Canadian Standards Association
Mississauga, Ontario
To the Part I Committee

Subject No. 3035 Chair: Rene Leduc Date: March 26, 2003

Title: Use of Neutral Grounding Devices, Rule 10-1102(1) and (4)

Submitted by: Blair Baldwin of Startco Engineering Ltd., 406 Jessop Avenue, Saskatoon, Saskatchewan, S7N 2S5, Tel: (306) 373-5505, Fax: (306) 374-2245 on June 21, 2001.

Proposal: Amend Rule 10-1102 as follows:

1) For Subrule (1), end the sentence at "....artificial neutral." And delete the "where line-to-neutral loads are not served." portion.

2) Add a new Subrule (4) to read: "The neutral conductors shall all be insulated for the nominal system voltage."

Reasons for Request: We have recently had requests for the supply of a ground-fault protection unit which will meet the recently introduced requirements for ground-fault protection on heat trace (Section 62) and other applications (such as submersible pumps), where it appears there is an effort to strive for lower and lower detection of ground faults on larger and larger systems. Often these requests will be on a three-phase systems where three phase or single phase loads are being fed. In some cases the cost of implementing the ground-fault protection is very high and sometimes only gives a marginally operational system. As a manufacturer of ground-fault detection equipment we have tried to design, manufacture, and sell products that will meet these increasing demands on the sensitivity of the ground-fault detection equipment, but generally used on electrically larger pieces of equipment.

There also appears to be a lot of confusion with people thinking they are going to get or can get "people-protection" ground-fault levels on larger-sized or three-phase systems, when in fact, in most cases only "equipment-protection" ground-fault levels are practical. Any people protection afforded at these "equipment-protection" ground-fault levels is consequential and gives no guarantees of safety to the level of a Class A GFCI. There are limitations whether due to basic electrical system characteristics or electrical code requirements which, as I understand them, currently do not allow ground faults to be properly resolved down to the levels some people desire.

The first problem impeding this progress is the capacitive charging current that is part of any energized electrical system and as the systems get larger this charging current gets larger. On single-phase system this charging current can be rejected as it leads the voltage by 90 degrees or on smaller feeders the charging currents can be ignored as it is a low enough level to not cause nuisance tripping. For three-phase systems the capacitive charging current also exists but cannot be rejected as it is a net sum of the three phases and the resultant charging current has a phase relationship to the voltages that is undefined. Additionally, when a ground fault occurs the charging currents all flow to the fault and on a multiple branch system the flow of these charging currents to the fault can cause false detection (and tripping) on one or more of the branches which are not faulted. The one place where more sensitive ground-fault detection is achievable is at the supply or source of a system. At this location the fault currents can be detected without much influence from the charging currents. Fault currents can also be limited to much lower levels by connecting the supply neutral to ground through a limiting resistance. Requirements for this are given in section 10-1100 of CEC Part I, but it does not allow the use of line-to-neutral loads and in many cases it would be desirable and beneficial as long as the neutral conductors are insulated to the same level as the phase conductors, which today is generally the case.

Chair's Comments: Interesting proposal...... I look forward to your comments.

Subcommittee Deliberations (1st Round)
To assist in the Subcommittee deliberations, all members were provided with an information document from the Submitter (See attached .pdf file 502m.pdf),.

All but one of the Subcommittee members responded with a split decision… 6 agreeing with the proposal and 6 disagreeing. Following are the comments:

Section 10 Subcommittee - Ballot Summary Sheet
Subject number: 3035
Title: Use of Neutral Grounding Devices **Rule Number:** 10-1102(1) & (4)

NAME	AGREE WITH SUBMIT	DIS-AGREE	COMMENTS
René Leduc	∪		No Comment
Ken McLennan		□	I believe this would revise the age-old principle of maintaining a solidly grounded neutral on systems that actually employ the neutral (grounded conductor). I can’t comment on whether or not a floating neutral would be a principle we could live with, but I do believe we should establish that first.
Ken Almon	∪		I agree with the submission with comments as follows: I have had experience with the faults that the submitter has spoken about, whereby faults in trailing cables for open pit operations (4.16 kV resistance grounded systems) gave rise to ground fault equipment operating in the milling location. It is difficult to design against unless you use delta-wye transformers to isolate different systems. Nonetheless, I believe the submitter has raised a good subject for debate. Technically, what he is asking for is certainly achievable, and it appears that he has equipment waiting in the wings. One of the issues I have always been worried about is the unintentional grounding of the neutral conductor. Similar circumstances surrounding the installation of a padmount transformer outside, and a

Name	**Agree with Submit**	**Dis-agree**	**Comments**
			neutral grounding resistor (NGR) inside, resulted in having to run the X0 conductor (hate to use the word "neutral" in these circumstances) inside in a duct by itself. Knowing that the potential was there for the system to operate for (possibly) hours at a time in an industrial site, we always made sure that the neutral was: • Insulated for the same voltage as the phase conductors (as the submitter has suggested), and also, • Isolated from ground by carefully routing the cable and testing it against shorts to ground in the commissioning phase Where possible in the above scenario, was to ensure that the NGR was placed inside the doors of the padmount, and in this way, the X0 wiring was kept short, and the likelihood of unintentional grounding of the "neutral" could be diminished substantially, both initially and down the road in the future. My insistence then to the submitter, would be to ensure that his device also tests to confirm that the neutral is free from a ground and isolates (trips) otherwise. This could be taken care of with a modification (underlined below) to the new sub-Rule proposed by the submitter as follows: "The neutral conductors shall all be insulated for the nominal system voltage, shall be guarded against connection to ground (intentional or fortuitous), monitored for connection to ground or open circuits, and where found to be grounded or opened, provision shall be made to automatically de-energize the system." If the neutral happens to connect to ground, anywhere along it's length (and this could be thousands of feet depending on the design of the distribution system), it would then bypass the resistor and give rise to arcing fault dangers. In the past, when I have installed a plant addition to a previously existing building where a 600 V "effectively" grounded system exists, I take great pains to explain to safety officers, the local JOSH committees and to the management of the organization that the benefits (especially low arc potential) of the high resistance grounded systems are only available for the new addition, and that from a safety viewpoint, management should consider retrofitting their existing "effectively" grounded system to a high resistance system as soon as possible, so as to make the entire plant similar (KISS principle). In the present case, while I see benefits in the system proposed, I have some worry that the isolated neutral could become grounded and "short circuit" the benefits. (Consider the addition in the future by a less-experienced electrician who adds a panelboard and straps the neutral to the ground - certainly a code violation, but in this case, also bypassing the safety aspects of the system). Look forward to other peoples' submissions on this.
Dave Coleman		✓	Circuits that serve line-to-neutral loads (typical single-phase circuits) need to have full ground-fault current available to trip the overcurrent device in the event of a line-to-ground fault. The proposed change would encourage arcing ground faults. Of course sensitive ground tripping devices can be used in lieu of the conventional brute-force method, but the proposal does not specify such equipment.
Ed Court		✓	Need more background on original rule. I would like to know why the original code rule 10-1102 said, “where line-to-neutral loads are not served”. Perhaps it is because having unbalanced line-to-neutral loads will create slightly unequal line-to-ground voltage and capacitive charging currents from each phase. The small resultant current will flow in the neutral grounding resistor or grounding device. This might give false alarms or trips.

NAME	AGREE WITH SUBMIT	DIS-AGREE	COMMENTS
			Can anyone quantify this?
Mike Gardener	∪		No Comment
George Morlidge	∪		The problem with this has been the maintaining of the isolation of the neutral. High resistance systems were always applied to systems with no neutral (no single phase to ground loads) as this guaranteed that you could not have an alternate path to ground via some additional ground in the neutral thus eliminating the NGR. I am not sure that the rule changes here meet all the requirements. I think we need additional words around the integrity of the neutral besides those regarding the voltage level of the insulation.
Ted Olechna		□	In proposal 2 there is a requirement for insulated conductor, yet there is rule 10-1108 that is currently specified. Is not this where the change should be?
Jean-Louis Robert	∪		No Comment
Ian Simpson	∪		This proposal seems OK to me. I don’t think there is a technical reason why single phase loads should not be allowed. I think the wording of the proposed new Subrule(4) should be expanded to match wording of Subrules 1, 2 & 3. “(4) Where a neutral grounding device is used on an electrical system, all neutral conductors associated with it shall be insulated for the nominal system voltage.”
Nando Tedeschi			
George Timlick		□	I would like to know the rationale for the existing part of the Rule which is to be changed with this proposal. Somehow, current flow on the neutral must influence the operation of the NGD. If this is no longer the case, then I would not have an issue with the proposal.
Nino Mancini		□	I do not support the proposal, since it is not provided with a clear rationale as to why it is needed. And it also does not address the need to have the original CEC Subrule. I have never seen such circular, muddy thinking in a CEC proposal. The original Subrule was inserted since in an isolated three-phase system an indication that one of the phases has been grounded through some equipment or wiring fault is permitted because the one fault will not cause any operational problems. The fault can be rectified without shutting down the system. If a second phase faults to ground, then you have a phase to phase short circuit, and the overcorrect protection will shut down the system. This ground isolation system will not work if you permit the neutral to be grounded through a line to neutral load. This fact will not be altered if we require the neutral to be insulated as the submitter suggests. I do not really know why the submitter needs the proposed change. He states that there is a problem with capacitive charging when systems are energized. He states, "The one place where more sensitive ground-fault detection is achievable is at the supply or source of a system. At this location the fault current can be detected without much influence from the charging currents. 10-1102 (1) is dealing with a three-phase supply source, so what is the problem? I believe through the submitter's reference to Section 62 that he is building ground detection systems for heat trace cable. The problem faced in use of this product is that the heat trace is a very long run. If a fault develops between the heat trace and the metal braid on the out side of the cable, or if the heat trace develops a fault to bonded metal the fault current will be too low to operate the overcorrect device because the impedance of heat trace and long run of the braid back to the bond at the source. These leakage systems are one way to alleviate this problem to alert the user that the equipment has a problem. Perhaps the submitter has some need for his proposal. However, we will need to know why he

NAME	AGREE WITH SUBMIT	DIS-AGREE	COMMENTS
			really needs it, with specific problems that he is facing if he does not get the change. He also needs to address the consequence of changing the intent of the use of 10-1102 (1) to warn users of a grounded phase. ~~~~~~~~~~~~~~~~~~~~ I have reviewed the extra information provided by the submitter, and can see some issues more clearly than from his original submission. However, I still have a problem with his proposal to change Section 10. This will solve his problem, but it may cause problems for others that he does not envisage. The literature states that his device is designed solely for generators, so my suggestion would be to leave Section 10 alone and put in a proposal in 28-900 with a notwithstanding clause. But, I am still uncertain however that we have the whole picture. In his submission he talked about protection of deep well pumps. I believe that these would be single-phase, as it would have to be a good size pump to be three-phase. Somehow, I get the feeling that he has more products coming down the pike if we make the changes that he proposes. The products will probably be single-phase and three-phase. If we need to change Section 10 because of these other products I would support a change that would permit his proposed changes to 10-1102 only in devices specifically approved for the purpose. We did this in 10-806 to permit tingle voltage filters to be connected in the ground line. Up to that time we could not certify the devices as the ground conductor was required to be continuous from the ground terminal of the service disconnect to the ground rod.
Total (13)	6	6	12 out of 13 SC members responding

Chair's Comments toward a 2nd Round of Deliberations
After receiving the Subcommittee comments, I asked the submitter to review and respond to the comments. The submitter offers the following revised proposal and comments.

REVISED PROPOSAL: As per comments, Amend Rule10-1102 as follows:

(1) Neutral-grounding devices shall be permitted to be used only on a system involving a true neutral or an artificial neutral. Where line-to-neutral loads are served, the neutral conductors shall be insulated for the nominal system voltage and provision shall be made to automatically de-energize the system on the occurrence of a ground fault or a grounded neutral.

Comments on Section 10 Subcommittee comments:

Rene Leduc:
No comment.

Ken McLennan:
The neutral is not floating in a resistance-grounded system. The neutral will be at ground potential unless there is a ground fault on the system. The impedance of the fault determines the voltage on the neutral—zero when the impedance is infinite increasing to the line-to-neutral voltage with a bolted fault. Rule 10-1102(3) specifies the conditions under which the neutral is allowed to remain elevated at the line-to-neutral voltage. We are suggesting in the revised proposal that a resistance-grounded system with line-to-neutral loads be tripped on the occurrence of a ground fault.

Ken Almon:
Good understanding of the problem! It always was our intention to trip on a ground fault or a grounded neutral, and now it is stated in the revised proposal as suggested. It should not be necessary to check for an open neutral. If the neutral conductor opens, single-phase loads will not run—just like an open phase conductor and we do not monitor for that.

Dave Coleman:
Resistance-grounded systems must use ground-fault relays with low tripping levels—"brute-force methods" do not work because brute-force currents are not available. In a resistance-grounded system, energy available to a fault is limited, arcing ground faults are not an issue, and the flash hazard is minimized. In a resistance-grounded system, we have the advantage of knowing what the ground-fault current will be and the ground-fault trip level is usually set at or below 20% of the prospective ground-fault current.

Ed Court:
Most resistance-grounded systems feed three-phase loads. We suspect that the exclusion of single-phase loads relates to the concern that Ken Almon expressed regarding a ground fault on a neutral conductor that would short the NGR. This could result in larger than anticipated ground-fault currents and inoperative ground-fault protection. The requirement to trip on a grounded neutral should eliminate this concern.

Mike Gardener:
No Comment.

George Morlidge:
The requirement to trip on a grounded neutral should eliminate the concern.

Ted Olechna:
Rule 10-1108 refers to the connection between the neutral of the transformer (or generator) and the neutral-grounding device. Single-phase loads receive power from a phase conductor and a neutral conductor. It is the neutral conductors carrying load current that is being talked about. Three-phase loads do not require neutral conductors to the load. The change belongs with the rule on single-phase loads.

Jean-Louis Robert:
No Comment.

Ian Simpson:
We also do not know a technical reason why single-phase loads should not be allowed.

Nando Tedeschi:
No Comment.

George Timlick:
Current flow in the neutral has no influence on the neutral-grounding device.

Nino Mancini:
We will attempt to restate the need for change.

Capacitive current flows to ground from each phase of ungrounded, resistance grounded, and solidly grounded systems. Capacitive current increases with the system size and conventional zero-sequence detection responds to unbalanced capacitive current to ground. That is why small single-phase loads can be ground-fault protected at the Class-A GFCI levels and larger three-phase systems are not.

The system proposed avoids the capacitance problem by measuring dc resistance to ground of the entire system (neutral included). If resistance to ground is less than the value required to allow Class-A GFCI levels to flow, the relay trips and will not allow a reset until the fault is cleared. Since resistance to ground is measured for the entire system, the system can't be solidly grounded—it must be resistance grounded. Rule 10-1102 does not allow resistance-grounded systems to serve single-phase loads. Some three-phase systems serve single-phase loads that would benefit from Class-A GFCI levels. That is the reason for the request to remove the restriction on single-phase loads on a resistance-grounded system. The requirement to trip on a grounded neutral should eliminate any concerns, and there does not seem to be any technical reason to not allow single-phase loads.

Chair's Comments (continued)
To better fit in with current Rule 10-1102, and to align it with proper CSA formatting, I proposed the following wording to the submitter:

10-1102 Use (see Appendix B)

(1) Neutral grounding devices shall be permitted to be used only on systems involving a true neutral or an artificial neutral.

(2) Where line-to-neutral loads <u>are not</u> served, a neutral grounding device used on an electrical system shall have provision to automatically de-energize the system on the detection of a ground fault

unless the electrical system is operating at 5 kV or less, in which case it shall be permitted to remain energized on the detection of a ground fault provided;

(a) The ground fault current is controlled at 5 A or less; and

(b) A visual and/or audible alarm is provided to clearly indicate the presence of the ground fault.

(3) Where line-to-neutral loads <u>are</u> served, a neutral grounding device used on an electrical system shall have provision to automatically de-energize the system on the occurrence of a ground fault or of a grounded neutral.

The submitter in turn replied as follows:

From: Blair Baldwin [blair.baldwin@startco.ca]
Sent: Wednesday, August 28, 2002 3:30 PM
To: 'Rene Leduc'
Cc: garry.paulson@startco.ca
Subject: RE: CSA Subject 3035

Hi Rene,

Thank you for checking over our revised proposal and introducing proper CSA formatting. Your suggested words reflect the intent proposed in our requested change, however we further suggest that the wording we had added about the insulation of all neutral conductors be specifically stipulated at this section. How about 10-1102 (1) reading as:

(1) Neutral grounding devices shall be permitted to be used only on systems involving a true neutral or an artificial neutral and where all neutral conductors are insulated for the nominal system voltage.

With the remainder of the words for 10-1102 as you proposed below in your August 27/02 email. One thing that I have always been curious about is to what the portion about "systems involving a true neutral or an artificial neutral" adds to the code as this is pretty inclusive of all the possible systems to which a neutral grounding devices could be connected. In our minds this subrule could eliminate this part and simply stated as "Neutral grounding devices shall be permitted to be used on systems where all neutral conductors are insulated for the nominal system voltage."

Per my August 27/02 email, I also propose the addition of a fourth subrule to 10-1108 regarding the size of the wires to the neutral grounding device:

(4) Notwithstanding Subrules (1) and (3) the size of the conductors connecting to the neutral grounding device may be as small as No.12 AWG, if still sized to conduct the rated current of the neutral grounding device and the continuity of these conductors is monitored such that on the lack of continuity of these conductors {from the neutral point through the neutral grounding device to the system grounding electrode}, provision shall be made to automatically de-energize the system.

The words in the curly brackets above can be omitted, but I show them as in our view the integrity of the neutral grounding device is just as critical as the conductors to it in the overall system safety and operation of the protection equipment. From our background, in the mining industry where much of the gear is portable and gets moved and bumped, the continuity of the neutral grounding device can be just as likely suspect as than of the wires to it, so we tend to try to establish the monitoring of continuity right from the supply neutral point to the system ground.

These words will need to be massaged for CSA code formatting. If you have any initial questions or comments please let us know.

Again thank for your patience and also for your assistance on the format and intent of this request for change.

Best Regards,

Blair Baldwin

Chair's Comments (continued)
I know that there is a lot of information here but I believe it is necessary for all of the S/C members to be aware of all comments made regarding this proposal. Based on all of the above information I would suggest that a suitable Subcommittee recommendation could read as follows:

10-1102 Use (see Appendix B)

(1) Neutral grounding devices shall be permitted to be used only on systems involving a true neutral or artificial neutral and all neutral conductors are insulated to the nominal system voltage.

(2) Where line-to-neutral loads <u>are not</u> served, a neutral grounding device used on an electrical system shall have provision to automatically de-energize the system on the detection of a ground fault unless the electrical system is operating at 5 kV or less, in which case it shall be permitted to remain energized on the detection of a ground fault provided;
- (a) The ground fault current is controlled at 5 A or less; and
- (b) A visual and/or audible alarm is provided to clearly indicate the presence of the ground fault.

(3) Where line-to-neutral loads <u>are</u> served, a neutral grounding device used on an electrical system shall have provision to automatically de-energize the system on the occurrence of:
- (a) A ground fault; or
- (b) A grounded neutral.

(4) The size of the conductors connecting to the neutral grounding device shall be sized to conduct the rated current of the neutral grounding device and in no case smaller than No.12 AWG

(5) The continuity of the conductor connecting the neutral grounding device from the neutral point through the neutral grounding device to the system grounding electrode shall be monitored such that on the lack of continuity of this conductor the system is automatically de-energized.

Subcommittee Deliberations (2nd round)
Eight (8) of a possible 12 subcommittee members responded, 6 agreeing with the Chair's last round proposal, one disagreeing and one member abstaining.

The member that disagreed asked, "Why do have to treat Subrule (3) different from Subrule (2)? Why do we have to trip when we have a neutral load?" He proposes we treat the two the same.

The members that agreed offered some suggestions to improve the wording of the recommendation:
1. (1) agree with submitter that words "involving a true neutral or artificial neutral and" be replaced with "where". Not a strong feeling here, but given the fact we are making major changes, this "bit" does not seem to add, only confuse...
2. (2)(a) Probably the subject of another topic, but note that many manufacturers offer standard equipment higher than 5 A (IPC offer to 17 A let through continuously), and that depending on the voltage, that level is not sacred. The 5 could be 10... perhaps another time.

3. (2) (b) see my comments on subject 3073/3075 for changes in these words to "Ground Detection Device"
4. (4) if the resistor has multiple ratings: continuous/60 seconds/30 seconds/10 seconds should we clarify size selection? Suggest "...conduct the continuously rated current..." I also have a concern relating to the mechanical integrity of the conductor recognizing the use of ferrous metal as a protection means to be forbidden, owing to the "choke effect". Can we beef this up with a change to this sub-rule as follows: "...neutral grounding device, in no case smaller than #12 AWG, and, where smaller than #4 AWG, shall be protected from mechanical damage." Maybe #10 AWG is a better choice for integrity's sake?
5. We don't need to say "Where a neutral grounding device is used", because it is already implied it is being used – 10-1102 heading is Use and the whole Rule 10-1100 is about neutral grounding devices.

   Therefore, 2 & 3 should be re-worded as follows (or something similar):
   "(2) For systems operating above 5 kV, provision shall be made to automatically de-energize the system on the detection of a ground fault.
   (3) for systems operating at 5 kV or less, provision shall be made to automatically de-energize the system on the detection of a ground fault, unless:
   (a)………"

Chair's Comments (2nd Round)
In response to the disagreeing member, the submitter specifically requested that a resistance-grounded system with line-to-neutral loads trip on the occurrence of a fault (see submitter's comments to Ken McLennan and Ken Almon on page 6).

In regards to the comments from the members in agreement, I offer the following comments in the same order as above:

1. Incorporated into S/C recommendation
2. This issue has already been ratified in letter ballot 4134 regarding Subject #3074 which revises 10-1102(3)(a) to read: "the ground fault current is controlled at 10A or less; and". This change is reflected in the S/C recommendation below.
3. Noted
4. I believe the resistor ratings to be a design issue and non-germane to the proposal. The issue of mechanical protection and increasing minimum size of ground to #10 is also non-germane.
5. Incorporated into S/C recommendation

Subcommittee Recommendation

10-1102 Use (see Appendix B)

(1) Neutral grounding devices shall be permitted to be used only on systems where all neutral conductors are insulated to the nominal system voltage.

(2) Where line-to-neutral loads <u>are not</u> served, provision shall be made to automatically de-energize the system on the detection of a ground fault unless the electrical system is operating at 5 kV or less, in which case it shall be permitted to remain energized on the detection of a ground fault provided;

  (a) The ground fault current is controlled at **10 A** *[subject 3074]* or less; and
  (b) A visual and/or audible alarm is provided to clearly indicate the presence of the ground fault.

(3) Where line-to-neutral loads <u>are</u> served, provision shall be made to automatically de-energize the system on the occurrence of:

  (a) A ground fault; or

(b) A grounded neutral.

(4) The size of the conductors connecting to the neutral grounding device shall be sized to conduct the rated current of the neutral grounding device and in no case smaller than No.12 AWG

(5) The continuity of the conductor connecting the neutral grounding device from the neutral point through the neutral grounding device to the system grounding electrode shall be monitored such that on the lack of continuity of this conductor the system is automatically de-energized.