IEEE Guide to Current Interruption with Horn-Gap Air Switches

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National Electrical Manufacturers Association

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Abstract: IEEE C37.36b-1990, *IEEE Guide to Current Interruption with Horn-Gap Air Switches,* is intended to aid air switch users in establishing suggested maximum values of excitation, resistive and capacitive currents that may be successfully interrupted while using outdoor air switches. This guide pertains to air switches mounted in the normal horizontal-upright position and not equipped with interrupting aids.
Keywords: air switch, capacitive current, current interruption, excitation current, horn-gap air switches, resistive current

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Foreword

(This Foreword is not a part of IEEE C37.36b-1990, IEEE Guide to Current Interruption with Horn-Gap Air Switches.)

This guide is intended to aid air switch users in establishing suggested maximum values of excitation, resistive and capacitive currents that may be successfully interrupted while using outdoor air switches. This guide pertains to air switches mounted in the normal horizontal-upright position and not equipped with interrupting aids.

The subject of current interruption using an air switch is so common to the industry that everyone appears to have an opinion concerning this matter. Some opinions hold that an air switch should never be used to interrupt any current except the capacitive current from insulators on the shortest length of bus or miscellaneous equipment. Others can document good experiences in interrupting excitation or capacitive currents two to ten times the maximum suggested levels in this guide. Both ends of this spectrum and the variations in the middle have merit based on individual experiences. However, this guide must achieve a consensus position among switch manufacturers, engineering consultants, governmental bodies, users, and many other interested parties in order to exist. Subsequently, the suggestions in this guide have been forged upon the consensus that the current interruption levels are at least as high as the values specified herewithin. No criticism is directed toward any organization for exceeding the suggestions of this guide. Finally, this guide will continue to require feedback in the future to develop suggestions that accurately address the needs of industry.

Table 1 of this guide provides the user with a quick procedure to establish the capability of a switch for current interruption when the switch is *near grounded equipment.* The user should note that this procedure should only be utilized after the user has thoroughly reviewed this guide and is confident of proper application. In a similar manner, Table 2 of this guide provides the user with a quick procedure to establish the capability of a switch for current interruption when the switch is *not near grounded equipment.*

The user is required to calculate his or her own current interruption values for applications that differ from the assumptions of Tables 1 and 2. Refer to the Appendixes for calculation methods and sample calculations.

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IEEE Guide to Current Interruption with Horn-Gap Air Switches

1. Scope

This guide is intended to provide air switch users with a means for determining the magnitude of excitation as well as resistive and capacitive currents that may be successfully interrupted with horn-gap, vertical-break air switches in outdoor locations mounted in the normal horizontal-upright position and not equipped with interrupting aids. The minimum centerline-to-centerline phase spacing of each switch is based upon dimensions stated in ANSIC37.32-1972 [B1][1], Table 5, Column 6. This guide assumes that the switches are applied to an effectively grounded wye system. A guide for ungrounded systems is being considered.

NOTE — Do not apply this guide to other types of switches. At this time, the confidence level for proper operation is not acceptable for other types of switches.

Use of suggestions within this guide by the air switch user should be done after proper evaluation of any adverse consequences that might result from a failure to properly interrupt the current. Adverse consequences may include phase-to-ground or phase-to-phase dielectric breakdowns, damage to other system equipment, etc.

This guide does not modify other standards such as ANSI/IEEE C37.30-1971 (Reaff 1987) [B2] or ANSI C37.32-1972 [B1]. Therefore, the application of this guide is entirely within the domain of the air switch user. Moreover, air switch manufacturers are not required to warrant suggestions made by this guide.

2. Introduction

Over the years air switches have been used to interrupt transformer excitation currents; capacitive currents in short lengths of bus, cable or overhead lines; small load currents, and loop currents. However, because of the many uncontrollable conditions under which air switches must interrupt currents, they have been given no interrupting rating. This lack of rating and the absence of standard guidelines have led to the following problems:

1) Various and inconsistent user policies (practices) regarding the utilization of air switches to interrupt currents
2) Improper use of air switches, which results in switch failures, system faults and outages
3) Excessive surge arrester operations during interruption of small currents with air switches

[1]The numbers in brackets correspond to those of the bibliography in Section 5.

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4) Installation of complex switching arrangements that could be replaced by simpler schemes that utilize the interruption capabilities of air switches
5) Extensive switching operations to avoid opening air switches in the energized mode wherein they might be required to interrupt small currents

In an effort to mitigate some of these problems, this guide provides guidelines for the use of air switches to switch limited currents (up to 11.0 A) characterized by the following:

1) Unloaded transformer switching (including small resistive loads)
2) Short-bus, overhead-line, and cable switching

These guidelines recognize the fact that the successful interruption of unconfined arcs in air, as between the contacts of an air switch or arcing horn extensions of these contacts, depends upon installation variables such as adjacent phase and ground clearances; environmental variables such as altitude, wind direction and velocity, and weather conditions. The effects of these variables are incorporated in the guide through calculation methods and safety factor utilization. This approach, while it does not eliminate the possibility of occasional failures due to those variables that are uncontrollable, does give a high degree of confidence to the suggestions of this guide.

Switching of large load or of loop current is not suggested by this guide.

3. Definitions

The definitions of terms contained in this document are applicable only to the subject treated in this guide and may not be consistent with definitions given in other standards documents.

air switch: A switching device designed to close and open one or more electric circuits by means of guided separable contacts that separate in air. The switching device may be equipped with arcing horns.

arc reach: The distance from a point midway between the arc extremities to the most remote point of the arc at the time of its maximum length.

arcing horn: One of a pair of diverging electrodes on which an arc is extended to the point of extinction after the main contacts of the switching device have parted.

horn-gap switch: A switch provided with arcing horns.

interrupting aids: An arc-interrupting device that can be attached to an air switch to improve its interrupting capability.

4. Suggested Practices

4.1 General

Care should be taken to assure that the switch has operated properly. Do not assume that the switch has interrupted the current in each phase because the switch was operated to open.

If operating personnel are in the vicinity of the switch, personnel should ascertain by visual inspection that the switch has interrupted the circuit. Otherwise, control or relay devices should be used that independently verify circuit interruption.

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If the switch has not properly interrupted the circuit before the switch blade is 2/3 of the way toward its “open” position, the switch should be reclosed if practical to minimize equipment damage and hazard to personnel. In this circumstance, the current or voltage magnitudes, environmental conditions, etc. may be too adverse for current interruption with the air switch.

4.1.1

The basic suggestions of this guide are given in Tables 1 and 2. The values from Table 1 or Table 2 should be selected depending upon the application of the switch. Suggested values given in Table 1 are based on minimum phase clearance to grounded objects as shown in Column 3 of Table 1, calculated maximum arc reach using the method suggested in [B5] and [B11], and rated maximum voltage. In addition, the air gap beyond the extremity of the calculated maximum arc reach is equal to the minimum phase-to-ground clearances found in Table 1 of NEMA SG6-1974 (Reaff 1979) [B3].

Suggested values given in Table 2 are based on minimum phase-to-phase clearance of an air switch equipped with arcing horns as shown in Column 3 of Table 2, calculated maximum arc reach using the method suggested in [B5] and [B11], and rated maximum voltage. In addition, the air gap beyond the extremity of the calculated maximum arc reach for resistive or excitation current interruption is capable of withstanding a 2-per-unit (phase-to-ground), slow-front surge. Conversely, for capacitive current interruption, the air gap is capable of withstanding a 2-per-unit (phase-to-ground), fast-front surge per [B11]. See Appendix B for sample calculations.

4.1.2

Switches not equipped with arcing horns may sustain damage if interruption of current is attempted.

4.1.3

Before using air switches to switch limited currents as suggested in Tables 1 and 2, the user should evaluate the possible effects of switching surges or overvoltages on system equipment such as transformers and cables.

4.2 Unloaded Transformer Switching

The following guidelines apply to the switching of unloaded transformers.

NOTE — Frequent switching of transformers may generate severe transients that may lead to premature failure of transformer insulation.

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Table 1— Suggested Guide for Interrupting Currents with Vertical-Break Air Switches Equipped with Arcing Horns and Mounted in Horizontal-Upright Position (Based on Minimum Phase Clearance to Grounded Objects, Calculated Arc Reach, and Maximum Operating Voltage)

1	2	3*		4	5	6	
Rated Maximum Voltage L—L	Rated Withstand Voltage Impulse	Minimum Phase Clearance to Grounded Objects		Resistive or Transformer Excitation Current	Bus, Line, or Cable Capacitive Current	Calculated Maximum Arc Reach	
(kV)	(kV)	(in)	(mm)	(Amps)	(Amps)	(in)	(mm)
15.5	110	12	305	3.1	1.1	5	130
25.8	150	19	485	3.0	1.1	9	230
38.0	200	25	635	2.8	1.0	12	305
48.3	250	32	815	2.8	1.0	15	380
72.5	350	43	1090	2.2	0.8	18	460
121.0	550	68	1730	1.8	0.6	25	660
145.0	650	82	2085	1.9	0.7	32	815
169.0	750	94	2390	1.9	0.6	36	915
242.0	900	112	2845	1.5	0.5	41	1040
242.0	1050	131	3330	1.7	0.6	48	1220
362.0	1050	125	3175	1.0	0.3	42	1070
362.0	1300	143	3630	1.2	0.4	49	1245
550.0	1550	176	4470	†	†		
550.0	1800	203	5160	†	†		
800.0	2050	364	9245	†	†		

Suggested values for current interruption are derived from Table 2 of this guide, the calculation method shown in Appendix A and subsequently modified by consensus of Air Switch Working Group.

NOTE — Do not use this table without prior and careful review of the entire guide. It is the user's responsibility before applying the suggestions made by this guide to evaluate any adverse consequences that may result if the switch should fail to interrupt current.

*Column 3—The distance over the switch insulators to the grounded base can be ignored.
†Insufficient data.

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Table 2— Suggested Guide for Interrupting Currents with Vertical-Break Air Switches Equipped with Arcing Horns and Mounted in Horizontal Upright Position [Based on Horn-Gap Switch-Phase Spacing (Centerline to Centerline), Calculated Arc Reach, and Maximum Operating Voltage]

1	2	2A		3*		4†	5†	6	
Rated Maximum Voltage L—L	Rated Withstand Voltage Impulse	Assumed Width of Live Parts		Air Switch Phase-to-Phase Spacing (C—C)		Resistance or Transformer Excitation Current	Bus, Line, or Cable Capacitive Current	Calculated Maximum Arc Reach	
(kV)	(kV)	(in)	(mm)	(in)	(mm)	(Amps)	(Amps)	(in)	(mm)
15.5	110	12	305	36	915	10.7	3.8	19	485
25.8	150	12	305	48	1220	10.3	3.7	30	760
38.0	200	12	305	60	1525	9.5	3.4	41	1040
48.3	250	12	305	72	1830	9.5	3.5	53	1350
72.5	350	12	305	84	2135	7.6	2.7	63	1600
121.0	550	18	460	120	3050	6.4	2.2	89	2260
145.0	650	18	460	144	3660	6.5	2.3	110	2795
169.0	750	24	610	168	4270	6.5	2.2	126	3200
242.0	900	24	610	192	4880	5.1	1.7	141	3580
242.0	1050	24	610	216	5490	6.0	2.0	165	4190
362.0	1050	24	610	216	5490	3.5	1.2	146	3710
362.0	1300	24	610	240	6100	4.1	1.4	170	4320
550.0	1550	36	915	300	7620	‡	‡		
550.0	1800	36	915	324	8230	‡	‡		
800.0	2050	48	1220	600	15240	‡	‡		

Suggested values for current interruption are derived from the calculation method shown in Appendix A and subsequently modified by consensus of Air Switch Working Group.

NOTE — Do not use this table without prior and careful review of the entire guide. It is the user's responsibility before applying the suggestions made by this guide to evaluate any adverse consequences that may result if the switch should fail to interrupt current.

*Values given in Column 3 are from ANSI C37.32-1972 [B1], Table 5, Column 6.
†Values given in Columns 4 and 5 are for vertical-break switches, horizontal-upright-mounted with minimum phase clearance to grounded objects at least equal to values in Column 3 of this table. The distance over the switch insulators to the grounded base can be ignored.
‡Insufficient data.

4.2.1

Table 1, Column 4 gives the suggested currents that may be switched with an air switch that is equipped with arcing horns and has minimum phase clearance to a grounded object as listed in Column 3.

4.2.2

Table 2, Column 4 gives the suggested currents that may be switched with an air switch that is equipped with arcing horns and has phase-to-phase spacing and phase clearance to a grounded object at least as large as shown in Column 3.

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4.2.3

All air switches used for such switching should be group-operated. Motor or equivalent remote control operation should be considered.

4.2.4

When a transformer is equipped with a load-tap changer, it should be placed in the neutral position before being switched. See 4.2.5.

4.2.5

Overexcited transformers should not be switched with an air switch unless it is determined that the excitation current of the transformer in the overexcited condition is equal to or less than the values given in Column 4 of Table 1 or 2 as applicable.

4.2.6

Surge arresters should be connected between the air switch and the transformer to reduce transient overvoltages.

4.3 Bus, Line, and Insulated Cable Switching

It is more difficult to interrupt a capacitive current in air than it is to interrupt excitation or resistive current. This type of interruption is similar to excitation current interruption in which there is a succession of interruptions near zero current, each followed by restrikes. The difference between the two types of interruptions is that for each capacitive current interruption, a charge is more likely to be retained by the capacitive device. Each of these trapped charges creates an additive bias voltage that increases the probability of restriking across the open gap of the switch 1/2 cycle later when the source voltage has reversed its polarity. Consequently, longer arc reaches have been experienced when switching capacitive currents than when switching excitation currents. In addition to creating a complex high-frequency transient, oscillatory current, the overvoltages may be up to 3 per unit of the normal system voltages.

The following guidelines apply to the switching of bus, line, or insulated cable charging currents.

4.3.1

Table 1, Column 5 gives the suggested currents that may be switched with an air switch that is equipped with arcing horns and has minimum phase clearance to a grounded object as listed in Column 3.

4.3.2

Table 2, Column 5 gives the suggested currents that may be switched with an air switch that is equipped with arcing horns and has phase-to-phase spacing and phase clearance to a grounded object at least as large as shown in Column 3.

NOTE — In selecting a minimum phase clearance to a grounded object, the distance over the switch insulators to the grounded base is not used to determine the current that can be interrupted.

5. Bibliography

The following documents were used in the preparation of this guide and are suggested for use in establishing guidelines for applications under conditions that differ from those given in Tables 1 and 2.

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[B1] ANSI C37.32 1972, American National Standard Schedules of Preferred Ratings, Manufacturing Specifications, and Application Guide for High-Voltage Air Switches, Bus Supports, and Switch Accessories.[2]

[B2] ANSI/IEEE C37.30-1971 (Reaff 1988), American National Standard Definitions and Requirements for High-Voltage Air Switches, Insulators, and Bus Supports.

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[2]ANSI C37.32-1972 was withdrawn by the American National Standards Institute in 1989. It is included for information only.
[3]NEMA SG6-1974 was withdrawn by the National Electrical Manufacturers Association in 1985. It is included for information only.

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Annex A

Calculation Method for Arc Reach, Determination of the Adequacy of Switch Clearance, and Calculation of Suggested Current Information

(Informative)

(These appendixes are not a part of IEEE C37.36b-1990, IEEE Guide to Current Interruption with Horn-Gap Air Switches, but are included for information only.)

A.1 Arc Reach

A.1.1 Resistive or Excitation Current Interruption

$$L_{rm} = 5.03 \cdot V_p \cdot I_r / 1000 \quad (1a)$$

[B11]

or

$$L_{rf} = 0.0165 \cdot V_p \cdot I_r \quad (1b)$$

[B5]

where

L_{rm} = Arc reach in meters
L_{rf} = Arc reach in feet
V_P = Voltage across open switch air gap in rms kilovolts
I_r = Resistive or excitation current to be interrupted in rms amperes

A.1.2 Capacitive Current Interruption

$$L_{cm} = 2.75 \cdot 5.03 \cdot V_p \cdot I_c / 1000 \quad (2a)$$

$$L_{cf} = 2.75 \cdot 0.0165 \cdot V_p \cdot I_c \quad (2b)$$

where

L_{cm} = Capacitive arc reach in meters
L_{cf} = Capacitive arc reach in feet
V_p = Voltage across open switch air gap in rms kilovolts
I_c = Capacitive current to be interrupted in rms amperes

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A.2 Adequacy of Switch Clearance

A.2.1 Minimum Phase Clearance to Grounded Objects

Minimum phase clearance to grounded objects (see Table 1, Column 3 of this guide) is determined by adding the calculated arc reach to the minimum phase-to-ground clearances found in Table 1 of NEMA SG6-1974 [B3]. The arc reach should be limited to the values indicated for rated maximum voltage in Table 1, Column 6 or Table 2, Column 6 of this guide as applicable.

A.2.2 Phase-to-Phase Clearance for Resistive, Excitation, or Capacitive Current Interruption

The air gap between the extremity of the arc formed during resistive or excitation current interruption and the adjacent phase is capable of withstanding a 2-per-unit (phase-to-ground), slow-front surge per [B11] as follows:

$$V_{ra} = 0.79 \cdot 1.45 \cdot (100 \cdot \mathrm{SQRT}[(50 \cdot d) + 1] - 250) \quad (3)$$

$$V_{rr} = 2 \cdot V_t \cdot \mathrm{SQRT}(2/3) = 1.63 \cdot V_t \quad (4)$$

where

d = Air-gap length in meters from extremity of arc to adjacent phase
V_{ra} = Withstand voltage of air gap for a slow-front surge in kV crest
V_l = Rated maximum voltage phase-to-phase (rms kilovolts)
V_{rr} = Required level of withstand voltage for 2-per-unit, slow-front surge in kV crest

Conversely, the air gap between the extremity of the arc formed during capacitive-current interruption and the adjacent phase is capable of withstanding a 2-per-unit, fast-front surge per [B11] as follows:

$$V_{ca} = 0.79 \cdot 530 \cdot d \quad (5)$$

$$V_{cr} = 1.63 \cdot V_t \quad (6)$$

where

d = Same as Eq 3 above
V_{ca} = Withstand voltage of air gap in kV crest for a fast-front surge
V_l = Same as Eq 4 above
V_{cr} = Required level of withstand voltage for 2-per-unit, fast-front surge in kV crest

A.3 Calculation of Suggested Current Interruption

$$I_{er} = [344/V_l \cdot \{(D_l + 0.02) - (2 \cdot 10\text{^}[-6] \cdot (1.43 \cdot V_l + 250)\text{^}2\}] \quad (7, \text{See Note below.})$$

$$I_{cr} = [125/V_l \cdot \{D_l - (0.0039 \cdot V_l)\}] \quad (8)$$

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where

I_{er} = Suggested maximum excitation or resistive current (rms amperes)
I_{cr} = Suggested maximum capacitive current (rms amperes)
V_l = Same as Eq 4 above
D_l = Phase-to-phase clearance (meters)

NOTE — Eq 7 is a correction by author of [B11].

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Annex B

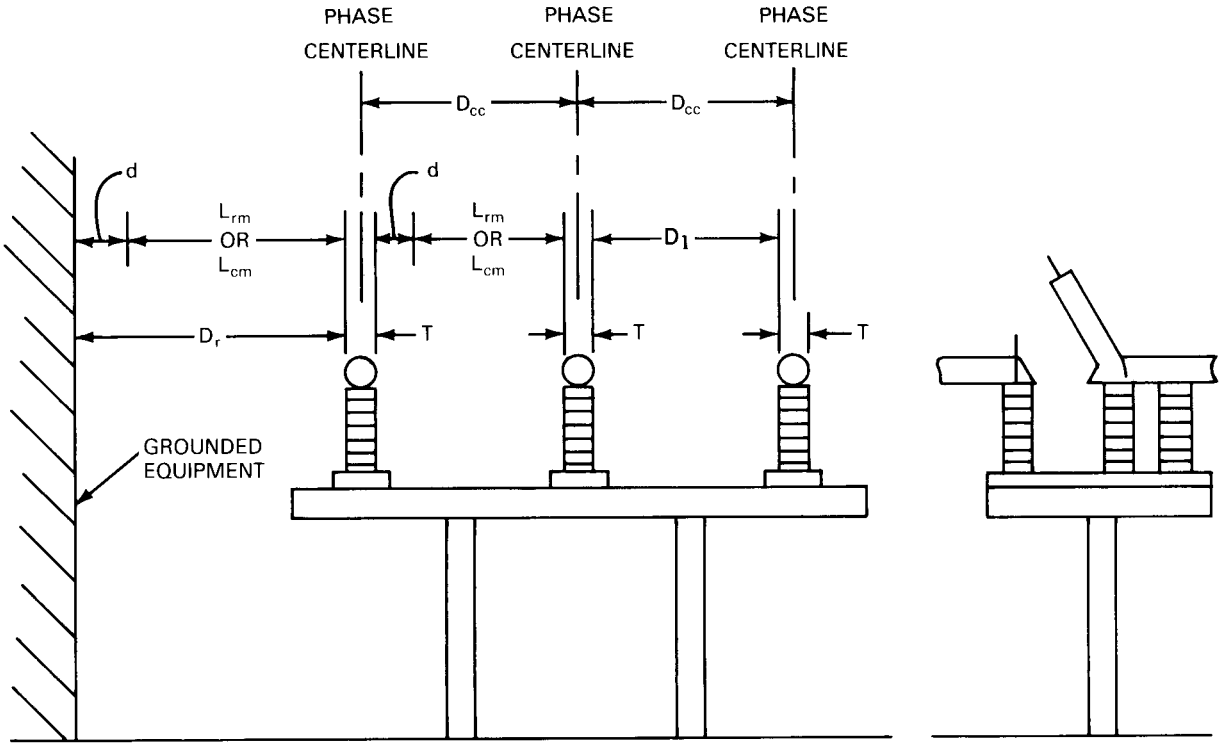
Sample Calculations (See Fig B.1 and Tables 1 and 2.)

(Informative)

B.1 Example 1

B.1.1 Problem

Determine the suggested maximum excitation, resistive, and capacitive currents that may be successfully interrupted with a 3PST, vertical-break, horn-gap switch on a wye effectively grounded electrical system. The switch is horizontal, upright-mounted, and has a rated maximum voltage of 15.5 kV, a minimum phase clearance to grounded objects of 60 in, and a centerline-to-centerline phase spacing of 42 in.



LEGEND

D_{cc}	=	Centerline-to-centerline phase spacing
T	=	Width of switch pole, live parts
D_l	=	Phase-to-phase clearance $(D_{cc} - T)$
L_{rm}	=	Arc reach for resistive or excitation current
L_{cm}	=	Arc reach for capacitive current
D_r	=	Phase clearance to closest grounded object
d	=	Air-gap length measured from extremity of arc to adjacent phase or to closest grounded object as applicable

Figure B.1—Outdoor Vertical-Break Air Switch—Horizontal-Upright Mounting

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B.1.2 Solution

The phase clearance to grounded objects (D_r) is 60 in. Inspection of Table 1 for the line showing rated maximum voltage of 15.5 kV indicates that D_r is at least equal to 12 in, minimum phase clearance to grounded objects (D_g) in Column 3. Therefore, the switch has at least the capability of interrupting the currents as specified in Table 1, Columns 4 and 5, which are as follows:

I_{eg} = Excitation or resistive current = 3.1 A
I_{cg} = Capacitive current = 1.1 A

Moreover, the centerline-to-centerline phase spacing of the switch is 42 in. Inspection of Table 2 for rated maximum voltage of 15.5 kV indicates that 42 in meets the requirement forminimum centerline-to-centerline phase spacing (D_{cc}) in Column 3. Although D_r is greater than D_{cc} the switch should be limited to interrupting the maximum currents as specified in Table 2, Columns 4 and 5, which are as follows:

I_{er} = Excitation or resistive current = 10.7 A
I_{cr} = Capacitive current = 3.8 A

B.2 Example 2

B.2.1 Problem

Determine the suggested maximum excitation, resistive, and capacitive currents that may be successfully interrupted with a 3PST, vertical-break, horn-gap switch on a wye effectively grounded electrical system. The switch is horizontal, upright-mounted, and has a rated maximum voltage of 121 kV, a minimum phase clearance to grounded objects of 80 in, and a centerline-to-centerline phase spacing of 144 in.

B.2.2 Solution

The phase clearance to grounded objects (D_r) is 80 in. Inspection of Table 1 for rated maximum voltage of 121 kV indicates that $_{\mathrm{D}}$ is at least equal to 68 in, minimum phase clearance to grounded objects (D_g) in Column 3. Therefore, the switch has at least the capability of interrupting the currents as specified in Table 1, Columns 4 and 5, which are as follows:

I_{eg} = Excitation or resistive current = 1.8 A
I_{cg} = Capacitive current = 0.6 A

Moreover, the centerline-to-centerline phase spacing of the switch is 144 in. Inspection of Table 2 for rated maximum voltage of 121 kV indicates that 144 in meets the requirement for minimum centerline-to-centerline phase spacing (D_{cc}) in Column 3. Accordingly, the switch would normally be limited to interrupting the maximum currents as specified in Table 2, Columns 4 and 5, which are as follows:

I_{el} = Excitation or resistive current = 6.4 A
I_{cl} = Capacitive current = 2.2 A

In this case, however, the actual phase clearance to grounded objects, D_r, is 80 in, which is less than 120 in. Thus D_r limits the switch current interrupting capability to a level greater than the values in Columns 4 and 5 of Table 1, but less than those in Columns 4 and 5 of Table 2. Therefore, the suggested maximum current interruption capability of the switch is to be determined by linear extrapolation as follows:

Centerline-to-centerline phase spacing (D_{cc}) of 120 in less adjustment of 18 in for width of switch pole [from Table 2, Columns 3 and 2A equals phase clearance (D_l) of 102 in]. Note that the suggested maximum current that may be interrupted is based upon the centerline-to-centerline phase values given in Table 2.

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I_{er} = Suggested maximum excitation or resistive current
I_{cr} = Suggested maximum capacitive current
$I_{er} = I_{eg} + [(I_{el} - I_{eg})/(D_l - D_g)] \cdot (D_r - D_g)$
$I_{cr} = I_{cg} + [(I_{cl} - I_{cg})/(D_l - D_g)] \cdot (D_r - D_g)$
$I_{er} = 1.8 + [(6.4 - 1.8)/(102 - 68)] \cdot (80 - 68)$ A
$I_{cr} = 0.6 + [(2.2 - 0.6)/(102 - 68)] \cdot (80 - 68)$ A

Therefore, the maximum currents that may be successfully interrupted are as follows:

I_{er} = Excitation or resistive current = 3.4 A
I_{cr} = Capacitive current = 1.2 A

B.3 Example 3

B.3.1 Problem

Determine the suggested maximum excitation, resistive, and capacitive currents that may be successfully interrupted with a 3PST, vertical-break, horn-gap switch on a wye effectively grounded electrical system. The switch is horizontal, upright-mounted, and has a rated maximum voltage of 242 kV, a BIL of 900 kV, a minimum phase clearance to grounded objects of 118 in, and a centerline-to-centerline phase spacing of 144 in.

NOTE — The centerline-to-centerline phase spacing of the switch is less than the minimum spacing required for use of Table 2.

B.3.2 Solution

The phase clearance to grounded objects (D_r) is 118 in. Inspection of Table 1 for rated maximum voltage of 242 kV at 900 kV BIL indicates that D_r is at least equal to 112 in, minimum phase clearance to grounded objects (D_g) in Column 3. Therefore, the switch has at least the capability of interrupting the currents as specified in Table 1, Columns 4 and 5, which are as follows:

I_{er} = Excitation or resistive current = 1.5 A
I_{cr} = Capacitive current = 0.5 A

However, the centerline-to-centerline phase spacing (D_{cc}) of 144 in is less than the minimum spacing in Column 3 of Table 2. Consequently, the suggested maximum interruption currents are less than those stated in Columns 4 and 5 of Table 2 and may be calculated as outlined below.

The phase-to phase clearance between live parts is determined by subtracting the assumed width of live parts (Column 2A) from the phase-to-phase spacing (Column 3) or 144 in – 24 in = 120 in. Note, however, that the phase clearance to grounded objects is given as 118 in, which is less than the 120 in calculated above. Therefore, the value D_i = 118 in should be used for the calculations. This will provide suggested maximum current interruption values that are adequate for phase clearance to grounded objects as well as for phase-to-phase clearances.

Convert D_l (inches) to D_l (meters) and use the following formulas from [B11]:

D_l = 118 in to D_l = 2.99 m
$I_{er} = [344/V_l \cdot \{(D_l + 0.02) - (2 \cdot 10 \wedge [-6]) \cdot (1.43 \cdot V_l + 250) \wedge 2\}]$
I_{er} = 3.2 A
$I_{cr} = [125/V_l - \{D_l - (0.0039 \cdot V_l)\}]$
I_{cr} = 1.0 A

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B.3.3 Calculation Check

1) Arc reach for resistive or excitation current
   L_{rm} = 5.03 · V_p · I_{er}/1000
   L_{rm} = 5.03 · 242/1.73 · 3.2/1000
   L_{rm} = 2.25 m
2) Arc reach for capacitive current
   L_{cm} = 2.75 · 5.03 · V_p · I_{cr}/1000
   L_{cm} = 2.75 · 5.03 · 242/1.73 · 1.0/1000
   L_{cm} = 1.93 m
3) Air-gap length for resistive or excitation current
   d = D_l – L_{rm} = 2.99 – 2.25 = 0.74 μ
   a) Voltage withstand of air gap
      V_{ra} = 0.79 · 1.45 · (100 · SQRT R50 ·d) + 1] – 250)
      V_{rr} = 2 · V_l · SQRT (2/3) = 1.63 – V_l
   b) Solving
      V_{ra} = 420 kV crest
      V_{rr} = 395 kV crest

   Therefore, suggestion for resistive or excitation current interruption is valid because $V_{ra} > V_{rr}$.
4) Air-gap length for capacitive current
   d = D_l – L_{cm} = 2.99 – 1.93 = 1.06 μ
   a) Voltage withstand of air gap
      V_{ca} = 0.79 · 530 ·d
      V_{cr} = 1.63 · V_l
   b) Solving
      V_{ca} = 443 kV crest
      V_{cr} = 395 kV crest

   Therefore, suggestion for capacitive current interruption is valid because $V_{ca} > V_{cr}$.

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