Capacitor banks can present unique difficulties for many interrupter technologies. Because capacitive currents are generally small, considerably lower in magnitude than short-circuit currents, in designs where the energy of the arc helps create the pressure used to extinguish high currents, interruption can be difficult. Additionally, capacitor bank applications generally have higher recovery voltages, which can challenge the dielectric capabilities of the interrupter. When selecting a circuit breaker for capacitive duty, the continuous current rating required is determined by the bank rating in mvar. While there is no specific relation between the rated capacitor bank current, peak inrush current and inrush current frequency, these values should be known to properly apply a circuit breaker on a capacitive circuit. The ratings of the circuit breaker selected should include allowances for the manufacturing tolerance, voltage fluctuation and harmonic component. One normally considers short-circuit current to be the most challenging for a circuit breaker, but the unique nature of the capacitor bank presents its challenges during normal switching. A good rule of thumb is to select a circuit breaker with a continuous current rating about 35% greater than the nominal rating for the capacitor bank.

Closing into a capacitor bank produces a large transient current which can greatly exceed the normal current of the circuit. This is due to the low surge impedance of the capacitor bank. When the interrupter closes onto a capacitive load, there is enough voltage stress prior to contact touch to initiate the flow of current. The pre-touch arcing (or pre-strike) can soften the contacts such that they weld on full closure. Closing into a capacitor bank in a back-to-back (or parallel) configuration increases the difficulty. The surge impedance for the system is lower as one capacitor bank can now feed current to the second. The current transient is controlled by the surge impedance and the voltage at the time of closing. It can be shown that for an identical set of banks and system parameters, closing into a back-to-back arrangement produces inrush currents at least four times greater than a single bank.

De-energizing a capacitor bank produces a different set of issues. When the current is interrupted, the voltage is trapped on the capacitor and will remain there until it bleeds off through the capacitor series resistance. This means that the recovery voltage during interruption can rise to a value of 2 times the system voltage. Grounding plays an important role in limiting the recovery voltage. In ungrounded systems the recovery voltage is been observed at 2.5 times.
CAPACITANCE CURRENT SWITCHING OF POWLVAC CIRCUIT BREAKERS

The application considerations for disconnecting cables are similar to those associated with switching an isolated capacitor bank. The interruption of current will trap a charge on the cable. This results in a slow rising recovery voltage across the interrupter contacts which can reach a peak of 2 per unit on individually grounded cables and 2.3 per unit on ungrounded cables.

Fortunately, vacuum interrupters have a history of excellent performance on capacitive loads. Our experience utilizing CuCr contact vacuum interrupters for capacitor switching on different circuit breaker designs has shown the interrupter designs are capable of switching current levels well in excess of the values suggested by ANSI/IEEE Standards.

Powell circuit breakers are tested to IEEE Std C37.09 requirements. The latest revision of that document includes changes specifically for capacitor switching; changing the test to a statistical evaluation rather than a single target value. As all circuit-breakers have a certain restrike probability in service, the new test procedure looks for the probability of contact re-strike and identifies it using three classes of circuit-breakers:

Class C0 has a probability of restrike up to one re-strike per operation, and its capacitance current switching performance can be compared to the former “general purpose circuit breaker” defined in IEEE Std C37.04 -1979.

Class C1 has a re-striking performance similar to the old “definite purpose circuit breaker” defined in IEEE Std C37.04-1979 and is called “low probability of restrike.

Class C2 is intended to have a very low probability of re-striking, about 1/10 or less than that of a class C1 circuit breaker. A probability of re-strike classification is assigned to each capacitance current switching rating.

Powell has standardized on specific vacuum interrupters across product lines, so that equipment of similar voltage, continuous current, and interrupting current utilize the same components and performance characteristics. Since the performance of a vacuum interrupter is determined by operating speed, contact pressure, and timing, the interrupters will perform similarly on different models with equal ratings and operating characteristics. The interrupters specified have been tested by KEMA Laboratories and have received KEMA Test Certification recognition. Additionally, all testing was witnessed by Underwriters Laboratories.
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CAPACITANCE CURRENT SWITCHING OF POWLVAC CIRCUIT BREAKERS

The ratings met for the medium-voltage circuit breaker products are:

Maximum Voltage – 15kV
Recovery Voltage – 33.33kV (highest observed value) typically >30kV

Capacitance Switching Ratings assigned:

<table>
<thead>
<tr>
<th>TEST DUTY</th>
<th>CLASS</th>
<th>CURRENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable Charging Current</td>
<td>C2</td>
<td>25A</td>
</tr>
<tr>
<td>Overhead Line Current</td>
<td>C2</td>
<td>100A</td>
</tr>
<tr>
<td>Isolated Bank &amp; Back-to-Back Bank Current</td>
<td>C2</td>
<td>1800A</td>
</tr>
</tbody>
</table>

Class C2 was attained for all capacitive switching ratings. The probability of re-ignition is Class C2, approximately a 10X improvement over the Definite Purpose rated breaker from the previous revision of the test standard.

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