Canadian Standards Association
Etobicoke, Ontario
To the Part I Committee

Subject No. 3045 Chair: R. Leduc Date: October 31, 2003

Title: Size of Grounded Conductor, Rule 10-204(5)

Submitted by: Vince Rowe of Vice Rowe Electrical Consulting Ltd., 13750 Forest Hill Dr., Winfield, British Columbia, V4V 1A5, Tel: (250) 766-9065,Fax: (250) 766-9067 on November 27, 2001.

Proposal: Add a new Subrule (5) to 10-204 as follows:

> (5) Notwithstanding Subrule (2), where the grounded conductor of a service is not intended to carry neutral current, the grounded conductor shall be permitted to be sized in accordance with Table 16 where the ampacities of column 1 in Table 16 shall be based on the maximum ampacity of the largest ungrounded service conductor.

Reasons for Request:
The grounded conductor of a service supplying only 3-phase 3-wire loads will only carry fault currents… same as a bonding conductor; there would be no neutral currents. For this reason it is reasonable to apply Table 16 requirements. Following are 2 examples that demonstrate some inconsistencies:

1. If we have a service feeding a 1600A motor (3-phase 3-wire load) supplied by a 4000A breaker, we need to size the bonding conductor between the service and the motor at 500 kcmil according to Table 16. However, current Rule 10-204 requires that the grounded conductor between the service and the utility transformer be sized according to Table 17 at 3/0. Yet in the event of a fault on this system both conductors would be required to carry the same current.
2. Conversely, a service supplying a 3-phase 3-wire load of 800A requires a 1/0 bonding conductor between the service and the load (Table 16) while the grounded conductor between the service and the supply transformer would have to be a 3/0 conductor in accordance with Table 17.

In both cases above, we are inconsistent with how we size the two non-current-carrying conductors (bonding and grounded). These conductors will only carry fault currents.

Supporting Information:
Interpretation of this rule in the field is causing confusion and unnecessary cost. A typical installation in the field would use a 3 conductor TECK cable to as a service entrance to feed a three phase, three wire load(s). The star point of the transformer is connected to ground. The

bonding wire in the cable is also connected to ground. There are no phase to ground loads connected to the system. Some utilities consider the bonding wire meets the definition of a "neutral" and apply rule 10-204(2), which requires the bonding conductor in the cable from the transformer to the meter to be sized to table 17. The bonding conductor in TECK cables does not in all cases meet table 17. In order to meet table 17, a 4-conductor TECK cable is often required. After the meter, a standard 3-conductor TECK cable (the bonding conductor in TECK cables are sized to meet table 16) is used. The requirement to use a 4-conductor cable up to the meter not only adds unnecessary cost, it often causes unnecessary delays as 4-conductor TECK cable is not readily available in larger sizes. It does not make sense to require a 4-conductor cable up to the meter where the feeder from the meter will be only a 3-conductor cable. This rule will allow the use of a 3-conductor cable for the service where the bonding conductor is not required to carry load current (3-phase, 3-wire services).

Chair's Comments: I agree with the proposal. This proposal raises a number of other questions such as the difference between a "grounded conductor" and a "grounding conductor" and the fact that Part II wiring product standards size the bonding conductor in cables based on the ampacity of the current-carrying capacity of the ungrounded conductors while Part I sizes the bonding conductor based on the O/C protection ahead of the circuit. I look forward to your comments.

Subcommittee Deliberations (1st Round)

Of a total 13 members responses were as follows:

- Agree with submission	7 (3 with comments)
- Disagree with submission	4
- No response	2

Some comments were lengthy (see attached "Ballot Summary Sheet").
Following are some highlights of the comments provided:

There is a potential for discrepancy in the size of the grounded conductor depending on whether the installation between the transformer and the service is part of the utility's facility or part of the consumer's.
Chair's Comment: Regardless of who is responsible for the installations, shouldn't the technical justification for a given installation arrive at the same results? The size of the grounded conductor should be the same for a utility as it is for a non-utility.
Where a service will not require a neutral, then an ungrounded service should be installed.
Chair's Comment: The code allows either a grounded or ungrounded system to be used. The issue is really that when a grounded system is used without any neutral loads being applied, what is an appropriate size for the grounded conductor.
The presence of a neutral conductor at the consumer service allows for the possibility of adding single-phase loads in the future.
Chair's Comment: Adding single-phase loads in the future would require that the owner review and upgrade the size of the grounded conductor.
Service conductors do not have overcurrent protection ahead of the circuit. Table 16 is not appropriate to use since it is based on having OC protection ahead of the circuit.
Chair's Comment: This is the reason for the submission.
We should eliminate Table 17.
Chair's Comment: This would be another subject.
What are the differences between feeder bonding and service bonding?
Chair's Comment: Good question.
We should not have a maximum size limited to 3/0; a larger conductor may be required.

> *Chair's Comment: Using Table 16 instead of Table 17 would achieve this goal.*
> We seem to be mixing the functions of a grounding conductor versus a grounded conductor.
> *Chair's Comment: Agree!*
> Wording of proposal needs to be clearer on what the intent is.

Chair's comments (2nd Round)
The title of Table 17 is to size the "grounding conductor". "Grounding conductor" is a defined term, which is: the conductor used to connect the service equipment or system to the grounding electrode. Rule 10-204(2) speaks of the grounded (not grounding) conductor, which begs the question "Is Table 17 designed for grounding conductors the appropriate table to use for sizing grounded conductors?"

The grounding conductor is not intended to carry any appreciable fault currents due to the unknown impedance of earth. The main purpose of the grounding conductor is to establish a connection to earth so that there is no potential difference between earth and the neutral point of the service and ultimately all non-current carrying metal parts of the system (equipotential grounding).

The grounded conductor on the other hand, will carry fault currents back to the source. Similarly, bonding conductors are also designed to carry fault currents, making Table 16 the more appropriate table to use. The only difference between the grounded conductor and the bonding conductor is that the size of the overcurrent device ahead of the grounded conductor is usually not known (i.e., utility fuse at the transformer). Furthermore, the reference to Rule 4-022 requires that in addition, the grounded conductor must also be adequately sized to be able to carry any neutral currents.

The only problem in sizing the grounded conductor based on Table 16 is not knowing the size of the O/C device ahead of it. For this reason I believe the submitter's proposal to be a reasonable alternative. Another option would be to actually re-write Table 16 so that the figures are base on the size of the ungrounded conductors in the circuit in the same way that C22.2 No. 51 does.

I agree with the submission, but if we were to try and make any clarification, I would suggest simply revising Subrule (2) as follows

> (2) Where the system is grounded at any point, the grounded conductor shall be run to each individual service and shall have an ampacity not less than that ~~of the required grounding conductor~~ specified in Table ~~17~~ **16** and, where the grounded circuit conductor also serves as the neutral, the requirements of Rule 4-022 shall be met

To accommodate the problem of sizing based on the size of the OC device ahead of the equipment where we don't have one to base it on, I would also suggest that we replace Table 16 with a new table based on Table 7 in C22.2 No. 51(attached). This would create consistency between Part I and Part II. It would make sizing of the bonding (or grounded) conductor based on the size of the ungrounded conductors in the circuit.

Note to Part I Members

There are 42 pages omitted here that detail several rounds by the Subcommittee. If you would like a copy of the omitted pages, please let us know.

Subcommittee Deliberations (6th Round)

11 of 12 subcommittee members responded, in the end all voting in favour of the latest S/C proposal. One member who had consistently voted in favour of the direction this proposal was going, at first disagreed with round 5. In discussions with him, he cited his main reason being that the proposal was moving away from harmonization with the NEC. However, when it was explained that the current method of sizing the grounded conductor is technically flawed he agreed to withdraw his negative making the vote in favour, unanimous.

One member offered comments for editorial changes, some of which have been incorporated. Another member offered additional wording to introduce the issue of harmonic currents into one of the Rules. The Chair rules this to be non-germane but could be submitted as a new subject.

Subcommittee Recommendation

1. **Amalgamate Table 17 with Table 18, and name it Table 17 to read as follows:**

Table 17
(See Rules 10-206, 10-812)
Minimum Size of Grounding Conductor

Ampacity of Largest Service Conductor or Equivalent for Multiple Conductors Not Exceeding – Amperes	Size of Copper Grounding Conductor AWG
100	8
200	6
400	3
600	1
800	0
Over 800	00

Note: *The ampacity of the largest service conductor, or equivalent if multiple conductors are used, is to be determined from the appropriate Code Table taking into consideration the number of conductors in the raceway or cable and the type of insulation.*

Rationale: *This change provides for a single table to deal with the size of grounding conductors for AC systems, either grounded or ungrounded. It also aligns with the principle that the grounding conductor should not be required to be larger than the corresponding bonding conductor.*
No longer references #8 conductor for 60A since 100A already takes care of it.
No longer references Conduit or EMT (formerly in Table 18) since these were more a reference to bonding conductors at service equipment, which is taken care of by Table 16. The grounding conductor (conductor between service and ground electrode) is required to be of copper in accordance with Rule 10-802, therefore metal conduit and EMT would not be acceptable.

2. **To recognize "grounded" conductors by the rule reference to 10-204 as follows:**

Table 16
(10-204, 10-518, 10-814, 10-816, 10-906, 12-1814,24-104, 24-202, 66-202, 68-058, and 68-406)
Minimum Size for Bonding Conductors

Rationale: Includes reference to Rule 10-204 (specifically the change in reference in Subrule (2) from T17 to T16). The defined term for "Bonding Conductor" allows us to remove "Raceways and Equipment" in the title.

3. Replace the heading in Column 1 of Table 16 with:

"Ampacity of Largest Ungrounded Conductor in the Circuit or Equivalent for Multiple Parallel Conductors"

Rationale: This change allows for a better alignment with the Part II standard for sizing bonding conductors in cables where the size of the bonding conductor is based on the ampacity of the circuit conductors. It thus allows for proper reference when sizing a grounded conductor where the size of O/C device ahead of it is not known.

4. Rewrite Rule 10-204

10-204 Grounding Connections for Alternating-Current Systems (see Appendix B)

(1) Alternating-current circuits which are to be grounded shall have:

(a) A connection to a grounding electrode at each individual service, except as provided for in Rule 10-200; and

(b) The grounding connection made on the supply side of the service disconnecting means either in the service box or in other service equipment, except for areas or buildings housing livestock, the grounding connection shall be permitted to be made within another device specifically intended for the purpose located in the grounding circuit and not more than 3 m from the service equipment; and

(c) At least one additional connection to a grounding electrode at the transformer or elsewhere; and

(d) No connection between the grounded ~~circuit~~ conductor on the load side of the service disconnecting means and the grounding electrode, except as provided for in Rule 10-208.

(~~1~~2) Notwithstanding Subrule (1), for circuits that are supplied from two sources in a common enclosure or grouped together in separate enclosures and employing a tie, a single grounding electrode connection to the tie point of the grounded circuit conductors from each power source shall be permitted.

~~(2) Where the system is grounded at any point, the grounded conductor shall be run to each individual service and shall have an ampacity not less than that of the required grounding conductor specified in Table 17 and, where the grounded circuit conductor also serves as the neutral, the requirements of Rule 4-022 shall be met.~~

~~(3) Where service conductors are run in parallel in separate metal raceways, and the system is grounded at any point, a grounded conductor shall be run in each raceway and, notwithstanding the requirements of Rule 12-108, the total ampacity of all grounded conductors shall be permitted to be not less than the ampacity of the conductor required by Rule 4-022(3).~~

(3) Where the system is grounded at any point, the grounded conductor shall:

(a) be run to each individual service; and

(b) have a minimum size as specified in Table 16; and

(c) also comply with Rule 4-022 where it serves as the neutral; and
(d) be included in each parallel run where the service conductors are run in parallel.

(4) Notwithstanding Rule 12-108, the size of the grounded conductors in each parallel run shall be permitted to be smaller than 1/0.

Rationale: *Existing Subrule (4) is re-numbered to (2) for a better flow when reading the Rule. Existing Subrule (2) and (3) are re-worded and simplified for clarity and amalgamated into a Subrule (3) and (4). It accommodates the reference to Table 16.*

- *The Appendix B note will be expanded to reinforce the need to be aware of other factors that may require the grounded conductor to increase in size such as neutral or harmonic currents.*
- *Since the grounded conductor is sized to carry fault currents (sometimes in the tens of thousands Amperes), it really does not have an ampacity in the conventional sense but is rather "sized".*
- *Removes sizing requirement to "grounding conductor specified in Table 17" since it now refers to Table 16, which is the appropriate table for sizing conductors to carry fault currents.*

5. Amend Rule 10-812 as follows:

10-812 Grounding Conductor Size for AC Systems (See Appendix B)

Table 17 shall be used to determine the size of:
(a) A grounding conductor of an AC system; or
(b) A common grounding conductor; or
(c) A grounding conductor for service equipment where the AC system is not grounded.

Rationale: *Re worded to improve clarity… lines up with the definition of "grounding conductor". Also recognizes the AC System grounding conductor of Rule 10-204 and 10-206, the common grounding conductor of Rule 10-502 and the service equipment grounding conductor of 10-502 as referenced in the defined term. Reference to Appendix B is added where Appendix B will have a diagram depicting an AC system that is not grounded.*

6. Revise Rule 10-814 as follows:

10-814 Bonding Conductor Size (see Appendix B)

(1) The size of a bonding conductor shall be not less than that given in Table 16, but in no case does it need to be larger than the largest ungrounded conductor in the circuit.

~~(2) Where the overcurrent device in the secondary circuit of a transformer is omitted, the rating of the overcurrent device to be used in determining the bonding conductor size for the secondary circuit shall be the next standard size above a value determined by multiplying the rating of the overcurrent device in the primary by the ratio of the primary to secondary voltage.~~

(~~3~~2) Where circuit conductors are paralleled in separate cables or raceways, the bonding conductor shall be permitted to be paralleled and the size of bonding conductor in each parallel run shall not be less than that specified in Table 16 based on the size of the circuit conductors contained in the raceway or cable.. ~~but shall not be smaller than that determined by dividing the rating or setting of the overcurrent device by the number of bonding conductors and selecting from Table 16 a conductor size to satisfy this result.~~

(3) Notwithstanding the requirements of Rule 12-108, the size of the bonding conductor in each parallel run shall be permitted to be smaller than 1/0.

Rationale: Table 16 now uses circuit conductor size rather than O/C device size, therefore Subrule (2) can be deleted. Subrule (3) is re-worded in to Subrules (2) and (3) to simplify/clarify, to recognize the sizing based on size of circuit conductors rather than O/C device and to permit the bonding conductor to be smaller than 1/0.

7. Add to Appendix B a note for Rule 10-204(3)

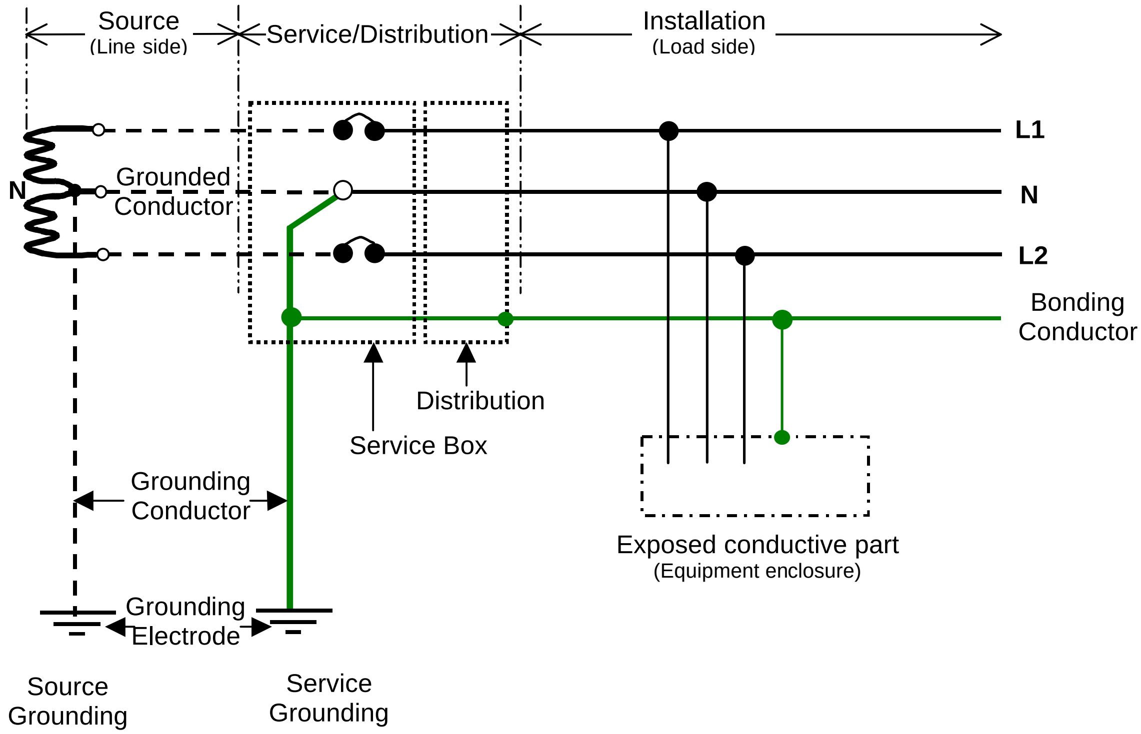
Rationale: This note is to reinforce the main purpose of the grounded conductor and to alert users to consider neutral and harmonic currents. Diagrams (extrapolated from IEC 60364) are added to guide the user in distinguishing different types of grounding and to show the relationship between grounding, grounded, and bonding conductors.

10-204(3) *Like the bonding conductor, the grounded conductor's primary function is to provide a low impedance path capable of withstanding any fault currents that may be imposed on it. In addition, the grounded conductor may have to carry neutral or harmonic currents Therefore, in addition to sizing the grounded conductor as specified in Table 16, further consideration for increasing the size of the grounded conductor is required where line-to-neutral loads are present as prescribed in Rule 4-022. Consideration should also be given to the possibility of further increasing the size of the grounded conductor to accommodate any non-linear loads that may impose harmonic currents on the grounded conductor.*

10-204 Types of System Grounding
10-812 *The following types of system grounding are examples of grounded AC systems*
10-814 *commonly used in Canada.*

- *Figure 1 shows an example of a single-phase solidly grounded system.*
- *Figures 2 & 3 show examples of 3-phase solidly grounded systems.*
- *Figure 4 shows an impedance grounded system.*

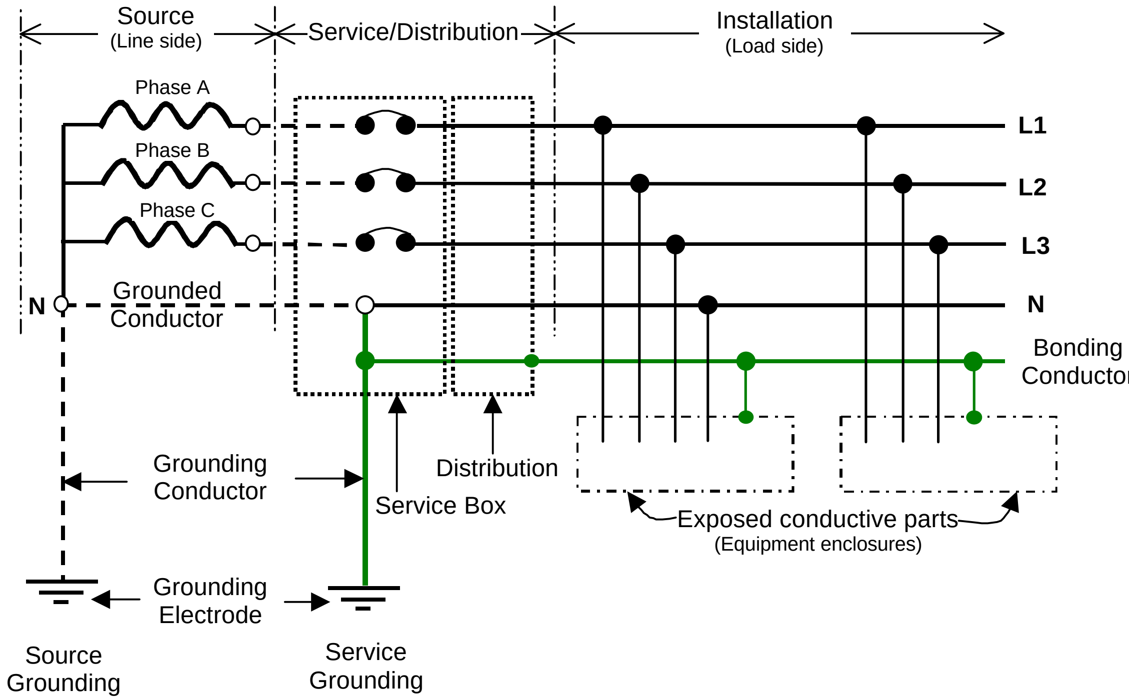
Fig. 1 – Single-phase 3-wire solidly grounded system (midpoint grounded)



Neutral and bonding conductor functions are combined in a single conductor (grounded conductor) on the line side of the service [Rule 10-516(2)].

Neutral and bonding conductor are separate on the load side of the service [Rule 10-516(1)].

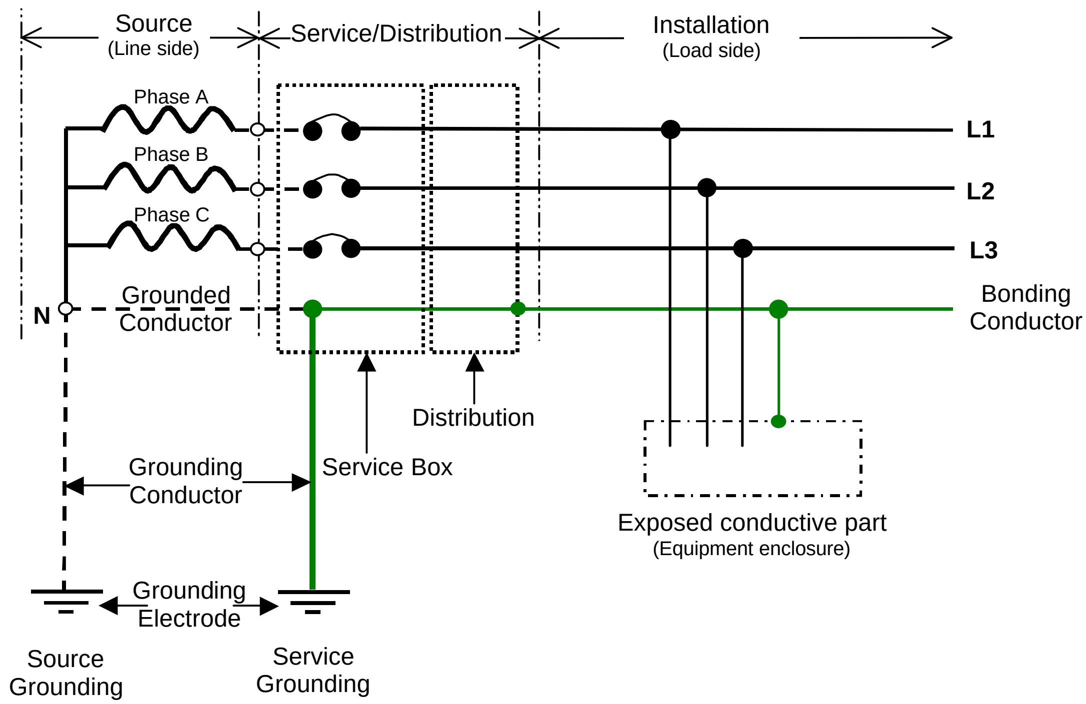
Fig. 2 – Three-phase 4-wire solidly grounded system (midpoint grounded)



Neutral and bonding conductor functions are combined in a single conductor (grounded conductor) on the line side of the service [Rule 10-516(2)].

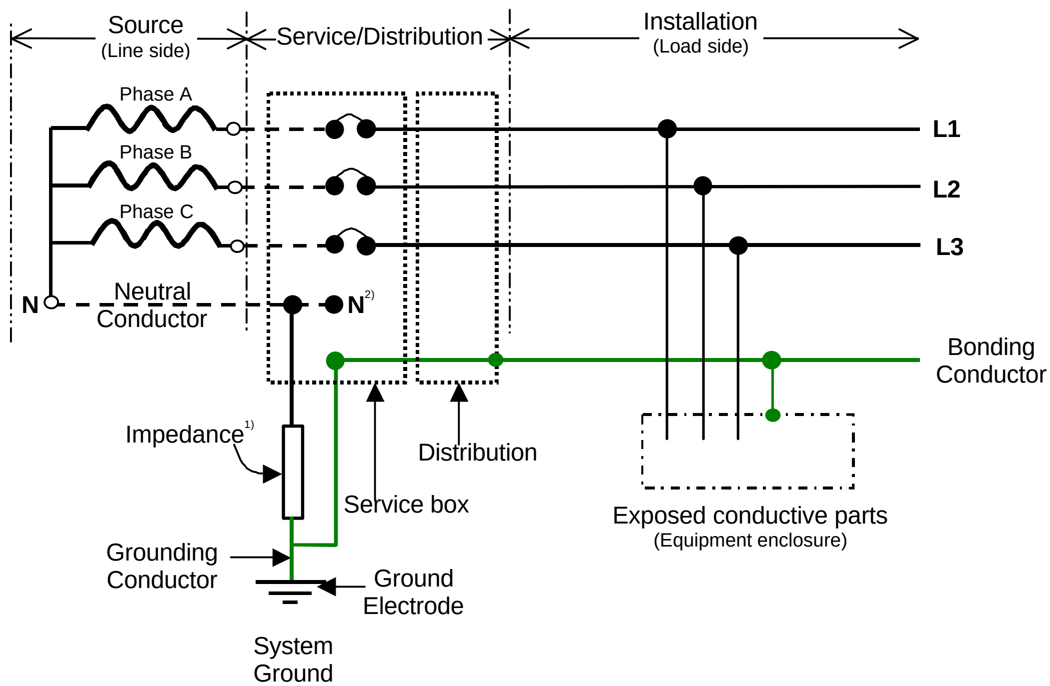
Neutral and bonding conductor are separate on the load side of the service [Rule 10-516(1)].

Fig. 3 – Three-phase 3-wire solidly grounded system (midpoint grounded)



The grounded conductor on the load side of the service functions as a bonding conductor with no distributed neutral throughout the system.

Fig. 4 – Three-phase 4-wire impedance grounded system (midpoint grounded)



1) System connected to ground via sufficiently high impedance.

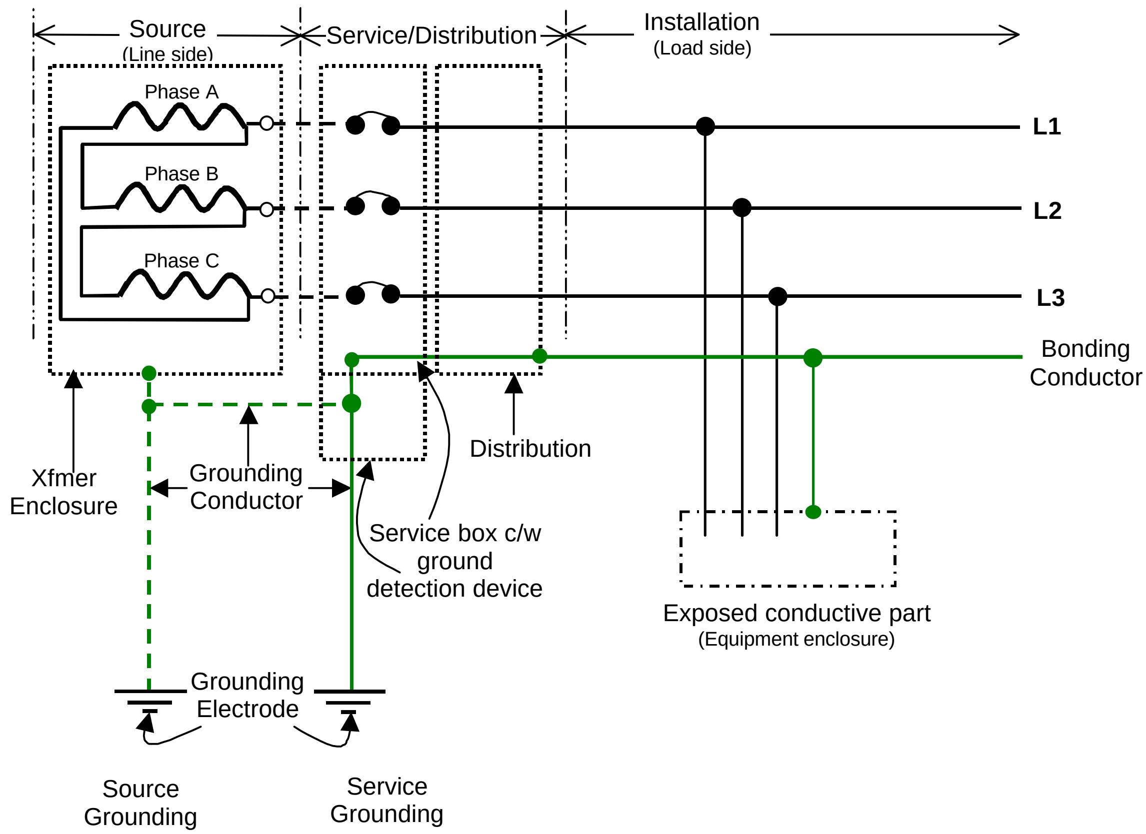
2) The neutral may or may not be distributed

See Subsection "Installation of Neutral Grounding Devices" (1100 series) of Section 10.

8. Add to Appendix B a note to Rule 10-814(c)

10-814(c) ***The following diagram depicts an AC system that is not grounded.***

Three-phase 3-wire ungrounded (delta) system



An ungrounded system is required to have a ground detection device in accordance with Rule 10-106(2).