Group Capacitor Fusing for Pole-Mounted Capacitor Banks in Grounded and Ungrounded Wye Applications

Group fusing is generally used for protecting pole-mounted distribution capacitor racks. In this type of application, the fuse links are installed in cutouts and mounted on a cross arm above the capacitor rack.

The main purpose of the fuse on a capacitor rack is to clear a fault if a capacitor unit or any of the accessories fail. The fuse must clear the fault quickly to prevent any of the equipment from failing violently and to assure continuous operation of the rest of the system (the unfaulted portion).

The fuses must be sized to withstand normal currents, including harmonics, inrush, and outrush. This document describes the following considerations for selecting a group fuse:

- Continuous current
- Transient current
- Fault current
- Tank rupture curve coordination
- Voltage on good capacitors

Continuous current

The fuse protecting the capacitor is chosen such that its continuous current capability is equal to or greater than 135% of rated capacitor current for grounded-wye connected racks, and 125% for ungrounded-wye racks. This overrating includes the effects of overvoltage, capacitor tolerance, and harmonics. The minimum size fuse link for a grounded-wye application is calculated as follows:

$$I_{link} = \frac{1.35}{1.50} * \frac{kVAR_{3\Phi}}{\sqrt{3}\, kV_{L-L}}$$

This calculation is based on the link being 150% rated. That is, in the case of 150% NEMA type T and K tin links, they can carry 150% of rated current continuously.[1]

Transient current

Fuses can be damaged due to high-magnitude, high-frequency currents. It is desirable to minimize spurious fuse operations by selecting an appropriately large fuse link so as to withstand these transient currents.

Three sources of transient currents are capacitor bank switching, lightning surges, and discharge through to external faults (primarily on grounded-wye systems).

Switching is typically only a concern when capacitor banks are switched on the same bus, i.e., back-to-back switching. This is seldom the case for pole-mounted capacitors. However, capacitor fuses are subject to high-frequency transients due to lightning surges and discharges through external faults.

1 The 150% current-carrying capability applies to tin links, not silver links. Silver T and K links can carry 100% of their rating continuously.

Fault current

The fuse link/cutout and the capacitor must be able to handle the available fault current adequately. When capacitors are connected grounded-wye or delta in a pole-mounted rack application, a capacitor failure (terminal-to-terminal) will cause system fault current to flow. The capacitor must be able to withstand the fault current until the fuse interrupts the circuit. Additionally, the fuse must be able to successfully interrupt the available fault current.

The available symmetric fault current should not exceed the limits shown in Table 1 or the limits for the selected cutout.

Table 1. Fault current limitations: Cooper Power Series Type SD, HD & XD capacitors

Capacitor Type	Maximum Symmetric Fault Current (RMS amps) when X/R is:				Maximum Link Rating Which Coordinates with Available Fault Current	
	0	5	10	15	NEMA K	NEMA T
SD & HD	10,000	7,800	6,900	6,500	100K*	65T*
XD	15,000	11,700	10,350	9,750	100K*	65T*

* These fuse links coordinate with the capacitor tank rupture curves only up to the currents given in the table.

When the available fault current for a given application exceeds the capacitor or cutout capability, possible solutions include the following:

- Use current-limiting fuses which will limit the available fault current seen by the capacitor.
- Unground the neutral and operate the bank ungrounded-wye. This is generally a more cost-effective solution.[2] In this type of connection, the available current is limited to three times the line current due to the impedance of the capacitors in adjacent phases. See Table 1 for proper fuse selection. (If a major insulation failure or simultaneous failures in two phases should occur, then fault current could flow. These events are usually very rare and are normally not considered when applying fuses in an ungrounded-wye application.)
- Move the capacitor rack to a location with an acceptable fault current level.

Tank rupture curve coordination

The maximum clearing time-current curve (TCC) for the fuse link must coordinate with the tank rupture curve for the capacitor. This coordination is necessary to ensure that the fuse will clear the circuit prior to tank rupture occurring.

For the maximum fault current, the fuse should melt and clear at a time faster than the corresponding time on the tank rupture curve for that fault current level. In other words, the fuse maximum clear TCC must fall below the tank rupture TCC curve at and below the level of available fault current. In the case of high fault currents, the tank rupture curve should be compensated for asymmetry.

In general, the largest fuse size recommended for coordination with the tank rupture curve for the Cooper Power Series type SD, HD and XD capacitors is a NEMA 100K link and a NEMA 65T link. (See publications R230-91-1, R230-91-2, R240-91-1, and R-240-91-2 for tank rupture curves and fuse time-current curves.)

Voltage on good capacitors

For ungrounded-wye capacitor banks, the voltage on the good capacitor units, when one is shorted, is equal to system line-to-line voltage, i.e., 1.73 times its rating. If the failed unit is not cleared from the circuit quickly, this high overvoltage condition could lead to a second capacitor failure, resulting in a phase-to-phase fault. For this reason, it is desirable to use the fastest clearing fuse possible so as to minimize the possibility of a second unit failure. This criterion pushes for a fast-clearing fuse, such as a K-link, while the transient-current criterion dictates a slow-clearing fuse, such as a T-link. Therefore, fuse-selection criteria for ungrounded-wye applications are more restrictive than for grounded-wye applications.

2 Additional factors must be considered for operating the bank ungrounded-wye. Capacitor units need to have two bushings and, if the bank has a switch, the switch should be capable of handling the transient recovery voltage (TRV) present in an ungrounded-wye installation.

Summary of group fusing recommendations for pole-mounted capacitor racks

Table 2 and Table 3 list group fusing recommendations for the Cooper Power Series type SD, HD and XD capacitors. These recommendations are given assuming a typical level of lightning incidence. Consult Eaton's Power Systems Division technical staff when unusual operation conditions are encountered or where other types of fusing products are utilized.

Table 2. Grounded wye pole-mounted capacitor racks

Line-to-Gnd. Voltage	Recommended Link/Alternate Link NEMA 150% Rated T or K Links										
	3-Phase KVAR										
	150	300	450	600	900	1200	1350	1800	2400	2700	3600
2400	20T	40T/40K	65T/65K	80K							
2770	20T	40T/40K	50T/50K	65T/65K	100K						
4160	12T	25T/30K	40T/50K	50T/50K	65T/65K	100K	100K				
4800	12T	20T/30K	30T/40K	40T/50K	65T/65K	80K	100K				
7200	12T	15T/30K	20T/40K	25T/50K	40T/65K	50T/65K	65T/65K	80K	100K		
7620	12T	15T/30K	20T/40K	25T/50K	40T/50K	50T/65K	65T/65K	80K	100K		
7960	12T	15T/30K	20T/40K	25T/50K	40T/50K	50T/65K	65T/65K	80K	100K		
8320	12T	15T/30K	20T/40K	25T/50K	40T/50K	50T/65K	50T/65K	65T/80K	100K	100K	
9540	12T	15T	20T/40K	25T/40K	30T/50K	40T/65K	50T/65K	65T/80K	80K	100K	
9960	10T	15T	20T/30K	25T/40K	30T/50K	40T/65K	50T/65K	65T/80K	80K	100K	
12470		12T	15T/30K	20T/40K	25T/50K	30T/50K	40T/65K	50T/65K	65T/80K	65T/80K	100K
13200		12T	15T/30K	20T/40K	25T/50K	30T/50K	40T/65K	50T/65K	65T/80K	65T/80K	100K
13800		12T	15T/30K	20T/40K	25T/50K	30T/50K	30T/65K	40T/65K	65T/80K	65T/80K	100K
14400		12T	15T/30K	20T/40K	25T/50K	30T/50K	30T/65K	40T/65K	50T/80K	65T/80K	100K
19920		10ET	12ET	15ET/30EK	20ET/40EK	25ET/50EK	30ET/50EK	30ET/65EK	40ET/65EK	50ET/80EK	65ET/80EK
21600			12ET	15ET/30EK	20ET/40EK	25ET/50EK	25ET/50EK	30ET/65EK	40ET/65EK	40ET/80EK	50ET/80EK

Table 3. Ungrounded wye pole-mounted capacitor racks

Line-to-Neut. Voltage	Recommended Link NEMA 150% Rated T or K Links										
	3-Phase KVAR										
	150	300	450	600	900	1200	1350	1800	2400	2700	3600
2400	20T	40K	65K	80K							
2770	15T	30K	50K	65K	100K						
4160	10T	20T	30T	40T	65K	80K	100K				
4800	10T	20T	30K	40K	65K	80K	80K				
7200	6T	12T	20T	25T	40K	50K	65K	80K	100K		
7620	6T	12T	20T	25T	40K	50K	50T	65T	100K	100K	
7960	6T	12T	15T	25T	30T	50K	50K	65T	100K	100K	
8320	5T	10T	15T	20T	30T	40T	50K	65K	80K	100K	
9540	5T	10T	15T	20T	30K	40K	40T	65K	80K	80K	
9960	5T	10T	15T	20T	25T	40K	40K	50T	65T	80K	100K
12470		8T	10T	15T	20T	30K	30T	40T	65K	65K	80K
13200		8T	10T	15T	20T	25T	30K	40K	50T	65K	80K
13800		6T	10T	12T	20T	25T	30K	40K	50T	65K	80K
14400		6T	10T	12T	20T	25T	30K	40K	50K	65K	80K
19920		5ET	8ET	10ET	15ET	20ET	20ET	25ET	40EK	40EK	50ET
21600			6ET	8ET	12ET	15ET	20ET	25ET	30ET	40EK	50EK

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