



**Environmental Engineering (EE);
Safety Extra Low Voltage (SELV) DC power supply network for
ICT devices with energy storage and grid or renewable energy
sources options**

Reference

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Foreword

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

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

With the massive development and convergence of Telecom and IT, there are more and more customer Premises Equipment such as ICT devices terminals and home network. Each of them requires an electric adapter and an AC plug to be powered. That creates a forest of cables and energy losses, so the need of mutualising power at the level of a room with a SELV DC network has appeared with the benefit of reducing the amount of adapters and plugs, reducing by the way quantity of material used (plastic, copper, electronic) and thus reducing electronic wastes.

In addition this will allow simpler reuse of the output of this common power supply for new ICT devices by using the universal power adapters for fixed devices as standardized by ETSI and recommended by ITU-T. There would also be a significant saving on power consumption from a better efficiency on a wide range of power and reduced no load power losses.

For each of USB-A charger avoided by connecting a USB-A detachable charging cable to the DC network, it has been roughly assessed for 1 Billion units, a potential saving of 100 000 tons of power supply material, and 2 TWh consumption, 1 million tons of CO2 emission each year.

Other benefits are offered to users in the zone or room where the SELV DC networks operate such as autonomy by the battery and grid energy cost reduction by using renewable energy sources, PV being the easiest to install having a very long lifetime.

Moreover, it is an enabler and extender of telecom service use in emerging countries where there is no electricity grid and it brings at the same time some additional electricity for other use such as lighting with LEDs.

Finally, the SELV distribution is the natural extension in rooms of the Building 400 VDC distribution when it will be widely spread as it seems to be a useful complement to distribution AC to offer more resilience to disaster and improve efficiency and use of renewable energy at building level in smart cities and micro grids.

1 Scope

The present document specifies a Safety Extra Low Voltage DC power supply unit for powering at home or in public area (stores, hotels, railway stations, etc.) any ICT devices equipped with DC input or any ICT adapter with DC input compliant with EN 300 132-3-1 [i.17].

It gives information on:

- architecture with multi-outputs or DC network and powering area (room, zone);
- input and output voltage interface;
- configuration of interface voltage;
- optimization of efficiency and cost by mutualising several devices on the same DC power system;
- compatibility with future building using the up to 400 VDC power interface defined in EN 300 132-3-1 [i.17];
- integrated power shutdown management, to save energy as much as possible;
- reliability;
- EMC and resistibility;
- power autonomy to enable standalone power of ICT in case of crisis (electric grid failure, climatic crisis, earthquake, etc.);
- possibility to use renewable energy especially in emerging countries with no grid or of poor quality grid: which input interface, and how to make the sizing?
- possibility to power devices other than ICT such as low power light which highly increases life quality and sustainable development;
- some information on product safety;
- ecodesign principles with assessment of gains in mass of material use, energy and CO2 emission.

The present document also gives an overview of other existing standards in the field.

The detailed description of power generators and power converters or controllers are out of the scope.

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 referenced 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.

Not applicable.

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] Recommendation ITU-T L.1000: "Universal power adapter and charger solution for mobile terminals and other hand-held ICT devices".
- [i.2] Recommendation ITU-T L.1001: "External universal power adapter solutions for stationary information and communication technology devices".
- [i.3] Recommendation ITU-T L.1002 "External universal power adapter solutions for portable information and communication technology devices".
- [i.4] "Code of Conduct on Energy Efficiency of External Power Supplies": European Commission Directorate-General JRC Joint Research Centre Institute for Energy and Transport Renewable Energy Unit.
- [i.5] ETSI EN 302 099: "Environmental Engineering (EE); Powering of equipment in access network".
- [i.6] Recommendation ITU-T K.74: "EMC, resistibility and safety requirements for home network devices".
- [i.7] IEC 61000-3-2: "Electromagnetic compatibility (EMC) -Part 3-2: Limits -Limits for harmonic current emissions (equipment input current less than or equal to 16 A per phase)".
- [i.8] IEC 60038: "IEC standard voltages".
- [i.9] IEC 60950-1: "Information technology equipment - Safety - Part 1: General requirements".
- [i.10] ETSI EN 300 132-2: "Environmental Engineering (EE); Power supply interface at the input to telecommunications and datacom (ICT) equipment; Part 2: Operated by -48 V direct current (dc)".
- [i.11] IEC 60896 series: "Stationary lead-acid batteries".
- [i.12] ETSI ES 202 336 (all parts): "Environmental Engineering (EE); Monitoring and control interface for infrastructure equipment (Power, Cooling and environment systems used in telecommunication networks)".
- [i.13] IEC 60364-4-41: "Low-voltage electrical installations - Part 4-41: Protection for safety -Protection against electric shock".
- [i.14] IEC 62430: "Environmentally conscious design for electrical and electronic products".
- [i.15] ETSI TS 103 199: "Environmental Engineering [EE]; Life Cycle Assessment (LCA) of ICT equipment, networks and services; General methodology and common requirements".
- [i.16] Recommendation ITU-T L.1410: "Environmental impact Assessment method for goods network and service".
- [i.17] ETSI EN 300 132-3-1 (V2.1.1): "Environmental Engineering (EE); Power supply interface at the input to telecommunications and datacom (ICT) equipment; Part 3: Operated by rectified current source, alternating current source or direct current source up to 400 V; Sub-part 1: Direct current source up to 400 V".
- [i.18] IEEE UPAMD™ P1823™: "Universal Power Adapter for Mobile Device".
- [i.19] IEC TC 100: "Project P1683 of Technical Specification of "Universal charger for PC".
- [i.20] Recommendation ITU-T K.66: "Protection of customer premises from overvoltages and overcurrents".
- [i.21] ISO 11898-3: "Road vehicles -- Controller area network (CAN) -- Part 3: Low-speed, fault-tolerant, medium-dependent interface".

- [i.22] Recommendation ITU-T K.21: "Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents".
- [i.23] EU directive on charger efficiency and no load power Energy Star V2.
- [i.24] Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal.
- [i.25] IEC 60320-1: "Appliance couplers for household and similar general purposes - Part 1: General requirements".
- [i.26] ISO 14040: "Environmental management -- Life cycle assessment -- Principles and framework".
- [i.27] ISO 14044: "Environmental management -- Life cycle assessment -- Requirements and guidelines".
- [i.28] "The first thousand optimized solar BTS stations of Orange group, A very positive experience full of learning", Didier Marquet Orange et alii., IEEE Intelec 2011 Amsterdam.
- [i.29] "Spread of DC power in telecom/data centres and homes/offices with renewable energy and energy autonomy" Didier Marquet (Orange), Toshimitsu Tanaka (NTT-f), Kensuke Murai, Tanaka Toru, Tadatoshi Babasaki (NTT), IEEE/Intelec 2013 Hamburg.
- [i.30] Darnel study, "External AC-DC Power Supplies: Economic Factors, Application Drivers, Architecture/Packaging Trends, Technology and Regulatory Developments", Tenth Edition, Feb 2011.
- [i.31] GSMA 2010: "Green Power for Mobile", Bi-annual Report November 2010.
- [i.32] ITU-D: "ICT 2011 development outlook".
- [i.33] "New power supply optimised for new telecom networks and services Didier Marquet et alii, France Telecom CNET, Jean-Paul Gabillet et alii ALCATEL-CIT", IEEE Intelec 1999 Copenhagen.
- [i.34] Recommendation ITU-T K.85: "Requirements for the mitigation of lightning effects on home networks installed in customer premises".
- [i.35] IEC 62619: "Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for large format secondary lithium cells and batteries for use in industrial applications".
- [i.36] Emerge Alliance[®].
- NOTE: Available at: <http://www.emergealliance.org/>.
- [i.37] Green Grid Platform At Home voluntary organization in Japan.
- NOTE: Available at <http://ggpah.org/>.
- [i.38] GeSI-ITU-T Study 2012, An Energy-aware Survey on ICT Device Power Supplies.
- NOTE: Available at <http://www.itu.int/ITU-T/climatechange/report-ict-device.html>.
- [i.39] CENELEC EN 55022: "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement".
- [i.40] CENELEC EN 55024: "Information technology equipment - Immunity characteristics - Limits and methods of measurement".

3 Abbreviations and symbols

3.1 Symbols

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

I	current
P _u	Useful Power of the load
R	resistance
U	voltage

3.2 Abbreviations

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

AC	Alternating Current
ASCII	American Standard Code for Information Interchange
CAN	Controller Area Network
CMOS	Complementary Metal Oxide Semiconductor
CPE	Customer Premises Equipment
CPS	Common Power Supply
DC	Direct Current
DIN	Deutsches Institut für Normung
GGPAH	Green Grid Platform At Home
GHG	Green House Gas
HF	High Frequency
ICT	Information and communications technology
LCA	Life Cycle Assessment
MPPT	Maximum Power Point Tracker
MTBF	Mean Time Between Failure
NTT	Nippon Telegraph and Telecom
PC	Personal computer
PoE	Power over Ethernet
PSU	Power Supply Unit
PV	PhotoVoltaic
PWM	Pulse-width modulation
RH	Relative Humidity
SCCP	Short Chain Chlorinated Paraffins
SELV	Safety Extra Low Voltage
UCPS	Universal Common Power Supply
UPA	Universal Power Adapter.
UPAMD™	Universal Power Adapter for Mobile Devices
VAC	Volt in Alternating Current
VDC	Volt in Direct Current
XML	eXtended Mark-up Language

4 General architecture of a CPE SELV DC network

Many studies are showing the extension of the use of ICT terminals in Customer Premises all over the world. For example the ITU-D outlook [i.32] is showing that Telecom network and terminals are developing in Emerging countries faster than the electric grid.

For the mobile network a GSMA study [i.31] and for example an IEEE/intelec 2011 paper [i.28] have shown that the massive deployment would be more based on renewable energy and single legacy Diesel generator could be replaced by hybrid power system. As a consequence of this fast Telecom network development, there is an increased need of electricity in customer premises, that can bring at the same time more comfort and social benefit, such as low power consumption lighting for emerging countries. The universal adapter solution already promoted for powering ICT devices Recommendation ITU-T L.1000 [i.1], Recommendation ITU-T L.1001 [i.2] or Recommendation ITU-T L.1002 [i.3] ensures the compatibility with renewable energy systems such as those based on PV modules, either small system in SELV voltage and these Recommendations introduce compliance of the chargers with EN 300 132-3-1 [i.17] at building level. IEEE/intelec paper 2013 [i.29] is showing a possible start of wide spread of these solutions.

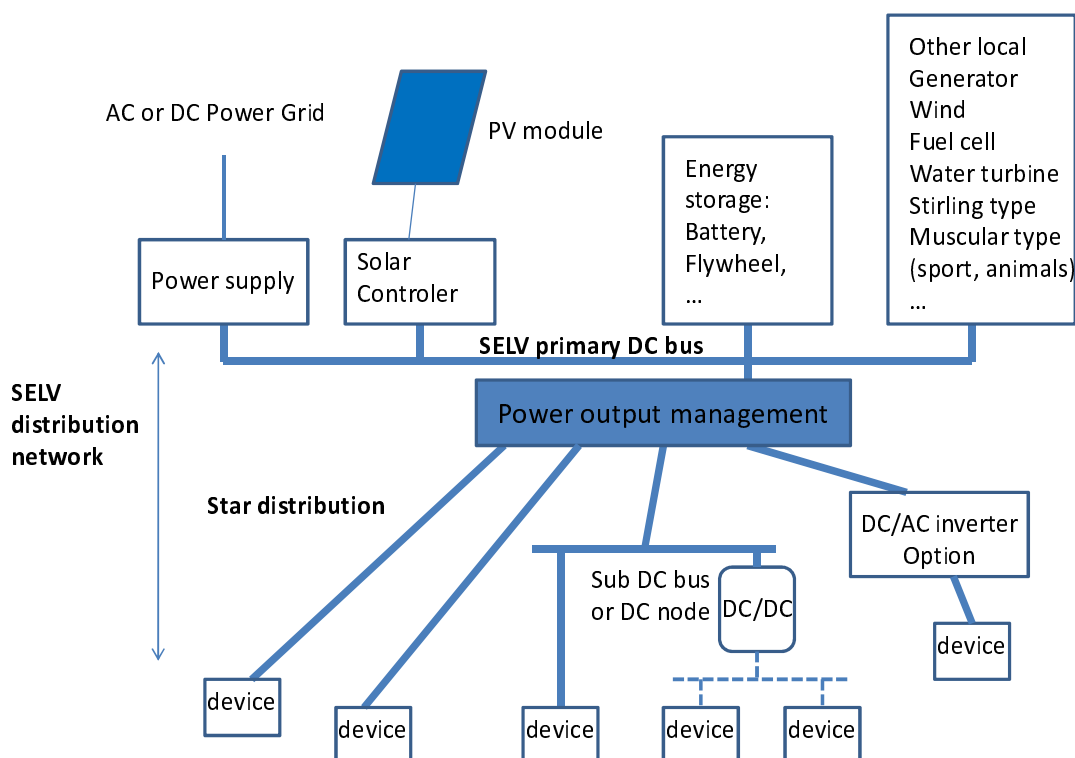
As in many homes there is not only one terminal but several, and because there is a need of shared charging points for users (public or private), it appears that a DC network solution could be an optimized solution. It was already stated as already presumed in IEEE/Intelec 1999 paper [i.33].

Other solutions based on AC inverter using for example DC from solar PV module or battery allow the use of AC adapter but the efficiency and reliability is poor. Even if the up to 400 VDC interface is possible for complete swap of the distribution inside buildings but it seems there is also a space for a more optimized and progressive zone or room lower voltage DC network. The best solution for safety is a SELV voltage lower than 60 VDC in compliance to IEC 60364-4-41 [i.13]. The DC voltage level, would depend on the environment where it is used (e.g. dry or wet). For maximal safety, it seems better to keep this limit for wet area not at the maximum value of 120 VDC. 30 VDC limit is even better for human safety if there is a serious risk of water ingress.

Considering the increasing need of security and availability of ICT, this solution can also in developed countries. Japan has an initiative on that in greengrid@home [i.37]. There will be compatibility with up to 400 VDC network.

In addition, a SELV DC network mainly for telecom, health and safety ICT can bring at the same time a back-up possibility for more autonomy and less failure of sensible ICT devices while reducing the use of fossil energy resources and the CO₂ emission and other environmental or human risks.

Figure 1 is presenting the general architecture of a home SELV DC grid able to power home CPE equipment. It can also be applied in other customer premises: small office, commercial or business building. Not all possible voltage converters are represented, refer to DC distribution network description list in this clause.



NOTE 1: This architecture can include also an optional reverse power feeding module connected to the DC distribution network compliant with EN 302 099 [i.5].

NOTE 2: DC/DC Converter on sub DC bus or DC nodes are called POL.

Figure 1: Architecture of a SELV DC power system and distribution grid solution in CPE

This architecture takes into account other studies and ongoing standardization:

- Darnel study on charger and power supply, [i.30]
- Emerge Alliance[®] 24 V distribution for lighting and ICT device in office or commercial building rooms [i-36]
- ITU-T SG5 L.1000 [i.1], L1001 [i.2], L.1002 [i.3]
- IEEE UPAMD[™] P1823[™] [i.18]
- IEC TC 100 P1683 [i.19] on universal interface for computers [i.19]
- SELV home power distribution in Japan Green Grid Platform At Home [i.37]

Refer to annex B for more details.

The power generating system includes:

- A primary SELV DC bus where are connected: energy storage, primary power supply using DC or AC grid, generators and output power distribution management system.
- A SELV DC distribution network feeding power to loads directly or through DC/DC and sub distribution.

NOTE 1: The input liaison of the controller to the external sources (grid, PV, wind generator, etc.) is out of the scope of this CPE primary distribution.

NOTE 2: The DC grid is compliant with EN 300 132-3-1 [i.17], and should be compliant with future standards for DC safety and DC plugs under definition by IEC.

The SELV DC distribution network includes:

- SELV DC power output management including protected outputs against short-circuit and optional limitation of power or energy consumption.
- Possible DC subdistribution of different types: bus, star.
- Connection nodes.
- Optional Voltage DC/DC adapter or converter that can be dedicated or common to several devices: it can be floor level converter (e.g. 24/12 V) or final POL converter (e.g. 12/5 V).
- Optional DC/AC inverter for using existing AC adapters of devices.
- Optional DC/DC step-up converter (e.g. 24/300 V) for using existing DC adapters of devices.
- Plugs for detachable power cable towards devices.

NOTE 3: The power output management and the battery management have to share information. They can be designed as a common unit.

NOTE 4: Due to possibility of DC/DC conversion in this network there can be more than 1 SELV voltage used to optimize the copper section and voltage drops and losses on the cables.

4.1 Power distribution efficiency and voltage choice considerations

A detailed study in annex A is showing the relation between the voltage, the power and the cable section and length.

It appears that 5 V is clearly too low a voltage for power higher than 10 W, 12 V or 10 - 15 V range could be convenient till 100 W for lower distance than 10 meters as it is in small vehicle for DC sub-network allowing reuse of common accessories manufactured for car.

It should be noticed that 24 V has been chosen for bigger vehicles such as vans, and that manufacturers have considered higher voltage for high class vehicles equipped with high power comfort equipment. After a long trend to 36 V or 42 V, the new trend in car industry is 48 V with dual battery 12 V lead-acid for starter, 48 V for other accessories.

In fixed or mobile homes 12 V is already very common for lighting with incandescent bulbs or LED lights and for small accessories with motors (fans, etc.). For large working zones or office rooms Emerge Alliance [i.36] is promoting 24 V.

A good compromise could be also a voltage range of 18 V - 28 V that match the common voltage range of battery by using two "12 V" blocs in serie and a 24 V solar panel voltage.

Power over Ethernet is based on voltage up to 60 V, but such a high voltage can create some complications for battery and single PV panel solution for only hundreds of watts. PoE is already standardized and is based on specific cable for Ethernet and worldwide standardized connector. However, thin copper pairs may not be the best solution for long life time in salted environment and there can be over cost to use communication cables for power purposes.

The 48 V voltage has the advantage of compatibility with telecom equipment EN 300 132-2 [i.10], but such voltage could be a little bit too high for small PV systems as explained for Ethernet PoE. It is not well adapted for small battery capacity as it requires more cells in series to manage than 12 V or 24 V.

New single PV panel of some hundreds Watts have voltage of about 50 V but the battery regulator can in general adapt the output voltage to 12 V or 24 V battery.

If AC is required, a wide range of inverters using either 12 V, 24 V or 48 V exists.

Energy efficiency and cost are maximized by reducing the number of conversion stages and a battery for small power system (< 1 kW) using a reduced number of cells whatever is the technology, so using 12 V or 24 V is very common in small PV systems. Maybe a 12 V system with possible extension to 24 V could be a solution. It can be also a good choice for compatibility with car voltage and many existing fixed or portable equipment. It is also well suited to small energy systems. There can be a possible 3 wire distribution in 12 V and 24 V with or not common return.

Figure 2 gives an example of possible implementation with two SELV DC voltage levels for multi-floor home:

- A 24 V battery bus voltage (e.g. 18 V - 28 V) for home distribution
- A constant voltage (chosen between 12 V and 14 V) for room distribution

If 48 V is required for PoE or telecom reverse power feeding with power interface as defined in EN 302 099 [i.5], as it is not a general case, it could be considered as a specific load and does not impact the primary bus and the DC network voltage choice.

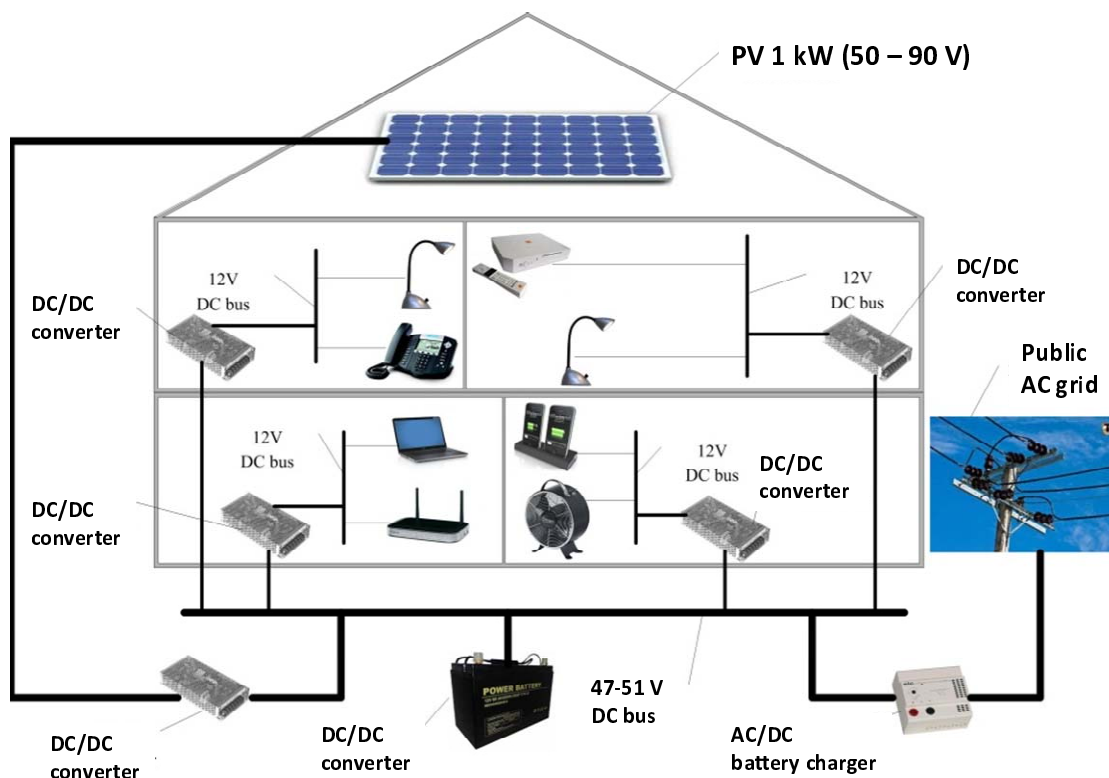


Figure 2: Example of possible SELV network implementation with two SELV voltage levels: home 48 V and room 12 V

For higher power, 48 V or 60 V and even higher voltage would be preferred to reduce cable section inside home distribution (see clause 4.7.3) and are convenient as large PV modules are working at 50 V or more voltage. It would allow lighter battery blocks as capacity can reach some hundreds of Ah and tens of kg even in Lithium technology.

4.2 Efficiency targets for element of the DC power supply network solution

The loss in cable should not be higher than 5 % of load use. Detailed calculation is in annex A.

AC or DC grid power supply module

The efficiency and no load of primary AC/DC power supply or DC/DC adapter modules used on this SELV DC network should comply with values defined for AC/DC adapters in table 1. The efficiency of power supply from AC or DC grid should follow latest Code of Conduct on Energy Efficiency of External Power Supplies [i.4] Version 5.

No load power should be lower than 30 mW and lower than 150 mVA.

NOTE 1: Comparison made on 4 loads 25 %, 50 %, 75 % and 100 % on a set of individual power adapters of 5 W - 20 W and a common power supply in the SELV grid have shown a gain of about 10 % inefficiency by using a power supply of more than 60 W. There is also an additional gain due to less no load power consumption.

NOTE 2: For higher AC/DC power system of some hundred of W used in server, there can be even more gain, because power supply efficiency can reach more than 90 %.

Battery efficiency

Self discharge of battery or any other energy storage should be lower than 1 % per day from 0 °C to 45 °C when the battery state of charge is below 90 % of its capacity.

Energy efficiency of cycle charge/discharge should be higher to 80 %.

Battery charge control

The battery charger controller for local sources (PV, wind, etc.) has an efficiency higher than 95 % for power ranging from 10 % to 100 % of the generator. The controller power consumption should be lower than 1 W in standby mode.

It is recommended to use a MPPT controller for solar module or wind generator.

On latitude lower than 30 degree, the MPPT is not necessary.

NOTE 3: An on-off regulation is to be avoided, as it will create additional small cycles charge-discharge ageing the battery. A floating solution is much better in that respect. This is the case for PWM and MPPT charge controller.

DC/DC optional module in final subdistribution

The DC/DC optional module are used:

- from battery voltage (e.g. 24 V, 36 V, 48 V, 60 V) to room DC network (e.g. 12 V, 24 V) with efficiency higher than 90 %
- in final conversion to useful voltage (e.g. 12/5 V USB-A POL DC/DC converter)

In all cases, no load power should be lower than 30 mW.

The efficiency should be calculated at loads 10 %, 25 %, 50 %, 75 % and 100 %.

The insulation is not required.

4.3 Power expendability, modularity and power regulation

4.3.1 Modularity and Power expandability

The architecture is designed modular which requires some precautions.

Primary bus:

It should be built to accept higher power and current than one module is able to give in order to allow expendability.

Power modules or sources

New modules as depicted in figure 1 can be connected to the primary DC bus in parallel mode providing the global current and power limits are respected for the bus and connectors.

The AC/DC source are equipped with AC plugs either using IEC 60320-1 [i.25] connector or an intermediate backplane to have only one AC plug for several AC/DC modules.

NOTE: The home or office 400 VDC sockets and plugs of current lower than 10 A are under standardization in IEC.

Battery

There can be extension from 12 V to 24 V by serial blocs, and of capacity by putting battery in parallel.

The battery management matches the bus current and power limit with the battery capacity and type. There should be a clear configuration setting procedure and the default mode is a safe configuration. This is very important for safety operation and to get a long battery lifetime.

Grid power supply unit

There can be extension in the limit of the primary bus and respecting the battery current limit.

PV controller and panels

There can be PV extension in the limit of the controller, the primary bus and respecting the battery current limit.

That means that input PV modules should respect input voltage and current of the controller.

PV panels in parallel work at the same voltage.

Other sources

The limit conditions are the same as PV.

Loads

The loads are limited by the maximum current allowed in connectors and in the distribution and by output protection. The battery can also imposes its limit.

The autonomy of the system can be also a limit. Normally to ensure long lifetime of the battery, the overall load expressed in current should not be higher than $C/20$, where C is the nominal capacity of the battery at the corresponding discharge rate.

4.3.2 Transient power regulation

Modern ICT are being designed to dynamically optimize their energy performances. Their consumption is more and more variable and related to the dynamical behaviour (e.g. service, bit rate, etc.). The power distribution will then experience loads power transients on all the power range. So the voltage and current regulation should be fast and precise enough. Typically considering electrolytic capacitor at the input of device, a typical regulation time of 20 ms to recover normal voltage range would be convenient.

The considered AC input of AC/DC PSU is in the range defined in IEC EN 60038 [i.8] nominal voltage range.

4.3.3 Voltage regulation, ripple, noise, inrush current

The SELV DC voltage distribution should provide a clean power. So the ripple are limited, regulation to dynamic load change is defined. The battery sizing and cable impedance is also defined for limiting inrush current effect providing these inrush currents are limited. Absolute or relative values are given in table 1.

Table 1: Regulation, ripple, inrush current

Power characteristics Interface	Voltage regulation	within ± 5 % @ rated voltage
	Ripple/Ripple noise	within ± 2 % @ rated voltage
	Current limitation of AC/DC charger	Controlled to match battery limitation and recharge curve
	Dynamic characteristic	Under study
	Inrush current characteristic	Under study
	Start-up characteristics	Under study

The inrush current and big load variations can create a voltage disturbance for other loads, but also for sources controller and regulation on the DC bus system when there is no battery or when the battery is ageing and its impedance is becoming higher.

Low frequency ripple measurement method is measured with an oscilloscope on an electrolytic capacitor of 47 μ F and a HF capacitor of 100 nF in parallel which simulates power input stage of ICT/telecom equipment.

4.4 Reliability and maintenance

4.4.1 MTBF

The MTBF of battery should be higher than 100 000 h over the life time period (see clause 4.7.1 ecodesign and clause 4.7.2 lifetime).

NOTE: MTBF is supposed constant excluding youth failures and end of life failures.

The MTBF of power electronic should be higher than 100 000 h.

Further studies are required depending on distribution configurations and power sources reliability.

4.4.2 Failure detection and replacement

The replaceable elements are the following:

- batteries;
- power modules;
- output high power connectors for DC distribution with screw for cable and connector replacement;
- replaceable fuses or circuit breakers.

The following list gives some possible fault detections leading to alarms (LEDs, or messages):

- Low battery threshold
- Very low battery threshold corresponding to imminent disconnection of load
- Battery voltage too high
- Battery loss of capacity over a defined threshold Battery temperature too high (this indicates a risk of short lifetime)
- DC bus disconnected
- One output failure
- 24 h without solar input
- 24 h without mains input

NOTE: The alarms depends on options on the system (solar, mains, etc.).

If a remote interface is provided, it should be compliant with ES 202 336-1 interface [i.12].

4.5 SELV plugs discussion

Some ongoing-standards are trying to define the plugs at the device side in USB specification, in IEC project for PC [i.19], in IEEE UPAMD™ [i.18]. The last one is also considering the possibility of using the same plug for power supply side. The advantage is also the use of signal pins and a very compact design.

The legacy plugs used nowadays for non electrician users are:

- USB A: on PC side or on Recommendation ITU-T L.1000 [i.1] charger side or on some other devices. This plug is dedicated to 5 V and 1,5 A limited, maybe some more in future specification from USB association or in IEC standard. They have advantage of mixing signal pins.

- Car cigarette plugs are usually designed for typically 13,8 V (10 V - 15 V) - 10 A. Many ICT chargers are already compatible with these plugs and voltage. They have no signal pin.
- Caravanning 12 V (10 V - 15 V) plugs for at least 10 A, They are more compact than cigarette plugs and there is no signal pin. They exist in wall socket configuration, which is convenient for home distribution.
- Coaxial barrel plugs can reach 30 V - 6 A for PC recharge. They are rather used on ICT side.
- Barrels plugs with 1 pole as middle pin : they are safe 12 V - 5 A and maybe some more voltage. They are used on Universal Power Adapter in Recommendation ITU-T L.1001 [i.2] and L.1002 [i.3].
- HIFI speaker plugs. As they are specific to sound, there is a risk of error that can create damages to equipment.
- DIN standard plugs, they are used in many configurations with different numbers of pins, and especially for medical power adapters with ratings till 60 V and some A.

NOTE: Banana plug are very common and can reach 25 A. But in general, they are not coupled and so not error free and not very friendly for a non electrician user. Some of them have the same shape and diameter as AC plug, so the error can be very dangerous and produce big damage to equipment.

Many other specific SELV plugs exists in industry, e.g. for battery recharge.

It should be better to create a brand new one and use existing one already common in cars (because used for ICT recharge).

There are also research or development of plug less surface contact interconnection as for portable tools or wireless energy transfer.

In the past there has been project in IEC to define SELV wall socket.

The preliminary conclusion could be to define a dedicated series of wall sockets for 12 V, 24 V or 48 V.

For 24 V, there may be some intention to do so in some industry Alliance such as Emerge Alliance [i.36].

4.6 EMC requirements

This clause covers the whole system and its elements (DC/DC or AC/DC converter, energy and storage sources power controller, DC output power management unit, distribution cables, DC plugs).

The EMC of Universal charger, CPS, generators and sources connected to the DC network is out of the scope.

NOTE: The power factor of AC supply should be compliant with IEC 61000-3-2 [i.7].

4.6.1 EMC emission and immunity

Recommendation ITU-T K.74 [i.6] includes all EMC, resistibility useful for the DC network, while ICT equipment EMC is out of the scope of the present document.

NOTE: Recommendations ITU-T K.21 [i.22] and ITU-T K.85 [i.34], EN 55022 [i.39], and EN 55024 [i.40] are included in the Recommendation ITU-T K74 [i.6].

4.6.2 Voltage regulation, ripple, noise, inrush current

The SELV DC voltage distribution should provide a clean power. So the ripple are limited, regulation to dynamic load change is defined. The battery sizing and cable impedance is also defined for limiting inrush current effect providing these inrush current are limited. Absolute or relative values are given in table 2.

Table 2: Regulation, ripple, inrush current

Power characteristics Interface on the SELV distribution and subdistribution	Ripple/ Ripple noise	Within ± 2 % @ rated voltage
	Voltage Drop characteristic	Fold Back or Intermittent drop at Minimum 105 % Maximum 135 % @ rated current
	Voltage regulation	within ± 5 % @ rated voltage
	Dynamic load characteristics	Regulation time < 20 ms
	Inrush current characteristic	The inrush current is the same as defined in EN 300 132-2 [i.10]
	Start-up characteristics	The DC/DC converter should reach their regulated voltage in less than 1 s. And they should stay below maximum limit in the starting time.

NOTE 1: The inrush current and big load variation can be a problem for other loads, and for sources controller and regulation on system with battery of too small capacity or battery at end of life to be replaced.

NOTE 2: The definition of measurement method are out of the scope of the present document.

4.7 Eco-Environmental specification

Environmental criteria are gaining importance in all aspects of electric and electronic equipment design.

Power supply including battery and renewable energy sources represent a very significant part of the whole weight and material used for the ICT. It is important to set requirements to materials and end of life compatibility so to minimize their impact on the environment.

A Life Cycle Assessment (LCA) should be established in compliance with ISO 14040 [i.26] and ISO 14044 [i.27].

NOTE: TS 103 199 [i.15] or Recommendation ITU-T L.1410 [i.16] could also be used.

The system should be compliant with IEC 62430 [i.14] Environmentally conscious design for electrical and electronic products.

The requirements of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (1992) [i.24] apply to the SELV DC battery described in the present document.

The amount of copper used in the power distribution has also to be compared between SELV voltage solution and common solution at higher voltage in AC distribution for example (see clause 4.7.3).

4.7.1 Ecodesign

Ecodesign has increased in importance due to full life cycle environmental impact considerations (GHG emissions and waste material).

Environmental criteria for electronic goods key domain areas cover eco materials, reuse, recycling and design considerations.

It is recommended that due consideration is given to the environmental performance categories that are listed below:

- a) Environmentally sensitive materials:
 - Comply with regulations, which restrict cadmium, mercury, lead, hexavalent chromium, and selected brominated flame retardants.
 - Eliminate SCCP (Short Chain Chlorinated Paraffins used as flame retardants and plasticizers).
 - Eliminate paints and coatings that are incompatible with recycling or reuse.
 - For recycling purposes, identify environmentally sensitive components and hazardous materials.

b) Environmental impact:

- minimize size (fewer materials and components);
- user guidance - e.g. a reminder to unplug unused loads and power adapters or chargers.

c) Packaging:

The ICT sector as a whole will be reviewing various improvements concerning packaging to decrease waste and landfill.

- Recyclable packaging materials
- Separable packing materials
- Packaging 90 percent recyclable and plastics labelled
- Design for End of Life
- Declaration of recycled content.

4.7.2 Lifetime

The expected lifetime of the element of a DC network solution should be designed so that it is of sufficient duration to deliver waste reduction through extended normal use.

For distribution (cables, interconnections, protective devices): 20 years minimum.

NOTE 1: This is relevant considering the common 20 or 25 years warranty for PV modules, and AC distribution lifetime.

For electronic power converter: 10 years minimum.

For battery: 10 years minimum at 25 °C yearly average temperature considering one daily cycle of 25 % of the initial capacity. The end of life criteria being for example a loss of 50 % of initial capacity. The lifetime at 80 % capacity would be of at least 5 years at 30 °C.

NOTE 2: As temperature is a very important factor for battery capacity and lifetime, it is highly recommended to install the battery at a place of home or flat without lot of solar irradiation, no hot spot due to heating, and gas exhaust for safety. In hot climate a buried chamber with proper gas ventilation can be a solution.

Further studies are required to analyze the effects of various parameters e.g. temperature, use, on the lifetime values proposed in the present document.

Product longevity/life cycle extension topics are covered below:

- Availability of additional longer life warranty.
- Spare or replacement parts should be made available for five years as well as information on how to obtain the parts.
- The expected lifetime should be obtained in the following conditions:

Operation temperature and humidity	10 °C to 50 °C RH 5 % to 95 %.
------------------------------------	-----------------------------------

4.7.3 Copper used in distribution and energy efficiency

The assessment of copper can be done by choosing a configuration and efficiency e.g.:

- Max power of ICT 300 W
- Mean daily power < 100 W

- Voltage 230 VAC or 48 VDC
- Distribution length < 30 m

	Source to wall socket	Losses at device level	To device
AC home grid	3 x 1,5 to 2,5 mm ² copper distribution to each wall socket, from AC distribution board	< 1 % + 10 % In UPA	UPA plugged on the wall socket + detachable DC cable to device
DC SELV network	2 x 1,5 to 2,5 mm ² copper distribution to each wall socket from battery From DC distribution frame	5 %	No UPA, same DC cable to device

We have not accounted precisely the AC line from the AC input to meter + breaker on AC and earth line (in general > 25 mm²), and the DC line from PV panels in DC in general 6 to 10 mm².

We found at first order comparison 1/3 less copper volume in the home distribution in DC compared to AC. To be fair we should not account DC in addition to AC distribution, as the AC one would be not installed in new buildings.

Main reason are that in AC 3 wire are used, while 2 are sufficient in DC; the minimum cable section is 1,5 mm² in general as all plugs are sized for at minimum 8 A i.e. about 2 kW.

In AC losses are not in cable but in UPA, generally > 10 %.

In DC, 1,5 mm² distribution section from battery to load is sufficient for only 5 % annual losses from PV to final use in loads, and there is no UPA, so no additional loss.

Detailed calculations are in annex A.

4.8 Safety aspects

The safety of local generators and energy sources is out of the scope of the present document. They are covered in IEC 60364-4-41 [i.13] and the AC/DC and DC/DC power modules should be limited power source in accordance with the safety requirements of Recommendation ITU-T K.74 [i.6].

NOTE: EN 60950-1 [i.9] and Recommendation ITU-T K.66 [i.20] are included in Recommendation ITU-T K.74 [i.6].

Battery should be compliant with the applied test and safety standard corresponding to stationary use and their technology, e.g. Lead-acid Battery should be compliant with IEC 60896 [i.11] tests standard, Lithium or Alkaline battery should be compliant with IEC 62619 [i.35].

National regulations may override the content of the present document.

The power system adapter should have a safety circuit in order to prevent any heat generation, leakage of electricity, fire ignition, etc. in fault condition, especially because it is using a battery able of high short circuit current.

The DC interconnection, DC plugs should not harm the human body by heat generation, leakage of electricity, fire ignition, etc. during normal/abnormal usage. They should have sufficient endurance not to be easily damaged during normal use.

The detachable cable for ICT devices powering are not covered by the present document but specification can be found in Recommendation ITU-T L.1000 [i.1], Recommendation ITU-T L.1001 [i.2] and Recommendation ITU-T L.1002 [i.3].

Safety aspects of different possible combinations of adapters, detachable cables and device load to the SELV DC network are partially addressed and would be complemented in further steps.

All device and DC/DC POL adapters should be compliant with standards and regulations for battery equipped devices.

The detachable AC cable solution should be provided with a standard socket compliant with IEC 60320-1 [i.25] of type C13- C14.

The materials used in the DC network system for the enclosures should be of incombustible material to avoid any risk of fire. The connexion and disconnection at AC or DC plug can cause fire, so the plug should be of protected type.

4.9 Control/monitoring aspects

There is at least one local management unit for battery charge/discharge management and power output management.

A remote control-monitoring interface can also be offered for telemaintenance, or for some remote command, prevision of use, prevision of weather and available energy or autonomy, etc.

The remote monitoring and control interface should respect ES 202 336-1 [i.12]. In the future a specific information model could be defined in a new data information model (ES 202 336 series [i.12]). It could include the following data:

- Power production
- Source energy share in the production of DC power
- DC power consumption (in ICT or other equipment connected to this power system)
- Thermal parameters
- Alarms for remote support and maintenance (power equipment or subpart failure, battery failure or negative test, etc.)

Annex A: Loss and section design for SELV DC network distribution and example

Distribution Loss optimisation

The loss calculation in the following part of this annex shows that a voltage between 12 V and 24 V is compliant to high efficiency. 24 V is better for relatively long power line, 12 V has the advantage to cover many existing device and car voltage standard. +12, 0, -12 V, can be a compromise.

Loss in the DC cord is a key point. As the resistance is around 40 mohm per meter and per mm² and the loss is in RI^2 , it is easy to understand, that for the same cable, the voltage cannot reasonably stay as low as USB 5 V for the device power higher than 10 W. It is not efficient to power high current at low voltage as it will use a lot of copper (see details in the following). The other problem is that the voltage drop is too high for a voltage regulation required for proper operation.

This voltage takes into account the peak power required for charging battery compared to the operation power with charged battery (example of notebook or net book at 50 W to 100 W for battery charge and 15 W to 30 W in operation with charged battery). The time of operation in the different modes is quite different (a few hours at charge power and hundreds of hours at operation power).

This annex shows the detailed calculation of voltage loss and power loss on a defined power line depending on the device power and the power supply voltage output.

To simplify we have considered a constant voltage power supply output.

We have considered a different cable length (2 m cord set) and 10 m copper cable.

This means $2 \times 2\text{m}$ or $2 \times 10\text{ m}$ wires.

We have considered section of 1 mm² section not too thin, but still low cost and flexible.

Worse loss calculations are assumed at about 40 °C.

The equations used are the following:

$$R = r_0 \cdot 2l/s$$

$$RI^2 - UI + P_u = 0$$

$$\Delta = U^2 - 4RP_u$$

$$I = (U - \sqrt{\Delta}) / 2R$$

$$\text{Cable Voltage drop} = RI$$

$$\text{Cable Power Loss} = RI^2$$

$$\text{Relative Loss} = RI/U = RI^2/P_u$$

Where U is the output voltage of the UCPS, P_u the useful power on the load, R the resistance of the cable, I the current in wire, r_0 is the copper resistivity at 40 °C (approximated to $2 \cdot 10^{-8}$ ohm.m).

It can be seen that losses are proportional to R and to I^2 , $1/U^2$.

R is proportional to length l and to inverse of section 1/s.

It is more efficient in order to reduce the losses, to increase the voltage rather than increase the copper section.

A voltage between 12 V and 24 V should be a good choice.

Case 1: length 2 m

In the case of 2 m cable, figure A.1 shows the effect of power on voltage drop with 5 V and 12 V power supply. Practically, the voltage drop should stay below 5 %, which limits the useful power on the load at 15 W in 5 V and 80 W in 12 V. With 3 % loss, these limits are around 5 W in 5 V, and 50 W in 12 V.

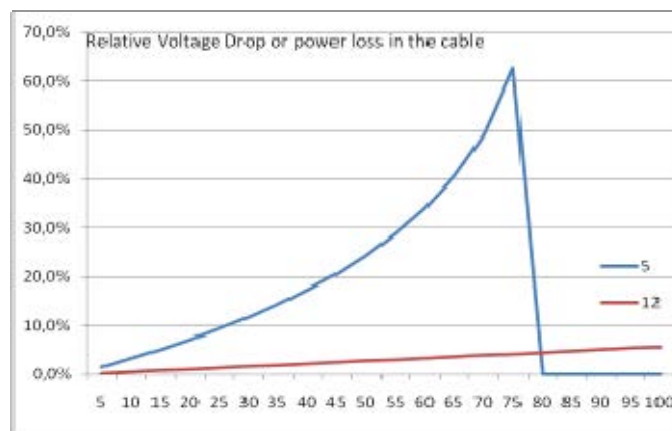


Figure A.1: Loss function of device power in W at 5 V and 12 V with 2 m cable of section 1 mm²

Case 2: length 10 m with single copper section

In case of DC network, with $l=10$ m, figure A.2 shows the loss at 12 V and 19 V.

NOTE: 12 V is common voltage for boxes and cars; 19 V is common voltage for portable computer

Figure A.3 shows the comparison between 19 V and 24 V which might be obtained by distribution of -12 V and +12 V maybe referenced to ground.

3 % loss corresponds to 10 W in 12 V, 25 W in 19 V and 45 W in 24 V and respectively 5 % loss to 15 W, 40 W and 70 W.

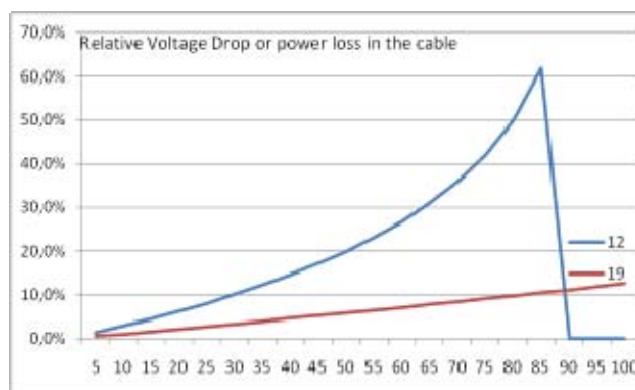


Figure A.2: Loss function of device power in W at 12 and 19 V with 10 m cable of section 1 mm²

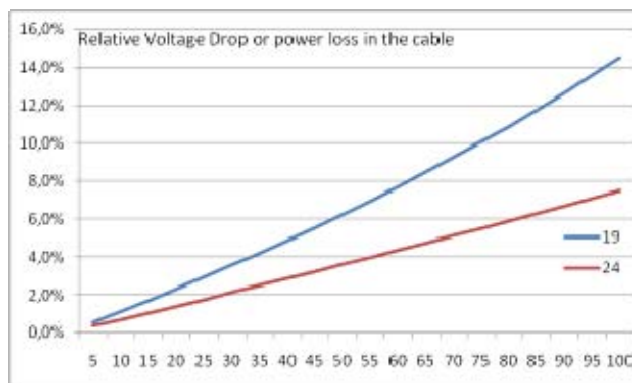


Figure A.3: Loss function of device power in W at 19 V and 24 V with 10 m cable of section 1 mm²

Case 3 length 10m with hybrid copper section

Another possibility is to increase the section of a part of the line, e.g. 8 m in 2,5 mm² and 2 m cord set in 1 mm² (equivalent to 10 m in section 2,2 mm²). In that case (see figure 4) 5 % loss, corresponds to 35 W in 12 V, 95 W in 19 V.

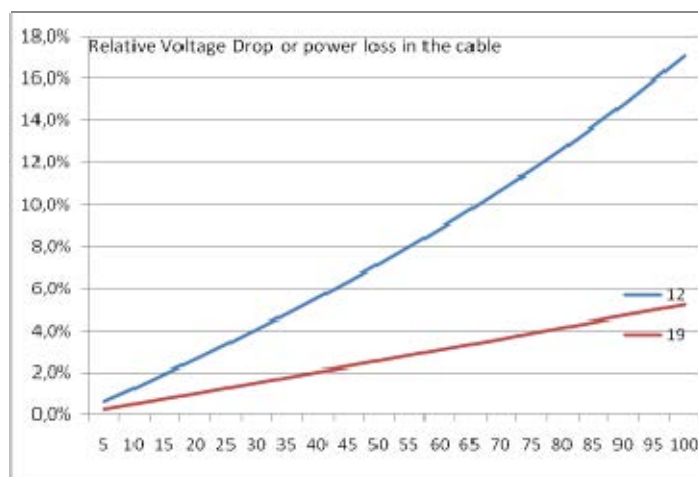


Figure A.4: Loss function of device power in W at 19 and 24 V with hybrid 10 m cable of average section 2,5 mm²

Energetic Losses Calculation in a PV DC System Power Distributions

The following calculation in table A.1 gives:

- Energy losses between the solar Pannels to the battery
- Energy losses between battery and load use
- Global annual energy losses from panel to load use

Table A.1: Losses calculation details

ANALYSE DES PERTES RESEAU DC													
PV - batterie	250	Wc											
k	10	Wc/W	25	Wmoyen	Energie	219150	Wh/an						
rho	0,02	Ohm*mm ² /m											
s	6	mm ²											
		Delta U (V)				Pertes en W							
L (m)		10	20	30		L	10	20	30	L	10	20	30
U (V)	I (A)	U				U				U			
15	16,7	1,1	2,2	3,3		15	18,5	37,0	55,6	15	7%	15%	22%
30	8,3	0,6	1,1	1,7		30	4,6	9,3	13,9	30	2%	4%	6%
50	5,0	0,3	0,7	1,0		50	1,7	3,3	5,0	50	1%	1%	2%
90	2,8	0,2	0,4	0,6		90	0,5	1,0	1,5	90	0%	0%	1%
120	2,1	0,1	0,3	0,4		120	0,3	0,6	0,9	120	0%	0%	0%
240	1,0	0,1	0,1	0,2		240	0,1	0,1	0,2	240	0%	0%	0%
400	0,6	0,0	0,1	0,1		400	0,0	0,1	0,1	400	0%	0%	0%
Batterie - prise	100	Wmoyen	2192	h									
s	1,5	mm ²	6,0	h/jour									
		Delta U (V)				Pertes en W							
L (m)		10	20	30		L	10	20	30	L	10	20	30
U (V)	I (A)	U				U				U			
15	6,7	1,8	3,6	5,3		15	11,9	23,7	35,6	15	12%	24%	36%
30	3,3	0,9	1,8	2,7		30	3,0	5,9	8,9	30	3%	6%	9%
50	2,0	0,5	1,1	1,6		50	1,1	2,1	3,2	50	1%	2%	3%
90	1,1	0,3	0,6	0,9		90	0,3	0,7	1,0	90	0%	1%	1%
120	0,8	0,2	0,4	0,7		120	0,2	0,4	0,6	120	0%	0%	1%
240	0,4	0,1	0,2	0,3		240	0,0	0,1	0,1	240	0%	0%	0%
400	0,3	0,1	0,1	0,2		400	0,0	0,0	0,1	400	0%	0%	0%
Batterie - prise	300	Wmaxi	731	h									
			2,0	h/jour									
										Pertes totales en % de l'énergie annuelle avec UPV=UB			
										L	10	20	30
										U			
L (m)		Delta U (V)				Pertes en W				L	10	20	30
U (V)	I (A)	10	20	30		L	10	20	30	15	19%	39%	58%
15	20,0	5,3	10,7	15,0		15	106,7	213,3	300,0	30	5%	10%	14%
30	10,0	2,7	5,3	8,0		30	26,7	53,3	80,0	50	2%	3%	5%
50	6,0	1,6	3,2	4,8		50	9,6	19,2	28,8	90	1%	1%	2%
90	3,3	0,9	1,8	2,7		90	3,0	5,9	8,9	120	0%	1%	1%
120	2,5	0,7	1,3	2,0		120	1,7	3,3	5,0	240	0%	0%	0%
240	1,3	0,3	0,7	1,0		240	0,4	0,8	1,3	400	0%	0%	0%
400	0,8	0,2	0,4	0,6		400	0,2	0,3	0,5				

Annex B: Inputs for defining SELV DC network architecture and energy gain assessment compared to individual adapters

This annex gives overview of several approaches of SELV DC network.

B.1 GGPAH home DC distribution architecture solution

GGPAH (Green Grid Platform At Home voluntary organization in Japan at <http://ggpah.org/>) is a voluntary organization in Japan. The project is including the building DC up to 400 V distribution and propose local DC bus 12 - 24 VDC about 100 W distribution for Telecom/PC devices and 24 - 48 VDC about 300 W distribution for lighting, fans, media player and large screens. Solar and battery are on the up to 400 VDC building network. Synopsis can be found in NTT review or GGPAH internet site or in Synopsis can be found in Recommendation ITU-T L.1001 [i.2].

B.2 Emerge Alliance 24 V ceiling distribution specification

The Emerge alliance project (Emerge Alliance. <http://www.emergealliance.org/Standard/SystemGraphics.aspx>) is a local SELV DC distribution in the ceiling to simplify office or commercial building installation and maintenance. Synopsis can be found in Recommendation ITU-T L.1001 [i.2].

B.3 IEEE UPAMD™ P1823™ project

The universal power architecture described in IEEE UPAMD™ P1823™ [i.18] project gives an overview of the various use of ICT device and related accessories (e.g. battery packs). Synopsis can be found in Recommendation ITU-T L.1001 [i.2]. One can see in the architecture AC and DC sources, adapters with multi-inputs AC/DC and multi DC outputs, main power system, and expansion boxes, solar modules as one of the most common DC source.

There is a battery option but location is not clear: inside, or outside on a bidirectional link.

Annex C: Setting solution for DC/DC converter

C.1 UI setting solution

The setting can be done in 2 ways:

- By selector on the DC/DC box;
- By cable setting solution (use the detachable cable record and transfer UI information to DC/DC), see clauses C.2.1 and C.2.2.

C.2 Cable setting solution

In the case of the cable setting solution, 2 possibilities are proposed:

- Passive analogical solution: voltage and current setting by resistance.
- Digital solution: when powered, the cable gives sequence of ASCII characters with voltage and current information.

The DC/DC is able to read both if provided by the detachable cable on signal pins.

C.2.1 Passive solution example

It can be done by 2 resistances referenced to the power minus when 2 wire interface A or midpoint in case of 3 wires interface A (-12 V, 0, + 12 V):

- R1 and R2 are resistances in the cable.
- R1 on signal 1 gives information on the voltage (100 ohm/V). e.g. the DC/DC provides current to signal 1 pin, under 1 mA, if 1,2 V is read, the resistance is 1 kohm, which means a requirement of 12 V output).

NOTE: The power loss in resistor is 12 μ W, which is much lower than no load power defined in Energy Star [i.23]. The full power loss with reading circuitry should be lower than 1 mW.

R2 on signal 2 gives information on the current (1 kohm/A). e.g. under 1 mA, if 2 V is read and gives the information of a 2A required.

The advantage of these kind of passive solution is simplicity and robustness the default is lack of flexibility.

C.2.2 Digital solution example

As soon as the detachable is connected, an active device (e.g. a small controller able to run on the default voltage 5 V present on the interface A) provides a serial message in ASCII code, including the voltage and current in clear, e.g. the ASCII sequence of characters <DC>xx.xVy.yA</DC>, where x and y are figure from "0" to "9".

NOTE 1: The XML syntax is proposed.

NOTE 2: Other information can be added later as it is easy in XML file. They never use the same header <DC>.

NOTE 3: In default mode the parameters of the serial port are set to clock = 9600 bps, Parity = pair, 1start bit, 1 stop bit.

It is recommended that the DC/DC converter be able to auto-detect the parameters.

NOTE 4: The very common small CMOS microcontroller or equivalent logical circuitry can have very low consumption, of some mW or lower with standby mode, in this kind of application requiring very low processing power.

The advantage of the digital solution is more flexibility than the analogical solution but it uses less robust processor as it requires a solid design to avoid failure and also bit transfer errors.

NOTE 5: IEEE P1683 UPAMD™ [i.18] is defining a protocol exchange supported on CAN bus [i.21].

Annex D: Assessment of the benefit of the SELV DC network

The assessment of the gain in mass of power supply is as follows.

A single mobile AC/DC charger of 5 V 1 A weight is 50 g without detachable USB-A cable, a PC charger 19 V 4A weighs 350 g with cable. It exists same common charger with PC and a USB output without any overweight. So we can assess a gain of at least $50/400 = 12,5\%$ at minimum by using a common DC supply.

A charger on 12 V auto smoke socket has a weight of 200 g, so the reduction is about 150 g. Let us assume a reduction of 100 g.

For 1 Billion charger, this means around 100 000 t saving.

In Recommendation ITU-T L.1001 [i.2], table 3 the target efficiency of 5 V 1 A power adapter is 73,7 % in range 25 % - 100 % load, and the target efficiency of 12 V 5A power adapter is 88 % in range 25 % - 100 % load and 83 % at 10 % load, so the minimum gain is of 10 %.

The efficiency is around 10 % higher on a bigger charger so the saving is $10\% \times 5\text{ W} = 0,5\text{ W}$, for 100 recharge of 3 hours per year, i.e. 300 h. The saved energy is 1,5 TWh for 1 Billion units.

The no load power would be saved, which corresponds to $0,15\text{ W} \times 8\,766 \times 1\text{ B} = 1,2\text{ TWh/year}$ for transitional period and then with 0,03 W, the reduction would be less: 0,2 TWh/year.

The total energy saving would be between 1,7 up to 2,7 TWh/year per billion of avoided USB AC/DC charger. Let's assume 2 TWh saving.

In terms of CO₂, with a European world mix of 0,5 kg of CO₂/kWh, the saving in CO₂ emission would be at minimum of 1 Mt.

University Study [i.38] can be helpful to understand this kind of assessment as well as Recommendation ITU-T L.1000 [i.1].

Annex E: Bibliography

GeSI-ITU-T Study 2012, An Energy-aware Survey on ICT Device Power Supplies.

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