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The reduction of energy consumption
in telecommunications equipment and related infrastructure

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Environmental Engineering (EE).

Introduction

Recent Life Cycle Assessment (LCA) studies have revealed that the energy consumption of telecom equipment during operation is the most significant environmental impact factor of the telecom business.

In future also the energy consumption during the manufacture phase will increase the impact on the LCA

The cost of energy is significant and rising due to the cost of raw materials and government policies, which will impact on the operating cost of telecomm services. It is therefore in the interest of operators to reduce their energy usage, distribution and unit cost.

The present document covers various methods of increasing the efficiency of telecom systems by controlling/reducing the energy consumption in the telecommunication network equipment and related infrastructure.

This first version of the document is in particular dedicated to the Broadband Access technology.

1 Scope

The present document is an accumulation of ideas from operators and manufacturers on the methods to increase the energy efficiency of telecommunication systems in order to reduce its operational energy use; the present document considers telecommunication equipment and infrastructure equipment (power station, air cooling, control of equipment, etc.) in telecommunication centres. The energy efficiency of end-user equipment is not considered.

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2.1 Normative references

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Not applicable.

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area**.** For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] ETSI EN 300 019-1-0: "Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1-0: Classification of environmental conditions; Introduction".

[i.2] ETSI EN 300 132-2: "Environmental Engineering (EE); Power supply interface at the input to telecommunications equipment; Part 2: Operated by direct current (dc)".

[i.3] ETSI EN 300 132-3: "Environmental Engineering (EE); Power supply interface at the input to telecommunications equipment; Part 3: Operated by rectified current source, alternating current source or direct current source up to 400 V".

[i.4] IEC EN 60896-21:2004: "Stationary lead-acid batteries; Part 21: Valve regulated types. Methods of test".

[i.5] IEC EN 60950-22: "Information technology equipment Safety; Part 22: Equipment to be installed outdoors". .

[i.6] BS EN 50272-2: "Safety requirements for secondary batteries and battery installations - Part 2: Stationary batteries".

[i.7] ETSI TS 102 533: "Environmental Engineering (EE) Measurement Methods and limits for Energy Consumption in Broadband Telecommunication Networks Equipment".

[i.8] IEC 60950-1: "Radiation monitoring equipment for accident and post-accident conditions in nuclear power plants. Part 1: General requirements".

[i.9] ETSI TR 102 532: "Environmental Engineering (EE) The use of alternative energy sources in telecommunication installations".

[i.10] ETSI EN 300 132: "Environmental Engineering (EE); Power supply interface at the input to telecommunications equipment".".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

infrastructure equipment: power, cooling and building environment systems used in telecommunications centres and Access Networks locations

telecommunication centre: location where telecommunications equipment is installed and which is the sole responsibility of the operator

3.2 Symbols

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

Ln	Line
Po	Power output
V	Volts
W	Watt

3.3 Abbreviations

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

3rdpp/	3rd party products
AC	Alternating Current
Aux Eq.	/ Auxiliary Equipment
BB	BroadBand
BBCoC	BroadBand Code of Conduct
CDF	Cumulative Distribution Function
COP	Co-efficient Of Performance
CPA	Central Power Architecture
DC	Direct Current
DPA	Distribution Power Architecture
DS Mbps	Down Stream Mbps
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Module
DSM	Dynamic Spectrum Management

EC	Electrically Commutated
EN	European Norm
HVDC	High Voltage Direct Curren
HW	HardWare
IBA	Inter media Bus Architecture
ICT	Information communication technology
ISDN	Integrated Services Digital Network
ISO	International Standards Organisation
LCA	Life Cycle Assessment
MOD	Mask On Demand
MODEM	MOdulator and DEModulator

NOTE: I.e. receiver and transmitter function.

NPC	Normalized Power Consumption
NPC	Normalized Power Consumption
OEM	Original Equipment Manufacturer
PA	Power Amplifier
POTS	Plain Old Telephony Service
SLA	Service Level Agreement
SW	SoftWare
Transm/	Transmission equipment
UPS	Uninterruptible Power Supply
US Mbps	UpStream Mbps
VDSL	Very high speed Digital Subscriber Line
VDSL2	Very high speed Digital Subscriber Line 2
VRLA	Valve regulated lead acid

4 Company Environmental Procedures

4.1 Guidance on Company Environmental Procedures

A number of international standards and guides related to companies' environmental work have been prepared or are under preparation. Some of these are given in bibliography (see item 1).

5 Telecom System Power and Energy Efficiency

5.1 Introduction

Power consumption figures are comparable, if done on similar equipment, with similar performance and measured at the same interfaces. However, if we want to compare products with different technology, with new features and higher bit rates or improved distance coverage, we need to evolve our view from power consumption towards energy efficiency. If we want to set requirements on new technology, we need to consider the demands for increased performance and corresponding impact on power consumption. A measure of power or energy efficiency is needed.

In the following, a number of terms are proposed in order to properly define power consumption and energy efficiency.

The energy efficiency is understood as the relation between the Useful Output and the Energy or Power Consumption. This efficiency measure could either be defined on power scale, or on energy scale as an integration of power consumption over time.

In the following examples, for Broadband access equipment, Useful Output is defined as the peak performance of bit rate and reach distance. Useful Output is compared with the long term Average Power Consumption.

The power consumption is related to a number of conditions as:

- Configuration and involved equipment.

- Operational conditions.
- Measurement interfaces.

A set of definitions is needed. The following terms are proposed:

- Reference models.
- Operating conditions.
- Power efficiency.
- Useful unit.

NOTE: This covers use phase only, not production phase.

5.2 Power consumption of telecom systems - ICT view

Average power consumption of ICT and telecom systems is indicated in figure 1, for further information see bibliography. The Broadband Access part is used for further analysis.

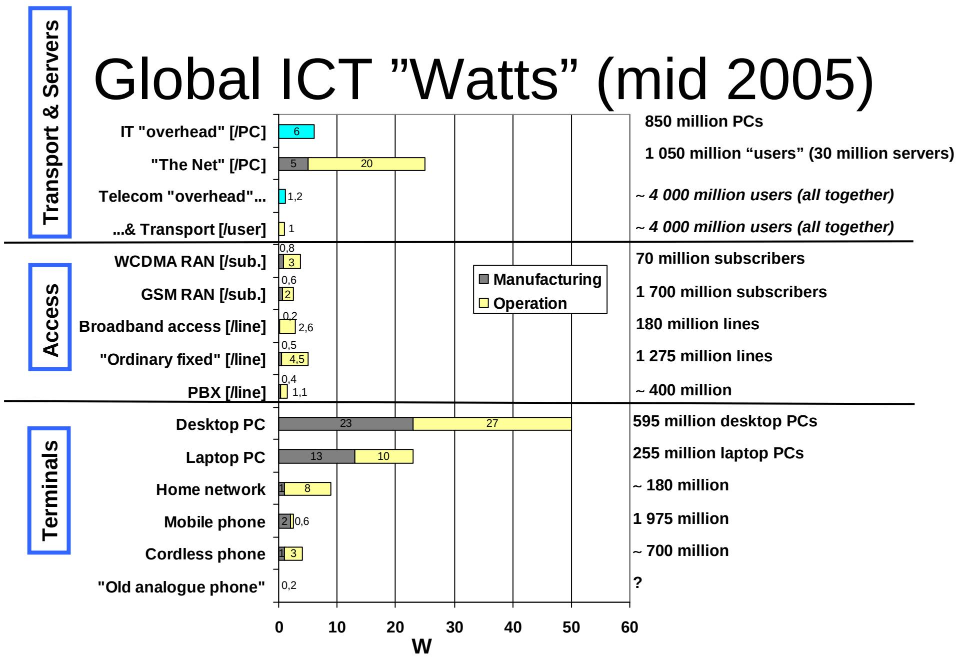


Figure 1: Average power consumption of ICT equipment, use phase and production

5.2.1 Manufacturing impact on the power consumption

The CO2 equivalent of the complete manufacturing chain, from mine through end of life treatment, is estimated. The CO2 value is recalculated into electrical energy, using the global energy production mix index of 0,6 kg CO2/kWh. The energy is distributed over the life-time of the device, resulting in average power consumption of manufacturing.

Life time assumptions used in the examples reported in the present document:

- Mobile handset: 2,5 Year.
- DSL modem: 5 Year.
- Server: 4,25 Year.
- DSLAM: 10 Year.

- Radio Base Station: 10 Year, mechanically, 5 Year for the circuit boards.
- Radio Base Station Site: 20 year for Tower, Antenna and Shelter, 3,5 Year for the batteries.

5.2.2 Sources

Three different sources are used (see bibliography for details).

5.3 Reference models

A Reference model is needed to indicate what equipment is involved and what measurement interfaces are used. Example: The reference model will make it clear whether power consumption is measured at DC or AC, what functional units/configurations are included in the power measurement.

A number of reference models may be needed to cover different types of telecom equipment.

Reference model example proposals for DSLAM and Radio Base nodes are provided below.

5.3.1 Reference model content

The reference model is a block diagram that may include:

- Interfaces, internal and external.
- Climate shell(s).
- Hi Level functional parts like nodes - for a model network, or functional units like climate equipment, rectifiers, modems, etc., for a node site model.

5.3.2 Reference Model Network

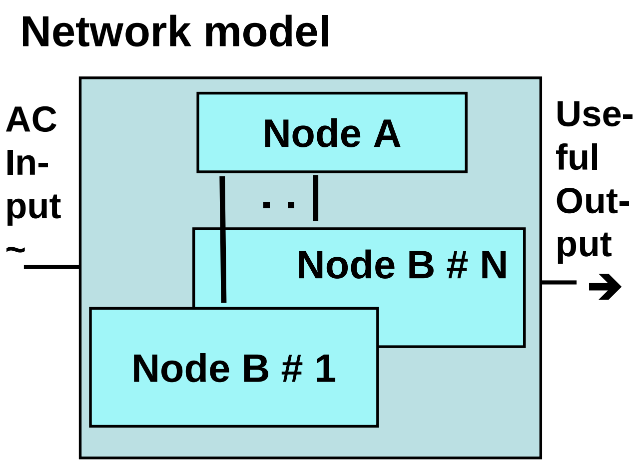


Figure 2: Reference Model Network

Basic reference model network is needed to calculate the overall efficiency of telecom networks and the impact of different nodes in the Network.

It is important to include the nodes typically needed and to capture the typical proportions of the different node types in order to estimate how the different nodes contribute to power consumption of a typical network

5.3.3 Node Site Reference Model

It is important to compare equipment power consumption at similar conditions. Usually the power consumption at site is relevant. A site model should be applied that includes climate equipment, rectifiers and other infrastructure equipment, if typically needed on a site level.

Preferable the site power should be measured at the AC level. See annex A for explanation.

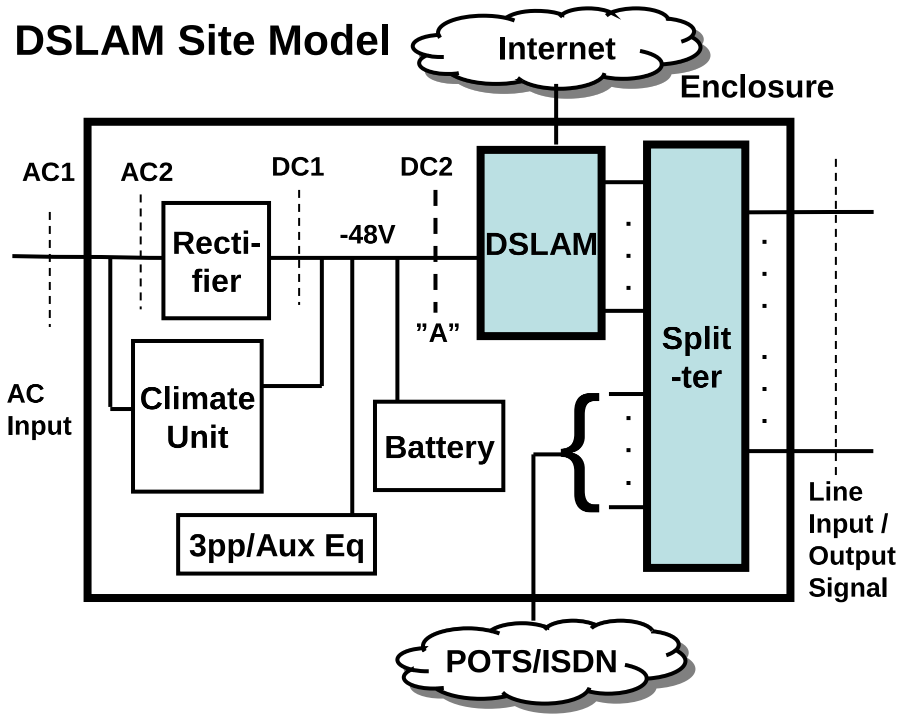


Figure 3: DLSAM Node Site reference model

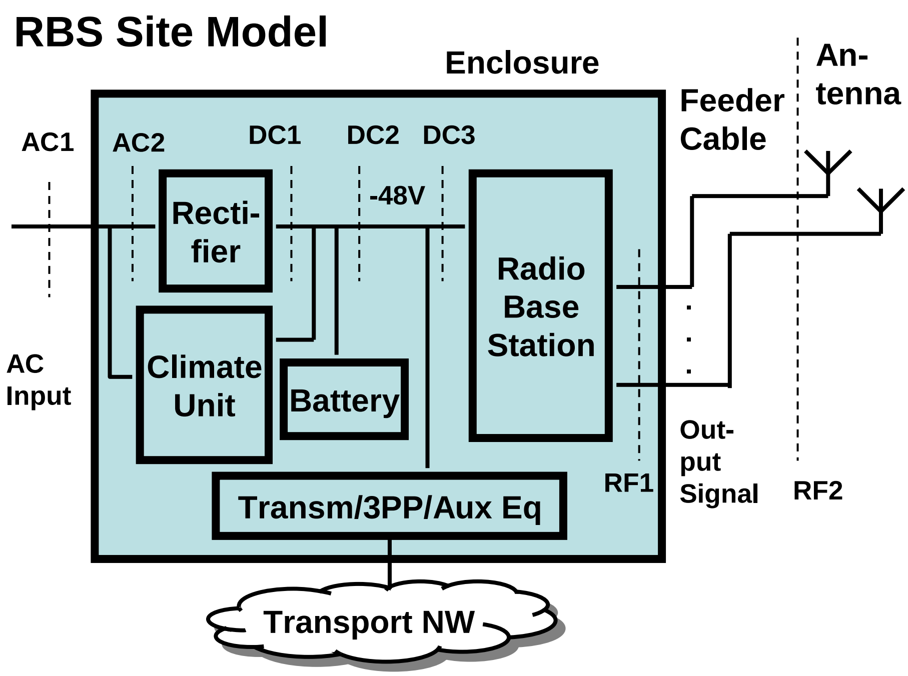


Figure 4: RBS Node site reference model

Different reference points are available to support different aspects of energy optimisation. E.g. consideration of "RF2" reference point may lead to support "Remote Radio Head" technology instead of using coaxial feeder cables.

5.4 Operating conditions

Power consumption depends on a number of operating conditions like:

- traffic pattern;
- operational mode;
- reach;
- climate (including temperature operating condition).

5.4.1 Traffic pattern

Traffic pattern and traffic intensity has an impact on energy consumption. The impact varies with the type of telecom system. For POTS and cellular systems, traffic intensity has a substantial impact on power consumption. For fixed line BB systems like DSL and VDSL, the traffic impact on consumption is negligible if low power modes are not activated, but considerable if low power modes are activated. See examples in clause 5.4.4.

5.4.2 Operational modes and power management

Telecom equipment energy consumption varies with the mode of operation. Power saving modes should be implemented in telecom systems, like L2 and L3 modes in DSLAM equipment and corresponding or standby modes in modem equipment. Corresponding examples on power saving techniques for GSM/UMTS radio equipment are Standby power saving modes like TRX shutdown, HW/SW-triggered PA bias switching.

As the subscriber equipment is in active use only a fraction of the time, it is imperative for every standard to make energy saving modes fully operable at low or no traffic periods. It is imperative to have a power management that effectively will activate the different power saving modes minimizing the power consumption.

Traffic models indicating the typical traffic intensity and statistic behaviour over day and week are important tools to calculate the power consumption as a result of the combination of traffic pattern and power management behaviour. When defining the traffic models, the impact of subscription rate as well as impact from different services and use cases should be considered. A common use case is a computer that is always on - even when not in active use. The computer may send "keep alive" signals periodically. VoIP will be a future common use case, with a requirement for access "to the line" in <1 second. As the power saving effect of low power mode is also wanted, a solution would be to define a low power mode that can transmit a low rate signal for control, "keep alive", equalizing and VoIP start up. 100 kbps is proposed as relevant rate for such signalling.

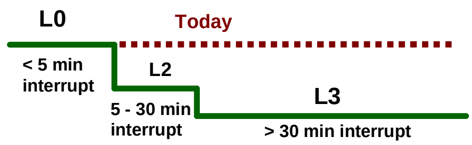
The examples in clause 5.5 assume that complete traffic interruptions occur when not in active use and that energy saving modes are controlled by inactivity period triggers. The different trigger criteria and the assumed active time per mode and per day are shown in figures 5 and 6.

5.4.3 Traffic models and operational modes

When traffic models are defined and used in combination with assumed power management, the fraction of time that different power modes are active can be calculated. Thus the power consumption and saving per day can be estimated. In the following examples, a simple traffic pattern and mode management according to clause 5.4.2 is assumed. Traffic models indicating the typical traffic intensity and statistical behaviour over a day and week are important tools for calculation of power consumption. When defining those models, the subscription rate structure impact on traffic patterns should be considered.

DSLAM

Operational Modes & user traffic models

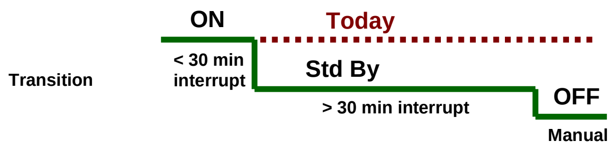


User type	L0 time/Day	L2 time/Day	L3 time/Day
Private DSL	1hr	1hr	22hr
Private 3-play & SOHO	6hr	2hr	16hr
Average user	3,5hr	1,5hr	19hr

Figure 5: Example DSLAM operational modes L0-L3 and 24 hour traffic model

DSL - Modem

Operational Modes & user traffic models



User type	ON, time/Day	Std By, time/Day	OFF
Private DSL	2hr	22hr	0hr
Private 3-play & SOHO	8hr	16hr	0hr
Average user	5hr	19hr	0hr

Figure 6: Example DSL Modem operational modes and 24 hour traffic model averaged on 1 year period

5.4.4 Reach/coverage/rate impact

Modern Broadband Radio and wire line Broadband systems share the same behaviour - the bandwidth and power usage is depending on the reach or coverage.

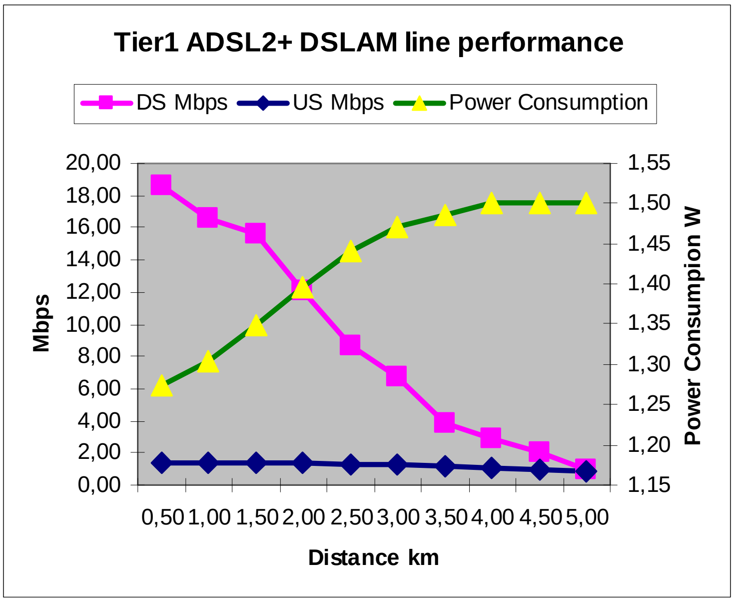


Figure 7: Example, performance simulation ADSL2+ line bit rate performances and line power consumption, based on TS 102 533 [i.7]

5.4.5 Climate impact and models

The power consumption of climate equipment and fans is dependent of the temperature. Use of standard climate models is essential for estimating peak and average power consumption of the climate equipment.

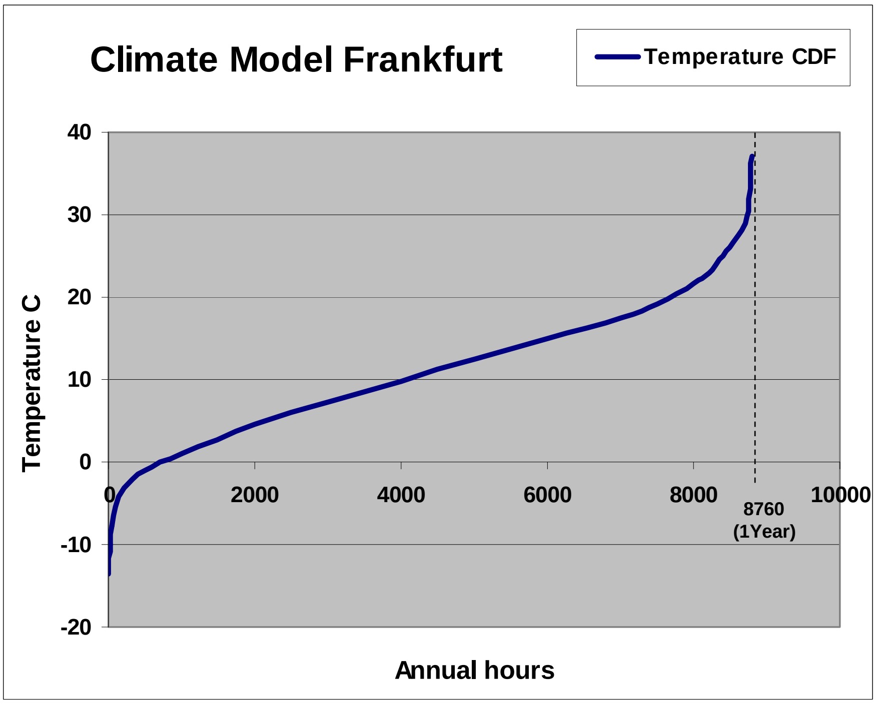


Figure 8: Climate model for Frankfurt as temperature CDF over an average year

NOTE: When dimensioning cooling systems it should be noted that temperatures >30 °C occur for only a limited period each year.

5.5 Power efficiency

There is a need to measure and bench-mark power consumption consistently, i.e. relate the power consumption to the useful output, i.e. a need to define power efficiency.

Useful output or "useful unit" should be defined. Usually capacity and coverage are the most important parameters. It may not be possible to find a single efficiency definition that covers all telecom systems and the definitions may be multiple, depending on the type of telecom system.

When Power efficiency is defined and measured, it is an important tool for comparing different products and technologies. The power efficiency is simply the useful output divided by the power consumption. The inverse measure - the power consumption divided with the useful output, could be used as an alternative. This measure is chosen in the examples in this clause.

5.5.1 Useful output

Bit rate and power consumption is dependant on the distance from the BB Network node to the subscriber.

As distance reach is important for the operator - enabling improved subscriber coverage or lower density of nodes - the reach aspect should be considered as a desirable aspect, in parallel with bit-rate. A relevant "Useful unit" should be the product of reach [km] and Bandwidth [Mbps].

5.5.2 Power consumption dependencies

As described previously in the present document, the power consumption is depending on the configuration, the measurement interfaces and the operating conditions. By combination of those factors, average power consumption can be properly estimated as a base for energy consumption calculations.

5.5.3 Proposed Energy Efficiency definition for fixed BB equipment

Normalized Power Consumption (NPC), i.e. the power consumption related to useful output.

NPC = Average Power Consumption [mW]/Useful output, i.e. Bit rate x distance [Mbps x km]

NPC could be used at different equipment levels like magazine level - DSLAM, based on DC consumption, or on site or node level, based on AC consumption.

5.5.4 Examples

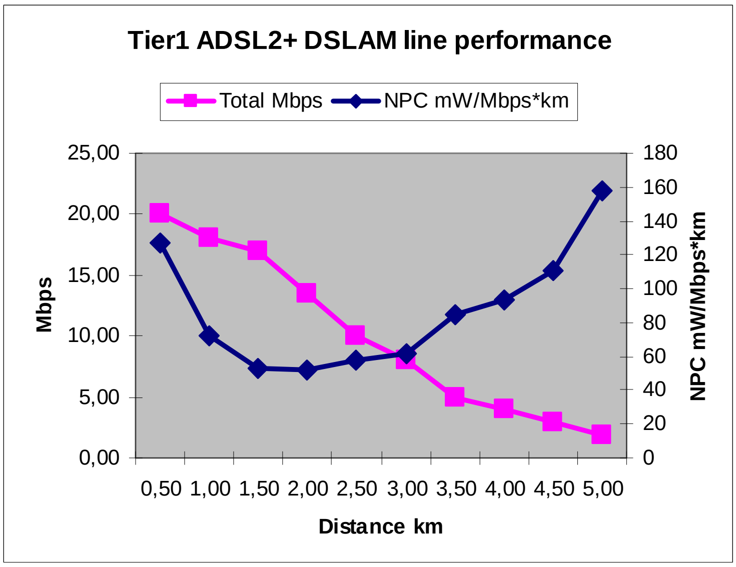
5.5.4.1 Power consumption values used

DSLAM DC power consumption limit values from TS 102 533 [i.7] are used in the following examples. DSL Modem AC power consumption limit values from TS 102 533 [i.7] are used in the following examples.

5.5.4.2 NPC for DSLAM, ADSL2+ Tier 1 and VDSL2 Tier 2 DC consumption

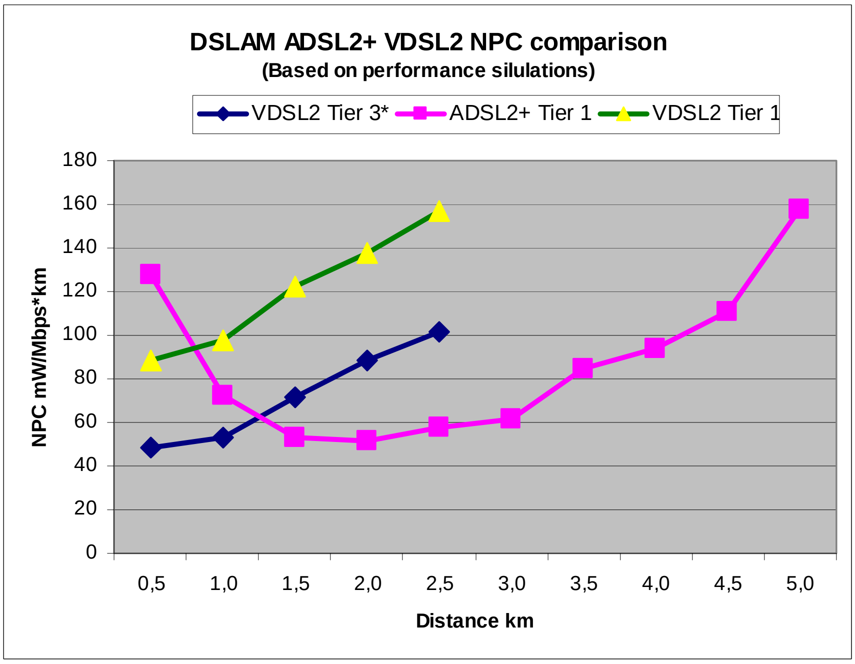
The calculation is based on:

- Simulations of DSL performance with 24 disturbers. See annex B for any details.
- Power consumption based on TS 102 533 [i.7], for DSLAM DC power consumption. AC values can be achieved by multiplying the NPC values with a site correction factor. Typical value is 1,7 for an air-conditioned site. For details, see clause A 1.
- L2 and L3 modes are not considered operable, i.e. traffic model has negligible impact on power consumption.



NOTE: Total bit rate upstream/downstream and NPC figures, based on example in annex C. Best NPC value is 52 at 2 km distance.

Figure 9: ADSL Tier 1



NOTE: Conclusion is that ADSL2+ is the most efficient access for distances above 1,3 km, while VDSL2 Tier 3 is the most efficient for shorter distances.

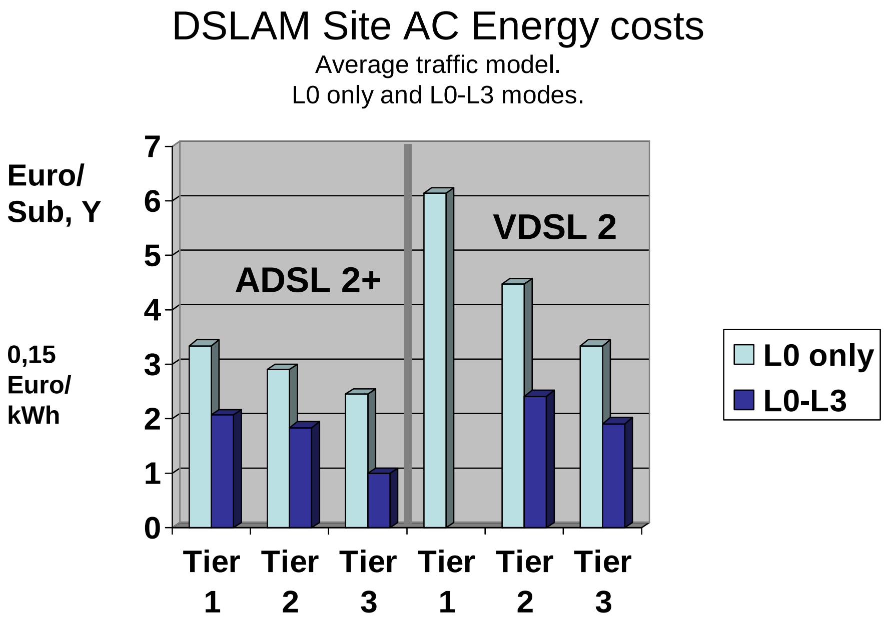
Figure 10: NPC comparison ADSL2+ Tier 1 and VDSL2 Tier 1 and 3.Best NPC values: Tier1 ADSL2+: 52 at 2 km. Tier3 VDSL 2: 48 at 0,6 km

5.5.4.3 AC Site energy consumption and cost for DSLAM and Modem ADSL 2+ Tier1 and VDSL2 Tier 2

The calculation assumptions for the graphs in this clause are:

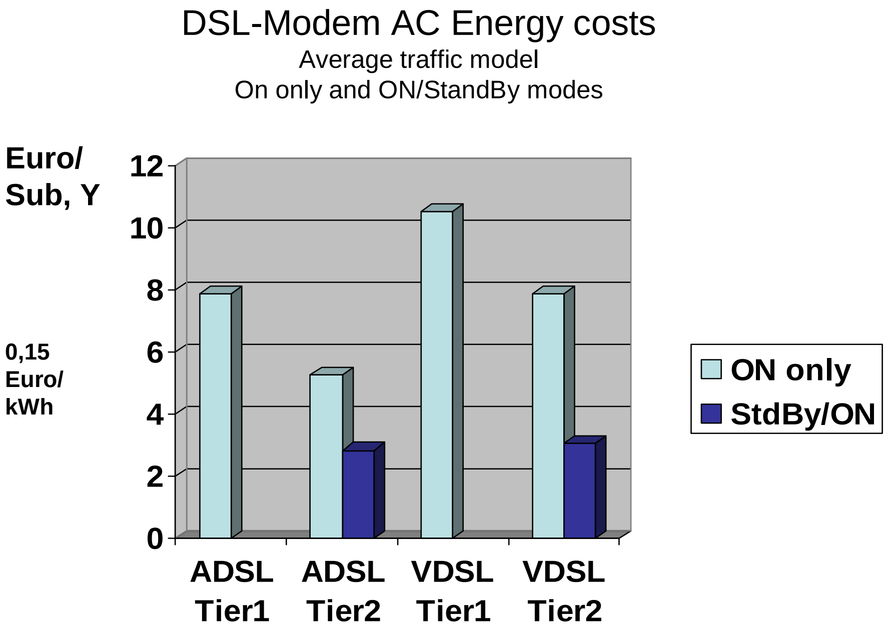
- Power consumption values according to tables in clause 5.5.4.1.
- DSLAM L2 and L3 modes are considered operable.
- Modem Standby mode is considered operable.

- User traffic profile and management of low power modes as described in clause 5.4.2.
- Site energy consumption correction factor from DC to AC is 1.7 according to clause A.1.
- Comparison based on site power consumption per line, not on energy efficiency.
- Energy cost is 0,15 €/KWh.



NOTE: Light blue - full power mode only. Dark blue - L0 and low power modes L2-L3 are active according to clause 5.4.2. Tier 1 is products available on market 2007, Tier 2, products available 2008 and Tier 3 products available 2009.

Figure 11: DSLAM Site AC Annual Energy costs - per line



NOTE: Light blue - full power mode only. Dark blue - L0 and low power modes L2-L3 are active according to clause 5.4.2. Tier 1 is products available on market 2007, Tier 2, products available 2008.

Figure 12: DSL Modem AC Annual Energy costs - per modem

5.5.5 Way forward, using power/energy efficiency view

Power consumption can be reduced using different improvement methods. The efforts should focus on investigation of the power saving potential of different improvement proposals. Each combination of improvements - features as well as Hardware solutions - could be evaluated on a system energy efficiency level, either on an average power dimension, or, by integrating over time - evaluated in the energy dimension.

However, requirements should be set on an efficiency dimension, not in implementation terms. Each vendor or operator needs to make their own decision on selection of methods for power efficiency improvements. The resulting power or energy efficiency could then be estimated, using the described tools.

For equipment with similar "useful output", the comparison could be done in the power consumption dimension, considering the parameters impacting the annual average site power consumption.

For equipment with different "useful output" - the comparison should be done in the efficiency dimension.

6 Energy saving methods for telecom infrastructure equipment

The different methods listed here should be used at the vendors or operators discretion in a way that optimizes the energy efficiency of the nodes and the network.

Power consumption of the support systems is more or less proportional to the power consumption of the telecom equipment. As power consumption of the access or transport equipment is reduced, the infrastructure equipment like cooling and rectifiers can be downsized with substantial energy and cost savings at the site.

6.1 Infrastructure equipment introduction

The telecom equipment power and cooling infrastructure equipment are vital in maintaining the operation of the telecomm equipment in providing service to the customer - No Power, No Service, No Revenue. If the power or cooling system is not available for the telecomm equipment it will not be operational and therefore no service can be provided and revenue will not be generated. Customers will seek compensation for the loss of service and ultimately change to a different provider.

The area of equipment that could be optimized is depicted in figure 13.

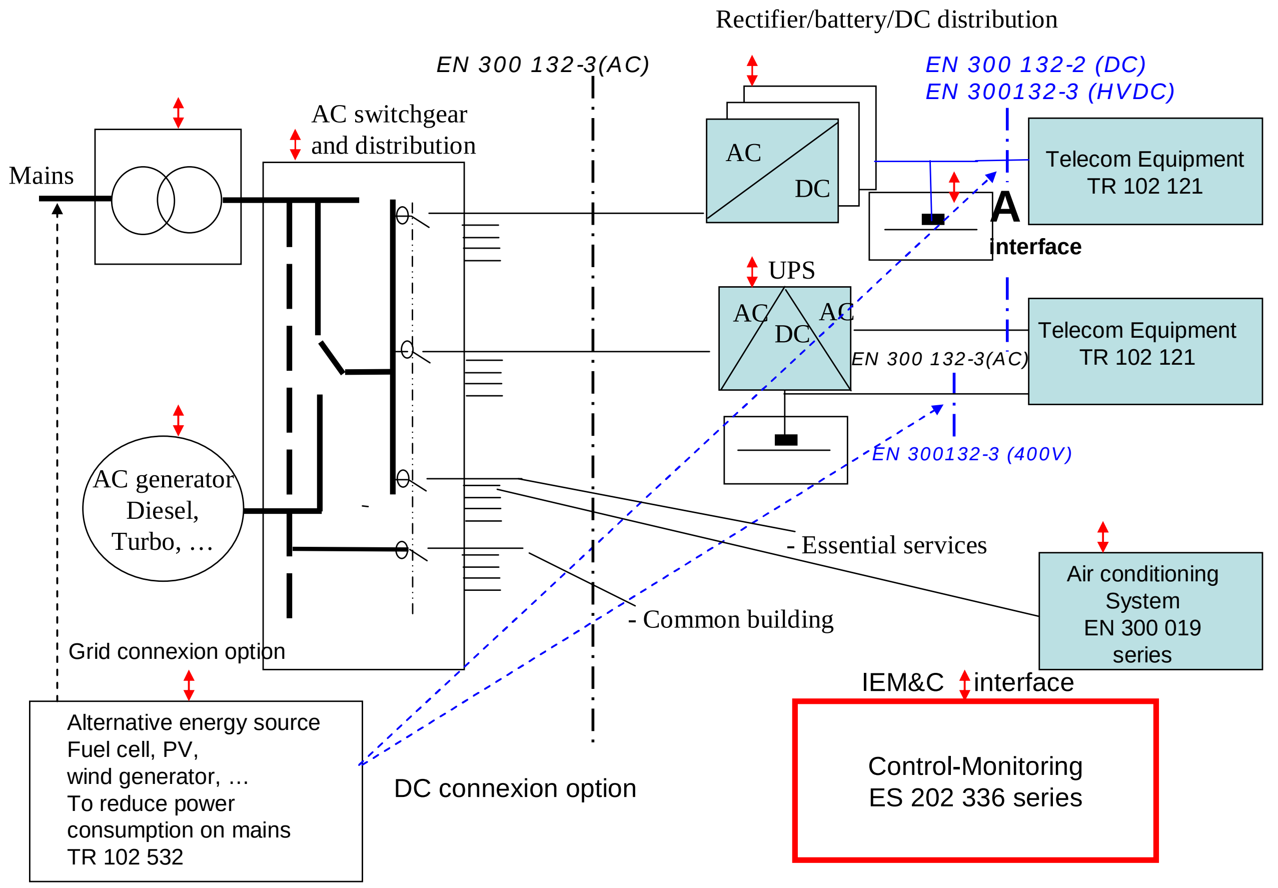


Figure 13: Area of equipment contributing to power consumption reduction or optimization (grey rectangle)

NOTE: In figure 13 the power interface EN 300 132-3 [i.3] is either a HVDC or an AC.

6.2 Cooling systems

Cooling systems are an integral part of the telecomm system. Without cooling (regardless of which form it takes) the telecomm system is likely to overheat and fail or greatly shorten its life. In some cases temperatures that are too low can have the same effect of equipment failure and shortening of its life. The effect of lifetime reduction should be balanced with the operator's expectation on lifetime. Product life cycle, market conditions and costs should be taken into account.

6.2.1 Use of fresh air cooling

The environmental classes of EN 300 019 [i.1] allows the environment in which the equipment is installed to vary. For examples Class 3.1 allows the room temperature to vary from 5 °C to 40 °C and class 3.2 "partly temperature controlled" allows the room temperature to vary from -5 °C to +45 °C.

In many European locations fresh air can be used which results in the chilling system not being required and in other locations not operating for the majority of the year.

6.2.2 Use of water cooling

The vast majority of cooling of indoor cabinets is achieved by air convection. In contrast to the past, air cooling is not as effective at removing heat created by high device densities; increasing amounts of energy which is expended to simply continue air cooling. Water can conduct much more heat than the same volume of air and requires much less energy to move a given volume. The preconception of water cooling methods which directly contact the circuitry (adding a failure risk) has limited its implementation.

6.2.3 Fans

Fan technology has improved which allows the energy requirements to be significantly lowered. The common method of adjusting speed is to regulate the power-supply voltage of the fan. If the power-supply voltage is varied using a linear pass device, the efficiency is poor, the saved energy by lower fan speed has become the heat dissipation of the pass device. Better efficiency can be obtained using a switch-mode power supply for the fan, although this increases cost and component count. Electrically commutated (EC) fan technology can be deployed in cooling systems that can reduce the energy cost by approximately 50 %.

6.2.4 Room temperature set-points

Guidelines relating to acceptable temperature environments for equipment operation may be too low and result in unnecessary air conditioning.

Technical characteristics provided by manufacturers frequently overstate the heat dissipation and peak electrical requirements, making it difficult for operators to optimize cooling and electrical supply to minimize energy use.

The goal should be to increase temperatures to extend free cooling applications. The maximum duration of "worst case" higher temperatures in emergency cases should be defined by the operator and balanced with the decrease of product lifetime.

An alternative to a fixed temperature set-point is to use a variable temperature set-point depending on the season of the year.

6.2.5 Thermal management

Thermal management for outdoor plant systems, such as heat exchanger, heater, air conditioner and cooling fan are important parts of power consumption. Manufacturers of outdoor plant systems should consider the following points described below:

1) To adopt suitable working temperature area for outdoor plant systems and reduce the working time of air conditioning, heat exchangers and heaters to as short as possible. High temperature set-points inside of cabinets could be raised to delay the switch-on of cooling and low temperature set-points inside of cabinets could be lowered to delay the switch-on of heating.

2) Adjustment of fan speed to comply with the requirements of equipment. This method can save energy, more than 50 % of fan cooling consumption power. Manufacturers should evaluate each hot point of their equipment and confirm the lowest fan speed requirement that would guarantee equipment working safely.

3) Choosing appropriate external airflow distribution avoids mixing of airflow out of and into cabinets and ensures the fresh air flows into the cabinet.

4) Guidance and recommendations should be given in choosing the cooling style. Priority of choosing cooling style can be listed here as convection cooling, fan cooling, heat exchange, air conditioner. Obviously, the power consumption becomes larger and larger from convectional cooling to air-conditioning. Where free or natural convectional cooling can be used then no fan cooling is necessary, where fan cooling can meet requirement then no heat exchanger is necessary, etc.

5) Paint materials, which are light and absorb less solar radiation, should be suggested for outdoor equipment surfaces.

6) A cooling-efficient Cabinet design is important.

6.3 Power system

Power systems are an integral part of the telecomm system. The power system will consume energy during power conversion and transportation. In some cases, power system self power consumption should not be neglected.

6.3.1 Power architecture

It is the responsibility of OEMs and carriers to adopt suitable power architecture for higher efficiency of power converter and transportation. The OEM should declare the power architecture adopted inside of telecom equipments and efficiency of each power converter at different modes. The power architecture of designs should cover the considerations below.

Choose optimized power architecture to achieve higher power converting efficiency of system. For the whole power system, there are several kinds of power architecture, such as Central Power Architecture (CPA), Distribution Power Architecture (DPA) and Inter media Bus Architecture (IBA), etc. The appropriate power architecture should be adopted corresponding to different loads to ensure the whole power system has a higher converting efficiency.

Choosing the right power supply suitable for telecom requirements. It is recommended that the working average load exceeds 40 % but is lower than 80 % of the power converter rating.

The power supply vendors could explore the control method so that power modules adjust working mode by tracking load variations. This would result in power modules working at high efficiency under most load conditions.

Choose high efficiency power converters that integrate new switch power supply techniques, such as soft switch and synchronous rectifier. The convection cooling power supply is encouraged to be used in the telecom system, which means the higher efficiency of power converter and no power consumption of a cooling fan. Even if a fan cooling method is employed in power converters, the fan should not run in cases of low load or low room temperatures.

Choosing the right power distribution route and power connector will help to reduce power distribution loss as much as possible.

6.3.2 -48V DC power distribution

In order to reduce the power loss of distribution, it is better to reduce the distance between the power supply and load. The voltage drop of power distribution units should be less than 0,5 V. The supervision card of DC distribution units should be of a low power consumption design (e.g. less than 20 W).

An "AC integrated" concept can be used to reduce distribution power and equipment space. With this concept the AC distribution is physically part of the DC power supply system rack.

6.3.3 AC/DC power systems

AC/DC power supply systems are typically most efficient at maximum loads but often run at half capacity due to reliability redundancy. At night or other periods of predictably low power usage, as well as when operating with equipment that is not fully configured, supply redundancy can limit loads on a single supply even lower - far less than of maximum capacity.

Power supplies rarely operate at the full-load condition for which they are usually designed. It is suggested that using energy management software to turn off some modules during periods of low usage will increase system efficiency.

Power supply vendors should define the system efficiency at different loads, including average efficiency and no-load power loss. The highest efficiency set point of a power converter is typically between half load and full load, and the recommended operating point is between 40 % and 80 % of the rated power output.

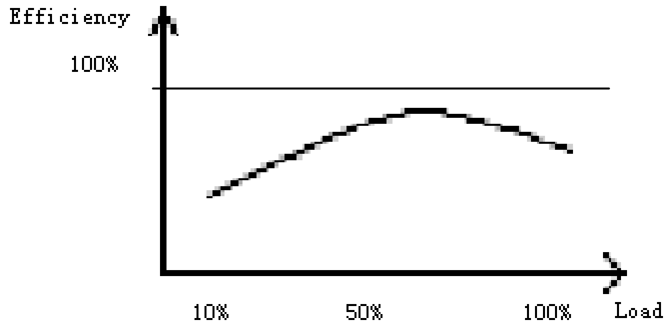


Figure 14: Efficiency of a typical AC/DC System

The efficiency of a power converter is normally quoted when working at 25 %, 50 %, 75 % and 100 % load condition and is typically above 90 % for loads higher than 50 %.

6.3.4 DC/AC power supply systems (inverters)

DC/AC power supply systems convert -48 V DC to 230 V AC. These are typically most efficient between 90 % and 100 % of the full load, but often run at half capacity due to reliability redundancy. At night or other periods of predictably low power usage, as well as when operating with equipment that is not fully configured, supply redundancy can limit loads on a single supply even lower - far less than of maximum capacity.

Power supply systems rarely operate at the full-load condition for which they are designed. It is suggested that using energy management software to turn off some modules during periods of low usage will increase system efficiency (it means that working modules will work close to the conditions for which they are usually designed).

Power supply vendors should define the system efficiency at different loads and consumption without load. The highest efficiency set point of a power converter is typically between half load and full load, and the recommended operating point is between 60 % and 90 % of the rated power output.

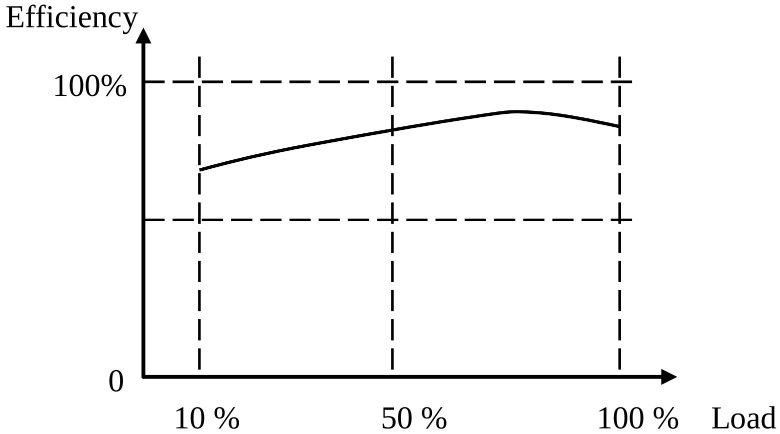


Figure 15: Efficiency of a typical DC/AC Power Supply System

The efficiency of a power converter is normally quoted when working at 25 %, 50 %, 75 % and 100 % load condition and it is typically above 90 % for loads higher than 60 %.

Figure 16 shows a DC/AC Power System that can be optimized and incorporated into the power system infrastructure schematic shown in figure 13.

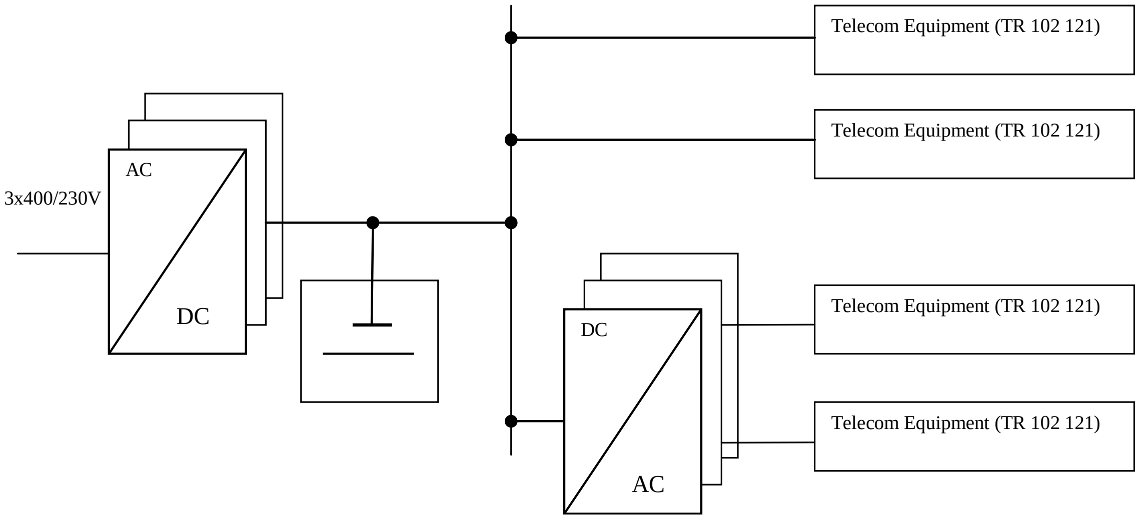


Figure 16: Typical DC/AC Power System connection in Telecommunication Centres

6.3.5 Diesel generator (Diesel GenSet)

As mentioned before in the present document, power consumption in telecommunication centres can vary and depends on many factors (power consumption of telecommunication equipment, temperature, etc.).

Diesel GenSets are typically most efficient between 80 % and 100 % of the full load, but often run at half capacity. Diesel GenSets rarely operate at the full-load condition for which they are usually designed.

Diesel GenSet manufacturers also recommend that this kind of equipment is not operated at low loads for long periods of time. For this reason is very important to choose an appropriately sized Diesel GenSet to avoid under-load working conditions. Operating a correctly dimensioned Diesel GenSet will also help to reduce CO2 emission and fuel consumption per kW/h.

In situations where a group of two or more Diesel GenSets are operated in parallel for power feeding of large high power consumption telecommunication centres, appropriate automatic controls with energy management software should be used. Software with automatic control functionality can be used to turn off some Diesel GenSets during periods of low usage, reducing consumption of electrical energy.

Where an automatic control mode of operation is employed to operate the appropriate number of Diesel GenSets, the benefits are:

- efficiency per GenSet is higher;
- group efficiency is higher;
- fuel consumption per kW/h is lower;
- fuel consumption for group is lower;
- number of working hours decrease per GenSet. It means that maintenance costs will be reduced and life time will increase (both are define for number of working hours);
- CO2 emission per kW/h is lower;
- CO2 emission per group is lower.

6.3.6 AC distributions

An "AC integrated" concept can be followed to reduce power cable loss and equipment space. In this concept the AC distribution is physically part of the power supply system rack.

6.3.7 UPS

Switch type and online uninterrupted power supply should be employed at telecommunication centres. Typical UPS efficiency is shown in figure 17.

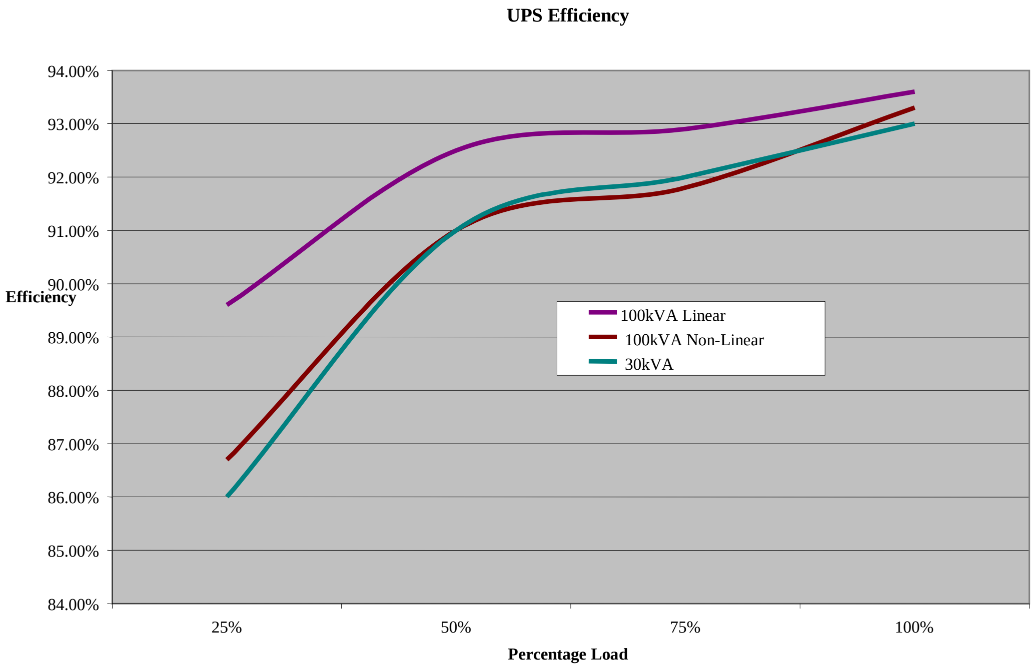


Figure 17: Efficiency of Power UPS Systems

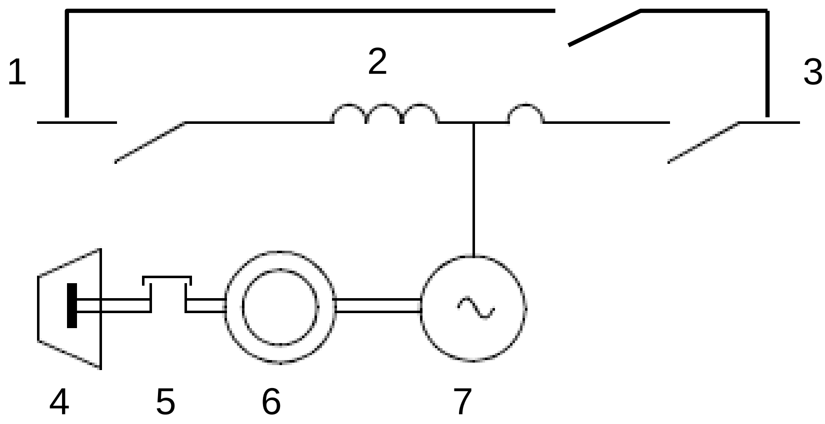
NOTE: Efficiency levels shown in figure 17 and table 1 assume a fully charge battery condition.

The minimum efficiency of a UPS is recommended to be no less than the values in table 1.

Table 1: Minimum efficiency of UPS systems

Capacity	1 KVA	2 KVA	3 KVA	6 KVA	10 KVA
Efficiency at mains power supply	>83 %	>85 %	>86 %	>88 %	>88 %
Efficiency at battery power supply	>81 %	>81 %	>82 %	>85 %	>85 %

As an alternative to static UPS the use of rotary UPS (see schema in figure 16) for critical power applications is also suitable. Such a UPS can be of particular interest at high loads (> 500 kVA) as for instance for powering data centres. In such systems a kinetic energy accumulator is used for energy storage. It replaces the common batteries used by static UPS. Rotary systems are generally more efficient than static UPS at higher power loads (>50 % of rated load). It is therefore important that such systems are planed for operation at high rate. The minimum efficiency of a rotary UPS is recommended to be not less than 90 %.



1) Input (mains).
2) Choke.
3) Output (Load).
4) Diesel Engine.
5) Electromagnetic Clutch.
6) Kinetic Energy Accumulator.
7) Synchronous Motor/Alternator.

Figure 18: Basic Principle Diagram of a Rotary UPS

6.3.8 Architecture comparison

ETSI proposes 2 main power interfaces to telecom datacom equipment, EN 300 132-2 [i.2] for DC -48 V, and EN 300 132-3 [i.3] for HVDC and AC from UPS < 400 V.

Efficiency comparison between DC 48V power supply, UPS and HVDC leads to the following results.

The comparison architecture basis for a DC system is provided on figure 19. The following three configurations have been considered for -48 VDC:

- centralized DC power plants with long DC distribution.
- decentralized -48V DC cabinets close to the equipment.
- centralized HVDC + decentralized converters HVDC/48V (equivalent to offline UPS + DC rectifiers - see note).

NOTE: UPS plus -48 Vrectifier has not been considered: in online mode the efficiency of some UPS systems can be poor due to many serial power conversions and battery recharging, in offline mode a UPS is almost equivalent to HVDC.

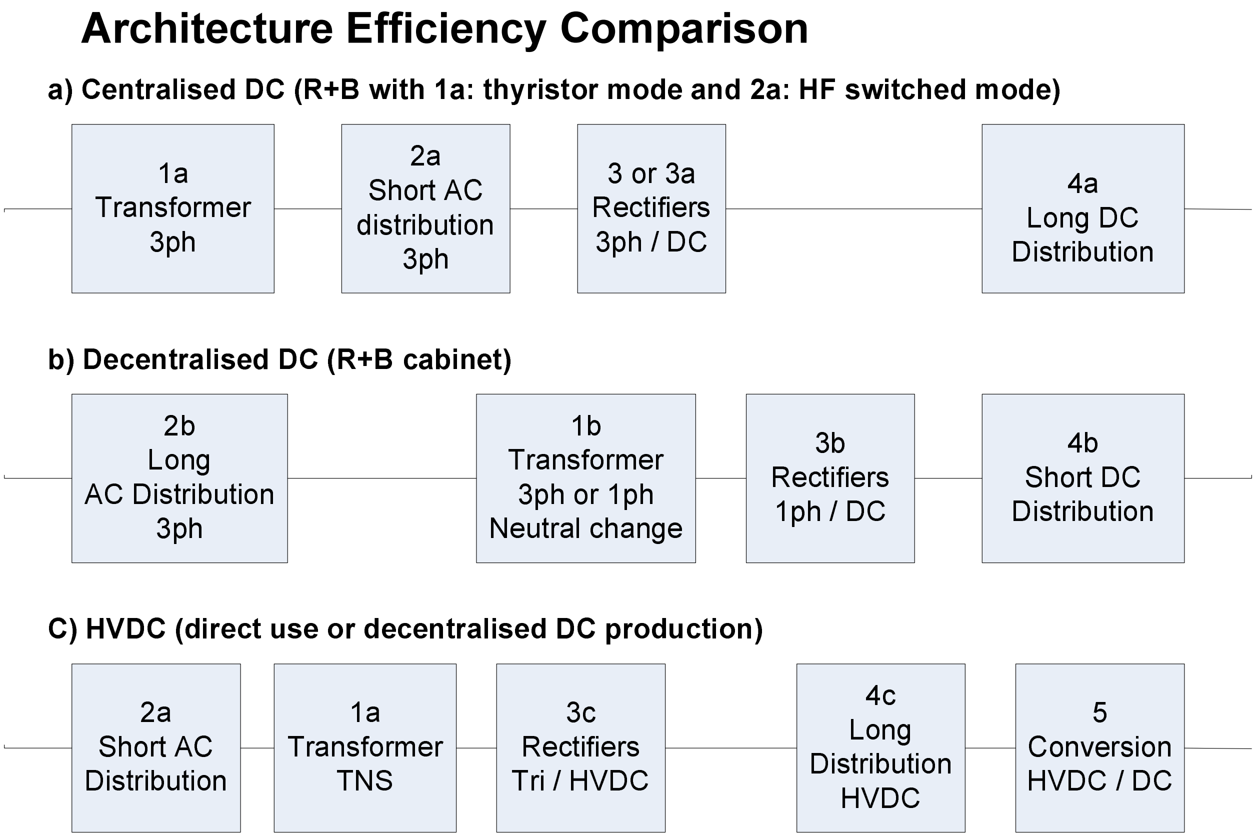


Figure 19: Architecture comparison basis

The efficiency calculations are detailed in annex D. This is the global efficiency between mains input and interface A (as described in EN 300 132 serie) at the input of equipment. It is based on a hypothesis that can depend on operators' buildings and integration of telecom systems. The absolute value can be discussed, but the relative comparison is relevant over a wide range of hypothesis.

TELECOM in DC:

Centralized thyristor rectifier	76 %
Centralized -48V DC	81 %
Decentralized -48V DC	83 %
HVDC + converter (or offline UPS+DC)	90 %

DATACENTER:

AC UPS (online)	90 %
HVDC	97 %

In a very big system with online UPS e.g. for data centres, the losses associated with dedicated cooling systems should be added. In the case of HVDC, dedicated cooling systems can probably be replaced by fans.

6.3.9 Battery

Battery manufacturers should provide battery charge efficiency of more than 95 % for valve regulated lead acid batteries. Battery charge management should adopt a two stage (boost charge stage and float charge stage) current limit charging method to recovery battery energy.

Battery reserve has a great effect on saving energy.

DC power consumption should be also taken into account when designing back-up time of batteries. This results in the battery recharge energy reducing, which reduces the number of rectifiers.

Operators try to reduce expensive diesel running time by using batteries. An increase of battery capacity can help to reduce the running time.

6.3.10 Batteries in outdoor enclosure

VRLA batteries are used in the socket area of outdoor cabinets with a thermal isolation box. Therefore it will be realizing the optimal operation battery temperature for a long life time till +25 °C.

Valve regulated lead acid batteries have to conform to EN 60896-21 [i.4].

In a floating mode operation, the battery can be kept charged at a voltage level corrected as a function of the temperature. The charging current is limited in accordance with the manufacturer's recommendations.

In a discharge mode operation, a disconnecting device can be used to isolate the battery from the load at the end of discharging when the value of low-voltage disconnection defined by the manufacturer is reached.

The compartment housing a vented battery, where gassing is possible during normal usage or over charging, should have adequate normal air ventilation to prevent the hydrogen/air concentration from exceeding 4 % by volume. See clause 4.3.8 of IEC 60950-1 [i.8] for evaluating the overcharging of a rechargeable battery and safety requirements for risk of ignition according EN 60950-22 [i.5] and EN 50272-2 [i.6].

New battery technologies (e.g. lithium ion or "high temperature batteries") which are able to operate safely within a wider ambient temperature range could be used. This has potential energy savings.

6.4 DC generators

6.4.1 PV systems as energy saving system

Connected to HVDC bus in data centres or connected to 48 V in telecom centres, photovoltaic system can reduce the consumption on the mains. Details are in TR 102 532 [i.9].

6.5 Energy aware design

The designer is usually concerned about the performance and reliability and can neglect to improve energy efficiency which is just as important to reduce environmental impact.

Design to real needs is important for optimisation. Important is the installation date power consumption report, power utility mains outage reports (number of main losses, duration of outage, etc.),Optimisation should start with the highest power consumer at a site.

6.6 Energy efficiency benchmark

Benchmarks relating performance to energy use in telecomm equipment is not widely applied. Embedding energy management units to implement energy efficiency measures in telecom equipment could increase the energy efficiency of telecomm equipment increasing "performance per watt", or other similar designation highlighting energy use.

6.7 Software or firmware techniques to reduce energy

With the rapid progression of computing power, programmers do not have as much financial incentive to optimize code as they do to release it to market. There are many useful codes in the software and although the hardware will allow it to run well, the programmers should make a program run more efficiently in order to avoid energy use.

The standby mode is the most well known method to reduce energy consumption when the client does not require the service (cf BBCoC for DSL and terminals). This technique is also well known for computers in data centres. The power may vary a lot with these kind of features, and precautions are needed on the power supply to avoid instabilities.

Another method to reduce power consumption is the Dynamic Spectrum Management defined in DSL forum (DSM). The principle is to dynamically adjust the power of DSL modulation depending of noise margin on the line due to its length and to other reasons.

The main target is to extend high speed DSL to a long line. There are 4 DSM levels (0 to 3) depending on the number of lines under DSM in a cable. The DSM reduces short lines disturbances.

The Mask On Demand (MOD) is one of the way to implement DSM.

6.8 Energy management unit

Develop built-in energy management units and corresponding control protocols to monitor, alarm if set points are reached and reduce the power consumption of equipment, while meeting reliability and performance requirements.

The energy management unit should monitor system performance requirements according to equipment status and adjust the system performance level by changing the system running status to effectively reduce their power consumption, i.e. configure those parts, such as devices, circuits or cards of the unused service and switch them into a more energy efficient mode, e.g. standby mode or off.

6.9 Increase efficiency of components

Telecomm equipment should have as standard energy efficiency modes that reduce the energy consumption to a minimum while the equipment is not in use or in a standby mode.

To make the operating energy usage clearer for the end user an energy usage per mode should be established so that comparison can be made.

Equipment should have operating modes, suitable for the equipment operation that allows the equipment to go in to off, standby, reduced operation and full operation modes.

Each time the power supply to equipment is rectified or transformed there are energy losses. Reducing the number of occasions that power is transformed or rectified will reduce the energy losses. The monitoring software should be able to record power consumption and provide information on its use over time.

6.10 Sub-metering

If equipment areas are not sub-metered it can be difficult to determine if the area is being operated at its optimum power usage. By ensuring that each discrete area is sub-metered and even each system, i.e. the transmission equipment, switch equipment, the cooling system, the areas can be monitored and benchmarked to determine if energy is being wasted.

Sub metering on an AC and DC level is important to get reliable input data for an energy aware design. It is possible apply the sub metering only at selected sites and not at all sites to gather the data required.

6.11 Subrack fans

Subrack air fans are being incorporated in the design of subracks due to the heat density of the subracks or due to the number of subracks installed in a single rack. These fans generally operate at low speed up to a certain temperature related set-point above which the fans will operate at high speed. This mode of operation is not the most energy efficient mode of operation. If the fans were to operate linear with the temperature, i.e. low speed when there is low temperature and high speed at maximum temperature the energy required and the costs can be reduced plus the life of the fans can be extended. Also the noise emitted by the equipment would also be lower.

Annex A: Use of reference models

A.1 Central office node site, AC and DC consumption

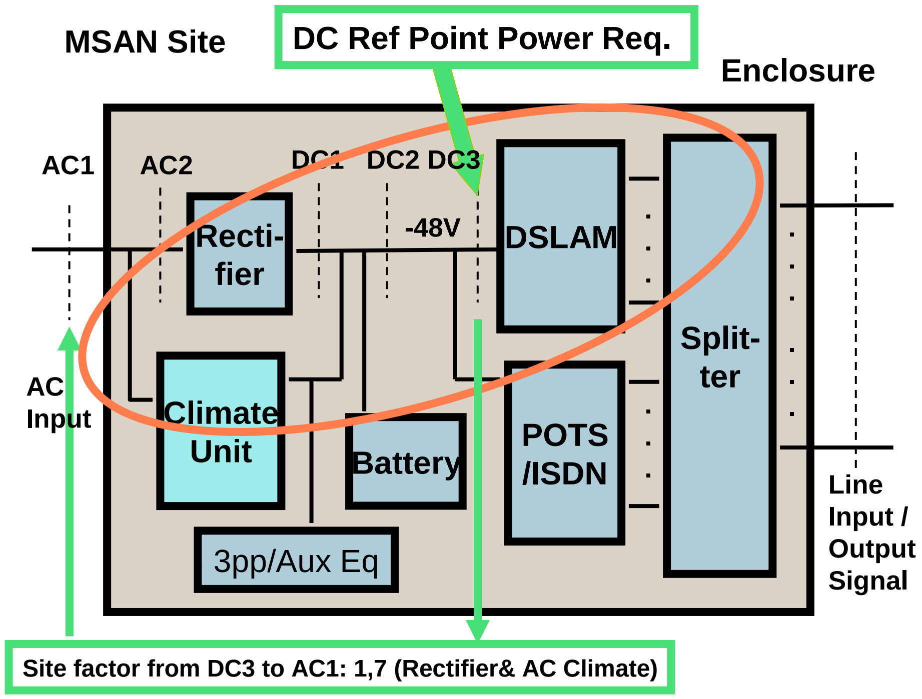


Figure A.1: DSLAM node site reference model

The power consumption of the site is much higher at the AC input, than at the -48 V input to the telecom devices, as the AC consumption also includes rectifier losses and climate system consumption, which are basically proportional to the DC power consumption. The power consumption relation at DC and AC interfaces is expressed as a site factor. The site factor is then used to estimate the impact on AC consumption from the DC consumption of the different telecom equipment that are hosted at the site. The typical site factor from -48 V interface (DC 3) to mains input interface (AC1) is 1,7, based on a rectifier efficiency of 85 % and Air Condition climate equipment with COP value = 3, which is a typical annual average value for a Central European site. See clause 5.4.5, figure 8, Frankfurt climate model.

Annex B: DSL simulation results

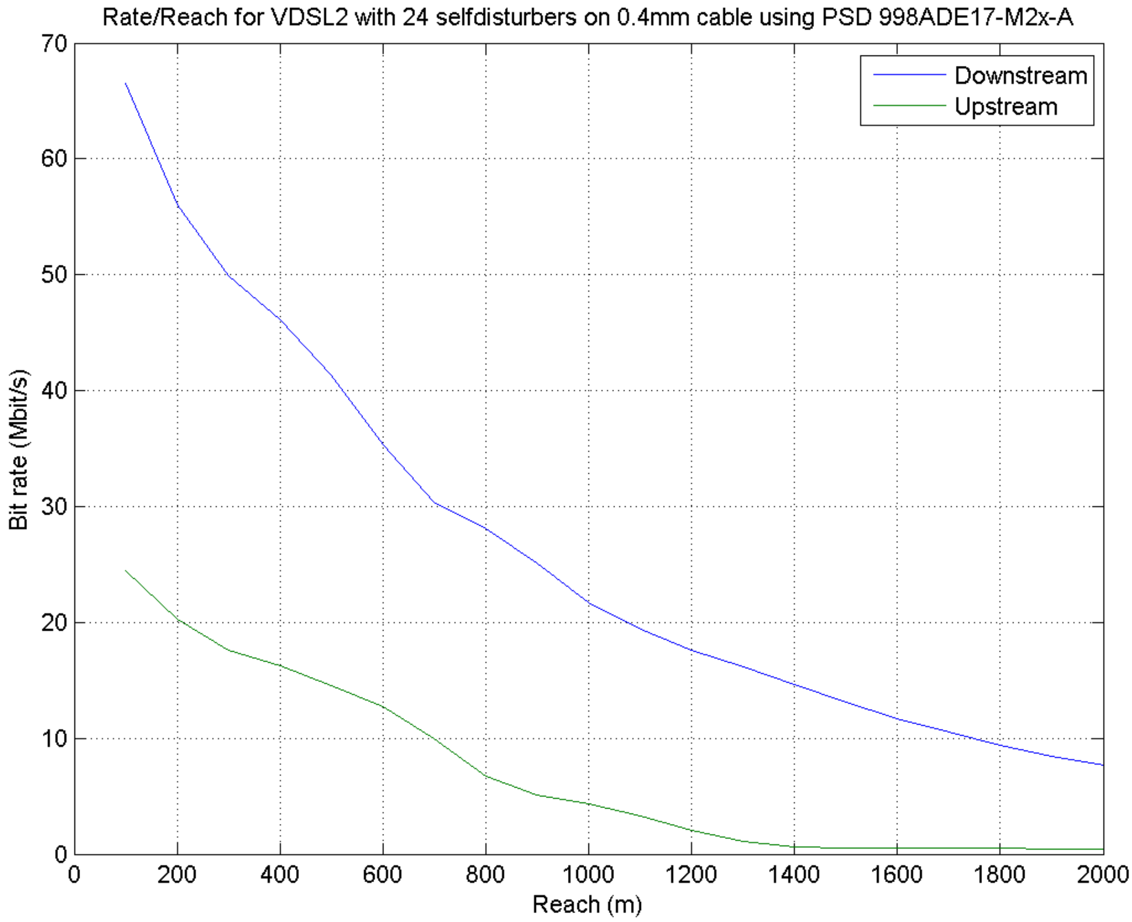


Figure B.1: VDSL2 simulation results with 24 self-disturbers on 0,4 mm cable, upstream and downstream results.

Annex C:
DSLAM power consumption and performance

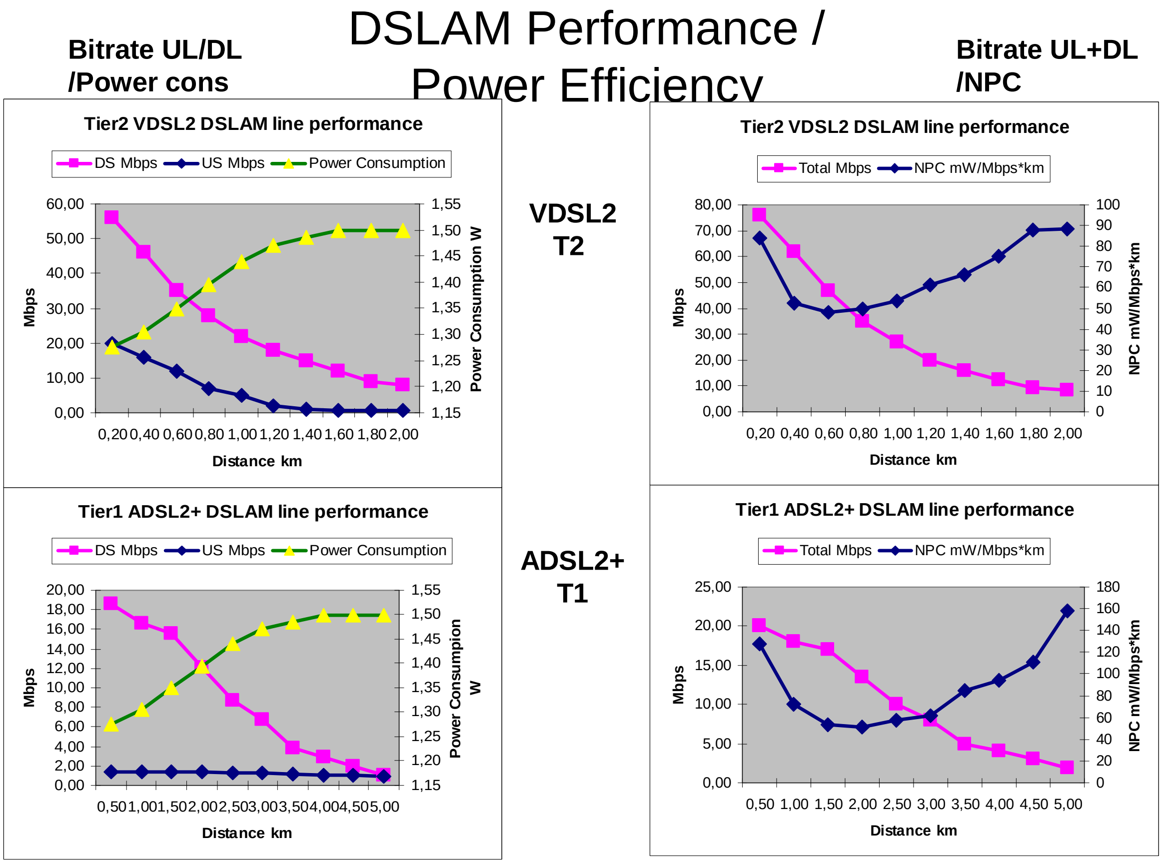


Figure C.1: DSLAM performance, power consumption and NPC

Background data for figure C.1:

- All comparisons done in the power dimension.
- Performance data source is an Ericsson simulation with 24 disturbers.
- Maximum power consumption values according to clause 5.3.5. Reduction of power consumption at shorter distances is based on estimation.
- All power consumption values at full power mode, L0. Low power modes not considered operable.

Annex D: Efficiency calculation of different power architecture

The following table gives the basic calculation of efficiency for different power chain architecture:

- 48 V with centralized thyristors rectifiers.
- 48 V with centralized HF rectifiers.
- 48 V with decentralized HF rectifiers.
- HVDC with HVDC/48 converters.

In table D.1 each line gives individual loss or efficiency. Equipment columns, contain figure 1 when the item is in the chain.

The EFFICIENCY line gives the global efficiency calculated as the product of individual efficiency in serial in the power chain.

Table D.1

Data	Ref	Power (kW)	length (m)	voltage (V)	Losses (V)	Losses	Efficiency	Thyristor	central HF Rect.	Decentralized	HVDC
3 phases transformer	1a	50		400	ohmic + iron	4,0 %	96 %	1	1		1
single phase transformer	1b	20		230	ohmic + iron	6,0 %	94 %			1	
Short AC distribution	2a		20	230	2	0,9 %	99 %	1	1		1
long AC distribution	2b		100	400	5	1,3 %	99 %			1	
Thyristor rectifiers	3	50			PF=0,6 ---> iron losses		85 %	1			
centralized HF rectifiers	3a	n x 5 à 10					91 %		1		
decentralized HF rectifiers	3b	n x 1,5 à 4					90 %			1	
centralized HVDC rectifiers	3c	50			3 phases PFC		96 %				1
Long 48 V distribution	4a		100	54	3,3	6,2 %	94 %	1	1		
Short 48V distribution	4b		25	54	0,6	1,2 %	99 %			1	
Long HVDC distribution	4c		100	380	5	1,3 %	99 %				1
HVDC/54 V converter	5						95 %				1
EFFICIENCY								**76 %**	**81 %**	**83 %**	**90 %**
Voltage loss in distribution											
Cupper resistivity at 40 °C	20	mV/mm²/A									
	outputs (A)	section (mm²)	distance(m)	voltage loss (V)							
cabinets	50	80	25	0,6							
centralized 48 V	500	600	100	3,3							
centralized 48 V	120	120	25	1,0							

Annex E: Bibliography

1) Company Environmental Procedures:

- ISO 14001:2004: "Environmental management systems - Specification with guidance for use".
- ISO/TR 14062:2002: "Environmental management -- Integrating environmental aspects into product design and development".
- IEC Guide 114 (Ed 1.0, 2005-05): "Environmentally conscious design - Integrating environmental aspects into design and development of electro technical products".
- ECMA-341 (2nd Edition, December 2004): "Environmental design considerations for electronic products".

2) Sources used in clause 5.2:

- Ericsson (internal report) Data on Power consumption of telecom systems.
- ESTIMATING TOTAL POWER CONSUMPTION BY SERVERS IN THE U.S. AND THE WORLD Jonathan G. Koomey, Ph.D, Staff Scientist, Lawrence Berkeley National Laboratory and Consulting Professor, Stanford University. Final Report, Feb 15 2007.
- EPA Report on Server and Data Center Energy Efficiency. On August 2, 2007 and in response to Public Law 109-431 (available at: http://www.energystar.gov/ia/products/downloads/Public_Law109-431.pdf) the U.S. EPA ENERGY STAR Program released to Congress a report assessing opportunities for energy efficiency improvements for government and commercial computer servers and data centers in the United States. Please note that the present document is considered final and therefore, EPA is not taking any additional comments on the report at this time.Energy consumption by consumer Electronics in U.S. Residences. Kur W. Roth & Kurtis McKenney. TIAX LLC. TIAX Reference: D 5525.

History

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