Harmonic Passive Filter Discussion: Do You Really Need the Capacitor Contactor Option?

I have heard a lot of disinformation about when you need to specify a Capacitor Contactor Option for a Passive Harmonic Filter (L-C-L Configuration). From the blanket excuse that any leading power factor is "BAD", to you should always specify it when you have a Generator as a potential source. To understand the role of capacitance reactance within a circuit, you need to:

- Understand the operating characteristics of the primary and alternate potential source. This would include all existing capacitance reactance from power factor correction within the circuit and significant Utility voltage regulation banks which can trigger resonance/ringing within the circuit.
- Have a defined scope of your harmonic reactive power profile and the linear load displacement power factor.
- Know how much capacitance reactance the L-C-L Passive filter contains, which is seldom advertised by the manufacturer. Also, the control scheme for the capacitor contactor should be understood if it is determined that a Capacitance contactor is required.

In majority of the applications I work on, the advent of the capacitor contactor assembly is not required when you understand the characteristics and properly specify the passive filter based on that insight.

There are three evaluations that should be reviewed:

(These considerations are appropriate whether you are deploying Power Factor Correction equipment, Passive Harmonic Mitigation assemblies, or any form of capacitance reactance treatment within any circuit.)

- ***No-Load or Low Load Voltage Output Boost:***
  When significant capacitance reactance or Passive Filter assemblies utilizing capacitors are used, the level of capacitance reactance to power ratio of the equipment/harmonic filter will indicate the potential for no-load or low load voltage boost. The higher the kVAR/kW profile the greater the associated no-load (NL) and low load (LL) voltage boost. VFD/ASDs are prone to nuisance over-voltage tripping when the source voltage is greater than 500V. Most specifications allow for a +10% over rated nominal voltage. So, based on a nuisance trip condition at around 505V, the nominal voltage rating of the VFD is in fact 460V and not 480V. This trip is usually experienced during the ramp up and can also be triggered on the decel ramp as well. ***Most harmonic filters have a relatively high capacitance reactance to power ratio of 35% or greater.*** This can create NL and LL voltage boost of 5% or greater of nominal. With this extreme voltage boost potential, it is necessary to have a nominal voltage within the circuit at 480V or less, which is not always possible due to Utility distribution voltages.

  Rarely is the source 480V or less, since many utilities increase the nominal voltage within their grids to avoid voltage drop during heavy or peak demand periods. In some cases, I have seen Utility sources as high as 500V nominal. Under that circumstance, the NL voltage boost can exceed 526V, which would prevent the VFD from ramping up during the start and operating per specification. If the harmonic filter does have an elevated reactive power ratio, you will have to do one of two things, add the capacitor contactor option or retap the Utility/Source transformer to 480V nominal. The first option is expensive, and the second option might not be possible depending on the transformer configuration.

  The key is to specify and confirm that the Passive Harmonic Filter has a Reactive Power Ratio of 15% or less for your application.

Most manufacturers have this low capacitance reactance design available within their product catalog, but do not offer it due to competitive cost concerns. It is typically only made available upon specification or request. The advantage of utilizing this **15% or less kVAR /kW ratio** within the specification and application is that your NL voltage boost is significantly less with the probability of the capacitance-reactance within the circuit triggering a resonance with the source and/or the load will be dramatically reduced. If the reactive power ratio is less than 15%, then typically the NL voltage boost will be only around 2-3%, meaning that the filter without a capacitor contactor and with the nominal voltage as high as 495V is possible without creating a nuisance trip condition.

- ***Capacitance Reactance Contactor Control Notes:***
  When a capacitor contactor assembly is utilized within the assembly, then the control aspects of the contactor assembly must be considered:

  ~ What control scheme configuration will be utilized and what value will be utilized for the Time Delay Relay. The TDR is used to allow the harmonic output of the VFD to build during the ramp, which then will help to limit the voltage boost once the capacitors are brought into the circuit. Typically, the manufacturer will provide a permissive contact that must be terminated to the run command of the VFD/ASD which then actuates the TDR (Time Delay Relay) which is preset by the factory. This delay should be coordinated with the ramp of the VFD during the start-up. If the delay is too short and the ramp is still at a low load level, then actuation may create a transient voltage that can trigger a nuisance trip or even damage the drive because of the transient stress. Should the TDR be set for too long of a delay sequence, the high current harmonic during the ramp cycle will be allowed to be injected into the systemic impedance, which can trigger transient voltage distortion events, tripping other equipment within the circuit such as control DC power supplies, PLC packages and other more vulnerable equipment. The greater the Reactive Power Ratio, the more critical the TDR time interval coordination to the programmed ramp characteristics.

  ~ Another means for Capacitor contactor actuation is by using a manufacturer integrated CT within the passive filter assembly which will recognize when the VFD begins its ramp sequence and then trigger the TDR operation to bring on the capacitance reactance within the circuit. This is becoming a more popular means of actuating the capacitor contactor circuit since it eliminates the need for contractor or third-party interconnect and coordination.

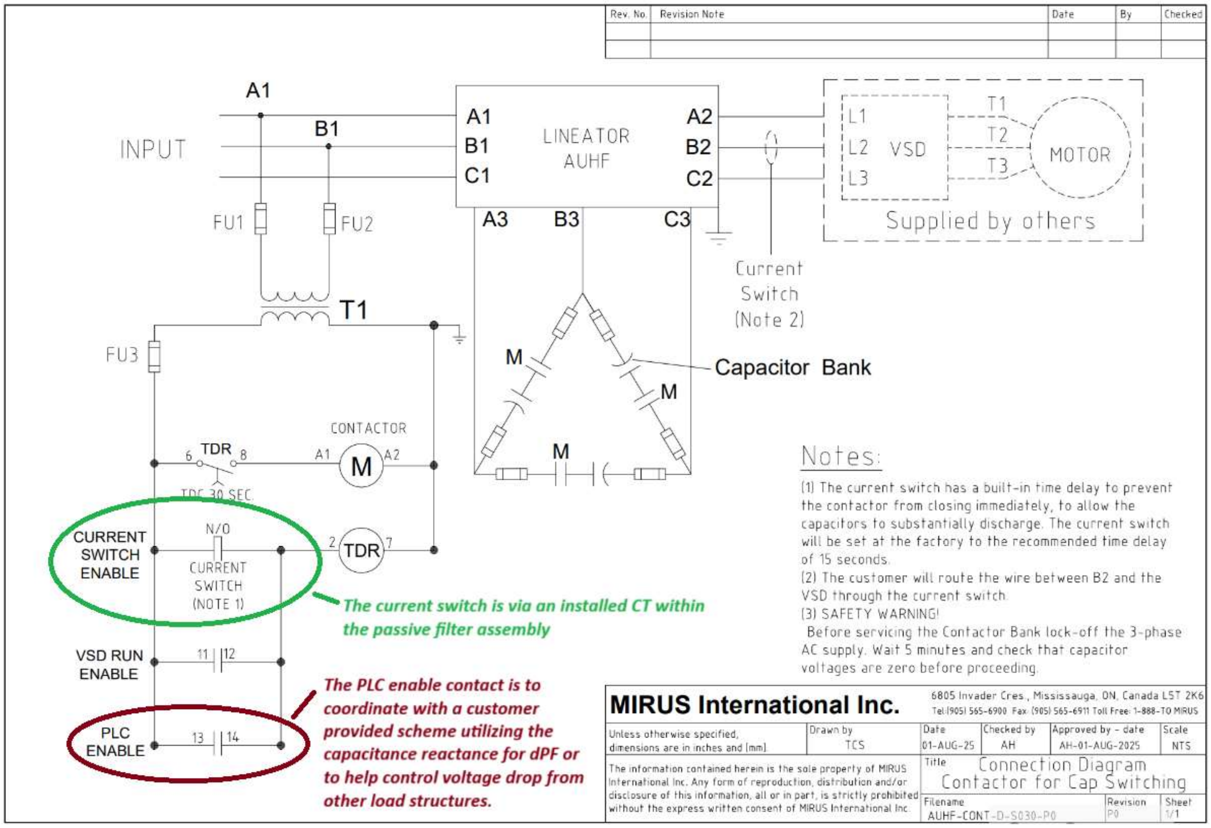
  ~ A third means of control, which can be deployed in conjunction with the “Run Contact” and “CT” scheme is a PLC run contact. This is a useful option and is being deployed to utilize the capacitance reactance from the harmonic filter where the drives are not running, the unutilized capacitance reactance can then be brought on-line for displacement power factor correction and/or to stiffen the circuit to control voltage drop due to other significant loads. It is also possible to utilize this same contact to bring in the capacitance reactance to provide displacement power factor control for “cross the line” bypass of the associated VFD/ASD for emergency conditions. This is a more complicated subject and will be explored in a paper under development.

Under all three scenarios above, the advent of a low reactive power ratio within the passive filter assembly will make successful coordination and deployment easier to achieve.

As discussed previously, if a capacitor contactor is selected, you do have options available via a PLC sub-routine and permissive contact for control of un-utilized passive filter capacitance to achieve displacement power factor targets.

Below is a schematic of a capacitor contactor control scheme available from Mirus International which is available for just such an application.

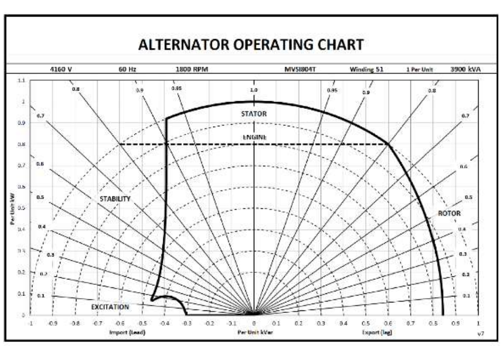
The Five Star Electric/Mirus International Option Designation is: CA2 for a CT/Current switch enabled control and a PLC enabled control requirement. Please contact Five Star Electric for further information or assistance with design and implementation.

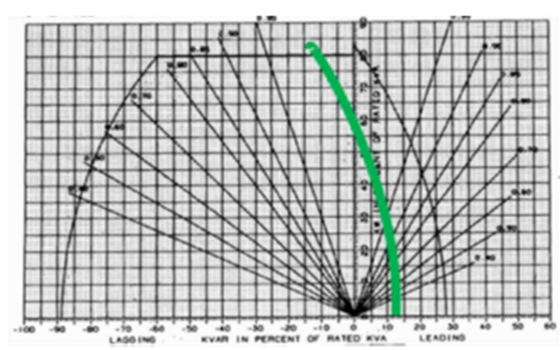


- ***Leading kVAR injection into a Low impedance or Generator Source:***

  If a primary or back-up generator source or alternate technology source is contained within the circuit, you must have the capacitance withstand curve for the potential source and determine if there is a leading VAR relay within the source regulator assembly.

➢ The Capacitance Withstand Curve: Below are two examples of a typical curve. The area within the outline delineates the capacity of the generator to withstand a capacitance load at various total load profiles. Per the detail, the generator "can handle 30% kVAR at 0 kW draw. The generator is 3900kVA, so generator capability is 1170 kVAR. The second example is curve with a kVAR injection traced in green.





- From this information and data, it can determined if a passive harmonic strategy will require capacitance reactance control to avoid over-exciting the alternate source. This data is available for any commercially available generator or alternate source supplier. The Data should be reviewed and suitability determined by the harmonic mitigation manufacturer or VFD/ASD manufacturer within their product submittal package.

The supplier/manufacturer of the harmonic solution should be required to review and qualify this data and the one-line to determine their offering complies with "suitability of purpose" and to determine if the passive harmonic treatment will require capacitance control.

- **Generator/Alternate Regulation:** In many cases, manufacturers of alternate source equipment will include a leading VAR relay within the regulator control to avoid operation with a leading power factor condition on the line. Uncontrolled passive harmonic capacitance reactance can create a slight leading power factor at no load, thereby activating the relay which will trip the generator/alternate source off-line. This relay is provided since in the past due diligence in reviewing the load circuit was not followed, which has caused challenges with their equipment integrity. In many cases, this relay can be adjusted to allow some leading pf/capacitance load structures within the circuit to be operational. In others, for deployment of load power factor correction equipment and passive harmonic filters which incorporate significant leading kVAR injection the relay may be deactivated.

In both cases, as part of the approval process for both power factor correction and passive harmonic mitigation, a capacitance withstand curve and circuit analysis should be initiated and a detailed review of the alternate source specification to determine what coordination may be required. This analysis should be done in conjunction with the supplier/manufacturer of both the generator/alternate source and the load equipment with a registered PE detailing the results.

- ***Avoidance of Leading kVAR:***

One of the best White Paper's I have read on this subject was published by Mirus International back in 2013, MIRUS-TP003-A: HOW HARMONICS HAVE CONTRIBUTED TO MANY POWER FACTOR MISCONCEPTIONS, Anthony (Tony) Hoevenaars, P. Eng., President and CEO Mirus International Inc. Copyright © 2014 Mirus International Inc.& I would recommend you download a copy at

https://www.mirusinternational.com/downloads/MIRUS-TP003-A-How%20Harmonics%20have%20Contributed%20to%20Many%20Power%20Factor%20Misconceptions.pdf

Another great discussion: How Harmonics have led to 6 Power Factor Misconceptions, Copyright 2017 Mirus International, again authored by Anthony (Tony) Hoevenaars

One specific subject of both references is summarized below:

"Misconception #6: Any leading PF is bad."
"Reality: There are many conditions under which a leading PF will not cause problems. In fact, if the other loads on a power system are inductive, introduction of some capacitive reactive power can be a good thing as it could provide some compensation to improve overall PF."

This is an important concept. Unutilized or underutilized capacitance reactance will provide a level of linear load displacement power factor correction that will help avoid expensive and complicated “De-tuned” Power Factor Correction schemes. De-tuned PFC’s feature a detuning inductor within the assembly to avoid attracting typical harmonic frequencies which can trigger resonance/ringing within a circuit, functionally isolating the power factor correction for displacement (COS Θ) linear load power factor conditions.

The capacitance reactance within a passive harmonic filter is “by design” tuned to avoid attracting low frequency harmonics such as the 5^{th} and 7^{th} harmonic to avoid becoming overloaded from source voltage distortion (Vthd-bg) and in some designs utilized as a high frequency trap (11^{th} and 13^{th} harmonic frequencies). Every manufacturer has their own specific design, consult the manufacturer for details. So, un-utilized capacitance reactance from a passive filter is available to help with displacement power factor correction and can offset the need for more traditional power factor correction designs. Harmonic modeling should be required for all passive filter submittal requirements that clearly delineate displacement power factor and true/total power factor within its analysis.

Conclusion:

In most of the applications I work on, capacitance reactance present from a passive filter is not a concern or challenge. In only about 10% of the installations is there enough concern to consider this option. But there will be applications where it is required. The discussions contained were forwarded for your consideration and to function as a guide to understand when a capacitor contactor may be required. The key element is the proper qualification and specification of the passive filter by requiring a low reactive power ratio to control instances of over-excitation, voltage boost, and resonance/ringing which can impact your systemic integrity.

To ensure compatibility with engine generators and avoid VFD/ASD over-excitation at no-load/low load, the harmonic mitigation equipment must never introduce a capacitive reactive power (kVAR) which is greater than 15% of its kW rating for sizes ≥ 100HP and 20% for sizes ≤ 75HP.

For more information on this topic or discussions related to your installation or application, please feel free to contact me at:

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