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

Sponsor

**Surge Protective Devices Committee
of the
IEEE Power Engineering Society**

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Abstract: *This guide is the introduction to the C62.92 series of five IEEE guides on neutral grounding in three-phase electrical utility systems. It provides system grounding definitions and considerations that are general to all types of electrical utility systems.*

Keywords: *class of grounding, coefficient of grounding (COG), earth-fault factor (EFF), earth-return path, effectively grounded, electrical utility systems, grounded solidly, ground-fault current, impedance grounding, means of grounding, neutral grounding, power-system grounding, reactance grounded, system grounding*

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Introduction

(This introduction is not a part of IEEE Std C62.92.1-2000, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part I: Introduction.)

This guide is the introduction to the IEEE C62.92 series of five guides on neutral grounding in electrical utility systems. In this series of guides, individual considerations and practices are given to the grounding of synchronous generator systems, generator-station auxiliary systems, distribution systems, and transmission and subtransmission systems.

In the entire IEEE C62.92 series, emphasis is on power-system grounding practices as contrasted with the grounding, e.g., of industrial systems, which are covered in other guides and standards. Those guides and standards should be referenced, when appropriate, to gain a full picture of other grounding practices.

Besides updating the format of the guide, this revision expands the bibliography, adds a new annex to clarify the effects of grounding resistances and grounded conductors, and attempts to clarify areas that elicited questions or comments in IEEE Std C62.92-1987.

It is impossible to give recognition to all those who have contributed to the technology and practices of grounding of power systems. However, the assistance of members, past and present, of the Neutral Grounding Devices Working Group of the Surge Protective Devices Committee, and other similar groups with comparable purposes, is gratefully acknowledged.

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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 is Part I of the five-part IEEE C62.92 series. This part provides definitions and considerations that are general to all types of 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 and subtransmission systems (IEEE Std C62.92.5-1992).

1.2 Purpose

This guide presents basic considerations for 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. References

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

IEEE Std 80-2000, IEEE Guide for Safety in AC Substation Grounding.¹

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

¹IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

ASC C2-1997, Accredited Standards Committee, National Electrical Safety Code[®] (NESC[®]).²

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.

IEEE Std C62.92.4-1991 (Reaff 1996), IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part IV: Distribution Systems.

IEEE Std C62.92.5-1992 (Reaff 1997), IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part V: Transmission Systems and Subtransmission Systems.

3. Definitions

For the purpose of this guide the following terms and definitions apply. Terms other than those defined here have standard definitions as listed in *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition [B10].³

3.1 class of grounding: A specific range or degree of grounding; e.g., effectively and noneffectively.

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

4. Basic considerations

There is no one simple answer to the problem 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]).

4.1 Goals of system grounding

The basic goals 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], 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 Accredited Standards Committee C2-1997 (National Electrical Safety Code[®]) (NESC[®]) and IEEE Std 80-2000)⁴

²The NESC is 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/>).

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

⁴For more information on references see Clause 2.

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

4.2 System neutral grounding vs 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. It is the neutral grounding of specific pieces of power-system apparatus, especially power transformers and generators, that effects system neutral grounding.

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 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 of the system. For example, a system supplied by a single transformer whose neutral is grounded through a resistance would typically be classed as a *resistance-grounded system*.

In more complex systems, like typical high voltage (HV) or extra-high voltage (EHV) transmission systems, 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 (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].)

5. Means of grounding

5.1 Solidly grounded

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

The term *grounded solidly*, though commonly used, may be somewhat misleading since a transformer may have its neutral connected solidly to ground, and yet the resulting zero-sequence impedance (see Figure 1) could be so high, due to the system or transformer characteristics, that high phase-to-ground voltages would develop during ground-fault conditions. Instead, so as to define grounding positively and logically as to degree, the term *effectively grounded* has come into use, as is discussed in 7.1.

5.2 Inductance grounded

Definition: Grounded through an impedance, the principal element of which is inductance. This class of grounding is sometimes loosely referred to as *reactance grounded*. The class is often subdivided into *low-* or *high-inductance* categories.

The inductance may either be inserted directly in the neutral connection to ground or obtained indirectly by increasing the reactance of the ground return circuit. The latter may be done by intentionally increasing the zero-sequence reactance of apparatus connected to ground or by omitting some of the possible connections from apparatus neutrals to ground.

5.3 Resistance grounded

Definition: Grounded through an impedance, the principal element of which is resistance. This class is frequently subdivided into *low-* or *high-resistance* categories.

The resistance may be inserted either directly in the connection to ground or indirectly as, for example, the following:

- a) In the secondary of a transformer, the primary of which is connected between neutral and ground.
- b) In the corner of a broken-delta connected secondary of a wye-delta grounding transformer.

(See IEEE Std C62.92.2-1989 and IEEE Std C62.92.3-1993 for application information on resistance grounding.)

It should be noted that a grounding resistor may have a considerable inherent inductance. For example, a cast-iron grid resistor may have a power factor of 98% or less, resulting in a reactance of about 20% of the resistance, at system frequency (see T&D Reference Book [B5]).

5.4 Resonant grounded

Definition: Inductance grounded through such values of reactance that, during a fault between one of the conductors and ground, the power-frequency inductive current flowing in the grounding inductance(s) and the power-frequency capacitance current flowing between the unfaulted conductors and ground are substantially equal in magnitude and 180° out of phase. Therefore, they almost cancel each other in the fault. The type of grounding inductor used is commonly referred to as a *ground fault neutralizer*, *arc-suppression coil*, or *Peterson coil* (see Transmission Grounding Guide [B3], and Willheim and Waters [B23]).

It is expected that the quadrature component of the rated-frequency, single-phase-to-ground fault current will be so small that an arcing fault in air will be self-extinguishing. See Ground Fault Neutralizer Guide [B8], and Willheim and Waters [B23] for application information about resonant grounding in transmission and subtransmission systems; and IEEE Std C62.92.2-1989 for application to synchronous generator grounding.

5.5 Capacitance grounded

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

Capacitance is seldom, if ever, inserted directly in a connection to ground for system grounding purposes. However, capacitance may be connected to ground for voltage surge front-of-wave sloping purposes. Also, neutrals of shunt capacitor banks have been connected solidly to ground on otherwise ungrounded systems. Such applications should be carefully analyzed for overvoltages during fault conditions (see Ground Fault Neutralizer Guide [B8], and Peterson [B20]). Capacitance grounding should be avoided, or carefully analyzed, for resonance conditions or increased fault current.