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INTERNATIONAL STANDARD

colour inside

Power line communication systems for power utility applications –
Part 3: Digital Power Line Carrier (DPLC) Terminals and hybrid ADPLC Terminals

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Power line communication systems for power utility applications – Part 3: Digital Power Line Carrier (DPLC) Terminals and hybrid ADPLC Terminals

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CONTENTS

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POWER LINE COMMUNICATION SYSTEMS FOR POWER UTILITY APPLICATIONS –

Part 3: Digital Power Line Carrier (DPLC) Terminals and hybrid ADPLC Terminals

FOREWORD

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This International Standard has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

This first edition of IEC 62488-3 cancels and replaces the relevant parts of IEC TR 60663 and IEC 60495, which will be withdrawn at a later date.

The text of this standard is based on the following documents:

FDIS	Report on voting
57/2355/FDIS	57/2372/RVD

Full information on the voting for the approval of this standard 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.

A list of all the parts in the IEC 62488 series, published under the general title *Power line communication systems for power utility applications* can be found on the IEC website

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

Since the first introduction of power line carrier communications in the power systems industry this form of communication has become widely spread throughout the world. This worldwide development will be covered by new standards reflecting the current state of the art in digital PLC communications.

The communication services offered by modern digital power line carrier links and networks enable a high efficiency of data transmission and therefore a low level of operational costs of automation equipment especially for long high-voltage power transmission lines.

Analogue and digital PLC terminals may co-exist using principles of frequency division multiplexing, allowing a successive digitalization of PLC based communications.

Digital PLC terminals may also be combined with traditional analogue PLC transmission paths as hybrid analog & digital PLC equipment, offering reliable and seamless communication for control and/or protection operating at extra high-, high- and medium-voltage levels of the electrical transmission networks and at high-voltage electrical distribution networks.

IEC 62488 consists of four parts dealing with all aspects of power line communication systems operating over electricity power lines.

IEC 62488 applies to power line carrier terminals and systems (PLC) used to transmit information over power networks including extra high, high and medium voltage (EHV/HV/MV) power lines.

Currently this standard series is organised as follows:

- IEC 62488-1, *Planning of analogue and digital power line carrier systems operating over EHV/HV/MV electricity grids*
- IEC 62488-2, *Analogue Power Line Carrier terminals or APLC*
- IEC 62488-3, *Digital Power Line Carrier terminals or DPLC and hybrid ADPLC Terminals*
- IEC 62488-4, *Broadband Power Line systems or BPL*

NOTE IEC 62488-4 has not yet been published.

This document is the third part of IEC 62488 and is composed of the following Clauses:

- Clause 1 – Scope of IEC 62488-3
- Clause 2 – Normative references
- Clause 3 – Terms, definitions and abbreviation contains newly introduce in this document additionally to IEC 62488-1 and IEC 62488-2
- Clause 4 – Introduces generic architectures of DPLC and hybrid ADPLC terminals.
- Clause 5 – Defines access side interfaces of DPLC and hybrid ADPLC terminals.
- Clause 6 – Describes transmission line side high frequency interface and defines related parameters
- Clause 7 – Gives several requirements concerning quality and performance of a single or a couple of interconnected DPLC terminals
- Clause 8 – Defines test setup and describes testing methodology
- Clause 9 – Describes configuration and management requirements for DPLC terminals
- Clause 10 – Describes general requirements regarding cyber security
- Clause 11 – Specifies safety requirements
- Clause 12 – Specifies requirements for storage and transportation, operating conditions, power supply
- Clause 13 – Specifies EMC requirements

POWER LINE COMMUNICATION SYSTEMS FOR POWER UTILITY APPLICATIONS –

Part 3: Digital Power Line Carrier (DPLC) Terminals and hybrid ADPLC Terminals

1 Scope

This part of IEC 62488 applies to power line carrier terminals and networks used to transmit information over power networks including extra high, high and medium voltage (EHV/HV/MV) power lines using both digital and optionally analogue modulation systems in a frequency range between 16 kHz and 1 MHz (see also IEC 62488-1).

In many countries, power line carrier (PLC) channels represent a significant part of the utility-owned telecommunication system. A circuit normally routed via a PLC channel can also be routed via a channel using a different transmission medium such as point to point radio, optical fibre or open wire circuit.

It is therefore important that the input and output interfaces that are used between terminals in the communication system are standardised.

The issues requiring consideration of DPLC and/or APLC devices as parts of a telecommunication network can be found in IEC 62488-1.

Figure 1 shows the correspondence between the elements needed to implement PLC systems and the related International Standards.

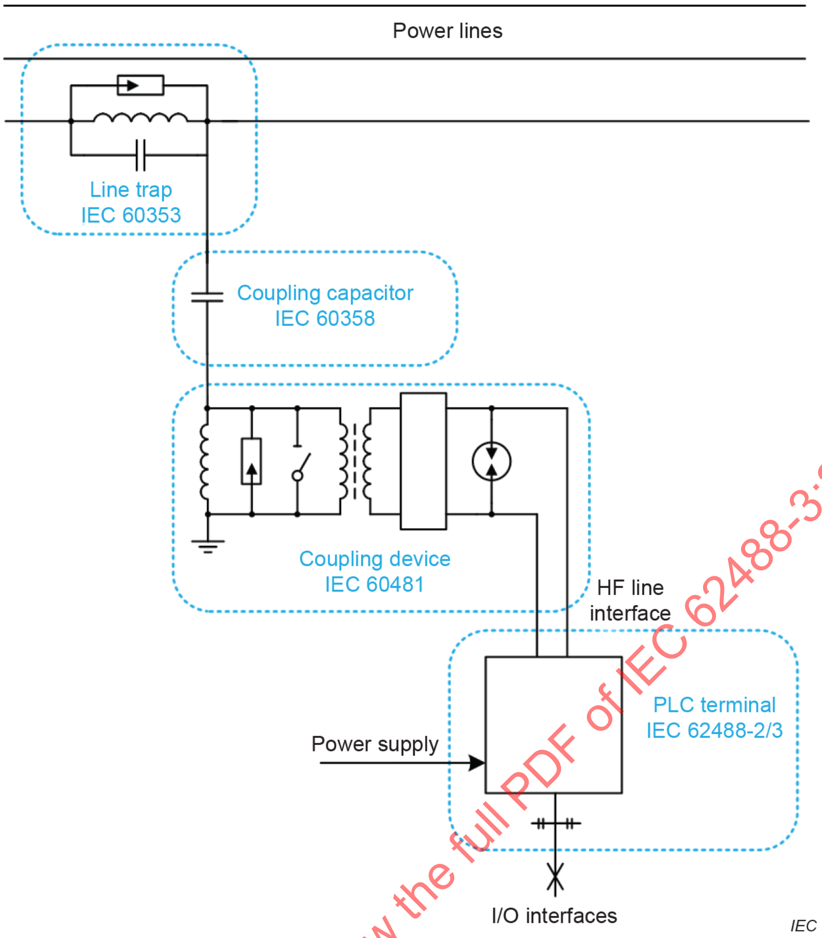


Figure 1 – Schematic representation of the elements needed to implement a PLC system

The scope of this document also includes the description of I/O interfaces and test set-ups that are necessary to qualify characteristics of DPLC or ADPLC terminal at link level.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60038, *IEC standard voltages*

IEC 60050-151:2001, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices*

IEC 60255-27:2013, *Measuring relays and protection equipment – Part 27: Product safety requirements*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

IEC 60721-3-1:1997, *Classification of environmental conditions – Part 3-1: Classification of groups of environmental parameters and their severities – Storage*

IEC 60721-3-3:2002, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Stationary use at weather protected locations*

IEC 60834-1:1999, *Teleprotection equipment of power systems – Performance and testing – Part 1: Command systems*

IEC 61000-6-4:2018, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61000-6-5:2015, *Electromagnetic compatibility (EMC) – Part 6-5: Generic standards – Immunity for equipment used in power station and substation environment*

IEC TS 62351-1:2007, *Power systems management and associated information exchange – Data and communications security – Part 1: Communication network and system security – Introduction to security issues*

IEC TS 62351-8:2011, *Power systems management and associated information exchange – Data and communications security – Part 8: Role-based access control*

IEC 62488-1:2012, *Power line communication systems for power utility applications – Part 1: Planning of analogue and digital power line carrier systems operating over EHV/HV/MV electricity grids*

IEC 62488-2:2017, *Power line communication systems for power utility applications – Part 2: Analogue power line carrier terminals or APLC*

CISPR 32:2015/AMD1:2019, *Electromagnetic compatibility of multimedia equipment – Emission requirements*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62488-1, IEC 62488-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
DPLC equipment
PLC equipment transmitting information such as digital data or digitized analog signals over the power line using digital modulation techniques

3.1.2
HPLC
any combination of APLC, DPLC and BPLC elements in a single device

3.1.3
ADPLC
PLC equipment containing elements of APLC and DPLC. ADPLC is a sub-class of HPLC

3.1.4
nominal high frequency band for DPLC or HPLC
frequency band in which a particular DPLC or HPLC transmitter or receiver is operating within the carrier frequency range

3.1.5
nominal output power in the high frequency band for DPLC or HPLC
output power of an DPLC or HPLC terminal in the nominal high frequency band (L_{nom}) expressed as PEP for which the terminal has been designed, compatible with the requirements for spurious emissions and inter-channel interference (for multi-channel PLC terminals), available at the high frequency interface output across a resistive load equal to the nominal impedance

3.2 Abbreviated terms

AC	alternating current
AGC	automatic gain control
APLC	analogue PLC
ADPLC	analogue and digital PLC
AWGN	additive white Gaussian noise
BPLC	broadband PLC
BLER	block error rate
BER	bit error rate
B_{nom}	nominal high frequency band for DPLC or HPLC
CDF	cumulative distribution function
CPF	composite peak factor
DC	direct current
DPLC	digital PLC
DSP	digital signal processing
HF	high frequency
HPLC	hybrid PLC
LAN	local area network
LCL	longitudinal conversion loss

LED	light-emitting diode
LF	low frequency
L_{nom}	Output power of an DPLC or HPLC terminal in the nominal high frequency band
L_{DPLC}	Output power of an DPLC terminal in the nominal high frequency band
MIB	management information base
OFDM	orthogonal frequency division multiplexing
OSB	output signal balance
PEP	peak envelope power
PDF	probability density function
PLC	power line carrier
QAM	quadrature amplitude modulation
RMS	root-mean-square
Rx	receiver, receive
SNMP	Simple Network Management Protocol
SNR	signal-to-noise ratio
SSB	single side band
TP	twisted pair
Tx	transmitter, transmit
UDP	User Datagram Protocol
WAN	wide area network

4 Generic structure of DPLC and ADPLC terminals

The generic structure describes the main building blocks of DPLC and ADPLC terminals. All other building blocks which are necessary for proper functioning (e.g. power supply, device control units) are not considered in Clause 4.

Figure 2 shows the block diagram of a DPLC terminal with the digital and analog interfaces on the left side and the HF line interface on the right side. If only one interface is available, the function of the time division multiplexer / demultiplexer and optional Ethernet switch may be replaced by a simple direct connection to the digital PLC modem. The resulting pass band signal is amplified and matched to the coupling device using the power line interface.

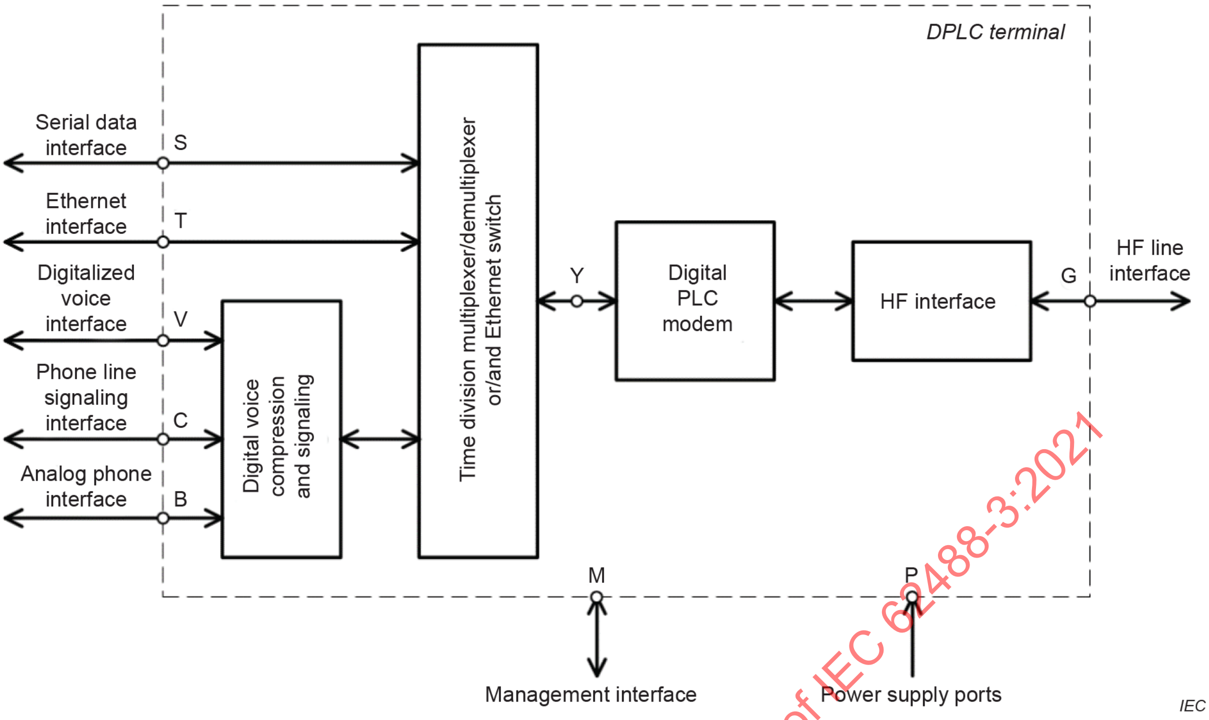


Figure 2 – Generic architecture of a DPLC terminal

Figure 3 shows the block diagram of an ADPLC terminal, which contains both a digital PLC modem as well as an analogue SSB modem, compliant with IEC 62488-2, that shall be used to convey signals coming from teleprotection or analogue I/O interfaces, with the digital and analogue interfaces on the left side and the HF line interface on the right side. An ADPLC terminal contains a digital PLC path, that was introduced above and shown in Figure 2, and may contain a teleprotection path and/or an APLC path according to IEC 62488-2. The output pass band signal of the digital PLC modem may be combined in the frequency domain with the output pass band signals of the optional teleprotection and/or APLC paths. The resulting pass band signal is amplified and matched to the coupling device using the power line interface.

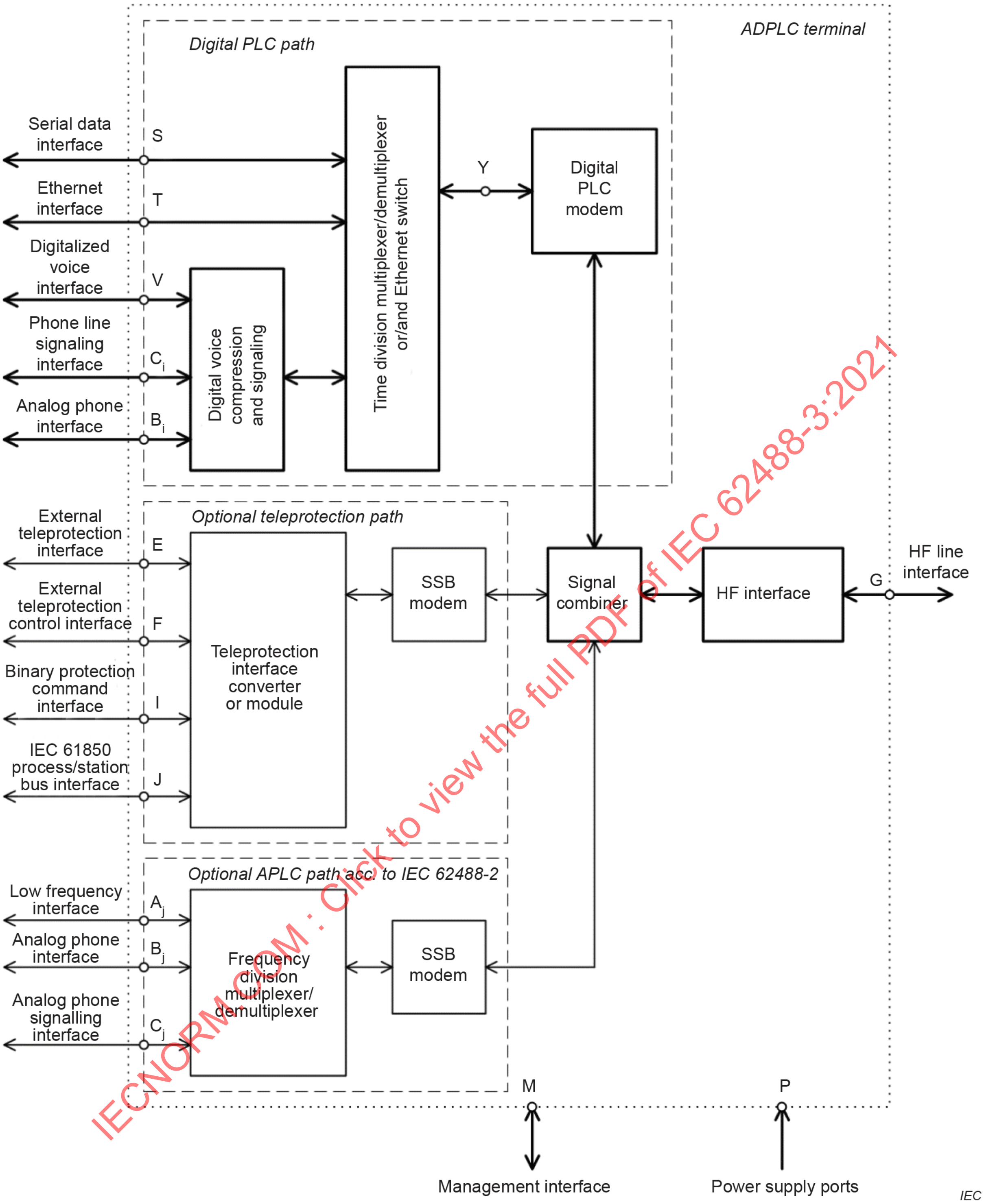


Figure 3 – Generic structure of an ADPLC terminal

NOTE Digital PLC modems use QAM-, OFDM-based digital modulation schemes or other types of digital modulation methods. IEC 62488-1 contains more details.

For planning of a point-to-point DPLC links the manufacturer of the DPLC terminals shall specify the following characteristic of the DPLC terminal:

- Set of transmission efficiency levels in bit/s/Hz under condition of equal bit-loading for all used carriers in a transmission scheme (e. g. OFDM);
- A typical dependence of BER or BLER from SNR for each transmission efficiency level;

- Possible RMS output power of the DPLC terminal;
- Typical time delay of a point-to-point DPLC link.
- If applicable, a typical delay of the voice signal on interfaces B_i and/or V in a point-to-point DPLC link.

5 Access side interfaces

5.1 General

Access side interfaces related to DPLC equipment are described in Clause 5.

5.2 Digital interfaces

5.2.1 Ethernet IEEE 802.3 interface

5.2.1.1 General

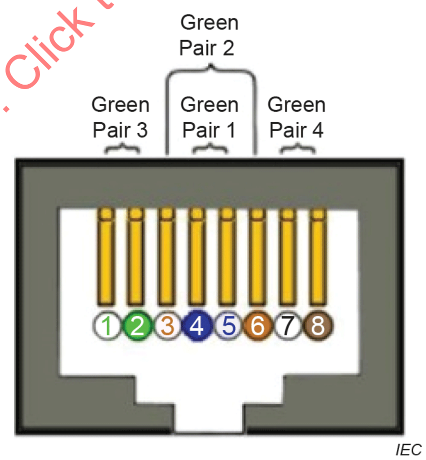
In some cases, it is required to interface DPLC links with local area networks in order to implement switching or bridging functionalities.

This integrated interface often implements both the Ethernet 10/100BaseT (copper) as well as 100FX (optical) standard interfaces.

Ethernet frames are first serialized, elaborated and then transmitted through an internal integrated high-speed data serial modem connected to the DPLC terminal.

5.2.1.2 Physical layer

For Ethernet interfaces, TP (twisted pair copper) or optical connectors are commonly used. Possible examples of these connectors are given in Figure 4 and Figure 5.



Key

1	TX +	2	TX –	3	RX +	4	NC
5	NC	6	RX –	7	NC	8	NC

Figure 4 – ETH IEEE 802.3 RJ45 type connector

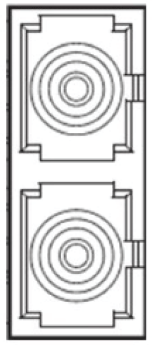


Figure 5 – ETH IEEE 802.3 SC type connector

For the physical characteristics (voltage, connector form factor, insulation, and pinout) of these interfaces, the relative reference standard shall be applied.

An electrical Ethernet interface may optionally provide power over Ethernet of power level 1 or higher, according to IEEE 802.3.

5.2.1.3 Data link layer

For this application the link layer should be compliant with the Ethernet standard IEEE 802.3.

Normally for practical reasons more than one Ethernet port should be made available to implement switching functionalities for local network connection.

Remote Ethernet connectivity may contain an implementation of the basic transparent WAN bridging functionalities, according to IEEE 802.1d.

5.2.2 Serial interface

The following serial data interfaces may be optionally supported by a DPLC terminal:

– TIA-232;
– TIA-422;
– TIA-485;
  ITU-T V.11 / ITU-T X.24;
– ITU-T G.703 (64kBit).

It is recommended for the DPLC part to have a flow control mechanism implemented to be able to deal with the possible differences of the bit rate on both sides of a DPLC link.

If necessary, DPLC equipment shall be able to generate or deal with the serial data clock signals required for or generated by an external equipment.

5.3 Analogue interfaces

The description and specification of the Analogue Phone Interface and all possible interfaces of an optional APLC path are given in IEC 62488-2.

5.4 Teleprotection system interface

5.4.1 Description

A typical goal of a selective teleprotection device consists of accelerating, delaying, locking or conditioning the protection relay (line distance protection, SF6 low pressure protection) installed in the field at both sides of an ADPLC link.

This is achieved by transmitting a command from one teleprotection device to the other by a suitable transmission system, fast, secure and dependable in order to control the way the protection relay at the other end of the line section behaves.

ADPLC terminals optionally may have on board an integrated selective teleprotection device with its interface enabling communication with protection devices.

Another possible option includes an interface enabling the communication between an external teleprotection device and an ADPLC terminal.

In the first case the interface processes signals/commands directly exchanged with the field protection relay. This means no low frequency signals are exchanged but simply logic criteria/commands are processed. This may be done using GOOSE messages defined in IEC 61850 or digital input or output signals according to IEC 60834-1.

The inputs and outputs should preferably be decoupled from the other signal/command input/output.

In the second case the interface connected to an external selective teleprotection device. Therefore the interface is a voice frequency input/output or fiber optic tranceiver with control circuit, which convert the teleprotection commands into base band signals, which are transmitted to the remote ADPLC terminal and an external teleprotection.

5.4.2 Integrated teleprotection

In case of integrated teleprotection or external selective teleprotection the functional requirements of teleprotection command systems, as defined in IEC 60834-1, shall be applied.

5.4.3 Teleprotection interface frequency band

The nominal frequency band used for the teleprotection service shall be specified within the frequency range of the nominal high-frequency band.

This may be a fully dedicated and pre-allocated frequency band or an alternative one which is allocated when the terminals switch to the teleprotection mode.

For this second operational mode, to avoid the risk of interference and optimize command transmission, the other signals present at the low frequency interface may be inhibited, while the commands signal is boosted.

In the same way, in order to get the best possible signal to noise ratio for transmitting a command, the signal resulting from the digital modulation may also be inhibited.

5.4.4 Teleprotection interface impedance

- Input/output impedance 600 Ω

5.4.5 Teleprotection interface reflection

- Return loss ≥ 14 dB

5.4.6 Teleprotection interface signal levels

- The minimum range of the transmit input level shall be -20 dBm to 0 dBm
- The minimum range of the received output level shall be -20 dBm to 0 dBm

5.4.7 Teleprotection interface control circuits

Control inputs may be provided to accomplish boosting of the teleprotection signal to a maximum specified high frequency PEP output power, and to interrupt the other signals for a short time of typically less than 500 ms, during teleprotection transmission.

ADPLC terminals shall include control circuits to shift the terminals from communication mode to teleprotection mode if the temporary band is allocated for transmitting the teleprotection signal.

The control inputs shall operate with a loop resistance of up to 500 Ω.

Control outputs are often provided to give an alarm to the teleprotection terminal in case of failure or degradation of the ADPLC link.

6 HF line interface

6.1 DPLC high frequency band & channeling

The typical high frequency ranges used in Europe span from 40 kHz to 500 kHz (up to 1 000 kHz in some countries and for special application (e.g. cables) ranges down to 16 kHz may be used). Parts of this range may be barred by national regulations.

The used nominal high frequency band for one direction is divided into a digital PLC band (DPLC band), that may be fragmented by other APLC bands or bands reserved for radio services, and optionally into a number of analogue PLC bands (APLC bands) with a bandwidth of 4 kHz or 2,5 kHz typically as described in IEC 62488-2.

A DPLC terminal usually operates in different high frequency bands for each direction of the transmission. The transmit and receive high frequency bands may be non-adjacent, adjacent or superimposed.

The nominal high frequency band of the ADPLC terminal has a bandwidth equal to

$$B_{\mathrm{nom}} = B_{\mathrm{D}} + \sum_{\mathrm{i}} B_{\mathrm{A}}(i) \qquad (1.1)$$

where:

B_{D} = bandwidth of DPLC band,

$B_{\mathrm{A}}(i)$ = bandwidth of the i-th APLC band.

The nominal high frequency band of the DPLC terminal has a bandwidth equal to

$$B_{\mathrm{nom}} = B_{\mathrm{D}} \qquad (1.2)$$

where: B_{D} = bandwidth of DPLC band.

For each DPLC terminal the possible set of nominal high frequency channel bandwidths and the set of nominal carrier frequencies, for which the recommended values are maintained, shall be stated.

The nominal high frequency band of the DPLC terminal may contain unused frequency ranges in order to achive a co-existance with other DPLC or APLC links or radio services.

6.2 Frequency accuracy

The high frequency, corresponding to the carrier suppressed during the modulation process (virtual carrier frequency), for any high frequency channel shall not differ from its nominal value by more than ±10 Hz.

6.3 Signal levels

The configurable range of PEP and RMS power of the high frequency signal at the transmission line side high frequency interface when loaded with nominal impedance shall be stated in the terminal user manual.

6.4 In-band emissions

In-band emissions are emissions, at one or more frequencies or sub-channels, located within the nominal high frequency transmit band.

The in-band emissions are quantified by peak envelope power and RMS power on the RF output of a DPLC or ADPLC terminal.

Additionally, the values of peak envelope power and RMS power on the HF line interface output for each path contained in an ADPLC terminal shall be stated in the terminal user manual.

The test procedure for measuring of the in-band emission is described in Clause 7.

The level of the in-band emissions shall be in accordance with the national frequency regulating authorities.

6.5 Nominal impedance

The nominal impedance within the nominal high frequency transmit band at the HF line interface shall be 75 Ω unbalanced or 150 Ω balanced.

Other values may be considered if needed. For each value, the HF line interface of the terminal shall comply with the requirements defined in Clause 7 and Clause 8.

6.6 Return loss

The test procedure for measuring the return loss is described in 8.4.

The return loss within the nominal high frequency transmit band shall be not less than 10 dB.

6.7 Degree of unbalance to earth

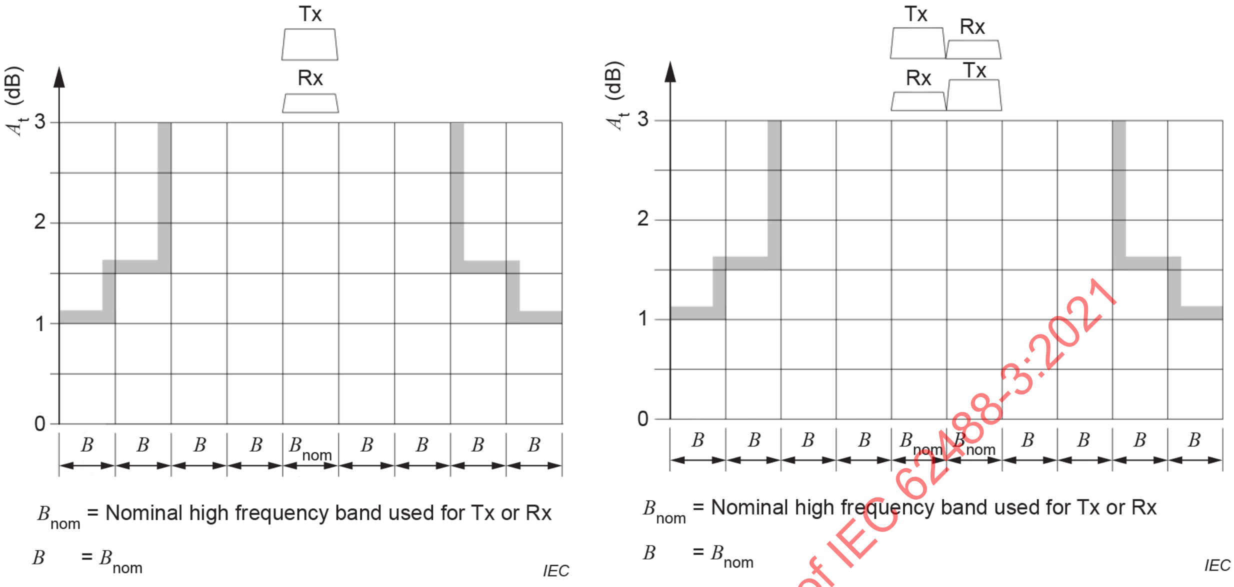
The test procedure for measuring the degree of unbalance to earth is described in 8.5.

For the HF line interface of the balanced type, the longitudinal conversion loss shall not be less than 40 dB at power frequency 50 Hz or 60 Hz.

6.8 Tapping loss

The test procedure for measuring the tapping loss is described in 8.6.

The impedance outside the nominal high frequency transmit and receive bands shall be such that any other APLC, DPLC or ADPLC terminal, connected to the same line matching unit with the same impedance, shall not suffer from a tapping loss higher than indicated in Figure 6.



a) Non-adjacent Tx and Rx bands

b) Adjacent Tx and Rx bands

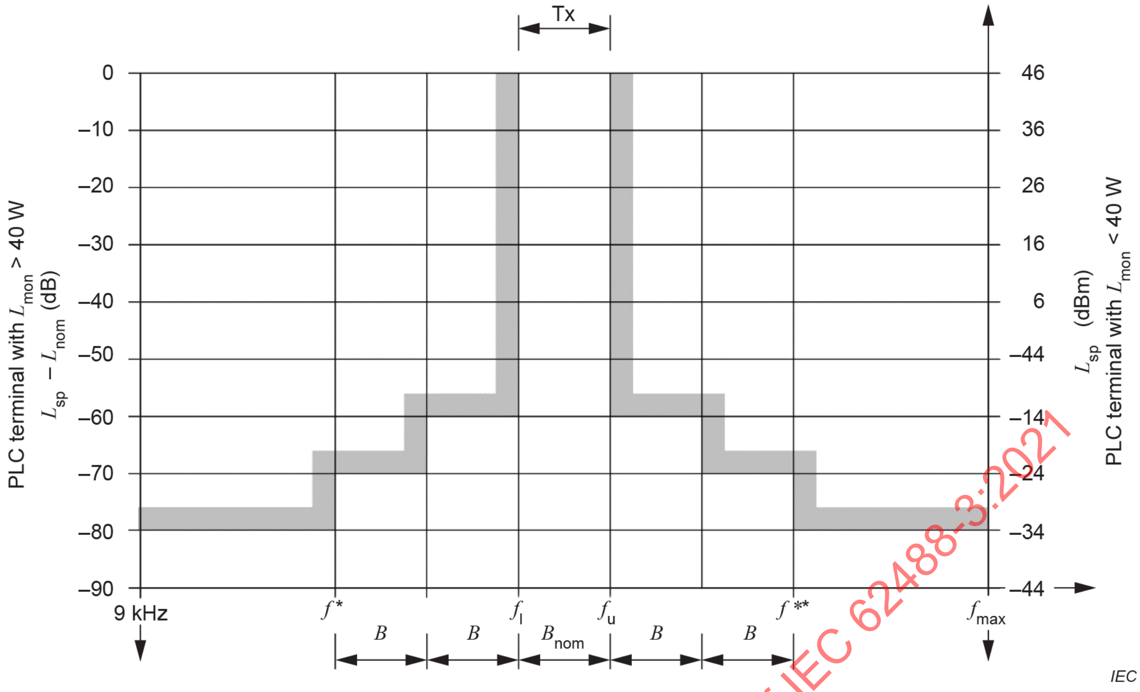
Figure 6 – Tapping loss limits for DPLC terminals

6.9 Spurious emissions

Spurious emissions are emissions, at one or more frequencies, located outside the nominal high frequency transmit band.

The test procedure for measuring the spurious emissions is described in 8.7.

The maximum permitted level of spurious emissions is indicated in Figure 7.



Key

B_{nom} = nominal high frequency band used for transmission

B = B_{nom}

L_{sp} = level of spurious emissions

L_{nom} = nominal high frequency band output power

f_l = lower cut-off frequency of the nominal high frequency band

f_u = Higher cut-off frequency of the nominal high frequency band

Figure 7 – Max level of spurious emissions outside the high frequency band

6.10 Nominal output power in the high frequency band

DPLC or ADPLC terminals are qualified by a nominal output power in the high frequency band available at the HF line interface output across a resistive load equal to the nominal impedance (see 8.7) expressed as PEP for which the terminal has been designed.

The terminal under test at the nominal output power shall be compatible with the requirements for spurious emissions to avoid inter-channel interference.

7 Quality and performance

7.1 General

In Clause 7 several requirements concerning quality and performance of a single or a two DPLC terminals, which are interconnected via HF line interface will be given.

In particular the focus will be on DPLC requirements referring to serial data interface, Ethernet interface or Digital voice as well as HF line interface for a single or a pair of terminals simulating a DPLC link.

Figure 8 shows the reference points for measuring DPLC parameters.

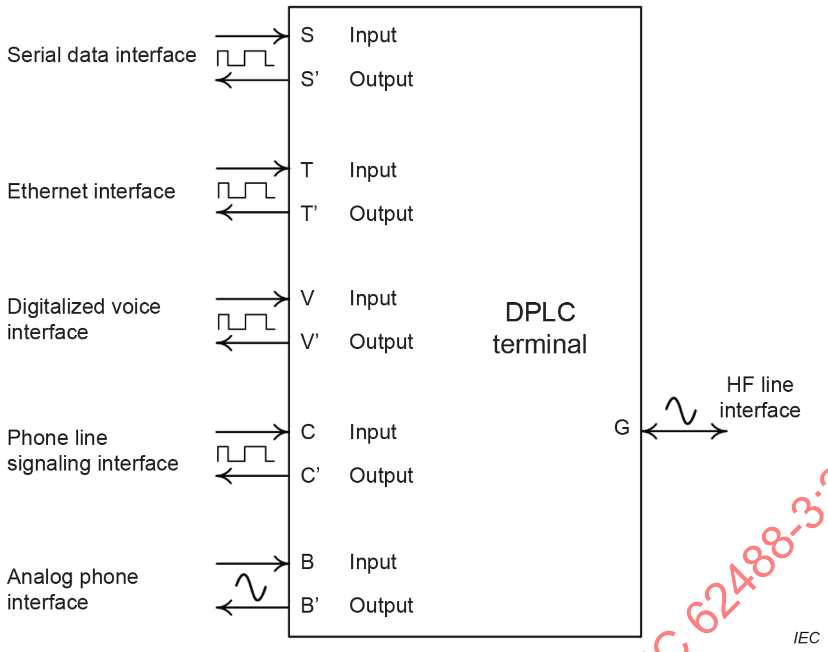


Figure 8 – Reference points for measuring DPLC parameters

7.2 Dynamic range of the DPLC receiver

The DPLC link under test shall operate with the specified maximum BER or BLER measured at one of the DATA interfaces of the terminal after complete stabilisation of the AGC control loop, if available, within a dynamic range of the DPLC receiver of at least 40 dB.

Dynamic range of the DPLC receiver is defined as the difference between the maximal RMS level of the received signal at specified bandwidth, bit or block rate, maximum BER or BLER and the sensitivity RMS level of the receiver at the same bandwidth and the minimum bit or block rate (see the test definition in 8.10).

If applicable for ADPLC, the automatic gain control characteristic shall be coordinated with the teleprotection requirements.

7.3 Bit rate

The DPLC equipment shall be characterized by at least a minimal and a maximal bit rate of the transmission achievable at specified bandwidth, SNR conditions and BER or BLER (refer to 8.9).

For DPLC terminals the bit rate V_Y is defined as the number of bits per second transmitted via the digital PLC modem at its input Y in Figure 2 and Figure 3.

The relationship between the bit rate V_Y at the PLC modem input Y and the raw bitrate V at the input of the serial data interface or the Ethernet interface may be given by the following Equation (2):

$$V = k_1 \cdot V_\mathrm{Y} - k_2 \qquad (2)$$

where:

V raw bit rate on serial or Ethernet interface;

V_Y bit rate at the input of the DPLC modem;

k_1 multiplicative coefficient specified for the DPLC terminal;

k_2 additive coefficient specified for the DPLC terminal.

The bit rate V is defined for a data transmission via serial data interface S or the Ethernet interface T without any kind of data or frame compression before the interface Y.

NOTE The rational for introducing of the Equation (2) is a possible difference between the raw bitrate at the serial data interface S or the Ethernet interface T and the bit rate at the DPLC modem input due to an overhead in the time division multiplexer/demultiplexer or Ethernet switch or/and the presence of additional internal control channels.

7.4 Start-up time

Start-up time is defined as the duration from power up of the DPLC terminal under test (see 8.13) to the time point at which the synchronisation of the link is established.

Start-up time of the DPLC terminal may include a firmware booting procedure, self-diagnosis procedure, synchronisation of the DPLC link and an adaptation phase (for equalization, AGC or echo adaptation for example). The start-up time should be below the maximum value of 180 seconds.

7.5 Recovery time after synchronization loss

After a loss of synchronization (e.g. caused by a noise burst or a signal interruption) the time to recover the normal operation of the DPLC link at 30 dB SNR should be less than the maximum value of 60 seconds for a minimum data rate.

7.6 Sensitivity

The sensitivity of a DPLC terminal is defined as the minimum value of the received signal level at its HF line interface, at which the DPLC link is able to establish synchronisation and data transmission on the lowest possible transmission rate.

The manufacturer of the DPLC equipment shall provide information about the lowest transmission rate and corresponding BER or BLER supported by DPLC equipment at defined bandwidth.

7.7 Selectivity

A DPLC terminal shall be able to operate at the specified maximum BER or BLER measured on a serial or Ethernet interface of the DPLC terminal, while a sinusoidal disturbance signal with a frequency which is outside of the nominal high frequency band (B_{nom}) and with levels specified in 8.8, is applied to the DPLC terminal HF line interface.

7.8 Adaptability to line conditions

If an automatic rate adaptation to ensure the continuity of the communication services supported by DPLC equipment is available, the range of automatic rate adaptation depending on the transmission conditions shall be specified for the DPLC equipment.

The behaviour of the DPLC link in case of instant attenuation changes in the transmission channel shall be specified.

7.9 Quality of voice channels

For the definition of the voice channel quality, refer to ITU-T P862 (PESQ) or ITU-T P863 (POLQA). Table 1 shows a typical dependence of voice channel quality vs. DPLC capacity.

Table 1 – Dependence of voice channel quality vs. DPLC capacity

Vocoder	Bit Rate (kbps)	PESQ*	MOS (according to ITU-T P800)
G.729 CS-ACELP	8	3,41	3,92
G.729 × 2 Encodings	8	3,20	3,27
G.729 × 3 Encodings	8	3,03	2,68
G.729a CS-ACELP	8	3,33	3,7
G.723.1 MP-MLQ	6.3	3,40	3,9
G.723.1 ACELP	5,3	3,31	3,65
FS-1016 CELP	4,8	3,15	3,1
FS-1015 LPC	2,4	2,72	1,8
* (calculated values according to P862.1 mapping)			

7.10 Telephone signalling transmission

For the description of this optional interface, refer to IEC 62488-2.

7.11 Quality on the serial DATA channels

7.11.1 General

The serial DATA channel comprises two DPLC terminals communicating with each other over power line interfaces (see Figure 9). Typically following serial data interfaces can be used in DPLC terminals RS232, RS422, RS485, X.24, V.11, V.24.

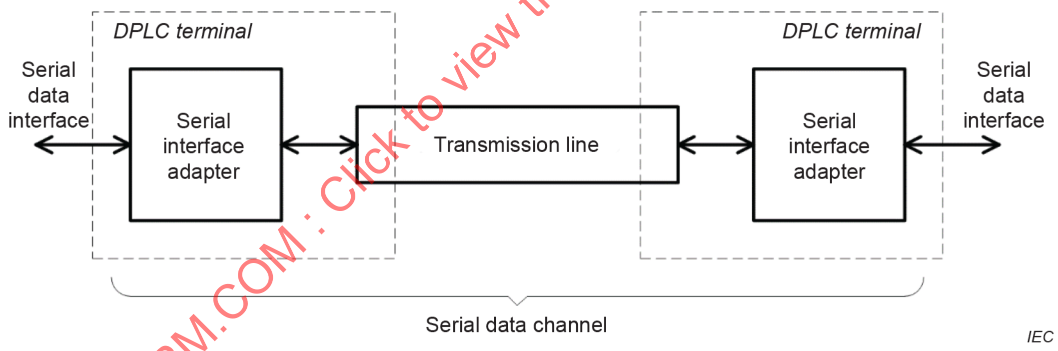


Figure 9 – Block diagram of a serial data channel

The quality of the serial data channel between the serial data interfaces of the DPLC terminals can be qualified by the following measurements:

- Bit rate
- Bit error ratio
- Transmission delay

7.11.2 Bit rate

See 7.3 for the bit rate definition.

7.11.3 BER

The BER shall be considered at a specified bandwidth and SNR using an external additive white Gaussian noise source with a limited bandwidth, which is bigger than and includes the nominal high frequency band of the DPLC terminal under test.

The BLER may be measured as well.

NOTE The SNR calculated for additive white Gaussian noise and for a corona noise are different to achieve the same BER. This may be taken into account during the engineering of the DPLC link.

7.11.4 Nominal transmission link delay

Transmission link delay is the time necessary for transmission of a data bit or block from a serial data interface input of one DPLC terminal to the serial data interface output of the remote DPLC terminal connected with the first one over PLC interface and without the signal transmission delay in the medium.

The nominal transmission link delay value is defined as the value, which is above the values of 95 % of all measured transmission link delays.

7.12 Quality of the frame transmission using Ethernet interfaces

7.12.1 General

When Ethernet interfaces are used in DPLC terminals and provide a LAN to LAN service channel, it must comply with the following requirements.

7.12.2 LAN to LAN Speed

The LAN to LAN transmission rate should be stated at least for configurations with a minimal and a maximal bandwidth of the nominal high frequency band and bit rate and different Ethernet frame sizes specified in 8.12.

7.12.3 LAN to LAN latency

LAN to LAN latency should be as stated by the manufacturer as a minimum, mean and maximum latency value based on the specified number of frames, their length and transmission rate used during testing.

The manufacturer shall make sure, that the number of frames used for the test allows the achievement of reproducible test results.

7.12.4 Packet loss on the LAN transfer

The relation between the Ethernet frame loss on a point to point DPLC connection and the SNR on the HF line should be given at least for configurations with a minimal and a maximal bandwidth of the nominal high frequency band and bit rate.

8 Testing

8.1 General

In this Clause a description of the test setup and methodology to be applied for assessing the main features of an DPLC terminal will be given. All tests shall be performed in order to measure and verify that the terminal meets the requirements expressed in Clauses 5, 6 and 7.

The tests of the DPLC terminal shall be at least performed with its configurations with a minimal and a maximal bandwidth of the nominal high frequency band.

All tests verifying the requirements shall be considered as type tests as defined in the International Electrotechnical Vocabulary (IEC 60050-151:2001, 151-04-15).

If the DPLC equipment is used together with an APLC part or analog interfaces, the tests and definitions specific to IEC 62488-2 shall be referenced.

Each DPLC terminal or the DPLC path of each ADPLC terminal shall allow a configuration of a data interface (e.g. serial or Ethernet interface), on which it should be possible to allocate the entire transmission capacity at the input Y of the digital PLC modem shown in Figure 2 and Figure 3 in terms of the bit rate for testing.

8.2 Test setup for DPLC link tests

In all test procedures which require the use of a pair of DPLC terminals, the high frequency side interfaces shall be connected by the artificial lines (resistive attenuators with a total attenuation A according to Equation (3), matched to the nominal impedance of the terminals.

$$A = L_{\text{DPLC}} - 12 - 10\log(B_{\text{nom}}/4) \tag{3}$$

where L_{DPLC} is the value of the RMS output power in dBm and B_{nom} is the nominal high frequency band in kHz. The calculated attenuation value A will to be rounded up to an integer dB-value. The selected attenuation value in the test setup may vary from value A by -1dB to +2dB.

8.3 Signal to noise ratio

Signal to noise ratio at the input of the DPLC terminal under test is defined as:

$$SNR = L_{\text{DPLC\_RX}}/L_{\text{AWGN}} \tag{4}$$

where:

$L_{\text{DPLC\_RX}}$ is the RMS power of the DPLC signal at the input of the DPLC terminal under test in the nominal high frequency band of the DPLC receiver under test;

L_{AWGN} is the RMS power of the AWGN at the input of the DPLC terminal under test in the nominal frequency band of the DPLC receiver under test.

An SNR measurement may be carried out using a selective true RMS voltmeter or spectrum analyzer at the input of the DPLC terminal under test. In a first step an $L_{\text{DPLC\_RX}}$ of the receiving DPLC signal at the input of the DPLC terminal under test is measured without adding an AWGN as shown in Figure 16. In the second step L_{AWGN} is measured in the same frequency band without a signal transmission to the DPLC terminal under test.

NOTE If the selective true RMS voltmeter or spectrum analyzer has a limited bandwidth, the finally measured $L_{\text{DPLC\_RX}}$ and L_{AWGN} are both calculated from the measured intermediate values of $L_{\text{DPLC\_RX}}$ and L_{AWGN} respectively.

8.4 Return loss

This subclause describes the test procedure for measuring the return loss. The return loss of the high frequency line interface of an DPLC terminal shall be measured to verify that it meets the requirement defined in 6.6.

The return loss measurement shall also be performed on all the 2-wire analogue phone interfaces and low frequency interfaces of the DPLC terminal.

The test circuit shown in Figure 10 may be used.

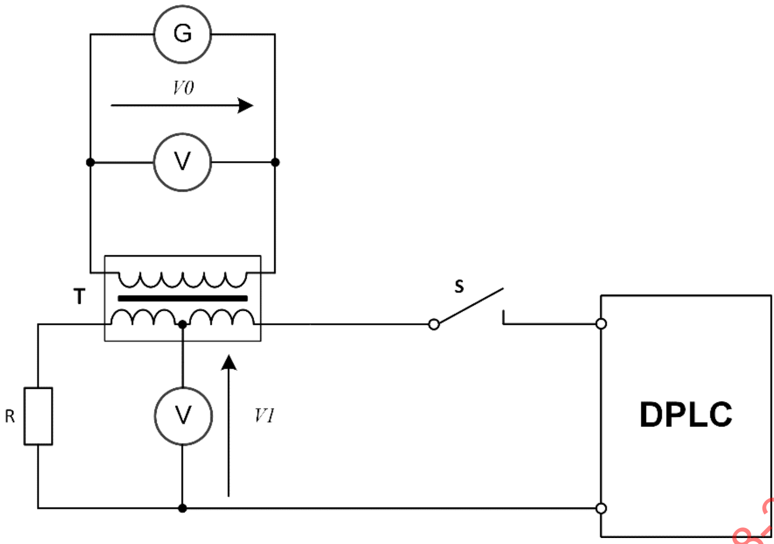


Figure 10 – Test circuit for return loss measurement

The resistor R shall be equal to the nominal impedance Z_{nom} of the DPLC interface under test. That is generally 600 Ω for the audio frequency interfaces, and 75 Ω or 150 Ω for the high frequency line interface.

G is a sine wave generator, and $V0$ shall be a sinusoidal signal with a constant voltage throughout the specified frequency range. The voltage level shall be the same in both positions of the switch S. A voltage of 1 V_{rms} is recommended.

T is a symetric differential transformer wound around a magnetic material suitable for the given frequency band. It is composed of two windings, the primary on the generator side, the secondary, centre tapped, on the DPLC side. In principle, the transformer ratio is 1:1 primary to secondary (centre tapped).

The measurement of voltages $V0$ and $V1$ shall be carried out with a suitable frequency selective voltmeter with high impedance across the specified frequency range. The DPLC is in idle state with no signal transmitted.

For each frequency, the measurement is carried out with switch S in open position giving the voltage $V1_{open}$ and with S in closed position giving the voltage $V1_{closed}$.

The return loss A_{RL} is given by Equation (5):

$$A_{RL} = 20 \times \log_{10} \left| \frac{V1_{open}}{V1_{closed}} \right| dB \quad (5)$$

Pay attention to the measurement with the differential transformer. As the elements of the measurement circuit are not perfect, the value of $V0$ may change slightly when closing/opening the switch S and may also change from one frequency to another. It is then mandatory to adjust and verify $V0$ at each point. This can be avoided using a transformer with a turn ratio of 10 for example. This shall mask the variation of the impedance of the secondary seen from the generator side.

Alternatively, another equivalent method for measurement of return loss may be used.

8.5 Degree of unbalance to earth

8.5.1 General

This subclause describes the test procedure for measuring the longitudinal conversion loss (LCL) and the output signal balance (OSB) which are related to the degree of unbalance to earth at inputs and outputs of the DPLC terminal under test respectively.

The LCL shall be measured on all the analogue phone interfaces, low-frequency interfaces and external teleprotection interfaces.

It shall also be measured on the balanced HF line interface at mains power frequency 50 Hz or 60 Hz.

The OSB shall be measured on all the analogue phone interfaces, low-frequency interfaces and external teleprotection interfaces.

8.5.2 Longitudinal conversion loss

The test circuit is given in Figure 11 (other arrangements may be considered as long as they follow the ITU-T Recommendation O.9).

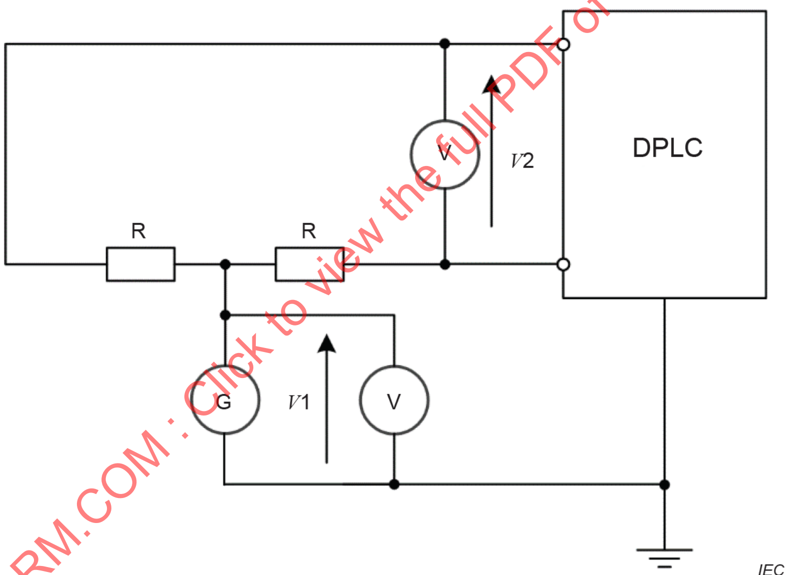


Figure 11 – Test circuit for LCL measurement (transmission port)

The resistors R shall be $Z_{nom}/2$ (that is generally R = 300 Ω for the analog phone interface and R = 75 Ω for the balanced HF line interface).

G is a sine wave generator, and $V1$ shall be a sinusoidal signal with a constant voltage throughout the specified frequency range which is:

- 50 Hz to 3400 Hz at the voice frequency channel inputs
- 50 Hz to 60 Hz at the HF line interface

A voltage of 1 Vrms is recommended. The voltages $V1$ and $V2$ measurement shall be carried out with a suitable frequency selective voltmeter with impedance >> R across the specified high frequency range.

The measured values of $V1$ and $V2$ are used to calculate the LCL by using Equation (6) at each measurement point:

$$LCL = 20 \times \log_{10} \left| \frac{V1}{V2} \right| dB . \tag{6}$$

For measuring voltage $V2$, voltmeter shall have a floating input, which does not degrade the unbalance to earth to be measured.

8.5.3 Output signal balance

The test circuit is given in Figure 12 (other arrangements may be considered as long as they follow the ITU-T Recommendation O.9).

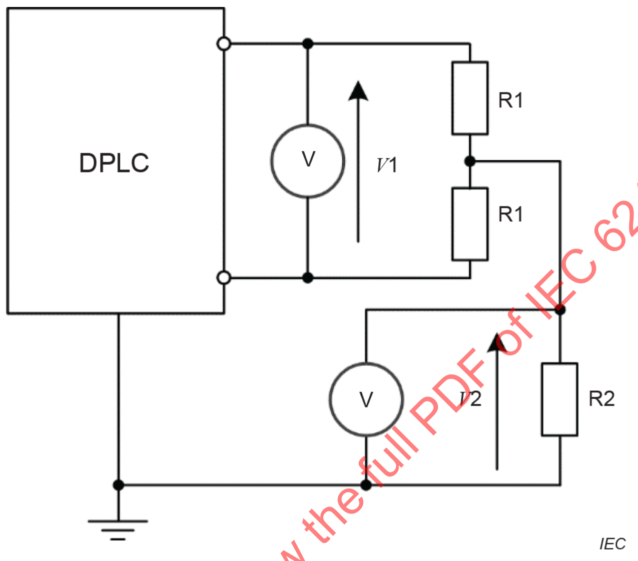


Figure 12 – Test circuit for OSB measurement (Rx port)

The resistors R1 shall be $Z_{nom}/2$ and the resistor R2 shall be $Z_{nom}/4$ (that is generally R1 = 300 Ω and R2 = 150 Ω).

The voltages V1 and V2 measurement shall be carried out with a suitable frequency selective voltmeter with impedance >> R across the specified frequency range (50 Hz to 3 400 Hz). The DPLC shall generate appropriate test signals from 50 Hz to 3400Hz at the TX port.

The measured values of $V1$ and $V2$ are used to calculate the OSB by using Equation (7) at each measurement point:

$$OSB = 20 \times \log_{10} \left| \frac{V1}{V2} \right| dB . \tag{7}$$

For measuring voltage $V2$, the voltmeter shall have a floating input, which does not degrade the unbalance to earth to be measured.

8.6 Tapping loss

This subclause describes the test procedure for measuring the tapping loss. The test circuit is given in Figure 13. The closing of switch S simulates the insertion of the DPLC into a matched circuit.

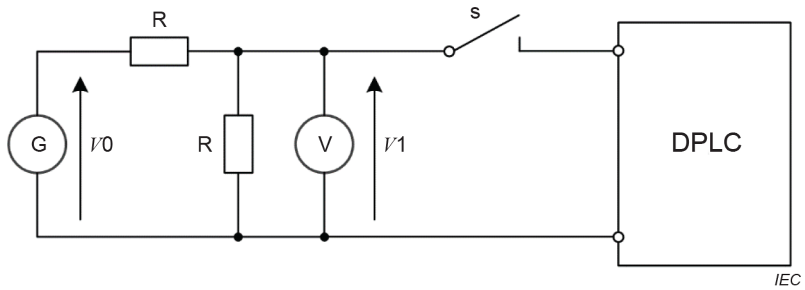


Figure 13 – Test circuit for tapping loss measurement

The resistors R shall be equal to the nominal impedance of the DPLC high frequency line interface Z_{nom}.

G is a sine wave generator, and $V0$ shall be a sinusoidal signal with a constant voltage of 775 mV RMS throughout the specified voltage range.

The measurement of voltage $V1$ shall be carried out with a suitable frequency selective voltmeter with impedance >> R across the specified frequency range. The DPLC is in idle state with no signal transmitted.

For each frequency, the measurement is carried out with switch S in open position giving the voltage $V1_{\text{open}}$ and with S in closed position giving the voltage $V1_{\text{closed}}$. The tapping loss attenuation A_{TL} is then given by Equation (8):

$$A_{\text{TL}} = 20 \times \log_{10} \left| \frac{V1_{\text{open}}}{V1_{\text{closed}}} \right| dB . \quad (8)$$

Alternatively another equivalent method for measurement of return loss may be used.

8.7 Spurious and in-band emissions

In order to measure spurious emissions, the DPLC terminal shall be set into a test mode in order to generate two sinusoidal test signals of equal amplitude while all other signals are switched off. The transmitter shall be terminated with a resistive load equal to the nominal impedance.

The test signal frequencies shall be $f_c \pm B_{\text{nom}}/4$,

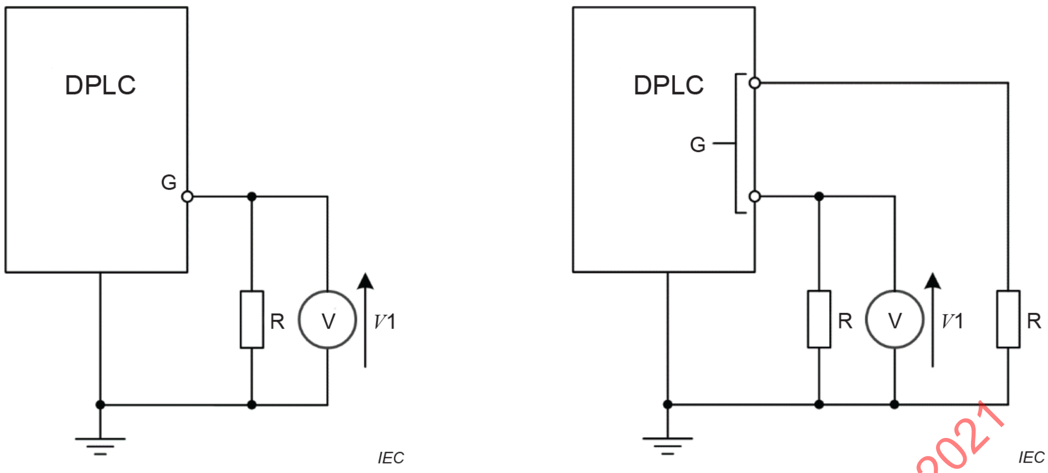
where

f_c centre frequency of the nominal high frequency transmission band,

B_{nom} nominal high frequency bandwidth.

The amplitude of the test signals shall be chosen so that each produces a quarter of the stated nominal high frequency output power to achieve the in-band emissions equal to the nominal PEP of the DPLC terminal.

The measurement shall be made with the aid of a selective level measuring set with an adequate bandwidth. Alternatively, a spectrum analyzer may be used.



a) Unbalanced high frequency interface **b) Balanced high frequency interface**

Figure 14 – Test circuit for spurious and in-band emissions measurement

The test circuit in Figure 14a) is used for unbalanced and in Figure 14b) for balanced HF line interface. The value of the resistors R in Figure 14 shall be 75 Ω, equal to the nominal unbalanced impedance of the high frequency interface within the nominal high frequency transmit band during the signal transmission.

The measurement of the voltages $V1$ for spurious and in-band emissions shall be made with the aid of a selective level measuring set with bandwidth defined below and with impedance not less than 10 kΩ. Alternatively, a spectrum analyzer may be used.

NOTE The in-band emission at balanced HF line interface of the DPLC or ADPLC under test is higher by 6 dB than the measured value of the voltage $V1$ in Figure 14b).

The measurement instrument (e.g. selective voltmeter or spectrum analyzer) shall use a bandwidth equal to B_{nom} for measurement of in-band emissions and a bandwidth between 100 Hz and 300 Hz for spurious emissions out of the nominal high-frequency band.

During spurious emissions measurement the DPLC or ADPLC terminal under test shall operate in the mode with maximal spurious emission. The measured spurious emissions shall be below the limits defined in Figure 7.

For the verification of PEP, a measurement device shall be used with the measurement bandwidth bigger than the B_{nom}.

The spurious and in-band emission measurements shall be made between 9 kHz and a frequency $f_{\text{max}} = fu\_max + 2 \cdot Bnom$, where fu_max is the maximal upper cut-off frequency fu of a nominal high frequency band, which can be used by DPLC terminal or DPLC path (see Figure 7).

The typical maximal value of fu_max used in Europe is 500 kHz. In some countries fu_max could be up to 1 000 kHz.

8.8 Selectivity

The test is carried out on a link by injecting the sinusoidal disturbance signal at the HF line interface of one terminal by means of an external disturbance signal source and an additive signal coupler using a test circuit as shown in Figure 15.

The test shall be performed at the nominal high frequency output power of the DPLC in the Figure 15.

The test setup shown in Figure 15 may be adapted to the needs of the equipment under test to be tested according to the requirements of this document.

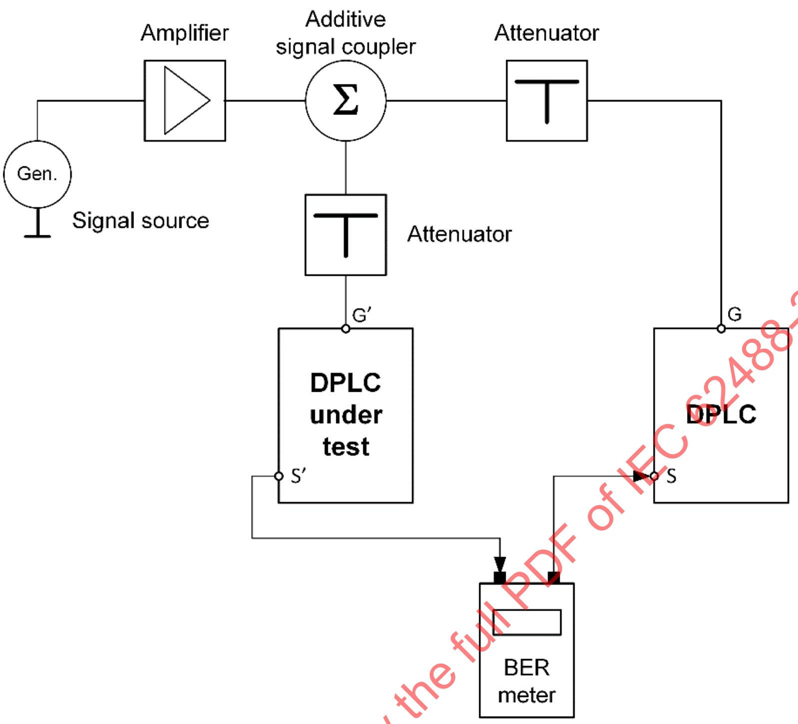


Figure 15 – Test circuit for selectivity measurement

In Figure 15 S' is the data output of the DPLC under test receiving the PLC signal transmitted by DPLC with the data input S.

The selectivity shall be tested separately in four different tests using the following test frequencies and corresponding levels at the HF line interface of the DPLC terminal under test:

- 300 Hz below the lower nominal carrier high frequency receive band with the sine signal level +10 dBm0;
- 300 Hz above the upper nominal carrier high frequency receive band with the sine signal level +10 dBm0;
- B_{nom} below the lower nominal carrier high frequency receive band with the sine signal level +20 dBm0;
- B_{nom} above the upper nominal carrier high frequency receive band with the sine signal level +20 dBm0.

The reference signal (0 dBm0) is the RMS of the signal received by the DPLC terminal under test shown in Figure 15.

The recommended conditions of test are the following.

- Serial DATA rate: data rate of the DPLC under this test, which is possible in the configuration of the used DPLC terminals.
- BER measurement shall be performed using a pseudorandom data pattern
- BER measurement duration: at least 10^7 bits shall be transmitted

- Maximum allowed BER: 10^{-6}

Alternatively, the test may be performed using BLER under following conditions:

- Serial DATA rate: data rate of the DPLC under this test, which is possible in the configuration of the used DPLC terminals.
- BLER measurement shall be performed using frames with a length of 128 bits
- BLER measurement duration: at least 10^{5} frames shall be transmitted
- Maximum allowed BLER: 10^{-4}

If there is no serial DATA interface available, the test should be performed on the Ethernet interfaces using a packet loss and BLER measuring equipment. In this case test following conditions shall be used:

- BLER measurement duration: at least $2{,}5 \times 10^{4}$ frames with a length of 64 octets shall be transmitted
- Maximum allowed BLER: $2{,}5 \times 10^{-3}$

The BER or BLER tester should be synchronized before generating the out-of-band signal.

NOTE The attenuation between the DPLC terminals in Figure 15 is the sum of both attenuators and the attenuation of the additive coupler (e.g. a 6 dB resistive star) as defined in 8.2. The distribution of the attenuation values between these 3 components is arbitrary as long as the correct impedance at both DPLCs high frequency ports is maintained.

8.9 Bit error rate

The test is carried out on a link by injecting the noise signal at the HF line interface of one terminal by means of an external Gaussian white noise signal generator and a additive signal coupler using a test circuit as shown in Figure 16.

The test setup shown in Figure 16 may be adapted to the needs of the equipment under test according to the requirements of this document.

The SNR used for the test is defined at the HF line interface of the DPLC terminal under test.

The test shall be performed at the nominal high frequency output power of the DPLC equipment.

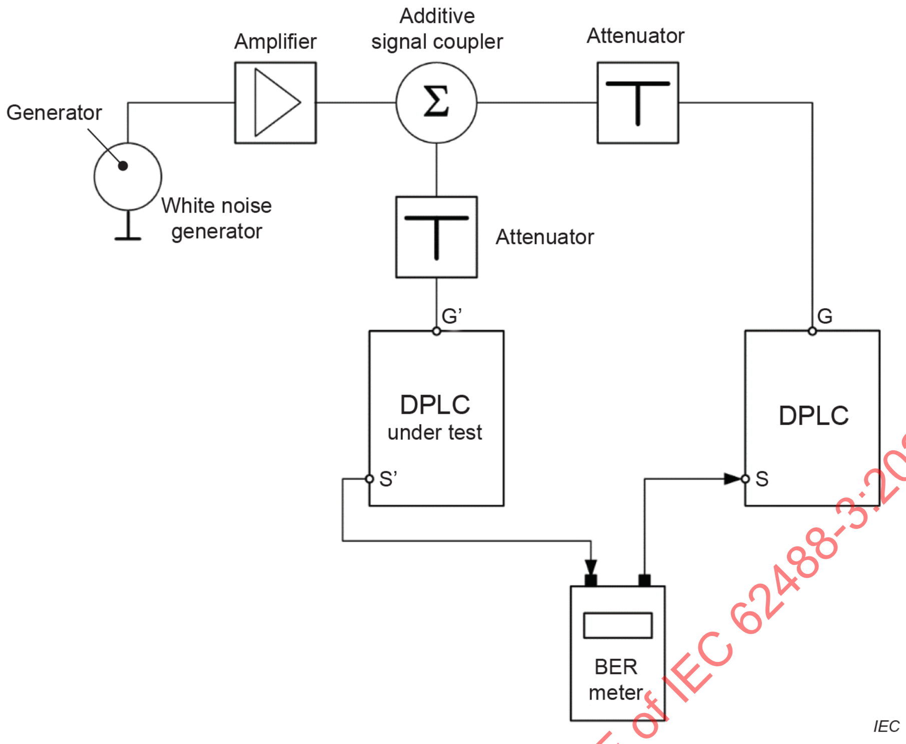


Figure 16 – Test circuit for bit error rate measurement

The bit error rate is usually measured on a serial interface, e.g. V.11. Alternatively, the test can be performed on an Ethernet interface using block error rate (BLER) measuring equipment.

The BER shall be considered at specific bandwidth and SNR settings.

The recommended conditions of test are the following.

- BER measurement shall be performed using a pseudorandom data pattern
- BER measurement duration: at least 10^7 bits shall be transmitted
- Maximum allowed BER: 10^{-6}

Alternatively, the test may be performed using BLER under following conditions:

- BLER measurement shall be performed using frames with a length of 128 bits
- BLER measurement duration: at least 10^5 frames shall be transmitted
- Maximum allowed BLER: 10^{-4}

If no serial DATA interface is available, the test should be performed on the Ethernet interfaces using a packet loss and BLER measuring equipment. In this case the following conditions shall be used:

- BLER measurement duration: at least $2{,}5 \times 10^4$ frames with a length of 64 octets shall be transmitted
- Maximum allowed BLER: $2{,}5 \times 10^{-3}$

NOTE The attenuation between the DPLC terminals in Figure 16 is the sum of both attenuators and the attenuation of the additive coupler (e.g. a 6dB resistive star) as defined in 8.2. The distribution of the attenuation values between these 3 components is arbitrary as long as the correct impedance at both DPLCs high frequency ports is maintained.

8.10 Serial data transmission delay

The serial data transmission delay can be measured on a similar but simplified setup as for BER testing. Specific test equipment might be available for some serial interface types. Before starting the measurement, the DPLC terminals under test need to be synchronized properly. During a measurement period of a few minutes the minimum, maximum and average transmission delay can be determined.

Transmission delay measurement can be performed using a dedicated tester as shown in Figure 17.

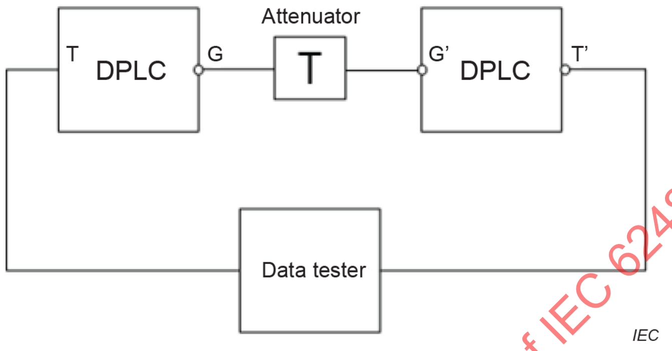


Figure 17 – Test circuit for serial data transmission delay measurement with a data tester

If the tester allows it, latency tests should be performed for various serial frame sizes.

For an asynchronous serial data interface, e.g. RS232, it is also possible to replace the data tester by a serial data generator and a two-channel oscilloscope as shown in Figure 18.

The data generator is setup to match the configured data rate of the DPLC terminals under test and to generate a data frame, which should be longer than the expected transmission delay. The oscilloscope is used to measure the lag time between the ends of the sent and the received data frames.

A serial data generator shall be able to manually send a frame to the DPLC system. The scope is configured to trigger upon the signal level detection on the first channel. The second channel should show the same signal pattern affected by the DPLC system latency.

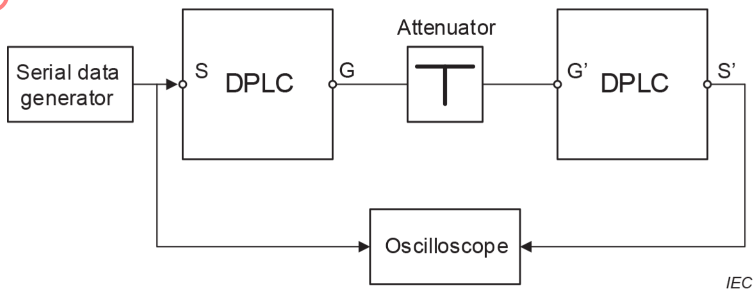


Figure 18 – Test circuit for serial data transmission delay measurement

The attenuation value of the attenuator between the DPLC terminals in Figure 17 and Figure 18 is defined in 8.2.

8.11 Dynamic range of the DPLC receiver

The test is carried out using the test setup shown in Figure 16. The total attenuation value of the two attenuators is set so that a receive level on the input of DPLC under the test is equal to the sensitivity level and the maximal allowed Rx signal for two separate tests. No additional noise is added from the noise generator. For this test the two attenuators between both DPLC terminals shown in Figure 16 may be replaced by only one attenuator. After the communication channel is ready, take measurements of BER for Serial data and BLER for Ethernet.

NOTE No additional test setup changes of the DPLC terminal under test shall be made between the sensitivity and maximum Rx signal tests.

The recommended conditions of the test are the following.

- BER measurement shall be performed using a pseudorandom data pattern
- BER measurement duration: at least 10^7 bits shall be transmitted
- Maximum allowed BER: 10^{-5}

Alternatively, the test may be performed using BLER under following conditions:

- BLER measurement shall be performed using frames with a length of 128 bits
- BLER measurement duration: at least 10^4 frames shall be transmitted
- Maximum allowed BLER: 10^{-3}

If no serial DATA interface is available, the test should be performed on the Ethernet interfaces using a packet loss and BLER measuring equipment. In this case the following conditions shall be used:

- BLER measurement duration: at least $2{,}5 \cdot 10^3$ frames with a length of 64 octets shall be transmitted
- Maximum allowed BLER: $2{,}5 \cdot 10^{-2}$

The tests shall be performed using the minimum data rate provided by DPLC under test, but not less than the data rate defined by the following Equation (9):

$$DR = 2\,400 \text{ bit/s } B_{\text{nom}}/1\text{kHz} \quad (9)$$

8.12 LAN to LAN testing

8.12.1 General

This test can be performed using test equipment capable of sending frames of variable sizes, counting and measuring transit delays.

A laptop or test device shall be connected to one of the DPLC terminals. During any test, one should be configured as a source and the other as a receiver.

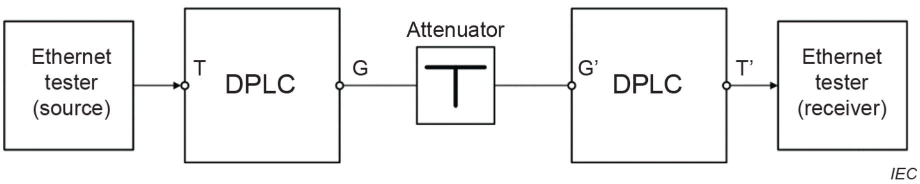


Figure 19 – Test circuit for maximal throughput and latency measurement

The DPLC link under test shall be operated in a mode allowing the measurement of the maximal throughput.

Throughput and latency tests should be performed for various Ethernet frame sizes. A typical set is:

– 64 octets
– 150 octets
– 1 500 octets
– 1 800 octets (optional).

In case testers cannot define the traffic as pure Ethernet layer 2, UDP traffic can also be used. If the speed is given at UDP level (layer 4), it has to be corrected considering the overhead of IP and UDP headers.

The tests may be performed according to IETF RFC 2544.

The attenuation between the DPLC terminals in Figure 19 is defined in 8.2.

8.12.2 Maximum LAN to LAN throughput

Maximum LAN to LAN throughput requires a continuous flow of Ethernet frames from the source to the receiver that slightly matches the channel capacity. Given the frame size and the number of frames received over the duration of the test, speed is defined as the corresponding bit-per-second rate. An iterative method is recommended to reach the optimal value.

NOTE Side effects may occure, if the traffic exceeds the capacity.

The test should be performed on the Ethernet interfaces using BLER measuring equipment. In this case the following conditions shall be used:

- BLER measurement duration: at least 5×10^3 frames with a length of 1500 octets shall be transmitted
- Maximum allowed BLER: $1{,}33 \times 10^{-3}$

8.12.3 LAN to LAN latency

LAN to LAN latency measurement requires a low speed but steady transmission of test frames. Source and receiver must be synchronised. Test frames should also be marked so it is possible to identify them and for each measure the time elapsed between emission and reception.

8.13 Start-up time

The test is carried out using the test setup shown in Figure 19. Before the test both DPLC terminals shall be switched off, i.e. not powered, for at least 5 minutes. Start-up time is the time interval between the time of power-on and the beginning of data reception. A serial data tester may also be used instead of an Ethernet tester.

8.14 Recovery time after synchronization loss

The test is carried out using the test setup shown in Figure 16 and under the following conditions: attenuation of the artificial line is established by Equation (2); SNR of 30 dB at HF line interface G’ during the signal reception is applied. Before the test the artificial line is disconnected from HF line interface G long enough to ensure that the synchronisation of the DPLC link has been lost. Recovery time is the time interval between connection of the artificial line to the HF line interface G and the beginning of data reception. A serial data tester may also be used instead of an Ethernet tester.

9 Configuration and management

9.1 General

Every DPLC terminal using the DSP technology has its own supervisory and programming interface. It allows the configuration and management (including monitoring and firmware upgrade) of all main parts composing the terminal. It also may allow terminal registration and activation. For this purpose the management interface shown in Figure 2 and Figure 3 is used.

9.2 Configuration

A web-based interface or software application shall be made available for the local configuration and the execution of the key maintenance operations.

This interface can be used to configure the main DPLC terminal parameters in software mode as well as bandwidth, transmission and reception frequency, transmission power, user services, teleprotection services.

However, in order to complete the terminal configuration, certain hardware pre-settings may be adjusted.

9.3 Network management system

The network management system allows diagnostics and maintenance of the DPLC terminals from a remote-control centre.

A dedicated software, which is out of the scope of this document, allows the user through configuration and maintenance remote operations to manage DPLC terminals and links by an easy-to-understand interface display.

It is therefore often requested to integrate DPLC management function into a generic SNMP (simple network management protocol) manager. In this case the DPLC terminal MIB (management information base) shall be made available.

In particular to make access available to the MIB information or execute a command, sending alarm traps to the SNMP manager, the DPLC terminal shall use the management interface M shown in Figure 2 and Figure 3.

9.4 Local terminal alarms

DSPs ensure a very high level of reliability and in case of any DPLC terminal cards or line failure the internal diagnostic routine shall return to the operator an alarm, displayed on the front of the DPLC terminal or signalled by dry relay contacts.

DPLC terminals shall have on board a number of LED indicators that will summarize the status of operation of the DPLC terminal and/or the link highlighting the proper link operation or the presence of anomalies/failures.

Whenever a DPLC terminal enters a wrong operation an alarm occurs. According to the alarm returned, at least two different types of conditions shall be shown. Commonly used are:

	Alarm type	Meaning
1	Transmitter alarm	A hardware error has been detected in the transmitter and/or the transmitted signal is missing or low
2	Receiver alarm	A hardware error has been detected in the receiver and/or the received signal is low or distorted
3	Hardware alarm	A hardware error has been detected in the local terminal
4	Link alarm	The received signal is low, distorted or link synchronisation lost

9.5 Event logging

The equipment should provide logging of events, e.g. alarms, warnings etc. stored in a non-volatile memory with time stamps. The number of entries in the list of events should be at least 500.

The resolution of the time stamps shall be at least 1 s. If an external more accurate time source is available, the internal clock of the DPLC equipment shall be corrected using this time source.

10 Cyber security

10.1 General

The scope of this Clause is to describe the best practice and recommendations for cyber security of the DPLC terminal. This description is informative and does not replace the cyber security assessment of the DPLC terminal as a part of a system.

DPLC and ADPLC terminals are sensitive devices regarding security, particularly if they are used to transmit teleprotection commands. The issues concerning data and communication security in power systems management and associated information exchange are covered by the IEC 62351 series. For an overview, refer to IEC TS 62351-1.

The main goal of cyber-security is assuring confidentiality, availability and integrity of the information transmitted through the PLC link as well as the information transmitted on the management interfaces of the PLC terminals.

10.2 Transmitted payload

A possible threat on the integrity and the availability of the information by physical access to EHV, HV or MV power lines is extremely low.

Privacy of the information may be disrupted by an unauthorized person detecting radiated emissions from power lines and decoding them. Although it appears very unlikely, this risk can be mitigated encrypting the transmitted information. The encryption / decryption of the information should be managed and done by the data terminals devices and not by the DPLC and ADPLC terminals. It should be noted that the use of cryptography while being transparent requires an additional transmission capacity of the PLC link.

10.3 Management interface

10.3.1 General

There are two types of management interfaces (see 10.3.2 and 10.3.3) carrying data which need to be protected.

10.3.2 Legacy-style management interfaces / Manufacturer-specific management interfaces

These management interfaces are generally used locally (in factory for the manufacturer-specific ones) and are not connected to a network. The only risk is an attack by a disgruntled employee, and it is therefore recommended to use a sufficient password-based authentication to control access to these interfaces. The highest privileges should be given only to trusted and competent persons.

10.3.3 LAN/WAN connected management interfaces

These interfaces (shown as M in Figure 2 and Figure 3) must be protected against unauthorized access, especially if they are connected using an external network (public operator links for example). The main concerns are:

- Unauthorized access shall be prevented by a strong authentication mechanism.
- Denial of service by a third-party degrading availability by preventing the operator to access to the DPLC or ADPLC terminal. The risk for such an attack shall be reduced using external measures (i.e. well-defined cyber security architecture of the LAN/WAN).

10.3.4 Authentication and role-base model

From Subclause 10.3, we can see that the key security requirement for configuration and management interface is a strong authentication with a role-based access control.

Authentication is the mechanism controlling the terminal access to users having the necessary privileges only; at least one of the following authentication mechanisms may be implemented in the DPLC terminal for configuration and management interface:

- The local authentication mechanism evaluates credentials supplied by the user, comparing them with those stored in the DPLC terminal; there are at least two different user profiles: Admin and Viewer, that define the different levels of privilege.

  The local access password can be modified via the local DPLC terminal configuration software after the user has been authenticated as Admin.
- The remote authentication mechanism sends authentication requests received by the DPLC terminal to a remote authentication server, which use the credentials shared between the DPLC terminal and the server for authenticating the access requests from the user. The server authenticates the user, provides role-based access and a feedback on whether the credentials provided by the user are accepted or not.

There are at least two different user profiles: Admin and Viewer, that define the different levels of privilege. Additional roles may be defined according to IEC TS 62351-8:2011.

All necessary parameters for these authentication modes can usually be defined through the DPLC terminal configuration software after the user has been authenticated as Admin.

10.4 Network management system interface

This interface could be physically the same as configuration and management interface. It is used to connect the terminal to a remote supervision application to monitor events and alarms DPLC or ADPLC terminal, remotely acknowledge them, to get information about internal resources, and to set some internal variables values or configuration data.

The SNMP protocol is the most widely used today for these purposes. It is strongly recommended to use the SNMP V3 protocol especially if internal resources can be controlled by Set commands. It includes authentication, privacy and access control. If the only possible exchange is sending of SNMP Trap or Get command messages or if private networks are used, the SNMP V2 protocol may be enough.

10.5 Security-related event logging

The equipment should provide logging of cyber security-related events, e.g. alarms, login events, configuration changes, firmware updates, manual time and date changes, password changes etc. stored in a non-volatile memory with time stamps.

11 DPLC safety

11.1 General

This clause specifies the requirements for the terminal in order to reduce the risk of fire, electric shock or injury to the user. It is assumed that access to the terminal in normal service is restricted to personnel aware of working procedures to ensure safety.

This document does not cover the functional safety requirements. It does not cover the safety requirements of installations.

11.2 Safety reference standard

The safety reference standard for the DPLC terminal is IEC 60255-27. As the scope of IEC 60255-27 is the safety requirements for protection devices, it applies to terminals which will normally be installed in a restricted access area within a power station, substation or industrial/retail environment. It is therefore an obvious choice to extend its application to the DPLC terminal safety requirements.

Alternatively, IEC 62368-1 may be used to prove the conformity of DPLC regarding safety.

11.3 Classification of DPLC terminals

The DPLC terminal shall meet the requirements of Table C.6 of IEC 60255-27:2013 and Table C.10 of IEC 60255-27:2013, reproduced in Table 2 and Table 3.

Table 2 – Basic insulation (Table C.6 of IEC 60255-27:2013)

Nominal rated insulation voltage or working voltage (RMS or DC) up to	Clearance	Creepage distance mm					Withstand voltage[c] V		
		In equipment			On printed wiring board		Peak impulse	RMS. 50/60 Hz	DC
		Material group			Not coated	Coated[a b]			
		I	II	III					
V	mm	CTI ≥ 600	CTI ≥ 400	CTI ≥ 100	CTI ≥ 175	CTI ≥ 100	1,2/50 µs	1 min	1 min
50	0,15	0,60	0,85	1,20	0,15	0,10	800	490	700
100	0,50	0,70	1,00	1,40	0,50	0,50	1 500	820	1 150
150	1,50	1,50	1,50	1,50	1,50	1,50	2 500	1 350	1 900
300	3,00	3,00	3,00	3,00	3,00	3,00	4 000	2 200	3 100
600	5,50	5,50	5,50	6,00	5,50	5,50	6 000	3 250	4 600
1 000	8,00	8,00	8,00	10,00	8,00	8,00	8 000	4 350	6 150

[a] Also applies to PCB-mounted components with mechanically stable distances between leads.

[b] See C.2.2 of IEC 60255-27:2013 for minimum coating requirements.

[c] For proving the clearance in air, see 11.6.3 and Table C.11 of IEC 60255-27:2013.

Linear interpolation may be used between the nearest two points, the calculated minimum CLEARANCE and CREEPAGE DISTANCE being rounded up to the next higher specified increment. The specified increment is 0,1 mm.

Table 3 – Double or reinforced insulation (Table C.10 of IEC 60255-27:2013)

Nominal rated insulation voltage or working voltage (RMS or DC) up to	Pollution degree 2 – Overvoltage category III								
	Clearance	**Creepage distance** mm					**Withstand voltage[c]** V		
		In equipment			**On printed wiring board**		**Peak impulse**	**RMS 50/60 Hz**	**DC**
		Material group			**Not coated**	**Coated[a b]**			
		I	**II**	**III**					
V	mm	CTI ≥ 600	CTI ≥ 400	CTI ≥ 100	CTI ≥ 175	CTI ≥ 100	1,2/50 µs	1 min	1 min
50	0,50	1,20	1,70	2,40	0,50	0,50	1 500	820	1 150
100	1,50	1,50	2,00	2,80	1,50	1,50	2 500	1 350	1 900
150	3,00	3,00	3,00	3,00	3,00	3,00	4 000	2 200	3 100
300	5,50	5,50	5,50	6,00	5,50	5,50	6 000	3 250	4 600
600	8,00	8,00	11,00	12,00	8,00	8,00	8 000	4 350	6 150
1 000	14,00	14,00	14,00	20,00	14,00	14,00	12 000	6 500	9 200

[a] Also applies to PCB-mounted components with mechanically stable distances between leads.

[b] See C.2.2 of IEC 60255-27:2013 for minimum coating requirements.

[c] For proving the clearance in air, see 11.6.3 and Table C.11. of IEC 60255-27:2013

Linear interpolation may be used between the nearest two points, the calculated minimum clearance and creepage distance being rounded up to the next higher specified increment. The specified increment is 0,1 mm.

The following conditions should be applied:

- pollution degree 2
- overvoltage category III

as applicable for equipment operating in harsh environments of substations according to IEC 60255-27.

These conditions may be reduced if special measures are taken to limit transient voltages to appropriate values and/or additional protections are used to reduce the pollution degree.

In this case, these measures and protections should be clearly described in the safety chapter of the terminal user manual.

11.4 Ingress protection

The terminal shall have an ingress protection equal or better than IP2x according to IEC 60529.

11.5 Type and routine tests

Table 4, taken from Table 12 of IEC 60255-27:2013, gives the list of the type and routine tests that are required to demonstrate the DPLC terminal is compliant to the requirement.

The second column (Type Tests – Safety (Normative)) gives the minimum set of type tests to be carried out to demonstrate the compliance.

The third column gives the minimum set of tests that should be carried out as routine test in factory on each single DPLC terminal.

Table 4 – List of Type and Routine Tests (Table 12 of IEC 60255-27:2013)

Test	Reference in IEC 60255-27:2013	Type tests [b]		Routine test [c]
		Validation [a] (informative)	Safety (normative)	
Environmental tests				
Dry-heat test – operational	10.6.1.1	X	---	---
Cold test – operational	10.6.1.2	X	---	---
Dry-heat test at maximum storage temperature	10.6.1.3	X	---	---
Cold test at minimum storage temperature	10.6.1.4	X	---	---
Damp-heat test	10.6.1.5	X	---	---
Cyclic temperature with humidity	10.6.1.6	X	---	---
Vibration	10.6.2.1	X	---	---
Shock	10.6.2.2	X	---	---
Bump	10.6.2.3	X	---	---
Seismic	10.6.2.4	X	---	---
Reverse polarity and slow ramp	10.6.6	X	---	---
Safety-related tests				
Clearances and creepage distances	10.6.3	---	X	---
Accessible parts test	10.6.2.5	---	X	---
IP rating	10.6.2.6	---	X	---
Impulse voltage	10.6.4.2	---	X	---
AC or DC dielectric voltage	10.6.4.3	---	X	X
Insulation resistance	10.6.4.4	X	---	---
Protective bonding resistance	10.6.4.5	---	X	---
Protective bonding continuity	10.6.4.5.2	---	---	X
Flammability of insulating materials, components and fire enclosures [d]	10.6.5.2	---	X [d]	---
Single-fault condition	10.6.5.5	---	X	---
Electrical environment tests				
Maximum temperature of parts and materials	10.6.5.1	X	---	---
Thermal short time	10.6.5.3	X	---	---
Output relay, make and carry	10.6.5.4	X	---	---

[a] Validation tests are normally carried out as type tests during product development but they may have an impact on product safety. After validation testing, the equipment under test should be checked for compliance with safety requirements, for example, due to cracking or distortion of parts providing insulation.

[b] Compliance with type-test requirements may be carried out by testing, measurement, visual inspection or assessment, as appropriate, for example, clearance and creepage distance measurement (or visual inspection where the distances are obviously large) or technical argument such as assessment of single-fault conditions where the result would be known. There shall be no electrical shock or fire hazard during or after conducting the normally applied type tests to demonstrate claimed compliance.

[c] For sample test guidance, refer to 10.6.4.3.2.3. of IEC 60255-27:2013.

[d] Testing of plastic parts may be necessary where the material does not meet the minimum flammability specified in Clause 7 of IEC 60255-27:2013 or its thickness is below the minimum specified for that material to achieve the required minimum flammability.

X applicable

--- not applicable

12 Storage and transportation, operating conditions, power supply

12.1 Storage and transportation

12.1.1 Climatic conditions

12.1.1.1 Storage

The terminal may be stored in partially open-air locations and be partially exposed to limited wind-driven precipitation. Therefore, the DPLC terminal, together with its packaging and protection (not the terminal itself), shall meet the requirements of IEC 60721-3-1, class 1K5.

Table 5 shows the classification of climatic conditions to be applied for terminal storage.

Table 5 – Classification of climatic conditions (Table 1 of IEC 60721-3-1:1997)

Environmental parameter	Unit	Class [10]										
		1K1	1K2	1K3	1K4	1K5	1K6	1K7	1K8	1K9	1K10 [11]	1K11 [11]
a) Low air temperature	°C	+20 [6]	+5	–5	–25	–40	–55	–20	–33	–65	+5	–20
b) High air temperature	°C	+25 [6]	+40	+45	+55	+70	+70	+35	+40	+55	+40	+55
c) Low relative humidity [1]	%	20	5	5	10	10	10	20	15	4	30	4
d) High relative humidity [1]	%	75	85	95	100	100	100	100	100	100	100	100
e) Low absolute humidity [1]	g/m^3	4	1	1	0,5	0,1	0,02	0,9	0,26	0,003	6	0,9
f) High absolute humidity [1]	g/m^3	15	25	29	29	35	35	22	25	36	36	27
g) Rate of change of temperature [2]	°C/min	0,1	0,5	0,5	0,5	1,0	1,0	0,5	0,5	0,5	0,5	0,5
h) Low air pressure [3]	kPa	70	70	70	70	70	70	70	70	70	70	70
i) High air pressure [3]	kPa	106	106	106	106	106	106	106	106	106	106	106
j) Solar radiation	W/m^2	500	700	700	1120	1120	1120	1120	1120	1120	1120	1120
k) Heat radiation	None	No	[7]	[7]	[7]	[7]	[7]	[7]	[7]	[7]	[7]	[7]
l) Movement of surrounding air [4]	m/s	0,5	1,0 [8]	1,0 [8]	1,0 [8]	5,0 [8]	5,0 [8]	[8]	[8]	[8]	50 [8]	50
m) Condensation	None	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
n) Precipitation (rain, snow, hail, etc.)	None	No	No	No	Yes [9]	Yes [9]	Yes [9]	Yes	Yes	Yes	Yes	Yes
o) Rain intensity	mm/min	None	None	None	None [9]	None [9]	None [9]	6	6	15	15	15
p) Low rain temperature [5]	°C	None	None	None	None [9]	None [9]	None [9]	+5	+5	+5	+5	+5
q) Water from sources other than rain	None	No	No	[7]	[7]	[7]	[7]	[7]	[7]	[7]	[7]	[7]
r) Formation of ice and frost	None	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

Notes to Table 5

1) The low and high relative humidities are limited by the low and high absolute humidities, so that, for example, for environmental parameters a) and c), or b) and d), the severities given in Table 5 do not occur simultaneously.

2) Averaged over a period of time of 5 min.

3) The value of 70 kPa represents a limit for open-air conditions, normally at an altitude of 3 000 m. In some geographical areas, open-air conditions may occur at higher altitudes. Conditions in mines are not considered.

4) A cooling system based on non-assisted convection may be disturbed by adverse movement of surrounding air.

5) This rain temperature should be considered together with high air temperature b) and solar radiation j). The cooling effect of the rain has to be considered in connection with the surface temperature of the product.

6) These are air-conditioned locations with a tolerance of 2 °C on stated temperature value.

7) Conditions occurring at the location concerned to be selected from Table 2 of IEC 60721-3-1:1997.

8) If applicable, a special value may be selected from Table 2 of IEC 60721-3-1:1997.

9) Applies to wind-driven precipitation at partially weather protected locations.

10) The classes of climatic conditions of this doument include the classes of IEC 60721-3-3 and IEC 60721-3-4 as follows:

1K1 covers 3K1 1K3 covers 3K5 1K5 covers 3K7 1K7 covers 4K1 1K9 covers 4K4 1K11 covers 4K6

1K2 covers 3K3 1K4 covers 3K6 1K6 covers 3K8 1K8 covers 4K2 1K10 covers 4K5

11) Further information on classes 1K10 (tropical damp) and 1K11 (tropical dry) is given in Annex C of IEC 60721-3-1:1997.

For any worse conditions that may arise, for example in very cold or very wet countries, refer directly to A.2.1 of IEC 60721-3-1:1997.

12.1.1.2 Transportation

The requirements for the terminal, including protection (not the terminal itself) depend on the means of transportation and the transportation route.

IEC 60721-3-2:1997 can serve as reference guide for transportation. Note that the conditions apply for the terminal together with its packaging, pallet and all the protections suitable for each particular means of transportation.

12.1.1.3 List of climatic tests for storage and transportation

Table 6 gives the minimum set of type tests to be carried out to demonstrate the conformity of the terminal.

Table 6 – Climatic tests for storage and transportation

Climatic Tests					
Test	**IEC Standard**		**Temperature**	**Relative Humidity**	**Duration**
Cold	IEC 60068-2-1	Test Ab	−40 °C	No	16 hours
Dry Heat	IEC 60068-2-2	Test Bb	+70 °C	No	16 hours
Damp Heat Cyclic	IEC 60068-2-30	Test Db	+40 °C	95 %	(12 + 12 hours) x2 cycles

12.1.2 Mechanical

The packing is of primary importance in the withstanding of the terminal to mechanical constraints during transportation and storage and should be adapted to the different conditions that may be encountered.

The normal transportation conditions include all kinds of Lorries and trailers in areas with a well-developed road system, transportation by planes, modern train system and ships. This corresponds to class 2M1 of the IEC 60721-3-2:1997 (as shown in Table 7).

Table 7 – Classification of mechanical conditions for transportation (Table 5 of IEC 60721-3-2:1997)

Environmental parameter	Unit	Class		
		2M1	2M2	2M3
a) Stationary vibration sinusoidal[1)] *:*				
displacement amplitude	mm	3,5	3,5	7,5
acceleration amplitude	m/s^2	10 15	10 15	20 40
frequency range	Hz	2-9 9-200 200-500	2-9 9-200 200-500	2-8 8-200 200-500
b) Stationary vibration, random[1)] *:*				
acceleration spectral density	m^2/s^3	1 0,3	1 0,3	3 1
frequency range	Hz	10-200 200-2000	10-200 200-2000	10-200 200-2000
c) Non-stationary vibration including shock[2)] *:*				
Shock response spectrum type I, peak acceleration â	m/s^2	100	100	300
Shock response spectrum type II, peak acceleration â	m/s^2	No	300	1000
d) Free fall:				
mass less than 20 kg	m	0,25	1,2	1,5
mass 20 kg to 100 kg	m	0,25	1,0	1,2
mass more than 100 kg	m	0,1	0,25	0,5
e) Toppling:				
mass less than 20 kg	None	Toppling around any of the edges		
mass 20 kg to 100 kg	None	No	Toppling around any of the edges	
mass more than 100 kg	None	No	No	Toppling around any of the edges
f) Rolling, pitching:				
angle[3)]	degree	No	±35	±35
period	s	No	8	8
g) Steady-state acceleration	m/s^2	20	20	20
h) Static load	kPa	5	10	10

1) The frequency range may be limited to 200 Hz for transportation on parts of the vehicle with high internal damping.

2) See figure 1.

3) An angle of 35° only occurs temporarily, but angles up to 22,5° can be reached for long periods of time.

For any worse transportation conditions, for example transportation in areas without a well-developed road system, it is recommended to pack the terminal respecting class 2M2 of IEC 60721-3-2:1997.

If testing is required, the following standards shall be applied on the packed equipment:

- Sinusoidal vibrations (IEC 60068-2-6)
- Shocks (IEC 60068-2-27)
- Free fall and Toppling (IEC 60068-2-31)

12.2 Operating conditions

12.2.1 Climatic conditions

Usually, DPLC terminal equipment is installed in the control room building of the substation. This room may not always be air conditioned. In any case the room is equipped with a heating system. Consequently, the DPLC terminal equipment shall meet the requirement of IEC 60721-3-3:2002, class 3K5, amended as follows:

– **High air temperature:**
  - +45 °C
  - +55 °C for not more 24 hours per month without any degradation of performances.
– **Low air temperature:**
  - To prevent a complete loss of DPLC communication in case of failure of the heating system in very cold countries, the terminal shall operate without damage at temperatures down to −10 °C for a period of at least 16 hours per month without any degradation of performances and the lowest temperature for cold start shall be 0°C.
– **Condensation, formation of ice:**
  - In normal operation the formation of ice shall not occur. The terminal equipment shall not be exposed to any type of water.
  - Temporary condensation may occur during maintenance when spare parts are introduced which have been stored at a lower temperature than that prevailing in the telecommunication terminal environment.

Table 8 shows the classification of climatic conditions from IEC 60721-3-3.

Table 8 – Classification of climatic conditions from Table 1 of IEC 60721-3-3:2002

Environmental parameter	Unit	Class												
		3K1	3K2	3K3	3K4	3K5	3K6	3K7	3K7L	3K8	3K8H	3K8L	3K9[8]	3K10[8]
a) Low air temperature	°C	+20[3]	+15	+5	+5	–5	–25	–40	–40	–55	–25	–55	+5	–20
b) High air temperature [5]	°C	+25[3]	+30	+40	+40[5]	+45[5]	+55	+70	+40	+70	+70	+55	+40	+55
c) Low relative humidity	%	20	10	5	5	5	10	10	10	10	10	10	30	4
d) High relative humidity	%	75	75	85	95	95	100	100	100	100	100	100	100	100
e) Low absolute humidity	g/m^3	4	2	1	1	1	0,5	0,1	0,1	0,02	0,5	0,02	6	0,9
f) High absolute humidity	g/m^3	15	22	25	29	29	29	35	35	35	35	29	36	27
g) Rate of change of temperature [1]	°C/min	0,1	0,5	0,5	0,5	0,5	0,5	1,0	1,0	1,0	1,0	1,0	1,0	1,0
h) Low air pressure [7]	kPa	70	70	70	70	70	70	70	70	70	70	70	70	70
i) High air pressure [2]	kPa	106	106	106	106	106	106	106	106	106	106	106	106	106
j) Solar radiation	W/m^2	500	700	700	700	700	1120	1120	None	1120	1120	1120	1120	1120
k) Heat radiation	None	No	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]
l) Movement of surrounding air [4]	m/s	0,5	1,0[5]	1,0[5]	1,0[5]	1,0[5]	1,0[5]	5,0[5]	5,0[5]	5,0[5]	5,0[5]	5,0[5]	5,0[5]	5,0[5]
m) Condensation	None	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
n) Wind-driven precipitation (rain, snow, hail, etc.)	None	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
o) Water from sources other than rain	None	No	No	No	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]
p) Formation of ice	None	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

1) Averaged over a period of time of 5 min.

2) Conditions in mines are not considered.

3) These are air-conditioned locations with a tolerance of ±2 °C on stated temperature values.

4) A cooling system based on non-assisted convection may be disturbed by adverse movement of surrounding air.

5) If applicable, a special value may be selected from table 2.

6) Conditions occurring at the locations concerned to be selected from table 2.

7) Severity value of 70 kPa covers worldwide application (altitudes up to 3 000 m). For some restricted applications, a value may be selected from table 2.

8) Further information on classes 3K9 (tropical damp) and 3K10 (tropical dry) is given in annex E.

12.2.2 Mechanical

The terminal is generally installed in the telecommunication room of electricity substations, where the vibrations are of low significance. Therefore, the DPLC terminal equipment shall meet the requirements of class 3M1, as specified in IEC 60721-3-3:2002 (see Table 6 of IEC 60721-3-3:2002, reproduced here as Table 9). Only when located very close to sources of high vibrations (e.g. generators within power stations) a higher level should be applied.

Table 9 – Classification of mechanical conditions from Table 6 of IEC 60721-3-3:2002

Environmental parameter	Unit	Class							
		3M1	3M2	3M3	3M4	3M5	3M6	3M7	3M8
a) *Stationary vibration, sinusoidal:*									
displacement amplitude	mm	0,3	1,5	1,5	3,0	3,0	7,0	10	15
acceleration amplitude	m/s²	1	5	5	10	10	20	30	50
frequency range	Hz	2-9 9-200	2-9 9-200	2-9 9-200	2-9 9-200	2-9 9-200	2-9 9-200	2-9 9-200	2-9 9-200
b) *Non-stationary vibration including shock:* (see figure 1)									
shock response spectrum type L, peak acceleration â	m/s²	40	40	70	None	None	None	None	None
shock response spectrum type I, peak acceleration â	m/s²	None	None	None	100	None	None	None	None
shock response spectrum type II, peak acceleration â	m/s²	None	None	None	None	250	250	250	250

The following mechanical tests shall be carried out:

- Sinusoidal vibrations (IEC 60068-2-6)
- Shocks (IEC 60068-2-27)

Any other specific requirements for the mechanical environment, for example earthquake withstanding or installation in harsh industrial environment should be taken into account at the level of the cabinet, not at the level of the DPLC terminal itself.

12.2.3 Operating conditions set of tests

Table 10, Table 11 and Table 12 give the minimum set of type tests to be carried out to demonstrate the conformity of the terminal for climatic and mechanical conditions withstanding.

The way the tests should be carried out, the performance criteria and the configuration of the terminal to be tested are described in the appropriate clauses/subclauses of this document.

Table 10 – Climatic Tests

Test	IEC Standard		Temperature	Relative Humidity	Duration
Cold (nominal)[(1)]	IEC 60068-2-1	Test Ae	0°C	No	24 hours
Cold (limit) [(1), (2)]	IEC 60068-2-1	Test Ae	−10 °C	No	16 hours
Dry Heat	IEC 60068-2-2	Test Be	+55 °C	No	24 hours

(1) If the test at the cold limit temperature is extended to duration of 24 hours, the test at the nominal temperature can be skipped.

(2) Cold start not required at −10 °C

Table 11 – Sinusoidal vibration test

Ref. IEC Standard	60068-2-6 – Test Fc. Both vibration response and vibration endurance(1) tests shall be carried out		
Frequency range	Displacement	Acceleration	Axes
1Hz to 10Hz	0,3 mm	-	3 axes
10Hz to 200Hz	-	1 m/s^1	3 axes
(1) Endurance by sweeping should be preferred, with 10 sweep cycles in each axis			

Table 12 – Non-repetitive shock test

Ref. IEC Standard	60068-2-27 – Test Ea.	
Pulse Shape	Half-sine	
Peak Acceleration	40 m/s^2	
Duration	11 ms	
Number of shocks	18	3 successive shocks in each direction of 3 mutually perpendicular axes

12.3 Power supply

12.3.1 AC supply

Nominal AC voltages shall be in accordance with the preferred values listed in IEC 60038.

The following values are the most common:

230 V ± 10 %	50 Hz or 60 Hz,
120 V ± 10 %	60 Hz,

where the frequency tolerance shall be ± 5 % and harmonic content < 10 %.

12.3.2 DC supply

12.3.2.1 General

Nominal DC voltages shall be in accordance with the preferred values listed in IEC 60038. The following values are the most common.

24 V +20 %, −15 %
48 V +20 %, −15 %

Where the residual ripple peak-to-peak shall be ≤ 5 %.

The terminal shall be capable of operating in any of the following conditions:

– Positive pole earthed,

– No reference to earth.

12.3.2.2 Reverse polarity

Reverse polarity protection or clear labeling at the DC power supply connector shall be provided in order to protect the terminal against the inadvertent inversion of the DC power supply voltage.

13 EMC

13.1 Emission and immunity reference standards

The DPLC terminal shall comply with the EMC requirements of the generic standard IEC 61000-6-4 for emissions and the generic standard IEC 61000-6-5 for equipment used in power station and substation environment for immunity requirements.

It should be noted that IEC 61000-6-4 and IEC 61000-6-5 correspond to the European standards EN 61000-6-4 and EN 61000-6-5 respectively which are harmonized standards that can be used for conformity with the essential requirements of the EMC European Directive.

The requirements of the IEC 61000-6-2 series for industrial environments are covered by those of IEC 61000-6-5.

13.2 Emission

13.2.1 Radiated and conducted emission

Radiated and conducted emission limits are given in Tables 1, 2 and 3 of IEC 61000-6-4:2006, reproduced here as Table 13, Table 14 and Table 15.

Table 13 – Emission – Enclosure port (Table 1 of IEC 61000-6-4:2011)

Table Clause	Port	Frequency range	Limits	Basic standard	Applicability note	Remarks
1.1	Enclosure Test facility: OATS or SAC	30 MHz to 230 MHz 230 MHz to 1 000 MHz	40 dB(μV/m) quasi-peak at 10 m 47 dB(μV/m) quasi-peak at 10 m	The measurement instrumentation shall be as defined in 4 of CISPR 16-1-1. The measuring antennas shall be as defined in 4.4 of CISPR 16-1-4. The measuring site shall be as described in Clause 5 of CISPR 16-1-4. The measurement method shall be as specified in 7.2 of CISPR 16-2-3.	See [a, b and e]	May be measured at 30 m distance using the limits decreased by 10 dB. As stated in CISPR 16-2-3 the antenna height shall be varied between 1 m to 4 m. Additional guidance on the test method can be found in CISPR 16-2-3, 7.3 and 8.
1.2	Enclosure Test facility: FAR	30 MHz to 230 MHz	52 dB(μV/m) to 45 dB(μV/m) quasi-peak at 3 m Limit reducing linearly with the logarithm of the frequency.	The measurement instrumentation shall be as defined in 4 of CISPR 16-1-1. The measuring antennas shall be as defined in 4.4 of CISPR 16-1-4. The measuring site shall be as described in 5.8 of CISPR 16-1-4. The measurement method shall be as specified in 7.2.9.2 of CISPR 16-2-3.	See [a, b and e] Only applicable to table top equipment	May be measured at greater distances with the limits decreased by 20 dB/decade (relative to distance) The limitations on EUT size in CISPR 16-1-4 apply
		230 MHz to 1 000 MHz	52 dB(μV/m) quasi-peak at 3 m			
1.3	Enclosure Test facility: TEM Waveguide	30 MHz to 230 MHz 230 MHz to 1 000 MHz	40 dB(μV/m) quasi-peak 47 dB(μV/m) quasi-peak The small-EUT correction factor given in A.4.3 of IEC 61000-4-20:2020 shall be used. The limit relates to the OATS measurement distance of 10 m	IEC 61000-4-20	Only applicable to battery powered equipment not intended to have external cables attached. Restricted to equipment complying with the definition 6.2 in IEC61000-4-20. See [a, b and e]	

Table Clause	Port	Frequency range	Limits	Basic standard	Applicability note	Remarks
1.4	Enclosure Test facility: OATS, SAC or FAR	1 GHz to 3 GHz	76 dB(μV/m) peak at 3 m 56 dB(μV/m) average at 3 m	The measurement instrumentation shall be as defined in 5 and 6 of CISPR 16-1-1. The measuring antennas shall be as defined in 4.5 of CISPR 16-1-4. The measuring site shall be as described in 8 of CISPR 16-1-4. The measurement method shall be as specified in 7.3 of CISPR 16-2-3.	See [a], [c], [d] and [e]	May be measured at greater distances with the limits decreased by 20 dB/decade (relative to distance) For SAC and OATS facilities absorber may be required to achieve free space conditions as defined in CISPR 16-1-4.
		3 GHz to 6 GHz	80 dB(μV/m) peak at 3 m 60 dB(μV/m) average at 3 m			

[a] For apparatus containing devices operating at frequencies less than 9 kHz, measurements only need to be performed up to 230 MHz.

[b] The apparatus is deemed to comply with the enclosure port requirement below 1 GHz if it meets the requirements defined in one or more of the table clauses 1.1, 1.2 or 1.3.

[c] If the highest internal frequency of the EUT is less than 108 MHz, the measurement shall only be made up to 1 GHz.
If the highest internal frequency of the EUT is between 108 MHz and 500 MHz, the measurement shall only be made up to 2 GHz.
If the highest internal frequency of the EUT is between 500 MHz and 1 GHz, the measurement shall only be made up to 5 GHz.
If the highest internal frequency of the EUT is above 1 GHz, the measurement shall be made up to 6 GHz.
Where the highest internal frequency is not known, tests shall be performed up to 6 GHz.

[d] The peak detector limits shall not be applied to disturbances produced by arcs or sparks that are high voltage breakdown events. Such disturbances arise when devices contain or control mechanical switches that control current in inductors, or when devices contain or control subsystems that create static electricity (such as paper handling devices). The average limits apply to disturbances from arcs or sparks, and both peak and average limits will apply to other disturbances from such devices.

[e] At transitional frequencies, the lower limit applies.

Table clauses 1.2 and 1.3 are not relevant to DPLC.

OATS Open area test site

SAC Semi-anechoic method

Table 14 – Emission – Low voltage AC and DC mains port (Table 2 of IEC 61000-6-4:2011)

Table clause	Port	Frequency range	Limits	Basic standard	Applicability note	Remarks
2.1	Low voltage AC and DC mains	0,15 MHz to 0,5 MHz	79 dB(μV) quasi-peak 66 dB(μV) average	The measurement instrumentation shall be as defined in 4 and 6 of CISPR 16-1-1. The measuring networks shall be as defined in 4 of CISPR 16-1-2. The measurement set up and method shall be as described in 7 of CISPR 16-2-1.	See [a] and [b]	
		0,5 MHz to 30 MHz	73 dB(μV) quasi-peak 60 dB(μV) average			

[a] Impulse noise (clicks) which occur less than five times per minute is not considered. For clicks appearing more often than 30 times per minute, the limits apply. For clicks appearing between 5 and 30 times per minute, a relaxation of the limits is allowed of 20 log 30/N dB (where N is the number of clicks per minute). Criteria for separated clicks may be found in CISPR 14-1.

[b] At transitional frequencies, the lower limit applies.

Table 15 – Emission – Telecommunications/network port (Table 3 of IEC 61000-6-4:2011)

Table clause	Port	Frequency range	Limits	Basic standard	Applicability note	Remarks
3.1	Telecommunications/ network	0,15 MHz to 0,5 MHz	97 dB(μV) to 87 dB(μV) quasi-peak 84 dB(μV) to 74 dB(μV) average 53 dB(μA) to 43 dB(μA) quasi-peak 40 dB(μA) to 30 dB(μA) average The limits decrease linearly with the logarithm of the frequency	CISPR 32	See [a and b]	
		0,5 MHz to 30 MHz	87 dB(μV) quasi-peak 74 dB(μV) average 43 dB(μA) quasi-peak 30 dB(μA) average			

[a] The current and voltage disturbance limits are derived for use with an impedance stabilization network (ISN) which presents a common mode (asymmetric mode) impedance of 150 Ω to the telecommunication port under test (conversion factor is $20 \log_{10} 150 / 1 = 44$ dB).

[b] When performing measurement using an ISN, the EUT shall meet the voltage limits of this table. All elements within CISPR 32 shall be followed, including but not limited to selection of test method, test configuration, cable characteristics.

For the HF line interface the recommended conducted in-band and out-band emission limits produced by DPLC terminal are given in 6.9 and Figure 7.

13.2.2 Low frequency disturbance emission

If the terminal is powered by a DC power supply source, in order to verify the limits of LF conducted disturbance generated by the terminal which may affect other terminals connected to the same DC power source, the noise measured across the power supply terminals of the terminal under test shall not be greater than 3mV, psophometrically weighted, or 10 mV peak to peak.

The measurement shall be carried out using a filter across the DC power source shown in Figure 20, where C1 is a ceramic or plastic film capacitor and C2 an electrolytic capacitor.

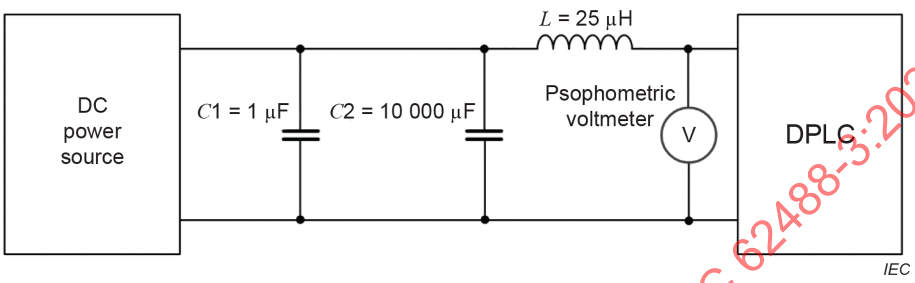


Figure 20 – LF disturbances measurement setup

13.3 Immunity

13.3.1 EMC environment

Due to the fact that IEC 61000-6-5 adds some particular tests and gives greater or equal levels of severity for the tests common with IEC 61000-6-2 it is requested for the immunity test DPLC terminal shall comply with the requirements of IEC 61000-6-5.

Table 1 of IEC 61000-6-5:2015 (reproduced in Table 16) shows the electromagnetic phenomena. Typically, DPLC terminals are installed in the control room area according to IEC 61000-6-5.

Table 16 – Characterization of the electromagnetic phenomena (Table 1 of IEC 61000-6-5:2015)

Continuous phenomena	Transient phenomena with high occurrence	Transient phenomena with low occurrence
Voltage variations: – a.c. power supply – d.c. power supply [a] Harmonics, interharmonics [a] Signalling voltages [a] Ripple on d.c. power supply Power frequency variation [a] Conducted disturbances in the range 2 kHz to 150 kHz [a] Conducted disturbances in the range 1,6 MHz to 30 MHz [a] Power frequency magnetic field (according to IEC 61000-4-8) Radiated, radio frequency electromagnetic field Conducted disturbances, induced by radio-frequency fields Mains frequency voltage (according to IEC 61000-4-16)	Voltage dips (duration ≤ 0,02 s): – a.c. power supply – d.c. power supply Voltage fluctuations Fast transient/burst Damped oscillatory/ring wave Damped oscillatory magnetic field Electrostatic discharge	Voltage dips (duration > 0,02 s): – a.c power supply – d.c. power supply Voltage interruptions: – a.c. power supply – d.c. power supply Short duration power frequency variation [a, b] Surge Short duration power frequency voltage Short duration power frequency magnetic fields (according to IEC 61000-4-8) Radiated pulsed disturbances

[a] Not covered in this standard by dedicated immunity requirements.

[b] In case of islanded systems (e.g. not connected to a public network), the characterization of the phenomenon changes from "low occurrence" to "high occurrence".

For easy application of the standard it is essential to classify the DPLC signal ports according to Figure 3 and Figure 4 of IEC 61000-6-5:2015. The classification of DPLC terminal interfaces as ports according to IEC 61000-6-5 is given in Table 17.

Table 17 – Port classification

DPLC terminal interface	Type of signal ports acc. to IEC 61000-6-5
HF line interface (G)	4
Digitalized voice interface (V), low frequency interface (Aj), analogue phone interface (B, Bj), analogue phone signalling interface (C, Cj).	2
Serial data interface (S)	2
IEC 61850 process / station bus interface(J)	2
External teleprotection interface(E)	2
External teleprotection control interface(F)	2
Binary teleprotection commands (I)	4
Management interface (M)	2
Ethernet interface (T)	2
Alarm relays (M)	2

13.3.2 Functional requirements

The tests shall be carried out with the terminal in operation. The terminal shall not suffer permanent damage from the tests, and after the tests the terminal shall be checked for correct operation.

The performance criteria for DPLC are defined on the basis of the functions "Teleprotection" and "Data transmission and telecommunication" of Table 2 of IEC 61000-6-5:2015 (reproduced in Table 18):

Table 18 – Performance criteria

Performance criteria	Description
A	The equipment shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed
B	Temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention

The DPLC terminal functions to be considered for EMI testing are at least the following:

– Protection and Teleprotection
– Data Transmission and telecommunication

13.3.3 Immunity test list

Table 19 summarizes both the immunity test to be performed as well as the corresponding levels to be used according to IEC 61000-6-5 and IEC 61000-6-2.

Table 19 – Immunity test list

Test	Standard	Immunity Level						Performance Criteria
		Enclosure	AC Power Supply	DC Power Supply	Signal / Control Ports			
					1	2	3 & 4	
Electrostatic discharges	IEC 61000-4-2	6 kV (Contact) 8kV (Air)						B
Radiated Electromagnetic field	IEC 61000-4-3	10 V/m 80 MHz to 1 GHz 1kHz, 80 % AM 3 V/m 1,4 GHz to 6 GHz 1kHz, 80 % AM						A
		3 V/m 1 GHz to 2,7 GHz 1kHz, 80 % AM						A
		1 V/m 2,7 GHz to 6 GHz 1kHz, 80 % AM						A
Fast transient/burst [e]	IEC 61000-4-4		2 kV [a] 5 kHz or 100 kHz	2 kV [a] 5 kHz or 100 kHz	1 kV [b] 5 kHz or 100 kHz	2 kV [b] 5 kHz or 100 kHz	4 kV [b] 5 kHz or 100 kHz	A, B according to notes (a) and (b) respectively
Surge	IEC 61000-4-5		2 kV (1,2/50 µs) line to ground [a] 1 kV (1,2/50 µs) line to line [a]	2 kV (1,2/50 µs) line to ground [a] 1 kV (1,2/50 µs) line to line [a]	1 kV [b,f,g] line to ground	1 kV [b,f, g] line to ground	2 kV [b,f,c,g] line to ground	A, B according to notes (a) and (b) respectively
Conducted disturbances, induced by radio frequency fields	IEC 61000-4-6		10 V 150 kHz to 80 MHz 1 kHz, 80 % AM	10 V 150 kHz to 80 MHz 1 kHz, 80 % AM	3 V 150 kHz to 80 MHz 1 kHz, 80 % AM	10 V 150 kHz to 80 MHz 1 kHz, 80 % AM	10 V 150 kHz to 80 MHz 1 kHz, 80 % AM	A
Power Frequency Magnetic fields	IEC 61000-4-8	100 A/m (continuous) 1 000 A/m 1 sec.						A
AC voltage dips and interruptions	IEC 61000-4-11		70 %U_T, 1 period					A
			0 % U_T, 5 periods					B

Test	Standard	Immunity Level						Performance Criteria
		Enclosure	AC Power Supply	DC Power Supply	Signal / Control Ports			
					1	2	3 & 4	
Mains frequency voltage (50/60 Hz)	IEC 61000-4-16			30V Continuous [(d)]		30V Continuous [(d)]	30V Continuous [(d)]	A
				300V for 1 s [(d)]		300V for 1 s [(d)]	300V for 1 s [(d)]	B
Ripple on DC power supply	IEC 61000-4-17			10 % U_N				A
Damped oscillatory wave	IEC 61000-4-18		2,5 kV CM [(a)] 1 kV DM [(a)] 1 MHz	2.5 kV CM [(a)] 1 kV DM [(a)] 1 MHz	1 kV CM [(b)] 0,5 kV DM [(b)] 1 MHz	1 kV CM [(b)] 0,5 kV DM [(b)] 1 MHz	2.5 kV CM [(b)] 1 kV DM [(b)] 1 MHz	A, B according to notes (a) and (b) respectively
DC voltage dips and interruptions	IEC 61000-4-29			70 % U_T, 100 ms 0 % U_T, 10 ms				A
				40 % U_T, 100 ms				B
CM = Common Mode (Line to Ground) DM = Differential Mode (Line to Line)								
(a) Performance criteria A								
(b) Performance criteria B								
(c) The surge waveform 10/700 µs is recommended for testing signal ports intended to be connected to telecom network or remote equipment via unshielded outdoor symmetrical communication lines. This surge form requires a different surge pulse generator and a different coupling impedance (e. g.40 Ohm).								
(d) Only the country specific mains frequency shall be used.								
(e) No test is needed for cables shorter than 3 m.								
(f) No test is needed for cables shorter than 10 m.								
(g) Performance criteria A is applied for teleprotection functon, For IEC 61850 process / station bus interface(J) no loss of communication is allowed, but a bit error rate degradation is posible. Temporary bit error rate degradation can affect the communication efficiency; automatic restoration of any stoppage of the communication is mandatory								

During immunity tests of telecommunication ports according to IEC 61000-4-6, the performance criterion A is only applicable if test signals contain frequency components outside the nominal receive and transmit high frequency band (B_{nom}) of DUT and outside of frequency guard intervals with the bandwidth 2B = 2 B_{nom} on both sides of B_{nom} respectively. Otherwise the performance criterion B shall be used.