

Grounded Versus Ungrounded Substation Capacitor Banks

In Kilovar Brief Issue 20, the various advantages and disadvantages of grounded and ungrounded wye pole mounted capacitor racks are discussed. In this issue, the same subject is explored for substation banks.

Fusing Considerations

The only substation bank configuration in which the grounding method is a consideration in fuse selection is for a single series group, grounded wye substation bank. In this case the failure of a unit will result in line-to-ground fault current to flow through this unit and its fuse. Although some capacitors can handle fault currents as high as 10 kA (for example, Cooper Power Systems' EX-line), the expulsion fusing system used in substation banks is well below this level. In addition, it is common to have well in excess of 10 kA fault current availability in a substation. Therefore, if grounding is still desired, current limiting fuses should be used. Alternatively, the bank could be connected ungrounded wye. The latter is generally the less expensive option.

Equipment Considerations

There are three important equipment considerations in the grounded versus ungrounded decision making process:

1. Ungrounded wye banks must be insulated from ground at the system BIL level. Grounded wye bank structures must only be insulated from ground at whatever potential exists between the bank frame and ground. The net effect of this is that grounded wye banks are generally mounted on lower voltage, and therefore lower cost, insulators, than are ungrounded wye banks. This can save as much as 5 - 10% of the cost of a bank.
2. When a bank is de-energized, a charge is trapped on the capacitor bank equal to the system peak voltage. This trapped voltage is associated with one of the breaker terminals. After clearing, the system connected terminal of the circuit breaker or switching device sees a continuously varying voltage. The potential difference between these two voltages is called the transient recovery voltage, or TRV. See Figure 1. The TRV is 2.0 pu for grounded wye banks, and can be as high as 4.1 pu for ungrounded wye banks. These TRVs may be even higher if the bus voltage is above 1.0 pu. As a result, breakers which must switch ungrounded wye banks are generally more expensive than those required to switch grounded wye banks. It is very difficult, or even impossible, to find a breaker above 300 kV rated for switching ungrounded wye banks. See Kilovar Brief Issue #1 for more information on the voltages associated with de-energization.
3. Another economic consideration involves the unbalance protection scheme. The unbalance protection relay schemes for grounded and ungrounded wye banks are very similar. At lower voltages, where

compensation for any system voltage imbalance is not usually required, grounded wye banks typically utilize a current transformer rated at 20% of the system voltage level. Ungrounded wye banks require a more expensive potential transformer rated at full system BIL. Once system voltage imbalance compensation is required (typically at 115kv and above), the additional PTs and or CTs required by the relay schemes effectively eliminate any cost differential.

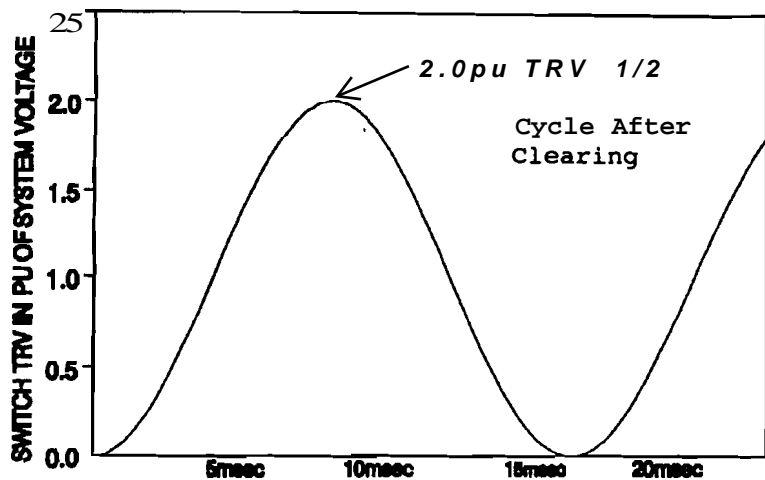


Figure 1
Transient Recovery Voltage
For Grounded Wye Banks

System Considerations

The single most important area in the decision making process between grounded and ungrounded wye banks has to do with system considerations unrelated to the cost or protection of the capacitor bank. This is also the area with the least definitive answers. The most commonly studied system concerns are listed below.

4. Unbalance in a capacitor bank can occur for three reasons:
 - Inherent phase-to-phase unbalance in the capacitance of the three phases of the bank;
 - System phase-to-phase voltage unbalances; and,
 - Unbalance which occurs when one or more capacitor units have been removed from service due to fuse operations.

When any form of these unbalances exist on a grounded wye bank, some amount of current will flow through the banks neutral to ground. This may cause relaying problems if sensitive ground fault relaying is used.

5. Grounded wye banks provide a path for harmonics to flow to ground whereas ungrounded wye banks do not. This can be an advantage from a relaying standpoint.
6. For ungrounded wye banks it is generally preferred to apply lightning arrestors across the phase to neutral, not phase to ground, terminals of the bank. This also provides protection against possible restrikes of the circuit breaker. For grounded banks, any line-to-ground connected arrestors that exist within the substation will provide the capacitors with sufficient protection.

7. Switching surges caused by the energization of capacitor banks occur at approximately the same rate with grounded and ungrounded banks, however the average magnitude of the surges is generally higher with ungrounded wye banks.
8. When a capacitor bank is energized, a significant amount of inrush current flows into the bank. On grounded wye banks, the unbalanced nature of this inrush current can also cause transient currents to flow in the substation ground mat as well. Some utilities have found this ground mat current may couple with electronic equipment in the substation causing problems. The use of ungrounded wye banks reduces this concern.
9. A close-in fault is one which occurs on a line very close to the substation. See Figure 2. The concern with capacitor banks is that the energy stored in the bank will also want to discharge into the fault. The additional I^2t duty on the breaker as a result of the capacitor discharge can possibly damage the breaker. Reactors are usually added to the circuit to limit the outrush current. However, if the bank is ungrounded wye, there is no path for the bank to discharge into the close-in fault if the fault is a line-to-ground fault. Only if the fault is phase-to-phase or three-phase can an ungrounded wye bank discharge. Grounded wye banks will discharge with any type of fault.

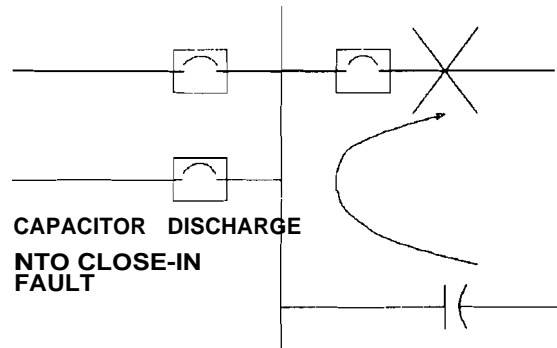


Figure 2
Capacitor Discharge into
Close-In Fault

Summary

The ultimate decision as to whether the grounded or ungrounded wye connection is preferred is a function of economics and system operating concerns. The latter are highly variable and require knowledge of the utility system. The following generalizations can be made:

- Single series group banks should generally be connected ungrounded wye to allow the use of expulsion fuses.
- Grounded wye substation banks are less expensive than ungrounded wye, both in terms of the capacitor bank and the switching device.
- Ungrounded wye banks will reduce, but not eliminate, problems associated with harmonics, close-in faults, ground mat transients, and unbalance currents flowing to ground.
- Grounded wye banks will in general result in lower switching surge magnitudes, lower TRVs for the switch or breaker, and reduce the need for dedicated station arrestors to protect the capacitors.

