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**Access, Terminals, Transmission and Multiplexing (ATTM);
European Requirements for Reverse Powering
of Remote Access Equipment**

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**may not**", "**need**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

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Introduction

As various Operators consider the deployment of fibre-fed remote nodes that contain xDSL DSLAM equipment, it is necessary to consider the means of powering such remotely located equipment. One such method, known as "reverse power feed", transmits the power from the customer premises to the fibre-fed remote node using the distribution-side copper network. The present document defines a reverse power feed transmission standard which allows Operators to source suitably compliant equipment for inclusion in their networks. The reverse power feed methodology can be used to power a remote node hosting any metallic transmission system (e.g. FAST [i.6], VDSL2 [i.7], etc.).

1 Scope

The present document defines architectures for reverse powering of remote network nodes from multiple CPEs. The architectures describe how to combine reverse power feed with POTS and data transmission. Options for combining reverse powering with battery backup are also described. The present document identifies requirements for POTS signalling translation when operated over reverse power feed. Start-up protocols are defined that will ensure safe connection of reverse powered systems. Management requirements for reverse power feed and power combining within the remote network node are specified.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at <http://docbox.etsi.org/Reference>.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

- [1] ETSI ES 202 971: "Access and Terminals (AT); Public Switched Telephone Network (PSTN); Harmonized specification of physical and electrical characteristics of a 2-wire analogue interface for short line interface".
- [2] CENELEC EN 60950-1: "Information Technology Equipment - Safety, Part 1: General requirements (IEC 60950-1:2005 + Cor.:2006 + A1:2009, modified)".
- [3] ETSI ES 203 021: "Access and Terminals (AT); Harmonized basic attachment requirements for Terminals for connection to analogue interfaces of the Telephone Networks; Update of the technical contents of TBR 021, EN 301 437, TBR 015, TBR 017".
- [4] Recommendation ITU-T G.994.1: "Handshake procedures for digital subscriber line transceivers".

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] IEEE 802.3: "LAN/MAN CSMA/CD (Ethernet) Access Method".

NOTE: Available at <http://standards.ieee.org/getieee802/802.3.html>.

- [i.2] NICC ND 1645 (V1.1.2) (2011-06): "NGA Telephony; Architecture and requirements".

NOTE: Available at <http://www.niccstandards.org.uk/files/current/ND1645v1.1.2.pdf?type=pdf>.

- [i.3] ETSI TS 101 952-1: "Access network xDSL splitters for European deployment; Part 1: generic specification of xDSL over POTS splitters".
- [i.4] Recommendation ITU-T G.993.2: "Very high speed digital subscriber line transceivers 2 (VDSL2)".
- [i.5] Recommendation ITU-T G.993.2 Amendment 5: "Short reach VDSL2 with reduced power and enhanced data rate".

- [i.6] Recommendation ITU-T G.9700 (04/14): "Fast access to subscriber terminals (FAST) - Power spectral density specification".
- [i.7] ETSI TS 101 271 (V1.2.1): "Access, Terminals, Transmission and Multiplexing (ATTM); Access transmission systems on metallic access cables; Very High Speed digital subscriber line system (VDSL2) [Recommendation ITU-T G.993.2 modified]".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

power splitter: device that performs a frequency splitting/combining function between the services being carried (which can include POTS and xDSL based services) and the injected DC electrical power

service splitter: low pass filter that separates baseband POTS from xDSL frequencies

NOTE: The relevant specifications for the service splitter can be found in ETSI TS 101 952-1 [i.3].

3.2 Symbols

For the purposes of the present document, the following symbols apply:

R	2-wire analogue presented interface
U-R	Reference point at CPE containing both DC power and service data
U-R2	Reference point at CPE containing the filtered service data
U-R2P	Reference point at CPE containing the injected DC power
U-R2S	Reference point at CPE containing the baseband POTS and the converted POTS signalling
U-O	Reference point at DPU containing both DC power and service data
U-O2	Reference point at DPU containing the filtered service data
U-O2O	Reference point at DPU containing the baseband POTS and the converted POTS signalling
U-O2P	Reference point at DPU containing the extracted DC power

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

4PPoE	4-Pair Power over Ethernet
ACT	Active
ATA	Analogue Telephone Adapter
BAT	Battery
CBSU	Communications based Start-Up protocol
CO	Central Office
CP	Customer Premises
CPE	Customer Premises Equipment
CPE ME	CPE's Management Entity
DBPSK	Differential Binary Phase Shift Keying
DC	Direct Current
DN	Distribution Network
DP	Distribution Point
DPU	Distribution Point Unit
DPU ME	DPU's Management Entity
DSL	Digital Subscriber Line
FTTdp	Fibre To The distribution point
FTTP	Fibre To The Premises

FTU FAST Transceiver Unit

NOTE: See Recommendation ITU-T G.9700 [i.6].

FTU-O	FTU at the DPU
FTU-R	FTU at the remote site
GPON	Gigabit Passive Optical Network
HON	Higher Order Node
LPF	Low Pass Filter
LR	Long Range
ME	Management Entity
NMS	Network Management System
NT	Network Termination
NTE	Network Termination Equipment
NTU	Network Terminating Unit
OAM	Operations And Maintenance
OLT	Optical Line Termination
ONU	Optical Network Unit
PD	Powered Device
PDU	Power Distribution Unit
PE	Power Extraction
PHY	Physical (layer)
PME-C	CPE's Power Management Entity
PME-D	DPU's Power Management Entity
PMT	Power Management Transceiver
PoDL	Power over Data Line
POTS	Plain Old Telephony Service
PS	Power Splitter
PSE	Power Sourcing Equipment
PSU	Power Supply Unit/Combiner
PWD	PoWereD
RDY	Ready
RFT	Remote Feed Telecommunication
RPCE	Reverse Power Control Entity
RPD	Remote Powered Device
RPF	Reverse Power Feed
RPFA-DRP	Reverse Power Feed Architecture - Derived POTS
RPFA-DRPSW	Reverse Power Feed Architecture - Derived POTS Sharing in-premises Wiring
RPFA-EXP	Reverse Power Feed Architecture - Exchange POTS
RPFA-EXPSW	Reverse Power Feed Architecture - Exchange POTS Sharing in-premises Wiring
RPFA-NOP	Reverse Power Feed Architecture - No POTS
SELV	Safety Extra Low Voltage
SG	Service Gateway
SR	Short Range
SS	Service Splitter
SU	Service Unit
TNV	Telecommunication Network Voltage
VA	Volt Ampere
VDSL	Very high speed Digital Subscriber Line
VoIP	Voice over Internet Protocol

VTU VDSL2 Transceiver Unit

NOTE: See Recommendation ITU-T G.993.2 [i.4].

VTU-O	VTU at the ONU
VTU-R	VTU at the remote site
xDSL	Unspecified DSL variant
xTU-O	FTU-O or VTU-O
xTU-R	FTU-R or VTU-R

4 Introduction to Reverse Power Feed

4.1 Introduction

The basic architecture of a fibre-fed remote node with reverse power feed is shown below in Figure 1.

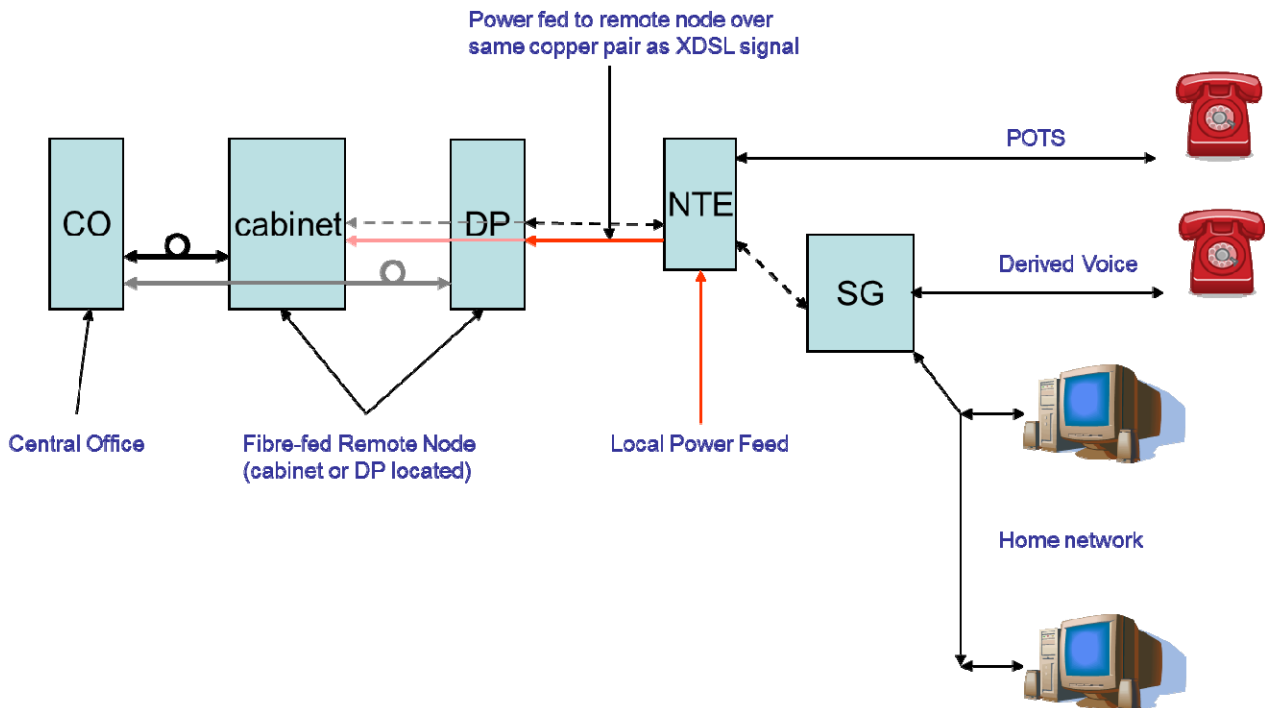


Figure 1: Generic Fibre-fed Remote Node Architecture with reverse power feed

Figure 1 shows power being injected at the NTE from a local power source (located within the home and/or building) which traverses the local loop to power a fibre-fed remote node which can be located at either the distribution point (DP) or cabinet using the same copper pair cable that is used to transmit the xDSL to/from the home/fibre-fed remote node. A metallic POTS service is shown at the NTE. Voice services can also be implemented as a derived service from the service gateway (SG).

An issue with regards to reverse powered fibre-fed nodes is that of who or what is responsible for the powering of common circuitry contained within the node. It is easy to envisage that an individual user should be responsible for the powering of the remote line terminating/driver electronics corresponding to his particular circuit. However, it is not so easy to determine who or what is responsible for powering of say the ONU that terminates the fibre link.

There may be occasions where only a single user is providing power to the remote node but this may not be sufficient to power all of the remote node electronics for proper operation. Also, there may be occasions where say a GPON feed requests a response from the ONU (for ranging or management purposes) when no users are currently connected and providing electrical power.

It is recognized that one single (i.e. generic) specification cannot consider all possible architectural variants, therefore the present document has been organized as a series of architecture options and equipment shall adhere to one or more of these options.

5 Reverse Power Feed Architecture

5.1 Introduction

There shall be compatibility with other architectures such as forwards powering of remote equipment from the CO or the provision of local mains powering.

Service Providers may provide options for power back-up capability at the remote node and/or the customer premises. It shall be possible to combine these power-feed options, for example when there is not enough power to operate a remote node by reverse powering from a single customer alone. Under such circumstances it shall be possible to augment this power with forwards power from the CO or local mains derived power.

Reverse powering shall have a power splitter (located at the customer premises and another at the remote node) to enable power to be inserted at the customer end of a link and extracted at the remote node. The power splitter performs a frequency splitting and combining function between the services being carried (which can include POTS and xDSL based services) and the injected DC electrical power. The power splitter shall have an upper frequency limit for powering of 300 Hz. In the case of POTS services being carried over the same metallic loop, and considering the emergence of wideband POTS services for high quality voice, the cut-over frequency of the reverse power feed power splitter should be in the order of 10 Hz or less.

Within the remote node, if it operates with multiple power-fed lines then there shall be a power extraction and combiner unit. The purpose of this unit is to combine the multiple power feed input to produce a single power source output. A fair power-sharing algorithm shall exist where the power load is fairly shared amongst the input power sources.

The technical specifications in the present document shall apply to each architecture described below as one of the five options shown in Table 1.

Table 1: Architecture Options for Reverse Power Feed

Option	Name	Description
1	RPFA-NOP	Reverse Power Feed Architecture - No POTS
2	RPFA-EXP	Reverse Power Feed Architecture - Exchange POTS
3	RPFA-EXPSW	Reverse Power Feed Architecture - Exchange POTS Sharing in-premises Wiring
4	RPFA-DRP	Reverse Power Feed Architecture - Derived POTS
5	RPFA-DRPSW	Reverse Power Feed Architecture - Derived POTS Sharing in-premises Wiring

5.2 Reverse Power Feed and POTS Co-Existence

5.2.1 Background

Table 1, option 2 to option 5 involve reverse power feed co-existing with POTS - whether this is exchange based POTS (RPFA-EXP, RPFA-EXPSW) or derived POTS (RPFA-DRP, RPFA-DRPSW).

When a POTS service is present on the same wires as reverse power feed (option 2, option 3 and option 5) the POTS DC signalling/low frequency signalling will be translated so that it uses another part of the baseband spectrum, but the basic analogue voice signal remains essentially untouched. At the CPE, the signalling is restored and POTS is presented as normal.

When POTS is provided by derived voice service (option 4 and option 5), low power (L2) modes may be used to provide the voice service even when the entire payload is not required by other services. The CPE presentation may be either an analogue presentation via an ATA or directly to a VoIP handset.

In order to achieve co-existence between reverse power feed and POTS various adaptors are required as described in clause 5.2.2 for use in the reverse power feed reference models.

5.2.2 POTS Adapters

The following three different types of POTS adaptor are specified for use in the reverse power feed reference models:

- 1) POTS Adapter - E (POTSA-E)
- 2) POTS Adapter - C (POTSA-C)
- 3) POTS Adapter - D (POTSA-D)

Where reverse power feed and POTS signals traverse the same copper wires a signalling system shall be implemented to allow the signalling at the POTS interface based on off-hook/on-hook DC impedance, and in those jurisdictions requiring it, line reversal for Calling Number ID alerting to be communicated across the copper pair from the DPU to the POTS terminals. This functionality can be provided by the various POTS adaptors described below.

5.2.2.1 POTS Adapter - E (POTSA-E)

POTS Adapter - E is the single adapter located at the DPU and this adapter shall perform the following functions:

- 1) Translate the downstream DC and low frequency POTS signalling into an in-band or out-of-band signalling system.
- 2) Translate the signals from the upstream in-band or out-of-band signalling system into DC and low frequency POTS signalling.

POTSA-E may provide a relay by-pass when un-powered (for life-line operation) or when signalled to provide direct access to the exchange to allow operations such as line-test to be performed.

5.2.2.2 POTS Adapter - C (POTSA-C)

POTS Adapter - C is the single adapter located at the NT module and this adapter shall perform the following functions:

- 1) Translate the upstream DC and low frequency POTS signalling from the POTS Terminal into an in-band or out-of-band signalling system.
- 2) Translate the downstream in-band or out-of-band signalling system into POTS signalling towards the POTS Terminal.
- 3) Provide sufficient current limit and DC voltage to supply one or more phone devices.
- 4) Provide a pre-defined rate of change of current increase when a phone device goes off-hook to allow for the detection of phone devices going off-hook that do not have the correct POTS adapter fitted.

POTSA-C may provide relay by-pass when un-powered (for lifeline operation) or when signalled to provide direct access to the exchange to allow operations such as line-tests to be performed.

5.2.2.3 POTS Adapter - D (POTSA-D)

POTS Adapter - D is the adapter that can be attached to every phone device connected to the in-premises wiring on the home network. This adapter operates in the presence of reverse powering. This adapter shall perform the following function:

- 1) Translate the signals from the upstream DC and low frequency POTS signalling from the POTS Terminal into an in-band or out-of-band signalling system.
- 2) Translate the signals from the downstream in-band or out-of-band signalling system into POTS signalling towards the POTS Terminal.
- 3) Provide sufficient current limit and DC voltage to supply a single phone device.
- 4) Provide a pre-defined rate of change of current increase when a phone device goes off-hook to allow for the detection of phone devices going off-hook that do not have the correct POTS adapter fitted.

5.3 Reverse Power Feed Architecture without POTS on the same pair (RPFA-NOP)

The functional reference model of the reverse power feed architecture without POTS on the same pair (RPFA-NOP) is shown in Figure 2. In this option, the reference model illustrates the RPF architecture with the broadband service only and no underlying narrowband service, neither exchange-based POTS nor derived POTS.

The xTU-O is located inside the Distribution Point Unit (DPU) at the network side of the wire pair (U-O reference point). The xTU-R is located inside the Network termination (NT) at the customer premises side of the wire pair (U-R reference point). Each DPU is located at a distribution point and can contain one or more xTU-O transceivers (xTU-O-I, $I = 1 \dots N$), with each transceiver connected to an NT.

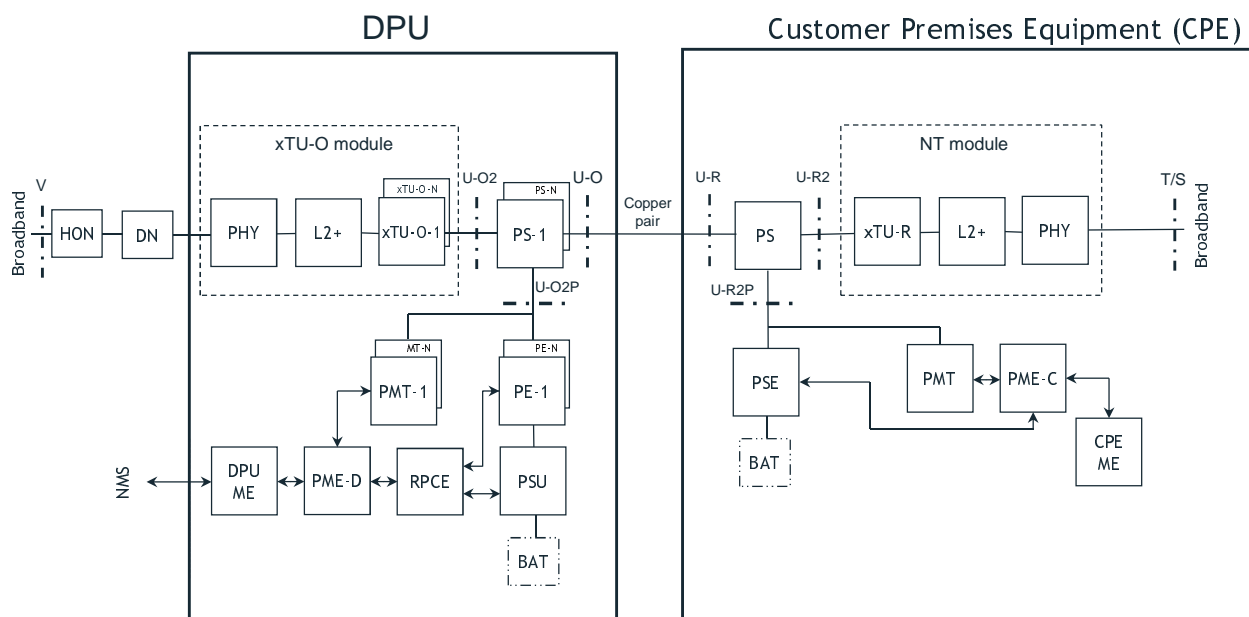
At the backhaul link termination, the PHY blocks represent the physical layer of the xTU-O module towards the access network and of the NT towards the customer premises (CP). These blocks are shown for completeness of the data flow but are out of scope of the present document. The L2+ blocks represent the Layer 2 and above functionalities contained in the xTU-O module and the NT. These blocks are shown for completeness of the data flow but are out of scope of the present document.

The traffic from all DPUs is aggregated by a backhaul transmission system operating over the Distribution Network (DN) and Higher Order Node (HON) up to the V reference point. The type of transmission system is out of scope of the present document.

The management of a DPU is performed by the network management system (NMS), passing management information to the DPU's management entity (DPU ME) over a management communications channel that is provided over the backhaul transmission system. The details of the management communications channel and most of the management functionality required for the DPU are out of scope of the present document.

As there is a need for management transactions between the DPU and the CPE for controlling the start-up of reverse powering to the DPU when mains power is applied to the CPE and for monitoring powering in normal operations, power management transceivers are connected to the copper drop in the DPU (PMT-I, $I = 1 \dots N$) and the customer premises (PMT) to support a management protocol. The management information is exchanged between the PMT-I and DPU ME through the power management entity PME-D. At the customer premises, the information flow takes place between the PMT and CPE ME through the power management entity PME-C.

The power is inserted on the line (i.e. copper pair) by the Power Source Equipment (PSE) located in the customer premises and extracted from the line by the Power Extractor (PE-I, $I = 1 \dots N$) located in the DPU. Power is extracted from each active port and combined in the Power Supply Unit (PSU) and coordinated over all lines by the Reverse Power Control Entity (RPCE). The PE and PSU are separated from the broadband signal on the line (at reference point U-O and U-R) by a power splitter (PS). Reverse power battery backup at the PDU and customer premises is illustrated in block BAT.



Fi+

Figure 2: RPFA-NOP Reference Model

Table 2: RPFA-NOP Reference Points

Reference Point	Broadband Signals	Reverse Power Feeding	Analogue Voice Signals	Out of band POTS Signalling
U-O2	Yes	No	No	No
U-O2P	No	Yes	No	No
U-O /U-R	Yes	Yes	No	No
U-R2P	No	Yes	No	No
U-R2	Yes	No	No	No

5.4 Reverse Power Feed Architecture with Baseband POTS from the Exchange (RPFA-EXP)

The functional reference model of the reverse power feed architecture with baseband POTS from the exchange (RPFA-EXP) is shown in Figure 3 and Figure 4.

This option includes two different variants. Figure 3 illustrates the case where a dedicated POTS port is used to connect a single POTS device while the remaining customer premises equipment (CPE (power splitter (PS), service splitter (SS), power source equipment (PSE) and NT module) may be located anywhere on the in-premises wiring. The single POTS adapter (POTSA-C) is also located at the same place as the rest of the CPE.

The second variant shown in Figure 4, illustrates the case where the CPE (power splitter (PS), service splitter (SS), power insertion (PSE) and NT module) and the POTSA-C adapter are installed at the master-socket location while multiple POTS devices are connected to the existed in-premises wiring.

In both cases it is expected that baseband voice is transmitted between the DPU and the customer premises and the function of the POTS adapter in the DPU (POTSA-E) and POTS adapter in the customer premises (POTSA-C) is concerned with the POTS signalling translation. Also in both cases, there is no requirement for an individual POTSA-D to be attached to each individual phone device within the customer premises.

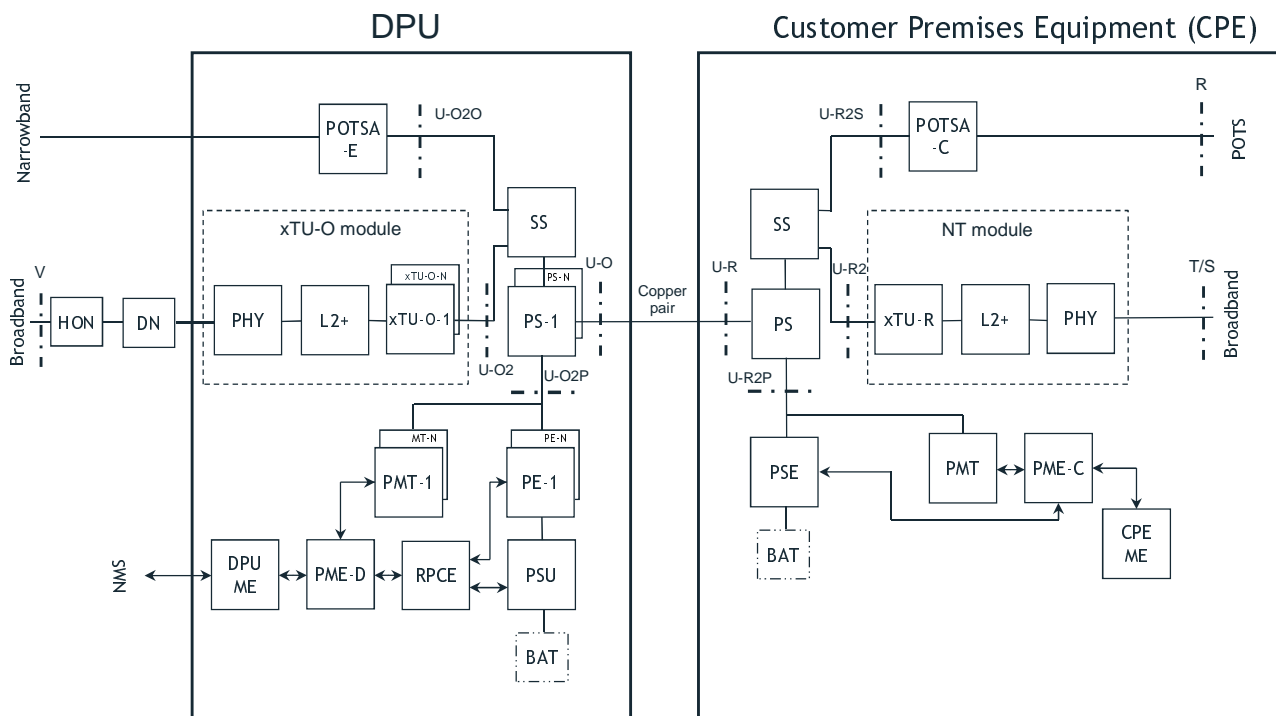


Figure 3: RPFA-EXP Reference Model

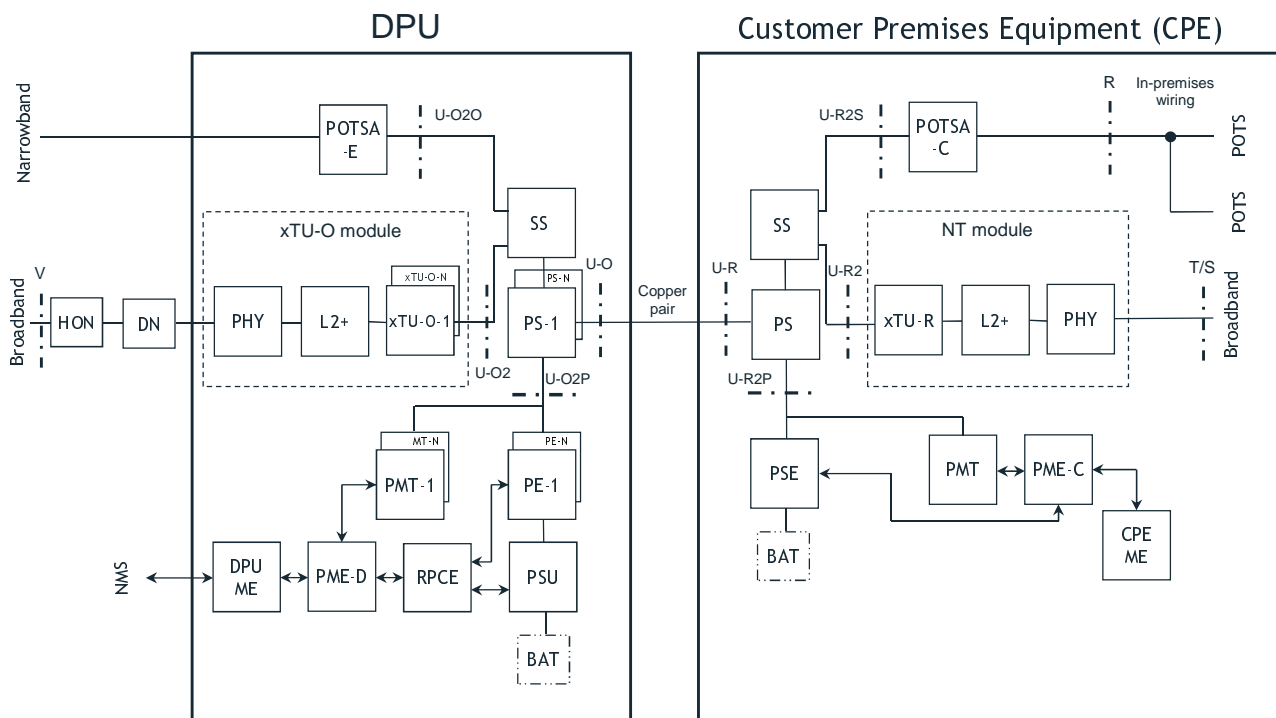


Figure 4: RPFA-EXP Reference Model with multiple POTS distributed over In-Premises Wiring

Table 3: RPFA-EXP Reference Points

Reference Point	Broadband Signals	Reverse Power Feed	Analog Voice Signals	Out of band POTS Signalling
U-O2	Yes	No	No	No
U-O2O	No	No	Yes	Yes
U-O2P	No	Yes	No	No
U-O /U-R	Yes	Yes	Yes	Yes
U-R2P	No	Yes	No	No
U-R2S	No	Yes (see note)	Yes	Yes
U-R2	Yes	No	No	No

NOTE: The POTSA-C adapter needs power for signalling conversion and will usually be locally powered if it is collocated with the PSE, but it needs access to RPF to detect its presence and may optionally be powered by RPF.

5.5 Reverse Power Feed Architecture with Baseband POTS from the Exchange Sharing the in-premises Wiring (RPFA-EXPSW)

The functional reference model of the reverse power feed architecture with baseband POTS from the exchange sharing the in-premises wiring (RPFA-EXPSW) is shown in Figure 5. In this application, each POTS device connected to the in-premises network is connected to an individual POTSA-D which provides POTS signalling translation. This reference model is used when a traditional voice solution is utilized but an analogue POTS presentation is required over the in-premises wiring including all extension wiring.

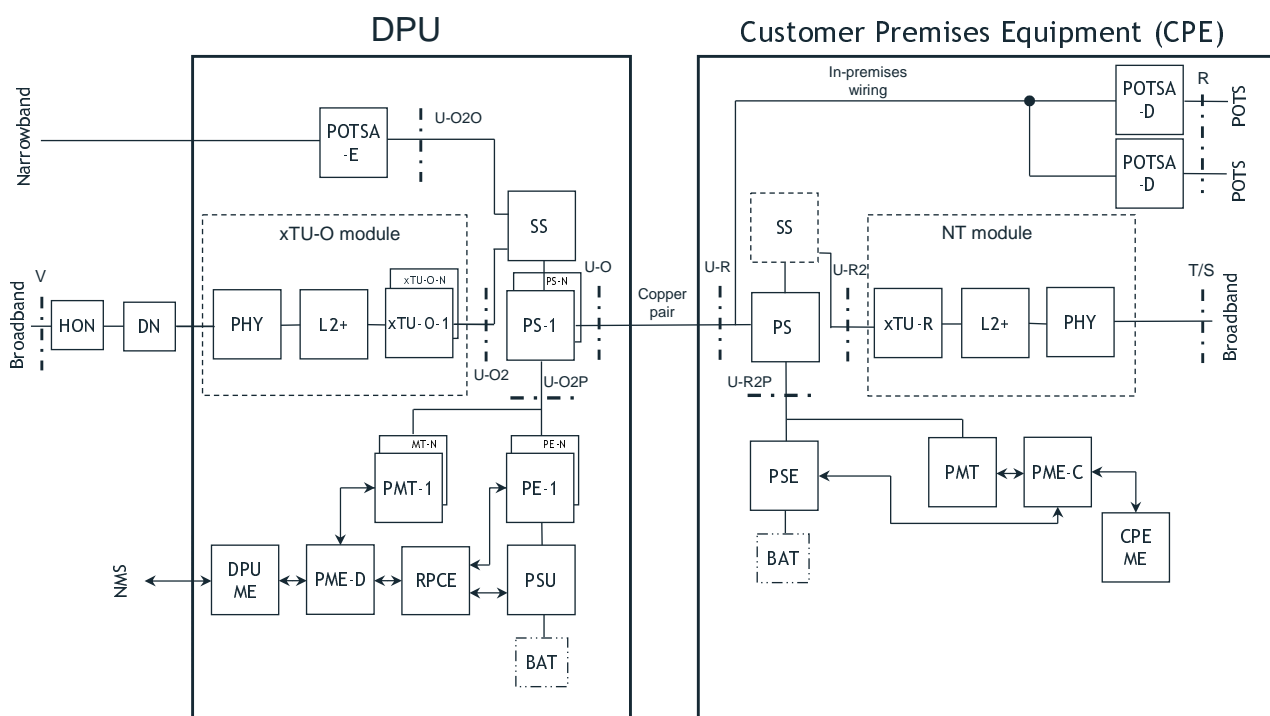


Figure 5: RPFA-EXPSW Reference Model

Table 4: RPFA-EXPSW Reference Points

Reference Point	Broadband Signals	Reverse Power Feed	Analog Voice Signals	Out of band POTS Signalling
U-O2	Yes	No	No	No
U-O2O	No	No	Yes	Yes
U-O2P	No	Yes	No	No
U-O /U-R	Yes	Yes (see note)	Yes	Yes
U-R2P	No	Yes	No	No
U-R2	Yes	No	No	No

NOTE: RPF provides power for signalling conversion.

It should be noted that the use cases for RPFA-EXP and RPFA-EXPSW may be combined so that POTSA-C and POTSA-D may both be present.

5.6 Reverse Power Feed Architecture with Derived POTS (RPFA-DRP)

The functional reference model of the reverse power feed architecture with derived POTS (RPFA-DRP) is shown in Figure 6 and Figure 7.

Similar to the RPFA-EXP architecture defined in clause 5.4, this option includes two different variants. Figure 6 illustrates the case when the CPE (power splitter (PS), power source equipment (PSE) and NT module) may be located anywhere on the in-premises wiring while a single analogue POTS interface is available on the dedicated line (i.e. POTS service uses one wire pair while the DSL service uses another wire pair). The second variant is shown in Figure 7 illustrates the case where the CPE is installed at the master-socket location and multiple POTS interfaces are distributed over the in-premises wiring. In this architecture, an analogue presentation of a VoIP service is provided at the CPE via an Analogue Terminal Adapter (ATA). Other application models are possible, where the ATA is connected to a cordless phone or a wireless phone device. The ATA can be integrated with the router in the same physical box NT1, or with the NT module. Such a scheme is inherently simpler than the POTS solutions described in clause 5.4 because there is no requirement for service splitter and POTS adapters. However, this solution proves to be the most difficult to arrange for POTS failover during power outages at the CPE. Such a solution is dependent upon local battery power at the CPE being able to also power the remote node (albeit the remote node may be operating in a low-power mode).

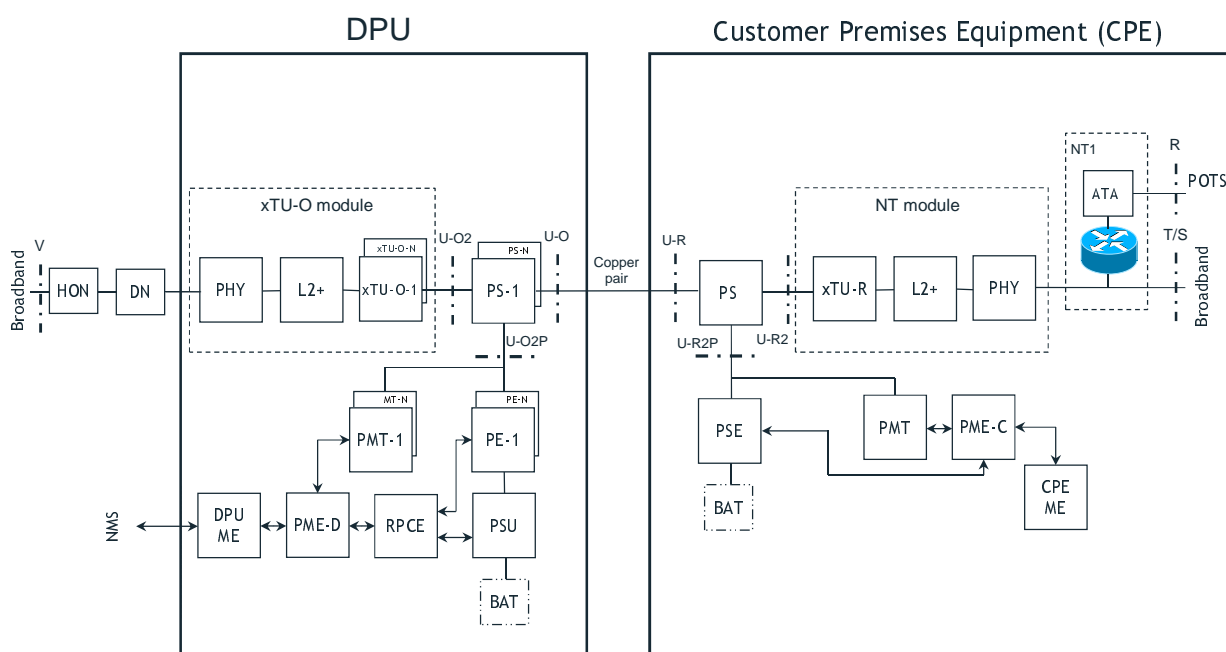


Figure 6: RPFA-DRP Reference Model with derived POTS and a single POTS port

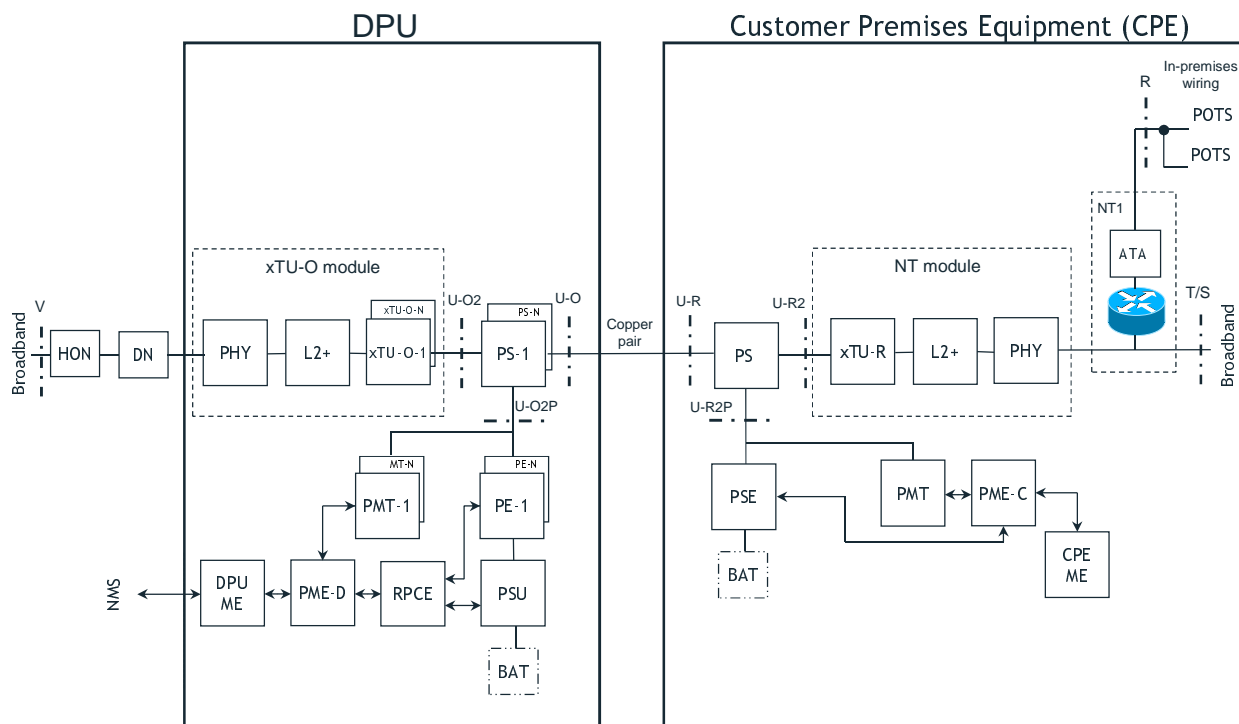


Figure 7: RPFA-DRP Reference Model with derived POTS distributed over In-Premises Wiring

Table 5: RPFA-DRP Reference Points

Reference Point	Broadband Signals	Reverse Power Feed	Analogue Voice Signals
U-O2	Yes	No	No
U-O2P	No	Yes	No
U-O/U-R	Yes	Yes	No
U-R2P	No	Yes	No
U-R2	Yes	No	No

5.7 Reverse Power Feed Architecture with Derived POTS Sharing the in-premises Wiring (RPFA-DRPSW)

The functional reference model of the reverse power feed architecture with derived POTS sharing the in-premises wiring (RPFA-DRPSW) is shown in Figure 8. In this application, POTS is carried as a derived voice stream within the broadband data. The voice stream is extracted via a router and then presented to a POTS adapter via an ATA. The voiceband POTS signal is injected onto the in-premises wiring via the voice-frequency path through the service splitter (SS). Because there is DC powering present on the in-premises wiring, it is not possible to include DC POTS signalling and therefore a POTSA-D is required for every POTS device that is not collocated with the NT module.

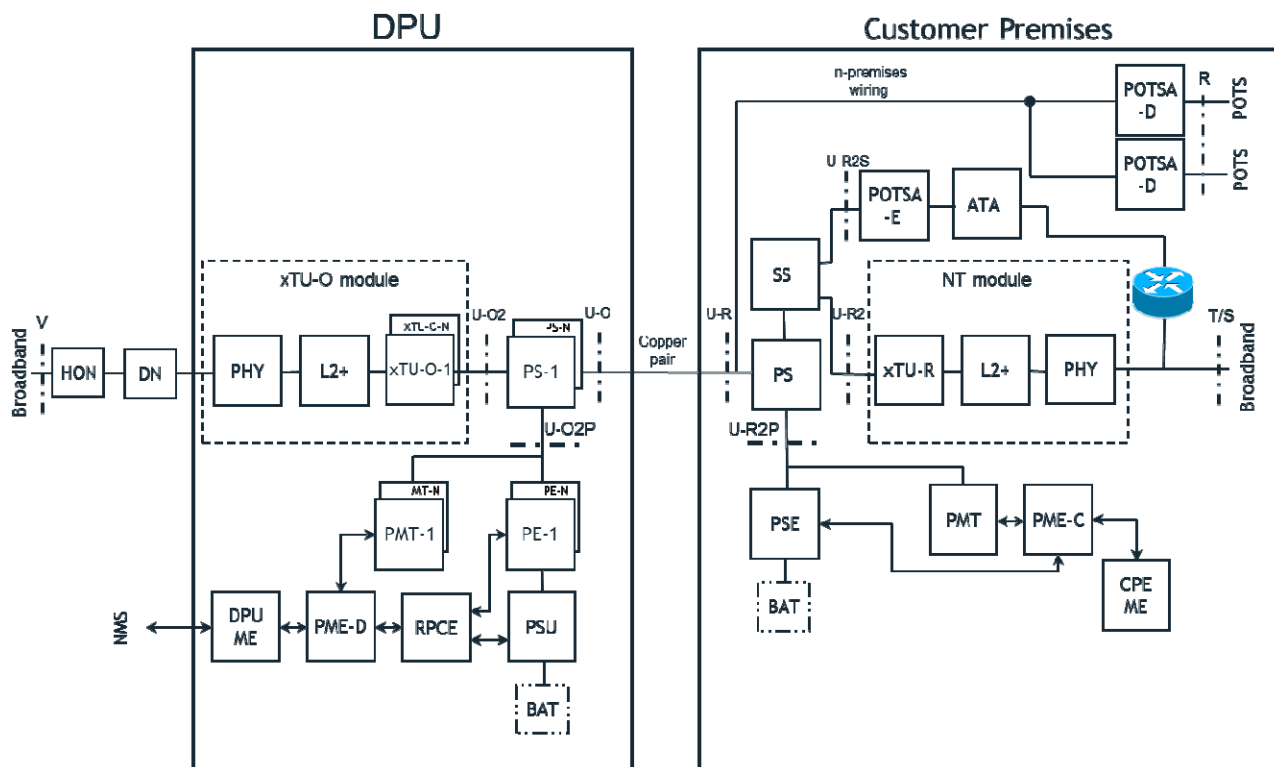


Figure 8: RPFA-DRPSW Reference Model

Table 6: RPFA-DRPSW Reference Points

Reference Point	Broadband Signals	Reverse Power Feed	Analogue Voice Signals	Out Of Band POTS Signalling
U-O2	Yes	No	No	No
U-O2P	No	Yes	No	No
U-O /U-R	Yes	Yes (see note 1)	Yes	Yes
U-R2P	No	Yes	No	No
U-R2S	No	Yes (see note 2)	Yes	Yes
U-R2	Yes	No	No	No

NOTE 1: RPF provides power for signalling conversion.
 NOTE 2: The POTSA-E adapter needs power for signalling conversion and is usually locally powered if it is collocated with the PSE, but it needs access to RPF to detect its presence and may optionally be powered by RPF.

It should be noted that the use cases for RPFA-DRP and RPFA-EXPSW may be combined so that a POTS port and POTSA-D may both be present.

6 Reverse Power Feed Start-Up Protocol

6.1 Introduction

As shown in clause 5, Reverse Power Feed can be applied either in conjunction with a baseband POTS service from a CO, or with a derived POTS service, or without any POTS service.

In any scenario, a procedure shall be followed to guarantee proper interaction between the elements of the RPF system (DPU - PSE - POTS adapters in the in-premises network). The procedure shall allow a proper start-up of RPF, and should cover all further states of the RPF system (operation, shut down, error conditions). There are several possibilities for implementing this, including a communications based start-up protocol and a metallic detection based start-up protocol. A communications based start-up protocol is specified below.

NOTE: An example of a metallic detection based start-up protocol can be found in IEEE 802.3 [i.1].

If reverse powering is present on the in-premises network it is important to detect directly connected off-hook phones and prevent them from becoming a safety hazard. If a directly connected off hook telephone is detected, a back off mechanism shall be initiated for the reverse powering.

6.2 Communications-based Start-up (CBSU) Protocol

Exchanges of signalling messages supporting the CBSU protocol are defined in Table 7.

Table 7: Signalling messages for CBSU protocol

Message	From > To	Use
REQ (Request)	PSE > DPU	PSE requests DPU to prepare for RPF
RDY (Ready)	DPU > PSE	DPU indicates it has switched the line from bypass to RPF mode and is ready to receive RPF
PWD (Powered)	DPU > PSE	Keep-alive message sent by DPU
ACT (Active)	PSE > DPU (and dongles since on same line)	Keep-alive message sent by PSE Trigger for the dongles to become (and stay) active

The start-up protocol is described in the flow chart in Figure 9.

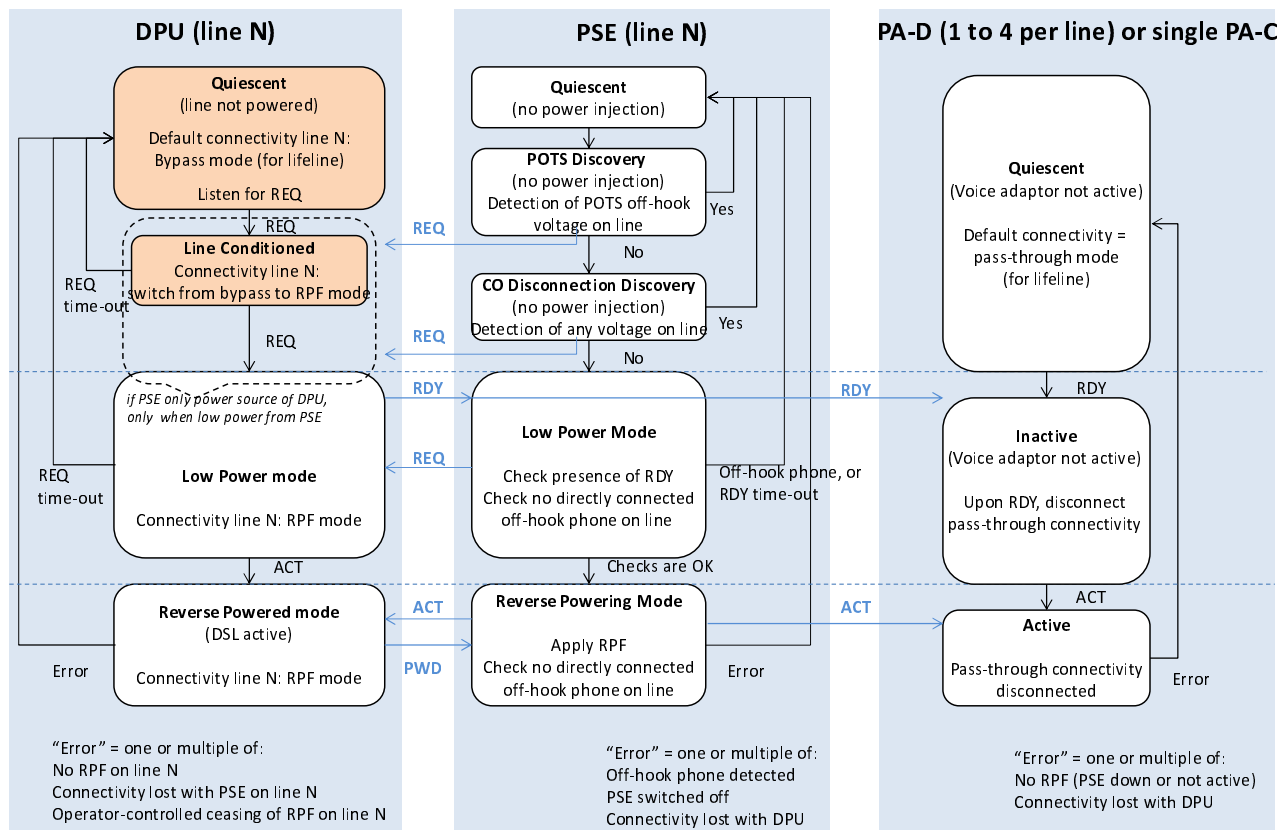


Figure 9: Flow-chart for CBSU protocol

A basic description of the flow chart for the case of Reverse Power Feed with POTS from the exchange (RPFA-EXP or RPFA-EXPSW) is as follows:

- 1) The PSE first checks that there is no off-hook phone, then signals that it requests to apply RPF by sending REQ message [POTS Discovery state], and waits for the absence of any voltage on the line [CO Disconnection Discovery state]. This REQ message is the start of the handshaking between PSE and DPU.
- 2) In case of an on-going call the PSE should return to the Quiescent state and wait for an on-going call to end.

NOTE: The REQ message is only sent after the off-hook voltage disappears, so that an on-going call is not interrupted.

- 3) The REQ message shall be detected by the DPU [Quiescent state], upon which the DPU interrupts the connection of the line to the CO side (e.g. by switching a relay) [Line conditioned state]:
 - In the [Quiescent] and [Line Conditioned] states (coloured in the figure), the DPU shall have some (limited) bootstrap power to perform these actions. The POTS signal is still on the line. If there is no local power source available at the DPU (such as a battery), in order to avoid conflict of DC power from the PSE with DC power from the POTS, the DPU shall get some limited (parasitic) power from the POTS line(s) from the CO side. A dedicated low-power circuitry and components are required to be implemented in the DPU to provide this functionality. In general, the maximum tolerable parasitic power is region and/or service provider specific.
 - In the states [Line Conditioned], [Low Power Mode], and [Reverse Powered], the DPU should notify presence of remote feed to the V reference point i.e. Exchange in order to allow a distinction between a regular operational state versus a metallic line failure like a broken line. This can be done by presenting a special metallic signature to the Exchange.
- 4) After step 3), the line is available for reverse powering; it is disconnected from the CO hence there will be no conflict of reverse DC with POTS DC. Prior to the full Reverse Power mode, the PSE goes in Low Power Mode state and applies a voltage and current that is safe for directly connected off-hook phones. This serves two goals:
 - Safe detection of off-hook phones.
 - Continue handshaking with the DPU:
The low power mode provides some bootstrap power to the DPU [Low Power Mode state]. With this power the DPU then generates a RDY message back to the PSE. If there is no RDY message coming back, the PSE shall abort the process (see step 7)). If the PSE receives the RDY message and there is no off-hook phone detected, the PSE can transition to step 5).
- 5) Once the conditions of step 4) are fulfilled (i.e. no off-hook phones detected and the RDY message is received), the PSE has detected that the DPU is present and ready so that the PSE can activate Reverse Powering [Reverse Powering state]. This is also signalled by the PSE sending the ACT message. As soon as the DPU system is powered and running [Reverse Powered state], it signals its operation by sending a PWD message.
- 6) Checking for presence of off-hook phones shall be continued during the normal RPF operation.
- 7) The ACT and PWD messages allow both sides to continue checking the connectivity. The PSE aborts RPF operation when an error occurs (loss of connectivity to the DPU, detection of off-hook phone, PSE being switched off), causing the other elements to return to a quiescent state. The PSE then retries to perform RPF (possibly after some waiting delay). Likewise, an error condition at the DPU (loss of connectivity to the PSE, interruption of RPF) or an operator overrule shall bring the DPU back to Quiescent state and cause the other elements to also return to their quiescent state.

A basic description of the flow chart for the case of Reverse Power Feed without POTS (RPPA-NOP) is as follows:

If there is no Exchange based POTS present to provide power to the DPU for the [Quiescent] and [Line Conditioned] states, and no local power source is available, the REQ message cannot be detected by the DPU and no RDY message can be generated in response. The PSE can however start a low-power mode together with sending a continuous or repetitive REQ messages. This is acceptable since there can be no conflict of reverse DC with POTS DC. By using this low-power from the PSE, the DPU can then start its low-power mode operation, detect the REQ message, switch the bypass relay if appropriate, and reply to the PSE with the RDY message. Hence for the DPU, the [Line Conditioned] state and [Low Power Mode] state are collapsed. Bypass relays may not be required (for example in greenfield deployments) where all customers are connected to the remote node.

Note that as for the case with POTS, if there is no RDY message coming back after a time-out, the PSE shall abort the process.

6.3 CBSU Protocol Specific Transmission Parameters

The signalling messages given in Table 7 between the DPU and the PSE shall be transported over the same medium as the xDSL service (legacy or FTTdp) and the DC reverse powering and potentially the POTS signal (full baseband POTS or POTS voice-band with adapted signalling, depending on the scenario). This is illustrated in Figure 10.

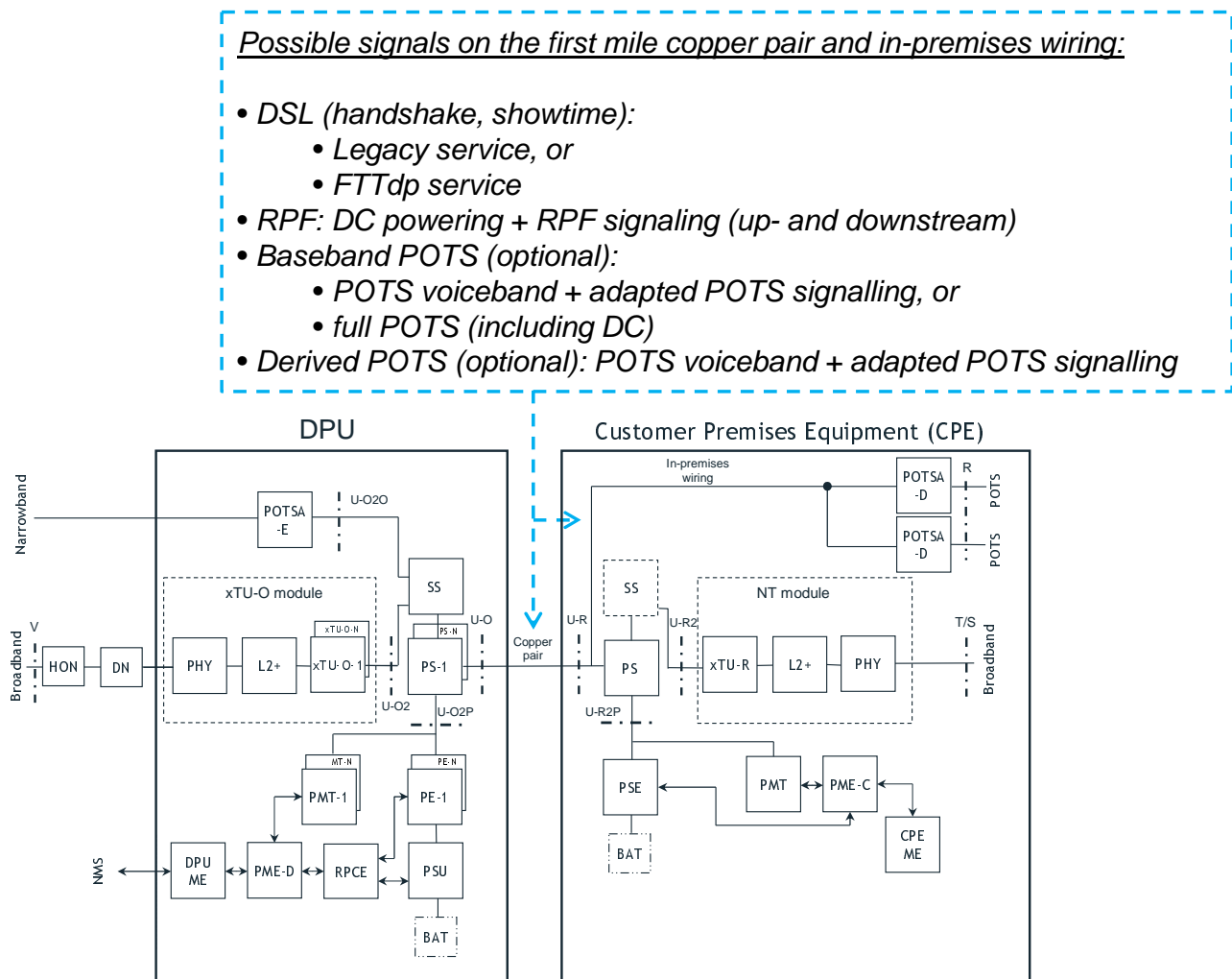


Figure 10: Context for RPF signalling – possible other signals on the line (e.g. case RPPA-EXPSW)

NOTE: PSE and NT and router and ATA and POTS adapter - E may be physically grouped or separate.

The transmission method for the RPF signalling messages shall therefore both allow correct reception in the presence of one or a combination of these other signals, while at the same time avoiding interference or corruption of these other signals. The only exception to this is the legacy DSL service which at start-up time may be impacted by the RPF signalling. This is acceptable since the purpose of reverse powering is to replace this service by the FTTdp DSL service.

The presence of other signals depends on the RPF status (start-up, initializing, operating), presence of POTS service, and DPU mode (line either bypassed to uplink copper access or disconnected from uplink copper access).

In particular the transmission method shall work without any reverse DC powering to the DPU (first messages before RPF is activated) and it shall co-exist with DC powering (either downstream from CO in case of traditional baseband POTS, or upstream once RPF is active).

Given the functional requirements in Recommendation ITU-T G.993.2 Amendment 5 [i.4] for implementations of G.993.2 with reduced power and enhanced data rates over short reach (e.g. for deployment from the distribution point (DP)), the VDSL2 US0 band i.4, specifically the lower end of the US0 band, is dedicated for transmission of RPF signalling messages.

Table 8 defines the frequencies, modulation and transmitter power.

The transmission method allows to:

- Minimize the impact on and influence from the above-mentioned other signals.
- Re-use the DSL signalling family of 4,3125 kHz for the carrier frequencies.
- Re-use the robust and efficient modulation of DSL handshake (Recommendation ITU-T G.994.1 [4]).
- Minimize the amount of carriers (one per direction) and avoid the impact of beat noise (carrier indices are relative primes).

The first message (REQ) shall be received when the DPU has a limited power source (e.g. parasitic powering from POTS). Also, its detection shall be able to cope with a noisy environment (legacy DSL service or handshake tones, possibly POTS metering pulses). Therefore the transmission power should be on the high side. For other messages, the DPU is either in the low power mode or full reverse power mode, hence the messages can be transmitted at a lower signal level.

Table 8: RPF signalling messages - Transmission Parameters

Message	Carrier index	Carrier frequency (kHz)	Modulation	Symbol rate (symbol / s)
REQ (Request)	5	21,5625	DBPSK	$4 \cdot 312,5 / 8 = 539,0625$
RDY (Ready)	12	51,75	DBPSK	$4 \cdot 312,5 / 8 = 539,0625$
ACT (Active)	5	21,5625	DBPSK	$4 \cdot 312,5 / 8 = 539,0625$
PWD (Powered)	12	51,75	DBPSK	$4 \cdot 312,5 / 8 = 539,0625$

7 Reverse Power Feed Power Supply Characteristics

7.1 RPF Range Options and Classes

In order for equipment to implement RPF schemes, it is necessary to define a series of parameters suitable for allowing operation in a number of scenarios. The scenarios are grouped into the following range options:

Range Option 1: 60 V DC Short Range (SR)

Range Option 2: 120 V DC Long Range (LR)

Each of these range options is further characterized in different corresponding classes, each class defining a set of parameters based upon the appropriate reference model and the RPF power supply characteristics. Table 9 defines the safety limit requirements for each of the range options and all classes defined for the corresponding range option. The values apply to the power sourcing equipment (PSE) at reference point U-R2P.

As a general rule, all PSE shall comply with the requirements of EN 60950-1 [2].

Table 9: Range options and safety limit requirements

Property	60 V DC Short Range TNV-1 (EN 60950-1 [2])	120 V DC Long Range TNV-3 (EN 60950-1 [2])
Maximum injected power by PSE per EN 60950-1 [2]	100 W	100 W
Maximum DC Voltage on Line applied by PSE	< 60 V DC	< 120 V DC
Maximum short-circuit Current generated by PSE per EN 60950-1 [2] (For all cable types)	1,3 A	1,3 A
Recommended maximum line current	385 mA	175 mA

Table 10 specifies three short range RPF classes, which includes the maximum power, DC voltage and line current:

- "RPF Class SR1" is defined to support (very) low power DPU designs, when they become available; the applicability of Class SR1 for a considered deployment type (amount of ports per DPU, cable losses, DPU uplink types, DPU feature scope at and beyond the physical layer, amount of additional devices (POTS-Adapters) to be fed from the same PSE, etc.) depends on the availability of low-power solutions.
- "RPF Class SR2" allows a higher maximum power to be transmitted than Class SR1. When compared to Class SR1, a solution that complies with Class SR2 can extend the type of deployments that can be supported, while still avoiding any additional safety measures in the home environment (below 15 W as per EN 60950-1 [2]).
- "RPF Class SR3" allows a higher maximum power to be transmitted than Class SR2, aiming to cover trials or demanding deployment situations for which Class SR1 or SR2-compliant power solutions are not available. A PSE of Class SR3 can inject more than 15 W and hence introduces additional safety measures compared to Class SR1 and Class SR2 (see SAFETY NOTE (a) and SAFETY NOTE (b) in Table 10).

The definition of the classes aims:

- to allow RPF designs to be optimized for high efficiency operation at the powers necessary for this particular class of application i.e. where minimal power shall be dissipated in sealed remote enclosures;
- to take into account the safety constraints for a deployment (safety measures in the context of residential home network depend on the level of injected power and applied voltage, safety requirements on the DPU depend on the power and voltage it is subjected to);
- to take into account the balance between on the one hand aiming for power-efficient DPU solutions (low power dissipation) and on the other hand covering as many deployment cases as possible from early on;
- to assist in interoperability.

Table 10: Short range reverse power feed class specifications

Parameter	60 V DC Short Range TNV-1 (EN 60950-1 [2]) RPF Class SR1 Safety Note (a)	60 V DC Short Range TNV-1 (EN 60950-1 [2]) RPF Class SR2 Safety Note (a)	60 V DC Short Range TNV-1 (EN 60950-1 [2]) RPF Class SR3 Safety Note (b)
Maximum power input at U-R2P	10 VA (see note)	15 VA	21 VA
Maximum DC Voltage on Line	60 V	60 V	60 V
Maximum line current	250 mA	275 mA	385 mA
Minimum range (for 0,5 mm gauge cable)	250 m	250 m	250 m
<p>NOTE: This value is based on either a DC Voltage of 60 V or a Line Current of 250 mA.</p> <p>SAFETY NOTE (a): In general, the DPU shall be designed according to specifications defined in EN 60950-1 [2]. In this RPF class a single-port DPU will not be subject to a power exceeding 15 W, while a multi-port DPU can be subject to a total power (sum across the ports) exceeding 15 W.</p> <p>SAFETY NOTE (b): In general, the DPU shall be designed according to specifications defined in EN 60950-1 [2]. A single-port and a multi-port DPU can be subject to a total power (sum across the ports) exceeding 15 W).</p> <p>Additionally, a single PSE can generate more than 15 VA and shall comply with the definition of "limited power source" as per clause 2.5 of EN 60950-1 [2].</p> <p>Additionally, any additional RPF device such as POTS Adapters or components such as plugs connected to the PSE that can be subject to the full PSE power shall also comply to clause 4.7.2 of EN 60950-1 [2].</p> <p>Additionally, in the local network environment of the PSE, it is not allowed to connect any part that does not comply with EN 60950-1 [2] to the PSE. E.g. devices, enclosures, plugs, etc. that are already installed in the home network or could be installed at a later stage by the end-user shall be isolated from the DC power injected by the PSE.</p>			

Table 11 specifies two long range RPF classes.

Table 11: Long range reverse power feed class specifications

Parameter	120V DC Long Range TNV-3 (EN 60950-1 [2]) RPF Class LR2 Safety Note (c)	120V DC Long Range TNV-3 (EN 60950-1 [2]) RPF Class LR3 Safety Note (d)
Maximum power input at U-R2P	15 VA	21 VA
Maximum DC Voltage on Line	< 120 V	< 120 V
Maximum line current	125 mA (see note)	175 mA (see note)
Maximum range (for 0,5 mm gauge cable)	1 000 m	1 000 m
<p>NOTE: The maximum line current is based on a DC voltage of 120 V.</p> <p>SAFETY NOTE (c): In general, the DPU shall be designed according to specifications defined in EN 60950-1 [2] (in this RPF class a single-port DPU will not be subject to a power exceeding 15 W, while a multi-port DPU can be subject to a total power (sum across the ports) exceeding 15 W).</p> <p>Additionally, when the PSE is installed at end-user premises, it shall not be possible for the end-user to access any PSE part or any part of the local network that can carry the voltage on the line (of up to 120 V), as such voltage exceeds the safe value of 60 V.</p> <p>SAFETY NOTE (d): In general, the DPU shall be designed according to specifications defined in EN 60950-1 [2] (a single-port and a multi-port DPU can be subject to a total power (sum across the ports) exceeding 15 W).</p> <p>Additionally, a single PSE can generate more than 15 VA and shall comply with the definition of "limited power source" as per clause 2.5 of EN 60950-1 [2].</p> <p>Additionally, when the PSE is installed at end-user premises, it shall not be possible for the end-user to access any PSE part or any part of the local network that can carry the voltage on the line (of up to 120 V), as such voltage exceeds the safe value of 60 V.</p>		

7.2 RPF Safety Requirements

7.2.1 Background

Safety aspects of Reverse Power Feed are covered by EN 60950-1 [2]. Reverse powering shall be capable of energizing a Reverse Powered Device (RPD) by a single customer over a single copper pair between the customers' premises and that powered device. That pair, besides reverse (DC) powering may be also carrying DSL data, POTS (voice) transmission and POTS signalling data. Also, it may also be necessary to ensure a continuous metallic path in order that services such as legacy copper line-testing can be conducted over that same copper pair.

There are two classes of reverse powering when applied with respect to POTS:

- 1) POTS originating in the exchange and Reverse Power Feed shall be simultaneously supported on the same wire-pair.

- 2) Reverse Power Feed and derived POTS originating in the CPE shall be simultaneously supported on the same customer premises wire-pair. There being no analogue POTS connection with the exchange.

There are two classes of reverse powering with respect to installation procedure:

- 1) Self-install
- 2) Engineer install

7.2.2 Unintended consequences

It should be noted that the operation of telephony apparatus connected to RPF circuitry without an appropriate protective POTSA-C or POTSA-D cannot be guaranteed. Indeed, excessive current may be drawn by telephony apparatus, when entering an off-hook state, which could destroy or cause permanent damage to that device.

To protect against such consequences, RPF systems shall be able to detect un-protected telephony devices going off-hook and reduce the source current to a value below 25 mA until the un-protected device has been removed from the network within 1 second.

7.3 Electrical reference model

An example electrical reference model for reverse power feed is shown in Figure 11. This is a high level representation which is based on a hypothetical contiguous copper path (drop wire and in-premises wiring for some options) connecting a remote node (e.g. DPU) to the customer's broadband CPE and telephony instruments. Each functional connection to that path is via an equivalent intermediate function, for example a Power Splitter Low Pass Filter in the case of the Power Source. Each functional connection is characterized by a noise generator and frequency dependent source impedance. Figure 11 shows clusters of functional connections that may be combined into one equivalent connection, if the CPE for example were to be implemented as a single entity, with one port for connection to the copper path. Figure 11 is an example specific to G.fast transport in downstream transmission configuration, where the maximum total drop length plus in home wiring length is 250 m.

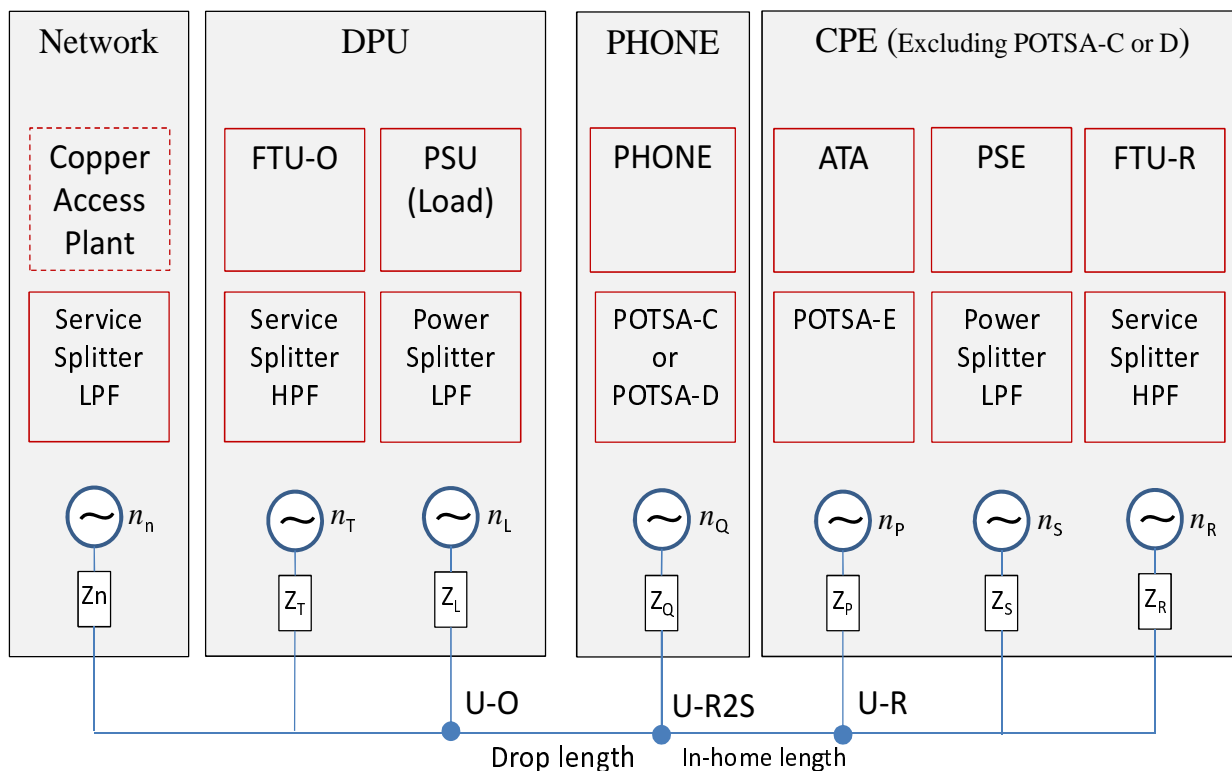


Figure 11: High Level Representation of RPF Electrical Reference Model (FAST [i.6])

n_n is a model of noise emanating from the upstream copper access network from source impedance Z_n .

n_T is a model of noise emanating from a DSL (G.fast) transmitter with source impedance z_T .

n_L is a model of noise emanating from a DPU RPF load (PSU) with source impedance z_L .

n_Q is a model of noise emanating from a POTS instrument and POTS signalling adaptor with source impedance z_Q .

n_P is a model of noise emanating from an ATA and POTS signalling adaptor with source impedance z_P .

n_S is a model of noise emanating from a DPU RPF source (PSU) with source impedance z_S .

n_R is a model of receiver noise expressed in DSL receiver with load impedance z_R .

In this example, the upstream model n_T , z_T and n_R , z_R are swapped between DPU and CPE. The FTU-O and FTU-R limits may be common but a separate definition will be required for both transmit and receive modes.

7.4 Zero touch DPU

A zero touch implementation means that an operator can remotely configure or enable services from a remote node (DPU) without the need for a technician to visit the site.

In this environment all lines at the DP may be provided with VDSL or FAST [i.6] functionality even if they are not currently enabled for the service. Figure 12 shows the basis for a zero touch solution which is derived from the reference model in Figure 11, but reconfigured for separation of legacy and RPF signals, and VDSL or FAST signals.

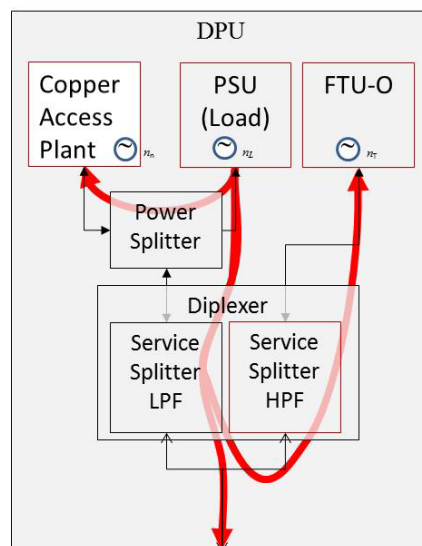


Figure 12: Example of a zero touch Integration

In Figure 12 the red arcs indicate noise coupling paths from the PSU (load) that are deviant from the reference model in Figure 11.

The functionality of the power splitter depends on DPU customer line state: pass-through or DP hosted service:

- The Power Splitter plus Service Splitter LPF defines the relationship between U reference point, power load noise budget and actual PSU load noise requirements. This shaping is vendor discretionary.
- The Power Splitter specification also controls how much PSU noise escapes upstream. This will be specified in RPF requirements.

Annex A (informative): Reverse power backup systems

A.1 Case 1 battery backup in the CPE

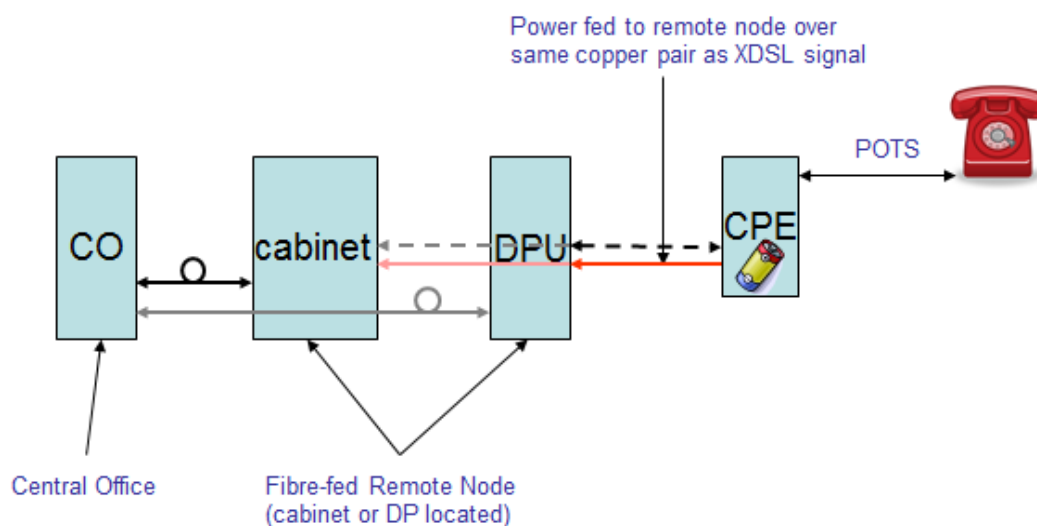


Figure A.1: Battery backup in the CPE Only

Figure A.1 shows the case where battery backup is placed in the CPE, the aim being that if there is a local power failure then lifeline POTS plus OAM support at the remote node can be provided by the battery backup.

A.2 Case 2 battery backup in the DPU and CPE

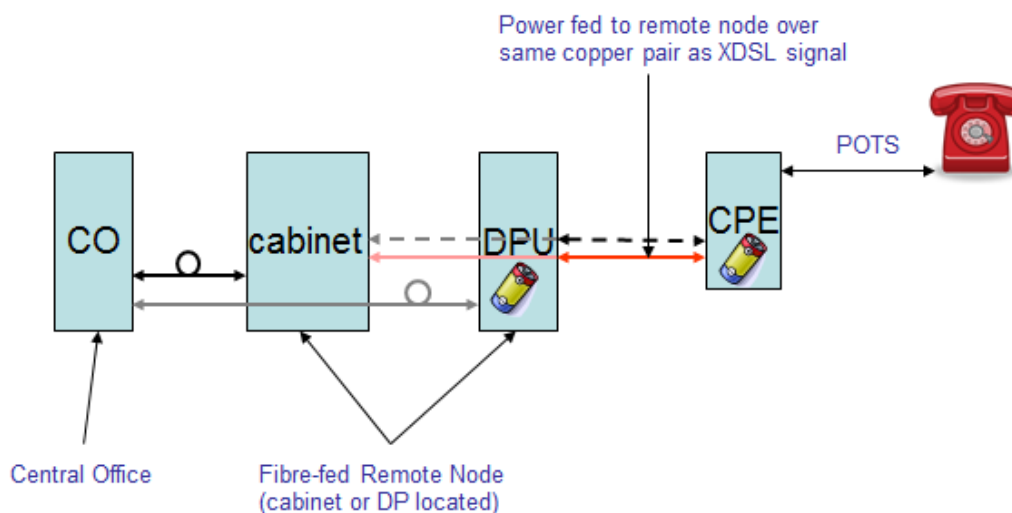


Figure A.2: Battery backup in the DPU and CPE

Figure A.2 shows the addition of another battery backup located in the DPU. This gives the advantage in that equipment located at the DP can remain powered even though no subscribers are connected and thus retaining OAM support.

Annex B (normative): General POTS requirements

This annex is applicable where POTS CPE are compliant with ETSI ES 203 021 [3].

The POTS interface presented by POTSA-C and POTSA-D shall comply with ETSI ES 202 971 [1].

NOTE: In cases where derived POTS is delivered then there is a case to consider a limited subset of requirements (equivalent to providing an analogue POTS presentation via an FTTP access network). For example one can consider the service and capability features listed in Table 1 and Table 2 given in ND1645 [i.2].

Annex C (informative): Bibliography

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ETSI TR 102 702: "Access, Terminals, Transmission and Multiplexing (ATTM) Study of issues related to POTS injection in the customer wiring from xDSL VoIP Home Gateway".

ETSI EN 302 099: "Environmental Engineering (EE) Powering of equipment in access network".

History

Document history		
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