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TECHNICAL SPECIFICATION

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Part 3: Supercapacitor

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Environmental Engineering (EE).

The present document is part 3 of a multi-part deliverable covering Innovative energy storage technology for stationary use, as identified below:

Part 1: "Overview";

Part 2: "Battery";

Part 3: "Supercapacitor".

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**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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Executive summary

The present document is based on ETSI TS 103 553-1 [i.4] and is the part related to supercapacitors.

It contains selection criteria for telecommunication application based on main performance parameters and the methods for proper use. In addition, some use cases and examples are given in an annex to help users.

Introduction

The present document is part 3 of a series covering innovative energy storage technology for stationary use. This series introduces the evolution of energy storage technologies applicable for use with stationary information and communication technology/telecommunication (ICT/TLC) equipment and provides global results of investigations in laboratories or from field tests in TLC/ICT network or customer premises (e.g. for resilience in a smart sustainable city). Mobile and portable batteries lie outside the scope of the present document.

The present document was developed jointly by ETSI TC EE and ITU-T Study Group 5 and published respectively by ITU and ETSI as Recommendation ITU-T L.1222 [i.6] and ETSI TS 103 553-3 (the present document), which are technically equivalent.

1 Scope

The present document provides an overview of available SuperCapacitor (SC) technology, with details of SC characteristics (electrical, mechanical, thermal) and applicability in the Telecommunication/Information and Communication Technology (TLC/ICT) domain [i.1].

A general overview of the evolution of energy storage technologies is provided in ETSI TS 103 553-1 [i.4] and Recommendation ITU-T L.1220 [i.5].

The adoption of SC technology is recommended for coverage of micro-interruptions of the public grid for indoor and outdoor applications.

Examples of sizing and essential tests used in the network are described.

2 References

2.1 Normative 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 https://docbox.etsi.org/Reference/.

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

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2.2 Informative references

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

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] ETSI TR 102 532 (V1.2.1) (2012): "Environmental Engineering (EE); The use of alternative energy solutions in telecommunication installations".

[i.2] IEC 60050-114:2014: "International electrotechnical vocabulary".

[i.3] US Department of Defence (1991): "Military handbook: Reliability prediction of electronic equipment", Revision F. Washington, DC: US Department of Defence. 150 pp.

[i.4] ETSI TS 103 553-1: "Environmental Engineering (EE); Innovative energy storage technology for stationary use; Part 1: Overview".

[i.5] Recommendation ITU-T L.1220 (2017): "Innovative energy storage technology for stationary use - Part 1: Overview of energy storage".

[i.6] Recommendation ITU-T L.1222: "Innovative energy storage technology for stationary use - Part 3: Supercapacitor technology".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in IEC 60050-114 [i.2] and the following apply:

electrochemical capacitor; supercapacitor: device that stores energy using a double layer in an electrochemical cell

3.2 Symbols

Void.

3.3 Abbreviations

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

AC	Alternating Current
CO	Central Office
DC	Direct Current
ELDC	Electric Double Layer Capacitor
FTTCab	Fibre To The Cabinet
FTTx	Fibre To The x (x:= E = Exchange; B = Building; dP = distribution Point; H = Home)
ICT	Information Communication Technology
MTBF	Mean Time Between Failures
NGAN	Next Generation Access Network
RMS	Root Mean Square
SC	Supercapacitor
SELV	Safety Extra Low Voltage
TLC	Telecommunication
UBB	Ultrabroadband
VAC	Volt Alternating Current
VDC	Volt Direct Current

4 General introduction to supercapacitors

SCs store electrical energy in the form of electrical charges in two electrodes and an electric field between them. They have very low internal impedance and can be recharged in seconds. They are characterized by very high values of specific power (watts per kilogram) and are particularly suitable for peak power applications.

On the other side, the specific energy (watt hours per kilogram or watt hours per litre) of SCs is much lower (about 10 times) than that of batteries and, in addition on discharge the voltage decreases from the nominal voltage to zero, thus limiting the useful energy in actual applications approximately to a quarter of the available energy (dictated by the minimum operational voltage of the apparatus).

In summary, SCs are very good in providing peak power demands, but they store low amounts of useful energy and cannot replace batteries in the majority of current applications. When integrated with a battery, SCs can significantly increase the high rate performance of storage systems and extend overall service life, as they can reduce high power drains from batteries, thus reducing battery degradation.

Figure 1 shows a typical example of a high-power SC bank, e.g. for peak power shaving and Figure 2 shows a typical SC used for Fibre To The x (FTTx) applications in the active access network.

Figure 1: Example of a supercapacitor bank, 360 VDC - 150 kW 320 Wh

Figure 2: Examples of supercapacitors for fibre to the x (0,5 Wh at 48 VDC on left - 1,6 Wh at 48 VDC on right) frontal view

SC modules are installed between the alternating current/direct current (AC/DC) converter (e.g. 230 VAC/60 VDC) and the TLC load, so that the TLC equipment can be powered at a Safety Extra Low Voltage (SELV) level, with primary energy source from public mains, without usage of standby batteries. These SC modules are able to provide uninterrupted power for micro-interruptions from the mains (e.g. power outages of less than few seconds), to avoid the rebooting of TLC/ICT systems (usually taking several minutes to bring back TLC/ICT service, as described in annex C of ETSI TS 103 553-1 [i.4]).

Operating temperature and cell voltage impact on SCs lifetime.

High temperature and a working voltage close to the nominal voltage reduce the lifetime.

Based on that, the designer can improve the lifetime by:

- reducing the working temperature;
- reducing the cell working voltage, e.g. by using more cells in series.

5 Working principle

SCs are devices that are able to store more electrical energy than equivalent electrostatic capacitors. They use positive and negative metallic plates (generally cylindrically shaped) with very large active surface and very short distance between the plates (e.g. 0,1 nm).

A SC consists of two electrodes, placed on aluminium supports that act as current collectors, with a dielectric separator and electrolyte between the electrodes.

Electrodes are made of porous materials, to create a larger contact surface available for the electrolyte. The dielectric separator, generally made of paper, plastic or ceramic, is needed to block the transfer of electrons inside the SC, meanwhile offering a high permeability for electrolyte ions.

A potential difference, applied across the terminals of a SC, starts a process of separation of electrolyte ions, which generates a double layer of charge on the electrode/electrolyte interfaces. In particular, the voltage applied causes electrons to gather on the positive electrode and to the deposition of positive ionic charge on the interface with the electrolyte. In a similar way, a surplus of positive charges will be present on the negative electrode and negative ionic charge will reside on the interface with the electrolyte (see Figure 3).

In SCs the storage of energy is performed through a reversible process of very quick charge transfer, without redox chemical processes. This allows fast charge and discharge of SCs, with a higher number of lifecycles compared to traditional electrochemical capacitors.

The very short distance between the two electrodes results in high values for the internal electrical fields, whose strength can approach the dielectric strength of the dielectric material. This implies the adoption of a voltage limitation between the electrodes and of the associated stored energy.

SCs are devices that are able to give high levels of power in a short time, and with very high numbers of charge and discharge cycles. These features of SCs allow them to be used in applications, such as compensation for power fluctuations in the electrical grids and for voltage regulation (power quality application, to improve voltage waveform).

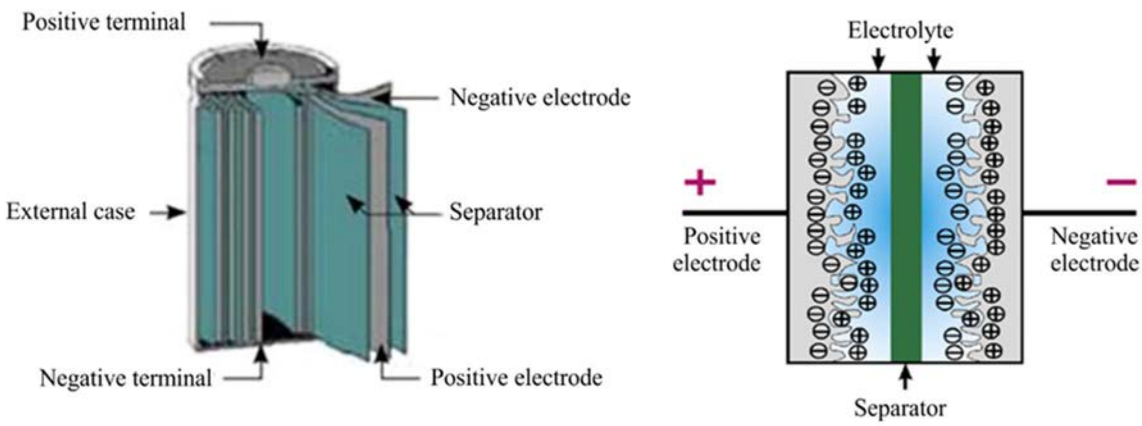

Figure 3: Cylindrical supercapacitor and schematic of the double layer of charge

6 Supercapacitor technology and performance

Table 1 provides data on the main SC performance parameters. The nominal voltage of an SC cell is dependent on its construction and the type of electrolyte (higher for organic electrolytes and lower for aqueous ones). SC specific energy is very low in general, since these devices are mainly intended to be used against transient power interruptions, not for energy back-up. Expected cycling lifetime, can reach values in the range of 500 000 to 1 000 000 cycles (with voltage ranging from a maximum value to half maximum during the working cycle).

Table 1: SC performance parameters

Parameter	Typical values
Nominal Voltage (V)	1 to 2,7
Capacity (F)	1 to 5 000
Specific power (W/kg)	300 to 100 000
Specific energy (Wh/kg)	0,5 to 10
Energy efficiency (%)	95 to 98
Daily self-discharge (%)	20 to 40
Expected life-time (years)	5 to 10
Number of cycles	> 50 000
Temperature operating range (°C)	-40 to -65
Auxiliary system	balancing system of the cell

NOTE: The lifetime is impacted by the capacitor temperature and Root Mean Square (RMS) current, as high values can increase the working temperature.

7 Applications

Applications for SC technology are related to Next Generation Access Networks (NGANs), using active loads spread outside traditional Central Offices (COs). In such a scenario, a TLC active load is generally supplied from the local public mains (in some cases, TLC loads are remotely powered from COs, with power backup provided by battery). In this case, use of an SC is of interest for coverage of grid micro-interruptions, which can cause several UltraBroadBand (UBB) service downtime periods, due to TLC equipment reboots (see annex C of ETSI TS 103 553-1 [i.4] for further details).

In field applications (e.g. FTTx deployments), SC units are controlled by internal electronic circuit, in order to properly manage charge and discharge phases. During the SC charge phase, a current limitation circuit manages the storage of energy in SC cells, to enable short recharging times (tenths of a second) and to avoid overloads on the power supply unit feeding the TLC load (and associated SC unit).

Details are given in annex B.

8 Economic and environmental topics

Taking into account their expected long lifetime, SC represent a very low cost for complete cycles of charge and discharge compared with traditional electrochemical storage systems that are more commonly defined in cost per kilowatt hour.

The most evident limit of SC is their very low autonomy (up to a few seconds, as a maximum). SCs do not have problems from the environmental point of view, since their construction materials are not toxic. If organic electrolytes are used, attention should be paid to the presence of inflammable, irritant and corrosive solvents, as for solvents in lithium/ion batteries.

To date, the disposal of SCs has been dealt with like any other piece of electronic equipment. Their recycling process is economically convenient, due to the presence of aluminium and other metals that can be extracted and reused.

Annex A (informative): Certification information

A.1 General

In order for SC cells to be used in field applications as power backup units, the following certifications should be provided:

- certification of single SC cells, provided by the cell manufacturer;
- certification of the whole assembly of the power backup SC unit (e.g. cells, control electronics and power interfaces and case).

The above certifications should be granted by a certification organization.

Annex B (informative): Application examples

B.1 General

The SC unit operates at 59 VDC (with SELV limits - it may need an electronic circuit adapting voltage to the voltage limits of interface A at the input of ICT equipment) and energy is stored in cells of the Electric Double Layer Capacitor (ELDC) type. This stored energy is given to the load when the input voltage from the mains is not present (e.g. micro-interruption).

Figure B.1 is a schematic of an SC unit for FTTx field application. An SC unit can be subdivided into five main blocks: power input interface (59 VDC, SELV circuitry is used for this application), output power interface (59 VDC), protection and section circuitry (responsible for separating the SC cell block from the input interface in the event of power outage on input interface itself, so as to avoid energy flow backwards to input), charge control block (constant current charging phase, up to cell complete recharging) and SC cell block (packaging of *N* SC cells, ELDC type).

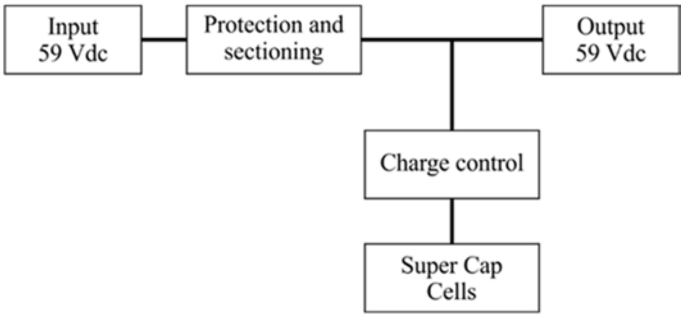

Figure B.1: Schematic of supercapacitor unit for fibre to the x application

Table B.1 gives an example of the electrical and environmental characteristics of an SC used in Fibre To The Cabinet (FTTCab) network deployments, with regard to two possible types of SC units.

Table B.1: Fibre to the cabinet supercapacitor characteristics

Parameter	Supercapacitor type A	Supercapacitor type B
Rated Capacity (F)	1,136	4
Cells	22 × 25 F	25 × 100 F
Capacity tolerance	-10 % to + 20 %	0 % to + 20 %
Accumulated energy at 59 V (J)	1 977	6 962
Minimum available energy (from 59 to 50 V) (J)	557	1 962
Nominal Voltage (V)	59	59
Maximum Voltage (V)	60	60
Maximum current (transit/discharge) (A)	8	25
Charge current (mA)	700	1 000
Leakage current (72 h at 25 °C) (mA)	< 0,049	< 0,0073
Mean time between failures (MTBF) at 25 °C (h) [i.3]	> 400 000	> 400 000
MTBF at 40 °C (h) [i.3]	> 200 000	> 200 000
Number of cycles (from V_n to V_n/2 at 25 °C)	500 000	500 000
Temperature operating range (°C)	-40 to +70	-40 to +70
Temperature storage range (°C)	-40 to +70	-40 to +70

NOTE: The lifetime is an independent parameter that cannot be derived from the MTBF, e.g. a MTBF of 200 000 h, would give about 18 years, while Table 1 indicates a 5 to 10 year lifetime.

Annex C (informative): Bibliography

- Ricerca sul Sistema Energetico (2011): "L'accumulo di energia elettrica [The accumulation of electrical energy]". Milan: Il Melograno. 10 pp.

NOTE: Available at http://www.nuova-energia.com/files/Monografia_2011_Accumulo_prime_pagine.pdf.

History

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