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Entwurf

**Systeme zur Kommunikation über Hochspannungsleitungen für
Anwendungen der elektrischen Energieversorgung –
Teil 1: Planung von Systemen zur analogen und digitalen
Nachrichtenübertragung über Hochspannungsleitungen
(IEC 57/1125/CDV:2011);
Englische Fassung FprEN 62488-1:2011**

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 57/1125/CDV:2011);
English version FprEN 62488-1:2011

Anwendungswarnvermerk

Dieser Norm-Entwurf mit Erscheinungsdatum 2011-10-31 wird der Öffentlichkeit zur Prüfung und
Stellungnahme vorgelegt.

Weil die beabsichtigte Norm von der vorliegenden Fassung abweichen kann, ist die Anwendung dieses
Entwurfes besonders zu vereinbaren.

Stellungnahmen werden erbeten

- vorzugsweise als Datei per E-Mail an dke@din.de in Form einer Tabelle. Die Vorlage dieser Tabelle kann
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DIN und VDE (Hausanschrift: Stresemannallee 15, 60596 Frankfurt am Main).

Die Empfänger dieses Norm-Entwurfs werden gebeten, mit ihren Kommentaren jegliche relevanten
Patentrechte, die sie kennen, mitzuteilen und unterstützende Dokumentationen zur Verfügung zu stellen.

Gesamtumfang 130 Seiten

DKE Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE

Nationales Vorwort

Die Englische Fassung des europäischen Dokuments FprEN 62488-1:2011 „Systeme zur Kommunikation über Hochspannungsleitungen für Anwendungen der elektrischen Energieversorgung – Teil 1: Planung von Systemen zur analogen und digitalen Nachrichtenübertragung über Hochspannungsleitungen“ (Entwurf in der Umfrage) ist unverändert in diesen Norm-Entwurf übernommen worden.

Die Internationale Elektrotechnische Kommission (IEC) und das Europäische Komitee für Elektrotechnische Normung (CENELEC) haben vereinbart, dass ein auf IEC-Ebene erarbeiteter Entwurf für eine Internationale Norm zeitgleich (parallel) bei IEC und CENELEC zur Umfrage (CDV-Stadium) und Abstimmung als FDIS (en: Final Draft International Standard) bzw. Schluss-Entwurf für eine Europäische Norm gestellt wird, um eine Beschleunigung und Straffung der Normungsarbeit zu erreichen. Dem entsprechend ist das internationale Dokument IEC 57/1125/CDV:2011 „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“ unverändert in den Entwurf FprEN 62488-1:2011 übernommen worden.

Das internationale Dokument wurde vom TC 57 „Power systems management and associated information exchange“ der Internationalen Elektrotechnischen Kommission (IEC) erarbeitet.

Bei der Abstimmung zu dem Europäischen Schluss-Entwurf bei CENELEC und dem Internationalen Schluss-Entwurf bei IEC [Final Draft International Standard (FDIS)] sind jeweils nur „JA/NEIN“-Entscheidungen möglich, wobei „NEIN“-Entscheidungen fundiert begründet werden müssen. Dokumente, die bei CENELEC als Europäische Norm angenommen und ratifiziert werden, sind unverändert als Deutsche Normen zu übernehmen.

Für diesen Norm-Entwurf ist das nationale Arbeitsgremium K 952 „Netzleittechnik“ der DKE Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE (www.dke.de) zuständig.

Für den Fall einer undatierten Verweisung im normativen Text (Verweisung auf eine Norm ohne Angabe des Ausgabedatums und ohne Hinweis auf eine Abschnittsnummer, eine Tabelle, ein Bild usw.) bezieht sich die Verweisung auf die jeweils neueste gültige Ausgabe der in Bezug genommenen Norm.

Für den Fall einer datierten Verweisung im normativen Text bezieht sich die Verweisung immer auf die in Bezug genommene Ausgabe der Norm.

Der Zusammenhang der zitierten Normen mit den entsprechenden Deutschen Normen ergibt sich, soweit ein Zusammenhang besteht, grundsätzlich über die Nummer der entsprechenden IEC-Publikation. Beispiel: IEC 60068 ist als EN 60068 als Europäische Norm durch CENELEC übernommen und als DIN EN 60068 ins Deutsche Normenwerk aufgenommen.

Das Präsidium des DIN hat mit Präsidialbeschluss 1/2004 festgelegt, dass DIN-Normen, deren Inhalt sich auf internationale Arbeitsergebnisse der Informationsverarbeitung gründet, unter bestimmten Bedingungen allein in englischer Sprache veröffentlicht werden dürfen. Diese Bedingungen sind für die vorliegende Norm erfüllt.

Da sich die Benutzer des vorliegenden Normentwurfs der englischen Sprache als Fachsprache bedienen, wird die Englische Fassung der E DIN EN 62488-1 veröffentlicht. Zu deren Abschnitt 2, der die Begriffe festlegt, wurde eine Übersetzung angefertigt und als Nationaler Anhang NA des vorliegenden Normentwurfs hinzugefügt. Dieser Normentwurf steht nicht in unmittelbarem Zusammenhang mit Rechtsvorschriften und ist nicht als Sicherheitsnorm anzusehen.

Nationaler Anhang NA (informativ)

2.2 Begriffe

2.2.1 System zur Kommunikation über Hochspannungsleitungen (PLCS)

System zur Kommunikation über Hochspannungsleitungen (PLCS) ist der festgelegte Oberbegriff für das Senden und Empfangen von Signalen über Hochspannungsleitungen. Im Zusammenhang mit dieser Norm werden folgende Begriffe, die sich auf spezifische Systeme zur Kommunikation über Hochspannungsleitungen beziehen, verwendet: Trägerfrequenz-Übertragung auf Hochspannungsleitungen, Telekommunikation über Hochspannungsleitungen und Trägerfrequenzübertragung über elektrische Verteilungsnetze.

ANMERKUNG Die Oberbegriffe „Kommunikation über Hochspannungsleitungen“ oder „Telekommunikation über Hochspannungsleitungen“ decken ein breites Spektrum von Anwendungen der Datenübertragung über Starkstromleitungen ab, die sich vor allem durch zwei Kriterien unterscheiden: die Bandbreite, die gefordert wird (Kommunikationsgeschwindigkeit) und die Netze und Leitungen für Niederspannung (LV), Mittelspannung (MV) oder Hochspannung (HV), die für das System verwendet werden.

In diesem Dokument werden PLCS (Systeme zur Kommunikation über Hochspannungsleitungen) oder PLT (Telekommunikation über Hochspannungsleitungen) in Bezug auf die allgemeine Datenübertragung über Leitungen für den elektrischen Strom verwendet. Die Abkürzung PLC (Trägerfrequenz-Übertragung auf Hochspannungsleitungen) bezieht sich auf die Anwendung der Trägerfrequenz, die üblicherweise für die Kommunikation auf schmalen Bändern über Hochspannungsleitungen verwendet wird und die für ein eigenes Fernsprechnet und für Fernsteuerung sowie Schutzsignalübertragung über die elektrischen Übertragungseinrichtungen genutzt werden.

2.2.2 Trägerfrequenzübertragung über elektrische Verteilungsnetze (DLC)

Die DLC (Trägerfrequenzübertragung über elektrische Verteilungsnetze) wird im Zusammenhang mit der Datenübertragung über das Stromverteilungsnetz (DPL) verwendet.

ANMERKUNG Dies kann die Schmalbandkommunikation mit Hochgeschwindigkeit über Spannungsverteilungsnetze als Medium oder Breitband/Schmalband-Kommunikationssysteme über Niederspannungsnetze betreffen.

2.2.3 Breitband über Stromleitung (BPL)

Die Abkürzung für Breitband über Stromleitungen ist BPL. Diese Systeme ermöglichen üblicherweise die Übertragung von Breitband-Daten in einem Frequenzbereich zwischen 1 MHz und 30 MHz. Alle Nieder- und Mittelspannungs-Stromnetze können dafür verwendet werden. Mit BPL-Systemen wird Breitbandkommunikation für Wohn- und für Geschäftsräume bereitgestellt. Bei den BPL-Systemen wird unterschieden zwischen Systemen, die außerhalb von Wohnungen und Büros verwendet werden (für den Internet-Zugang in den Räumlichkeiten oder das intelligente Netz der Energieversorgungsunternehmen, auch als BPL-Zugang bezeichnet) und den Anwendungen innerhalb von Räumen oder Gebäuden (grundsätzlich auf Ethernet-Netzwerktechnologie basierend) sowie für die Automatisierungstechnik. Diese werden gewöhnlich als Homeplug-Anwendungen bezeichnet.

2.2.4 PLC-Endgerät

Geräte, die in der Lage sind, eine Telekommunikationsverbindung vollständig zu verwalten, wobei das PLC-Endgerät für Hochspannungsleitungen hauptsächlich für eine sichere Übertragung von Sprachanwendungen, Daten und von Schutzsignalen des Energieversorgungsnetzes verwendet wird.

2.1.3 Stromleitung

Teil eines elektrischen Versorgungssystems, das zur Übertragung der elektrischen Energie von einem Punkt zu einem anderen verwendet wird.

2.2.5 Kopplersystem

Das Kopplersystem besteht aus der Gerätegruppe, die zur Kopplung des PLC-Hochfrequenzsignals mit der Stromleitung verwendet wird. Das Kopplersystem besteht aus Trägerfrequenzsperrern, Koppelkondensatoren und der Leitungs-Anpassungseinheit.

2.2.6 Trägerfrequenzsperre

Die Trägerfrequenzsperre ist eine Baugruppe, mit der auf dem Trägerfrequenzband eine hohe Impedanz entsteht, während die Impedanz bei Netzfrequenz vernachlässigbar ist.

ANMERKUNG Die hohe Impedanz begrenzt im Bereich des Energieversorgungsnetzes die Trägersignalleistung. Die Trägerfrequenzsperrern sind mit den Übertragungsleitungen in Reihe geschaltet. Meistens ist die Trägerfrequenzsperre direkt auf dem Koppelkondensator aufgestellt. Die Kennwerte sind durch die Empfehlung IEC 60353 genormt.

2.2.7 Koppelkondensator

Kondensator, der in einem PLC-System zur Kopplung mit der Stromleitung verwendet wird.

2.2.8 Leitungs-Anpassungseinheit

Einheit, welche die Schnittstelle zwischen EHV/HV-Seite der Stromleitung und PLC-Einrichtung bildet.

ANMERKUNG Üblicherweise in einem Gehäuse untergebracht und in der Nähe der Koppelkondensatoren installiert. Die Kennwerte sind durch die Empfehlung IEC 60481 genormt.

2.2.8.1 Trägerfrequenzbereich

Die für das spezifische Stromleitungs-Kommunikationssystem vorhandene Bandbreite.

ANMERKUNG In Europa liegt der typische Trägerfrequenzbereich für Schmalband-HV-PLC zwischen 3 kHz und 148,5 kHz sowie zwischen 1,6 MHz und 30 MHz für Breitband-PLC, wobei der Hersteller den Bereich der Trägerfrequenz angeben muss, innerhalb dessen die empfohlenen Werte einzuhalten sind. Für die USA liegt der IEEE-PLC-Standard für den Frequenzbereich zwischen 45 kHz und 450 kHz, wobei Teilbereiche davon durch nationale Bestimmungen ausgeschlossen sind.

2.2.8.2 Unterteilung in Kanäle

Grundlegende Aufteilung des Trägerfrequenzbereichs oder Teilen davon in jeweils einen PLC-Sende- und -Empfangskanal (bidirektional).

2.2.8.3 Hochfrequenzband-Nennbereich

Betriebsfrequenzband innerhalb des Trägerfrequenzbereichs eines bestimmten PLC-Senders oder -Empfängers

2.2.8.4 Effektiv übertragenes Signal-Frequenzband

Der Teil des Frequenzbandes, der für die Übertragung des Basisbandsignals verwendet wird.

2.2.9 Nennimpedanz

Die Nennimpedanz ist der Impedanzwert, für den ein Eingangs- oder Ausgangskreis ausgelegt ist und für den die festgelegten Anforderungen gelten.

2.2.10 Modulationsschema

Bezieht sich auf die Modulationsart, die angewendet wird, um über das Modulationsverfahren (AM-SSB, Bandspreizung, QAM, OFDM) den Inhalt der Information oder das Nutzsignal im Hochfrequenz-Ausgangssignal zuzuordnen oder abzubilden.

2.2.11 Amplitudenmodulation

Modulationstechnik, bei der die Übertragung der Information durch Amplitudenänderung einer Trägerschwingung erfolgt.

2.2.11.1 Einseitenbandmodulation (AM-SSB)

Variante der Amplitudenmodulation mit effizienterer Nutzung der Bandbreite und der elektrischen Energie.

2.2.12 Modulation mit Frequenzumtastung (FSK)

Frequenzmodulationstechnik, bei der die Information durch Änderung der diskreten Frequenz einer Trägerschwingung verschlüsselt übertragen wird.

2.2.13 Modulation mit Phasenumtastung (PSK)

Digitales Modulationsschema, bei dem die Datenübertragung durch Änderung oder Modulation der Phase eines Referenzsignals (der Trägerschwingung) erfolgt.

2.2.14 Quadraturamplitudenmodulation (QAM)

Kombination aus analogem und digitalem Modulationsschema. Zwei analoge Nachrichtensignale oder zwei digitale Bitströme werden mittels des digitalen Modulationsschemas Amplitudenumtastung (ASK) bzw. mit dem analogen Modulationsschema Amplitudenmodulation (AM) durch Amplitudenänderung (-modulation) zweier Trägerschwingungen übertragen.

2.2.15 Orthogonales Frequenzmultiplexverfahren (OFDM)

Frequenzmultiplexverfahren, auch FDM-Schema, das als digitales Mehrfachträger-Modulationsverfahren genutzt wird. Für die Datenübertragung werden viele dicht nebeneinander liegende orthogonale Subträger verwendet. Die Daten werden in mehrere parallele Datenströme oder -kanäle, jeder auf einen Subträger, aufgeteilt. Alle Subträger werden jeder für sich mit einem herkömmlichen Modulationsschema (wie der Quadraturamplitudenmodulation oder Phasenumtastung) mit geringer Symbolrate moduliert, wobei für dieselbe Bandbreite eine Gesamtdatenrate erreicht wird, die ungefähr den herkömmlichen Modulations-schemen mit einem einzigen Träger entspricht.

2.2.16 Multiplexverfahren

2.2.16.1 Mehrfachzugriff im Codemultiplexverfahren (CDMA)

Ein Verfahren mit Mehrfachzugriff, bei dem verschiedenen Endgeräten, die Zugriff auf eine Verbindung haben, orthogonale Codes zur Nachrichtenübertragung zugewiesen werden, wie zum Beispiel Bitfolgen mit Nullen oder geringer Kreuzkorrelation zur Unterscheidung der Signale, die gleichzeitig ein gemeinsames Frequenzband benutzen.

2.2.16.2 Frequenzmultiplex (FDM)

Multiplexverfahren, bei dem mehrere voneinander unabhängige Signale zur Nachrichtenübertragung über einen gemeinsamen Kanal einzelnen Frequenzbändern zugeordnet sind.

2.2.16.3 Zeitmultiplex (TDM)

Multiplexverfahren, bei dem in einem gemeinsamen Kanal jedem unterteilten Kanal ein bestimmtes, wiederkehrendes Zeitintervall zugeordnet wird.

2.2.16.4 Mehrfachzugriff im Zeitmultiplexverfahren (TDMA)

Multiplexverfahren, bei dem in einem gemeinsamen Kanal jedem unterteilten Kanal ein bestimmtes, wiederkehrendes Zeitintervall zugeordnet wird.

2.2.17 Hüllkurvenspitzenleistung (PEP)

Die Hüllkurvenspitzenleistung (der Trägerfrequenz) einer Mehrfachsignalübertragung ist die mittlere Wirkleistung, wenn das modulierende Signal während eines Trägerfrequenz-Zyklus seinen Spitzenwert hat (Abschnitt 1, Absatz 95 und CCIR-Empfehlung 326-1, Punkt 1.1).¹⁾

Zur Bestimmung der Hüllkurvenspitzenleistung wird empfohlen, den Sender innerhalb des effektiv übertragenen Signalfrequenzbandes mit zwei sinusförmigen Signalen im Sprachfrequenzbereich mit gleicher Amplitude zu modulieren. Der Sender wird mit einer Widerstandslast bei Nennimpedanz und ohne Begrenzer abgeschlossen.

Die Amplitude des Modulationssignals muss entsprechend den Anforderungen an die Störaussendungen gewählt werden. Die Hüllkurvenspitzenleistung liegt damit viermal höher als bei einem Einzelsignal (CCIR-Empfehlung 326-1, Punkt 3.1.3.1).

2.2.18 Verhältnis Spitzenwert/Mittelwert der Signalleistung (PAPR)

Bei einem Mehrfachträger-Modulationsverfahren erhöht sich die Leistung des gesendeten Signals, wenn die Signale aller Subträger addiert werden.

2.2.18.1 PLC-Nennausgangsleistung

Die Nennausgangsleistung eines PLC-Endgerätes ist die Hüllkurvenspitzenleistung PEP, für die das Gerät entsprechend den Anforderungen an die Störaussendungen ausgelegt ist und die am Trägerfrequenz-Ausgang über einer Widerstandslast bei Nennimpedanz vorhanden ist.

2.2.18.2 Mittlere PLC-Ausgangsleistung

Die mittlere Ausgangsleistung eines PLC-Endgerätes ist die Ausgangsleistung, gemittelt über eine im Verhältnis zum Zyklus der niedrigsten Modulationsfrequenz genügend lange Dauer, während der angenommen wird, dass diese mittlere Leistung den Höchstwert erreicht, für den das Gerät ausgelegt ist.

2.2.19 Störaussendungen

Aussendungen auf einer oder mehreren Frequenzen außerhalb des Bereiches der Trägerfrequenz.

Störaussendungen umfassen harmonische Aussendungen, parasitäre Signale und Intermodulationsprodukte.

¹⁾ XII. Plenartagung des CCITT, 1970, Band I.

2.2.20 Rückflusssdämpfung

Die Rückflusssdämpfung im Nennbereich des PLC-Sendebandes darf 10 dB nicht unterschreiten.

2.2.21 Nebenschlussdämpfung

Die Impedanz außerhalb des Nennbereichs des PLC-Sende- und -Empfangsbandes muss der anderer PLC-Einrichtungen, die am gleichen Kopplersystem angeschlossen sind, entsprechen und darf keinen höheren als den festgelegten dB-Wert für die Nebenschlussdämpfung aufweisen.

2.2.22 Signalschnittstelle

2.2.22.1 Analoge Schnittstelle

Schnittstelle, die für analoge Sprachsignale vorgesehen ist.

2.2.22.2 Serielle Schnittstelle

Schnittstelle, die für die serielle Datenübertragung vorgesehen ist.

2.2.22.3 Ethernet-Schnittstelle

Schnittstelle, die für Datenübertragung nach IEEE 802.3(2000) vorgesehen ist.

2.2.23 Dämpfung

Leistungsminderung für den jeweiligen Modus entlang einer Übertragungsleitung, die quantitativ ausgedrückt wird durch das Verhältnis oder den Logarithmus des Verhältnisses einer Eingangsleistung am Ausgangspunkt gegenüber der entsprechenden Ausgangsleistung am Endpunkt.

2.2.24 Empfindlichkeit

Bezieht sich auf die Empfindlichkeit (SL) oder den niedrigsten Leistungspegel eines HF-Signals, das am Empfängereingang anzulegen ist, damit der maximale Datendurchsatz, der bei einer festgelegten BER, z. B. SL = -60 dbm@64 kb/s und BER = 10^{-6} erzielt werden kann, erreicht wird.

2.2.25 Hintergrundrauschen

Rauschen, das auf allen vorhandenen Kanälen einer Hochspannungsleitung vorhanden ist und hauptsächlich durch Korona- und Teilentladungen sowie elektromagnetische Störungen durch weitere PLC-Einrichtungen, die das gleiche Stromnetz benutzen und durch Störungen von Sendern mit demselben Funkfrequenzspektrum verursacht wird.

2.2.26 Schmalbandrauschen

Rauschen im Schmalbandbereich, wie zum Beispiel das „Brummen“ von Stromversorgungen bei einer Frequenz von 50/60 Hz.

2.2.27 Weißes Rauschen

Zufällig auftretendes spektral flaches Rauschen. Manchmal ist es angebracht, auf Rauschen mit flachem Spektrum und begrenzter Bandbreite, auch als **bandbegrenztes weißes Rauschen** bekannt, Bezug zunehmen.

2.2.28 Koronarauschen

Wird durch Teilentladungen an Isolatoren und in der Umgebungsluft von Freileitungen verursacht. Die Entladungen treten an den drei Außenleitern zu unterschiedlichen Zeitpunkten auf. Der Pegel des Koronarauschens ist sehr wetterabhängig. Es ist allgemein bekannt, dass sich vor allem schlechte Witterungsbedingungen stark auf das Koronarauschen auswirken.

2.2.29 Farbiges Rauschen

Gegenteil von Weißem Rauschen bzw. jedes breitbandige Rauschen, das kein flaches Spektrum aufweist; Beispiele sind Rosa Rauschen, Braunes Rauschen und Autoregressives Rauschen.

2.2.30 Impulsrauschen

Besteht aus kurzen Impulsen mit zufälliger Dauer und zufälliger Amplitude.

2.2.31 Transientes Rauschen

Enthält relativ lange Rauschimpulse.

2.2.32 Signal-Rausch-Verhältnis (SNR)

Das Signal-Rausch-Verhältnis ist das Verhältnis der Höhe des Referenzsignals zur Höhe des Rauschens.

2.2.33 Bruttodatenrate

Gesamter Dateninhalt, der zum PLC-Endgerät am anderen Ende der Stromleitung übertragen wird.

2.2.34 Datendurchsatz

Nutzdatenrate, die zum PLC-Endgerät am anderen Ende der Stromleitung übertragen wird (frei von Bitfolgen, die zum Verwalten der Verbindung notwendig sind).

2.2.35 Bitfehlerrate (BER)

Verhältnis der empfangenen Bits gegenüber der Anzahl der Bits, die insgesamt gesendet wurden.

2.2.36 Messung der Bitfehlerrate (BERT)

Festlegen geeigneter Vorrichtungen und Messverfahren zur Ermittlung der Bitfehlerrate auf Übertragungsstrecken.

2.2.37 Anomalien und Defekte

Auf der Übertragungsstrecke auftretende Bedingungen, die Anomalien und Defekte zur Folge haben und zur Verminderung der Übertragungsleistung führen, wie z. B. Signalverlust, Ausfall der Synchronisation, Anzeige eines Alarmsignals, Verschiebung und Verlust der Rahmenausrichtung.

2.2.38 Fehlerhafte Sekunde (ES)

Eine Sekunde dauernder Zeitraum, in dem ein oder mehr Bits fehlerhaft sind.

2.2.39 Unakzeptable Sekunde (SES)

Eine Sekunde dauernder Zeitraum mit einer Bitfehlerrate von $1 \cdot 10^{-3}$ oder während der ein Signalverlust (LOS) bzw. die Anzeige eines Alarmsignals erkannt werden.

2.2.40 Fehlerfreie Sekunde (FES)

Alle Sekunden während der gesamten Übertragungsdauer ohne fehlerhafte Bits.

2.2.41 Anteil an Fehlerhaften Sekunden (ESR)

Verhältnis der Anzahl der Fehlerhaften Sekunden ES zur Dauer der Messung in Sekunden während der Verfügbarkeit innerhalb des Bezugszeitraumes.

2.2.42 Anteil an Unakzeptablen Sekunden (SESR)

Verhältnis der Anzahl der Unakzeptablen Sekunden SES zur Dauer der Messung in Sekunden während der Verfügbarkeit innerhalb des Bezugszeitraumes.

2.2.43 Gruppenlaufzeit

Signallaufzeit zwischen zwei Punkten, wobei das Signal idealerweise aus zwei sinusförmigen Wellen mit gleicher Amplitude und geringfügig unterschiedlichen Frequenzen gebildet wird, wodurch ein einheitlicher Grenzwert erhalten wird.

2.2.44 Jitter

Kurzzeitige, erhebliche Abweichung des Taktsignals von der zeitlich optimalen Einstellung (diese Abweichungen betreffen Frequenzen von mindestens 10 Hz).

2.2.45 Wander

Langzeitliche, erhebliche Abweichung des Taktsignals von der zeitlich optimalen Einstellung (diese Abweichungen betreffen Frequenzen unter 10 Hz).

2.2.46 Latenz

Die Latenzzeit in paketvermittelten Datennetzen bezieht sich auf die Dauer der Übermittlung eines Paketes von der Sendequelle bis zum Zielempfänger. Bei bidirektionaler Übertragung ist die Latenzzeit bezogen auf die Dauer des gesamten Umlaufs, die sich aus den einzelnen Latenzen von der Quelle bis zum Ziel und vom Ziel zurück zur Quelle zusammensetzt.

2.2.47 Rahmenverlustrate

Anzahl der Rahmen im Ethernet, die erfolgreich von der Quelle verschickt, aber nicht am Ziel empfangen wurden. Im Allgemeinen als Rahmenverlustrate bezeichnet, wird sie, bezogen auf die Gesamtzahl der gesendeten Rahmen, in Prozent angegeben.

2.2.48 Vorwärtsfehlerkorrektur

Fehlerkontrollsystem für die Datenübertragung, bei der das Empfangsgerät in der Lage ist, jeden fehlerhaften Daten- oder Codeblock, der weniger Zeichen enthält als vorgesehen, zu erkennen und zu korrigieren.

2.2.49 Rahmenprüfsumme

Algorithmus zur Fehlererkennung, bei dem polynomial verschlüsselte digitale Signale als Paritätsbits verwendet werden, die dem digitalen Signal angehängen und mit dem durch Entschlüsselung Fehler im empfangenen Signal erkannt werden.

2.2.50 Verfügbarkeit

Verfügbarkeit ist das Verhältnis der Verfügbarkeitsdauer eines Systems oder einer Komponente zur Gesamtzeit, für die gefordert oder erwartet wird, eine Funktion zu erfüllen. Diese kann in durchschnittlicher Ausfallzeit pro Jahr oder prozentual angegeben werden.

2.2.51 Zuverlässigkeit

Fähigkeit eines Systems, seine Funktion entsprechend seiner Spezifikationen beständig auszuführen.

2.2.52 Qualitätsziele

Subjektive Bewertung der Qualität einer Sprachkommunikation, bei der sachverständige Hörer die Übertragung z. B. als ausgezeichnet, gut, ausreichend, mangelhaft oder ungenügend klassifizieren.

2.2.53 Betriebsbedingungen

Kenngrößen, die das Betriebsverhalten eines Bauelements, eines Geräts oder eines Betriebsmittels beeinflussen können.

2.2.54 Umgebung

Bezieht sich auf die Einstufung der Umgebungsbedingungen, unter denen die Telekommunikationseinrichtungen betrieben werden, um die verschiedenen EMV/EMI-Einschränkungs- und Begrenzungsklassen festzulegen. Typische Umgebungen sind zum Beispiel Industrieumgebung, Gewerbebereich, Wohngebäude usw.

2.2.55 Dienstgüte

Die Dienstgüte (QoS) bezieht sich auf die Bereitstellung von Ressourcen für Überwachungsmechanismen des Telekommunikationssystems, um einen bestimmten Datenfluss zu garantieren, wie z. B. Datenrate, Laufzeit, Jitter, Paketverlust oder BER, die einzuhalten sind.

2.2.56 Telekommunikations-Management-Netz

TMN (Telekommunikations-Management-Netz) bezieht sich darauf, dass ein Netzwerk unabhängig vom Anbieter der Netzwerkkomponenten lückenlos verwaltet werden kann. TMN verwendet die OSI-Management-Standards als Framework. TMN gilt für alle Telekommunikationstechnologien, drahtgebunden, drahtlos, sowohl für private als auch für öffentliche Netze.

2.2.57 Intelligentes Stromnetz

Entsprechend des vom *Energy Independence and Security Act* von 2007 festgelegten Begriffs bezieht sich das „Intelligente Stromnetz“ auf die Modernisierung von Stromversorgungssystemen, die von zentralen und dezentralen Energieerzeugungen aus über das Hochspannungsnetz und -verteilungssystem zu industriellen Anwendern und Gebäudeautomationssystemen, zu Energiespeicheranlagen und zu den Temperaturreglern, elektrischen Fahrzeugen und Einrichtungen, sowie sonstigen Haushaltsgeräten der Endverbraucher eine Überwachung, die Absicherung und die Funktionsoptimierung der miteinander verbundenen Bestandteile ermöglicht.

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WORKING DRAFT

INTERNATIONAL ELECTROTECHNICAL COMMISSION

Planning of Analogue and Digital Power Line Carrier Systems –**Part 1: Operating Over EHV/HV/MV Electricity Grids**

FOREWORD

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This International Standard has been prepared by IEC Technical Committee No. 57: Power Systems Management and Associated Information Exchange, Working Group 20, Power Line Carrier Terminals and Systems Planning.

This first edition of IEC 62488 cancels and replaces both IEC 60663 as well as IEC 60495 previous standards related to the same matter.

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

FDIS	Report on voting
XX/XX/FDIS	XX/XX/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.

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 EHV/HV/MV Electricity Grids;

Part 2: Analogue Power Line Terminals or APLC;

Part 3: Digital Power Line Carrier Terminals or DPLC;

Part 4: Broadband Power Line Systems or BPL.

Annex A forms an integral part of this standard. Annexes B, C and D are for information only.

The committee has decided that the contents of this publication will remain unchanged until the stability date¹ 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.

¹ The National Committees are requested to note that for this publication the stability date is 2015.

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 control of electrical networks and transmission and reception of data are through a combination of analogue and digital communication systems controlling devices and systems distributed throughout the electrical network.

The emergence of digital communication systems for controlling the devices of the electrical distribution network enables faster data transmission. The ability to represent the various electrical parameters as an analogue signal and or digital signal ensures the quality and quantitative aspects of seamless communication to be maintained throughout the electrical power network.

Therefore, by using either Analogue Power Line Communication (APLC) or Digital Power Line Communication (DPLC) or a combination of both types of system, seamless efficient communication may be maintained throughout the power network.

The development of digital techniques for communications in the electrical distribution 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 conversion of the analogue signal into a binary signal requires the binary digits to be formed into a code for the transmission of the information. These codes take different forms to represent the information to be transmitted. However, the main advantage for this is that digital signals compared with analogue signals provide for virtually error free transmission and the minimum errors that do arise may be detected and corrected by using suitable data encoding techniques. Further digital transmission circuits generally are compatible with the digital devices in the communications circuit. The most commonly used multiplex systems are Frequency Division Multiplex (FDM) and Time Division Multiplex (TDM).

This document is composed by the following chapters:

- Chapter 1 provide for a description of the overall scope and objectives of this series of standards focusing mainly on the scope of this Part 1;
- Chapter 2 provide for a useful set of definitions terms and concepts extensively used in this standard;
- Chapter 3 gives a general introduction to Power Line Communication Systems their use also providing some indications concerning the most used modulation scheme
- Chapter 4 deals with Frequency Bands for PLC Systems and about the criteria used on different contexts to allocate PLC frequency spectrum;
- Chapter 5 provides for a comprehensive description of the characteristic of the media typically used for DPLC & APPLC Systems including coupling system device and noise;
- Chapter 6 concerns the planning of DPLC & APPLC links and also introduces some basic network planning concepts;

- Chapter 7 gives defines parameters and the main consideration to follow in order to evaluate the Performance of PLC Systems;
- Chapter 8 describes the key features of the applications to be transported by PLC Systems.

Finally in the Annexes are included some detailed analysis of specific concepts and examples like bandwidth efficiency, HF power calculation etc. and reference to a useful bibliography.

WORKING DRAFT

Part 1: Planning of Analogue and Digital Power Line Carrier Systems Operating Over EHV/HV/MV Electricity Grids

1 General

1.1 Scope and Objective of the full standard IEC 62488

The development of the technical report Planning of Power Line Carrier systems was first produced by the International Electrotechnical Commission through publication 663 in 1980 entitled Planning of (single sideband) Power Line Carrier systems. During 1993, the International Electrotechnical Commission produced standard 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 663 and IEC 60495, are being updated and replaced by the following International Electrotechnical Commission standards. IEC standard 663 will be replaced by IEC standard 62488-1, Planning of Analogue and Digital Power Line Carrier Systems Operating over EHV/HV/MV Electricity Grids and IEC standard 60495 will be replaced by IEC standards 62488-2, 62488-3, 62488-4 covering respectively Analogue, Digital Power Line Carrier and Broadband Power Line Terminals,.

The first part of this standard to be produced is International Electrotechnical Commission standard, IEC 62488-1. Following this standard, International Electrotechnical Commission standard parts IEC 62488-2, IEC 62488-3, IEC 62488-4 will follow. During the development of the above mentioned standards, the existing standards IEC 663 and IEC 60495 will be maintained in use. They will be subsequently phased out at a date to be agreed by the International Electrotechnical Commission in conjunction with IEC TC 57 Power Systems Management and Associated Information Interchange.

These International Standards apply to Power Line Carrier (PLC) Terminals used to transmit information over Power Networks including Extra High, High and Medium Voltage (EHV/HV/MV) Power Lines. Both analogue and digital modulation systems will be included.

1.2 Scope and Objective of IEC 62488-1 part of this standard

The object of these standards is to establish the planning of the services and performance parameters for the operational requirements to transmit and receive data efficiently over Power Networks.

The transmission media used by the different electricity supply industries will include analogue and digital systems together with more common communication services including national telecommunications authorities, radio links and fibre optic networks and satellite networks. With the developments in communication infrastructures over the last two decades and the ability of devices connected in the electricity communications network to internally and externally communicate, there is a variety of architectures to use in the electricity distribution network to provide efficient seamless communications.

These series of standards for the planning of power line carrier systems will also be an integral part of the development of the overall architecture, standard IEC 61850 developed within IEC TC57 which provides the fundamental architecture for the formation of the SMART GRID.

2 Terms, Definitions and Concepts

2.1 Abbreviated Test

For the purpose of this International Standard, the following definitions and concepts apply. 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).

AGC	automatic gain control
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
CDMA	code division multiple access
CENELEC	comité européen de normalisation électrotechnique
CF	carrier frequency
CISPR	comité internationale spécial des perturbations radioélectrotechnique
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
EMC	electro magnetic compatibility
EMI	electro magnetic interference
EMC	electro magnetic compatibility
ES	errored second
ESR	errored second ratio
ETH	Ethernet
ETSI	European telecommunications standards institute
FDM	frequency division multiplexing
FSK	frequency shift keying
FXO	foreign exchange office
FXS	foreign exchange subscriber
EHV	extra high voltage
ETSI	european telecommunications standards institute
FCS	frame check sequence
GMR	geometric mean radius
HF	high frequency
HV	high voltage
ICAO	international civil aviation organisation
IEEE	institute of electrical and electronics engineers
IETF	internet engineering task force
IP	internet protocol

ISO	international organisation for standardisation
ITU	international telecommunications union
LAN	local area network
LMU	line matching unit
LV	low voltage
MAC	media access control
MV	medium voltage
NAT	network address translation
OFDM	orthogonal frequency-division multiplexing
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
PLT	power line telecommunications
PLCS	power line communication system
PSK	phase shift keying
QAM	quadrature amplitude modulation
QoS	quality of service
QPSK	quadrature phase shift keying
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
SNR	signal to noise ratio
SSB	single side band
TCP	transmission control protocol
TDM	time division multiplexing
TDMA	time division multiple access
Tx	transmitte(r)
UDP	user datagram protocol

2.2 List of Terms

2.2.1 Power Line Communication System (PLCS)

Power Line Communication System (PLCS) is the generic name given to the transmission and reception of signals over electricity power lines. In the context of this standard the following terms are used to refer to specific Power Line communication systems: Power Line Carrier, Power Line Telecommunication and Distribution Line carrier.

Note: The generic terms of “Power Line Communication”, or “Power Line Telecommunications” cover a number of applications, all related to transmitting information over electric power lines, that can be classified mainly with two different criteria: the bandwidth required (the communication speed), and the area in which the system is used, that is in low voltage (LV), medium voltage (MV), and high voltage (HV) networks or lines.

In this document, we will use PLCS (Power Line Communication Systems) or PLT (Power Line Communications) to refer to the generic idea of transmitting information over electric lines. The abbreviation PLC (Power Line Carrier) is the technique of using carrier frequencies traditionally used to refer to the communications on narrow bands over the high voltage power lines that the electric transport facilities use for their own telephone network and for telecontrol and teleprotection.

2.2.2 Distribution Line Carrier(DLC)

DLC (Distribution Line Carrier) is used to refer to communications over the Distribution Power Lines (DPL).

Note: They can be narrow band high speed communication on the medium voltage distribution network, or broadband / narrow band communication systems on the low voltage distribution network.

2.2.3 Broadband over Power Line (BPL)

BPL is the abbreviation for Broadband over Power Lines. 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.

2.2.4 PLC Terminal Equipment

Is equipment able to manage a Telecommunication Link through and High Voltage Power Line PLC terminal equipment is mainly used to reliably transmit speech, data and power system protection signals.

2.1.3 Power Line

The component used to transfer electric energy from one point to another in an electric power system.

2.2.5 Coupling System

The Coupling System is the group of devices used to couple the PLC High Frequency Signals to the Power Line. The Coupling System is composed of Line Traps, Coupling Capacitors and Line Matching Unit.

2.2.6 Line Trap

Line Trap is a device presenting high impedance at the carrier frequency band while introducing negligible impedance at the power frequency.

Note: The high impedance limits the power of the carrier signal within the power system. Line Traps are connected in series with transmission lines. In most cases the Line Trap is mounted directly on top of the coupling capacitor. Its characteristics are normalized by the recommendation IEC 60353.

2.2.7 Coupling Capacitor

The Capacitor used for the coupling to the Power Line in a PLC system.

2.2.8 Line Matching Unit

Is the unit which interfaces the EHV/HV side of power line with the PLC equipment.

Note: Usually consist of a box mounted near the Coupling Capacitor. Its characteristics are normalized by the recommendation IEC 60481.

2.2.8.1 Carrier-Frequency Range

The bandwidth available for each specific power line communication technology.

Note: In Europe the typical carrier-frequency range for narrowband HV PLC is 3 kHz to 148.5 kHz or for broadband PLC is 1.6MHz to 30MHz and the manufacturer shall state the range of carrier frequencies within which the recommended values will be maintained. For the USA IEEE PLC standard the frequency range is 45 KHz to 450KHz Parts of the range may be barred by national regulations.

2.2.8.2 Channelling

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

2.2.8.3 Nominal High Frequency Band

The frequency band in which a particular PLC transmitter or receiver is operating within the carrier-frequency range.

2.2.8.4 Effectively transmitted signal-frequency Band

That part of the frequency band used for the transmission of baseband signal.

2.2.9 Nominal Impedance

The nominal impedance is the value of impedance for which an input or output circuit has been designed and for which the prescribed requirements apply.

2.2.10 Modulation Scheme

Refers to the modulation system used to associate or map the informative content or payload signal into a High frequency output Signal through the modulation process (AM-SSB, Spread Spectrum, QAM, OFDM,).

2.2.11 Amplitude Modulation (AM)

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

2.2.11.1 Single Side Band Modulation (AM-SSB)

Is a refinement of amplitude modulation that more efficiently uses electrical power and bandwidth.

2.2.12 Frequency Shift Keying Modulation (FSK)

Is a frequency modulation technique in which coded information is transmitted through discrete frequency changes of a carrier wave.

2.2.13 Phase Shift Keying (PSK)

Is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave).

2.2.14 Quadrature Amplitude Modulation (QAM)

Is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme.

2.2.15 Orthogonal Frequency Division Multiplexing (OFDM)

Is a frequency-division multiplexing (FDM) scheme utilized as a digital multi-carrier modulation method. A large number of closely-spaced orthogonal sub-carriers are used to carry data. The data is divided into several parallel data streams or channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

2.2.16 Multiplexing Techniques

2.2.16.1 Code Division Multiple Access (CDMA)

A multiple access technique in which the various terminals having access to a link are allotted orthogonal signals for transmission, for example sequences of bits with zero or little cross-correlation, such signals being distinguishable even when they share the same frequency bands and the same time intervals.

2.2.16.2 Frequency Division Multiplexing (FDM)

Multiplexing in which several independent signals are allotted separate frequency bands for transmission over a common channel.

2.2.16.3 Time Division Multiplexing (TDM)

Multiplexing in which a separate periodic time interval is allocated to each tributary channel in the common channel.

2.2.16.4 Time Division Multiple Access (TDMA)

Multiplexing in which a separate periodic time interval is allocated to each tributary channel in the common channel.

2.2.17 Peak Envelope Power (PEP)

The (carrier-frequency) peak envelope power of a multiplex signal transmitter is the average power present during one cycle of the carrier-frequency at the highest crest of the modulation envelope (clause 1, paragraph 95, and CCIR Recommendation 326-1, point 1.1).*

It is recommended that in order to determine the peak envelope power the transmitter should be modulated by two sinusoidal voice-frequency signals of equal amplitude, located within the effectively transmitted frequency band. The transmitter is terminated by a resistive load equal to its nominal impedance and the limiter is not in operation.

The amplitude of the modulation signals shall so be chosen as to satisfy the requirements for spurious emissions. The peak envelope power is then considered to be four times the power of one of these signals, selectively measured (CCIR Recommendation 326-1, point 3.1.3.1).

2.2.18 Peak Average Power Ratio (PAPR)

In a multi-carrier modulation is the power of the transmitted signal, when the signals of all sub-carriers are added constructively.

2.2.18.1 PLC Nominal Output Power

The nominal output power of a PLC terminal is the peak envelope power, PEP for which the equipment has been designed, compatible with the requirements for spurious emissions, available at the carrier frequency output across a resistive load equal to the nominal impedance.

2.2.18.2 PLC Mean Output Power

The mean output power of a PLC terminal is the output power averaged over a time sufficiently long compared with the cycle time of the lowest modulation frequency and during which this average power assumes the highest value for which the equipment has been designed.

2.2.19 Spurious Emission

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

Spurious emissions comprise harmonics, parasitic signals and intermodulation products.

2.2.20 Return Loss

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

2.2.21 Tapping Loss

The impedance outside the nominal PLC transmit and receive band shall be such that any other PLC equipment, connected to the same coupling equipment, shall not suffer from a tapping loss higher than specified db figure.

2.2.22 Signal Interface

2.2.22.1 Analogue Interface

Interface dedicated to the processing of voice analogue signals.

* XII plenary assembly of CCITT, 1970, Volume I.

2.2.22.2 Serial Interface

Interface dedicated to the processing of serial type data signals.

2.2.22.3 Ethernet Interface

Interface dedicated to the processing of data signals in accordance with the recommendation IEEE 802.3(2000).

2.2.23 Attenuation

The 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.

2.2.24 Sensitivity Level

It refers to minimum power level of an HF signal or Sensitivity Level (SL), to be applied at the receiver input in order to sustain the maximum specified data throughput affected by a predefined BER e.g. SL= -60dbm @64kb/s and BER=10⁻⁶.

2.2.25 Background Noise

It refers to the 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.

2.2.26 Narrowband Noise

Refers to a noise process with a narrow bandwidth such as a 50/60 Hz 'hum' from the electricity supply.

2.2.27 White Noise

A purely random noise that has a flat power spectrum. Sometimes it is useful to refer to noise with a flat spectrum and a limited bandwidth also known as **band limited white noise**.

2.2.28 Corona Noise

It is caused by partial discharges on insulators and in air surrounding electrical conductors of overhead Power Lines. Discharges occur on the three different phase conductors at different times. The corona noise level is considerably dependent on weather conditions. It is well known that the effect of the corona noise is particularly strong in foul weather conditions.

2.2.29 Coloured Noise

It is a non-white noise or any wideband noise whose spectrum has a non-flat shape; examples are pink noise, brown noise and autoregressive noise.

2.2.30 Impulsive Noise

Consists of short-duration pulses of random amplitude and random duration.

2.2.31 Transient Noise

Consists of relatively long duration noise pulses.

2.2.32 Signal to Noise Ratio (SNR)

The signal to noise ratio is the difference between the noise level and the reference signal level.

2.2.33 Gross Data Rate

The total data rates that are delivered to the PLC terminal at the other side of the power line.

2.2.34 Throughput

The User data rates that are delivered to the PLC terminal at the other side of the power line (clean of the bit rate necessary for link management).

2.2.35 Bit Error Ratio (BER)

The ratio of the number of bits received inverted to the total number of bits sent

2.2.36 Bit Error Ratio Test (BERT)

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

2.2.37 Anomalies and Defects

Anomaly and defect conditions occurring in the transmission path degrading its performance state e.g. loss of signal, sync loss, alarm indication signal, slip, and loss of frame alignment.

2.2.38 Errored Second (ES)

It is a one-second period in which one or more bits are in error.

2.2.39 Severely Errored Second (SES)

It is a one-second period which has a bit error ratio $\geq 1.10^{-3}$ or during which Loss of Signal (LOS) or Alarm indication signal (AIS) is detected.

2.2.40 Error Free Second (EFS)

All seconds included in the total transmission time without bit error.

2.2.41 Errored Second Ratio (ESR)

The ratio of Errored Second ES to total seconds in available time during a fixed measurement interval

2.2.42 Severely Errored Second Ratio (SESR)

The ratio of Severely Errored Second SES to total seconds in available time during a fixed measurement interval.

2.2.43 Group Delay

The propagation time between two points of a signal which may be ideally represented by two superimposed sinusoidal waves of equal amplitude and slightly different frequencies approaching a common limiting value.

2.2.44 Jitter

The short-term variations of the significant instants of a timing signal from their ideal positions in time (where short-term implies that these variations are of frequency greater than or equal to 10 Hz).

2.2.45 Wander

The long-term variations of the significant instants of a digital signal from their ideal position in time (where long-term implies that these variations are of frequency less than 10 Hz).

2.2.46 Latency

Latency in a packet-switched network refers to the time from the source sending a packet to the destination receiving it. When bidirectional transmission time is considered it is referred to as round-trip representing the one-way latency from source to destination plus the one-way latency from the destination back to the source.

2.2.47 Frame Loss Rate

Ethernet Frame Loss refers to the number of frames that were transmitted successfully from the source but were never received at the destination. It is usually referred to as frame loss rate and is expressed as a percentage of the total frames transmitted.

2.2.48 Forward Error Correction

A system of error control for data transmission wherein the receiving device has the capability to detect and correct any character or code block that contains fewer than a predetermined number of symbols in error.

2.2.49 Frame Check Sequence

An error-detection scheme that uses parity bits generated by polynomial encoding of digital signals, appends those parity bits to the digital signal, and uses decoding algorithms that detect errors in the received digital signal.

2.2.50 Availability

Availability is the ratio of time a system or component is functional to the total time it is required or expected to function. This can be expressed as in terms of average downtime per year or percentage of the time.

2.2.51 Reliability

The term reliability refers to the ability of a system to consistently perform according to its specifications.

2.2.52 Quality Objectives

A subjective rating of telephone communications quality in which listeners judge transmissions by qualifiers, such as excellent, good, fair, poor, or unsatisfactory.

2.2.53 Operating Conditions

Characteristics which may affect performance of a component, device or equipment.

2.2.54 Environment

It refers to the classification of the environment where telecommunication equipments are operated in order to define different classes of constraints and limits for EMC/EMI. Typical environments are for instance Industrial, Commercial, Home Building, etc.

2.2.55 Quality of Service

The term Quality of Service (QoS) refers to telecommunication system resource reservation control mechanisms in order to guarantee a certain level of performance to a data flow i.e. a required bit rate, delay, jitter, packet loss, or BER.

2.2.56 Telecommunication Management Network

TMN (Telecommunications Management Network) refers to a capability of a network to be managed consistently across all network element suppliers. TMN uses the OSI Management Standards as its framework. TMN applies to all telecommunication technologies wired, wireless as well as to private and public networks.

2.2.57 Smart Grid

According to the description given in the Energy Independence and Security Act of 2007 the term “Smart Grid” refers to a modernization of the electricity delivery system so it monitors, protects and automatically optimizes the operation of its interconnected elements, from the central and distributed generator through the high-voltage network and distribution system, to industrial users and building automation systems, to energy storage installations and to end-use consumers and their thermostats, electric vehicles, appliances and other household devices.

WORKING DRAFT

3 Power Line Communication Systems

3.1 Introduction to PLC

3.2 PLC usage

The electrical grids have been relatively steady from the middle of the 20th century until the 1980's when the digital processing techniques began to be of common use.

Since that time, the constant evolution in the telecom electronic and the need for more reliable power network have brought the PLC from single point to point link equipment used mainly for supporting teleprotection service and simple PABX interconnection to extend telephony service to modern networking equipment that can be used in service oriented telecom architectures.

The modern Power Line Carrier System can be integrated into IP communication network interconnecting nodes at Data Link Level as point to point links (on HV and EHV networks) or as part of the network itself (multipoint broadband applications on the MV and LV networks).

In addition, these new architecture provides solution for management, control and monitoring of the equipment (SNMP capabilities mainly) that reduce the cost of commissioning and maintenance.

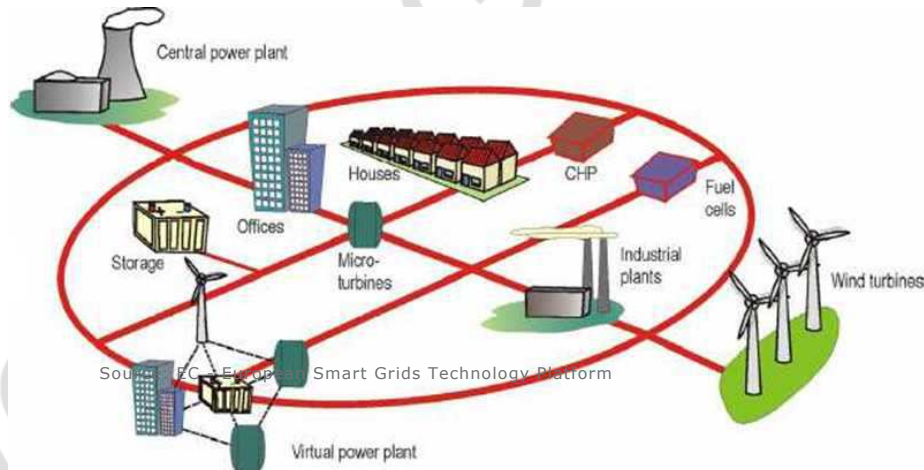


Figure 1 – Smart Grid Vision

Current electricity grids are developing into SMART GRIDS increasing the number of electricity business players' demand for an improvement in terms of communication resources. PLC will play a key role on this arena. An example of the Smart Grid is shown in Figure 1.

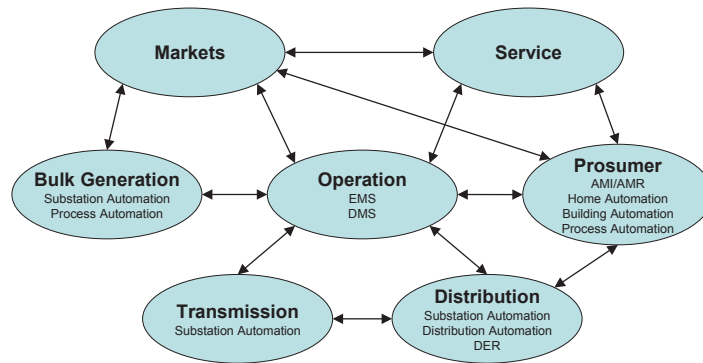


Figure 2 – Smart Grid Players (Source: IEC SMB/SG3 SMART GRID Survey - 2009)

They are ubiquitous and represent a well proven technology since long time exploited in any segment of the electricity grids from EHV/HV/MV to LV providing for very successful applications. An example is shown in Figure 2.

3.3 PLC Telecommunication System

A PLC Telecommunication System consists of one or more PLC links together with other telecommunications such as SDH communications. They can form a network of PLC or part of it. An example is shown in Figure 3.

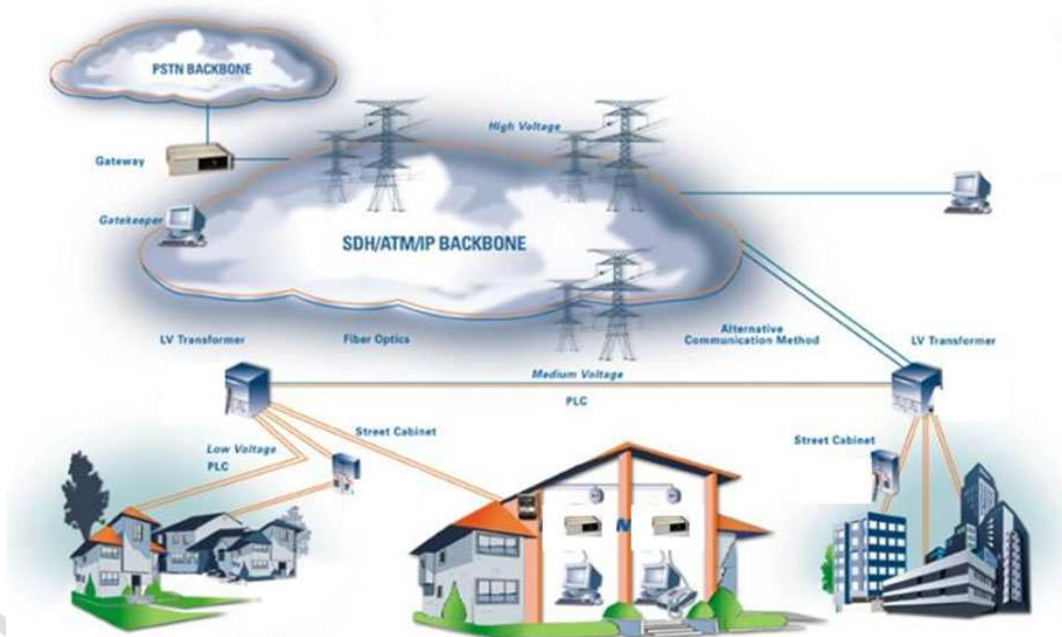


Figure 3 – Complex PLC Telecommunication System

According to the definition each PLC Telecommunication link consists of:

- two PLC terminals,
- two Coupling Systems,
- Electricity Power Line (EHV/HV/MV).

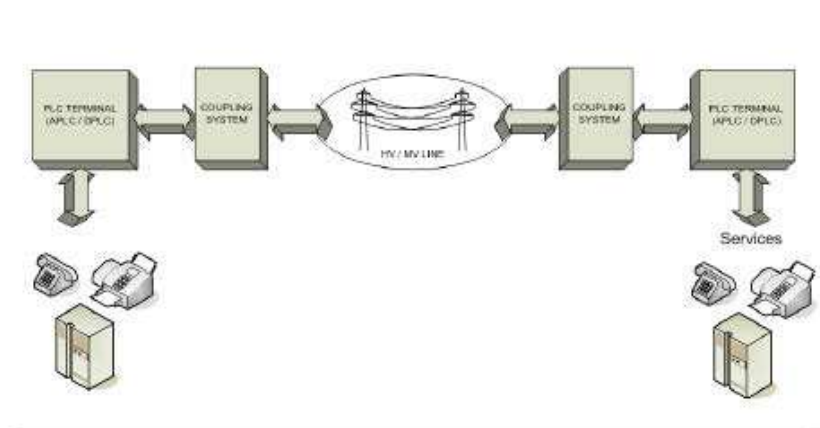


Figure 4 – PLC Telecommunication Link

Terminal equipments can be divided in two categories: Analogue PLC equipments and Digital PLC equipments respectively named APLC and DPLC systems. A general description of such equipments focusing on their main technical features will be provided in the followings paragraphs. An example of this type of link is shown in figure 4.

Detailed aspects concerning the Power Line transmission media and Coupling Systems are described in chapter 5 of this document.

3.4 Analogue and Digital PLC Systems (APLC & DPLC)

3.4.1 APLC Systems

APLC systems, as shown in Figure 5 have been in use from the 1930's and are commonly used by the electricity utilities for their communication (teleprotection, telephone and Data, Fax) mainly on the EHV and 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 20/500 kHz (sometime extended 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 bps per service because of the limited bandwidth and the nature of the modulation.

In the following some of the most used technologies within APLC systems are listed:

- Frequency-Division Multiplex
- Single Sideband modulation
- Channel equalisation
- FSK Modem (Rates $\leq 2400\text{bit/s}$)
- PSK or QPSK Modem (Rates $> 600\text{bit/s}$)

A typical APLC terminal equipment structure is given in the following Figure 5:

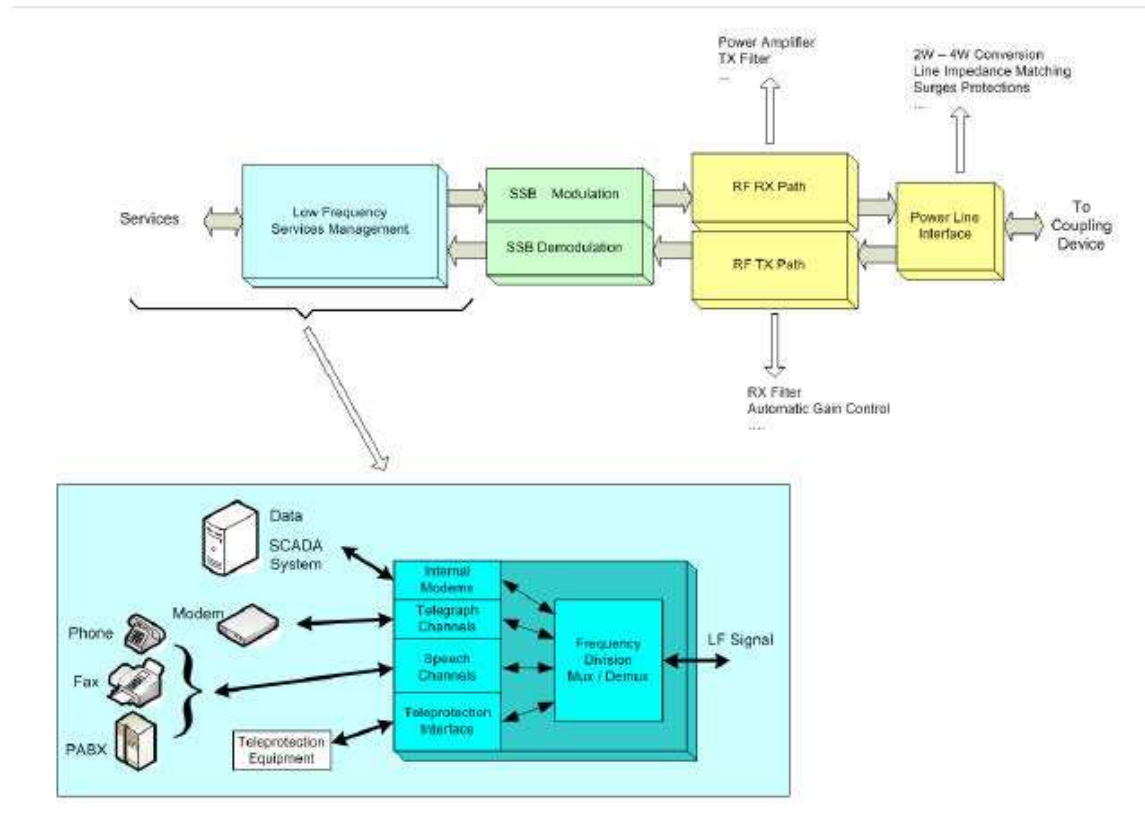


Figure 5 – Typical Structure of APLC Terminal Equipment

3.4.2 DPLC Systems

From the early 1980's, there has been a wide interest in developing PLC system based on digital modulation schemes. The original information can be either data in its original format or digitised signals, such as speech, fax or others.

When more than one service is to be transmitted Digital PLC makes use of Time Division Multiplexing to arrange the different services into a single stream.

The main advantage of Digital PLC links as compared to Analogue PLC links are the following:

1. Enhancing the transmission capacity compared with traditional Analogue PLC links for the same channel bandwidth:
 - more data channels (or data channels running at higher rates)
 - more speech channels using vocoding techniques.
2. Easy integration of the PLC network into a larger digital network (Digital PLC as an embedded component of a digital telecommunications network):
 - nx64 kbps channel as a tributary channel of a digital telecom network
 - Digital data interfaces for lower speed data avoiding intermediate modems
 - Data rate of DPLC allow their use for LAN to LAN connection (typically through an Ethernet access).
 - A native network access provide an easy way to integrate the DPLC links in a Network Management System
3. The use of time-division multiplexing provides greater degrees of flexibility as compared to frequency-division multiplexing.

Digital PLC links can be used in access links or network internal links, for the transmission of speech, data and teleprotection related signals.

In the following some of the most used technologies within DPLC systems are listed:

- Quadrature-Amplitude Modulation
- Multicarrier Modulation (OFDM)
- Trellis Coding
- Echo Cancellation
- Adaptive Equalisation
- Time-Division Multiplexing
- Speech Compression

A typical DPLC terminal equipment structure is given in the following Figure 6:

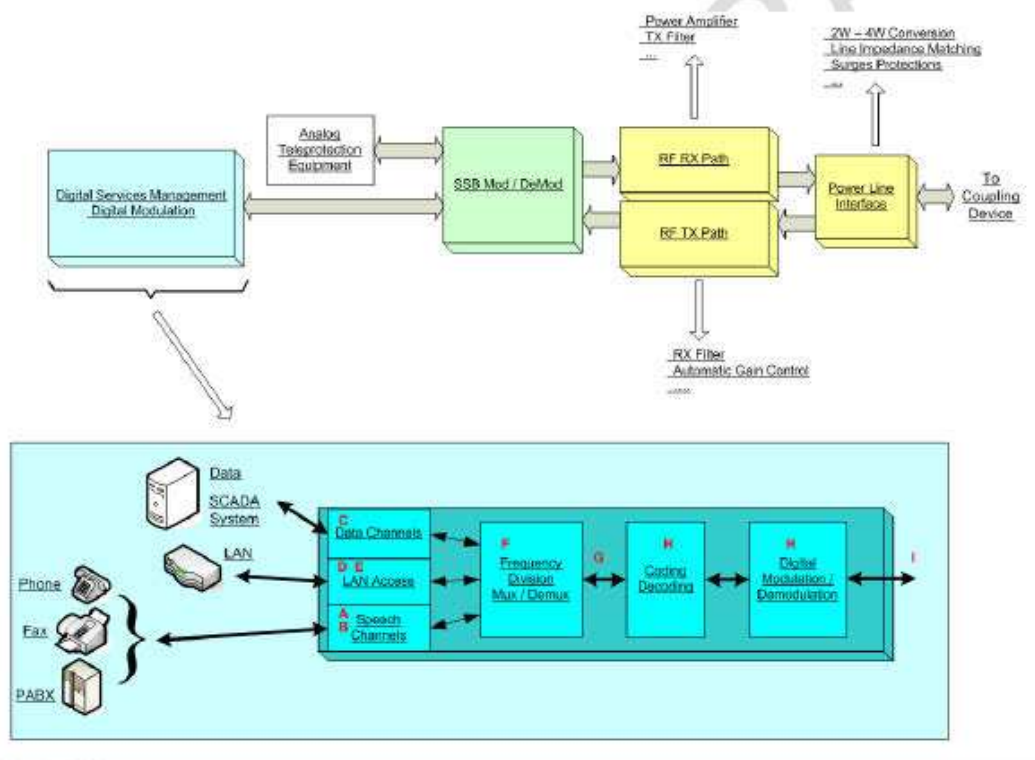


Figure 6 – Typical Structure of a DPLC Terminal Equipment

- A) Speech/Telephone interfaces: 2 wires or 4 wires with E&M signalling, FXO, and FXS
- B) Speech Coding and Management includes speech compression Decompression, Echo cancellation, digital management of signalling and call progress, FAX, etc.
- C) Interfaces for Data Service: V.24/V.28, V11 (X21, X24), G.703, etc.
- D) LAN interface. Mainly Ethernet Interface
- E) TCP or UDP /IP for LAN to LAN communication. Can also be at applicative level (FTP, SNMP.)
- F) Digital Time Division Multiplexer; multiplexes a number of channels into an aggregate serial bit stream.

G) Digital Interface, aggregate multiplexed serial data running at a given Gross Bit Rate. The specific value of this Gross Bit Rate depends on the implementation. For a given implementation it may have different possible values.

H) Signal Converter; converts the digital data into a signal which is suitable for transmission over band limited PLC channels, using a given modulation format. The two main modulation schemes currently used are QAM and OFDM.

Analogue Services on a mixed APLC/DPLC system. Refer to previous figure

I) Band limited signal carrying the digital information of G

It is worth to consider that the teleprotection functionality currently is still managed as analogue service.

Depending from the design it can be an access for an external analogue teleprotection, as well as a teleprotection device integrated into the PLC system.

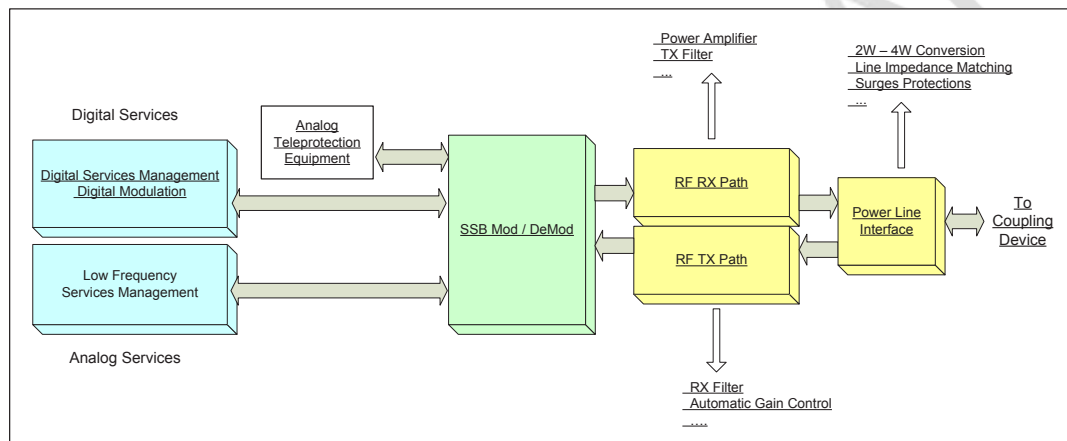


Figure 7 – APLC/DPC Terminal Equipment Structure

PLC systems can also be composed by a mix of APLC/DPLC terminals. The above figure 7 gives an example of such a PLC System.

A typical APLC/DPLC link carrying Telecontrol, Teleprotection and telephony services is shown in Figure 8.

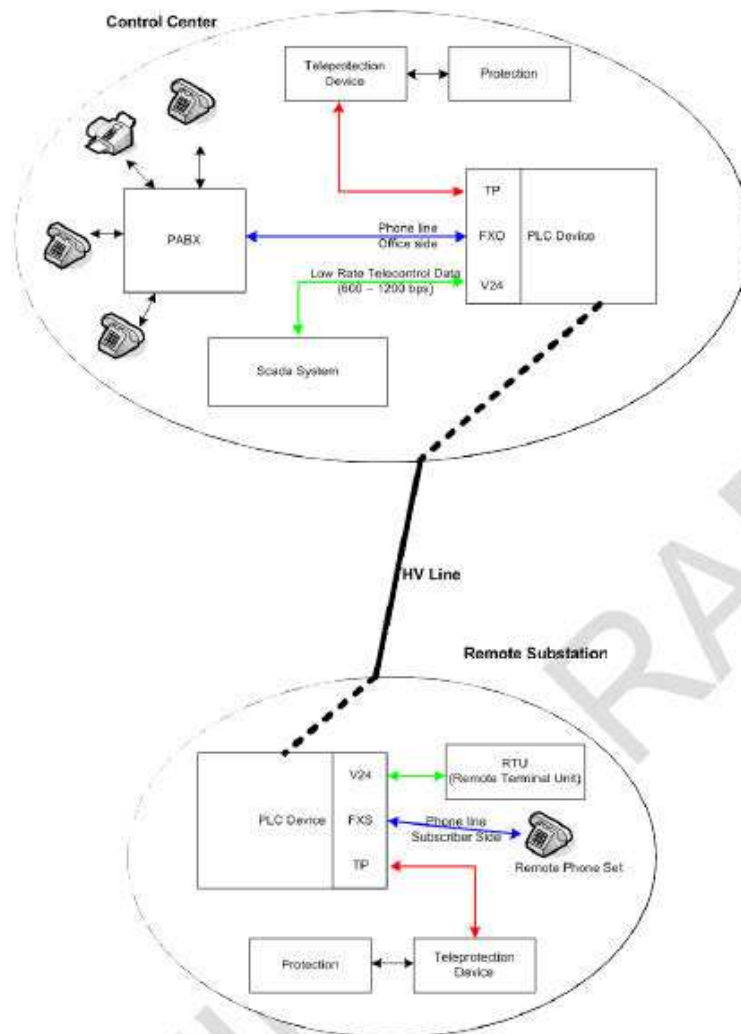


Figure 8 – APLC/DPLC link carrying Telecontrol, Teleprotection and Telephony Services

3.5 PLC Modulation Schemes

3.5.1 Introduction

The modulation technique to be adopted for PLC equipment is a design issue depending on several factors. In the following are summarized the key features and parameters to be considered to perform an evaluation and comparison of the most commonly used modulation techniques in the PLC field.

3.5.2 AM-SSB: See Table1

AM-SSB stands for Amplitude Modulation with Single Sideband. It is used as the modulation method in the Analogue PLC terminal equipments (IEC60495-1993). It can also be used as the final High Frequency modulation in a Digital PLC terminal. The Conventional Amplitude Modulation scheme (with both sidebands and full carrier transmission) was used in the early years of Analogue PLC, but has been replaced by the SSB modulation to provide a better efficiency of the transmission. Actually, the suppression of one of the sidebands and the suppression of the carrier (or the transmission of a reduced amplitude carrier) allow a significant reduction of the transmitted power to achieve the same quality of service with the same signal to noise ratio.

3.5.3 QAM: See Table1

Quadrature Amplitude Modulations are in fact combinations of ASK and PSK modulations. Often a geometric representation of these amplitude factors is used. This geometric representation is called signal space, and each waveform is represented by a dot in the signal space. The spectral efficiency, number of bits/sec that can be transmitted for each Hz of bandwidth, is high; this leads to high transmission rates R_b (bits/sec) in a narrow bandwidth B (Hz).

In a practical implementation the input binary stream to be transmitted is grouped into symbols of n bits. A symbol of n bits is used to address one out of the 2^n points in the signal space, in a process called “symbol mapping”. A simple example for 16-QAM is shown in the figure below:

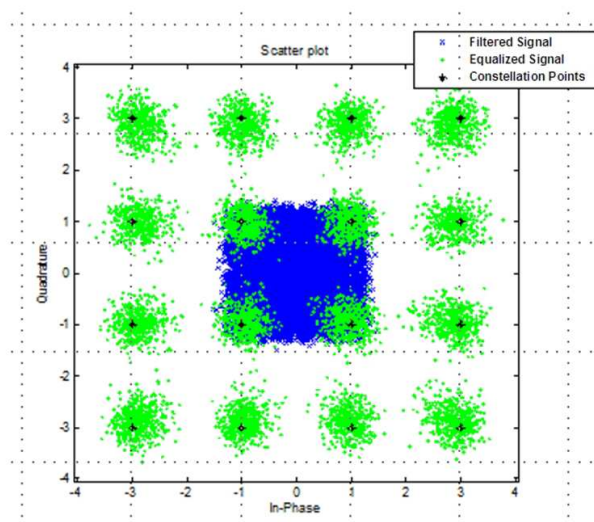


Figure 9 – Signal space for a 16-QAM constellation

It can be shown that the performance of a QAM modem depends basically on the geometry of the signal space. Robustness against noise, for instance, depends on the Euclidean Distance between points. The goal of the receiver is to detect the received points and decode the

corresponding bits, but the received signal will be corrupted by channel noise and other impairments. The effect of noise on the signal space is that the points will not be clearly defined but will be scattered over areas within which the received signal may lie. The receiver then defines a decision area around every theoretical point; if the received signal lies within the decision area the corresponding theoretical point will be decoded as valid. If, because of the noise, the received signal crosses the decision threshold, the wrong point will be decoded and subsequently the wrong information bits will be delivered to the user.

As with most digital transmission systems, there is a trade-off between bandwidth, probability of error and system complexity. For a given transmission rate, the higher the number of points in the signal space (2^n) the narrower the channel bandwidth but the greater the receiver complexity and the higher the probability of error for the same SNR.

3.5.4 OFDM: See Table 1

Known also as multicarrier modulation, it transmits the information by using many carriers, which are located in a limited frequency band.

In a conventional frequency division multiplex system, each of the modulated carriers are separated by filtering, so that there is no spectral overlap of the carriers. This means there is no interference between the carriers, and each carrier can be demodulated individually.

The multicarrier modulation, however, uses spacing between the carriers following special rules, so that the information of each carrier can be detected at the receiver, even if there is a spectral overlap of the carriers.

Data to be transmitted are grouped into blocks of K bits. This number of bits is distributed to the carriers and each carrier is modulated with a group of bits. A 2m-QAM (Quadrature Amplitude Modulation) is used to encode the data into the phase and magnitude of the carrier, where m is the number of the bits assigned to the carrier.

In a simple implementation every carrier is modulated with the same number of bits. This is a sufficient method, if the transmission characteristics are the same for each carrier. Transmitting via the power line, however, means having complex channel characteristics where the amplitude response is not flat and/or the group delay is not constant. By measuring the channel characteristics it is possible to determine the transmission characteristics for each carrier. The distribution of the bits to the carriers is done according to the results of this measurement => a carrier with good conditions for the transmission gets more bits to transmit than a carrier with bad conditions. Using this method a good adaptation to the characteristics of the transmission channel is possible.

The advantages of the multicarrier modulation are good protection against impulsive noise (such as that produced by switching in the power network) and the efficient use of the bandwidth. By splitting the channel into many narrowband subchannels the multicarrier modulation is resistant against frequency response distortion and does not rely on sophisticated equalisation techniques.

The simultaneous processing of many QAM-signals increases the complexity of the implementation and may be considered as a disadvantage of the multicarrier modulation.

3.5.5 Other Modulation Schemes

The other class of modulation scheme that can be used for Digital Power Lines Communication are Spread Spectrum modulation techniques. They are characterized by the use of a bandwidth much greater than the one required by the original signal to transmit. This is generally done by using a long pseudo-random code to spread the data into a large coded stream using a wide bandwidth (Direct Sequence Spread Spectrum). The inherent advantages of these techniques are: