IEC 60143-4

Edition 2.0 2023-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Series capacitors for power systems – Part 4: Thyristor controlled series capacitors

Condensateurs série destinés à être installés sur des réseaux – Partie 4: Condensateurs série commandés par thyristors

IEC 60143-4:2023-12(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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IEC 60143-4 has been prepared by IEC technical committee 33: Power capacitors and their applications. It is an International Standard.

This second edition cancels and replaces the first edition published in 2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) thyristor valve testing requirements refer to IEC 62823;
b) Formula (1) in Subclause 4.2 has been corrected;
c) Hardware-in-the-loop (HIL) tests, Subclause 7.5.4, replaces previously specified real time protection and control system test with network simulator.

The text of this International Standard is based on the following documents:

Draft	Report on voting
33/696/FDIS	33/702/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This part of IEC 60143 is to be used in conjunction with the following standards:

– IEC 60143-1:2015,

– IEC 60143-2:2012,

– IEC 60143-3:2015.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts of IEC 60143 series, under the general title *Series capacitors for power systems,* can be found on the iec website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
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IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

SERIES CAPACITORS FOR POWER SYSTEMS –

Part 4: Thyristor controlled series capacitors

1 Scope

This part of IEC 60143 specifies the testing of thyristor controlled series capacitor (TCSC) installations used in series with transmission lines. This document also addresses issues that consider ratings for TCSC thyristor valve assemblies, capacitors, and reactors as well as TCSC control characteristics, protective features, cooling system and system operation.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE If there is a conflict between this part of IEC 60143 and a standard listed below in Clause 2, this document prevails.

IEC 60050-436, *International Electrotechnical Vocabulary (IEV) – Part 436: Power capacitors*

IEC 60068-2-2, *Environmental testing – Part 2-2: Tests – Tests B: Dry heat*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60076-1, *Power transformers – Part 1: General*

IEC 60076-6:2007, *Power transformers – Part 6: Reactors*

IEC 60143-1:2015, *Series capacitors for power systems – Part 1: General*

IEC 60143-2:2012, *Series capacitors for power systems – Part 2: Protective equipment for series capacitor banks*

IEC 60143-3:2015, *Series capacitors for power systems – Part 3: Internal fuses*

IEC 60255-21 (all parts), *Electrical relays – Vibration, shock, bump and seismic tests on measuring relays and protection equipment*

IEC 60255-27, *Measuring relays and protection equipment − Part 27: Product safety requirements*

IEC 61000-4 (all parts), *Electromagnetic compatibility (EMC) − Part 4: Testing and measurement techniques*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) − Part 4-11: Testing and measurement techniques − Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase*

IEC 61000-4-29, *Electromagnetic compatibility (EMC) – Part 4-29: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations on d.c. input port immunity tests*

IEC 62823:2015, *Thyristor valves for thyristor controlled series capacitors (TCSC) – Electrical testing*
IEC 62823:2015/AMD1:2019

NOTE Additional useful references, not explicitly referenced in the text, are listed in the Bibliography.

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms and definitions given in IEC 60143-1, IEC 60143-2, IEC 60143-3, some taken from IEC 60050-436, and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

NOTE In some instances, the IEC definitions can be either too broad or too restrictive. In such a case, an additional definition or note has been included.

3.1 Terms and definitions

3.1.1
thyristor valve
electrically combined assembly of thyristor levels, complete with all connections, auxiliary components and mechanical structures, which can be connected in series with each phase of the reactor or capacitor of a TCSC

3.1.2
bypass current
current flowing through the bypass switch, protective device, thyristor valve, or other devices, in parallel with the series capacitor, when the series capacitor is bypassed

3.1.3
temporary overload
short duration (typically 30 min) overload capability of the TCSC at rated frequency and ambient temperature range

SEE: Figure 5 and Figure 10.

3.1.4
dynamic overload
short duration (typically 10 s) overload capability of the TCSC at rated frequency and ambient temperature range

SEE: Figure 5 and Figure 10.

3.1.5
thyristor-controlled series capacitor
TCSC
assembly of thyristor valves, TCSC reactor(s), capacitors, and associated auxiliaries, such as structures, support insulators, switches, and protective devices, with control equipment required for a complete operating installation

3.1.6
valve electronics
VE
electronic circuits at valve potential(s) that perform control functions

3.1.7
TCSC reactor
one or more reactors connected in series with the thyristor valve

SEE: Figure 1, item 7.

Note 1 to entry: In the context of TCSCs, the valve varistor is typically defined by its ability to limit the voltage across a thyristor valve to a specified protective level while absorbing energy. The valve varistor is designed to withstand the temporary overvoltage and continuous operating voltage across the thyristor valve.

3.1.8
valve blocking
operation to prevent further firing of a thyristor valve by inhibiting triggering

3.1.9
valve base electronics
VBE
electronic unit, at earth potential, which is the interface between the control system of the TCSC and the thyristor valves

3.1.10
capacitor current
I_C
current through the series capacitor

SEE: Figure 2.

3.1.11
line current
I_L
power frequency line current

SEE: Figure 2.

3.1.12
rated current
I_N
RMS line current (I_L) at which the TCSC should be capable of continuous operation with rated reactance (X_N) and rated voltage (U_N)

3.1.13
valve current
I_V
current through the thyristor valve

SEE: Figure 2.

3.1.14
capacitor voltage
U_C
voltage across the TCSC

SEE: Figure 2.

3.1.15
protective level
U_{PL}
magnitude of the maximum peak of the power frequency voltage appearing across the overvoltage protector during a power system fault

Note 1 to entry: The protective level can be expressed in terms of the actual peak voltage across a segment or in terms of the per unit of the peak of the rated voltage across the capacitor.

3.1.16
rated TCSC voltage
U_N
power frequency voltage across each phase of the TCSC that can be continuously controlled at rated reactance (X_N), rated current (I_N), frequency, and reference ambient temperature range

3.1.17
apparent reactance
$X(\alpha)$
TCSC apparent power frequency reactance as a function of thyristor control angle (α)

SEE Figure 4.

3.1.18
nominal frequency
f_N
frequency of the system in which the TCSC is intended to be used

3.1.19
rated capacitance
C_N
capacitance value for which the TCSC capacitor has been designed

3.1.20
physical reactance
X_C
power frequency reactance for each phase of the TCSC bank with thyristors blocked and a capacitor internal dielectric temperature of 20 °C

$$X_C = 1/(2\pi f_N \times C_N)$$

3.1.21
boost factor
k_B
ratio of $X(\alpha)$ divided by X_C

Note 1 to entry: $k_B = X(\alpha) / X_C$

3.1.22
rated reactance
X_N
rated power frequency reactance for each phase of the TCSC with rated line I_N and rated boost factor

3.1.23
conduction interval
σ
that part of a cycle during which a thyristor valve is in the conducting state, $\sigma = 2\beta$

SEE: Figure 3.

3.1.24
control angle
α
time expressed in electrical angular measure from the capacitor voltage (U_C) zero crossing to the starting of current conduction through the thyristor valve

SEE: Figure 3.

3.1.25
internal fault
line fault occurring within the protected line section containing the series capacitor bank

3.1.26
external fault
line fault occurring outside the protected line section containing the series capacitor bank

3.2 Abbreviated terms

FSC	fixed series capacitors
MC	master control
POD	power oscillation damping
RTU	remote terminal unit
SCADA	supervisory control and data acquisition
SER	sequence events recorder
SSR	sub-synchronous resonance
RMS	root-mean-square
BLK	blocked (mode of operation)
BP	bypass (mode of operation)
CAP	capacitive boost (mode of operation)
HMI	human machine interface

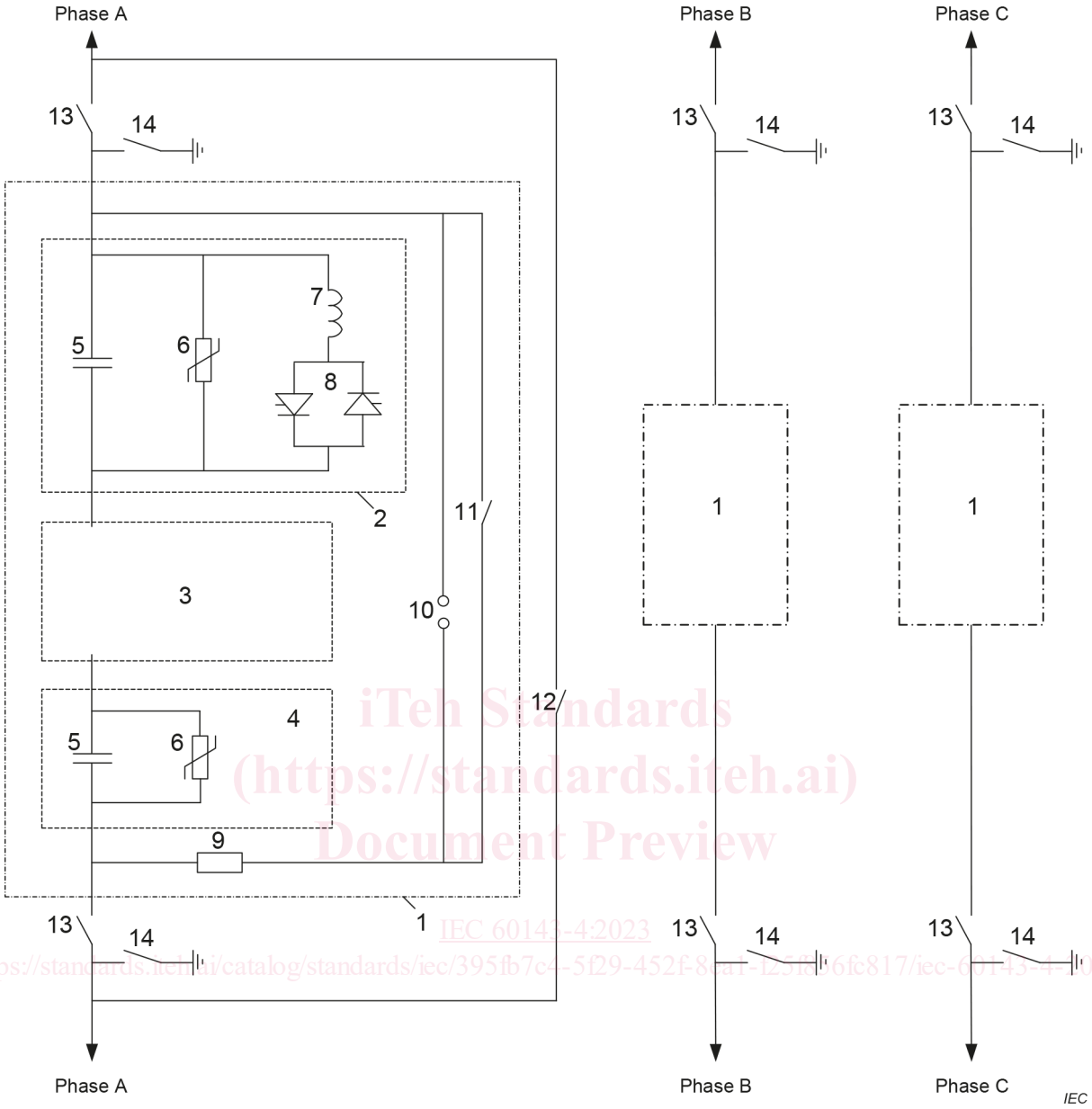
4 Operating and rating considerations

4.1 General

Transmission line series reactance can be compensated by combinations of fixed series capacitors and TCSC banks (see Figure 1). TCSC banks use one or more controllable modules to achieve the range of performance requirements specified by the purchaser. This clause discusses requirements of TCSC operating and rating considerations.

The TCSC circuit configurations discussed in this document (see Figure 2) consider three basic operating modes:

- BLK operation with thyristors blocked (no current through the thyristor valve),
- BP operation with continuous thyristor current,
- CAP operation with a capacitive boost.



Key

1	TCSC bank (1-phase)	8	thyristor valve
2	controllable subsegment	9	current limiting damping circuit
3	additional controllable subsegments when required	10	bypass gap
4	additional FSC segment when required	11	bypass switch
5	capacitor units	12	external bypass disconnector
6	varistor	13	external isolating disconnector
7	TCSC reactor	14	external grounding switch

Figure 1 – Typical nomenclature of a TCSC installation