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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Thyristor valves for thyristor controlled series capacitors (TCSC) – Electrical testing

Valves à thyristors pour condensateurs série commandés par thyristors (CSCT) – Essai électrique

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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THYRISTOR VALVES FOR THYRISTOR CONTROLLED SERIES CAPACITORS (TCSC) – ELECTRICAL TESTING

FOREWORD

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International Standard IEC 62823 has been prepared by subcommittee 22F: Power electronics for electrical transmission and distribution systems, of IEC technical committee 22: Power electronic systems and equipment.

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

CDV	Report on voting
22F/342/CDV	22F/354A/RVC

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.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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THYRISTOR VALVES FOR THYRISTOR CONTROLLED SERIES CAPACITORS (TCSC) – ELECTRICAL TESTING

1 Scope

This International Standard defines routine and type tests on thyristor valves used in thyristor controlled series capacitor (TCSC) installations for AC power transmission.

The tests specified in this International Standard are based on air insulated valves operating in capacitive boost mode or bypass mode. For other types of valve and for a valve operating in inductive boost mode, the test requirements and acceptance criteria are agreed between purchaser and supplier.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

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

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

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
thyristor valve
electrically and mechanically 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 of a TCSC

3.2
valve section
electrical assembly, comprising a number of thyristors and other components, which exhibits prorated electrical properties of a complete valve

Note 1 to entry: This term is mainly used to define a test object for valve testing purposes.

3.3
thyristor level
<of a valve> part of a valve comprising an anti-parallel connected pair of thyristors together with their immediate auxiliaries, and reactor, if any

3.4
redundant thyristor levels, pl
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

3.5
valve arrester
arrester connected across a valve

3.6
valve electronics
VE
electronic circuits at valve potential(s) that perform control functions

Note 1 to entry: This note applies to the French language only.

3.7
valve interface electronics unit
electronic unit which provides an interface between the control equipment, at earth potential, and the valve electronics or valve devices

Note 1 to entry: Valve interface electronics units, if used, are typically located at earth potential close to the valve(s).

Note 2 to entry: The term “valve base electronics” (VBE) is also used to designate this unit.

3.8
thyristor-controlled series capacitor bank
TCSC bank
assembly of thyristor valves, reactor(s), capacitors, and associated auxiliaries, such as structures, support insulators, switches, and protective devices, with control equipment required for a complete operating installation

3.9
TCSC reactor
one or more reactors connected in series with the thyristor valve

SEE: Figure 1, item 4.

3.10
valve enclosure
platform-mounted enclosure containing thyristor valve(s) with associated valve cooling and electronic hardware

3.11
temporary overload
short-term overload capability of the TCSC at rated frequency and ambient temperature range

SEE: Figure 5.

Note 1 to entry: Temporary overload is typically of several seconds duration, less than 10 s.

3.12
valve protective firing
means of protecting the thyristors from excessive voltage by firing them at a predetermined voltage

3.13
line current
i_L
power frequency line current

SEE: Figure 2.

3.14
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)

3.15
valve current
i_V
current through the thyristor valve

SEE: Figure 2.

3.16
bypass current
current flowing through the thyristor valve in parallel with the series capacitor, when the series capacitor is bypassed

3.17
capacitor voltage
U_C
voltage across the TCSC

SEE: Figure 2.

3.18
nominal reactance
X_N
nominal power frequency reactance for each phase of the TCSC with nominal boost factor

3.19
rated TCSC voltage
U_N
power frequency voltage across each phase of the TCSC that can be continuously controlled at nominal reactance (X_N), rated current (I_N), nominal power frequency, and ambient temperature range

3.20
apparent reactance
$X(\alpha)$
TCSC apparent power frequency reactance as a function of thyristor control angle (α)

SEE: Figure 3, Figure A.1 and Formula A.1.

3.21
rated capacitance
C_N
capacitance value for which the TCSC capacitor has been designed

3.22
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

$$X_C = 1/(\omega_N \cdot C_N)$$

3.23
boost factor
k_B
the ratio of apparent reactance $X(\alpha)$ divided by physical reactance X_C

$$k_B = X(\alpha) / X_C$$

3.24
conduction interval
σ
part of a half of a power frequency cycle during which a thyristor valve is in the conducting state

$$\sigma = 2\beta$$

SEE: Figure 3.

3.25
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.

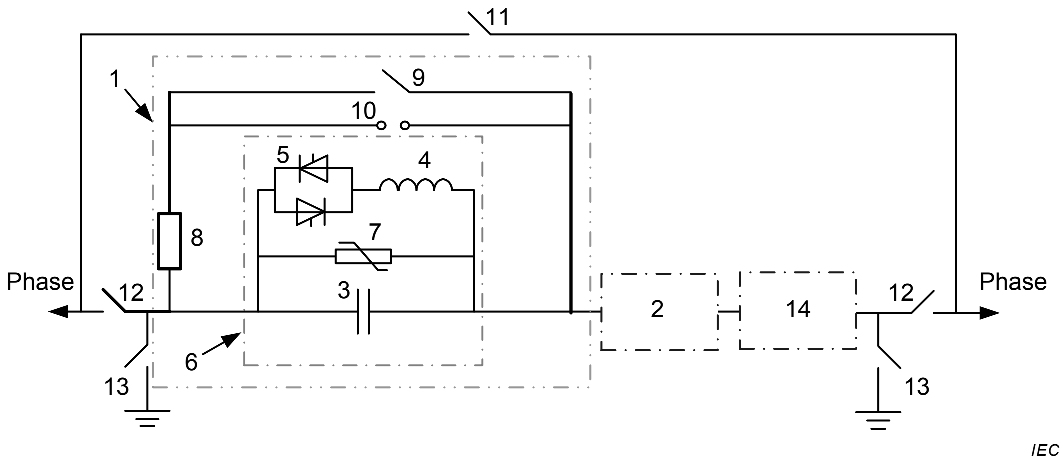
3.26
internal fault
line fault occurring within the protected line section containing the series TCSC subsegment

3.27
external fault
line fault occurring outside the protected line section containing the series TCSC subsegment

4 TCSC valve and valve operation in general

4.1 TCSC installation and TCSC valve

Transmission line series reactance can be compensated by combinations of fixed series capacitors (FSC) and TCSC based controllable segments, as shown in Figure 1. A TCSC subsegment uses a thyristor-controlled reactor (TCR) in parallel with a capacitor bank with the rated capacitance C_N, as shown in Figure 2. The thyristor valve used in this TCSC subsegment is a TCSC valve (See Figure 1, item 5).



Key

1	TCSC unit	8	Discharge current limiter, if applicable
2	Additional TCSC unit when required	9	Bypass switch
3	TCSC capacitor	10	Bypass gap
4	TCSC reactor	11	External bypass disconnector
5	TCSC thyristor valve	12	External isolating switch
6	TCSC subsegment	13	External earth switch
7	Capacitor arrester	14	Additional FSC unit when required

Figure 1 – Typical connection and nomenclature of a TCSC installation

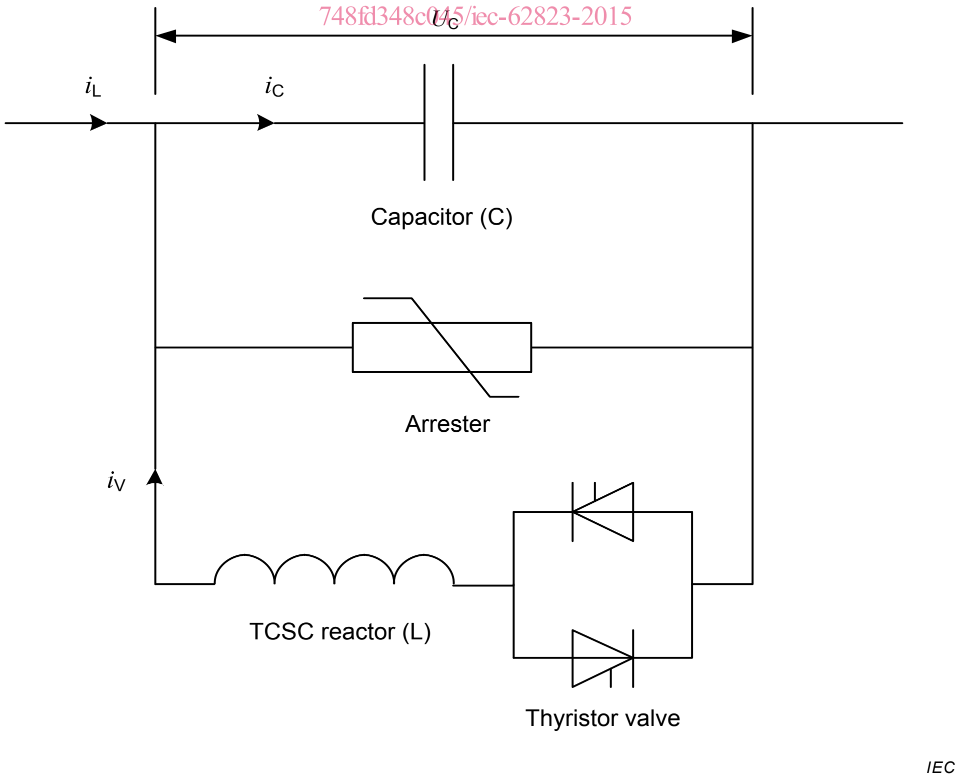


Figure 2 – TCSC subsegment

4.2 TCSC valve current and voltage at capacitive boost operation

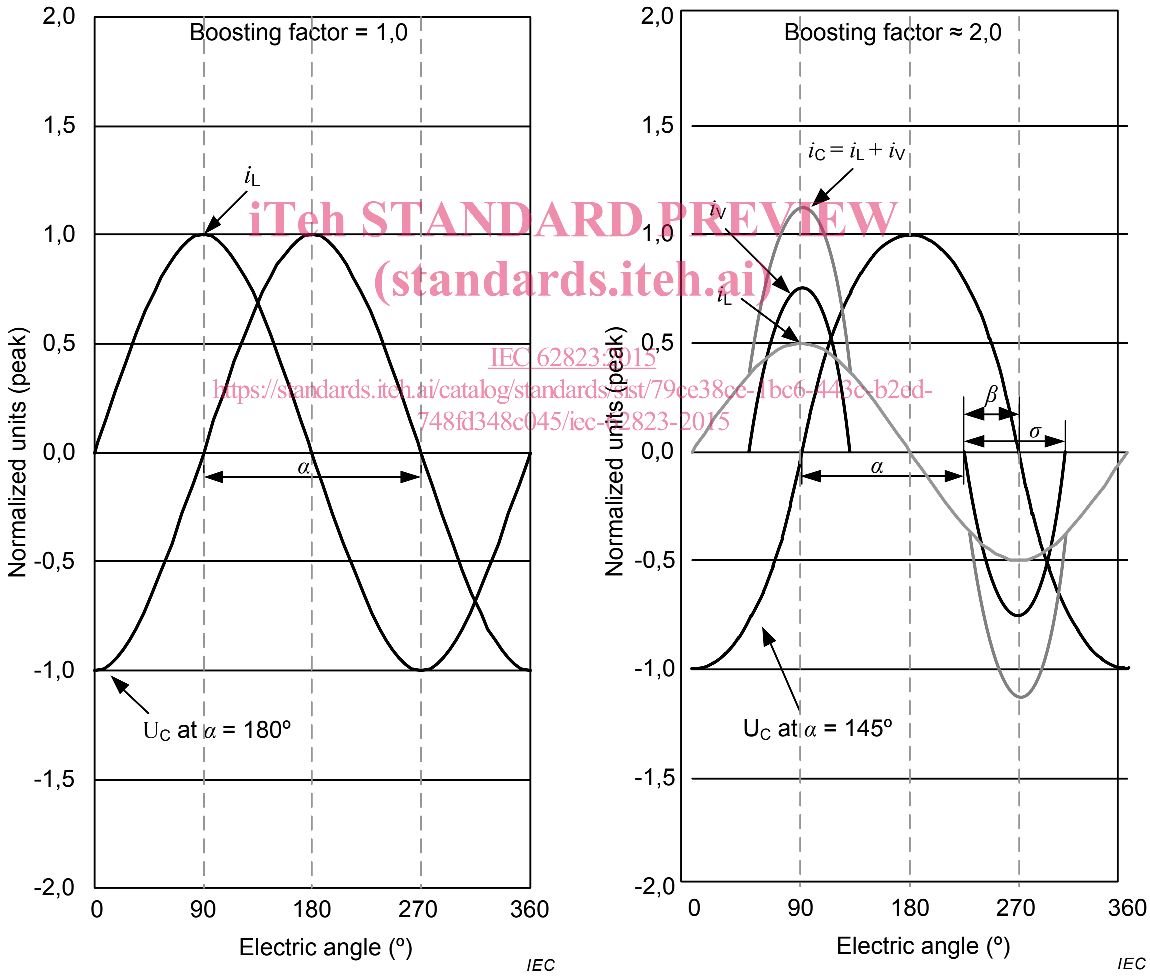
4.2.1 General

Even if a TCSC valve can be, theoretically, operated in an inductive boost mode, this operation is not used in practice in a TCSC installation due to the system compensation need and other limitations. Capacitive boost operation mode is a used operation mode of a TCSC valve.

4.2.2 Waveshapes of valve current and voltage in capacitive boost operation

At a sinusoidal line current and voltage (see Figure 3 a)), the capacitive boost operating of a TCSC valve leads to a deformed sinusoidal current flow through the capacitor bank, C, and TCSC valve (see Figure 3 b)). This current boosts the fundamental frequency voltage drop across the TCSC subsegment.

The waveform of the thyristor valve voltage in a TCSC is shown in Figure 4.



a) Capacitor bank voltage U_C and current i_L at α = 180°

b) Capacitor bank voltage U_C and current i_C at α = 145°

Figure 3 – TCSC steady state waveforms for control angle α and conduction interval σ

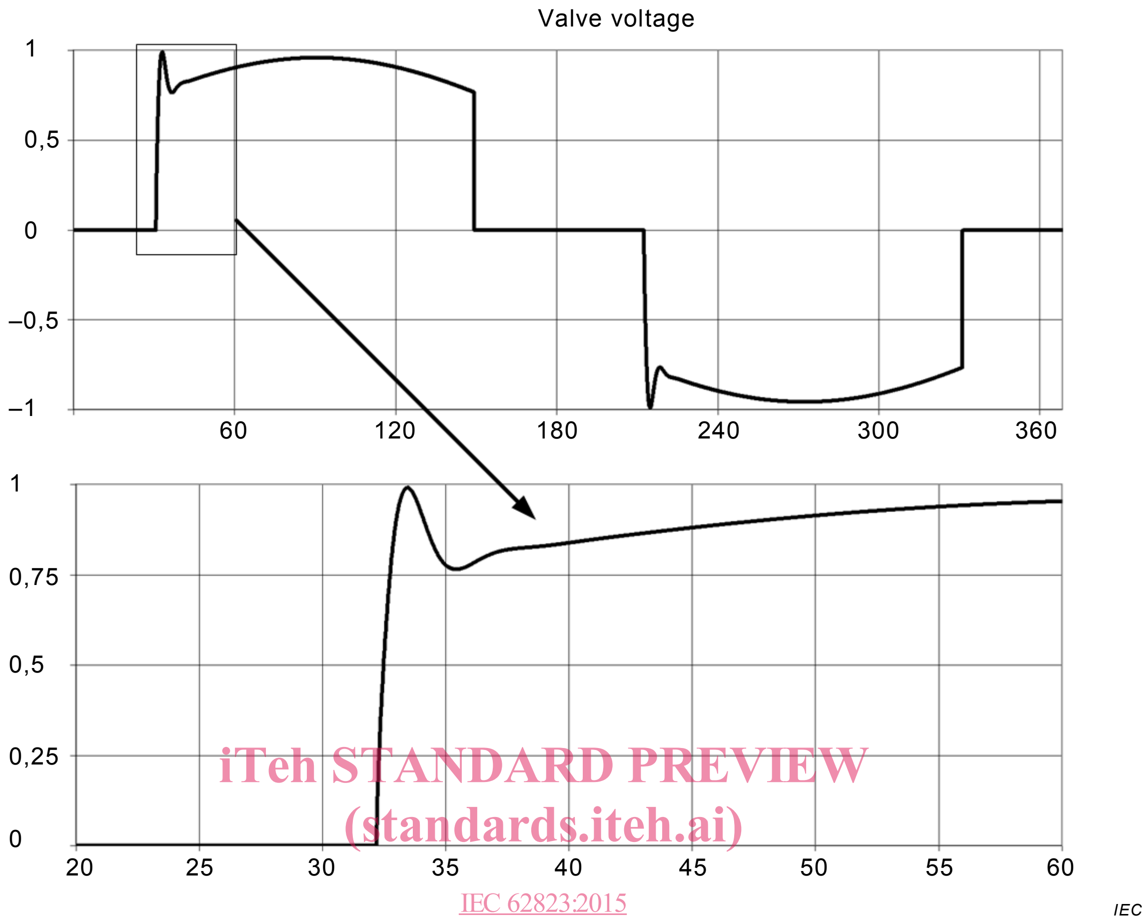


Figure 4 – Thyristor valve voltage in a TCSC

4.2.3 Formulas for TCSC valve current and voltage stresses calculation

4.2.3.1 Capacitive boost operation mode

In TCSC capacitive boost operation mode, the TCSC valve current follows the formulation below:

$$i_V = (-1)^n \cdot \frac{\lambda^2 \cdot i_L}{\lambda^2 - 1} \cdot \left(\cos \omega_N \cdot t - \frac{\cos \beta}{\cos \lambda \cdot \beta} \cdot \cos \lambda \cdot \omega_N \cdot t \right), \qquad n \cdot \pi - \beta \le \omega_N \cdot t \le n \cdot \pi + \beta$$

$$i_V = 0 \qquad n \cdot \pi + \beta < \omega_N \cdot t < (n+1) \cdot \pi - \beta$$

$$n = 0, 1, 2, 3, \ldots$$

where

λ is the ratio of TCSC subsegment LC branch natural frequency and AC system power frequency, $\lambda = \frac{1}{\omega_N \cdot \sqrt{L \cdot C}}$;

i_L is the AC system line current;

ω_N nominal angle frequency of AC system;

β is half of the maximum conduction angle of TCSC valves in one direction for capacitive boost at i_L.