



DPC: 23 / 30446858 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000

Fax: +44 (0)20 8996 7400

www.bsigroup.com

Date: 06 December 2023

Origin: International

Latest date for receipt of comments: 24 January 2024

Project No. 2021/03043

Responsible committee: PEL/57 Power systems management and associated information exchange

Interested committees:

Title: BS EN IEC 62488-1 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

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Responsible Committee Secretary: Ms Andreea Vieru (BSI)

Direct tel: 0208 996 7432

E-mail: andreea.vieru@bsigroup.com

Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

PROJECT NUMBER: IEC 62488-1 ED2	
DATE OF CIRCULATION: 2023-12-01	CLOSING DATE FOR COMMENTS: 2024-02-23
SUPERSEDES DOCUMENTS: 57/2442/RR	

IEC TC 57 : POWER SYSTEMS MANAGEMENT AND ASSOCIATED INFORMATION EXCHANGE	
SECRETARIAT: Germany	SECRETARY: Mr Heiko Englert
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☒ Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY	

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TITLE: Power line communication systems for power utility applications – Part 1: Planning of analogue and digital power line carrier systems operating over HV electricity grids
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NOTE FROM TC/SC OFFICERS:

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Version Management					
Changes /Version	Date	Name Author(s) or Committee	Domain Expert	Title	Approval Status <i>draft, for comments, for voting, final</i>
0.00	14.05.2019	J. Kussyk, Ph. Conq, F. Fontenelle, H.-J. Maag, J. Newbury		Results of the WG20 meetings on May 14 th -15 th 2019	Working draft
0.01	20.10.2021	J. Kussyk, Ph. Conq, F. Fontenelle, H.-J. Maag, I. Nazarov J. Newbury		Results of the WG20 meetings on October 20 th -21 st 2021	Working draft
0.02	27.01.2022	J. Kussyk, F. Fontenelle, H.-J. Maag, I. Nazarov F. Castro		Results of the WG20 meetings on January 26 th -27 th , 2022	Working draft
0.03	9.03.2022	J. Kussyk, F. Fontenelle, H.-J. Maag, R. Napolitano, J. Newbury		Results of the WG20 meeting on March 9 th , 2022	Working draft
0.04	28.04.2022	J. Kussyk, F. Fontenelle, H.-J. Maag, R. Napolitano, Ph. Conq, I. Nazarov		Results of the WG20 meeting on April 27 th -28 th , 2022	Working draft
0.05	02.06.2022	J. Kussyk, J. Newbury F. Fontenelle, H.-J. Maag, R. Napolitano,		Results of the WG20 meeting on June 2 nd , 2022	Working draft
0.06	27.09.2022	J. Kussyk, J. Newbury F. Fontenelle, H.-J. Maag, Ph. Conq		Results of the WG20 meeting on September 27 th -27 th , 2022	Working draft
0.07	23.11.2022	J. Kussyk, F. Fontenelle, H.-J. Maag, Ph. Conq		Results of the WG20 meeting on November 22 nd -23 rd , 2022	Working draft
0.08	11.04.2023	J. Kussyk, F. Fontenelle, H.-J. Maag, Ph. Conq		Results of the WG20 meeting on April 12 th -13 th , 2023	Working draft
0.09	11.04.2023	J. Kussyk, F. Fontenelle, T. Palmieri, H.-J. Maag, Ph. Conq, S. Buljore		Draft for the WG20 meeting on June 13 th -14 th , 2023	Working draft

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**POWER LINE COMMUNICATION SYSTEMS
FOR POWER UTILITY APPLICATIONS –****Part 1: Planning of analogue and digital power line carrier
systems operating over HV electricity grids**

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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 62488-1 cancels and replaces the relevant parts of IEC 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
57/1279/FDIS	57/1298/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 parts of IEC 62488 series, 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 web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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

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INTRODUCTION

The complexity and extensive size of present-day electricity generation, transmission and distribution systems are such that it is possible to control them only by means of an associated and often equally large and complex telecommunication system having a high order of reliability.

The simultaneous use of the power distribution network for both energy transmission and data communication is unique and reduces the costs of installing two services over one transmission path. This communication technology is called generically power line carrier (PLC) communications.

Therefore, by using either analogue power line carrier communication (APLC) or digital power line carrier communication (DPLC) or a combination of both types of system (ADPLC), seamless efficient communication may be maintained throughout the power network.

The development of digital techniques for communications in the HV electrical power networks is now very widespread along with other applications in electronics. This is especially relevant for the electrical distribution network where many of the devices have built into them analogue to digital converters, together with digital signal processing enabling them to perform many functions and offer fast seamless communication.

The development of the technical report "Planning of power line carrier systems" was first produced by the International Electrotechnical Commission through publication IEC 60663 in 1980 entitled Planning of (single sideband) power line carrier systems. In 1993, the International Electrotechnical Commission produced IEC 60495 "Single sideband power-line carrier terminals". In the intervening years, electronic systems and the associated communications systems for electronic devices evolved and developed considerably. The introduction of digital transmission and reception techniques improved the quality of transmission and reception within electronic devices, enabling them to provide more detailed quality analysis and control of the data being communicated throughout the electricity distribution network, from control centre to service provider.

Both of these standards, IEC 60663 and IEC 60495, are being updated and replaced by the following: IEC 60663 is replaced by IEC 62488-1 and IEC 60495 is replaced by IEC 62488-2 and IEC 62488-3 covering respectively analogue, digital and hybrid analog-digital power line carrier terminals.

These international standards apply to power line carrier (PLC) terminals used to transmit information over HV power networks. Both analogue and digital modulation systems will be included.

IEC 62488 series consists of the following parts under the general title: Power line communication systems for power utility applications:

Part 1: Planning of analogue and digital power line carrier systems operating over HV power networks;

Part 2: Analogue power line carrier terminals or APPLC;

Part 3: Digital power line carrier (DPLC) terminals and hybrid ADPLC terminals.

POWER LINE COMMUNICATION SYSTEMS FOR POWER UTILITY APPLICATIONS –

Part 1: Planning of analogue and digital power line carrier systems operating over HV power networks

1 Scope

This part of IEC 62488 applies to the planning of analogue (APLC), digital (DPLC) and hybrid analogue-digital (ADPLC) power line carrier communication systems operating over HV electric power networks. The object of this standard is to establish the planning of the services and performance parameters for the operational requirements to transmit and receive data efficiently and reliably.

Such analogue and digital power line carrier systems are used by the different electricity supply industries and integrated into their communication infrastructure using common communication technologies such as radio links, fibre optic and satellite networks.

2 Terms, definitions and abbreviations

2.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE Other terms used in this standard and not defined in this clause have the meaning attributed to them according to the International Electrotechnical Vocabulary (IEV).

2.1.1

amplitude modulation

AM

modulation technique in which information is transmitted through amplitude variation of a carrier wave

2.1.2

analogue interface

interface dedicated to the processing of voiceband analogue signals

2.1.3

anomaly

small discrepancy between the actually received and the desired data

Note 1 to entry: The occurrence of a single anomaly does not cause interruptions of the applications using the transmitted data.

2.1.4

attenuation

power reduction along a transmission line for the mode or modes under consideration, quantitatively expressed either by the ratio or the logarithm of the ratio of an input power at the initial point to the corresponding output power at the final point

2.1.5

availability

time or fraction of time a system is operational over a given time interval

2.1.6**background noise**

noise present over all real high voltage power-line channels due mainly to corona and, partial discharges and electromagnetic interference with other PLC equipments operated over the same electricity grid and other interferences due to radio stations working in the same radio frequency spectrum

2.1.7**bit error ratio****BER**

ratio of the number of bits errors received divided by the total number of bits sent

2.1.8**bit error ratio test****BERT**

set of instruments and measurement methodology to be adopted to evaluate the BER of a transmission system

2.1.9**broadband over power line****BPL**

technology that allows data to be transmitted over utility power lines using bandwidths of several MHz

Note 1 to entry: These systems typically run over a frequency spectrum in a range from 1 MHz to 30 MHz allowing the transmission of broadband communications. These systems can be found on all the range of power lines from LV to MV. The BPL systems are means to deliver broadband communications to homes and business facilities. Among the BPL systems, we can distinguish the systems used outside the homes or offices (to-the-home-internet access also called access BPL or smart-grid applications operated by the electricity companies) and the “in-home” or “in-house” applications used for home networking (Generally using an Ethernet network technology) and automation. These applications are generally called Home Plug applications.

2.1.10**carrier-frequency range**

bandwidth available for a specific power line carrier communication technology

Note 1 to entry: In Europe, the typical carrier-frequency range for narrowband HV PLC is 3 kHz to 148,5 kHz or for broadband PLC is 1,6 MHz to 30 MHz. For the USA IEEE PLC standard the frequency range is 45 kHz to 450 kHz. Parts of the range may be barred by national regulations.

2.1.11**channelling**

elementary subdivision of the carrier frequency range or part thereof allocated to a single PLC transmits and receive channel (bidirectional)

2.1.12**code division multiple access****CDMA**

multiple access technique in which a number of transmitters modulate their data on pseudo random signals which are orthogonal to each other, which prevents the demodulators from seeing signals other than their own

2.1.13**coloured noise**

non-white noise or any wideband noise whose spectrum has a non-flat shape

Note 1 to entry: Also called non-white noise; examples are pink noise, brown noise and autoregressive noise.

- 131 **2.1.14**
132 **corona noise**
133 noise caused by partial discharges on insulators and in air surrounding electrical conductors of
134 overhead power lines
- 135 Note 1 to entry: Discharges occur on the three different phase conductors at different times. The corona noise level
136 is considerably dependent on weather conditions. The effect of the corona noise is particularly strong under foul
137 weather conditions.
- 138 **2.1.15**
139 **coupling capacitor**
140 capacitor used for the coupling of the carrier signal to the power line in a PLC system
- 141 **2.1.16**
142 **coupling system**
143 group of devices used to couple the PLC high frequency signals to the power line. Usually
144 coupling system consist of an line trap, a coupling capacitor and a coupling device
- 145 **2.1.17**
146 **defect**
147 large discrepancy between the actually received and the desired data
- 148 Note 1 to entry: Defects cause interruptions of the applications using the transmitted data and are used as input for
149 performance monitoring, the control of consequent actions, and the determination of fault causes.
150 Examples are: loss of signal, sync loss, alarm indication signal, slip, loss of frame alignment.
- 151 **2.1.18**
152 **distribution line carrier**
153 **DLC**
154 system for communication over the distribution power lines
- 155 Note 1 to entry: They DLC systems can be narrow band high speed communication systems on the medium voltage
156 distribution network, or broadband/narrow band communication systems on the low voltage distribution network.
- 157 **2.1.19**
158 **effectively transmitted signal-frequency band**
159 that part of the frequency band used for the transmission of the baseband signal
- 160 **2.1.20**
161 **environment**
162 external conditions in which a system operates
- 163 Note 1 to entry: Different classes of constraints and limits for EMC/EMI are defined for environment classes such
164 as industrial, commercial, domestic.
- 165 **2.1.21**
166 **error free second**
167 **EFS**
168 a one second period without bit error
- 169 **2.1.22**
170 **errored second**
171 **ES**
172 a one-second period in which one or more bits are in error
- 173 **2.1.23**
174 **errored second ratio**
175 **ESR**
176 ratio of errored seconds ES to total seconds in available time during a fixed measurement
177 interval

178 **2.1.24**
179 **Ethernet interface**
180 interface dedicated to the processing of data signals in accordance with the recommendation
181 IEEE 802.3 (2000)

182 **2.1.25**
183 **forward error correction**
184 technique used for correcting errors in data transmission over unreliable or noisy
185 communication channels by encoding the message at the sender in a redundant way by using
186 an error-correcting code so as to enable the receiver to correct a limited number of bit errors

187 **2.1.26**
188 **frame check sequence**
189 **FCS**
190 extra bits or characters added to a data frame for error detection

191 **2.1.27**
192 **frame loss rate**
193 the number of frames that never reached the destination divided by the number of frames
194 transmitted successfully by the source

195 Note 1 to entry: It is usually expressed as a percentage.

196 **2.1.28**
197 **frequency division multiplexing**
198 **FDM**
199 multiplexing technique in which several transmitters are allotted separate frequency bands for
200 transmission over a common channel

201 **2.1.29**
202 **frequency shift keying modulation**
203 **FSK**
204 a frequency modulation technique in which coded information is transmitted through discrete
205 frequency changes of a carrier wave

206 **2.1.30**
207 **gross data rate**
208 number of bits per unit of time exchanged between the terminals of a PLC link

209 **2.1.31**
210 **group delay**
211 propagation time of a narrowband signal from input to output of a linear system

212 Note 1 to entry: Mathematically, group delay equals the negative derivative of the phase shift in radians between
213 input and output of a linear system versus angular frequency.

214 **2.1.32**
215 **impulsive noise**
216 noise consisting of short-duration pulses of random amplitude and random duration

217 **2.1.33**
218 **jitter**
219 short-term variations of the significant instants of a timing signal from their ideal positions in
220 time (where short-term implies that these variations are of frequency greater than or equal to
221 10 Hz)

222 **2.1.34**
223 **latency**
224 time from the source sending a packet into a packet switched network to the destination
225 receiving it

226 Note 1 to entry: One-way latency is distinguished from round trip latency, which is the one-way latency from source
227 to destination plus the one-way latency from the destination back to the source. Round-trip latency is more often
228 quoted, because it can be measured from a single point. Note that round trip latency excludes the amount of time
229 that a destination system spends processing the packet.

230 **2.1.35**
231 **Coupling device**
232 unit which interfaces the HV side of power line with the PLC equipment (also known as line
233 matching unit (LMU))

234 Note 1 to entry: It usually consists of a box mounted near the coupling capacitor. Its characteristics are normalized
235 by IEC 60481.

236 **2.1.36**
237 **line trap**
238 a device presenting high impedance at the carrier frequency band while introducing negligible
239 impedance at the power frequency

240 Note 1 to entry: The high impedance limits the power of the carrier signal within the power system. Line traps are
241 connected in series with transmission lines. In most cases the Line trap is mounted directly on top of the coupling
242 capacitor. Its characteristics are normalized by IEC 60353.

243 **2.1.37**
244 **modulation scheme**
245 technique used to convert a baseband signal into a high frequency carrier signal suitable for
246 transmission over power line

247 Note 1 to entry: Examples are: AM-SSB, Spread Spectrum, QAM, OFDM.

248 **2.1.38**
249 **multiplexing techniques**
250 method by which multiple analog message signals or digital data streams are combined into
251 one signal over a shared medium

252 **2.1.39**
253 **narrowband noise**
254 noise process with a narrow bandwidth such as a 50/60 Hz 'hum' from the electricity supply

255 **2.1.40**
256 **nominal high frequency band**
257 frequency band in which a particular PLC transmitter or receiver is operating within the carrier-
258 frequency range

259 **2.1.41**
260 **nominal impedance**
261 value of impedance for which an input or output circuit has been designed and for which the
262 prescribed requirements apply

263 **2.1.42**
264 **operating conditions**
265 set of conditions (e.g., voltage, temperature, humidity, and the like) over which the specified
266 parameters maintain their stated performance rating

267 **2.1.43**
268 **orthogonal frequency division multiplexing**
269 **OFDM**
270 modulation scheme that distributes the data over a large number of sub-carriers with
271 frequencies such that the sub-carriers are orthogonal, which prevents the demodulators from
272 seeing sub-carriers other than their own

273 Note 1 to entry: Each sub-carrier is modulated with a conventional modulation scheme (such as QAM or PSK) at a
274 low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same
275 bandwidth.

276 **2.1.44**
277 **peak envelope power**
278 **PEP**
279 average power of a carrier signal present during one cycle of the carrier-frequency at the
280 highest crest of the modulation

281 Note 1 to entry: It is recommended that in order to determine the peak envelope power, the transmitter should be
282 modulated by two sinusoidal voice-frequency signals of equal amplitude, located within the effectively transmitted
283 frequency band. The transmitter is terminated by a resistive load equal to its nominal impedance and the limiter is
284 not in operation. The amplitude of the modulation signals must be chosen as to satisfy the requirements for spurious
285 emissions. The peak envelope power is then considered to be four times the power of one of these signals, selectively
286 measured (CCIR Recommendation 326-1, point 3.1.3.1).

287 **2.1.45**
288 **peak to average power ratio**
289 **PAPR**
290 peak power of a signal divided by its average power

291 **2.1.46**
292 **phase shift keying**
293 **PSK**
294 modulation scheme that conveys data by changing, or modulating, the phase carrier signal

295 **2.1.47**
296 **PLC connection**
297 a connection that is established through between two or more specified interfaces of a PLC
298 network consisting of one or more interconnected PLC links

299 **2.1.48**
300 **PLC link**
301 telecommunication facility between two PLC terminals provided by means of electrical signals
302 transmitted between them via power lines. A PLC link can be unidirectional or bidirectional

303 **PLC mean output power**
304 output power of a PLC terminal averaged over a time sufficiently long compared with the cycle
305 time of the lowest modulating frequency and during which this average power assumes the
306 highest value for which the equipment has been designed

307 **2.1.49**
308 **PLC nominal output power**
309 output power of a PLC terminal expressed as the peak envelope power (PEP) for which the
310 equipment has been designed, compatible with the requirements for spurious emissions,
311 available at the carrier frequency output across a resistive load equal to the nominal impedance

312 **2.1.50**
313 **PLC terminal equipment**
314 equipment able to manage a telecommunication link over a high voltage power line, mainly used
315 to reliably transmit speech, data and power system protection signals

- 316 **2.1.51**
317 **power line**
318 installation used to transfer electric energy from one point to another in an electric power system
- 319 **2.1.52**
320 **quadrature amplitude modulation**
321 **QAM**
322 analog or digital modulation scheme conveying two analog message signals, or two digital bit
323 streams, by changing (modulating) the amplitudes of two carrier waves with 90° phase
324 difference, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude
325 modulation (AM) analog modulation scheme
- 326 **2.1.53**
327 **quality objective**
328 specified level of quality that shall be met by a system to be deemed acceptable
- 329 Note 1 to entry: In speech communication, quality objectives can be subjective when listeners judge transmission
330 quality by qualifiers such as excellent, good, fair, poor or unsatisfactory.
- 331 **2.1.54**
332 **quality of service**
333 **QoS**
334 defined measure of performance in a data communications system
- 335 **2.1.55**
336 **reliability**
337 degree of the ability of a system to consistently perform according to its specifications
- 338 **2.1.56**
339 **return loss**
340 loss of signal power resulting from the reflection caused by impedance mismatch
- 341 Note 1 to entry: The return loss is usually expressed as a ratio in decibels (dB).
- 342 **2.1.57**
343 **sensitivity level**
344 minimum power level of an HF signal to be applied at the receiver input in order to sustain the
345 maximum specified data throughput affected by a predefined BER
- 346 Note 1 to entry: Example: sensitivity level = –60 dBm at 64 kb/s and BER=10^{–6}.
- 347 **2.1.58**
348 **serial interface**
349 interface dedicated to the processing of serial type data signals
- 350 **2.1.59**
351 **severely errored second**
352 **SES**
353 a one-second period which has a bit error ratio $\geq 10^{-3}$ or during which loss of signal (LOS) or
354 alarm indication signal (AIS) is detected
- 355 **2.1.60**
356 **severely errored second ratio**
357 **SESR**
358 ratio of severely errored seconds SES to total seconds in available time during a fixed
359 measurement interval

- 360 **2.1.61**
361 **single side band modulation**
362 **AM-SSB**
363 refinement of amplitude modulation that more efficiently uses electrical power and bandwidth
- 364 **2.1.62**
365 **signal to noise ratio**
366 **SNR**
367 ratio between the signal power and the noise power
- 368 **2.1.63**
369 **smart grid**
370 application of computer intelligence and networking abilities to the electricity delivery system
371 so it monitors, protects and automatically optimizes the operation of its interconnected
372 elements, from the central and distributed generator through the high-voltage network and
373 distribution system, to industrial users and building automation systems, to energy storage
374 installations and to end-use consumers and their thermostats, electric vehicles, appliances and
375 other household devices
- 376 **2.1.64**
377 **spurious emissions**
378 emissions at one or more frequencies, which are located outside the nominal carrier-frequency
379 band
- 380 Note 1 to entry: Spurious emissions comprise harmonics, parasitic signals and intermodulation products.
- 381 **2.1.65**
382 **tapping loss**
383 measure of the loss of power sustained by a carrier frequency signal when connected to the
384 carrier output of a PLC equipment
- 385 **2.1.66**
386 **telecommunication management network**
387 **TMN**
388 architecture for management, including planning, provisioning, installation, maintenance,
389 operation and administration of telecommunications equipment, networks and services
- 390 Note 1 to entry: TMN uses the OSI management standards as its framework and applies to all telecommunication
391 technologies: wired, wireless as well as to private and public networks.
- 392 **2.1.67**
393 **throughput**
394 number of bits per unit of time available at the user data interface of a PLC link
- 395 **2.1.68**
396 **time division multiple access**
397 **TDMA**
398 multiple access technique using TDM
- 399 **2.1.69**
400 **time division multiplexing**
401 **TDM**
402 multiplexing technique in which several transmitters are allocated separate periodic time
403 intervals for transmission over a common channel
- 404 **2.1.70**
405 **transient noise**
406 noise consisting of relatively long duration noise pulses

407 **2.1.71**
408 **wander**
409 long-term variations of the significant instants of a digital signal from their ideal position in time
410 (where long-term implies that these variations are of frequency less than 10 Hz)

411 **2.1.72**
412 **white noise**
413 purely random noise that has a flat power spectrum

414 Note 1 to entry: Band limited white noise refers to noise with a flat spectrum and a limited bandwidth.

415 **2.2 Abbreviations**

ADSL	asymmetrical digital subscriber line
AGC	automatic gain control
AIS	alarm indication signal
AM	amplitude modulation
APLC	analogue power line carrier
AWGN	additive white Gaussian noise
BER	bit error rate
BERT	bit error rate test
BPL	broadband over power line
CC	coupling capacitor
CD	coupling device
CDMA	code division multiple access
CENELEC	comité européen de normalisation électrotechnique
CF	carrier frequency
CISPR	comité international spécial des perturbations radioélectrotechniques
CSMA/CD	carrier sense multiple access with collision detection
CVT	capacitor voltage transformer
DLC	distribution line carrier
DPLC	digital power line carrier
E&M	ear and mouth (telephone signalling wires)
EFS	error free second
EHV	extra high voltage
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EPS	electricity power system
ES	errored second
ESR	errored second ratio
ETH	Ethernet
ETSI	European telecommunications standards institute
FCS	frame check sequence
FDM	frequency division multiplexing
FIR	finite impulse response
FSK	frequency shift keying

FXO	foreign exchange office
FXS	foreign exchange subscriber
GMR	geometric mean radius
HF	high frequency
HTTP	hypertext transfer protocol
HV	high voltage
ICAO	international civil aviation organization
IEEE	institute of electrical and electronics engineers
IETF	internet engineering task force
IEV	International Electrotechnical Vocabulary
IP	internet protocol
ISO	international organisation for standardisation
ITU	international telecommunications union
LAN	local area network
LMS	least mean squares
LMU	line matching unit
LOS	loss of signal
LV	low voltage
MAC	media access control
MOS	mean opinion score
MV	medium voltage
NAT	network address translation
NIC	network information center
OFDM	orthogonal frequency-division multiplexing
OPGW	optical ground wire
OSI	open system interconnection
OSPF	open shortest path first
PABX	private automatic branch exchange
PAM	pulse amplitude modulation
PAPR	peak to average power ratio
PEP	peak envelope power
PESQ	perceptual evaluation of speech quality
PLC	power line carrier
PLCS	power line communication system
PLT	power line telecommunications
PSK	phase shift keying
QAM	quadrature amplitude modulation
QoS	quality of service
QPSK	quadrature phase shift keying
REN	renewable energy
RIP	routing information protocol
RMS	root mean square

RTU	remote terminal unit
Rx	receive(r)
SCADA	supervisory control and data acquisition
SDA	synchronous digital hierarchy
SES	severely errored second
SESR	severely errored second ratio
SNMP	simple network management protocol
SNR	signal to noise ratio
SSB	single side band
TCP	transmission control protocol
TDM	time division multiplexing
TDMA	time division multiple access
Tx	transmit(ter)
UDP	user datagram protocol
VDSL	very-high-bit-rate digital subscriber line
VoIP	voice over IP
WAN	wide area network
Wi-Fi	Wireless Fidelity

416 **3 Power line carrier communication systems**

417 **3.1 General**

418 Electricity power system or EPS is a complex system where several parts interact to reach a
419 common goal: delivering efficiently at competitive costs energy from generation plants to the
420 final customers. The architecture of the EPS includes several components: generation plants,
421 power lines at various voltage levels, electrical switching and/or transformer stations and
422 substations.

423 For purposes of power line carries communication, EPS should be considered as PLC
424 communication system simply divided into a collection of power line cables, operated at any
425 high-voltage level, which we would like to use as physical transmission media. Nevertheless, it
426 should be remarked that they were not designed to be used as communication lines.

427 In general a PLC communication system is a communication network comprising several
428 interconnected PLC links, which intentionally or non-intentionally interact with each other. The
429 interconnection of several PLC links enables to provide wide-area communication connections
430 over multiple HV line sections with eventually different voltage levels.

431 According to the definition a PLC link consists of at least:

- 432 • Two PLC terminals,
- 433 • two coupling systems,
- 434 • an HV power line.

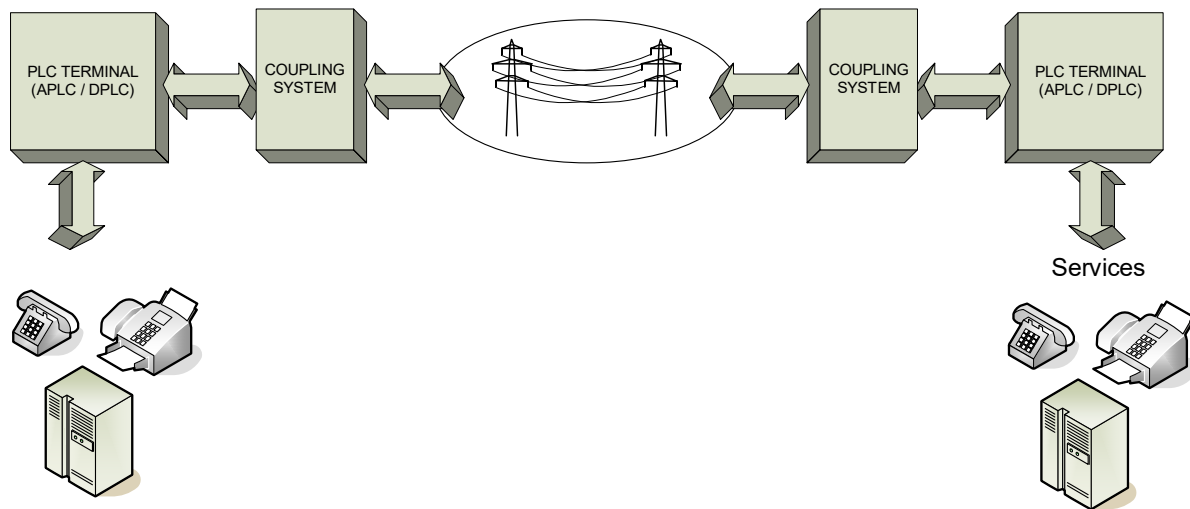


Figure 1 – PLC link

PLC terminals can be divided in two categories: Analogue PLC (APLC) terminals and Digital PLC(DPLC) terminals, which can be also combined in a hybrid ADPLC terminal. Refer to IEC 62488-2 and IEC 62488-3 regarding functional and EMC requirements as well as environmental conditions for APLC/DPLC terminals.

Detailed aspects concerning the power line transmission media and HV PLC coupling methods are described in the following Clauses.

The Figure 2 and the Figure 3 show more detailed typical structure of a point-to-point and a point-to-multipoint APLC, DPLC or ADPLC links.

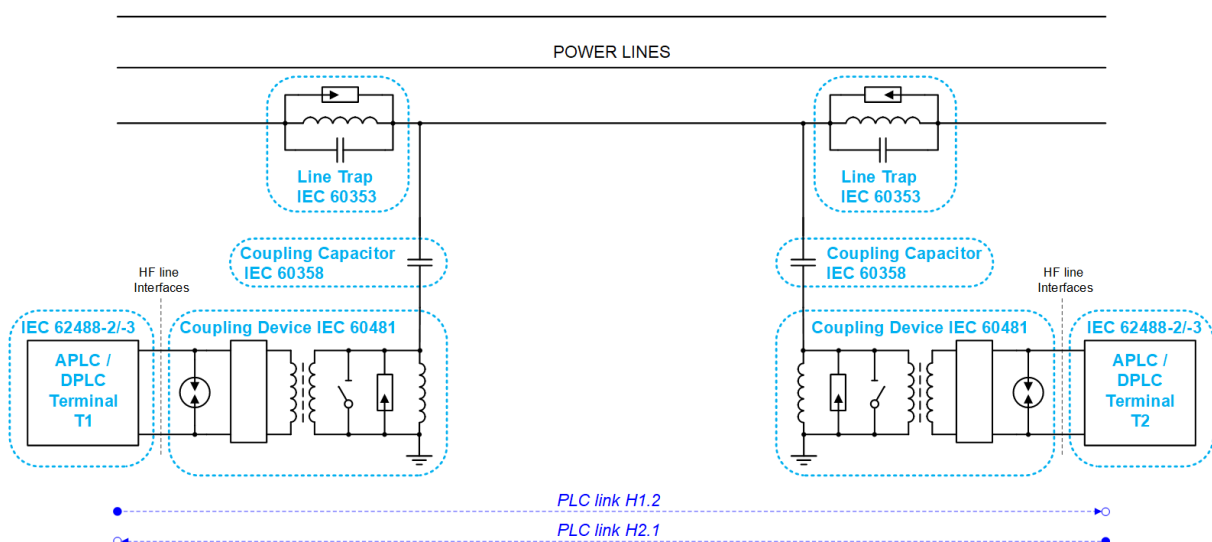


Figure 2 – General structure of a bidirectional point-to-point APLC, DPLC or ADPLC link

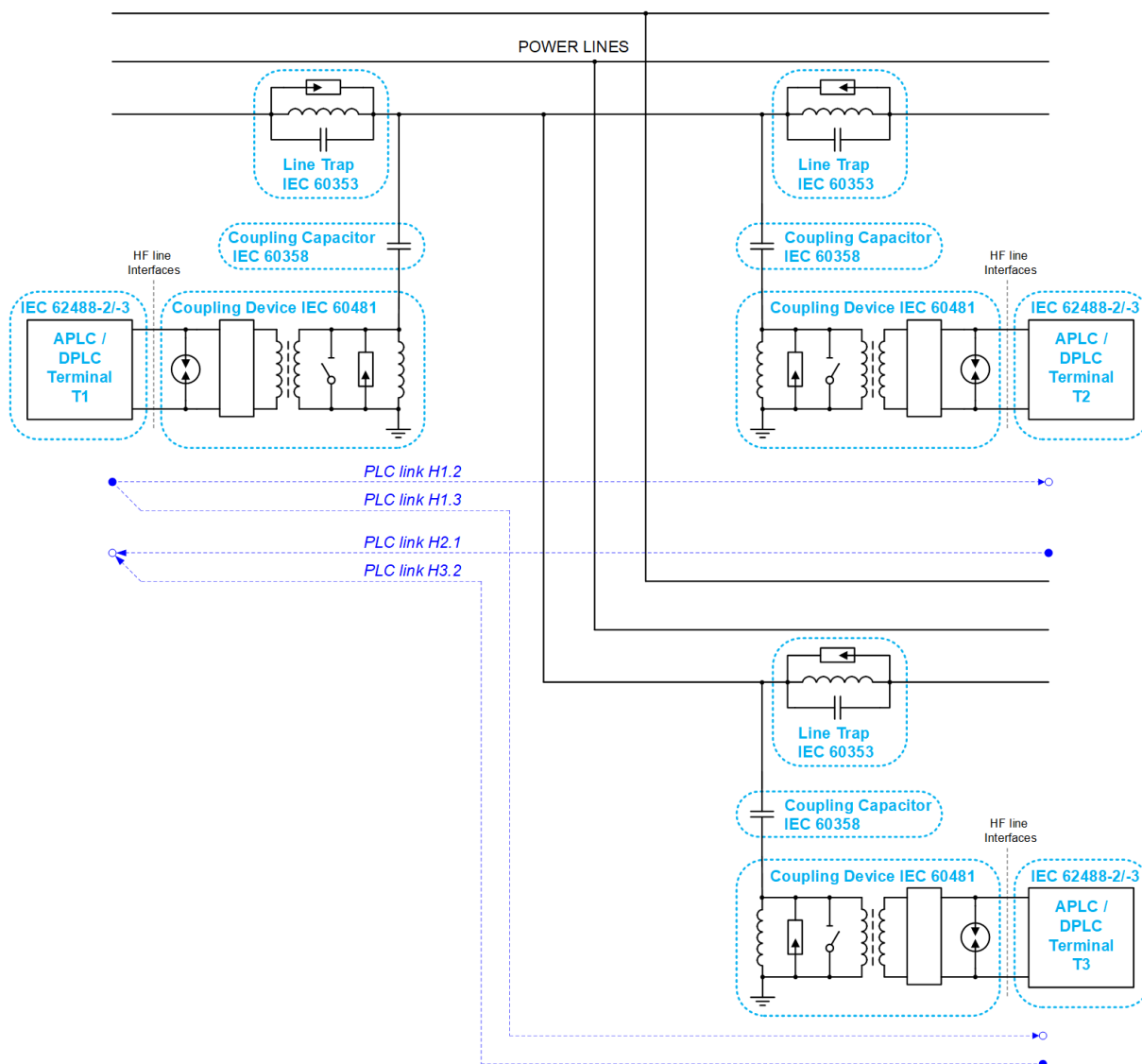


Figure 3 – General structure of a bidirectional point-to-multipoint APLC, DPLC or ADPLC link

NOTE: The HV power lines can be connected via a circuit breaker to a HV busbar, which could be connected with a HV transformer or via another circuit breaker with the neighbouring powerline section.

3.2 High voltage electricity power lines

In most countries, the power lines with the nominal voltage above 50 kV are defined as the high voltage (HV) power line and are mostly used for transmission of electrical power over long distances. A traditional transmission line is conceived as a sequence of self-supporting rigid towers. Most of the HV network is overhead line; underground cables are an alternative but more expensive.

Typical HV line conductors are from the aluminium reinforced with steel to withstand inclement weather conditions including ice, frost and wind, although all aluminium alloy conductors have a better resistance to corrosion. HV line conductors are carried by the insulating toughened glass (or porcelain) chains mounted on the HV tower pylons.

Other equipment that is used on transmission lines includes dampers, to avoid conductor damage in windy conditions, spacers, which maintain conductor separation at intervals along the span between towers, clamps, jumpers and dampers.

There is also usually an earth wire strung between the top of the pylons which protects the conductors from lightening.

3.3 Electricity power lines as transmission medium

3.3.1 Coupling system

3.3.1.1 General

To enable the conductors of a power line to be employed for communication purposes, coupling equipment is required allowing the injection of the high-frequency carrier signal without undue loss and at the same time de-couple the communication equipment from the power line in so far as the power system power-frequency voltage, switching surges, lightning surges, load variations are concerned.

Basically, to couple the signal to the power line a capacitive coupling approach is widely used. An example of capacitive coupling system is shown in Figure 2.

A capacitive coupling system includes the following elements:

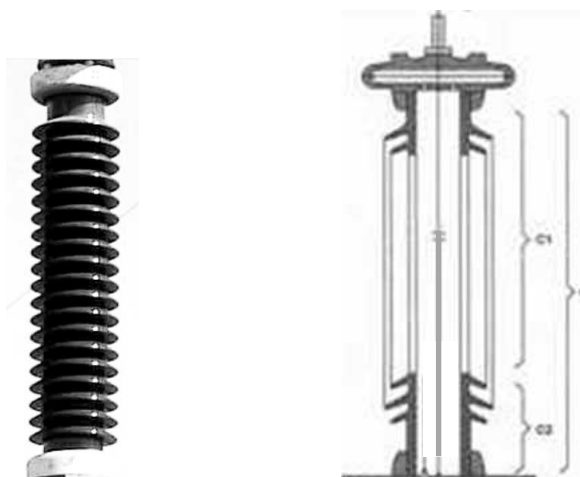
- Line trap with tuning device;
- Coupling capacitor;
- Coupling device.

3.3.1.2 Coupling capacitor

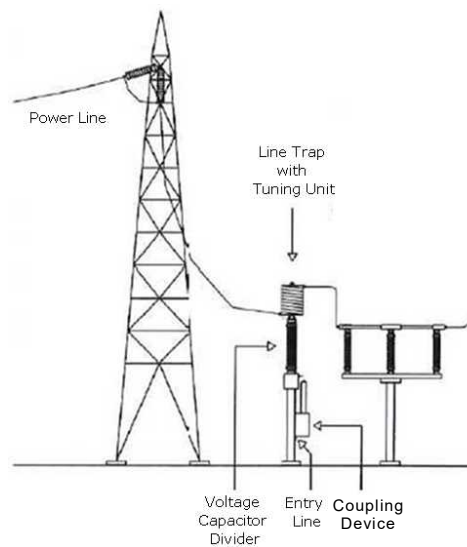
The coupling capacitor is the physical link to the transmission line that has a high impedance to the power frequency and a low impedance to carrier frequencies as shown in .

Coupling capacitor or capacitor voltage transformer (CVT) of suitable voltage withstand properties which is inserted between the coupling device and the high-voltage conductor. Values are of the order of 1 000 pF to 10 000 pF. shows a typical arrangement of devices for a capacitive coupling system.

Consideration shall be given to the choice of the coupler design to ensure an optimum selection based on capacitor cost versus bandwidth requirements. Reference should also be made to IEC 60358.



496

Figure 4 – HV typical coupling capacitor

497

498

499

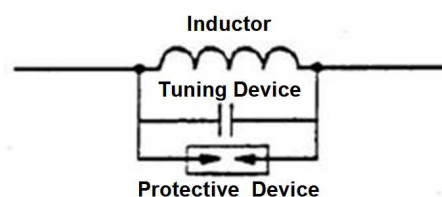
Figure 5 – Example of HV capacitive coupling system (single phase conductor to earth)

500 The equipment side of the matching transformer is generally only connected to earth, via the
 501 coaxial cable sheath to avoid the possibility of circulating currents, under fault conditions,
 502 saturating the transformer and effectively disabling the carrier channel. It shall however be
 503 borne in mind that unsafe voltages could then transiently exist at the line matching equipment.
 504 Some utilities may insist on connecting the coaxial cable sheath to earth at both the HV coupling
 505 device and PLC equipment ends.

506 3.3.1.3 Line trap

507 The line trap is inserted into the HV power lines to minimize the loss of carrier energy and to
 508 prevent external faults from shorting the carrier signal on the unfaulted line.

509 Basically, the line trap (or “wave trap”) consists of a choke coil, rated to carry the full line
 510 current, a tuning and protective device as shown in .



511

512

Figure 6 – Line trap electrical scheme



Figure 7 – HV line trap

shows an example of a HV line trap. This device is connected in series with the power line between the point of connection of the coupling capacitor and the substation, or at the line trap.

Line traps are available in various inductance ratings and continuous power-frequency current ranges. The value of line trap inductance is of the order of 0,1 mH to 2,0 mH as shown in .

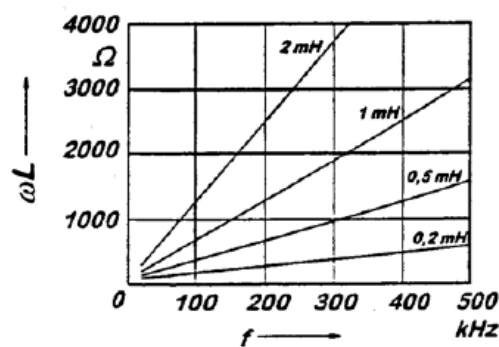


Figure 8 – Line trap impedance versus frequency

Line traps provide blocking of the carrier signal, preventing it from continuing into other transmission line sections.

The typical blocking impedance characteristic of a narrowband line trap is shown in . Single and two-frequency line traps are parallel L-C circuits with parameters of variable inductances and capacitances selected so as to resonate at a specific frequency (or at two frequencies) thus blocking the carrier frequency.

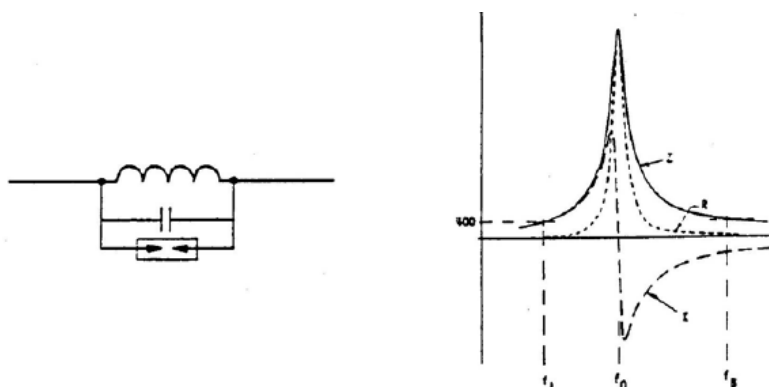


Figure 9 – Blocking impedance characteristic of a narrowband line trap

The tuning devices, used to improve the blocking efficiency of line traps, may be of different types. Those with narrow-band characteristics ensure a high blocking impedance for one carrier frequency (CF) channel.

Those with double-band characteristics present a high blocking impedance for two non-contiguous CF channels as shown in , and those with broad-band characteristics present a blocking impedance for several CF channels as shown in . The latter is typically tuned for a specified minimum resistive component as shown in .

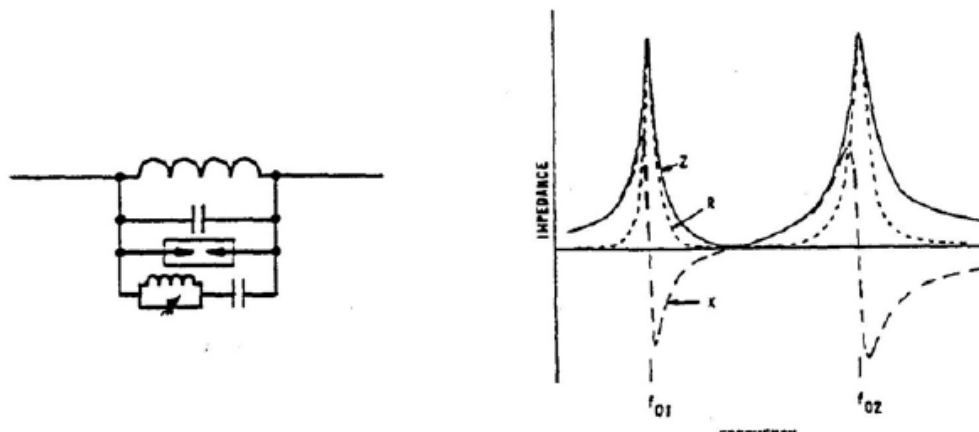


Figure 10 – Blocking impedance characteristic of a double band line trap

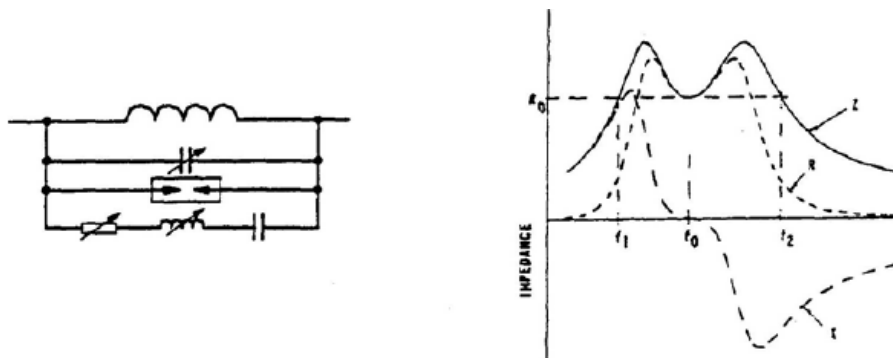


Figure 11 – Blocking impedance characteristic of a broadband line trap

3.3.1.4 Coupling device

The coupling device (also known as line matching unit (LMU)) as shown in provides a low impedance path to ground for power frequencies and a high impedance path for carrier frequencies. Moreover, it matches the impedance of the PLC terminal to the HV line and the coupling capacitor.

The coupling device is inserted between the low-voltage side of the coupling capacitor and the cable connecting the PLC terminal.

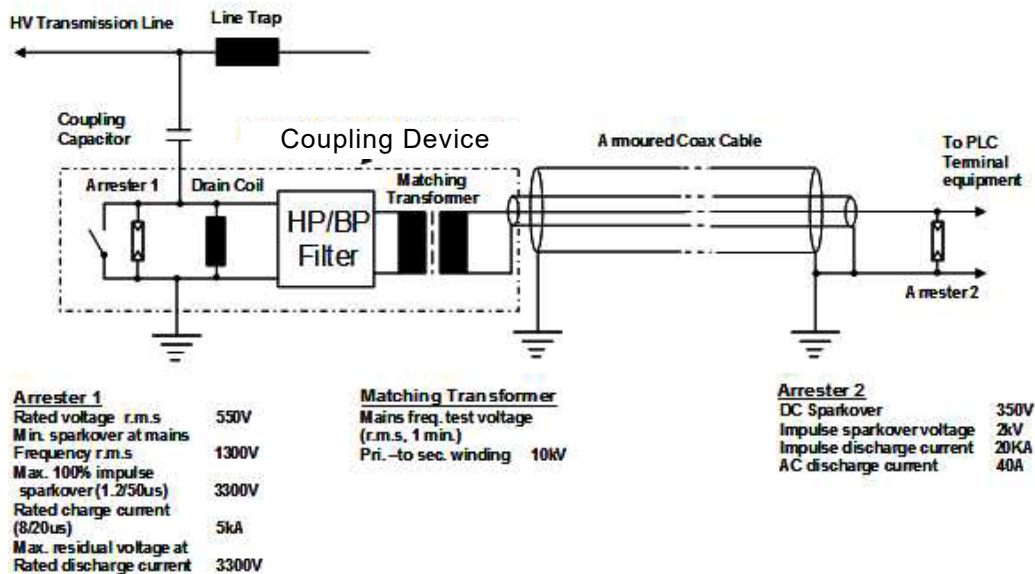


Figure 12 – Example of coupling device components and electric scheme

It comprises a drain coil, a surge arrester, and a matching transformer, which in some equipment is also designed as a drain coil to the power-frequency current. The surge arrester, inserted between the low-voltage side of the coupling capacitor and earth, absorbs high transient voltages for protection of the coupling device.

The function of the drain coil is to offer a low impedance at power frequency and high impedance at CF frequencies. It is designed to provide a path to earth for the power frequency current through the capacitor and so limit the potential of the capacitor terminal at the point of connection to the carrier equipment, in the interest of safety.

The requirements for coupling devices are covered by IEC 60481. Typical coupling device characteristics for coupling attenuation A and return loss R are shown in .

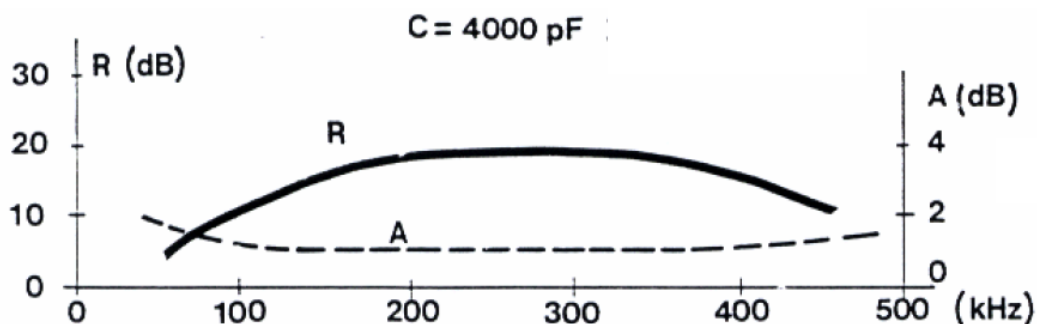


Figure 13 – Coupling device characteristics with a coupling capacitor of 4 000 pF

As the coupling device is inserted between the low-voltage terminal of the coupling capacitor and earth, a switch (blade earthed) is provided to ensure direct earth connection of the coupling capacitor during maintenance or commissioning.

Statutory safety rules may require different procedures for the operation of this earthing switch and typical arrangements are as follows:

An earthing switch earths the low voltage side of the coupling capacitor when the coupling device housing is opened. A manually-operated switch interlock may be provided which does not allow the cover to be removed before the switch is operated to the earthed position.

A pole-operated earthing switch with suitable warning notice may be provided. Whichever arrangement is used, it is recommended that an indication of the earthed position of the earthing switch should be clearly visible.

3.3.2 Coupling configuration for overhead HV lines

3.3.2.1 General

With regard to the type of coupling used, coupling devices may be of the phase-to-earth, or of the phase-to-phase types.

In the case of the latter, the coupling may be made with either a single phase-to-phase device or with two phase-to-earth devices properly connected. If the first arrangement is used, the distance between the low-voltage terminals of the capacitors and the coupling device is generally greater than with the second arrangement with a greater possibility of damage and interruption.

Consequently, in order to achieve higher reliability, use of phase-to-phase coupling should be made with two phase-to-earth units, with the connection between them made on the secondary side of the matching transformer.

3.3.2.2 Phase-to-earth coupling

In this type of coupling the PLC terminal is connected between one phase conductor and earth as shown in . Only one coupling capacitor and one line trap is required at each coupling point, so that this system offers economies in coupling system but it normally results in higher attenuation than phase-to-phase coupling and less reliability in the event of an earth fault on the coupled phase. It is to be noted that although the coupling takes place between one phase and earth, the actual transmission involves the two remaining phase conductors in a complex manner.

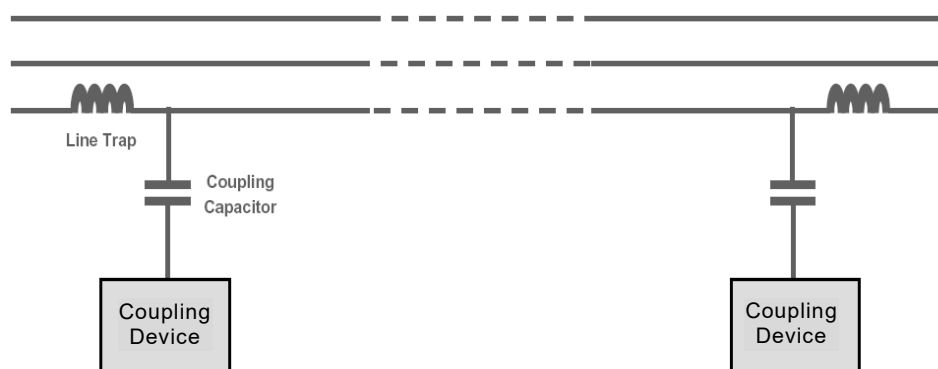


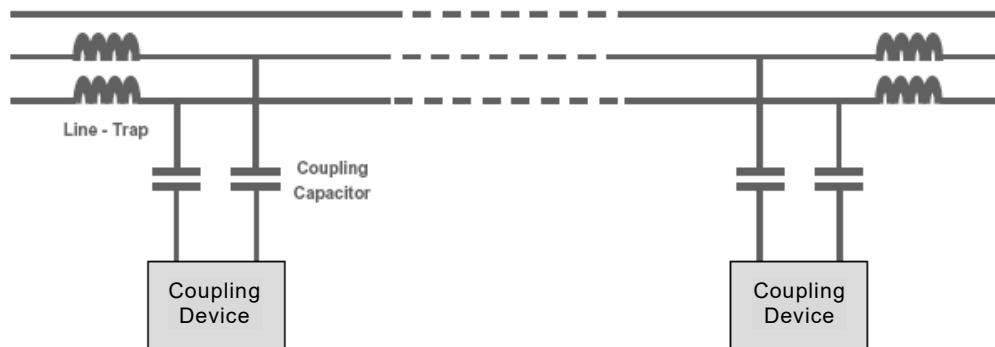
Figure 14 – Phase-to-earth coupling

Because of the economic advantages, phase-to-earth coupling may be employed where high reliability in the presence of line faults is not essential.

3.3.2.3 Phase-to-phase coupling

In this case, as shown in , two coupling capacitors and two line traps are required at each coupling point, so the cost of the coupling equipment will be approximately twice that of phase-

599 to-earth coupling. Phase-to-phase coupling however offers a number of important advantages,
 600 including lower attenuation, greater reliability against communication failure due to line faults,
 601 and less interference, both radiated and picked up.



602
 603 **Figure 15 – Phase-to-phase coupling**

604 The coupling may be made with either a single phase-to-phase device or with two phase-to-
 605 earth devices properly connected. If the first arrangement is used, the distance between the
 606 low-voltage terminals of the capacitors and the coupling device is generally greater than with
 607 the second arrangement, leading to a greater possibility of damage and interruption.
 608 Consequently, in order to achieve higher reliability, use of phase-to-phase coupling should be
 609 made with two phase-to-earth units, with the connection between them made on the secondary
 610 side of the matching transformer.

611 As approximately 80 % of all line faults are single-phase, this arrangement may be expected to
 612 give higher reliability.

613 **3.3.2.4 Inter-circuit coupling**

614 When two parallel high-voltage circuits are run without discontinuity on the same poles or
 615 towers, it is possible to utilize one phase on each of the circuits to provide the equivalent of
 616 phase-to-phase coupling on a single circuit line or two phases on each circuit to provide a
 617 double differential form of coupling. With this form of coupling, communication is maintained
 618 even if one power circuit is taken out of service and earthed. The lines and cables at both ends
 619 should be equal in length to avoid the possibility of phase cancellation.

620 **3.3.2.5 Insulated earth wire coupling**

621 It is customary on high-voltage lines, particularly those above 110 kV, to provide one or two
 622 earth wires above the phase conductors. These are primarily intended to protect the lines
 623 against lightning strokes, but they also serve to reduce the step voltage which would otherwise
 624 exist at the towers and substations under earth fault conditions on the lines. In addition, the
 625 earth wires help to minimize induction effects on nearby telecommunication circuits during earth
 626 faults on the power lines.

627 The earth wires are normally in metallic contact with the line towers, but it is known that their
 628 efficiency as lightning protectors is not affected if they are insulated from the towers, the
 629 insulators being by-passed by spark gaps rated to flash over at about 15 kV to 30 kV. This fact
 630 has led to the utilization of insulated earth wires for communication purposes, the principal
 631 advantage being the saving in coupling equipment since although coupling capacitors and
 632 choke coils are still required they need not be rated for the full operating voltage and current of
 633 the line.

634 However, the method has a number of disadvantages:

a) The attenuation at carrier frequencies is, in general, appreciably greater than that of the power line, where multi-strand steel conductor is employed for the earth wire. The attenuation on such lines increases dramatically in case of hoar frost or ice. Therefore, it is recommended to use this method for short distances. However, where composite conductors are used for the earth wire(s) the attenuation is more acceptable.

b) The need for insulating the earth wires at each tower and at the terminal points adds to the costs, and for longer distances the additional costs may exceed the savings in coupling equipment.

c) The effectiveness of the earth wires in their protective role under line fault conditions is reduced to some extent by the insulation at each tower.

d) Insulated earth wire links are not recommended for teleprotection.

Because of these drawbacks, the use of insulated earth wires for carrier communications has so far found only limited application.

3.3.3 Connecting cable

3.3.3.1 General

A “connecting cable” inserted between the secondary terminals of the coupling device and the PLC terminal. This connection may be made with either a balanced or unbalanced (coaxial) cable depending on the impedance of the carrier terminal.

Commonly used values for the impedance of the cable are 150 Ω for the balanced cable and 75 Ω for the coaxial type.

3.3.3.2 Coaxial or shielded cable earthing methods

When coaxial cable is employed, different methods of earthing the screen may be used depending if the coupling device and PLC terminal are or not part of the same earth mesh.

For cables lying within the same earth mesh, different methods could apply:

- Earthing at both ends of the coaxial cable: This method ensures the safety of maintenance personnel, as there will never be potential differences between local earth and the cable screen. Obviously, during faults, this connection may allow power-frequency currents to circulate in the screen and in the “hot” conductor;
- Earthing only one side of the screen at the PLC equipment end: This method of earthing may be used to avoid secondary problems due to i.e. coils and windings having magnetic cores. This practice, whilst eliminating power-frequency current circulation, may cause high voltage across the windings of the coupling transformer which will need to be designed for this duty. Consequently, maintenance personnel will need to take precautions against the possibility of potential differences, during faults, between cable screen and local earth.

For cables ending over different earth meshes different methods could apply:

- Earthing only one side of the screen at the PLC equipment end: This method of earthing may be used to avoid earth potential differences may be high in the case of a fault and circulating currents in the screen of the coaxial cable may be dangerous.

Similar problems can arise in the case of armoured and/or shielded cables, except that secondary problems are unlikely to occur, and the same considerations apply. By the use of balanced cables some of the above problems can be avoided.

It is good engineering practice to use for the interconnection between coupling device and CC/CVT a solid, uninsulated, large diameter copper rod, or something similarly robust, positioned at least 10 cm away from the supporting steel structure.

3.4 Analogue and digital PLC systems

3.4.1 APLC terminals

APLC systems, as shown in Figure 16 have been in use from the 1930s and are commonly used by the electricity utilities for their communication (teleprotection, telephone and data, fax) mainly on the HV electricity transmission grid.

The modulation scheme generally used for these systems is the single sideband (SSB) amplitude modulation to carry one or several basic telephone channels in the carrier range from 30 kHz to 500 kHz (sometimes extended from 16 kHz to 1 MHz).

When more than one service is required, the services are mixed using frequency-division multiplexing. The main limitation of APLC systems is the data rate which is limited to some hundred bit/s per service because of the limited bandwidth and the nature of the modulation.

In the following, some of the most used signal processing, modulation and channel division multiplexing technologies within APLC systems are listed:

- Frequency-division multiplexing;
- Single sideband modulation;
- Channel equalisation;
- FSK modem (rates $\leq 2\,400$ bit/s);
- PSK or QPSK modem (rates > 600 bit/s).

A typical APLC terminal equipment structure is given in Figure 16.

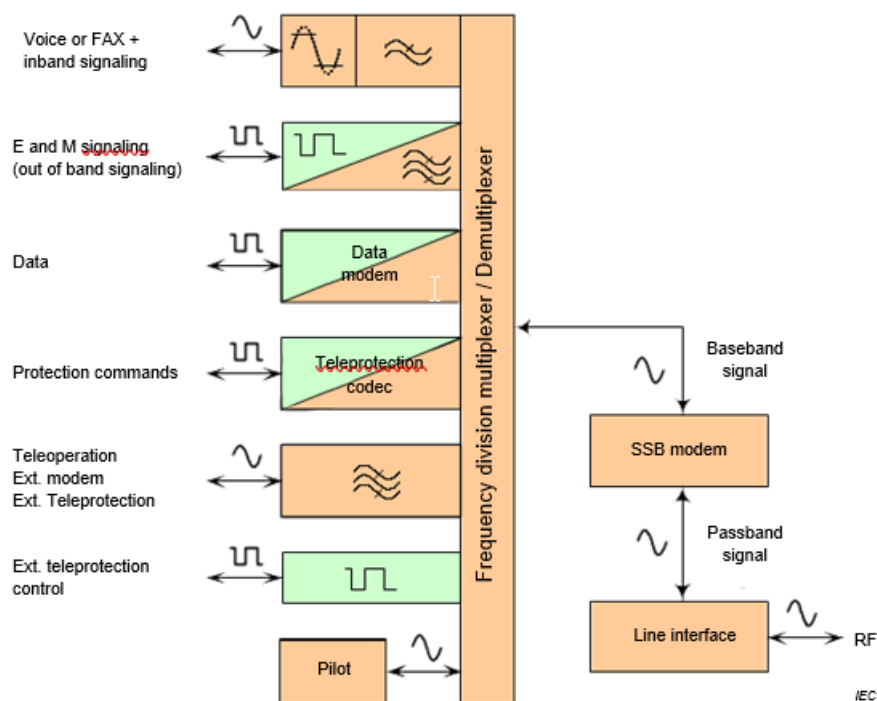


Figure 16 – Generic architecture of an APLC terminal acc. to IEC 62488-2