# Outrush Reactors for Capacitor Banks—The Solution or a Problem?

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**Abstract:**
The use of outrush reactors for limiting outrush currents from a capacitor bank during a fault is one of considerable debate and discussion. The issue surrounds the contention that the peak outrush current from a fault without a current limiting reactor could cause a circuit breaker to fail. The concern is that this surge is usually above the capacitor inrush current rating for a circuit breaker. The other side of the discussion is that while using outrush reactors will definitely limit the current to a value within the breaker's rating they cause some otherwise unfortunate consequences that have and do fail circuit breakers. The use of closing resistor switching devices limits inrush currents, and the concern for outrush currents is largely academic since these outrush currents are usually within the momentary current ratings of circuit breakers.

**Background:**
The use of outrush reactors is a good thing for capacitor switching devices that do not have an intrinsic current limiting feature such as a closing resistor. When multiple banks are in parallel, this back-to-back inrush limits the contact life of these non-resistor switching devices as well. This is because the daily switching produces very large currents which will and do cause contacts to erode and ultimately lead to their failure. These reactors should limit this damage by reducing the peak currents; however, their duration is much longer. It is fully agreed that the use of outrush reactors may be appropriate when no closing resistor is used in the switching device.

The downside of outrush reactor use is that should there be a capacitor bank failure the transient recovery voltage (TRV) is extremely high for the circuit breaker trying to interrupt the fault. This is because the reactor is now the only thing to limit fault current and it has a natural frequency of 50 to 100 kHz (air core type). In the event that a switching device energized a bank without the ground cables having been removed, the same thing will take place. The best solution here is to add a large capacitor between the circuit breaker and the reactor to control the TRV to within acceptable levels. The value of capacitance required is frequently in the 10,000 to 20,000 picofarad range. This capacitor frequently requires a separate foundation as well. The capacitor has a possibility of failing since it is also energized along with the capacitor bank and subject to similar voltage surges that limit capacitor bank life.

This concern is completely directed to nameplate ratings of conventional circuit breakers and not because of actual failures. It is unheard of for $SF_6$ circuit breakers to fail because of this outrush condition. It is believed that this is because the outrush current is frequently within the capability of the circuit breaker contacts to carry this momentary current that lasts only a few milliseconds. The peak outrush current is generally below the rated momentary current of most circuit breakers in use. Additionally, the current is damped out well before the relays have determined that there is a fault and hence the circuit breaker is completely closed and stationary. It is unreasonable to apply this capacitor momentary inrush current limit to the outrush condition.

**Analysis:**
Several simulations for these alternatives are shown for comparison and evaluation.

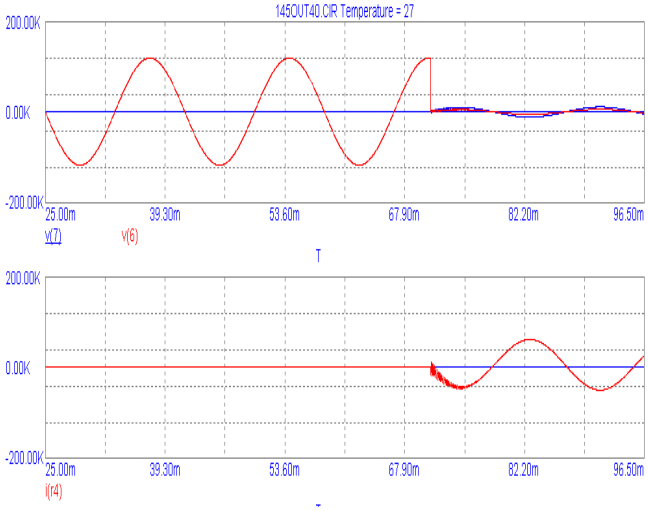


Figure 1

A substation with 63 kA of available fault current and 150 MVAR of capacitor banks are analyzed. Figure 1 shows the outrush for a conventionally applied current limited outrush condition with a large reactor. As can be seen, the current harmonics can last for several cycles. Figure 2 shows that without a current limiting reactor, the peak currents are well above the maximum value of 20 kA allowed by the standards but still within the 63 kA circuit breaker's peak current capability of 163 kA.

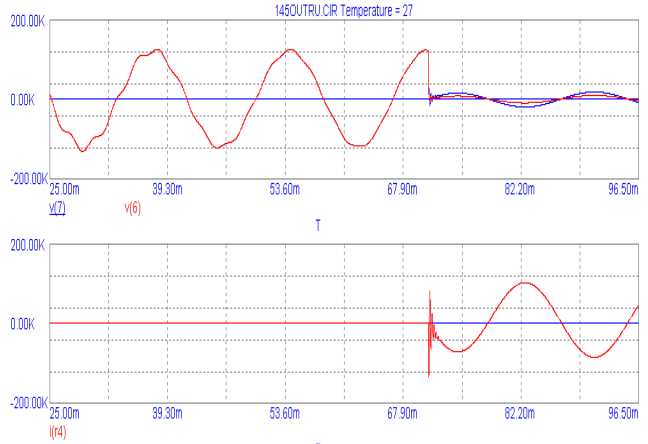


Figure 2

The current, while high, damps out very quickly in less than one half of a cycle. Figure 3 shows two large banks in parallel with 150 MVAR each without current limiting reactors.

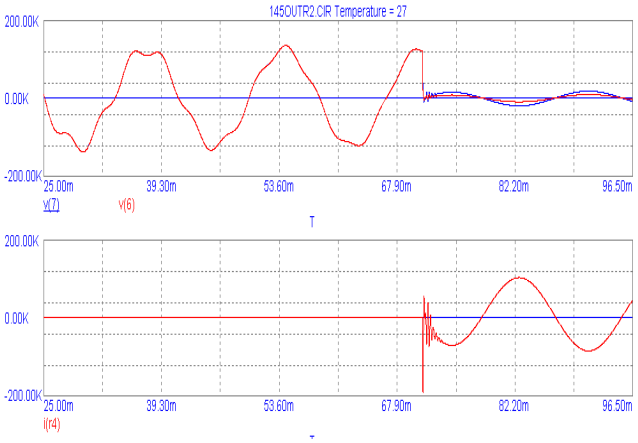


Figure 3

While this extreme condition shows peak currents above the circuit breaker tested momentary peak current capability of 163 kA, it lasts above that value for only about 200 micro seconds. At this point the model is too simple as compared to actual substations and hence it is believed that this condition rarely exists because of actual distributed inductances in a substation.

In the event that a fault should actually occur at voltage zero, Figure 4 shows that there is no outrush from the capacitors at all!

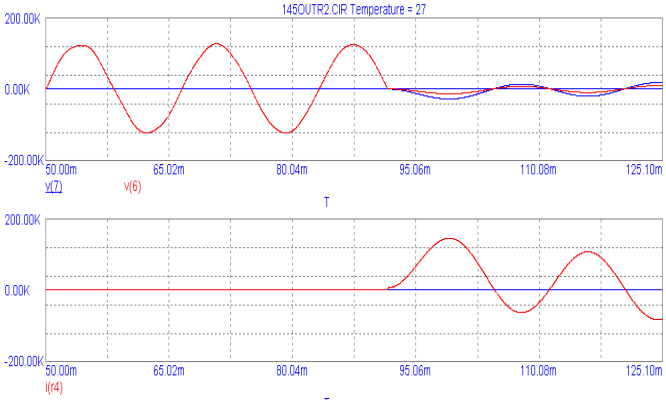


Figure 4

Figure 5 shows the TRV associated with the use of current limiting reactors when there is a fault to ground at the capacitor bank. As can be seen, the TRV is exceedingly high and will likely cause a circuit breaker failure should this occur in the field.

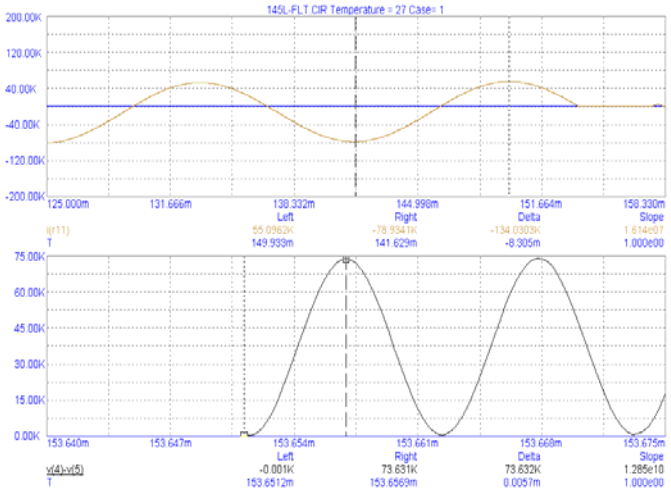


Figure 5

**Summary:**

It seems unreasonable to turn theoretical perceived problems into a real problem. This is what has been done by implementing a solution (current limiting reactors) to solve a problem (outrush) that does not cause any failures. I do know of several utilities that have found this TRV problem to be the cause of failure and they are now going back and eliminating these reactors or adding line-to-ground capacitors between the reactor and the circuit breaker to prevent this TRV problem from causing failures.

**Conclusion**:

Reactors limit currents and reduce frequency to that of ANSI circuit breaker standards. Unfortunately, reactors create TRV values that exceed the capability of most circuit breakers in cases when there is a capacitor bank fault. Outrush current peaks occur out of phase from the primary fault current and are generally below the rated and tested momentary capability of the circuit breakers. This means that the outrush currents are over before the relays even respond to the fault current. Switching capacitor banks with a pre-insertion resistor equipped device limits inrush currents, extends life, and reduces contact wear. This approach allows elimination of inrush reactors and the TRV problem without creating an outrush condition that exceeds the capability of the circuit breaker.

Overall system reliability is enhanced by using practical experience-based techniques (pre-insertion resistors) rather than by solving theoretical problems that do not actually exist.