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Technical Report

Sizing Copper Clad Steel (CCS) for Pole Grounds

Per the National Electrical Safety Code (NESC) [93A], "Grounding conductors shall be copper or other metals or combinations of metals that will not corrode excessively during the expected life under existing conditions and, if practical, shall be without joint or splice."

Copper Clad Steel (CCS) conductor has very good corrosion resistance. CCS conductors are steel member with copper bonded completely surrounding the outside. The copper thickness depends on the standard conductivity of the CCS selected. It comes in standard 30% & 40% conductivity sizes, considered appropriate for many grounding applications.

The other major requirement is to "have adequate capacity for fault current for the operating time of the system-protective device." The grounding conductor(s) must stay in operation during any fault current level that may be applied.

For any specific system you will need 1) the maximum available fault current and 2) the time before the fault is interrupted by a protective device (fuse, relay, or backup relay and associated breakers). The code allows a few other ways to determine the minimum conductor size if the fault current and interrupt time are not known, more on this after we get through what the code says.

[93A cont] "For surge arresters and ground detectors, the conductor shall be as short, straight, and free from sharp bends as practical." This is a good practice on any ground conductor.

[093.C.1] The conductor must be "adequate for fault current for the operating time of the system-protective device."…"If value not readily determined, then grounding conductor shall not be less than the full load continuous current of the system supply transformer or other source of supply."

One way to size the conductor with no other information is per the full load current. This would be considered very conservative approach! Let's consider this is our upper limit for the size needed. The following code sections give us other minimums depending on the application.

[093.C.2] For "Multi-grounded system conductors", which would include most pole grounds, "shall have total ampacities of not less than 1/5th of the conductors to which they are attached (see also Rule 93C8). The NESC is looking at fault duty so a #1/0 ACSR, for example, will fuse at 12.32kA (X/R=0) if applied for 30 cycles (see Southwire OHCM Section 3.2.5), #6_30% CCS will fuse at 3.88kA (see CommScope table, also at X/R=0). 3.88/12.32=0.315 or 1.57 times larger than the minimum. This assumes that the #1/0 ACSR neutral is sized appropriately and that the protective relay or fuse interrupts in 30 cycles or less. Appropriate criteria must be used for the system being evaluated if different from the example shown above.

[093.C.3] "Instrument transformer grounds shall not be less than AWG No. 12 copper or equivalent short time ampacity."

[093.C.4] "Primary surge arresters shall be no smaller than AWG No. 6 copper or AWG No. 4 aluminum. EXCEPTION: Arrester grounding conductors may be copper-clad or aluminum-clad steel wire having not less than 30% of the conductivity of solid copper or aluminum wire of the same diameter, respectively.

-[093.C.5] "For equipment, messenger wires, and guys: a) shall have adequate capacity for fault current for the operating time of the system-protective device. If no overcurrent or fault protection is provided, the ampacity of the grounding conductor shall be determined by the design and operating conditions of the circuit, but shall not be less than that of AWG No. 8 copper. b) Suitable connections shall not be disturbed in normal inspection, maintenance, or operation."

[093.C.6] "Fences: Meet Rule 93C5 and shall be not smaller than Stl WG No. 5."

[093.C.7] Bonding of equipment frames and enclosures shall be adequate and meet Rule 93C5."

[093.C.8] " No grounding conductor need have greater ampacity than either: a) Phase conductors supplying ground fault current or b) The max current that can flow through it to the ground conductor and connected electrode(s), this would be the supply voltage divided by the electrode resistance (approximate)."

Calculate a maximum fault current available as follows:

V_s = 12.47 kVolts, R_g = 10 Ohms, R_{pg} = 40' x 0.00134 Ohm/ft = 0.054 Ohms => $R_{tot} = R_g + R_{pg}$ = 10.054 Ohms => I_f = 1.240 kAmps

Where Vs is the supply voltage (phase to ground will be what is applied, use ph-ph level for added safety margin). Rg is the impedance at the ground level of your ground rod (remote ground). 10 Ohms is really good, but using this will give a higher design level of fault current for sizing the minimum ground conductor. For Rpg: #6_30% has a resistance of 1.34 Ohms/1000 Ft. The example above assumed a 40' pole.

Now check the selected pole ground used in the above calculation to see if it is capable of withstanding the calculated fault current without damage. In the example above a #6_30% CCS has a fusing current of 3.88kA at 30 cycles and this is certainly above our calculated value. Again appropriate criteria must be used for the system being evaluated.

[093.C.9] "Suitable mechanical strength for reasonable expected conditions. Unguarded conductors shall have a tensile strength not less than of AWG no.8 soft-drawn copper, except as in Rule 93C3." Any #8 or larger CCS conductor will meet this requirement. As shown above Copper Clad Steel is a very appropriate copper replacement for grounding per the NESC.

For more examples of possible pole ground sizes see AP1101. A1 APPENDIX – MINIMUM CCS_30% POLE GROUND EXAMPLES and AP1101.A2 APPENDIX MINIMUM CCS_40% POLE GROUND EXAMPLES.

REF: NESC C2-2007[], Southwire Overhead Conductor Manual, CommScope – Copper Clad Steel (CCS) Fusing Current Table

AP1101.A1 APPENDIX – MINIMUM CCS_30% POLE GROUND EXAMPLES

AAC or ACSR Neutral* Size		Relay Op Time + Bkr Clear	Neutral* Fusing Current FC	Minimum CCS** Pole Gnd Size		CCS** Fusing Current - FC	Gnd FC / Neutral FC
(mcm or AWG#)	(kcmils)	(cycles)	(kA)	(CCS_30%)	(kcmils)	(kA)	> 0.2
556	556.5	30	64.93	3NO.5	99.30	14.69	0.23
556	556.5	30	64.93	7NO.9	91.65	13.55	0.21
477	477.0	30	55.66	3NO.6	78.75	11.65	0.21
336	336.4	30	39.25	3NO. 7	62.45	9.24	0.24
266	266.8	30	31.13	#4	41.74	6.17	0.20
4/0	211.6	30	24.69	#4	41.74	6.17	0.25
2/0	133.1	30	15.53	#6	26.25	3.88	0.25
1/0	105.6	30	12.32	#6	26.25	3.88	0.31

*Neutral conductor fusing current (kA) calculations equations and constants for the above aluminum conductors were found in Southwire Overhead Conductor Manual Section 3.2.5 Fault Current Ratings

**The Copper Clad Steel (CCS) fusing currents are from the CommScope Bi-Metals tables for CCS_30% (use CCS_40% for higher fusing values).

The previous table assumes that the AAC or ACSR neutral is sized appropriately for the system connected and that the protective relay + the breaker operate time to interrupt is 30 cycles or less. Other conductor types and interrupt times will have different results.

Appropriate criteria must be used and all specific engineering and design issues must be evaluated for the system being considered.

AP1101.A2 APPENDIX – MINIMUM CCS_40% POLE GROUND EXAMPLES

AAC or ACSR Neutral* Size		Relay Op Time + Bkr Clear	Neutral* Fusing Current FC	Minimum CCS** Pole Gnd Size		CCS** Fusing Current - FC	Gnd FC / Neutral FC
(mcm or AWG#)	(kcmils)	(cycles)	(kA)	(CCS_40%)	(kcmils)	(kA)	> 0.2
556	556.5	30	64.93	7NO.9	91.65	15.23	0.23
556	556.5	30	64.93	3NO.6	78.75	13.08	0.20
477	477.0	30	55.66	7NO.10	72.68	12.08	0.22
336	336.4	30	39.25	3NO.8	49.53	8.23	0.21
266	266.8	30	31.13	#4	41.47	6.94	0.22
4/0	211.6	30	24.69	#4	41.47	6.94	0.28
2/0	133.1	30	15.53	#6	26.25	4.36	0.28
1/0	105.6	30	12.32	#6	26.25	4.36	0.35

*Neutral conductor fusing current (kA) calculations equations and constants for the above aluminum conductors were found in Southwire Overhead Conductor Manual Section 3.2.5 Fault Current Ratings

**The Copper Clad Steel (CCS) fusing currents are from the CommScope Bi-Metals tables for CCS_40% (see APPENDIX A1 for CCS_30% examples).

The above table assumes that the AAC or ACSR neutral is sized appropriately for the system connected and that the protective relay + the breaker operate time to interrupt is 30 cycles or less. Other conductor types and interrupt times will have different results.

Appropriate criteria must be used and all specific engineering and design issues must be evaluated for the system being considered.

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