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Grounded Versus Ungrounded Pole Mounted Capacitor Racks

One frequently asked question is whether or not capacitors should be applied in a grounded or ungrounded wye arrangement. Both types of connections will provide the same amount of reactive power compensation to one's system, and both can be equally well protected. The comparisons between the two connections can sometimes be subtle, and yet may have serious implications to your system. This issue of the Kilovar Briefs will attempt to summarize the most significant differences between the two.

Fusing Considerations

When a capacitor unit fails, it will generally fail to a short circuit. When a short replaces a capacitor unit in a pole mounted rack, the circuit becomes that as shown in Figure 1.

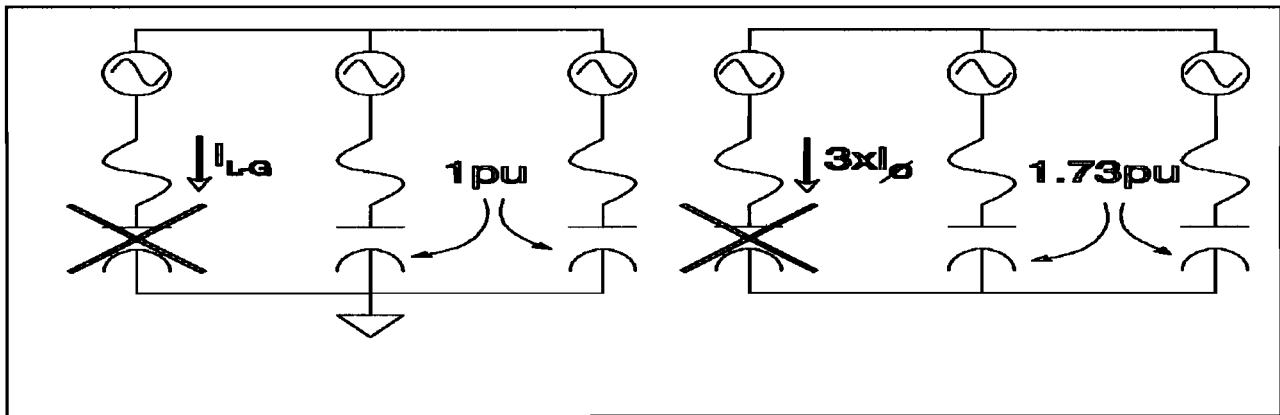


Figure 1

Fuse Current Flow and Overvoltage on Good Capacitors Before Fuse Operation in Group Fused Overhead Racks
(Grounded on Left and Ungrounded on Right)

Note that the current which flows is the system line-to-ground fault current for the grounded rack, but is only three times the normal capacitor rack's phase current for ungrounded racks. These current levels are very different and have many implications:

1. For grounded wye racks, the available line-to-ground short circuit current must be within the fault current rating capability of the capacitor unit; that is, the fault current must be equal to or less than the maximum current level on the capacitor unit's tank rupture curve. Capacitor units with probability curves make this verification somewhat more difficult. See Kilovar Brief #19. Note that for higher fault current levels, special double vented cutouts may be required.

If the fault current exceeds the capacitor unit's maximum tank rupture current level, three options exist: 1) The bank could be reconnected ungrounded wye, 2) the expulsion cutouts could be replaced by current-limiting fuses, or, 3) a current-limiting fuse could be placed in

series with the cut-out. All of these options will reduce the amount of fault current available to flow through the faulted capacitor unit.

2. The higher fault current available with grounded wye racks will result in very rapid fuse operation. This minimizes the amount of time a faulted unit remains energized on the system. Conversely, the "three times" current level flowing through the fuse in an ungrounded wye rack will result in very slow fuse operation.
3. When a capacitor fails to a short circuit, before the fuse operates the voltage impressed across the good capacitors in the unaffected phases is equal to 1.0 pu for grounded wye racks, and 1.73 pu for ungrounded racks. This overvoltage is a concern when considered in conjunction with the fact that the fuse can take a long period of time to operate at the low "three times" current available.

System Considerations

Fusing and overvoltage protection are not the only considerations when deciding between grounded or floating neutral connections. A number of system considerations must also be taken into account. Namely:

4. Once the fuse has operated and removed the faulty unit from service in an ungrounded wye rack, the capacitors in the other phases will deliver only 75% of their nameplate KVAR. This is because these capacitors are seeing only one-half line-to-line voltage (.866 pu). As the KVAR output of a capacitor varies with the square of applied voltage, only $(.866)^2$, or 75% of the nameplate kVAR is supplied. Note that for grounded racks, all three phases are always energized at 1.0 pu and will always supply nameplate KVAR to the system. See Figure 2.
5. If any system phase-to-phase voltage unbalance exists on a grounded wye rack, some amount of current will flow through the banks neutral to ground. This may cause relaying problems if sensitive ground fault relaying is used.
6. If a power line carrier communication system is used (for SCADA or distribution automation, for example), any capacitor installation can be a potential problem. As the impedance of a capacitor decreases with increasing frequency, the higher the frequency, the more a capacitor installation appears to be a short circuit. Power line carrier signals can be lost as they flow through the low impedance of the capacitor rack. The use of two bushing capacitor units, which is mandatory on ungrounded wye racks and optional on grounded racks, allows for the installation of a neutral blocking reactor between the capacitor bank's neutral and ground. The size of the blocking reactor is selected to cause a high impedance series resonance with the capacitor at the power line carrier's frequency. This makes the installation look like an open circuit to the power line carrier, leaving the signal on the system.
7. Just as power line carrier signals are attracted to distribution capacitor installations, so to are harmonic currents. As harmonics flow through grounded capacitors, the following may occur:

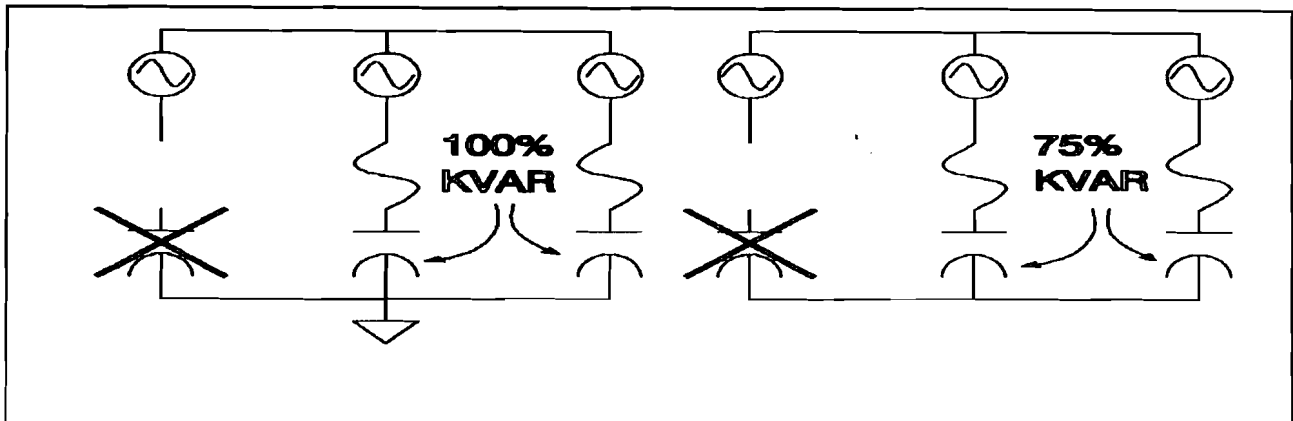


Figure 2
KVAR Output of Pole Mounted Racks After Fuse Operation
(Grounded on Left, Ungrounded on Right)

- Interference with communication circuits can occur as the harmonic currents are coupled into communications circuits by either induction or direct conduction.
- High voltages may result across the capacitors as a result of the harmonic currents if the parallel resonance of the capacitor and the system occurs at or near the same frequency at which harmonic currents are present.
- Capacitors may physically hum as the harmonic currents flow through them. This is not generally harmful to the capacitors themselves unless high overvoltages as a result of the harmonics are also present.

The above effects can usually be eliminated by going to an ungrounded wye connection. Note however that harmonic problems due to parallel resonance with the system can only be eliminated by either moving the rack or changing the KVAR size of the rack. Either of these two modifications will alter the frequency at which the capacitors and the system resonate.

8. For resonant grounded systems, (i.e. those using Peterson coils), ungrounded wye racks must be used to ensure proper operation of the resonant grounding system.
9. For delta connected systems, either delta connected or ungrounded wye connected racks can be used. To properly fuse a delta rack, a fuse must be placed on either side of the capacitors within the delta, therefore six fuses capable of interrupting line-to-line fault currents must be used. Due to the difficulty and expense in achieving this type of fuse connection in the field, it is preferable to use ungrounded wye connected racks on delta systems. There is no penalty in KVAR supplied to the system, i.e. a **600** KVAR delta rack supplies the same amount of PF correction to a delta system as a **600** KVAR ungrounded wye rack.

Equipment Considerations

The primary equipment consideration involved in grounded and ungrounded racks involves the selection of one or two bushing capacitor units. The underside of the hanger bracket of a capacitor unit is left unpainted so that the tank will be at the same potential as the frame they are mounted on. As the pole mounting frame is generally tied to ground for safety reasons, the tank of the capacitor units in a pole mounted rack will always be at ground potential. On one bushing capacitors the tank is electrically tied to the capacitor neutral terminal. Therefore ungrounded wye racks require the use of two bushing capacitor units where the two electrical terminals of the capacitor are both isolated from the tank. The additional cost for two bushing units is generally quite small.

Conclusions

There are many considerations in selecting between grounded and ungrounded connections for pole mounted distribution racks. Although a system's special requirements must always take precedence, the following application generalizations can be made:

- Grounded wye is preferred for the more rapid and predictable fuse operation which occurs due to the higher fault current levels. Grounded wye also eliminates the 73% overvoltage on the good phases while waiting for the fuse to clear the faulted phase.
- Ungrounded wye is preferred for systems with sensitive ground fault relaying, systems which are resonant grounded, or systems where the utility neutral physically parallels telephone lines.
- The use of two bushing capacitors is preferred as this type of unit may be used for grounded, ungrounded, or delta connected racks.