Common Factors that Affect EMI Filters

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In today's digital world, every electrical and electronic product needs power supplies, converters, and switching circuits to get the right amount of power and achieve reliable performance and intended output. Due to the inherent noise in digital and switching circuits, the need for electromagnetic interference (EMI) filters becomes paramount. The performance and reliability of EMI filters become crucial to the successful operation of any equipment. Filters are usually placed in the equipment's AC input line circuitry and as close to the point of power entry as possible. An EMI filter's primary role is preventing noise generated by the unit from exiting the equipment onto the power line and stopping the incoming noise from other devices that can potentially impact the intended operations of the equipment.

Filter circuits are made of passive components - inductors, capacitors, and resistors. These components have an extremely long life when operated within the design parameters. A number of Astrodyne TDI filters have been working in the field for over 25 years.

Unfortunately, neither all filters are built alike nor operated correctly due to which some filters can end up failing. Knowing what causes an EMI filter to fail can help engineers in selecting the right filter for their project which can increase product reliability and revenue by reducing failure, downtime, and expensive service call/field repairs.

Factors That Affect EMI Filters

There are several factors that can affect the useful life of an EMI filter as discussed below:

1. Inductor Design

Inductor windings carry full rated current of the filter. Differential mode inductors have one winding and common mode inductors have two. The windings must be designed with the correct gauge magnet wire to carry the rated current without overheating. Using insufficient gauge due to wrong design practices or cutting corners can be detrimental to the filter's longevity.

Additionally, inductors have core losses that also contribute to the heating. Proper temperature measurements must be done to ensure that the total temperature rise, added to ambient, does not exceed beyond the maximum rated temperature of the wire and other components around it.

Not following these design considerations can cause overheating resulting in melting of inductor winding or thermal failure of other components around it.

2. Capacitor Selection

In filters, capacitors are usually connected between the lines (phase to phase or phase to neutral) or from the line to ground. The capacitors connected between lines (X) see the full rated voltage of the filter. The capacitors connected between line and ground (Y) carry a full rated voltage current in a single-phase and 0.577*rated voltage in 3-phase filters.

To extend the useful life of capacitors, the voltage rating of capacitors must be at least 10% higher than the maximum line voltage for the X-capacitors (or the line to ground voltage for Y-capacitors). Although 250 VAC rated X-capacitors are usually sufficient for most single-phase applications, it is recommended to use 275 VAC ~ 305 VAC rated X-capacitors to extend the capacitor's life as these can handle line transients and voltage fluctuations better. Y-capacitors require special safety considerations because certain failures (short) can cause a shock hazard for the operator. These are rated higher than X-capacitors. Most Y-capacitors are rated for 275 VAC for single-phase applications, but it is recommended to use 305 VAC rated Y-capacitors.

In 3-phase applications, the phase-to-phase voltage is usually considered as 480 VAC which covers most global (except some less common 600 VAC/660 VAC/ 760 VAC) power utility supplies. The line (X) capacitors must be rated for a minimum (480 + 10% =) 528 VAC for Delta configurated system. This can also be achieved by:

- either using two (277 *1.1 =) 305 VAC rated X-capacitors in series, or
- connecting three 305 VAC-rated X-capacitors in a Y configuration (not to be confused with Y-capacitors or Wye configured 3-phase system).

For Wye configured systems, the X-capacitors are connected between the phase and the neutral, and these must be rated for a minimum (277 * 1.1 =) 305 VAC.

For both Delta and Wye configured systems, the line to ground capacitors must have a minimum rating of (277 * 1.1 =) 305 VAC. There are alternate ways of connecting Y-capacitors in a 3-phase system which can relieve the line voltages stress on these while still achieving the EMI mitigation.

- for Wye configured systems, Y-capacitors are connected between the neutral and ground, and
- for Delta connected systems these connections between the neutral point (*of Y connects X-caps*) and ground.

In a balanced 3-Phase system the neutral (or neutral point) voltage is zero which means the Y-capacitor sees no actual voltage across it. During unbalanced conditions, the voltages across the Y-capacitors can rise to 50~60 VAC which is still much below the rated voltage of the capacitor. This enhances the life of the capacitors while reducing the filter leakage current.

These are minimum suggested ratings; using capacitors with higher voltages ratings is highly recommended where excessive line transient conditions are expected. Not using capacitors with adequate voltage rating, will result in the breakdown of the capacitor dielectric. This can cause capacitor decay or eventual failure. If the difference in rated voltage and line voltage is unusually high, the failure can be catastrophic.

3. Electrical Disturbances

Depending on application and location in the system, an EMI filter can be exposed to electrical disturbances. These electrical disturbances include:

- Voltage surges
- Voltage distortion
- Voltage transients
- High ripple currents

- Voltage swells
- Temporary overvoltage
- Overcurrent
- Lightning strikes
- EMP/ HEMP

All of these electrical disturbances can lead to damage to the capacitors and insulation system of the EMI filter. The first four cause slow damage over an extended period and others can result in catastrophic failure. If necessitated by the line conditions, a surge, transient protection, overcurrent, or Lightning/EMP protection devices must be installed ahead (upstream) of the filter.

4. Applied Current

The current rating of a filter is the maximum steady-state RMS current that can flow through it continuously without causing any damage. The current draw can be lower but never higher than the rated current. There is no tolerance on the higher side. Drawing higher than rated current can damage the inductor windings. Based on the level of overcurrent the failure can be slow or catastrophic. ”

5. Specifications

Most filters are rated for the maximum available global voltages; 250 VAC for single phase and 480 VAC for 3-phase but some are designed for 120 VAC, 208 VAC, and 440 VAC only. It is acceptable to use these for the rated line voltages but not for global applications. Applying 480 VAC to a 208 VAC or 440 VAC rated filter will cause eventual failure. It is recommended that design engineers must select a filter with the highest available voltage rating (which are commonly available) to ensure the filter can be used globally.

6. Parasitics

Unlike power supplies, filters are not designed for power ratings (wattage). Filters are designed for maximum rated voltage and current. None of the two can be exceeded under any circumstances. Using a lower line voltage does not allow the designer to draw a higher current through it. While selecting a filter, design engineers must make sure that the rating is adequate for both highest rated input voltages and maximum current draw (usually at the lowest power supply voltage).

7. Ambient temperature

Filters dissipate power, resulting in heating and temperature rise. This temperature rise, when added to the air temperature around it (ambient), determines the actual filter temperature under operation. This temperature must never exceed the maximum rated temperature of any filter component. For this reason, each filter is designed for a specific ambient temperature. Operating a filter at an ambient temperature higher than its rated ambient temperature can lead to the failure of filter components. For higher ambient, there are two options:

- derated (draw lower current than rated) the filter.
- select a filter designed for higher ambient current.

Filters are commonly designed for 40 C ~50 C but designs are available for 55 C to 80 C ambient.

8. Operating Frequency

All AC filters can be used for 50/60 Hz. The 400 Hz operating frequency poses a challenge because it has two impacts on the filter:

- higher leakage current

increases core losses

These result in heating of both inductor and capacitors. Over a period, this can result in filter failure. For 400 Hz applications, it must be ensured that the filter is able to operate safely. Filter designs are available that can operate at 400 Hz and, wherever possible, these must be employed.

Design engineers can ensure a long operational life for the EMI filters if all the considerations are carefully evaluated during the filter selection process. Each application is unique with its own design challenges arising from power need, operating conditions, space, and product packaging. Should there be ambiguity, it is best to consult a filter expert to select the right filter for the application.

Contact Astrodyne TDI for EMI Filters

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Our products can be used in a variety of markets, such as industrial, medical, aerospace, semiconductor, and military applications. Browse our EMI filter applications and numerous types of EMI filters to find the right one for your project. We can also customize parts for your company if you submit a request. If you are looking for EMI filters, **contact us** at Astrodyne TDI today.