IEC 60143-4

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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

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FOREWORD

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

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

– IEC 60143-1:2004, *Series capacitors for power systems – Part 1: General*
– IEC 60143-2:1994, *Series capacitors for power systems – Part 2: Protective equipment for series capacitor banks*
– IEC 60143-3:1998, *Series capacitors for power systems – Part 3: Internal fuses*

The text of this standard is based on the following documents:

FDIS	Report on voting
33/472/FDIS	33/478/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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.

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SERIES CAPACITORS FOR POWER SYSTEMS –

Part 4: Thyristor controlled series capacitors

1 Scope

This part of IEC 60143 specifies testing of thyristor controlled series capacitor (TCSC) installations used in series with transmission lines. This standard 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 referenced documents are indispensable for the application 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 standard prevails.

IEC 60050-436, *International Electrotechnical Vocabulary – Chapter 436: Power capacitors*

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60068-1, *Environmental Testing – Part 1: General and guidance*

IEC 60068-2-2, *Basic environmental testing procedures – Part 2-2: Tests – Tests B: Dry heat*

IEC 60068-2-78, *Basic environmental testing procedures – Part 2-78: Tests – Tests C: Damp heat, steady state*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2, *Insulation co-ordination – Part 2: Application guide*

IEC 60076-1:1993, *Power transformers – Part 1: General*

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

IEC 60143-1:2004, *Series capacitors for power systems – Part 1: General*

IEC 60143-2:1994, *Series capacitors for power systems – Part 2: Protective equipment for series capacitor banks*

IEC 60143-3:1998, *Series capacitors for power systems – Part 3: Internal fuses*

IEC 60255-5, *Electrical relays – Part 5: Insulation coordination for measuring relays and protection equipment – Requirements and tests*

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

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

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 61954:1999, *Power electronics for electrical transmission and distribution systems – Testing of thyristor valves for static VAR compensators*

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

3 Terms, definitions and abbreviations

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

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

3.1 Abbreviations

ETT	Electrically triggered thyristors
FACTS	Flexible ac transmission systems
FSC	Fixed series compensation
LTT	Light-triggered thyristors
MC	Master control
MTBF	Mean time between failure
MTTR	Mean time to repair
POD	Power oscillation damping
RAM	Reliability, availability, and maintainability
RIV	Radio influence voltage
RTU	Remote terminal unit
SCADA	Supervisory control and data acquisition
ER	Events recorder
FR	Fault recorder
RTDS	Real time digital simulation
SSR	Sub synchronous resonance
SVC	Static var compensator
TCR	Thyristor-controlled reactor
RMS	Root mean square

3.2 Terms and definitions

3.2.1
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

3.2.2
bypass current
the 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

3.2.3
capacitive range
TCSC operation resulting in an effective increase of the power frequency reactance of the series capacitor (See Figure 5)

3.2.4
temporary overload
short duration (typically 30 min) overload capability of the TCSC at rated frequency and ambient temperature range

3.2.5
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)

3.2.6
platform-to-ground cooling/air-handling insulator
an insulator that encloses cooling/air handling paths between platform and ground level

3.2.7
thyristor-controlled series capacitor bank
TCSC
an 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

3.2.8
valve electronics
VE
electronic circuits at valve potential(s) that perform control functions

3.2.9
TCSC reactor
one or more reactors connected in series with the thyristor valve (see NOTE This figure contains material reproduced from IEEE Std 1534-2002. IEEE Std 1534-2002 IEEE Recommended Practice for Specifying Thyristor-Controlled Series Capacitors, Copyright 2002 IEEE. All rights reserved.

Figure 1, item 12)

3.2.10
thyristor valve enclosure
a platform-mounted enclosure containing thyristor valve(s) with associated valve cooling and electronic hardware

3.2.11
valve varistor
an assembly of varistor units that limit overvoltages to a given value. 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 overvoltages and continuous operating voltage across the thyristor valve

3.2.12
valve blocking
an operation to prevent further firing of a thyristor valve by inhibiting triggering

3.2.13
valve deblocking
an operation to permit firing of a thyristor valve by removing valve blocking action

3.2.14
valve base electronics
VBE
an electronic unit, at earth potential, which is the interface between the control system of the TCSC and the thyristor valves

3.2.15
voltage breakover protection
VBO
means of protecting the thyristors from excessive voltage by firing them at a predetermined voltage

3.2.16
redundant thyristor levels
the maximum number of thyristor levels in the thyristor valve that may be short-circuited, externally or internally, during service without affecting the safe operation of the thyristor valve as demonstrated by type tests, and which if and when exceeded, would require either the shutdown of the thyristor valve to replace the failed thyristors, or the acceptance of increased risk of failures

3.2.17
capacitor current
I_C
current through the series capacitor (see Figure 2)

3.2.18
line current
I_L
power frequency line current (see Figure 2)

3.2.19
rated current
I_N
the 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)

3.2.20
valve current
I_V
current through the thyristor valve (see Figure 2)

3.2.21
capacitor voltage
U_C
voltage across the TCSC (see Figure 2)

3.2.22
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 The protective level may 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.

3.2.23
rated TCSC voltage
U_N
the power frequency voltage across each phase of the TCSC that can be continuously controlled at nominal reactance (X_N), rated current (I_N), frequency, and reference ambient temperature range

3.2.24
apparent reactance
$X(\alpha)$
TCSC apparent power frequency reactance as a function of thyristor control angle (α) (see Figure 4)

3.2.25
rated frequency
f_N
frequency of the system in which the TCSC is intended to be used

3.2.26
rated capacitance
C_N
capacitance value for which the TCSC capacitor has been designed

3.2.27
physical reactance
X_C
the power frequency reactance for each phase of the TCSC bank with thyristors blocked and a capacitor internal dielectric temperature of 20 °C; $X_C = 1/(2\pi f_N \times C_N)$

3.2.28
boostfactor
k_B
the ratio of $X(\alpha)$ divided by X_C; $k_B = X(\alpha) / X_C$

3.2.29
nominal reactance
X_N
the nominal power frequency reactance for each phase of the TCSC with rated line I_N and nominal boost factor

3.2.30
conduction interval
σ
that part of a cycle during which a thyristor valve is in the conducting state, $\sigma = 2\beta$ (see Figure 3)

3.2.31
control angle
α
the 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)

3.2.32
internal fault
an internal fault is a line fault occurring within the protected line section containing the series capacitor bank

3.2.33
external fault
an external fault is a line fault occurring outside the protected line section containing the series capacitor bank

4 Operating and rating considerations

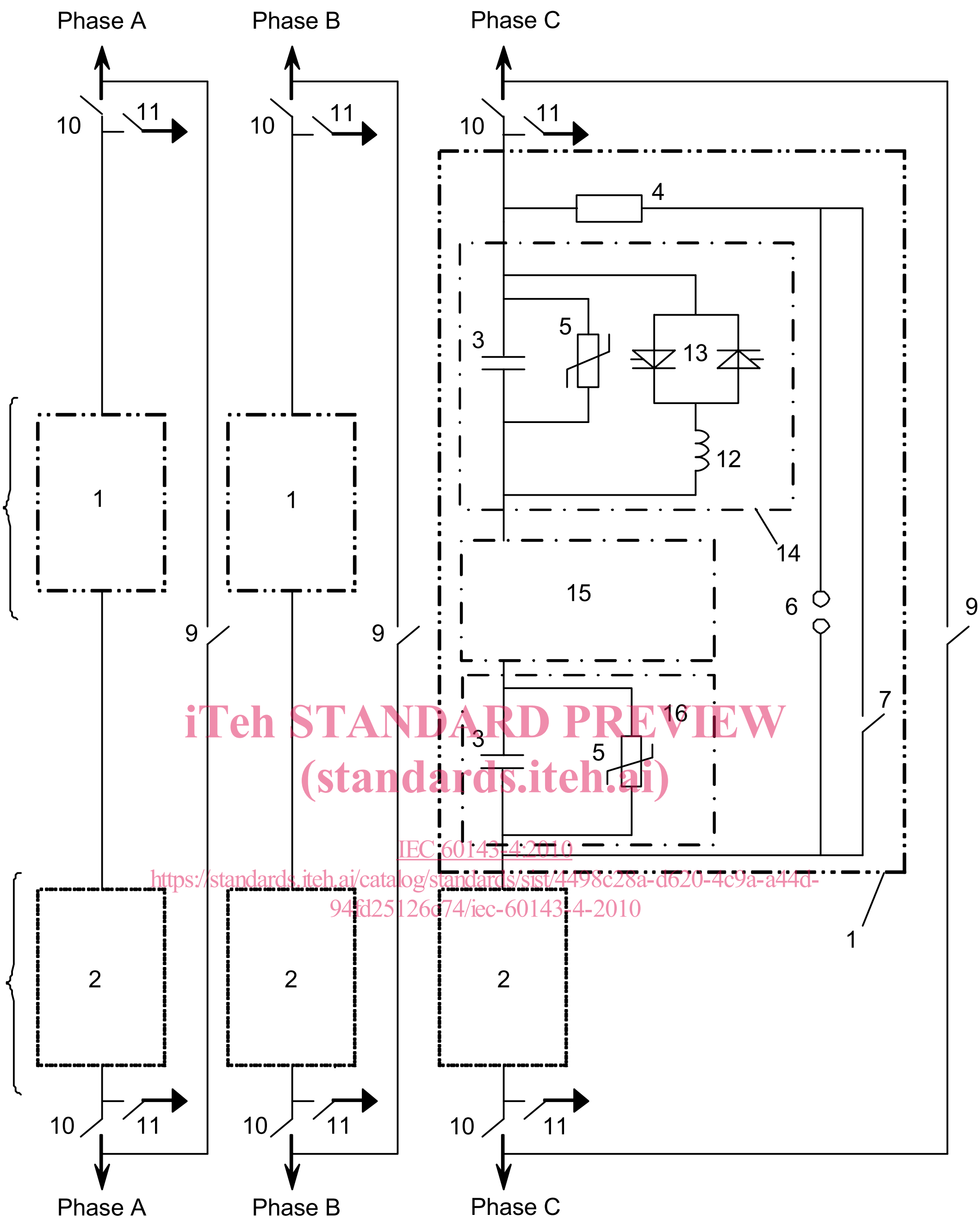
4.1 General

Transmission line series reactance can be compensated by combinations of fixed series capacitors and TCSC capacitors and TCSC banks (see NOTE This figure contains material reproduced from IEEE Std 1534-2002. IEEE Std 1534-2002 IEEE Recommended Practice for Specifying Thyristor-Controlled Series Capacitors, Copyright 2002 IEEE. All rights reserved.

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 standard (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 in capacitive boost mode.



Key

1 Segment (-phase)
2 Switching step or module (3-phase)
3 Capacitor units
4 Discharge current limiting and damping equipment
5 Varistor
6 Bypass gap
7 Bypass switch
8 Additional switching steps when required
9 External bypass disconnect switch
10 External isolating disconnect switch
11 External grounding disconnect switch
12 TCSC reactor
13 Thyristor valve
14 Controllable subsegment (1-phase)
15 Additional controllable subsegments when required
16 Additional FSC segment when required

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Figure 1 – Typical nomenclature of a TCSC installation

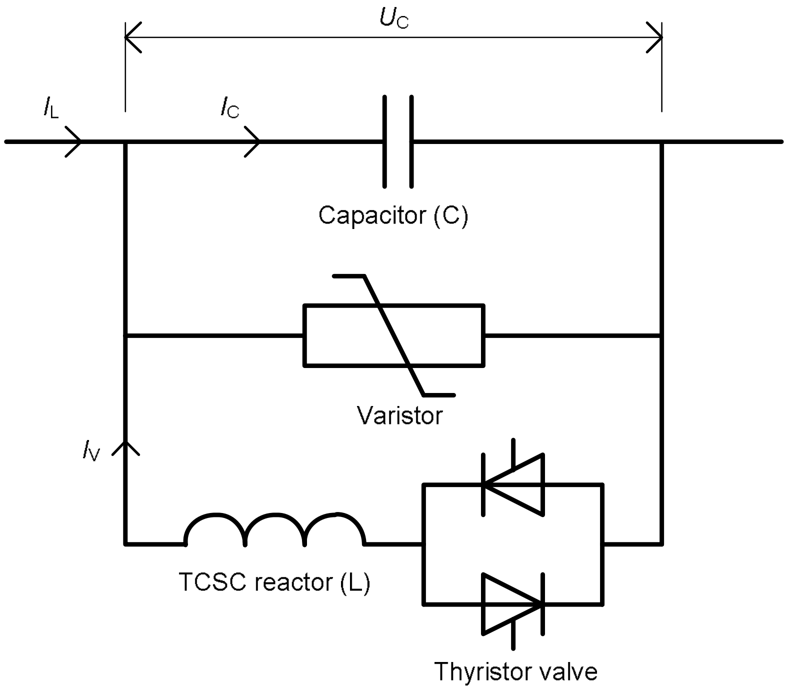

Figure 2 – TCSC subsegment

The definition of control angle (α) with reference to voltage zero crossing is selected to be consistent with other power electronic devices (see Figure 3). However, it should be noticed that many TCSC control systems use the line current wave form as an important control reference.

When a TCSC is operating in CAP mode, the current in the thyristor valve branch can boost the voltage across the capacitor, resulting in an apparent capacitive reactance larger than the physical capacitor reactance, see Figure 4. In a TCSC application, the increased capacitive reactance would increase the line current. The current pulses through the thyristor valve, distorts the capacitor voltage (U_C). The distorted waveform means that the capactor voltage includes non-power frequency components and that the relationship between total RMS and total peak voltage is not $\sqrt{2}$ as in the case for a pure sinusoidal waveform, see Table 1.

Table 1 – Peak and RMS voltage relationships

Boost factor k_B	Normalized discharge frequency λ	Power frequency RMS voltage	Power frequency peak voltage	Total RMS voltage	Total peak voltage
1,0	2,5	1,0	1,41	1,00	1,41
2,0	2,5	2,0	2,83	2,02	2,55
3,0	2,5	3,0	4,24	3,05	3,70
1,0	3,5	1,0	1,41	1,00	1,41
2,0	3,5	2,0	2,83	2,03	2,54
3,0	3,5	3,0	4,24	3,07	3,67