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Environmental Engineering (EE); Innovative energy storage technology for stationary use; 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.

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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.

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Not applicable.

2.2 Informative references

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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).

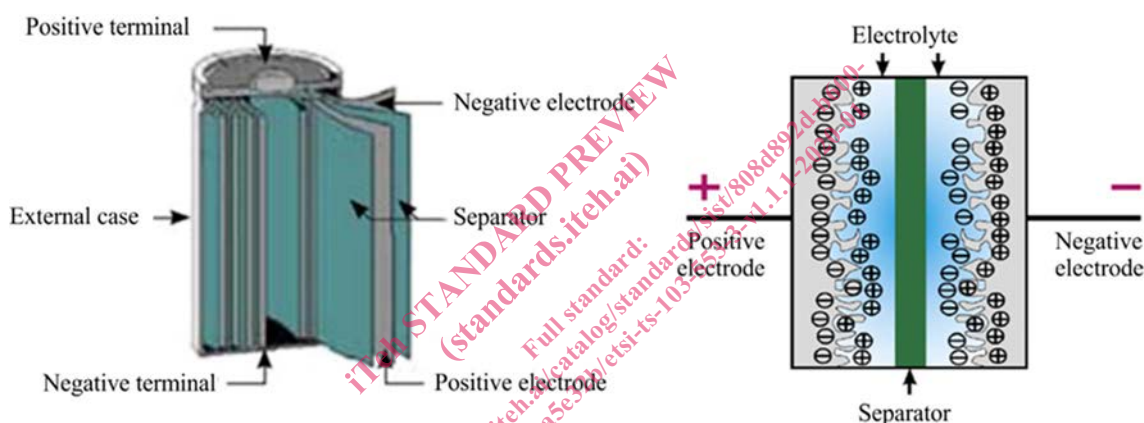


Figure 3: Cylindrical supercapacitor and schematic of the double layer of charge

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