

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



**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**



**THIS PUBLICATION IS COPYRIGHT PROTECTED**  
**Copyright © 2023 IEC, Geneva, Switzerland**

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Secretariat  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

#### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

#### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

#### IEC publications search - [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

#### IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [sales@iec.ch](mailto:sales@iec.ch).

#### IEC Products & Services Portal - [products.iec.ch](http://products.iec.ch)

Discover our powerful search engine and read freely all the publications preview. With a subscription you will always have access to up-to-date content tailored to your needs.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

#### A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

#### A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

#### Recherche de publications IEC -

[webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

#### Service Clients - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: [sales@iec.ch](mailto:sales@iec.ch).

#### IEC Products & Services Portal - [products.iec.ch](http://products.iec.ch)

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 300 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 19 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



**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**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

ICS 29.240.99, 31.060.70

ISBN 978-2-8322-8029-4

**Warning! Make sure that you obtained this publication from an authorized distributor.  
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

## CONTENTS

FOREWORD.....	5
1 Scope.....	7
2 Normative references .....	7
3 Terms, definitions and abbreviated terms .....	8
3.1 Terms and definitions.....	8
3.2 Abbreviated terms.....	11
4 Operating and rating considerations .....	11
4.1 General.....	11
4.2 TCSC characteristics .....	11
4.3 Operating range.....	15
4.4 Reactive power rating .....	16
4.5 Power oscillation damping (POD).....	16
4.6 SSR mitigation .....	16
4.7 Harmonics .....	17
4.8 Control interactions between TCSCs in parallel lines .....	17
4.9 Operating range, overvoltages and duty cycles .....	17
4.9.1 Operating range.....	17
4.9.2 Transient overvoltages .....	18
4.9.3 Duty cycles.....	18
5 Valve control .....	18
5.1 Triggering system .....	18
5.2 System aspects .....	19
5.3 Normal operating conditions.....	19
5.4 Valve firing during system faults .....	20
5.5 Actions at low line current.....	20
5.6 Monitoring.....	20
6 Ratings.....	20
6.1 General.....	20
6.2 Capacitor rating .....	21
6.3 Reactor rating .....	21
6.4 Thyristor valve rating .....	21
6.4.1 General .....	21
6.4.2 Current capability .....	21
6.4.3 Voltage capability .....	22
6.5 Varistor rating .....	24
6.6 Insulation level and creepage distance.....	25
7 Tests .....	25
7.1 General.....	25
7.2 Test of the capacitor .....	25
7.2.1 General .....	25
7.2.2 Routine tests .....	25
7.2.3 Type tests.....	26
7.2.4 Special test (ageing test).....	26
7.3 Tests of the TCSC reactor .....	26
7.3.1 General .....	26
7.3.2 Routine tests .....	26

7.3.3	Type tests.....	27
7.3.4	Special tests.....	27
7.4	Tests of thyristor valves.....	27
7.4.1	General.....	27
7.4.2	Routine tests.....	27
7.4.3	Type tests.....	28
7.5	Tests of protection and control system.....	28
7.5.1	General.....	28
7.5.2	Routine tests.....	28
7.5.3	Type tests.....	29
7.5.4	Special tests – Hardware-in-the-loop (HIL) tests.....	29
8	Guidance for selection of rating and operation.....	30
8.1	General.....	30
8.2	Thyristor controlled series capacitor.....	31
8.2.1	AC transmission system.....	31
8.2.2	TCSC operational objectives.....	32
8.2.3	TCSC ratings.....	32
8.3	Thyristor valves.....	34
8.4	Capacitors and reactors.....	34
8.4.1	General.....	34
8.4.2	Capacitor considerations.....	34
8.4.3	Reactor considerations.....	34
8.5	Fault duty cycles for varistor rating.....	35
8.6	Valve cooling system.....	36
8.7	TCSC control and protection.....	36
8.7.1	General.....	36
8.7.2	Control.....	37
8.7.3	Protection.....	39
8.7.4	Monitoring and recording.....	39
8.8	Precommissioning and commissioning tests.....	40
8.8.1	General.....	40
8.8.2	Pre-commissioning tests.....	40
8.8.3	Station tests.....	41
	Bibliography.....	43
	Figure 1 – Typical nomenclature of a TCSC installation.....	12
	Figure 2 – TCSC subsegment.....	13
	Figure 3 – TCSC steady state waveforms for control angle $\alpha$ and conduction interval $\sigma$ .....	14
	Figure 4 – TCSC apparent reactance characteristics according to Formula (1), with $\lambda = 2,5$ .....	15
	Figure 5 – Example of TCSC operating range for POD (left) and SSR mitigation (right).....	15
	Figure 6 – Valve base electronics (VBE).....	18
	Figure 7 – Valve electronics (VE).....	19
	Figure 8 – Thyristor valve voltage in a TCSC.....	23
	Figure 9 – Typical block diagram of a real time TCSC protection and control system simulation environment.....	30
	Figure 10 – Example of operating range diagram for TCSC.....	33

Table 1 – Peak and RMS voltage relationships .....	13
Table 2 – Typical external fault duty cycle with unsuccessful high speed auto-reclosing .....	35
Table 3 – Typical duty cycle for internal fault with successful high speed auto-reclosing .....	35
Table 4 – Typical duty cycle for internal fault with unsuccessful high speed auto-reclosing .....	36

Currently in preview, click buy full version

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SERIES CAPACITORS FOR POWER SYSTEMS –****Part 4: Thyristor controlled series capacitors**

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publications”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative References cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

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](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/publications](http://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](http://webstore.iec.ch) in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

**IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colour 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 60255-2 (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*