

IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part III-Generator Auxiliary Systems

Sponsor

Surge-Protective Devices Committee
of the
IEEE Power Engineering Society

Reaffirmed June 7, 2000

Approved August 1 1994

American National Standards Institute

Reaffirmed June 9, 2005

Approved December 2, 1993

IEEE-SA Standards Board

Abstract: Basic factors and general considerations in selecting the class and means of neutral grounding for electrical generating plant auxiliary power systems are given in this guide. Apparatus to be used to achieve the desired grounding are suggested, and methods to specify the grounding devices are given. Sensitivity and selectivity of equipment ground-fault protection as affected by selection of the neutral grounding device are discussed, with examples.

Keywords: electrical generating plants, electrical utility systems, generator auxiliary systems, ground-fault protection, grounding, neutral grounding

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 1994 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 1994. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by the Institute of Electrical and Electronics Engineers, Incorporated.

ISBN 1-55937-388-1

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 Technical Committees of the IEEE Societies and the Standards Coordinating Committees of the IEEE 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, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the view point expressed at the time a standard is approved and issued is subject to change 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 related 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 technical 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 Standards Board
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
USA

IEEE Standards documents may involve the use of patented technology. Their approval by the Institute of Electrical and Electronics Engineers does not mean that using such technology for the purpose of conforming to such standard is authorized by the patent owner. It is the obligation of the user of such technology to obtain all necessary permissions.

Introduction

(This introduction is not a part of IEEE Std C62.92.3-1993, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part III—Generator Auxiliary Systems.)

This guide is part of a series on neutral grounding in electrical utility systems. When the series of documents are approved and published, they will replace IEEE Std 143-1954, IEEE Guide for Ground-Fault Neutralizers, Grounding of Synchronous Generator Systems, and Neutral Grounding of Transmission Systems.

IEEE Std 143-1954 is a revision of AIEE No. 954, Oct. 1954, which was a compilation of the following three *AIEE Transactions* papers:

AIEE Committee Guide Report, “Application of Ground-Fault Neutralizers,” *AIEE Transactions (Power Apparatus and Systems)*, vol. 72, pt. III, pp. 183–190, Apr. 1953.

AIEE Committee Report, “Application Guide for the Grounding of Synchronous Generator Systems,” *AIEE Transactions (Power Apparatus and Systems)*, vol. 72, pt. III, pp. 517–530, June 1953.

AIEE Committee Report, “Application Guide on Methods of Neutral Grounding of Transmission Systems,” *AIEE Transactions (Power Apparatus and Systems)*, vol. 72, pt. III, pp. 663–668, June 1953.

The contents of Parts I–V of the revision of IEEE Std 143-1954 are based on the foregoing documents but are amplified and updated with new material from the IEEE tutorial course, “Surge Protection in Power Systems” [(79H)144-6-PWR], and other sources.

Part III covers the considerations and practices relating to grounding of generating station auxiliary power systems. The related parts are: Part I, Introduction (Theory and performance characteristics of classes of neutral grounding); Part II, Grounding of Synchronous Generator Systems; Part IV, Distribution; and Part V, Transmission Systems and Subtransmission Systems.

It is impossible to give recognition to all those who have contributed to the technology and practices of grounding of power systems since work involving the preparation of this guide has been in progress for over 30 years. However, the assistance of members, past and present, of the Neutral Grounding Devices Subcommittee of the Surge-Protective Devices Committee, and other similar groups with comparable purposes, should be acknowledged.

Disclaimer

This guide is specifically written for electrical utility systems and does not recognize the neutral grounding requirements for dispersed storage and generation. These requirements must recognize the restrictions imposed by the specific network to which the dispersed storage or generation is connected. Neutral grounding of dispersed storage and generation needs to be coordinated with the electrical utility system.

At the time this guide was approved, the Working Group for Part III of the Neutral Grounding Devices Subcommittee had the following membership:

David W. Jackson, Chair

C. L. Ballentine
A. Bengé
D. C. Dawson

J. R. Detweiler
E. Knapp
J. L. Koepfinger

B. R. Leuenberger
S. Mazumdar

Recognition is also given to a former member of the working group for significant contributions: G. A. Pillmore.

The following persons were on the balloting committee:

D. C. Dawson	R. A. Jones	J. C. Osterhout
G. L. Gaibrois	J. L. Koepfinger	K. B. Stump
C. D. Hansell	G. E. Lee	E. R. Taylor, Jr.
G. S. Haralampu	D. W. Lenk	R. Thallam
J. A. Hetrick	B. R. Leuenberger	S. G. Whisenant
A. R. Hileman	A. W. Maguire	
David W. Jackson	Y. Musa	

At the time this standard was published, it was under consideration for approval as an American National Standard. The Accredited Standards Committee on Surge Arresters, C62, had the following members at the time this document was sent to letter ballot:

Joseph L. Koepfinger, *Chair*
John A. Gauthier, *Secretary*

Organization Represented

Name of Representative

Association of American Railroads	Wayne Etter
Bonneville Power Administration	G. E. Lee
Canadian Standards Association	D. M. Smith
Electric Light and Power	R. A. Jones H. E. Foelker W. A. Maguire F. Martinez J. W. Wilson M. C. Mingoia (<i>Alt.</i>)
Exchange Carriers Standards Association	Chrysanthos Chrysanthou
Institute of Electrical and Electronics Engineers	J. L. Koepfinger J. J. Burke G. L. Gaibrois W. H. Kapp S.S. Kershaw, Jr. C. Hansell (<i>Alt.</i>) Edgar Taylor (<i>Alt.</i>)
National Electrical Manufacturers Association	Dennis W. Lenk Bernhard Wolff D. Worden Larry Bock (<i>Alt.</i>)
Members-at-Large	J. Osterhout B. Panesar R. B. Standler
Rural Electrification Administration	George J. Bagnall
Underwriters Laboratories	P. Notarian Larry Williams (<i>Alt.</i>)

When the IEEE Standards Board approved this standard on December 2, 1993, it had the following membership:

Wallace S. Read, *Chair*
Donald C. Loughry, *Vice Chair*
Andrew G. Salem, *Secretary*

Gilles A. Baril
José A. Berrios de la Paz
Clyde R. Camp
Donald C. Fleckenstein
Jay Forster*
David F. Franklin
Ramiro Garcia
Donald N. Heirman

Jim Isaak
Ben C. Johnson
Walter J. Karplus
Lorraine C. Kevra
E. G. “Al” Kiener
Ivor N. Knight
Joseph L. Koepfinger*
D. N. “Jim” Logothetis

Don T Michael*
Marco W. Migliaro
L. John Rankine
Arthur K. Reilly
Ronald H. Reimer
Gary S. Robinson
Leonard L. Tripp
Donald W. Zipse

*Member Emeritus

Also included are the following nonvoting IEEE Standards Board liaisons:

Satish K. Aggarwal
James Beall

Richard B. Engelman
David E. Soffrin

Stanley I. Warshaw

Mary Lynne Nielsen
IEEE Standards Project Editor

CLAUSE	PAGE
1. Overview.....	1
1.1 Scope.....	1
1.2 Purpose.....	1
2. References.....	2
3. Introduction.....	2
3.1 Principal characteristics	2
3.2 Past and present practice	2
4. Basic considerations.....	4
4.1 Basic factors	4
4.2 Service continuity	4
4.3 Damage criterion.....	5
4.4 Magnitude of overvoltages.....	6
4.5 Sensitivity and selectivity of ground-fault relaying.....	8
4.6 Magnitude of ground-fault current.....	9
4.7 Emergency, standby, vital, and safety-related ac and dc systems.....	10
5. Grounding classes usually applied	10
5.1 Ungrounded.....	10
5.2 Resistance grounding	11
5.3 Effective grounding (solid or direct).....	11
5.4 Grounding dc control systems.....	12
6. Selecting the grounding device	12
6.1 Grounding—general.....	12
6.2 Selection of a neutral grounding resistor	12
7. Bibliography.....	16
Annex A (Normative) Ground-fault protection	18
Annex B (Normative) Ground-fault location.....	20

IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part III—Generator Auxiliary Systems

1. Overview

1.1 Scope

This guide summarizes the general considerations in grounding of generating station auxiliary power systems and discusses the factors to be considered in selecting between the appropriate grounding classes and in specifying equipment ratings. This guide applies to both medium-voltage and low-voltage auxiliary power systems. Grounding and bonding to achieve practical safeguarding of persons is fulfilled by electrically connecting equipment frames and enclosures and interconnecting wiring raceways to the station grounding network (see IEEE Std 142-1991¹), as required by ANSI C2-1993. References to safety in this guide mean freedom from equipment damage. The emphasis is on reliability and availability of auxiliary system service achieved through control of ground-fault currents and transient overvoltages.

This guide is specifically written for electrical utility systems and does not recognize the neutral grounding requirements for dispersed storage and generation. These requirements must recognize the restrictions imposed by the specific network to which the dispersed storage or generation is connected. Neutral grounding of dispersed storage and generation needs to be coordinated with the electrical utility system.

1.2 Purpose

The purpose of this guide is to present some basic considerations for the selection of neutral grounding parameters that will provide for the control of ground-fault currents and overvoltage on auxiliary systems of electrical utility three-phase generators.

¹Information on references can be found in clause 2.

2. References

This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

Accredited Standards Committee C2-1993, National Electrical Safety Code (ANSI).²

IEEE Std 32-1972 (Reaff 1991), IEEE Standard Requirements, Terminology, and Test Procedures for Neutral Grounding Devices (ANSI).³

IEEE Std 80-1986 (Reaff 1991), IEEE Guide for Safety in AC Substation Grounding (ANSI).

IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).

IEEE Std 142-1991, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book) (ANSI).

IEEE Std C62.92.1-1987 (Reaff 1993), IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part I—Introduction (ANSI).

IEEE Std C62.92.2-1989, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part II—rounding of Synchronous Generator Systems (ANSI).

IEEE Std C62.92.4-1991, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part IV—Distribution (ANSI).

3. Introduction

3.1 Principal characteristics

The principal performance characteristics of the various classes of system neutral grounding, as well as the major considerations in selecting an appropriate class, are presented in IEEE Std C62.92.1-1987. Application techniques for high-resistance grounding are developed in the discussion and examples of IEEE Std C62.92.2-1989. These considerations are directly applicable to grounding generating station auxiliary service systems. The user of this guide is presumed to be familiar with these two standards.

3.2 Past and present practice

Station auxiliary systems have in the past been quite commonly operated ungrounded, and some still are. It has long been recognized that ungrounded systems are actually grounded without intent through the system capacitance to ground. Under certain fault conditions, such systems are susceptible to high transient overvoltages that can damage rotating machines and cable insulation. Consequently, neutral grounding is being increasingly used on station auxiliary systems to control transient overvoltages [B22].⁴

²The National Electrical Safety Code is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

³IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁴The numbers in brackets correspond those of the bibliography in clause 7.

Table 1 presents the grounding practices for 389 auxiliary power systems in 199 new utility power generating plants as recorded in the *Electrical World* Steam Station Design Surveys No. 13 through No. 18, 1974 through 1984. All systems reported in table 1 are those for which both a voltage and a grounding class were recorded.

When intentionally grounded, low-voltage systems have until recently usually been solidly grounded. Ground faults were expected to produce sufficient current to permit selective coordination of phase protective equipment to isolate the fault if the fault circuit was not too long and the ground-fault return circuit was of low enough impedance. Low-voltage direct-acting devices have usually had the capability to clear the faults fast enough to prevent excessive fault damage. There has been recent increased use of resistance grounding of large 480 V systems, as reported in table 1, and even of ground-fault protective tripping using equipment commonly employed on industrial systems [B18]. Only one 208 V directly grounded system was reported.

Table 1—Grounding practices on power plant auxiliary power systems

Voltage level	High resistance		Low resistance		Direct grounding		Ungrounded		Total in voltage class	
(kV)	Number	(%)	Number	(%)	Number	(%)	Number	(%)	Number	(%)
High										
23	1	0.3							1	0.3
Medium										
12-13-14	8	2.1	17	4.4	10	2.6	3	0.8	38	9.8
10			1	0.3					1	0.3
7-8	14	3.6	46	11.8	13	3.3	3	0.8	76	19.5
5					1	0.3			1	0.3
4	30	7.7	62	15.9	28	7.2	9	2.3	129	33.2
2.5	1	0.3							1	0.3
Low										
0.6 and less	34	8.7	74	19.0	24	6.2	10	2.6	142	36.5
Total in grounding class	88	22.6	200	51.4	76	19.5	25	6.4	389	100
NOTE — Practices for 199 plants and 389 systems. Percents are percentages of the total.										

Medium-voltage systems in new plants: 15 systems were ungrounded (6%), 52 systems were directly grounded (21%), 126 systems were low-resistance grounded (51%), and 54 systems were high-resistance grounded (22%). More than half the station auxiliary systems at these voltages have been grounded through a low resistance permitting up to one-third of the three-phase fault current amperes. This current range has permitted good selective protection using commonly available relays and phase current transformers in residual connection (IEEE Std 142-1991). Nearly a quarter of the reported systems adopted high-resistance grounding. The availability of core balance (window or through-type) zero-sequence current transformers and associated relays has made possible selectively coordinated protection for the low values of ground-fault current associated with high-resistance grounding [B19].