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IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part I: Introduction

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Approved 7 December 2016

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Abstract: The application of neutral grounding to three-phase electrical utility systems is described in this guide. It is Part 1 of the IEEE C62.92 series of guides for neutral grounding. This guide presents basic considerations of the selection of neutral grounding parameters that will provide for the control of overvoltage and ground-fault current on all parts of three-phase electrical utility systems rated greater than 1000 V.

Keywords: classes of grounding, effectively grounding, IEEE C62.92.1™, means of grounding, neutral grounding, undergrounded systems

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Introduction

This introduction is not part of IEEE Std C62.92.1–2016, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part I: Introduction.

This document is the first part of a five-part series of guides on the subject of electric utility system neutral grounding practices and serves as an introduction. When the series was first approved and published, it replaced IEEE Std 143™-1954, IEEE Guide for Ground-Fault Neutralizers, Grounding of Synchronous Generator Systems, and Neutral Grounding of Transmission Systems.

Each of the remaining four parts addresses a specific part of the utility system to serve as a guide for neutral grounding. The five parts are as follows:

a) IEEE Std C62.92.1™, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part I: Introduction[1]

b) IEEE Std C62.92.2™, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part II: Grounding of Synchronous Generator Systems

c) IEEE Std C62.92.3™, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part III: Generator Auxiliary Systems

d) IEEE Std C62.92.4™, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part IV: Distribution

e) IEEE Std C62.92.5™, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part V: Transmission and Subtransmission Systems

This series of guides is intended for application to three-phase electrical utility systems. They provide definitions and considerations that are general to all types of neutral grounding for electrical utility systems, as well as basic considerations of the selection of neutral grounding parameters that will provide for the control of overvoltage and ground-fault current on all parts of three-phase electrical utility systems. They are not intended to be used with the grounding, for example, of industrial systems, which are covered in other guides and standards. These guides and standards should be referenced, when appropriate, to gain a full picture of other grounding practices.

This document has been revised to address comments received as part of the most recent re-affirmation ballot. The most significant changes were to correct an error in one of the equations in the caption beneath Figure 1 in 6.3 and to correct an omission in the drawing itself. Equation A.2 and Equation A.3 were changed to correct arithmetic errors. Most of the other comments received during that re-affirmation ballot were editorial in nature and have been addressed. Other changes include the update of reference material publish dates that may have changed or been updated.

It is impossible to give recognition to all those who have contributed to the technology and practices of grounding of power systems, because work involving the preparation of this guide has been in progress for more than 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.

[1]Information on references can be found in Clause 2.

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IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part I: Introduction

1. Overview

1.1 Scope

This guide is intended for application to three-phase electrical utility systems~~. This~~ and is Part I of the ~~five-part~~ IEEE Std C62.92 series. This part provides definitions and considerations that are general to all types of neutral grounding for electrical utility systems. ~~The remaining four parts provide specific guidance on synchronous generator systems (IEEE Std C62.92.2-1989), generating station auxiliary systems (IEEE Std C62.92.3-1993), distribution systems (IEEE Std C62.92.4-1991), and transmission~~ Goals of system grounding, means of grounding, and ~~subtransmission systems (IEEE Std C62.92.5-1992)~~ classes of grounding are addressed in this part.

1.2 Purpose

This guide presents basic considerations ~~for~~ of the selection of neutral grounding parameters that will provide for the control of overvoltage and ground-fault current on all parts of three-phase electrical utility systems.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

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IEEE Std 80~~-2000~~ ™, IEEE Guide for Safety in AC Substation Grounding.[~~1~~ 3,4]

IEEE Std 142~~-1991~~ ™, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book ™).[5]

IEEE Std C62.92.2~~-1989 (Reaff 2000)~~ ™, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part II: Grounding of Synchronous Generator Systems.

IEEE Std C62.92.3~~-1993 (Reaff 2000)~~ ™, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part III: Generator Auxiliary Systems.

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3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the ~~purpose~~ purposes of this ~~guide~~ document, the following terms and definitions apply. ~~Terms other than those defined here have standard definitions as listed in *The Authoritative Dictionary of*~~ The *IEEE Standards* ~~*Terms*, Seventh Edition [B10].~~[3] *Dictionary Online* should be consulted for terms not defined in this clause.[6]

capacitance grounded: Grounded through an impedance, the principal element of which is capacitance.

class of grounding: A specific range or degree of grounding, e.g., effectively and non-effectively.

coefficient of grounding (COG): The ratio, ELG/ELL (expressed as a percentage), of the highest root-mean-square (rms) line-to-ground power-frequency voltage ELG on a sound phase, at a selected location, during a fault to ground affecting one or more phases to the line-to-line power-frequency voltage ELL that would be obtained at the selected location with the fault removed.

effectively grounded: An expression that means grounded through a grounding connection of sufficiently low impedance (inherent or intentionally added or both) that a ground fault that may occur cannot build up voltages in excess of limits established for apparatus, circuits, or systems so grounded.

ground fault factor (GFF): The ratio of the highest phase-to-ground power frequency voltage on an unfaulted phase during a line-to-ground fault to the phase-to-ground power-frequency voltage without the fault.

inductance grounded: Grounded through an impedance, the principal element of which is inductance.

[6] *IEEE Standards Dictionary Online* is available at: http://dictionary.ieee.org

~~[3] The numbers in brackets correspond to those of the bibliography in Annex C.~~

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means of grounding: The physical devices by which various degrees of grounding are achieved~~;~~, e.g., inductance grounding, resistance grounding, or resonant grounding.

non-effectively grounded: Grounded through a grounding connection of sufficient impedance (inherent or intentionally added or both) that a ground fault that might occur results in voltages in excess of limits established for apparatus, circuits, or systems as defined by an effectively grounded system.

resistance grounded: Grounded through an impedance, the principal element of which is resistance.

resonant grounded: A system in which one or more neutral points are connected to ground through reactors that approximately compensate the capacitive component of a single-phase-to-ground-fault current.

~~**Definition**~~ **solidly grounded**: Connected directly to ground through an adequate ground connection in which no impedance has been inserted intentionally.

ungrounded: A system, circuit, or apparatus without an intentional connection to ground, except through potential-indicating or measuring devices or other very-high-impedance devices.

3.2 Acronyms and abbreviations

COG Coefficient of grounding

EHV Extra high voltage

GFF Ground fault factor

HV High voltage

OHGW Overhead ground wire(s)

NOTE—This guide distinguishes high voltage (HV) from extra high voltage (EHV) as follows: HV refers to nominal system voltages less than or equal to 230 kV, whereas EHV refers to nominal system voltages above 230 kV.[7]

[7]Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

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4. Basic considerations

There is no one simple answer to the ~~problem~~ application of grounding. Each of a number of possible solutions to a grounding problem has at least one feature that is outstanding, but which is obtained at some sacrifice of other features that may be equally worthy. Thus, the selection of the class and means of grounding is often a compromise between somewhat conflicting solutions (see IEEE Tutorial Course [B17]).[8]

4.1 ~~Goals~~ Factors of system grounding

The basic ~~goals~~ factors in selecting a grounding scheme for any given system are as follows:

a) Voltage ratings and degree of surge-voltage protection available from surge arresters

b) Limitation of transient line-to-ground overvoltages (see ~~Generator Grounding Guide [B2],~~ IEEE Std C62.92.2 and IEEE Tutorial Course [B17])

c) Sensitivity and selectivity of the ground-fault relaying

d) Limitation of the magnitude of the ground-fault current

e) Safety (see ~~(~~National Electrical Safety Code®~~)~~ (NESC®) (Accredited Standards Committee C2-~~1997~~ 2017) and IEEE Std 80~~-2000~~)[4]

These basic ~~goals~~ factors, when properly evaluated, can have a significant influence on system economics, details of system design and physical layout, and service continuity.

[8]The numbers in brackets correspond with to those of the bibliography in Annex C.

~~[4]For more information on references see Clause 2.~~

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4.2 System neutral grounding ~~vs~~ versus apparatus neutral grounding

In power engineering, it is common to speak of grounding the system neutral either directly or through an impedance. Actually, ~~of course,~~ the system neutral is a convenient fiction, not a physical point ~~or conductor~~, and cannot be physically connected to ground. While it is possible to ground the neutral conductor of a four-wire, three-phase system, it is the neutral grounding of specific pieces of power-system apparatus, especially power transformers and generators~~,~~ that ~~effects~~ affects system neutral grounding the most.

In this guide, the term "means of grounding" is used to describe the particular technique used to ground the neutral of a specific piece of apparatus. For example, resistance grounding is a means of grounding the neutral of a piece of apparatus, in this case by means of a resistor. The term "class of grounding" is used to categorize system grounding in terms of its performance characteristics.

In a simple power system, like ~~the~~ a typical distribution system or power-plant auxiliary system, where a single transformer serves as both the power source and system-neutral grounding point, the means of grounding of that transformer neutral defines the grounding ~~class~~ technique (means) of the system. For example, a system supplied by a single transformer whose neutral is grounded through a resistance would typically be ~~classed~~ referred to as a resistance-grounded system.

In more complex systems, like a typical high voltage (HV) or extra-high voltage (EHV) transmission ~~systems~~ system, there are many pieces of apparatus (transformers, capacitor banks, reactors, etc.) that may have grounded neutrals. In such multiple-grounded systems, the class of grounding of the system is determined by the cumulative effect of all the grounding points. If most of the major transformer neutrals are grounded by similar means, then the system may loosely be described as being of one ~~class~~ means (e.g., an inductance grounded system). In general, where there are multiple grounding points of different types of apparatus and different means of apparatus neutral grounding, the class of grounding can only be determined by the zero-sequence to positive-sequence symmetrical component ratios, as viewed from a selected location. (See Clause 7 and Table 1.) (For further information see Clarke [B6], and Wagner and Evans [B22].)

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