Proper Fuse Selection For Capacitor Circuits

A bulletin addressing some concerns and application variants.

By Malcolm Bird

Over recent years, there have been many questions regarding fuses used on capacitor circuits.

The use of capacitors for power factor correction/power conditioning is increasing daily, and many capacitors use external HRC fuses to 'protect' the capacitors. The area of fuse/capacitor application is a difficult one due to the large variations in connection variations, field and circuit conditions, and lack of specialized knowledge in all these disciplines from any one source.

This bulletin addresses some of the concerns and application variants. Although this article is aimed at medium voltage users, the comments still apply to circuits of 600V or less. Generally, the consequences of misapplication on low voltage are not as spectacular as medium voltage.

The Fuse's Role

First, we must understand several aspects of HRC fuses as used on capacitors.

1. The fuse does not 'protect' the capacitor - but acts as an emergency 'disconnect device' should the capacitor develop an internal fault, the whole idea being to disconnect the capacitor from the supply before its case ruptures. The fuse cannot offer any degree of overload protection for the capacitor due to the necessity of using a high amp rating (relative to the capacitor FLA) to pass the charging current without nuisance operation.
2. Most HV fuses are what are termed 'partial range' devices inasmuch as they are not capable of reliably interrupting low overcurrents on the order of less than 300-400% of the fuse rating. The TCCF fuses are this type. 600V fuses can be considered full range devices.
3. Generally, the short circuit performance of today's current limiting fuses is so good that the use of higher fuse ratings still provides excellent protection against capacitor case rupture.
4. Other variables such as ±15% tolerance on capacitors, harmonics, and other capacitors nearby all affect choice of fuse size.

If we consider the above, it is apparent that there is nothing to be gained by fusing too small, and indeed, putting the fuse in a situation where normal operating transients could cause faulty operation is to be avoided.

With this in mind, it is advisable to fuse as large as possible while still protecting the capacitor against case rupture. In this manner, the fuse is kept from operating until the capacitor actually develops an internal fault.

CEC Rules

Rule 26-210 limits the fuse size to 250% of the nominal capacitor full load rating. ***This only applies to individual capacitors installed by the user in the field.***

Rule 26-200 overrides 26-210 for ***factory assembled capacitor banks***, where switching duties and close proximity to other capacitors often require the use of a higher fuse rating than 26-210 allows. This allows fuses to be installed per the recommended ratings shown in Figure 1.

Discussion Of Minimum Breaking Current

Most HV fuses are classified as partial-range devices and have a minimum breaking current (m.b.c) – i.e. a current level below which they cannot safely clear the overcurrent at full system voltage. This is because fuse elements require a certain amount of arc energy to quickly vaporize the fuse elements, melt the surrounding sand into an insulator, and quickly build up the internal resistance of the fuse to current flow. Current levels below a fuse's m.b.c will still cause the elements to melt (in accordance with their published time current curves) - but will not generate the necessary arc energy to successfully clear the circuit.

Because of this, fuses have to be selected to prevent operation on currents below their m.b.c., or have other devices in the circuit to operate in advance of the fuse on currents below the fuse's m.b.c.

Fuses can be designed to be true full range devices (ie. capable of clearing any current causing melting up to maximum interrupting rating) but this adds significantly to the cost, and generally is not a performance feature that is required if fuses are selected properly.

Fuse Application

In terms of application on capacitors, the following conditions must be kept in mind.

1. **Connection type of capacitors** – either delta or star.

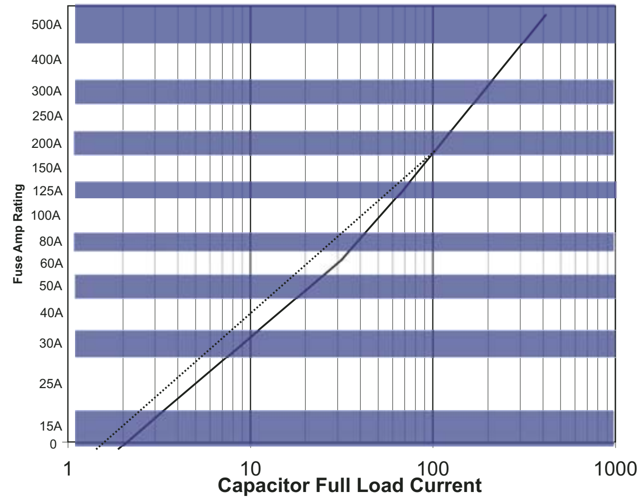

Figure 1: *This chart can be used for any HRC fuse – medium or low voltage.Use dotted line for single phase and star connections – solid line for delta connections. Above 100A the curves are identical. For switching applications or where other capacitor banks are nearby (less than 25') multiply capacitor nominal FLA x 1.6 and use resulting figure for fuse selection. Read up from capacitor FLA scale at bottom to intersection of appropriate curve (star or delta). Fuse rating is in whatever band the intersection occurs. Where recommended rating does not line up with available ratings – use next highest standard rating.*

2. **Proximity of other capacitors**. Other capacitors can 'dump' into failed capacitors - causing premature fuse operation of the fuses on the good capacitors.

3. **Harmonics**. Capacitors are generally used to address power factor considerations and can shift harmonic problems. The higher the harmonic current or frequency – the more heating effect it has on a fuse element.
4. **Switching**. If capacitors are repeatedly energized - this has a cumulative heating effect on the fuses and must be addressed through derating of the fuse (i.e. a larger rating)
5. **High ambient temperatures** (greater than 32° C) inhibit the fuse's ability to dissipate heat to surrounding air and may require fuse derating (ie: higher rating). Loose connections can also contribute additional heating into the fuse.
6. **Failure to replace fuses in sets of 3 on 3 phase circuits**. Circuit conditions that cause one fuse to operate, could have damaged other fuses. Unless these fuses are replaced also, they could operate prematurely, or unpredictably at a later date.
7. **Tolerances on the capacitor itself**. This can be as high as ±15%.

In the past, fuses have generally been applied at approximately 150%-180% of the capacitor's nominal full load rating. In many cases, particularly if any of the above conditions are encountered, this results in a fuse that is underrated for the application. This in turn results in nuisance operation at best, or catastrophic failure in worst case scenarios (particularly in HV circuits).

Figure 1 shows a capacitor/fuse selection graph. It can be used for any fast acting fuse - either HV or LV. Please note the multiplier (1.6x) if other capacitors are nearby (less than 20 feet).

Where the recommended fuse rating is not available - use the next standard rating higher than that recommended.

This chart will generally result in fuse ratings higher than what many users are used to, but will provide more than adequate protection against capacitor case rupture, and get the fuse away from normal operating transients that could cause nuisance fuse operation.

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