

Line Reactors Provide a Low Cost Solution to Inverter/Drive Power Quality



Reactors are installed in HVAC equipment, machine tools, elevators, printing presses, UPS equipment, computer mainframes, harmonic filters, robotics equipment, ski lifts, wind generators, electric cars, trams, and many other types of equipment using drives or inverters. For additional information, contact your local GE sales office.

Three phase line reactors offer an economical solution to a variety of application problems in variable-speed drive installations. Reactors solve problems on either the input or the output of the drive if the reactor is compensated to handle the effects of harmonics.

To see where these reactors fit in today's technology, we have to go back 25 years to the introduction of low-voltage industrial drives. Often, the installation required a voltage step-up or step-down and line isolation was almost universally recommended. The isolation transformer provided both line isolation and voltage transformation. It became standard practice to include a drive isolation transformer with nearly every drive installation.

As the industry progressed, drive voltage ratings increased. Some even developed with dual voltage ratings. Multiple power systems appeared in industrial plants and dual voltage motors became more popular. With these and other improvements, it became less necessary to alter the line voltage supplying the drive. Then, the drive industry developed internal isolation and ground fault protection systems. Thus the need for external isolation all but disappeared. The result was a significant cost reduction for a drive system and sales of the new electronic drives soared.

Soon, users of these new, economical and efficient drives began experiencing nuisance problems not previously encountered with the older, isolation transformer protected systems. With the isolation transformer gone, the quality of the power delivered to the drive became more evident. The drives were very sensitive to line fluctuations and other nuisance problems not noticed before. A solution had to be found because the isolation transformer was too expensive to be put back into the circuit.

The line reactor was developed as a low-cost solution to the problem. The reactor acts as a current-limiting device and filters the waveform and attenuates electrical noise and harmonics associated with the inverter/drive output. In this respect, the line reactor even surpasses the isolation transformer at a fraction of the transformer's cost. Line reactor costs are typically just 1/5 the cost of a comparable isolation transformer.

Among the harmonic compensated line reactors benefits are:

- Virtual elimination of nuisance tripping of drives due to utility power factor correction capacitor switching
- Attenuation of line harmonics
- Extended switching component life (transistors, SCRs)
- Extended motor life
- Reduced motor operating temperature (20 to 40°C)
- Reduced audible motor noise (3 to 5 db)
- Minimized power disturbances
- Filtered electrical noise (pulsed distortion and line notching)
- Waveform improvement

Harmonic Compensation

As the name implies, line reactors are typically used on the line side of an ASD (adjustable-speed drive), as shown in Figures 2(a) and 2(b) for single and multiple motors. Some higher level design reactors, are harmonic compensated and can be successfully used on the load side of the drive (between the drive and motor) as well as the input (line) side of the circuit. Figure 3(a) shows a typical reactor on the load side of a single motor and Figure 3(b) is the configuration for multiple motors.

Harmonic compensated line reactors are specially designed to handle the waveform's harmonic content. This compensates for the effect of higher total rms current as well as higher frequencies present in the waveform and may be used effectively on either the line or load side of any ASD.

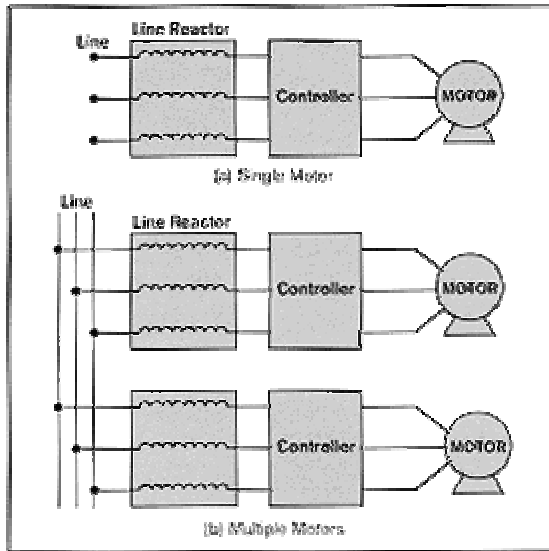


Figure 2. Typical Line Reactor Configuration

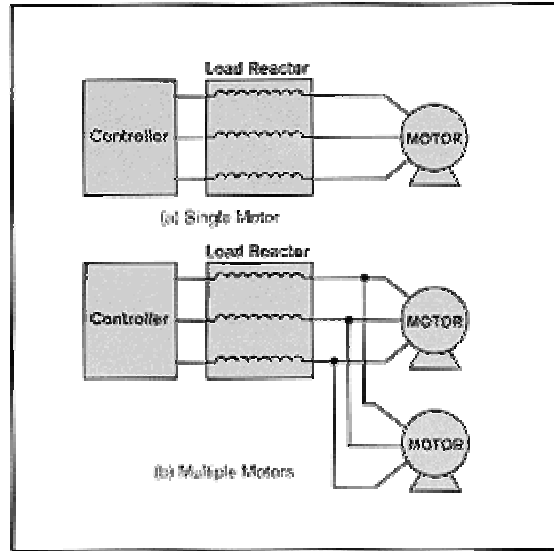


Figure 3. Typical Load Reactor Configuration

Reactors are used on the load side of an ASD as a current-limiting device to provide protection for the drive under motor short circuit conditions. Here, the line reactor slows the rate of rise of the short circuit current and limits the current to a safe value. By slowing the rate of current rise the reactor allows ample time for the drive's own protective circuits to react to the short circuit and trip out safely. Also, the reactor absorbs surges created by the motor load that might otherwise cause nuisance tripping of the drive. Machine jams, load swings and other application changes to the drive load cause motor load surges.

Looking at the load side reactor from the motor view, the ability of the reactor to filter the waveform produced by the ASD improves motor performance and the total system performance. Due to higher frequency pulses generated by the drive to produce the waveform, motors typically run hotter than normal, resulting in lower efficiency and shorter life. Unprotected motors must often be oversized to compensate for the higher frequencies and harmonic currents that are present in the drive output waveform. Waveform filtering by the reactor reduces the load side harmonic content, reduces thermal current affecting the motor and filters pulsed distortion. The reactor attempts to recreate a perfect sine wave, thus improving motor efficiency. This extends motor bearing life, increases horsepower output by 25-30%, and can reduce audible noise by as much as 3-5 decibels. Tests have shown that motor temperatures can be reduced as much as 20 to 40°C using a harmonic-compensated reactor.

On the line side of the ASD system, reactors also serve bidirectional functions. When the local utility switches power factor correction capacitors onto the electrical power grid, it creates voltage spikes. The proper impedance reactor in the input circuit virtually eliminates nuisance tripping of drives due to these voltage spikes. Also, the reactor can protect from line sags because it performs a line stabilizing function. Initially, this may seem unusual because the reactor adds impedance to the circuit, which causes a voltage drop. An important, overlooked factor is that the reactor has significant inductance so it opposes any rapid change in current. Most voltage sags are the result of excessive loading or current surges. Thus,

by stabilizing the current waveform, the reactor can indirectly solve both overvoltage and undervoltage tripping problems.

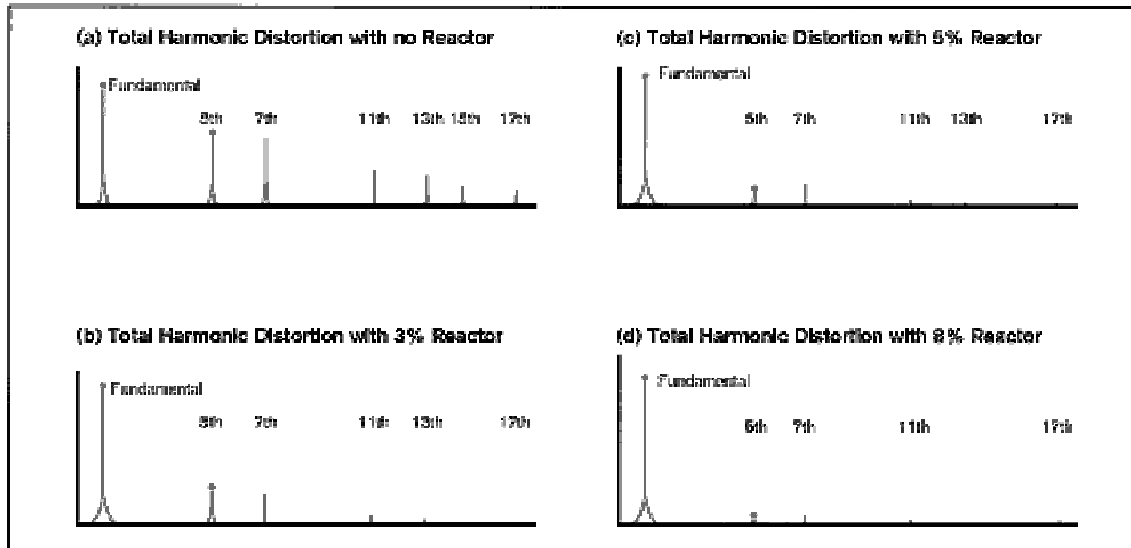


Figure 4. Harmonic Distortion Test Results

Looking on the line side from the opposite direction, the reactor filters out both pulsed and notched distortion. This minimizes interference with other sensitive electronic equipment (other ASDs, PCs, mainframe computers, logic controllers, telecommunications systems, monitoring equipment). The line reactor has been proven effective in reducing harmonics emitted by the drive onto the incoming power line. Harmonic distortion test results shown in Figure 4 verify the effects of harmonic current distortion on the input side of a 5HP inverter ASD.

Reactor Impedance

Line reactors are rated in percent impedance to retain some conformity with the ratings of conventional drive isolation transformers. We can determine the impedance rating of a conventional isolation transformer with the following procedure:

- 1) Short circuit the secondary winding.
- 2) Increase the primary voltage while monitoring secondary current.
- 3) Measure the primary voltage that causes rated secondary current to flow.
- 4) Compare this value with the rated primary voltage to obtain a ratio equal to the transformer impedance rating.

Reactor impedance must be measured differently because the reactor is a series, current-dependent device as opposed to the transformer that is a parallel, voltage-dependent device. To determine percent impedance of a single-phase reactor, measure its voltage drop with rated current flowing through it. Compare this voltage with the line voltage for percent impedance. You can connect two phases in series with single-phase voltage applied. Measure the total voltage drop across both coils and compare it with the system voltage for the impedance rating. For example, if the voltage drop across the reactor is 12V for a 480V line, the percent impedance is $12/480 \times 100$, or 2.5%.

Test a three-phase reactor with all three phases energized at rated current. With all phases energized, measure the voltage across any one phase and divide it by the system voltage. Multiply this value by 1.73 (square root of 3) and again by 100 for percent impedance. As an example, if the reactor drop is 8.3V with a 480V line, the percent impedance is $8.3/480 \times 1.73 \times 100$, or 2.99%.

If you energize only one phase of a three-phase reactor and compare the voltage drop with the system voltage for the impedance calculation, the calculated value indicates only 70-75% of actual value.

It is difficult for the user to test a reactor for conformance to a specification when reactors are rated only in percent impedance. For a more accurate test verification, it is helpful to find the reactor's actual inductance.

This can be done in a manner similar to the impedance calculation as follows:

First, energize all three phases of the reactor at rated current. The measured voltage equals the current times the inductive reactance (X_L , which is $2(\pi)$ times the frequency times the inductance). For a 60Hz system, the inductance equals the voltage divided by the current times $6.28 (2(\pi))$ times 60. Using a meter or bridge system to test line reactors usually produces false readings for two reasons. First, this is only for single-phase testing so it indicates a value that is 25-30 % less than actual. Second, meter or bridge tests are at such a low current level that the reactor's core and gap remain unenergized.

Request more information on line reactors from your local GE sales office!

Internet Site Address: www.ge.com/capacitor

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