

# IEEE Guide for the Protection of Shunt Capacitor Banks

Sponsor  
**Power System Relaying Committee  
of the  
IEEE Power Engineering Society**

Approved 30 January 2000  
Reaffirmed 14 September 2006

**IEEE-SA Standards Board**

**Abstract:** The protection of shunt power capacitor and filter banks are covered. Guidelines for reliable applications of protection methods intended for use in many shunt capacitor applications and designs are included. The protection of pole-mounted capacitor banks on distribution circuits and the application of capacitors connected directly to routing apparatus are not included.

**Keywords:** capacitor, fuseless, power capacitor, protection, relaying, shunt, unbalance protection

---

The Institute of Electrical and Electronics Engineers, Inc.

3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2000 by the Institute of Electrical and Electronics Engineers, Inc.

All rights reserved. Published 2 June 2000. Printed in the United States of America.

*Print:* ISBN 0-7381-1978-4 SH94831

*PDF:* ISBN 0-7381-1979-2 SS94831

*No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.*

**IEEE Standards** documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE that have expressed an interest in participating in the development of the standard.

Use of an IEEE Standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of all concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board  
445 Hoes Lane  
P.O. Box 1331  
Piscataway, NJ 08855-1331  
USA

Note: Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents for which a license may be required by an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

IEEE is the sole entity that may authorize the use of certification marks, trademarks, or other designations to indicate compliance with the materials set forth herein.

Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; (978) 750-8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

# Introduction

(This introduction is not a part of IEEE Std C37.99-2000, IEEE Guide for the Protection of Shunt Capacitor Banks.)

IEEE Std C37.99-2000 incorporates a significant number of additions and changes since the guide was issued in 1990. Significant changes were made in the clauses dealing with capacitor bank and filter bank protection, unbalance relaying methods, and calculations. The annexes underwent significant changes. Other changes put this guide in line with present-day technologies related to the protection of externally fused, internally fused, fuseless, and unfused capacitor banks.

This guide was revised by the Shunt Capacitor Bank Protection Guide Revision Working Group of the Substation Protection Subcommittee of the Power System Relaying Committee of the IEEE Power Engineering Society. The working group membership at the time of completion of this revision was as follows:

**Gerald E. Fenner, *Chair***  
**Simon R. Chano, *Vice Chair***

Stephen P. Conrad  
Albert N. Darlington  
Paul R. Drum

Philip J. Engel  
Stephen E. Grier  
J. E. Harder  
Roger A. Hedding

Pratap G. Mysore  
Kevin A. Stephan  
James E. Stephens

The following members of the balloting committee voted on this standard:

John Appleyard  
Robert W. Beckwith  
Kenneth Behrendt  
Stuart H. Bouchey  
John Boyle  
Larry Budler  
Mark Carpenter  
Simon R. Chano  
D. Mason Clark  
Stephen P. Conrad  
Albert N. Darlington  
Douglas C. Dawson  
Robert W. Dempsey  
Randall L. Dotson  
Paul R. Drum  
Walter Elmore  
Ahmed Elneweihi  
Philip J. Engel  
Karl Fender  
Gerald E. Fenner  
Jonathan D. Gardell  
Jeffrey G. Gilbert  
Lawrence P. Gradin  
John Kenneth Greene  
Stephen E. Grier  
E. A. Guro

Robert W. Haas  
J. E. Harder  
Roy E. Hart  
Irwin O. Hasenwinkle  
Roger A. Hedding  
Charles F. Henville  
John J. Horwath  
James D. Huddleston, III  
James W. Ingleson  
K. J. Khunkhun  
W. J. Marsh, Jr.  
John R. Matras  
Michael J. McDonald  
Jeffrey L. McElray  
M. Meisinger  
Gary L. Michel  
Daleep C. Mohla  
Brian Mugalian  
Pratap G. Mysore  
George R. Nail  
Bradley D. Nelson  
Jeffrey H. Nelson  
George R. Newcomb  
Alan C. Pierce  
Frank Plumptre

Roger E. Ray  
John G. Reckleff  
Thomas J. Rozek  
Donald R. Ruthman  
Bob Ryan  
Miriam P. Sanders  
Richard Seigny  
Tarlochan Sidhu  
Mark S. Simon  
Peter A. Solanics  
Kevin A. Stephan  
James E. Stephens  
William M. Strang  
Charles. Sufana  
Malcolm J. Swanson  
Richard P. Taylor  
James S. Thorp  
Joe T. Uchiyama  
Eric A. Udren  
Charles L. Wagner  
William P. Waudby  
David J. Zaprazny  
Karl Zimmerman  
John A. Zipp  
Stan Zocholl  
John A. Zulaski

When the IEEE-SA Standards Board approved this standard on 30 January 2000, it had the following membership:

**Richard J. Holleman, *Chair***  
**Donald N. Heirman, *Vice Chair***  
**Judith Gorman, *Secretary***

Satish K. Aggarwal  
Dennis Bodson  
Mark D. Bowman  
James T. Carlo  
Gary R. Engmann  
Harold E. Epstein  
Jay Forster\*  
Ruben D. Garzon

James H. Gurney  
Lowell G. Johnson  
Robert J. Kennelly  
E. G. "Al" Kiener  
Joseph L. Koepfinger\*  
L. Bruce McClung  
Daleep C. Mohla  
Robert F. Munzner

Louis-François Pau  
Ronald C. Petersen  
Gerald H. Peterson  
John B. Posey  
Gary S. Robinson  
Akio Tojo  
Hans E. Weinrich  
Donald W. Zipse

\*Member Emeritus

Also included is the following nonvoting IEEE-SA Standards Board liaison:

Robert E. Hebner

Greg Kohn  
*IEEE Standards Project Editor*

# Contents

1.	Overview.....	1
1.1	Scope.....	1
1.2	Purpose.....	1
2.	References.....	1
3.	Definitions.....	2
4.	Basic considerations.....	4
4.1	Capacitor unit capabilities.....	6
4.2	Arrangement of capacitor units.....	6
4.3	Capacitor bank design.....	7
4.4	Overvoltage on remaining capacitor units.....	9
5.	Bank connections.....	10
5.1	Grounded wye-connected banks.....	10
5.2	Ungrounded wye-connected banks.....	11
5.3	Delta-connected banks.....	12
5.4	H configuration.....	13
6.	Other considerations.....	13
6.1	Single-point and peninsula grounding.....	13
6.2	Neutral grounding.....	15
7.	Introduction to bank and system protection.....	16
7.1	Bank protection.....	17
7.2	System protection.....	21
8.	Unbalance relaying methods.....	24
8.1	Introduction.....	24
8.2	General unbalance relay considerations.....	25
8.3	Externally fused capacitor banks.....	34
8.4	Internally fused capacitor banks.....	45
8.5	Fuseless capacitor banks.....	59
8.6	Unfused capacitor banks.....	67
9.	Protection of capacitor filter banks.....	73
9.1	Filter bank protection.....	73
9.2	Multifrequency harmonic filter protection considerations.....	76
9.3	Static var compensator (SVC) capacitor protection.....	78
9.4	SVC filter protection.....	80

10.	Capacitor bank equipment considerations .....	80
	10.1 Capacitor bank switching devices.....	80
	10.2 Inrush control devices .....	83
	10.3 Surge arresters.....	84
	10.4 Voltage-sensing devices.....	84
	10.5 Current-sensing devices .....	84
	10.6 Transient currents.....	85
	10.7 Control cables .....	90
11.	System considerations.....	91
	11.1 Resonance .....	91
	11.2 Harmonics .....	91
	11.3 Telephone interference.....	91
12.	Commissioning, operation, and maintenance .....	92
	12.1 Preparation for initial energizing .....	92
	12.2 Response to alarm or lockout (trip) .....	93
	Annex A (informative) Symbol definitions .....	95
	Annex B (informative) Bibliography.....	97
	Annex C (informative) Equations for effect of inherent unbalances.....	99
	Annex D (informative) Inrush current and frequency for switching capacitor banks .....	100

# IEEE Guide for the Protection of Shunt Capacitor Banks

## 1. Overview

### 1.1 Scope

This guide applies to the protection of shunt power capacitor and filter banks. Included are guidelines for reliable applications of protection methods intended for use in many shunt capacitor applications and designs. The guide does not include a discussion of pole-mounted capacitor banks on distribution circuits or application of capacitors connected to rotating apparatus.

### 1.2 Purpose

This guide has been prepared to assist in the application of relays and other devices for the protection of shunt capacitor banks used in substations. It covers methods of protection for many commonly used shunt capacitor bank configurations. Capacitor bank design trade-offs are also discussed because bank design influences the protection. Additionally, this guide covers the protection of filter banks and large extra-high voltage (EHV) shunt capacitor banks.

## 2. References

This guide shall be used in conjunction with the following publications. If the following publications are superseded by an approved revision, the revision shall apply:

ANSI C37.06-1997, American National Standard AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis—Preferred Ratings and Related Required Capabilities.<sup>1</sup>

ANSI C37.66-1969 (Reaff 1988), American National Standard for Requirements for Oil-Filled Capacitor Switches for Alternating-Current Systems.

IEEE Std 18-1992, IEEE Standard for Shunt Power Capacitors.<sup>2</sup>

---

<sup>1</sup>ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>). The ANSI documents listed in Clause 2 are also available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).