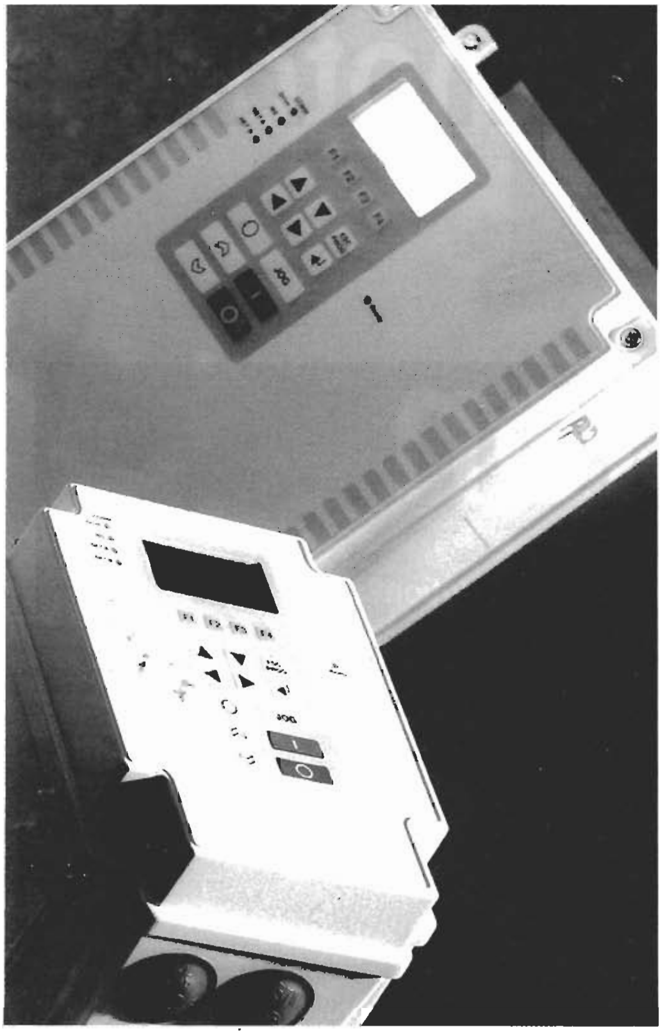
Keeping your drive alive



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Today's ac drives come loaded with many features. But they still often require supporting devices to help them do their job.

From a signal-level perspective, all ac drives feed reshaped current and voltage to motors to make them move in sophisticated ways. But because ac drives are usually the first component in an electromechanical system, directly manipulating raw input power — the lifeblood of everything downstream — they're subject to all sorts of variations, from voltage spikes to electromagnetic interference. In many cases, drives require help from ancillary components to cope with these challenges and avoid being damaged. Here's a review of the ones that are most important.

Line dance

Topping the list of protection devices for drvies, *line reactors* are rapidly replacing isolation transformers in the fight against electrical power variations. Line reactors use impedance to smooth out current spikes — useful where drives are close enough to induce electrical noise in neighboring drives. Line reactors also reduce voltage notching caused by sudden current draws characteristic of adjustable speed drives, and they protect drives from the damaging effects of current harmonics at multiples of the fundamental system frequency — usually 60 Hz.

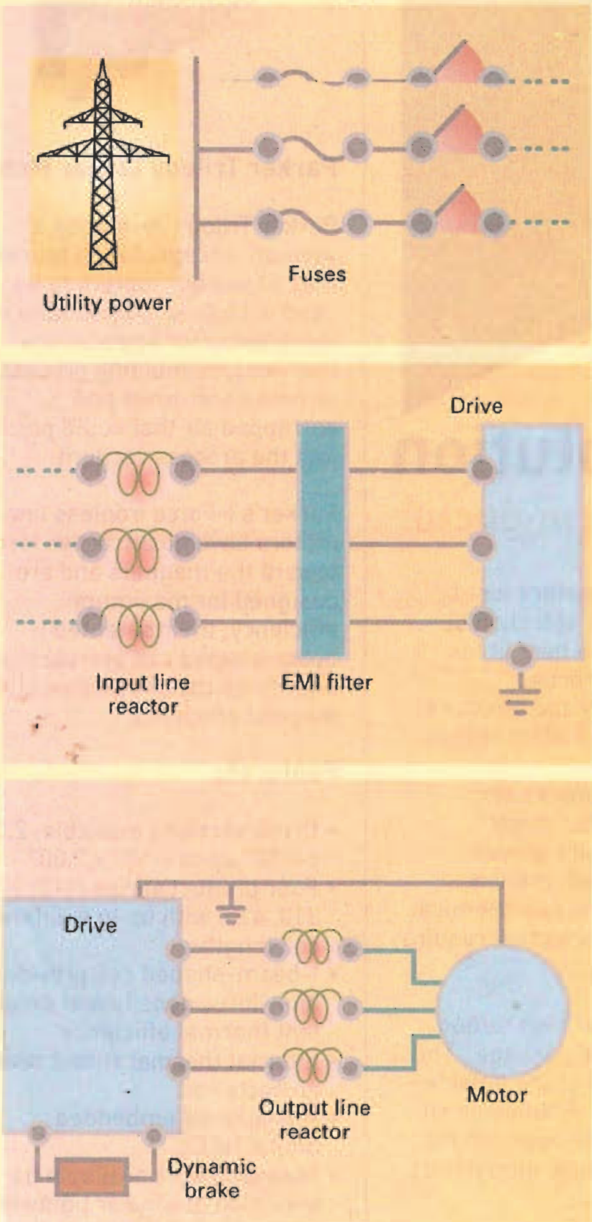
Line reactors connect to ac systems in series and include three windings. All line current flows through them. They're rated by percent of impedance to voltage and motor horsepower — which

Loads causing regeneration

With rotational load, energy is proportional to the square of the speed. For this reason, deceleration to stop results in a linear reduction in the energy transfer. Linear loads are similar. Decelerating to stop results in a linear decline in power.

However, overhauling loads are different in that they usually last indefinitely. This may occur on an inclined conveyer where items loaded on the belt provide a continuous regenerative energy source. Here, power to the dynamic brake is constant.

Protection options



The humble fuse

Input fuses protect ac drives from excessive input current — usually from short circuits, line surges, and ground faults. They're almost always recommended. Circuit breakers are another possibility. One is often required for UL listing.

Input EMI filter

Input EMI filters reduce electromagnetic noise on the input side of the inverter. They are required for CE compliance and recommended for installations sensitive to interference.

Protection in place

Dynamic brakes drain excess energy resulting from overdriving motors spinning faster than their command speed.

determines the line reactor current necessary.

Their current rating is total current drawn through the reactor by the load. Reactor impedance (measured in ohms) is proportional to frequency and inductance as follows:

$Z = 2\pi f L, \Omega$

Where f is frequency (Hz) and reactor inductance L is measured in Henries (H).

If the impedance of a line reactor is 10 Ω at 60 Hz, then at the fifth harmonic, it reduces current in connected lines with 50-Ω impedance. The higher the frequency, the lower the current.

Where are line reactors installed? They're connected on the input and output sides of drives. Some units are sized for either side.

Going in

The quality of power supplied by utility companies in the U.S. is excellent. Even so, downed lines, unavoidable fluctuations as loads come on and go off grid, even lightening strikes can send transient voltages through adjacent lines. Input-side line reactors protect ac drives from these over-voltages. Reactors sized according to voltage and horsepower can also reduce harmonics.

On the input side of motor-driven plants, however, especially those with many induction motors, other electrical components may be in place as well. Motor windings make current lag voltage. Average power in an ac circuit is $VI\cos\varphi$, where the power factor $\cos\varphi$ is R/Z. Ideally, this value is as close to unity as possible. In reality, a system's power factor is often far below it.

Power companies penalize plants for this, because they must supply more current for a given amount of power consumed. To keep power factors high and avoid fees, some plants install power-factor correction capacitors to compensate for their inductive motors. Line reactors must be installed upstream from these capacitors.

On motor drive circuits with no correction capacitors, or where utilities don't charge for low power factors, line reactors should be connected in series with drive power leads on the load side of drive disconnects.

Coming out

Line reactors on a drive's output side protect motor insulation against short circuits (in the drive) and switching transients released by transistors. A line reactor here can also reduce motor noise and improve efficiency. Efficiency gains are based on reactors smoothing motor-current waveforms, which make for cooler motor operation. Such reactors are recommended for lightweight motors and where wiring runs between the drive and motor exceeds 100 ft or so. Here, line reactors connect in series with the motor leads from the drive.

Recycle reuse

When a rotor turns faster than the synchronous speed set by its drive — say, when a downward-sloping conveyor is decelerated — shaft speed exceeds synchronous speed and the motor transforms mechanical energy into electrical. This is called *regeneration*.

Energy is never lost or gained, so unless otherwise routed, this electricity flows the only place it can: backward and through the delicate one-way inverter bridge diodes or SCR rectifier bridges there to convert utility power into dc. In reality, drives usually include an over-voltage trip to prevent this damaging situation. But there are more efficient ways to avert this problem.

One option is to use regenerative brakes. Here, bridge converters change dc bus energy into fixed-frequency utility power. They connect to the dc bus and bleed motor and load energy when a motor behaves as a generator. However, regenerative brakes have no voltage regulators or power resistors. They do not regulate drive bus voltage. Rather, they include switches synchronized to the line to provide a current flow path should the dc bus voltage exceed that of the line.

Another option (in systems with several drives) is to link dc bus connections together so that recaptured energy from one motor can be used by another.

Brake it up

The simplest solution, however, is to route energy from regeneration into a resistor and dissipate it as heat. Called dynamic braking, it involves a series circuit consisting of a voltage-regulated switching transistor and a high-power resistor placed across the dc bus. A control circuit monitors dc bus voltage and turns the switching device on and off at the appropriate levels.

Dynamic brakes must be connected at the capacitor bank nodes of the dc bus to avoid damage. Many drives also provide a dc bus connection point at the input bridge rectifier nodes, but if connections are made here, current in the dynamic brake can travel through the dc link choke and generate a voltage spike when the power switch (usually an IGBT) turns off. In most cases this spike far exceeds the switching device rating, resulting in failure.

How do dynamic brakes function? In a 460-Vac drive, for example, nominal dc bus voltage is about 650 Vdc. If the voltage reaches about 810 Vdc, the drive protects itself with an over-voltage trip.

A 460-Vac dynamic brake regulates dc bus voltage to about 750 Vdc for enough voltage margin to prevent the over-voltage trip, but without interfering with the 650-Vdc nominal level. When regeneration pushes the dc bus to 750 Vdc, the switching device turns on and allows current flow to the resistor. Regenerative energy is then released as heat and dc voltage drops. The switching device stays on until the bus voltage reaches about 735 Vdc, and then turns off — letting dc voltage bounce between 735 and 750 Vdc while the dynamic brake is active.

In fact, ac drives can typically produce up to 20% of a system's braking torque. Some low-horsepower drives have built-in braking circuits, but still require the addition of a braking resistor. Drives rated for more than 15 hp, on the other hand, require separate braking units in addition to the braking resistors.

Duty cycles greater than 20% usually require a different device for dynamic braking, called a *chopper*. Chopper resistors are separate components, so their size can be tailored to the application, and mounted in a remote place where dissipated heat will not damage other components.