Termination Clearance & Bending Radius

Introduction

Medium Voltage Capacitor banks and Harmonic Filter Banks are typically connected to power systems by Type MV-90 shielded power cable. In accordance with manufacturer recommendations and the NEC (Article 300-34), they shall not be bent to a radius less than 12 times the diameter for shielded or lead-covered conductors during or after installation. For multi-conductor or multiplexed single conductor cables having individually shielded conductors, the minimum bending radius is 12 times the diameter of the individually shielded conductors or 7 times the overall diameter, whichever is greater.

In consideration of the above constraints, and the fact that the termination has a length of 9" to 32", it is important that medium voltage capacitor bank and harmonic filter bank manufacturers provide enough space for conductor termination. The following can minimize the required space:

- Use of a cable that is appropriately sized for the current rating of the bank, accounting for future expansion. To large of a cable will increase the required bending radius and make for a more difficult installation.

- Use of high voltage terminations that are as flexible as the original cable. Raychem's HVT terminations are an example.

This document provides background information on bending radius for MV-90 shielded power cable and required termination clearances. NEPSI's capacitor bank and harmonic filter bank designs are based on meeting these constraints as well as the above recommendations. Therefore it is prudent for the installing contractor to follow the recommendations listed above.

Termination Clearance Requirements

The stress control systems of most flexible terminations provide a linear voltage distribution from the lug (at high voltage) to the shield termination (at ground potential). If the termination is installed too close to another termination or to another phase or grounded metal (enclosure wall), the electric stress between the terminations or termination and ground will rise to a level where discharge or flashover may occur. The electric field stress at the lug is greater than that at the shield end. The tables below along with the figures provide a guideline as to the minimum clearances needed between terminations as well as termination to ground. These clearances are based on IEEE BIL Levels. The table provides the line-to-line voltage of the system and the BIL. When choosing the line-to-line voltage in the table, the system voltage must be equal to or greater than your application voltage.

Table 1 - Minimum Clearance

System Voltage (KV)	BIL	A	B	C	D	E
4.76	60	3.5	2.5	0.6	0.4	9.5
8.25	75	4.0	3.0	0.8	0.6	9.25
13.8	95	6.5	3.5	1.2	0.8	15
14.4	110	7.0	4.0	1.4	0.9	15
23.0	125	9.1	6.0	1.6	1.0	26
34.5	150	9.0	6.0	1.6	1.0	33
34.5	200	13.0	9.0	2.0	1.4	33

Note: Values are based on normal operating conditions. Humid or poorly ventilated environments may require additional air clearance.

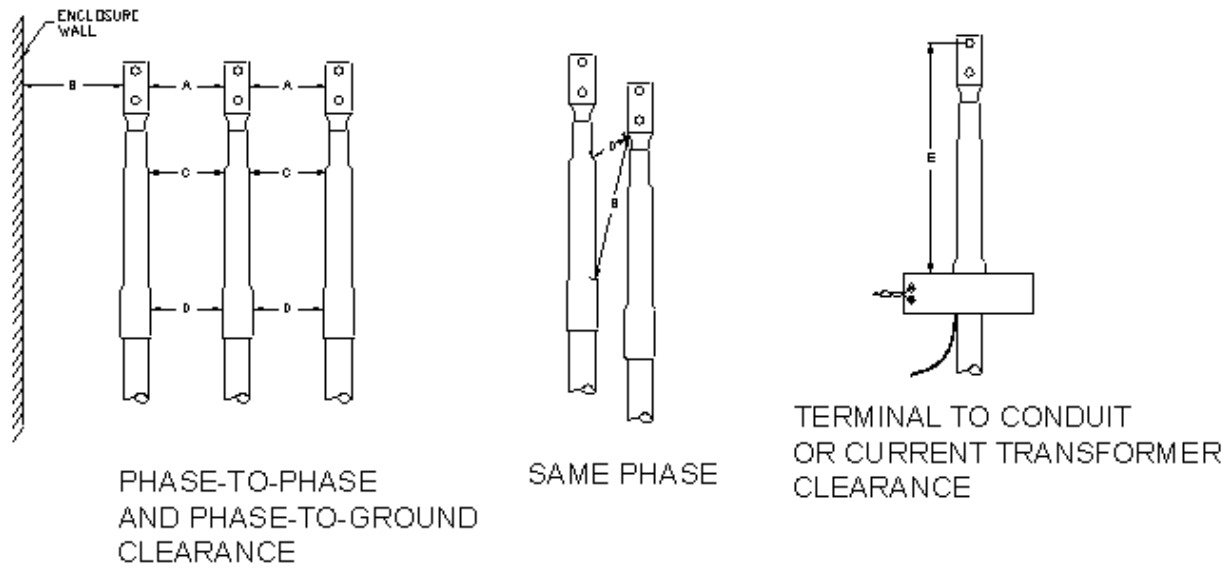

Figure 1 - Diagram For Use With Table 1 For Determining Minimum Clearances

When installing current transformers on medium voltage cables supplying capacitor banks and harmonic filter banks it is important that the shield wire be routed through the current transformer as shown in figure 1. This allows for proper operation of over current protection relays.

Recommended Cable Bending Radius

Many terminations are as flexible as the original cable. It is recommended that these types of terminations be utilized when installing NEPSI's harmonic filter banks and capacitor banks. When used, the cable end should not be bent to a radius less than that recommended by the manufacturer or 12 times the cable diameter as required by the NEC (whichever is smaller). The figure below provides a guideline as to the bending

radius in a typical installation. "D" in the figure is equal to the cable jacket diameter for a single-conductor cable or tubing-diameter for a three-conductor cable. In general the minimum bending radius for a single-conductor cable and multi-conductor cable with and overall shield is twelve times the overall singe cable diameter or seven times the overall tubing diameter. The tables below show typical diameters for shielded single conductor, 133% insulation level, XLP cable. The voltage for each class of cable is provided. From the tables, the minimum bending radius can be calculated. These tables are only to be used as a guideline since different manufactures have different dimensions and requirements. For specific information on the bending radius, the cable manufacturer should be consulted.

Table 2 - Typical Cable Characteristics

5000 Volt 133% Insulation Cable

Size AWG or Kcmil	Nominal Diameter Inches	* Ampacity Conduit
8	0.56	55
6	0.60	75
4	0.65	97
2	0.70	130
1	0.74	155
1/0	0.78	180
2/0	0.87	205
3/0	0.92	240
4/0	0.98	280
250	1.02	315
350	1.12	385
500	1.25	475
750	1.44	600
1000	1.58	690

15000 Volt 133% Insulation Cable

Size AWG or Kcmil	Nominal Diameter Inches	* Ampacity Conduit
-	-	-
-	-	-
-	-	-
2	1.05	150
1	1.09	170
1/0	1.13	195
2/0	1.17	225
3/0	1.22	260
4/0	1.28	295
250	1.34	330
350	1.44	395
500	1.57	480
750	1.82	585
1000	1.93	675

25000 Volt 133% Insulation Cable

Size AWG or Kcmil	Nominal Diameter Inches	* Ampacity Conduit
1	1.34	170
1/0	1.39	195
2/0	1.44	225
3/0	1.49	260
4/0	1.53	295
250	1.59	330
350	1.69	395
500	1.90	480
750	2.09	585
1000	2.24	675

25000 Volt 133% Insulation Cable

Size AWG or Kcmil	Nominal Diameter Inches	* Ampacity Conduit
-	-	-
1/0	1.60	195
2/0	1.64	225
3/0	1.68	260
4/0	1.70	295
250	1.81	330
350	1.93	395
500	2.06	480
750	2.24	585
1000	2.40	675

Note: The Ampacity is based on three cables in isolated conduit in air, 90 deg. C conductor temperature, 40 deg. C. Ambient. For other installation conditions, refer to the National Electrical Code. Please note that the NEC requires that the conductors feeding a capacitor bank must have a rating of at least 135% of the ampacity rating of the capacitor bank.

Conclusion

NEPSI's capacitor banks and harmonic filter banks are designed with adequate clearance for incoming power cables. The clearances are based on the use of appropriately sized cables and flexible cable terminations. When flexible terminations are not going to be used, or when a much higher ampacity cable is going be utilized, NEPSI should be notified. This will guarantee a trouble free, hassle free installation.

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