Minutes of the Fourth Meeting of the Working Group to develop installation standard for Medium Power Application held on 21.01.2022

List of Participants are enclosed at **Annexure-I.**

Mrs. Vandana Singhal, CE (DP&R, CEA) apprised the Members of the background and progress of the WG. She invited the Members for an active and fruitful discussion and to expedite the process of developing the Installation Standard for Medium Power Application.

2. **Mrs. Shivani Sharma, Director (DP&R, CEA)** shared with the Members that Para 7.2 'Recommended voltages' of the IEC 63282 'LVDC systems - Assessment of standard voltages and power quality requirements' clearly states that 12 V, 24 V, 48 V, etc. are not considered as the example of recommended voltages but they could be included as LVDC voltages for some distribution purposes.

3. **Sh. Kunnath, IIT-Madras,** shared that IEC-TC 64 has come up with Medium Power DC Application Standard, especially safety related prospects. However, they do not specify any voltage level. The document is attached as **Annexure-II**.

4. **Sh. Ritwik Anand, BIS** suggested that IEC-TC-64 may be taken as the reference document and it can be built upon further for a standalone/ non-grid-connected system, e.g., Island microgrid, Rooftop solar system etc.

5. On the matter of no specific voltage mentioned in IEC-TC 64, **CE (DP&R, CEA)** remarked that going forward with considering it as the reference document, the question of deciding on a voltage level remains. She inquired about how the IEC has developed their document without deciding upon a voltage level.

6. **Sh. Gopa Kumar from CapeIndia** clarified that TC64 only deals with protection from shock and other safety aspects and addresses it by specifying current rating.He further added that since voltage of less than 120 V DC is considered as ELV, the cases where CAT-III devices are employed, safety against shock protection in dry condition is not necessary. However, protection in such cases in wet condition (e.g. Bathrooms) has to be considered. Any voltage higher than 120 V DC need shock protection, in which case the system earthing comes into picture. TN-S is, in general, a reliable system. However, for standalone system, IT earthing with insulation monitoring would be more reliable, provided on a later stage if the user change stand alone to grid connected system, they need to change system earthing to TN-S.

He further suggested a scenario wherein multiple voltages are used in one building, e.g. a standalone system with 48 V DC for lights , fan etc. and another voltage for AC Water heater etc., and asked whether both wirings can be routed through the same conduit. The conventional disconnection time, conventional disconnection current, de-rating factor for wires etc. need to be considered. Whether the calculations used for AC can be used for DC as well, also needs to be considered.

7. **Sh. Burji, Schneider Electric** remarked that the Draft Standard should also cover storage aspects to address the cases wherein battery and storage system is used.

8. **Sh. Gopa Kumar** also pointed that as of now, we are discussing only standalone system, hence, Over-voltage and insulation categorisation is not important. However, how will these aspects be handled if the user changes the system or wants to use same product in a grid connected system, e.g. an LED light or a fan, considering that only CAT-III devices are allowed in fixed installation, whereas for stand-alone CAT-I can be used .

9. **Sh. Ritwik Anand, BIS** clarified that the present scope of the Working Group is limited to developing the Standard for a standalone system only.

10. **Sh. Rajesh Panda,L&T** stated that in the past few meetings, one of the concerns is higher current, power rating and losses of 48V ELVDC appliances, with DC – DC converter, EVSE, EV etc. With the rapid development of SiC and GaN wide-band semiconductor (MOSFET for DC application) which is replacing Si used in various electronic appliances, the overall leakage current is reduced at an appreciable rate. The overall size of the electronic device with SiC and GaN semiconductor is reduced and the cost implication is approximately at par with the Si device. Several benefits of SiC and GaN is higher electron charge density and hence current density, mobility (GaN), higher thermal conductivity, low hot- spot temperature due to higher heat dissipation, higher reverse breakdown voltage, higher switching frequency, low loss, better efficiency, higher power handling capacity for the same size etc.

    He further added that for the same impedance or resistance of human body, the leakage current would be less for a 48V ELVDC system, reducing the probability of shock vis-à-vis any higher voltage level.

11. **Sh. Santanu Sen from CESC Ltd.** pointed out that anything beyond the meter is not in the purview of Discoms. Many 350 V DC appliances are also available in

households and while deciding upon a specific voltage level, it may be taken into consideration that multiplicity of voltage options at consumer level may lead to requirement of different type of sockets for different application which might be confusing for the users / consumers.
He further stated that 48V DC will draw more current than any other higher voltage, heating of the internal wiring will be more.
Also, installation practice should include discussion on earthing practice for equipment under use including how to protect household LVDC apparatus against lightning strikes.

12. **Director, DP&R** suggested that 350 V DC standard may be used for medium power applications and for 48 V applications, DC/DC converters may be employed. However, insulation coordination might present a problem.

13. **Sh. Kunnath** added that arcing issues will also have to be addressed. He stated that IEC 63282 specifies a nominal voltage of 350 V and a mid-point supply. Assuming an upstream voltage level of 350 V and downstream voltage level of 48 V, power protection scheme and grounding topology, scope for RCD, earth fault detection, overcurrent protection etc. will also have to be decided.

14. **Director, DP&R** clarified that RCD has been recommended at each installation in Draft CEA (Measures relating to safety and Electric supply) Regulations.

15. **Sh. Gopa Kumar** remarked that market/ industry of RCD for DC is still in nascent stage. Further, information will also need to be gathered on the over current, short circuit and earth fault protective devices for DC available in the market, and the relevant standard thereof.

CE, DP&R requested the Members to furnish their views to populate the MoM of this meeting, and to contribute to the maximum extent possible to arrive at a consensus at the earliest.

Meeting ended with a vote of thanks to the Chair.

Annexure-I

1.	Smt. Vandana Singhal (Convener)	Chief Engineer, CEA
2.	Smt. Shivani Sharma	Director, CEA
3.	Ms. Bhaavya Pandey	Asstt. Director, CEA
4.	Sh. Ritwik Anand	Bureau of Indian Standards
5.	Shri Rajesh Panda	M/s Larson & Turbo
6.	Shri P.K Mukherjee	In Personal Capacity
7.	Shri Rajesh Kunnath	IIT Madras
8.	Shri Santanu Sen	CESC, Kolkata
9.	Shri Gopa Kumar	Cape India
10.	Shri Chidanand Burji	Schneider Electric India Private Ltd.

Annexure-II

64/2358/CD

COMMITTEE DRAFT (CD)

PROJECT NUMBER: **IEC TS 61200-102 ED1**	
DATE OF CIRCULATION: **2018-12-21**	CLOSING DATE FOR COMMENTS: **2019-03-15**
SUPERSEDES DOCUMENTS: **64/2257/CD,64/2355/CC**	

IEC TC 64 : ELECTRICAL INSTALLATIONS AND PROTECTION AGAINST ELECTRIC SHOCK	
SECRETARIAT: Germany	SECRETARY: Mr Wolfgang Niedenzu
OF INTEREST TO THE FOLLOWING COMMITTEES: TC 8,SC 8B,TC 21,TC 23,SC 23B,SC 23E,SC 23G,SC 32B,TC 61,TC 82,TC 88,TC 120,SC 121A,SC 121B,SyC LVDC,SyC Smart Energy	
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY	

This document is still under study and subject to change. It should not be used for reference purposes.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

TITLE:

Electrical installation guide, Part 102: Application guide on Low Voltage direct current electrical installation not intended to be connected to Public Distribution Network

NOTE FROM TC/SC OFFICERS:

CONTENT

IEC TS 61200-102, Electrical installation guide, Part 102: Application guide on Low Voltage direct current electrical installation not intended to be connected to Public Distribution Network

INTRODUCTION

Many people in the world still have no access to electricity. People living in these areas would benefit from access to electrical power. This can now become reality thanks to distributed electrical sources using renewable energy. It is noted that these electrical sources using renewable energy are all operating in direct current (e.g.: photovoltaic system, wind turbines)

Supply from these renewable energies is not constant, photovoltaic panels do not operate at night, and wind turbines require wind for generating electrical energy. Therefore, the use of storage units becomes a necessity. It is noted that manufacturers of stationary secondary batteries are investing a lot in these technologies and prices will soon become accessible to those people having no access to electricity.

In addition, new technologies such as Light Emitting Diodes (LED) or electronic devices generally operate in direct current.

Connecting these types of current-using equipment to electricity sources using renewable energy through DC. electrical installation is more and more realistic. For changing the DC voltage, DC/DC converters are available.

All requirements and recommendations in this guide comply with the IEC 60364 series.

IEC TS 61200-102, Electrical installation guide, Part 102: Application guide on Low-Voltage direct current electrical installation not intended to be connected to Public Distribution Network

1 Scope

This document applies to DC low-voltage electrical installations entirely supplied by local power sources and having a nominal voltage lower or equal to the Low-Voltage limit. These installations may be connected to collective or shared private electrical installations.

This document also applies to DC installations according to use cases TIER 2 and TIER 3 of the World Bank defined in ESMAP 008/15 report: BEYOND CONNECTIONS Energy Access Redefined.

2 Normative references

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

IEC 60038 *IEC standard voltages*

IEC 60364-1 *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60364-4-41 *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-5-52 *Low-voltage electrical installations – Part 5-52: Selection and erection of electrical equipment – Wiring systems*

IEC 60364-5-57 *Low-voltage electrical installations – Part 5-57: Selection and erection of electrical e Stationary secondary batteries*

IEC 60479-1 *Effects of current on human beings and livestock – Part 1: General aspects*

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

3 Definitions

3.1
Individual electrical installation
Single consuming and/or producing electrical installation

3.2

Collective electrical installation
Several consuming electrical installations sharing one common set of local power supplies and energy storage equipment

3.3

Shared electrical installation
Several consuming and/or producing electrical installations, similar to individual electrical installation, and sharing their individual power supplies and energy storage equipment

3.4

Island mode

Operating mode in which only local power sources and/or local storage units supply current-using equipment

3.5

Public Distribution Network (PDN)

Set of coordinated equipment intended to be used for the distribution of electrical energy to private electrical installations and operated by a public organization

4 General

4.1 Concept of electrical installation

Any low-voltage electrical installation is to be considered as a set of electrical equipment having the following functions:

- Supply (e.g.: local generator, photovoltaic systems, wind turbine, batteries…)
-
- Distribution (e.g.: distribution board, wiring systems, socket-outlets)
- Consumption (e.g.: fans, lighting, appliances, pumps, batteries…)

NOTE Battery may be considered as a power supply and as consuming unit (prosumer).

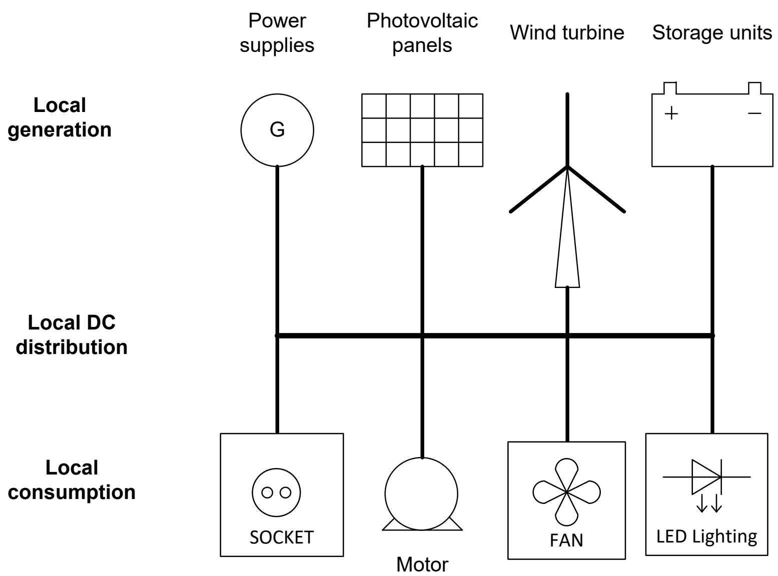


Figure 1 – Concept of DC low voltage electrical installation

4.2 Architecture and operating modes of installation

Various architectures and operating modes of installations are defined in Annex A.

Selection of the appropriate installation architectures shall be undertaken according to the environment of the installation and its foreseeable future modification.

5 Supplies

Examples of local power sources are:

– Local rotating generating set
– Storage units
– Photovoltaic system
– Wind turbine.

Any combination of different types of local power sources is possible.

.

Where power sources use renewable energy, which provides intermittent supply, storage of this energy is recommended.

6 Loads

6.1 Possible nominal voltages

IEC 60038 (table 6) only provides recommended DC voltage values for equipment indicated below in Table 1. Other commonly used voltages are included.

Preferred (V)	Supplementary (V)
	125
220	
	250
350	
400	
440	
	600
700 or +/–350	
1400 or +/–700	

Table 1 : Preferred and supplementary nominal DC voltages

Note: Selection of voltage levels requires consideration of protective measures.

Using only one single nominal DC voltage within the installation might require voltage adaptation at different levels (ex: through DC/DC converter) as all power sources, storage units and current-using equipment may not operate at the same rated voltage.

6.2 Minimum and maximum voltage values

In case Stationary Secondary Batteries (SSB) are used for supplying the DC electrical installation as backup power source, voltage level supplied by the batteries may be variable depending on their charge. This is particular the case where no voltage regulation is used for the SSB. Large voltage tolerance for the nominal voltage (U_n) of the installation shall be considered for equipment selection.

If no calculation is possible or no details from the batteries manufacturers are provided, the following minimum and maximum values can be used:

– Maximum voltage: 1,2 U_n
– Minimum voltage: 0,8 U_n.

7 Wiring systems

7.1 Type of wiring system

Where automatic disconnection of supply is used as protective measure against electric shock, cables shall include 3 or 4 core conductors:

– one conductor for positive polarity, and
– one conductor for negative polarity, and/or
– one conductor for mid-point, and/or
– one conductor the PE.

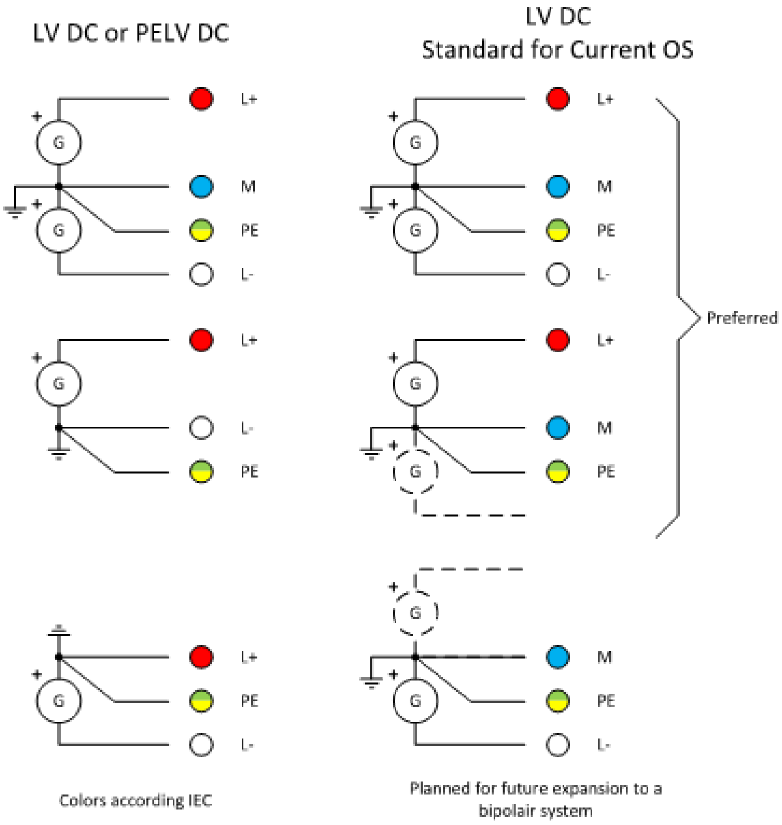
7.2 Identification of conductors and terminals

Positive polarity conductor shall be identified by the colour red and negative polarity conductor shall be identified by the colour white according to IEC 60445.

Mid-point conductor shall be identified by the colour blue.

PE conductor shall be identified by the bi-colour green and yellow.

If terminals have an identification then the symbols "+", "-", "M" and "PE" shall be used.



Key:

a) Colour coding according to IEC 60445

b) Planned for future expansion to a bipolar system

Figure 2 – Colour codes for conductors used in installation using direct current

If wiring with different colours is used, for example in previously installed AC systems, circuit conductors shall be clearly marked as identified in Figure 2.

7.3 Cross-sectional areas of conductors

Only one single cross sectional area of conductors shall be used for each circuit with a minimum cross sectional area of 1,5 mm² Cu. For nominal currents I_n higher than 16 A, a larger cross sectional area shall be selected.

All conductors of each circuit shall have the same cross-sectional area (polarity, mid-point and PE conductor).

8 Earthing

8.1 Direction of touch current

IEC 60479-1 states that the threshold of ventricular fibrillation for a downward current of a duration of 10 ms or more is about twice as high as for an upward current (see clause 6.3 of IEC 60479-1). For current pulses shorter than 10 ms there is no known directional sensitivity difference.

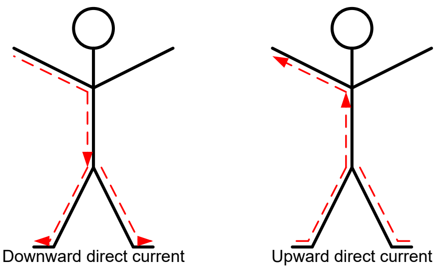


Figure 3 – Downward and upward direct current in human body

In a TN system, connecting the negative polarity to earth is recommended.

8.2 Earthing arrangement

In a TN system, mid-point or one polarity (positive or negative) of DC power supplies shall be connected to earth at one point only, and exposed-conductive parts shall be connected to this earthing arrangement.

In an individual installation, the earth connection shall preferably be made on the main busbar/terminal, thus ensuring connection of all possible power sources to earth.

9 Protection against electric shock

9.1 General

Protection of persons against electric shock requires that hazardous-live-parts shall not be accessible and accessible conductive parts shall not be hazardous-live.

This requires that persons shall not have access to parts normally live (basic protection) and exposed-conductive parts shall not become hazardous resulting from an insulation fault (fault protection). Any protective measure against electric shock shall be an adequate combination of two separate types or protection (basic and fault), or an enhanced protection, combining both types of protection in one single measure.

In addition, protective measures to be implemented shall consider that ordinary persons having access to electrical equipment are deemed not to be aware of the dangers of electricity.

9.2 Provision for basic protection

Ordinary persons having access to electrical equipment are deemed not to be aware of dangers of electricity; basic protection shall be applied.. Provision for fault protection

Ordinary persons having access to electrical equipment are deemed not to be aware of the dangers of electricity; fault protection shall be applied.

9.2.1 Protective measures

9.2.1.1 General

The implementation of the relevant requirements and recommendations given in this document, allow the installation to comply with IEC 60364-4-41.

9.2.1.2 Automatic disconnection of supply

9.2.1.2.1 General

Where automatic disconnection of supply is used as fault protection, nominal voltage can be higher than the ELV limit: U_n can exceed 120 V DC

9.2.1.2.2 TT systems

TT systems are not considered in this guide

Note: The use of TT systems requires additional measures e.g. corrosion protection and devices for automatic disconnection of supply

9.2.1.2.3 TN system

9.2.1.2.3.1 Use of devices for short-circuit protection

In TN system, the value of an earth fault current is similar to a short-circuit current between both polarities. Usually short-circuit protective devices can be used for protection against electric shock. Where the DC power supplies used are only photovoltaic system the short-circuit current may not be high enough to operate the devices for short-circuit protection within the time prescribed in IEC 60364-4-41.

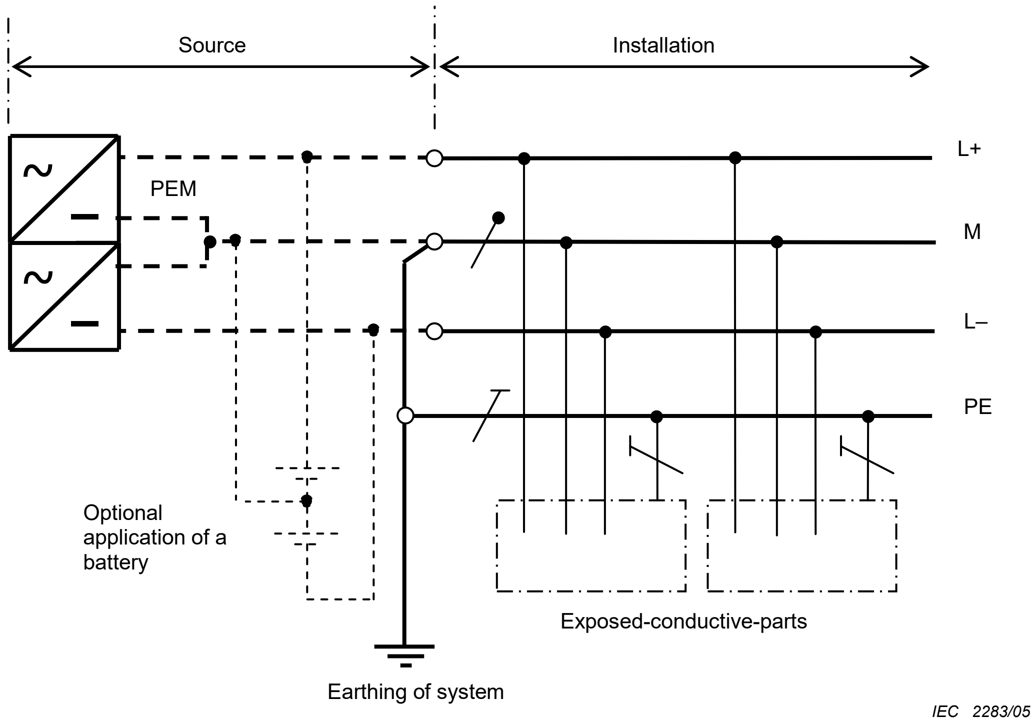
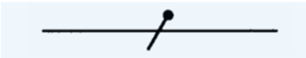
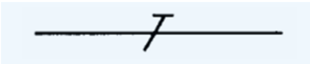


Figure 4 – Example of electrical installation in TN-S system

Note. This figure complies with the general requirements of IEC 60364-1.

Explanation of symbols for figure 4:

	Mid-point conductor (M)
	Protective conductor (PE)

Where stationary secondary batteries are permanently connected to the electrical installation, short-circuit current will also be supplied by these batteries, increasing the magnitude of the short-circuit current. Use of devices for short-circuit protection becomes possible for protection against electric shock (see Figure 5).

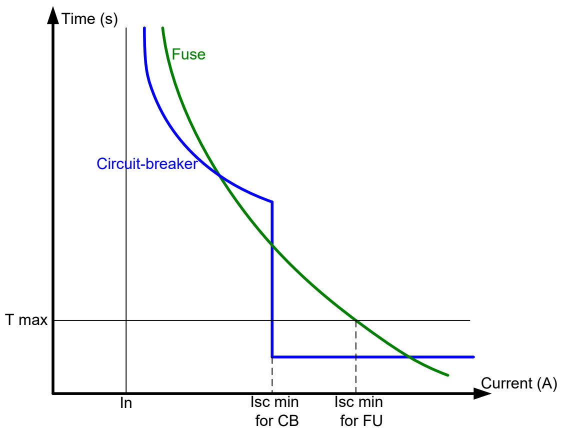


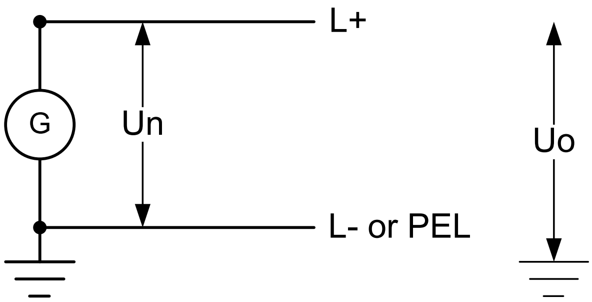
Figure 5 : Estimation of short-circuit level in TN system

For providing protection against electric shock in TN system, minimum short-circuit current shall always be higher than estimated "I_{sc} min for circuit breaker (CB)" or "I_{sc} min for fuse (FU)".

9.2.1.2.3.2 Types of TN system

IEC 60364-1 recognizes 3 varieties of TN systems

TN-C system: The Protective Earth (PE) conductor is common with mid-point conductor or the polarity connected to earth and called PEM or PEL conductor (see Figure 6)



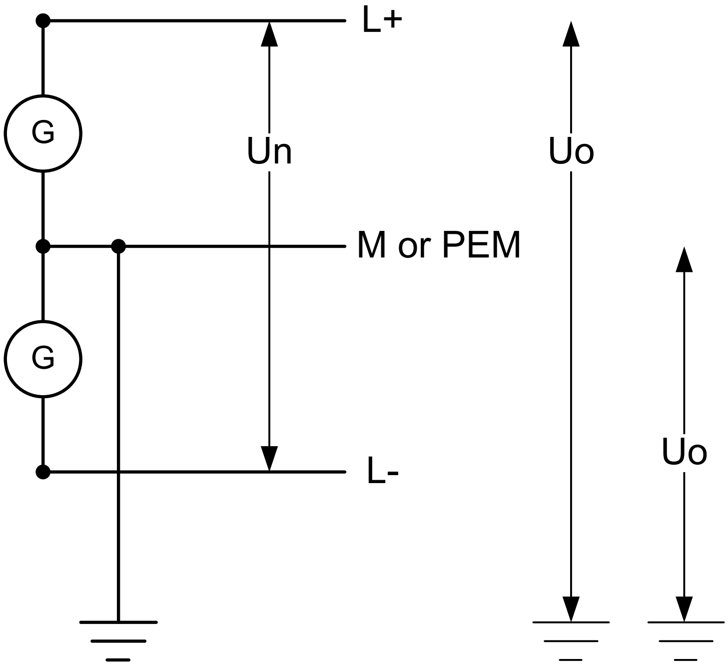


Figure 6 : Examples of TN-C systems in DC installation

In the case of disconnection or break of PEM or PEL conductor, voltage to earth of exposed-conductive part will be equal to polarity to earth.

TN-S system: The Protective Earth (PE) conductor is separate and only at source connected to the mid-point conductor or a polarity. The Protective Earth (PE) is also connected to earth and is called the PE conductor (see Figure 7)

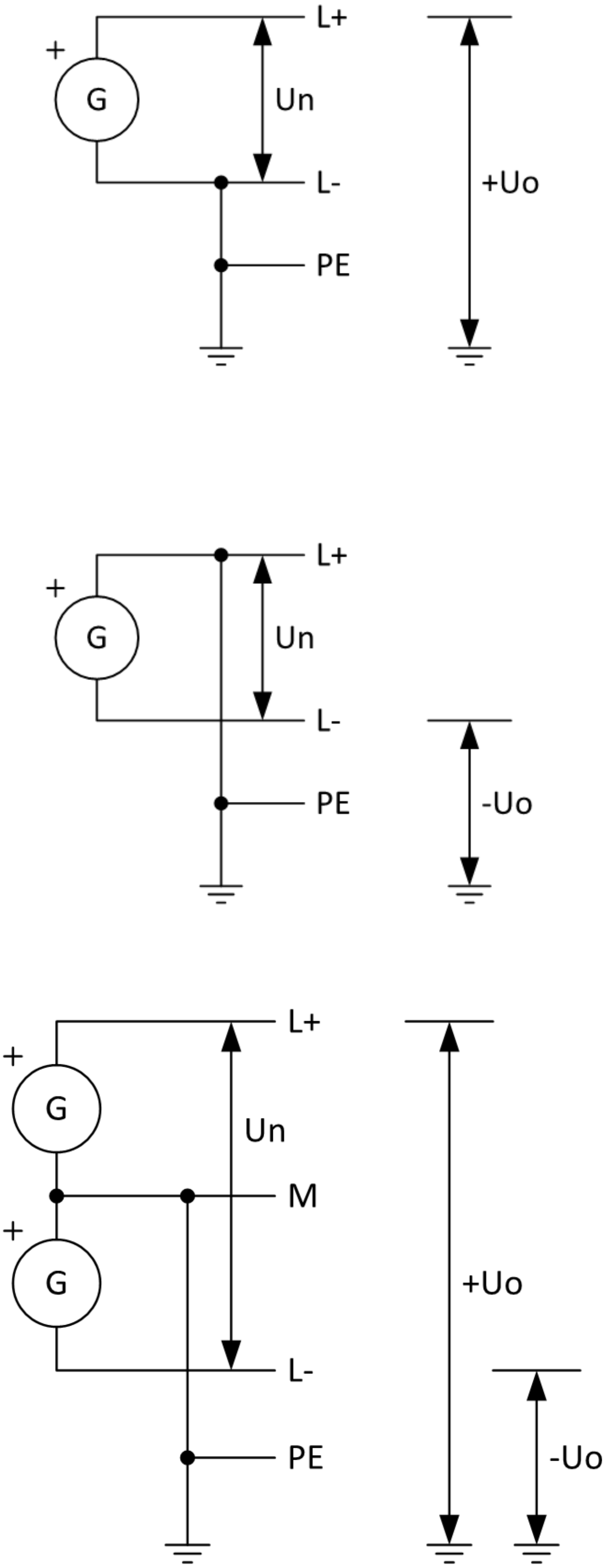


Figure 7 : Examples of TN-S systems in DC installation

DC electrical installations should be designed using a TN-S system. Where stationary secondary batteries are connected in the installation they shall not influence the architecture of the installation."

9.2.1.3 IT Systems

The use IT systems are not covered in this guide. For the use of IT system see IEC 60364 series

9.2.1.4 Electrical separation

Requirements proposed by IEC 60364-4-41 concern mainly the supply of one item of current-using equipment.

The protective measure of electrical separation shall not be used.

9.2.1.5 Double or reinforced insulation

Some parts of a DC installation that are not accessible to the user may employ double or reinforced insulation (e.g. a PV system).This protective measure shall not be used as the only protective measure for the whole DC electrical installation not intended to be connected to Public Distribution Network as it is essential that all equipment connected to the installation is designed with double or reinforced insulation. As persons using this type of installation are deemed not to be aware of dangers caused by electricity, it is possible that equipment not having reinforced insulation can be connected to this installation.

9.2.1.6 Additional Protection

In DC systems, the use of RCDs with a rated residual operating current not exceeding 80 mA, is recognized as additional protection in the event of failure of the basic protection and/or the fault protection or carelessness by users.

NOTE: 80mA is mentioned in IEC TS 63053

9.3 Protection against thermal effects

9.3.1 Protection against electric arc

Direct current once established does not cross the zero value as is the case for alternating current. In the case of a fault, an arc is quickly created between a faulty live part and another part and due to the high impedance of the arc and low level of current drawn arc faults could not be cleared by overcurrent protective devices. Additional care is necessary to reduce the risk of arcing, e.g. selection of electrical equipment.

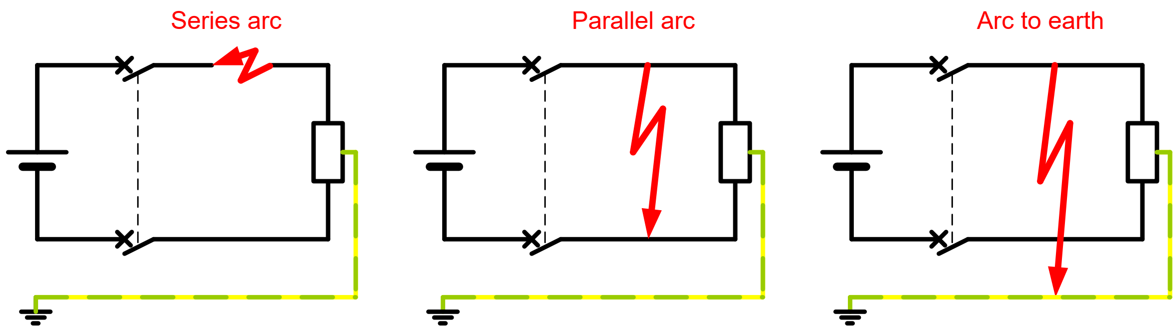


Figure 8 : Different types of arc fault to be considered

The internal impedance of the fault may vary and it may be difficult for a normal overcurrent breaking device to detect the presence of such a fault. An arc fault may not be detected by an overcurrent protective device as the current may be decreased compared to the normal design current.

Measures shall be taken to protect against the harmful effects of arc faults. Arc Fault Detection Device (AFDD) can be used for such protection.

9.3.2 Risk of explosion with batteries

Hydrogen and oxygen gases can be released from a lead acid battery during normal operation and also in case of excess of charging current (overcharge).

Hydrogen concentration between 4% and 72% is considered flammable and may provoke explosion in case of ignition. The ventilation system in a stationary battery location should be designed to keep hydrogen concentration below 1%.

Stationary secondary batteries shall be installed in a room with sufficient space and well ventilated to avoid risk of explosion. Additional information can be found in IEC 60364-5-57 (in development).

NOTE – Reference to IEC 62485-2: Safety requirements for secondary batteries and battery installation – Part 2: Stationary batteries, can be made.

9.4 Protection against overcurrent

9.4.1 Overload protection

9.4.1.1 General

Each source and final circuit shall be individually protected against overload by one overcurrent protective device (OCPD) suitable for DC (circuit-breaker or fuse).

As devices for overload protection are used for protecting insulation of wiring conductor against excessive temperature, they shall be installed at the origin of each circuit (e.g.: distribution board).

9.4.2 Short-circuit protection

9.4.2.1 General

Each source and final circuit shall be individually protected against short-circuit by one overcurrent protective device suitable for DC (circuit-breaker or fuse).

As devices for short-circuit protection are used for protecting insulation of wiring conductor against excessive temperature, they shall be installed at the origin of each circuit (e.g.: distribution board).

9.4.2.2 Devices for short-circuit protection

Protection against overload and against short-circuit can be integrated within the same overcurrent protective device This protective device shall be installed at the origin of each circuit

9.4.2.3 Breaking capacity

The minimum breaking capacity of the overcurrent protective device shall be higher than the maximum short-circuit current at the point where the device for short-circuit protection is installed. For achieving this requirement all local power sources shall be considered as operating in parallel simultaneously (ex: all photovoltaic panels and all stationary secondary batteries).

For individual electrical installation, estimation of the maximum short-circuit current is possible when considering

– Contribution of all local power sources fully operational, and
– Contribution of all local stationary secondary batteries fully loaded, and
– No reduction from wiring cables.

For collective electrical installation, estimation of the maximum short-circuit current is possible when considering:

- Contribution of all local power sources fully operational, and
- Contribution of all local stationary secondary batteries fully loaded, and
- Average reduction of short-circuit current from wiring cables.

For shared electrical installation, estimation of the maximum short-circuit current is possible when considering:

- Common contribution of all distributed power sources fully operational, and
- Common contribution of all distributed stationary secondary batteries fully loaded, and
- Average reduction of short-circuit current from wiring system external to the electrical installation.

9.5 Protection against overvoltage

9.5.1 Protection of low-voltage installations against temporary overvoltages due to earth faults in the high-voltage system and due to faults in the low-voltage system

As this document applies only where no connection to any Public Distribution Network is possible, no overvoltage from PDN shall be considered.

9.5.2 Protection against overvoltages of atmospheric origin or due to switching

Consideration shall be given to risk of overvoltage due to atmospheric origin or due to switching (see IEC 60364-4-44 Clause 443 and IEC 60364-5-53 Clause 534)

Annex A
(normative)

Architecture and operating modes of installations

A.1 Architecture of installations

A.1.1 Individual installation

Individual installation corresponds to a single consuming and/or producing electrical installation. Such an installation always includes current-using equipment (or commonly named loads), and may also include local power supply units (ex: photovoltaic panels, wind turbine…) and may also include local storage units (ex: stationary secondary batteries).

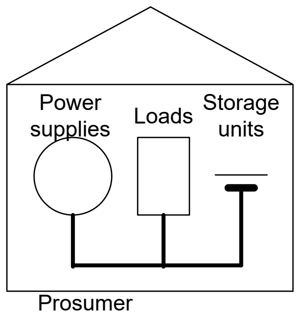


Figure A.1: Example of individual installation

Usually such installation may include several single electrical energy meters or measuring equipment.

A.1.2 Collective installation

Collective installation corresponds to several consuming electrical installations connected to the same private wiring system and sharing one common set of local power supplies and energy storage equipment.

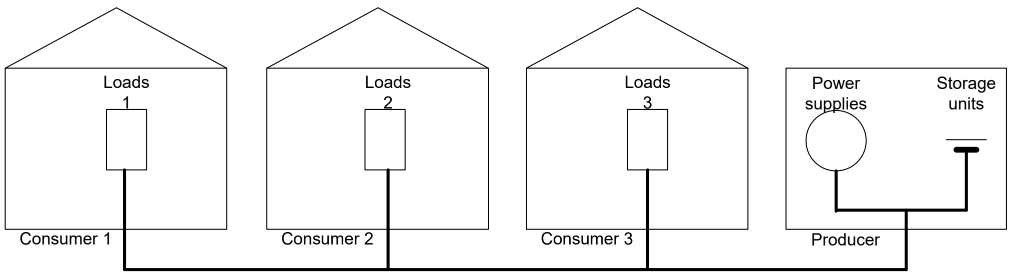


Figure A.2: Example of collective installation

Such installation may include several electrical energy meters or measuring equipment.

A.1.3 Shared installations

Shared installation corresponds to several consuming and/or producing electrical installations connected to the same private low-voltage public distribution wiring system and sharing their individual power supplies and energy storage equipment between themselves.

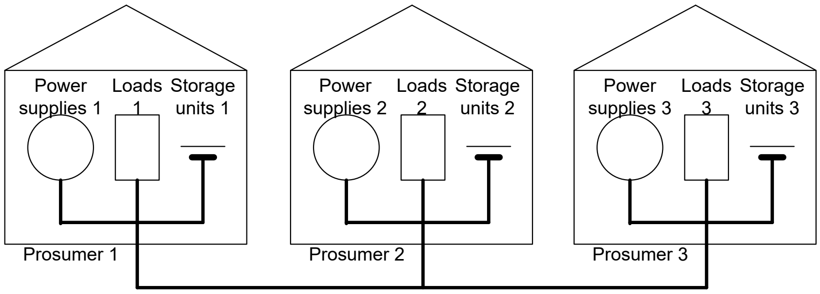


Figure A.3: Example of shared installation

Such installation may include several electrical energy meters or measuring equipment.

A.2 Operating modes

A.2.1 Direct feeding mode

In this operating mode, the electrical DC installation is connected to the other electrical installations, and partly or completely fed from them.

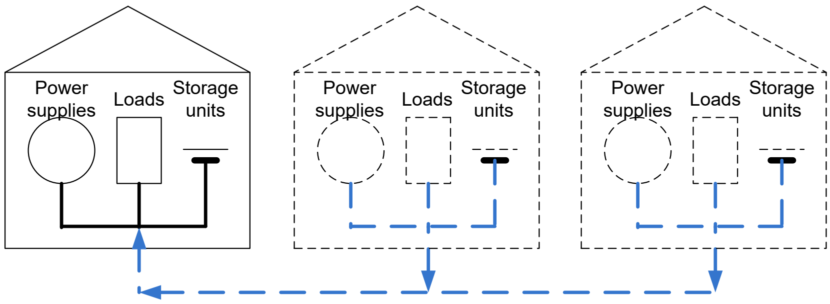


Figure A.4: DC electrical installation in direct feeding mode

A.2.2 Reverse feeding mode

In this operating mode, the electrical DC installation is connected to the other electrical installations, and partly or completely feed them.

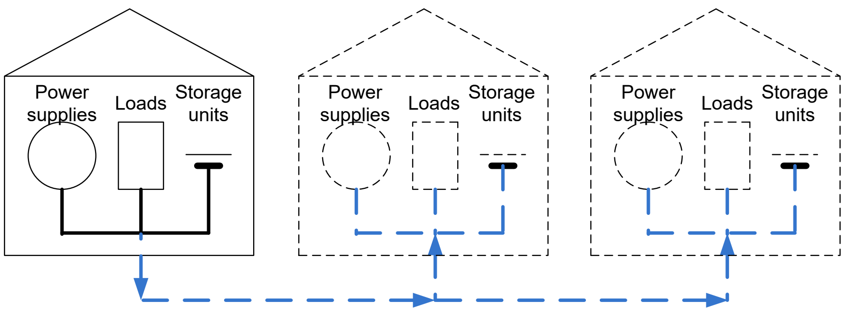


Figure A.5: DC electrical installation in reverse feeding mode

A.2.3 Autonomous mode

In this operating mode, the electrical DC installation is not connected to the other electrical installations, and is fed directly from local power sources.

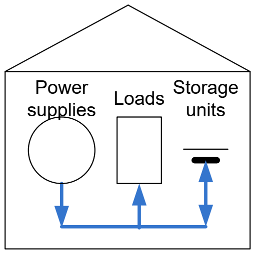


Figure A.6: DC electrical installation in autonomous mode

Annex B
(informative)

Limitation of lengths of cables

B.1 Limit of voltage drop in consumers' installations

Maximum voltage drop for each circuit of the installation shall be less or equal to 5%.

B.2 Estimation of voltage drop

In case of direct current, the voltage drop in given by the simplified formula as follows:

$$\Delta u = 2\left(\rho_1 \frac{L}{S}\right) I_B$$

Δu	is the voltage drop in volts
ρ_1	is the resistivity of conductors in normal service, taken equal to the resistivity at the temperature in normal service, i.e. 1,25 times the resistivity at 20 °C, or 0,0225 Ωmm²/m for copper and 0,036 Ωmm²/m for aluminium
L	is the straight length of the wiring systems, in meters
S	is the cross-sectional area of conductors in mm²
I_B	is the design current (in amps)

The relevant voltage drop in per cent is equal to:

$$\Delta u\% = 100 \frac{\Delta u}{U_0}$$

U_0	is the voltage between line/polarity and neutral, in volts at supply

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Annex C
(informative)
List of notes concerning certain countries

Country	Clause N°	Wording
US	**7.2**	***Add the following note*** In the USA, PE conductor insulation shall always be of a "green-and-yellow" mixed colour or "solid green" colour.
BE	**7.3**	***Add the following note*** The Belgian General Regulation for Electrical Installation (GREI- Art 198) specify that the minimum cross section shall be 2,5mm² or exceptions foreseen in this document (1,5mm² if not connected to plug and 0,5mm² for controls and commands).

Bibliography

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