective conductor between the point of the fault and the source.

I_a is the current in amps causing the automatic operation of the disconnecting device within the time required. When the protective device is a residual current protective device, this current is the rated residual operating current.

U_0 is the nominal a.c. or d.c. line to earth voltage in volts.

A.3.3 In TT systems

When a residual current device is used for fault protection, the following condition should be fulfilled:

$$R_A \times I_n \leq 50 \text{ V}$$

R_A is the sum of the resistance in ohms of the earth electrode and the protective conductor for the exposed conductive parts.

I_n is the rated residual operating current of the RCD.

NOTE Fault protection is also provided in this case if the fault impedance is not negligible.

When an overcurrent protective device is used for fault protection, the following condition should be fulfilled:

$$Z_s \times I_a \leq U_0$$

Z_s is the impedance in ohms of the fault loop comprising the source, the live conductor up to the point of the fault, the protective conductor of the exposed conductive parts, the earth electrode of the installation and the earth electrode of the source.

I_a is the current in amps causing the automatic operation of the disconnecting device within the time required.

U_0 is the nominal a.c. r.m.s. or ripple-free d.c. voltage in volts to earth.

A.4 Double or reinforced insulation

Double or reinforced insulation is a protective measure in which:

- basic protection is provided by basic insulation, and fault protection is provided by supplementary insulation, or

- basic and fault protection is provided by reinforced insulation between live parts and accessible parts.

NOTE This protective measure is intended to prevent the appearance of dangerous voltage on the accessible parts of electrical equipment through a fault in the basic insulation.

A.5 Extra-low-voltage (SELV and PELV)

Protection by extra-low-voltage is a protective measure which consists of two different extra-low-voltage systems:

- SELV
- PELV

in which protection is provided by:

- limitation of voltage in the SELV or PELV system to 50 V_{a.c.} or 120 V_{d.c.},
- protective separation of the SELV or PELV system from all circuits other than SELV and PELV circuits, and basic insulation between the SELV or PELV system and other SELV or PELV systems.

For SELV systems only, basic insulation is provided between the SELV system and earth.

A.6 Electrical separation

Electrical separation is a protective measure in which:

- basic protection is provided by basic insulation of live parts or by barriers and enclosures,
- fault protection is provided by simple separation of the separated circuit from other circuits.

This protective measure should be limited to the supply of one item of current using equipment supplied from one unearthed source with simple separation.

A.7 Additional protection

The use of residual current protective devices, with a rated operating residual current not exceeding 30 mA, is recognized in a.c. systems as additional protection in the event of failure of other basic protective provisions or carelessness by users.

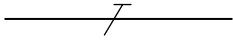
Annex B (informative)

Types of LV distribution systems earthing

B.1 Types of distribution system earthing used in DRES (Figures are from IEC 60364-1)

TN and TT distribution system earthing are taken into account in this specification. IT system is normally not used in DRES.

Figure B.1 to Figure B.4 show examples of commonly used a.c. systems. Figure B.5 to Figure B.8 show examples of commonly used d.c. systems. For the purposes of this Annex, the following symbols are used in Figures B.1 to B.8:

	Neutral conductor (N)
	Protective conductor (PE)
	Combined protective and neutral conductor (PEN)

NOTE The codes used have the following meanings:

First letter – Relationship of the power system to earth:

T = direct connection of one point to earth;

I = all live parts isolated from earth, or one point connected to earth through an impedance.

Second letter – Relationship of the exposed-conductive-parts of the installation to earth:

T = direct electrical connection of exposed-conductive-parts to earth, independently of the earthing of any point of the power system;

N = direct electrical connection of the exposed-conductive-parts to the earthed point of the power system (in a.c. systems, the earthed point of the power system is normally the neutral point or, if a neutral point is not available, a phase conductor).

Subsequent letter(s) (if any) – Arrangement of neutral and protective conductors:

S = protective function provided by a conductor separate from the neutral or from the earthed line (or in a.c. systems, earthed phase) conductor;

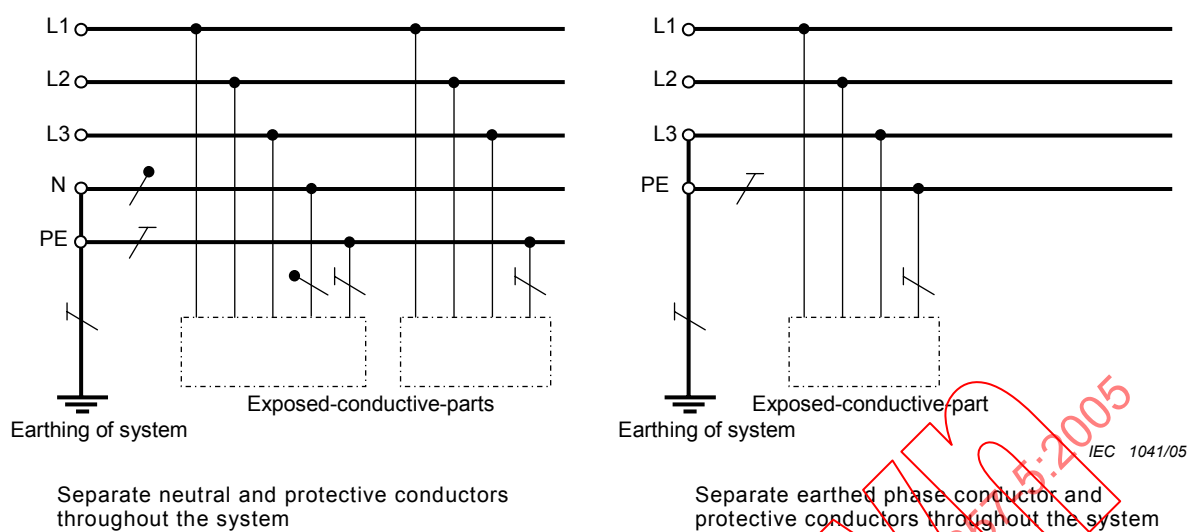
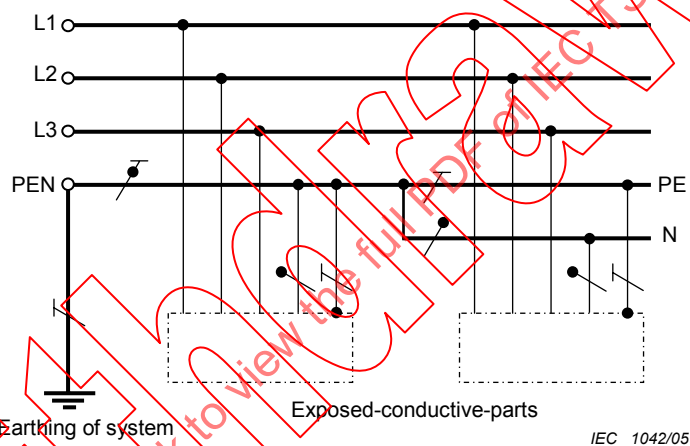
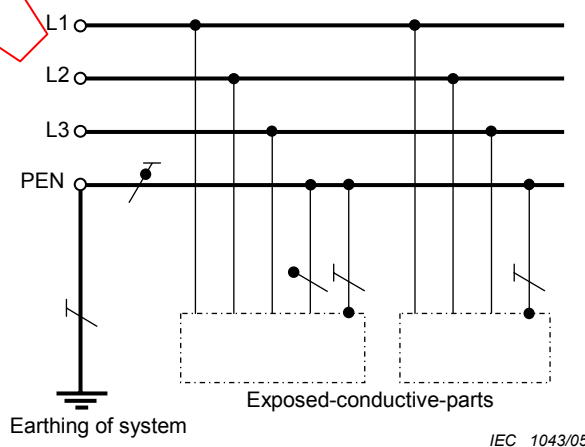
C = neutral and protective functions combined in a single conductor (PEN conductor).

B.2 Type of system earthing for a.c. systems

B.2.1 TN systems

TN power systems have one point directly earthed, the exposed conductive parts of the installation being connected to that point by protective conductors. Three types of TN system are considered according to the arrangement of neutral and protective conductors, as follows:

- TN-S system: in which throughout the system, a separate protective conductor is used;
- TN-C-S system: in which neutral and protective functions are combined in a single conductor in a part of the system;
- TN-C system: in which neutral and protective functions are combined in a single conductor throughout the system.

**Figure B.1 – TN-S system****Figure B.2 – TN-C-S system****Figure B.3 – TN-C system**

B.2.2 TT system

The TT power system has one point directly earthed, the exposed-conductive-parts of the installation being connected to earth electrodes electrically independent of the earth electrodes of the power system.

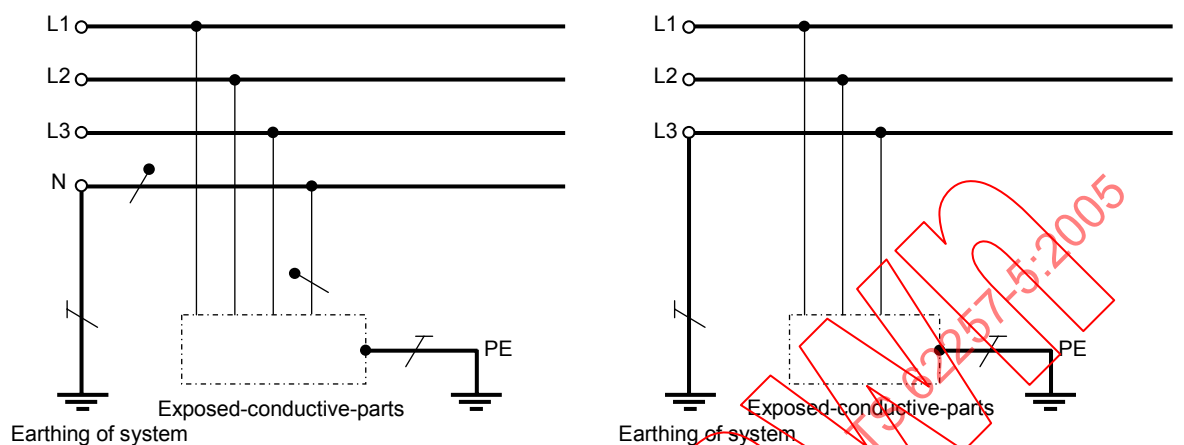
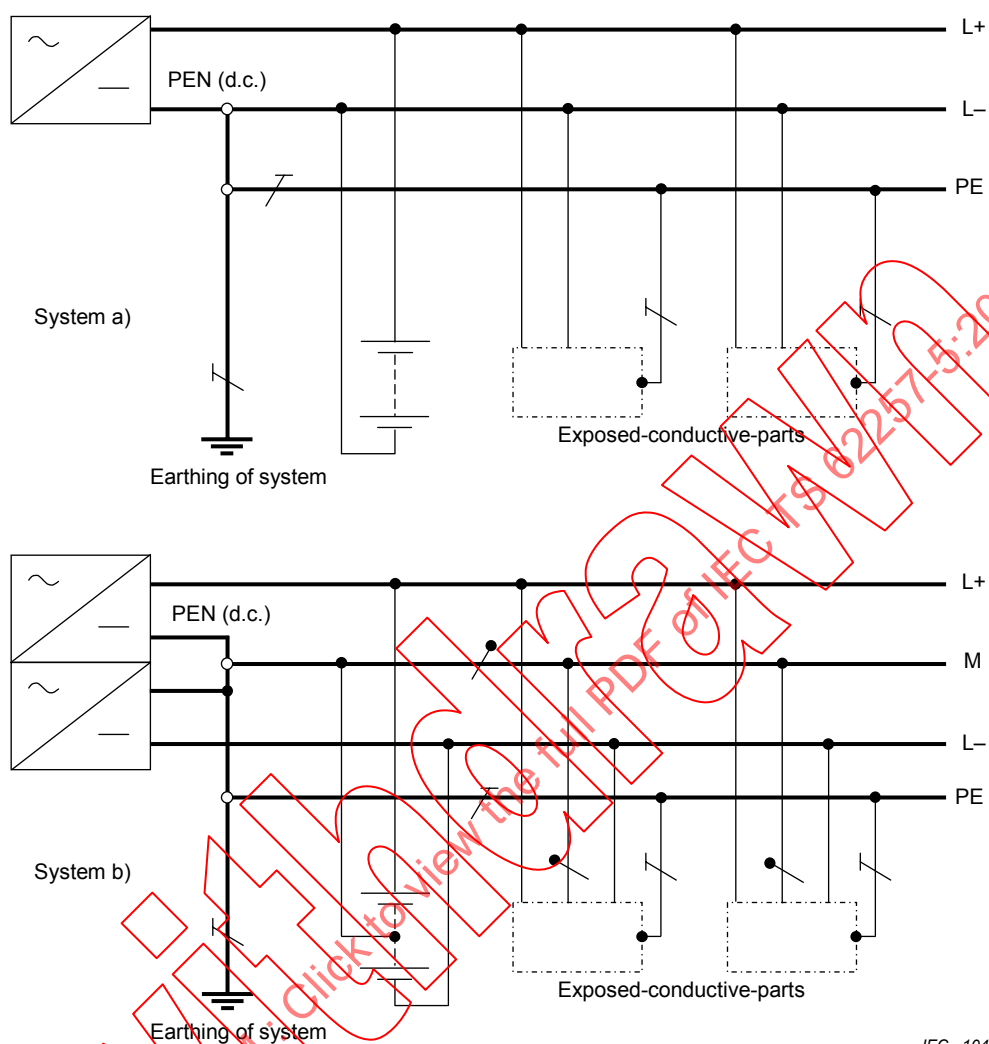


Figure B.4 – TT system

B.3 Type of system earthing for d.c. systems

NOTE In earthed d.c. systems, electromechanical corrosion should be considered.

Where the following figures B.5 to B.8 show earthing of a specific pole of a two-wire d.c. system, the decision whether to earth the positive or the negative pole should be based upon operational circumstances or other considerations.

B.3.1 TN systems**Figure B.5 – TN-S d.c. system**

In Figure B.5, the earthed line conductor (for example L– in system a) or the earthed mid-wire conductor (M in system b) are separated from the protective conductor throughout the system.

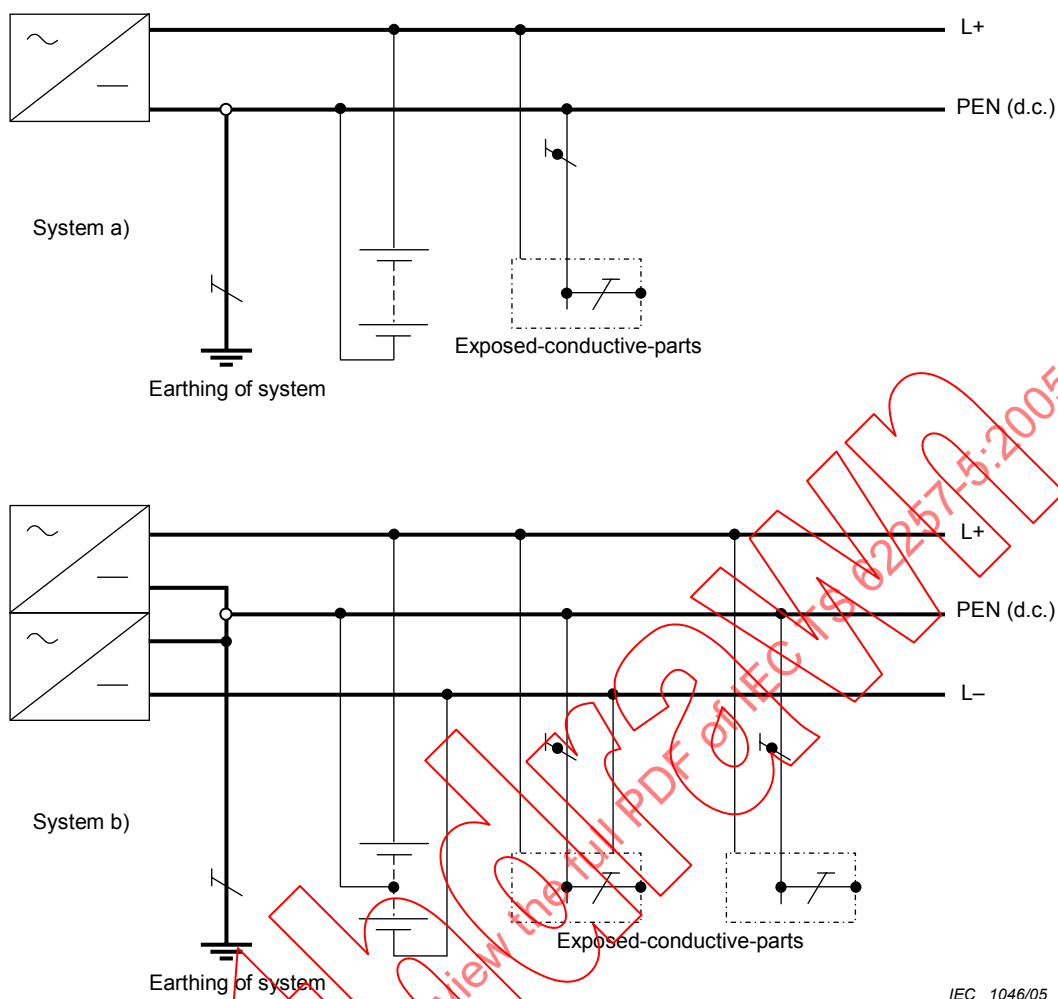


Figure B.6 – TN-C d.c. system

In figure B.6, the functions of the earthed line conductor (for example L– in system a) and protective conductor are combined in one single conductor PEN (d.c.) throughout the system, or the earthed mid-wire conductor (M in system b) and protective conductor are combined in one single conductor PEN (d.c.) throughout the system.

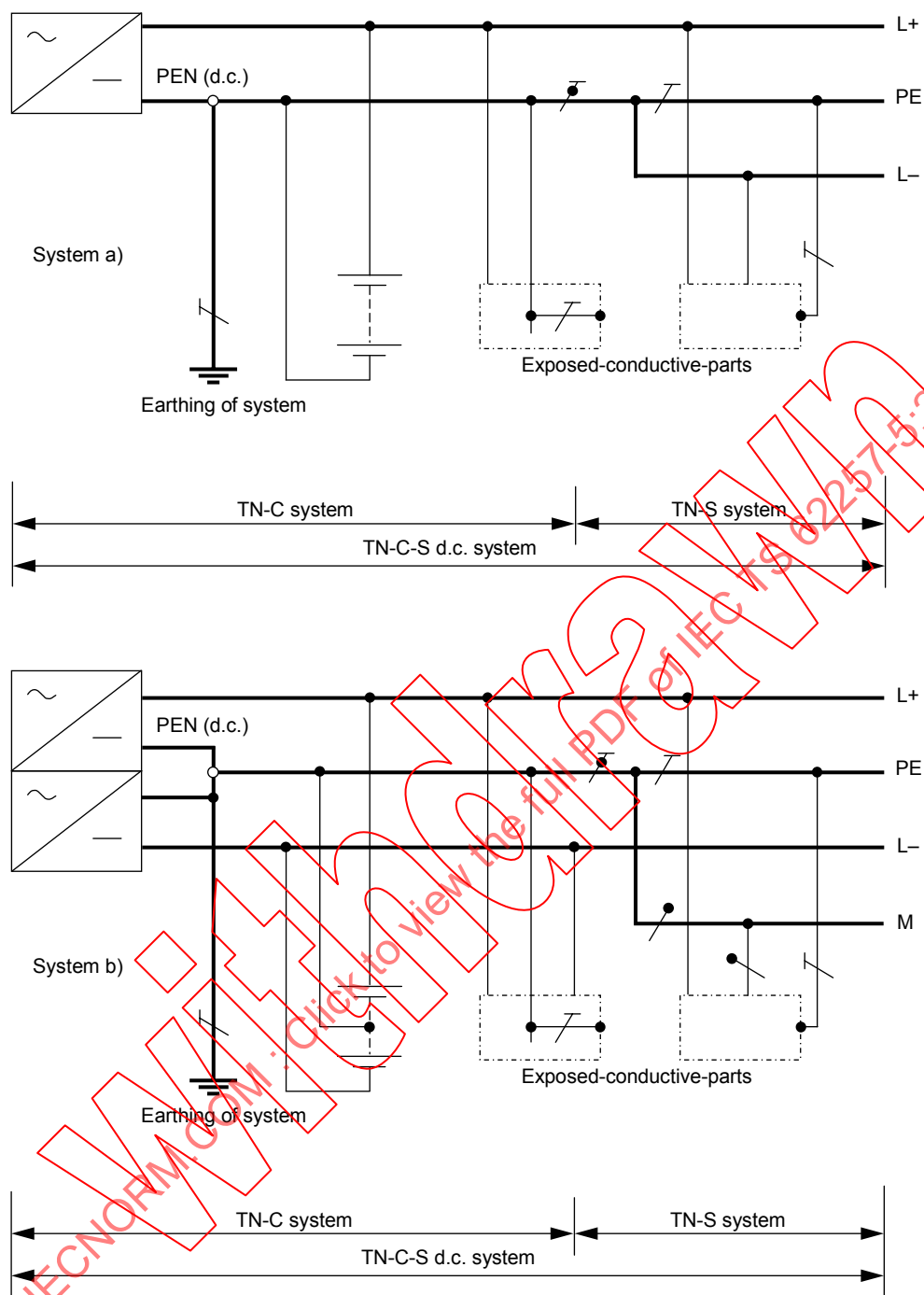
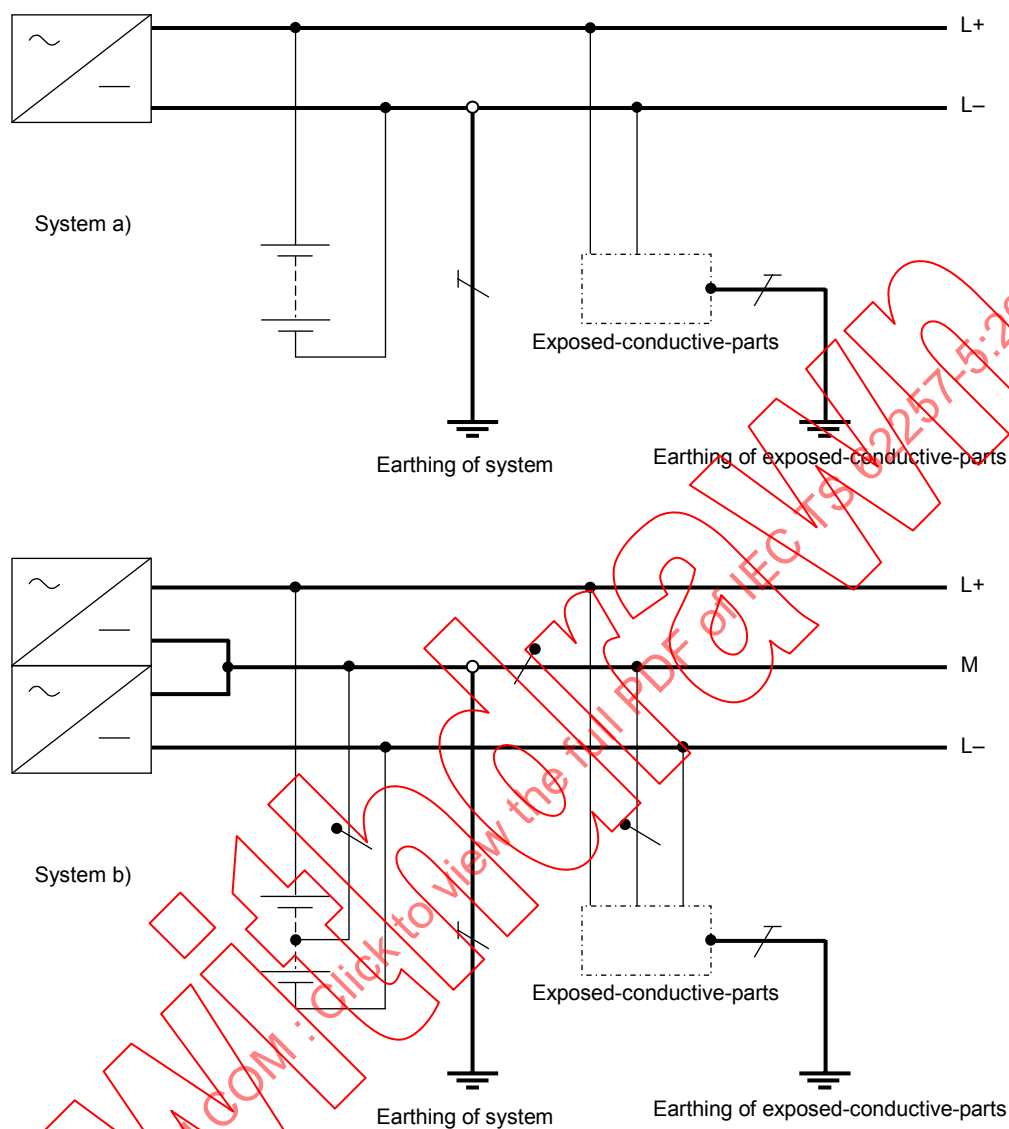


Figure B.7 – TN-C-S d.c. system

In figure B.7, the functions of the earthed line conductor (for example L– in system a) and protective conductor are combined in one single conductor PEN (d.c.) in parts of the system, or the earthed mid-wire conductor (M in system b) and protective conductor are combined in one single conductor PEN (d.c.) in parts of the system.

B.3.2 TT system



IEC 1048/05

Figure B.8 – TT d.c. system