AESI

Acumen Engineered Solutions International Inc.

Canadian Office
775 Main St. East, Suite 1B
Milton, Ontario, Canada L9T 3Z3
Office: (905) 875-2075
Fax: (905) 875-2062

United States Office
7000 Central Parkway, Suite 1475
Atlanta, Georgia, USA, 30328
Office: (678) 320-1895
Fax: (770) 522-8115

e-mail: aesi@aesi-inc.com
website: www.aesi-inc.com

COPPER-CLAD STEEL AN ALTERNATIVE FOR COPPER GROUNDING CONDUCTOR

Prepared For: HD SUPPLY UTILITIES

Prepared By:
Dr. Wallas H. Khella, P. Eng.
Senior Specialist Associate

Date:
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REGISTERED PROFESSIONAL ENGINEER
W. H. KHELLA
June 21/11
PROVINCE OF ONTARIO

COPPERWELD
AN ALTERNATIVE FOR GROUND CONDUCTOR

TABLE OF CONTENTS

1. INTRODUCTION

2. COPPER-CLAD STEEL CONDUCTOR

3. RELEVANT INDUSTRY STANDARDS

   3.1 Ontario Electrical Safety Code
   3.2 IEEE Std. 80-2000
      3.2.1 Copper Clad Steel
      3.2.1 Aluminum
      3.2.2 Steel
   3.3 ASTM Standard B 228-04

4. USER GUIDE AND APPLICATION

   4.1 Ground Fault Current
   4.2 Conductor Current Carrying Capacity
   4.3 Conductor Size Selection

5. TECHNICAL DATA

6. RECOMMENDATION

   6.1 Conductor Size
   6.2 Conductor Specifications
   6.3 Installation

7. REFERENCES

COPPERWELD
AN ALTERNATIVE FOR GROUND CONDUCTOR

1. INTRODUCTION

Bare copper has historically been the ground conductor of choice for utilities. With increased prevalence of theft caused by the rising price of copper, utilities are beginning to consider alternative conductors for their grounding needs.

Among other conductors that can replace copper, copper-clad steel (CCS) is considered to be the most suitable choice for the reasons outlined below. Copper-clad Steel conductor is sometimes called Copperweld conductor.

The purpose of this report is to outline the relevant industry standards that permit the use of CCS as an acceptable alternative to bare copper for use as a grounding conductor. In addition, it describes the construction, characteristics of CCS and provides an application guide for substituting copper conductor with CCS.

Use of CCS can lower a utility's total grounding costs through a reduced up-front purchase price and decreased prevalence of theft.

2. COPPER-CLAD STEEL CONDUCTOR

The combination of steel and copper offers the desired characteristics of strength, conductivity and resistance to corrosion, which makes it suitable for use as grounding conductor.

Dead Soft Annealed (DSA) copper-clad conductor should be specified to obtain the flexibility necessary for installation as down leads along the pole surface.

In addition, the user must specify "metallurgical bond" between the two dissimilar metals (steel and copper). This bond eliminates galvanic action and ensures the long life of the material.

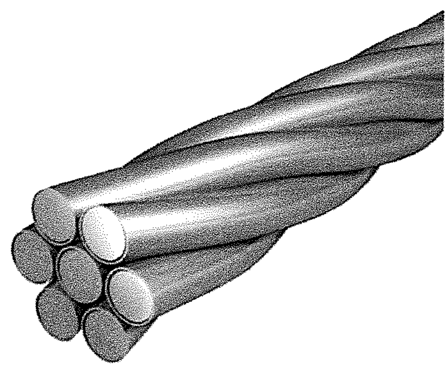

Figure 1: Copper-Clad Steel Conductor

3. RELEVANT INDUSTRY STANDARDS

3.1 Ontario Electrical Safety Code

Section 36-300 of the OESC covers grounding and bonding of high voltage installations (installations >750V). Section 36-300 covers the *"material and minimum size of grounding conductors and ground grid connections".* The following excerpt of section 36-300 is included to detail the OESC's position on grounding materials

*(2) Notwithstanding the requirement of Subrule (1), a galvanized steel, **copper-weld,** or other conductor shall be permitted for grounding purposes, provided that:*

(a) its current-carrying rating is equal to or greater than that of copper conductor as specified in rules 36-302 and 36-310
(b) consideration is given to galvanic action if such conductors are buried in the ground or come in contact with dissimilar metals; and
(c) the method of bolting or connecting such conductors to each other and to other surfaces is such as to maintain the required current-carrying capacity for the life of the electrode design

Table 51 in the OESC details the minimum size of bare copper grounding conductors for a given maximum short current for a given time duration. Table 51 refers the designer to appendix B for additional information on the selection of ground conductors. Appendix B then references IEEE Std. 80, which can be used by the designer to calculate the required size of copper-clad steel to meet the requirements of the OESC.

3.2 IEEE Std. 80-2000

Section 11.2 of IEEE Std. 80-2000 compares the various materials that can be used for grounding especially from the corrosion aspects, which impacts the integrity, longevity and effectiveness of the grounding system.

3.3.1 Copper Clad Steel

IEEE Std. 80-2000 notes the following. *"Copper clad steel is usually used for underground rods and occasionally for grounding grids, especially where theft is a problem. Use of copper, or to a lesser degree copper-clad steel, therefore assures that the integrity of an underground network will be maintained for years, so long as the conductors are of an adequate size and not damaged and the soil conditions are not corrosive to the material used."*

3.3.2 Aluminum

IEEE Std. 80-2000 cites a number of issues with using aluminum for grounding, including the fact that it is prone to corrosion and is anodic to both steel and copper. The standard recommends that aluminum only be used *"after full investigation of all circumstances".*

3.3.3 Steel

IEEE Std. 80 and the OESC both permit the use of galvanized steel, however; like aluminum, attention must be paid to the corrosion of steel.

3.3 ASTM Standard

ASTM B 228-04 *"Standard Specification for Concentric Lay-Stranded Copper-Clad Steel Conductors"* covers the construction, physical and electrical characteristics of the conductor.

The Standard lists 2 grades of copper-clad steel conductors:

- Grade 40 Density
- Grade 30 Density

The resistance (Ω/1000ft) of Grade 40 Density is 75% of that of Grade 30 Density. Therefore, Grade 40 is recommended for grounding applications.

This Standard should be referenced by utilities to ensure that when purchasing Copper-clad steel that it is manufactured correctly and that the material has been tested in accordance with the standard.

4. USER GUIDE AND APPLICATION

4.1 Ground Fault Current

When a fault occurs on a distribution system, a current will flow from the "faulted phase" to the source through multiple paths. Depending on the type of fault (phase-to-neutral or phase-to-ground), the current will return mostly through the system neutral wire and partly though earth. These parallel return paths will share the current depending on their relative impedances.

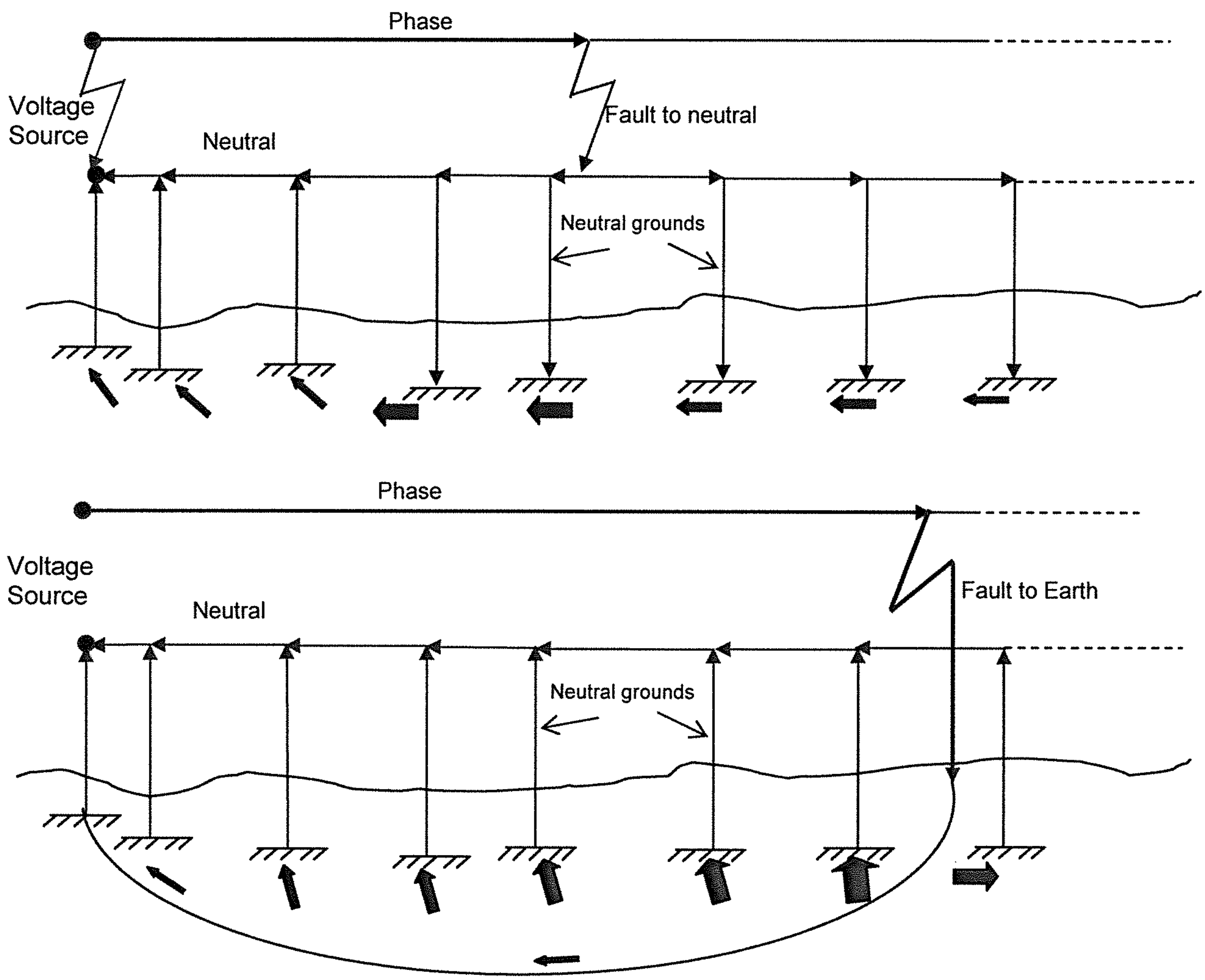

Figure 2: Diagrammatic representation of ground fault current

As it can be seen, the current in any grounding connection is less than the total ground fault current.

4.2 Conductor Current Carrying Capacity

Grounding conductors are sized to carry system fault currents, which are much higher than normal ground currents resulting from system phase unbalance. The magnitude and duration of system fault currents vary depending on system voltage, system configuration and the protective device used to clear the fault.

Various references list comprehensive equations for calculating the current carrying capacity (CCC) for conductors of different materials based on their fusing characteristics. Since the duration of system faults is small (≅ 1 second), the conductor CCC is based on its "Adiabatic Thermal Rating".

IEEE80-2000 Clause 11.3.1.2 lists the following simplified formula for calculating the required cross sectional area of ground conductor:

$$A_{kcmil} = I_{rms} \cdot K_f \cdot \sqrt{t_c}$$

Where: A_{kcmil} = Conductor area in kcmil

I_{rms} = The rms value of the fault current in Amps

t_c = The fault duration in seconds

K_f = Material factor

= 7.00 for soft drawn copper conductor

= 7.06 for hard drawn copper conductors

= 12.06 for Grade 30 copper-clad steel conductor

= 10.45 for Grade 40 copper-clad steel conductor

Compared to copper (both soft and hard drawn), the Material Factor of Grade 30 and Grade 40 copper-clad steel conductors is approximately 1.72 and 1.5 times respectively.

The following analysis will be based on using Grade 40 copper-clad steel conductor only.

The above relationship i represented graphically in figure 2 and figure 3 for soft drawn copper and 40% copper-clad steel conductors respectively. The relationship is plotted for various fault clearing times.

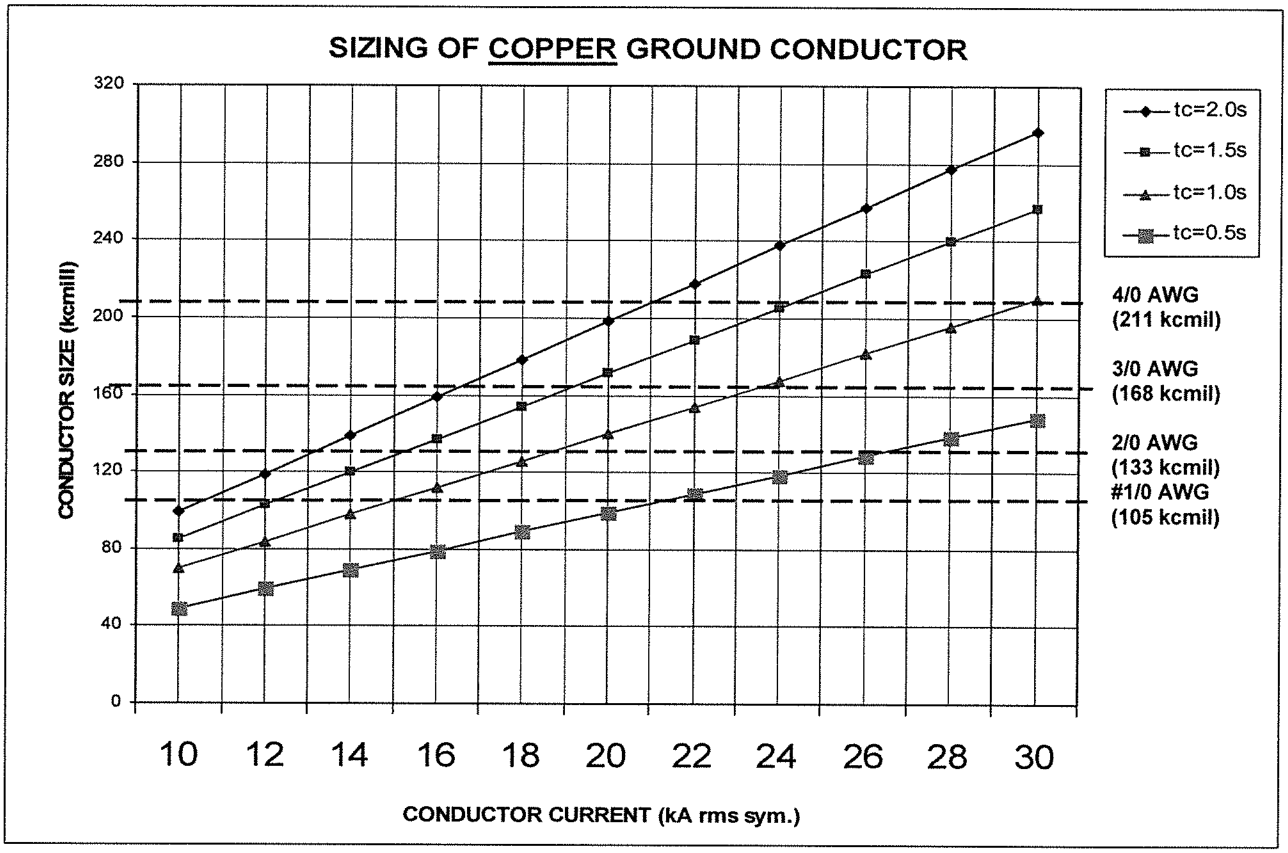

Figure 3: Minimum Conductor Size Soft Drawn

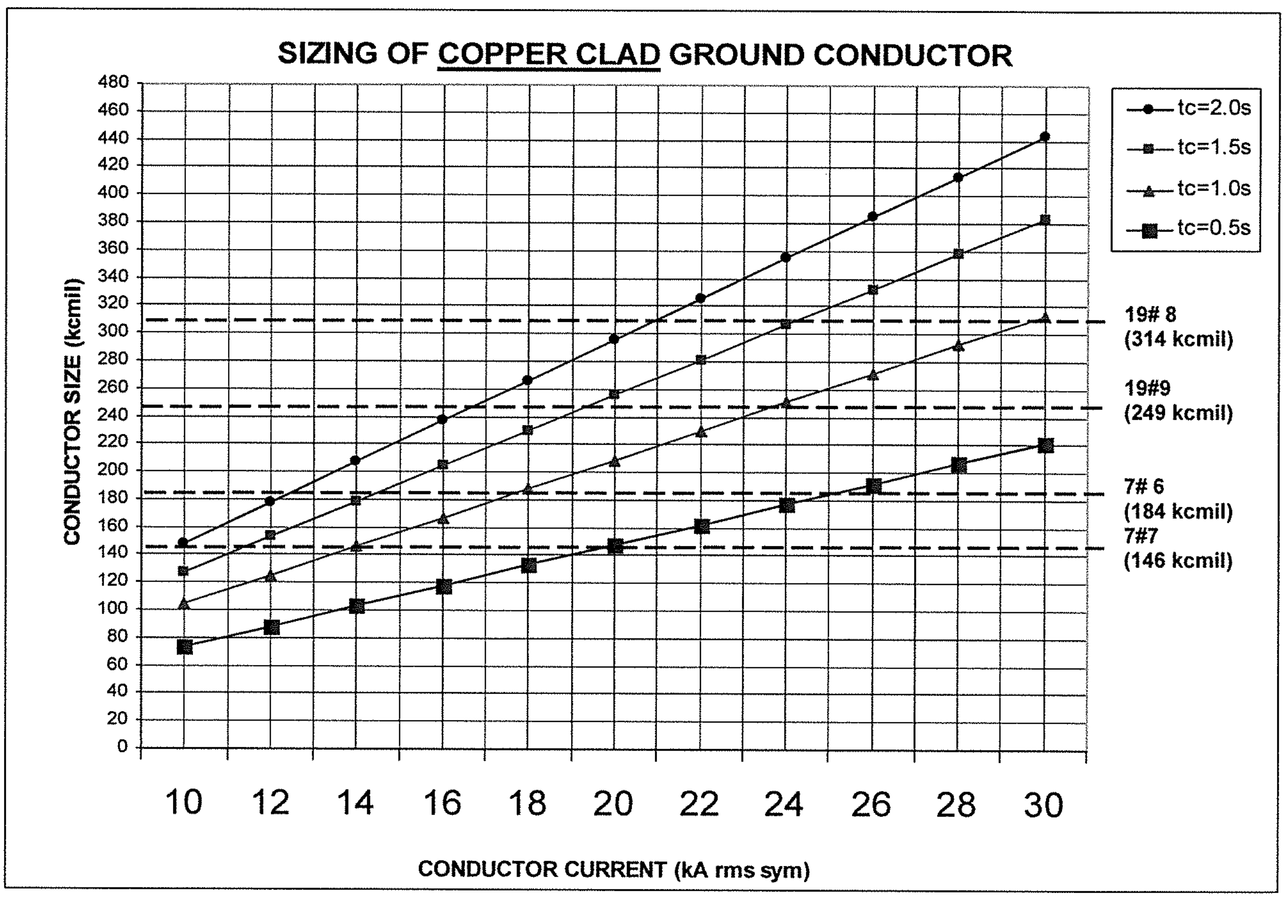

Figure 4: Minimum Conductor Size Grade 40 Copper-Clad Steel

4.3 Conductor Size Selection

In most medium voltage distribution systems, the ground fault current is less than or limited to 12,000A. The fault clearing time will vary depending on the type of the protective device used and its setting.

In transformer stations, the fault current will vary according to the transformer size and impedance.

The following table lists the allowable Current Ratings for most common **copper** ground wire sizes and the equivalent **copper-clad Steel** conductors as extracted from the equation and figures 3 and 4 above:

Conductor Size		Current Rating for Clearing Time of:	
		0.5 s	1.0 s
#4/0 Copper	**211.600 kcmil**	**42.7 kA**	**30 kA**
19 # 8 Cu-Clad	313.700 kcmil	42.5 kA	30 kA
#3/0 Copper	**167.800 kcmil**	**33.9 kA**	**24 kA**
19#9 Cu-Clad	248.800 kcmil	33.7 kA	23.8 kA
#2/0 Copper	**133.100 kcmil**	**26.8 kA**	**19 kA**
7 # 6 Cu-Clad	183.800 kcmil	24.9 kA	17.6 kA
#1/0 Copper	**105.600 kcmil**	**21.3 kA**	**15.1 kA**
7 # 7 Cu-Clad	145.700 kcmil	19.7 kA	14.0 kA

5. TECHNICAL DATA

The following table outlines the physical and electrical data for the 4 copper-clad steel conductor sizes listed above:

Conductor size	Nominal Diameter		Weight		Cross Section		Fusing Current @ 1.0s	Max. Resistance
	Inch	mm	Lbs/1000ft	kg/km	mm^2	kcmil	kA	Ohms/1000ft
19#8 Cu-Clad	0.642	16.31	892.0	1327.4	158.97	313.7	37	0.08550
19#9 Cu-Clad	0.572	14.53	707.3	1052.6	126.06	248.8	29	0.1078
7#6 Cu-Clad	0.486	12.34	520.3	774.3	93.10	183.8	22	0.1454
7#7 Cu-Clad	0.433	11.00	412.9	614.5	73.87	145.7	17	0.1833

6. RECOMMENDATION

6.1 Conductor Size

Reference to the above graph or table allows selection of the copper-clad conductor size for a given fault current and clearing time.

6.2 Conductor Specifications

When specifying copper-clad steel conductor the designer shall reference ASTM B228 and state:

- The recommended Grade 40 Density
- Dead Soft Annealed (DSA) copperweld for flexibility
- The copper cladding must be metallurgically bonded to the steel to eliminate galvanic action between the two dissimilar metals.

6.3 Installation

For a reliable and durable inter-connection to the grounding components, it is recommended to use either:

- Exothermic weld (Cadweld),
- Compression type connectors, or
- Wedge type connector

In addition, consideration may be given to "sealing" the ends of the conductor to minimize the corrosion of the exposed steel.

7. REFERENCES

(1) Ontario Electrical Safety Code, 24th Edition 2009
(2) ESA Bulletin 36-10-15 dated May 2009, High-Voltage Grounding and Bonding
(2) IEEE Std. 80-2000, IEEE Guide for Safety in AC Substation Grounding
(3) ASTM Standard B228-04, Specification for Concentric-Lay-Stranded Copper-Clad Steel Conductors
(4) Ontario Hydro, Guide for Grounding Design, dated 1979
(5) Fushi Copperweld: http://www.fushicopperweld.com
(6) ACA Conductor Accessories (A Division of AFL Telecommunications), 2006