Instruction Guide

Basic Guide to Installing an AC Drive

ABB

Intended audience

This guide is intended for people who specify, select, plan the installation and install LV AC Drives. The user is expected to know the fundamentals of electricity, wiring, electrical components and electrical schematic symbols.It is the responsibility of the user to comply with local, regional and national codes.

Installation and maintenance work

⚠ **WARNING!** Ignoring the following instructions can cause physical injury or death, or damage to the equipment:

- Only qualified electricians are allowed to install and maintain the drive.
- Never work on the drive, motor cable or motor when main power is applied. After disconnecting the input power, always wait for 5 min to let the intermediate circuit capacitors discharge before you start working on the drive, motor or motor cable.

Always ensure by measuring with a multimeter (impedance at least 1 Mohm) that:

1. Voltage between drive input phases U1, V1 and W1 and the frame is close to 0 V.
2. Voltage between terminals UDC+ and UDC- and the frame is close to 0 V.

- Do not work on the control cables when power is applied to the drive or to the external control circuits. Externally supplied control circuits may cause dangerous voltages inside the drive even when the main power on the drive is switched off.
- Do not make any insulation or voltage withstand tests on the drive or drive modules.
- When reconnecting the motor cable, always check that the phase order is correct.

Symbols used in warnings and notes

⚠ Great importance, used to highlight text or concepts of significant importance to the reader.

👍 Rule of thumb, used to indicate the equation or formula is a rough estimate that is generally applicable, but not an exact calculation or measurement.

Contents

Selection Considerations

Basic physical loading, environmental, mechanical, and electrical factors all impact correct drive selection. Each of these factors must be understood and reviewed before selecting and purchasing a specific drive. The most important points are discussed in the following sections.

Basic physical loading factors

Motor power / speed relationship

Induction motors have both a rated power and a rated speed. AC drives are commonly utilized to operate induction motors below their rated speed. It is vital to understand that when this is done motor power capability decreases by the same proportion that motor speed is decreased. If a motor is operated at half its rated speed it is only capable of half its rated power.

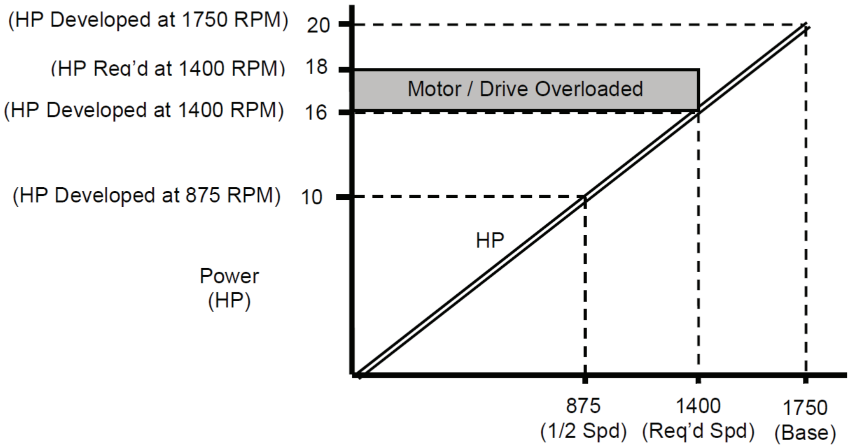


Figure 1. HP vs Speed

In Figure 1, assume that a particular fan needs to operate at 1400 rpm and develop 18 hp. It might be reasoned that a 20 hp, 1750 rpm motor could be used to directly drive the fan at 1400 rpm by employing a 20 hp drive to control the motor's speed down to this level.

Unfortunately, if this is done, both the motor and drive will be overloaded. The reason is that at 1400 rpm the motor can only develop 16 horsepower (20 x 1400 / 1750 = 16). The current required to develop 18 hp at 1400 rpm will overload both the motor and the drive.

Drive current / drive power

Drive selection tables normally list a power capability in addition to a current capability. It is important to understand that although the listed current capability is absolute, the power capability represents only an estimate based on the assumed utilization of a typical 2 pole, 4 pole, or 6 pole motor. Motors with higher pole numbers or other special construction may require a rated current higher than that listed for the drive. In such cases it is up to the person responsible for drive selection to ensure that the drive is capable of supplying the actual (not estimated) motor current.

⚠ Always treat drives as current rated equipment, not as power rated equipment.

Motor torque / current relationship

When utilizing a drive to control an induction motor, the torque developed by the motor is proportional to the current drawn by the motor. To develop rated torque requires rated current. To develop 150% rated torque requires 150% rated current.

This current demand needs to be taken into consideration when a drive is selected. Even if a motor only requires high torque during acceleration, this may necessitate selection of a larger drive to ensure that the peak current needed will be available. The same situation may apply if more than 100% torque is required when starting. Here again it must be ensured that the drive can supply the needed short term high current.

Most normal duty rated drives can provide peak currents between 110% to 130%. Most heavy duty rated drives can provide peak currents between 160% to 200%.

Motor torque / speed relationship

At or below base motor speed an induction motor can produce full rated torque with a power output which varies in proportion to speed. Above base speed the motor produces a torque which decreases in proportion to the ratio of base speed divided by operational speed while maintaining a constant power output. This mode is often called constant horsepower operation. Torque developed per ampere likewise follows the same ratio of base speed divided by operational speed. For example, if the motor requires ‘x’ amps to develop ‘y’ pound-feet of torque at rated speed, the same ‘x’ amps will develop only ‘½ y’ pound-feet of torque at twice rated speed.

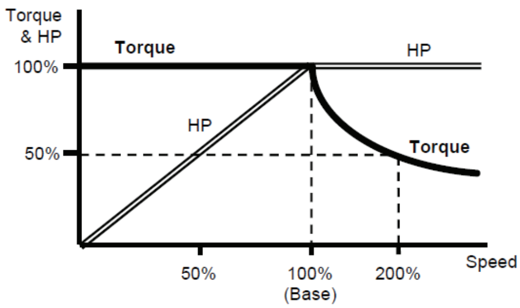


Figure 2. Torque above Base Speed Operation

The practical ramification of the above is that, although motors can be run above their base speeds, and although their power output capability remains constant, their torque output capability decreases by the amount that their operational speed exceeds their base speed.

Motor cooling versus speed

A final physical factor to keep in mind is that most AC motors are self cooled. Their cooling is normally designed around operation at rated speed. When a drive is used to operate such a motor at less than rated speed, the motor's ability to cool itself is reduced significantly. If the required torque at the lower operational speed also drops significantly then motor cooling typically isn't a problem. For example, it is usually possible to operate a centrifugal fan at reduced speed using a standard motor because the torque required from the motor drops off as the cube of speed. On the other hand, a constant torque load (e.g. a conveyor) requires the same torque regardless of operational speed. A constant torque requirement means that motor current draw will also be constant. It also follows that motor heating losses will remain constant. In this case, unless the motor is specially designed for constant torque operation, it will overheat due to lack of sufficient cooling. It is the obligation of the person responsible for specifying the motor to take cooling requirements into account when selecting the motor / drive combination.

Performance factors

Low speed torque

Some applications require high torque levels (>100%) near zero speed. Torque near zero speed is often limited on simple scalar drives. Vector drives, on the other hand, are normally better at providing low speed torque. ABB drives with Direct Torque Control (DTC) provide superior functionality with regard to this aspect (e.g. ACS800). If maintained operation near zero speed (one second or more below slip speed) is required an optional encoder is recommended.

Torque control

Some applications require torque control instead of speed control. For example, a drive may need to power a tension section in an inline process machine. In this application motor torque and not motor speed is what is important. The drive must be able to both calculate and regulate motor torque. This is only possible with a vector controlled drive.

Torque response

When an application requires rapid torque response, only vector controlled drives should be considered. Scalar drives don't calculate or control motor torque. On the other hand, vector drives include an adjustable speed regulator which generates a torque reference output. This torque reference is the input into a true torque regulator. Since torque is regulated its response can be accurately controlled. Here again ABB drives with Direct Torque Control (DTC) provide superior functionality with regard to this aspect (e.g. ACS800).

Speed regulation

Speed regulation percentages always use rated motor speed as their base. By convention, the percentage quoted represents the expected speed variance between a no load condition and a rated load condition. Scalar drives can provide about 1% to 2% speed regulation. Sensorless vector drives can provide about 0.1% to 0.5% speed regulation. Vector drives with an encoder can provide about 0.01% speed regulation. Vector drives implement a speed regulator stage that permits both the proportional and integral portions of speed regulation to be adjusted. Scalar drives don't include this functionality.

$$\text{Speed Regulation (\%)} = \text{Speed error / Base speed} * 100$$

$$\text{Speed Regulation (\%)} = \frac{\text{Actual Speed (Rpm)} - \text{Setpoint Speed (Rpm)}}{\text{Base Speed (Rpm)}} * 100$$

$$\text{Speed Regulation (\%)} = \frac{\text{501 (actual)} - \text{500 (setpoint)}}{\text{1750 (motor base speed)}} * 100 = 0.057\%$$

Where:
500 = Setpoint or target speed
501 = Actual motor speed
1750 = Motor base speed

Example. Speed Regulation Calculation

Regenerative capability

Identifying the need for having regenerative capability is a critical step in drive selection. It is very important to identify the need before ordering drive hardware. Many drives can't be field retrofitted to add a brake chopper. Adding an external chopper is both significantly more expensive and wastes panel space.

Drives can handle regenerative energy by either dissipating it as heat across a dynamic braking resistor or by returning it directly to the utility grid. The first approach offers a significantly lower initial cost. The second method can provide a significant reduction in long term utility cost. Normally a fully regenerative drive is only considered when (1) the equipment runs almost continuously, and (2) regenerative operation constitutes a significant portion of the overall duty cycle. Applications where regeneration only occurs infrequently during stopping almost always implement a Dynamic Braking (DB) solution.

One other factor that sometimes plays a part in the decision of whether to select a DB resistor solution or a regenerative drive solution is the fact that a regenerative drive will reduce line harmonics by almost a factor of 10 in comparison to a standard 6-pulse drive. This can mean that expensive harmonic filter equipment that would be needed for the 6-pulse solution can be eliminated. This additional cost saving may be sufficient to justify the regenerative drive solution.

Environmental factors – General

Physical location / enclosure type

The physical location of the drive is a vital factor to take into account. Enclosure designs are available that cover both indoor and outdoor service. Both North American and International standards exist which establish required enclosure characteristics and capabilities versus enclosure type code. In North America, a NEMA, UL, or CSA standard normally applies (NEMA 250, UL 50/50E, or C22.2 No. 94). In much of the rest of the world an IEC standard applies (IEC 60529).

Personal protection

Personal protection is essentially concerned with touch safety. NEMA 1 enclosures protect against penetration of objects with a diameter of ½ inch or larger. This is often referred to as “finger safe.” Drive modules intended for mounting inside another cabinet are often purchased without a NEMA rating (IP00). Such modules do not provide personal protection.

Wildlife damage

This very low tech factor nonetheless needs to be considered. Cabinets need to be sealed and protected in such a manner that rodents and other wildlife can’t gain entry. Problems associated with damage to insulation in covered locations can be particularly difficult to diagnose.

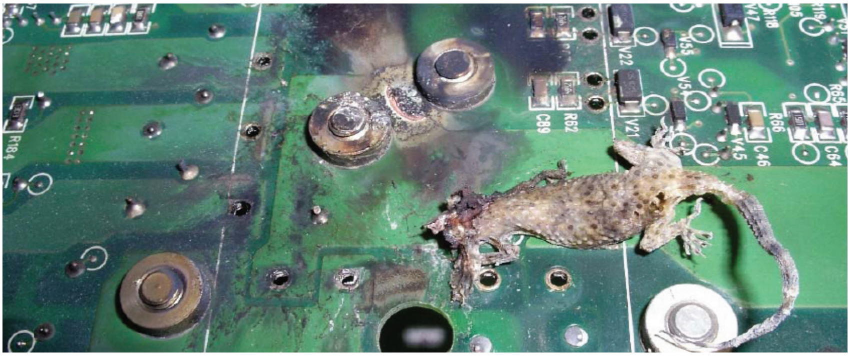


Figure 3. Drive Failure Due to Wildlife

Humidity / condensation / salt air

All ABB drives are covered by a specification that states that the relative humidity should be “5 to 95%, no condensation allowed, maximum relative humidity is 60% in the presence of corrosive gasses.” If it is expected that environmental conditions may lead to condensation then either a cabinet which includes a space heater or some form of air conditioning should be considered.

Only drives with coated circuit boards should be applied in a salt air environment. It is also extremely important that condensation be prevented when salt air is present.

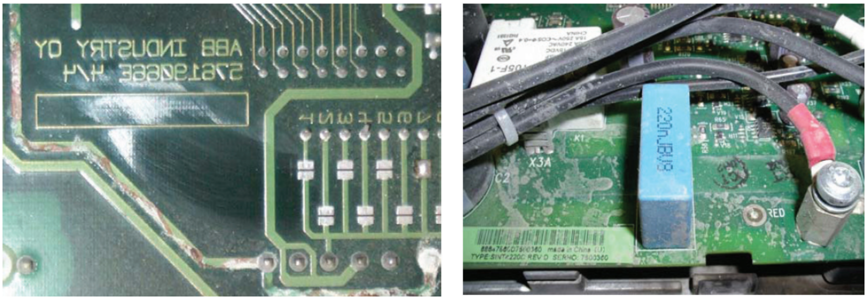


Figure 4. Corrosive Elements collecting on a Circuit Board

Solid particles and chemical gases

In general, drives have only a very limited tolerance of solid particle and chemical gas contamination. Tolerance levels in compliance with IEC 60721-3-3 apply. However, this compliance essentially only covers what most would consider a normal industrial environment. If special contamination issues are known to exist, contact ABB Application Engineering to discuss what special measures may be needed.

Fibrous dust is of most concern for clogging of a drives internal heatsink. Small symmetrical dust particles easily pass through the fins of the typical heatsink. However, fibrous dust with it’s long strings tends to collect at the heatsink entrance and will prevent air from flowing through the heatsink effectively. This will result in decreased cooling capacity and eventually the drive will be unable to cool itself and may fail to operate or have a component failure due to excessive heating.

A general rule is that if you can smell an odor, especially an odor similar to rotten eggs there are contaminants that may cause damage to electronic components. This does not mean if you cannot smell an odor that no hazardous contaminants exist.

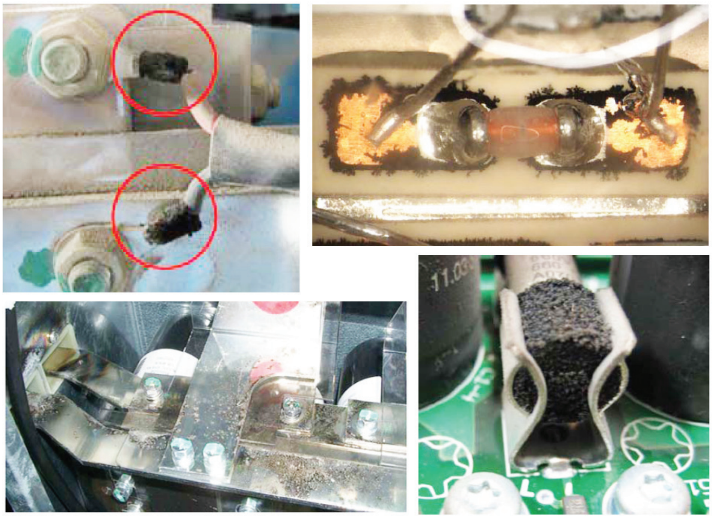


Figure 5. Corrosive Elements that Affect Electronics

Altitude

Altitude has a thermal impact on drives. Most drives can develop their normal rated output current up to 1000 m (3280 ft). Above this altitude, derating is usually required. Often the de-rate factor is 1% current reduction per 100 m (328 ft) increase in altitude above 1000 m. However, a check to ensure exactly what level and factor applies should always be made.

A less understood fact is that increased altitude also detrimentally impacts the voltage creepage and clearance capabilities of an electrical design. This factor normally establishes the upper altitude limit at which a drive may be applied. Most ABB drives have either a 2000 m (6560 ft) or a 4000 m (13120 ft) altitude limitation. If operation above these levels is required, contact ABB Application Engineering. In some cases, operation above these levels is possible based on reductions in voltage or other factors.

Temperature

Ambient temperature has a thermal impact on drives. Most drives can develop their normal rated output current up to 40º C (104º F). Above this ambient temperature, derating is usually required. Some drives carry their full rating up to 50º C (122º F). Often the de-rate factor is a 1% current reduction per degree Centigrade above 40º C (104º F). However, a check to ensure exactly what level and factor applies should always be made.

Drives also have minimum temperature ratings below which they can't operate. Usually these lower limits are based upon ensuring proper operation of the drive's control electronics. Typical lower temperature limits range from 0º C (32º F) to -15º C (5º F). Often, cabinet heaters are included to ensure that these lower temperature limits aren't exceeded.

Normally operation below rated maximum temperature has no impact on a drive's output current rating. However, if the drive's output current has been previously de-rated due to increased altitude, then the impact of this derating can be reduced by 1% for each degree Centigrade that the maximum operating temperature is below 40º C (104º F). For example, a drive operating at 2000 m normally requires a 10% current de-rate ((2000 – 1000) / 100 = 10%) due to altitude. However, if this drive only needs to operate at a maximum ambient temperature of 30º C (86º F) then the output current can be increased back up by 10% (40 - 30 = 10) totally offsetting the original de-rate. Note that this method can never be used to increase the drive's rating above its normal current rating because some components are limited by non thermal factors.

Note: temperature will impact the life of electronic components. In general, electronic components operated at 20º C (68º F) may operate up to 4 times as long as components operated at 40º C (104º F).

Hazardous locations

Standard ABB drives are not designed to operate in hazardous locations. If operation in a hazardous location is required, Engineered Drive Sales should be contacted to see whether a custom drive solution is possible.

If only the drive's motor is located in the hazardous location then a standard drive solution is likely possible. Both ACS800 and ACS550 drives are certified to work with ATEX qualified motors.

Environmental factors – Indoor

The most common indoor enclosures are North American types 1, 12, 4 and 4X. Although exact one to one relationships don't exist between North American and international enclosure types, NEMA 1 is usually equated to IP21, NEMA 12 to IP54 and NEMA 4 to IP56.

Dust and dirt

If protection against dust and dirt is required then an enclosure with at least a NEMA 12 rating should be specified. Per the NEMA standard, NEMA 12 enclosures are by definition non-ventilated. However, since drive power losses are normally sufficient to require ventilation, the drive industry has come to recognize what is traditionally referred to as a NEMA 12 ventilated enclosure. These designs effectively divide the drive into a control section and a power section. In wall mount sizes the control section follows true NEMA 12 guidelines and is non-ventilated. However, the drive's heatsink, cooling fan, and often select power components (e.g. reactor) are allowed full access to cooling air. In cabinet size drives the control section is again non-ventilated. The power section, on the other hand, includes one or more fans that provide sufficient air exchange to cool power components. The cabinet is also provided with door gaskets and air filters at all inlets and outlets to meet the NEMA 12 dust requirements.

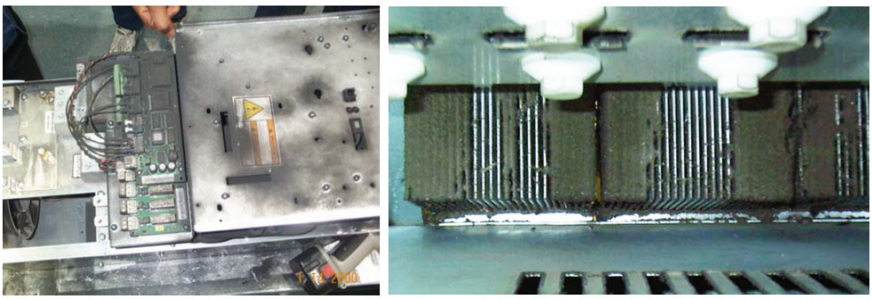


Figure 6. Inadequate Clean Air Circulation with Drives

Water

If only protection against dripping water is required then an ABB type 1 enclosure will suffice. Although neither NEMA 1 nor UL Type 1 enclosures mandate this capability, ABB drives are built to meet the international IP21 enclosure standard which does require protection against vertically falling drops of water.

If protection against splashing water or light water spray is required then an ABB Type 12 enclosure is required. NEMA 12 enclosure requirements only mandate protection against dripping water. However, both UL Type 12 and IP54 requirements mandate protection of splashing water or light water spray from any direction.

If protection against water hose-down or pressurized water jets is required then an ABB type 4 enclosure (IP66) is required. Only a limited number of standard drives are available that meet this requirement. However, it is also possible to purchase engineered drives if this is needed.

Environmental factors – Outdoor

The most common outdoor enclosures are North American types 3R, 4 and 4X. Although exact one to one relationships don't exist between North American and international enclosure types, NEMA 3R is usually equated to IP24, and NEMA 4 to IP56.

Rain, snow, sleet

This requirement is normally met by applying a 3R enclosure type which permits ventilation. It can also be met with a 4 or 4X enclosure type; however, these are non ventilated and thus are normally only applicable at low power levels where drive losses are minimal. A 4 or 4X enclosure may be applied at higher power levels if a heat exchanger or air conditioner is also included.

Sun loading (thermal)

Sun loading adds significantly to internal cabinet temperature. In full sun a non ventilated white cabinet will experience approximately a 5º C (10º F) rise. In comparison cabinets painted RAL 7035 gray, ANSI 61 gray, and black will experience rises of approximately 10º C (19º F), 15º C (27º F), and 18º C (32º F) respectively.

Assuming a 24” x 20” x 12” cabinet, this is equivalent to an internal power dissipation of 70 watts, 130 watts, 190 watts, and 250 watts respectively for white, RAL 7035 gray, ANSI 61 gray, and black cabinets.

Cabinets built with sun shields spaced an inch away from the main cabinet walls can reduce these temperature rises and effective power loads by 50% to 75%. External shading located 12 inches or more away from the cabinet renders sun loading negligible.

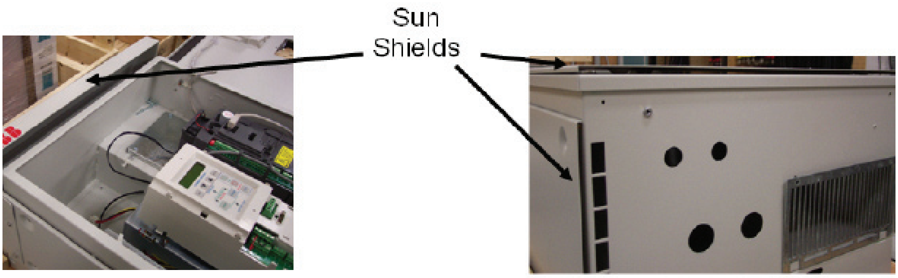


Figure 7. Sun Shields installed on drives

Mechanical factors

Optional flange mounting

Flange mounting provides the ability to dissipate 80% or more of drive losses external to a drive cabinet. In many instances, this allows the control section of the cabinet to be designed without ventilation.

Flange mounting kits are optionally available for many drives and drive modules. These kits include cutout and drilling templates in addition to full installation instructions. Typically, cabinets designed for flange mounting meet Type 12 enclosure criteria. With the addition of special hoods, Type 3R designs are also possible.

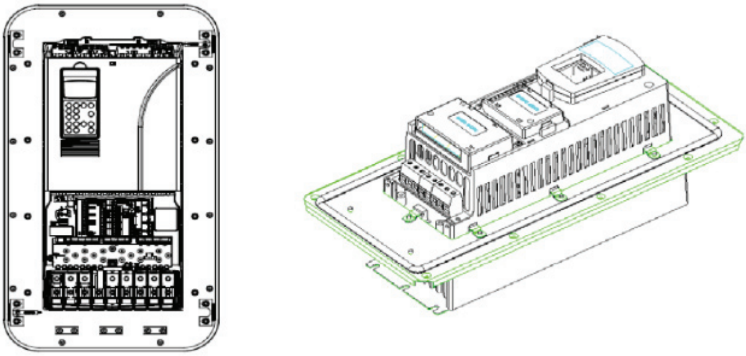


Figure 8. Flange-mounted Drive Option

Special shock and vibration levels

Standard drives are designed to meet normal levels of shock and vibration as typically seen in industrial applications. Design shock and vibration levels are documented in the Technical Data section of the applicable Hardware Manual or User’s Manual. Normally, international standard IEC 60068-2 applies.

In some drive instances, additional shock and vibration standards also apply. For example, the ACH550 drive is seismic certified per ICC-ES AC156. When special shock and vibration requirements are specified, contact ABB Application Engineering for assistance.

Electrical factors

Network factors

Acceptable and reliable operation of an AC drive is dependent on the characteristics and quality of the network to which it is connected. Although drives are quite forgiving and can tolerate broad ranges of line conditions, especially severe network circumstances can lead to drive shutdown, drive tripping, or even drive failure. It is always wise to review the general network situation to ensure that additional external equipment isn't required and that all intended drive options are compatible.

Voltage sags and surges

Most drives are designed to operate over a range of rated input voltage. In addition tolerances of +10% / -10% apply (or +10% / -15%) to the rated values. For example, a basic 480 VAC ACS550 drive is capable of operation from 323 VAC to 528 VAC. However, sags and surges beyond these ranges may cause drive tripping, and in severe surge cases, actual drive damage.

If the network to which the drive is to be connected is known to have significant sag or surge issues, other proactive steps should be considered. The extent of these steps is dependent on the criticality of continued drive operation. A minimal solution might include simply installing additional line reactance or insuring that automatic reset logic is provided. A complex solution may necessitate inclusion of a complete UPS system.

In all cases, it should be recognized that drives have finite input voltage requirements and that voltage excursions beyond rated limits will have operational consequences if they aren't dealt with by additional equipment external to the drive.

System grounding method

Systems may be solidly grounded, resistance grounded, or ungrounded (floating). Grounded systems include neutral point grounded, corner-of-the-delta grounded (grounded B phase), and midpoint grounded delta (high-leg / wild-leg / red-leg delta). In addition, grounding reactors, grounding transformers, and grounding resistors may be used to establish a symmetrical grounding point for a delta transformer secondary.

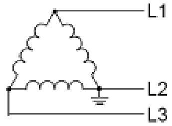
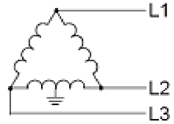
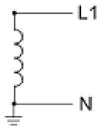
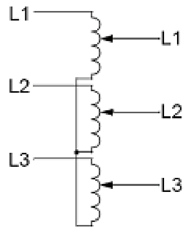
Corner grounded TN systems – EM1, EM3, F1 and F2 must be out			
Grounded at the corner of the delta		Grounded at the mid point of a delta leg	
Single phase, grounded at an end point		Three phase "Variac" without solidly grounded neutral	

Figure 9. Unsymmetrically Grounded Networks

Symmetrical system grounding provides the best protection and is the recommended type to use whenever possible. However, drives may be used on all of the above systems. In some cases EMC filters or MOV protection must be disabled. Consult the pertinent Hardware Manual or User's Manual for further information. Reference the Grounding & Cabling of the Drive System document number 3AFY61201998 for detailed ground information.

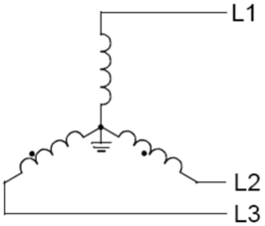


Figure 10. Symmetrically Grounded Network

In many cases, internal drive EMC filters can only be applied on symmetrical systems. The type of system grounding present should always be checked before specifying internal drive EMC filters.

Available short circuit current

All drives carry very high short circuit current ratings based on UL508C testing. It is nonetheless critical that the short circuit and ground fault protection device used to protect the drive's power input follows the recommendations made in the pertinent Hardware Manual or User's Manual. Failure to follow these recommendations can lead to unsafe equipment failure.

It is recommended that all LV Drive applications include short circuit and overload protection per the product Hardware Manual or User's Manual.

Power factor correction capacitors

In general, having power factor correction capacitors on the same network as a drive is not recommended. There are two reasons for this. First, unless sophisticated switching means are applied, capacitor switching generates ringing voltage transients that commonly cause drive Overvoltage trips (see Voltage transients below). Second, unless the power factor correction banks are combined with detuning reactors, drive current harmonics can cause series or parallel resonance between system inductances and the bank capacitance. Series resonance will lead to capacitor overheating or capacitor protection tripping. Parallel resonance can lead to large magnitude voltage ringing that can damage equipment insulation and cause drive overvoltage tripping.

If power factor correction must be present on the same network as AC drives, it should be reviewed by the bank supplier to ensure that appropriate reactor detuning is implemented.

Voltage transients

Voltage transients are present on all networks. Likewise all drives include design features to make them insensitive to voltage transients.

Voltage transients typically occur in one of two quite different forms. The first form is a ringing transient voltage. A common example of this is the transient voltage that occurs when power factor correction capacitors are switched on or off line. This action causes an exponentially decaying voltage ring which is superimposed on the fundamental voltage. The magnitude of the peak voltage is less than twice the normal peak line voltage. The frequency of the ring is usually in the 400 Hz to 2000 Hz range. Peak voltages are, thus, present for 100 microseconds to 500 microseconds and occur more than once over a period of about 10 milliseconds. This type of transient typically causes a drive DC bus overvoltage fault. Many drives include either line reactors or DC link reactors to protect against this type of transient.

The second type of transient involves peak voltages that are much greater in magnitude and much shorter in duration. Peak voltages in the thousands of volts with durations of 50 microseconds or less are most common. Such transients usually occur singly and without ringing. They are associated with lightening strikes or short circuit failures of other equipment on the network. Most drives include transient voltage surge suppressors (TVSSs / MOVs) to protect against this type of transient voltage.

The unknowns in dealing with voltage transients are their variable duration and their variable energy content. Most drives can handle typical industrial transients without taking any special steps. However, some applications lead to the presence of especially severe transients (e.g. arc furnace installations). Likewise, some drive designs are more sensitive to transients (e.g. machinery drives that don't include reactors). In such cases, the application should be reviewed to determine whether additional steps should be considered (e.g. extra line reactance or external TVSS circuitry).

Open delta

Open delta networks can be especially troublesome when applying AC drives. Open delta networks inherently have different impedance levels on a phase to phase basis. Directly this doesn't typically create a problem. However, as a consequence of the different impedances present, line voltage balance often suffers. If the voltage imbalance exceeds 3%, the current into the drive becomes excessively unbalanced (20% or more). This can cause excessive drive heating. If the voltage imbalance is extreme, the drive starts to operate in a single phase input mode and will likely trip on a phase fault.

Another issue associated with open delta networks is that in the presence of single phase switching loads on the "real" phases, a large 3rd harmonic voltage develops. The two real phase to phase voltages become trapezoidal (flat topped) whereas the third vector sum generated phase to phase voltage becomes very triangular with an inordinately high peak voltage. This again leads to single phasing at the drive input and a likelihood of phase fault trips.

The recommendations here are to keep the drive kVA small with respect to the network feeder transformer kVA and to avoid single phase switching loads. Once such a problem is present, it is very difficult to circumvent without greatly over sizing the drives involved.

Existing harmonic content

Existing harmonic content will not adversely effect drive operation. However, if a system specification requires that the drive not cause harmonics above a specified level, remember that pre-existing harmonics are additive to newly generated harmonic content from the drive.

Operation from a local generator

Local generators often experience voltage regulator problems when operating nonlinear loads such as AC drives. In general to help ensure stable operation the kVA rating of the generator should be at least twice the kVA of all connected nonlinear loads. The generator may be loaded above this effective 50% loading point with additional linear loads. To ensure voltage regulator stability it is also recommended that the base load on the generator not be allowed to drop below 10%. This helps avoid surging and over voltage trips.

Single phase input operation

A limited number of drives are designed, rated, and listed to operate from a single phase power source. In some cases de-rating must be carefully followed and applied. It is also sometimes possible to use a drive designed for three phase input with single phase input. However, this capability is not always available and the de-rate required varies widely. ABB Application Engineering should always be contacted before attempting this approach. Only drives listed for single phase input maintain a UL listing when fed from a single phase source.

Motor factors

Maximum motor lead length

All drives are limited with respect to the maximum motor lead length that they can support. This limitation occurs because the drive must supply additional current to charge or discharge cable capacitance. The cable charging current is relatively large for small motors and relatively small for larger motors. Cable capacitance (and thus charging current) increases as cable length increases. For this reason small drives are typically limited to about 100 ft whereas large drives may support up to 1000 ft. When multiple motor cables or parallel motor cables are involved the motor lead length that applies is the sum of all motor lead lengths.

Charging current is also impacted by the switching frequency at which the drive operates. This is why permissible cable length may increase at lower switching frequencies.

Insertion of an output reactor (or dv/dt filter) between the drive output and motor often allows the motor cable distance to be increased. This is because any reactance inserted in series with the cable causes the peak capacitive charging currents to be reduced. Consult the Hardware Manual or User’s Manual for more details.

Selection of a drive that is sized one size larger than that which would normally be applied also often allows the motor lead lengths to be increased from those listed in the Hardware Manual or User’s Manual. Contact ABB Application Engineering for more information.

A requirement to meet EMC standards limits motor lead lengths to even a greater degree. This is because the motor leads act like an antennae when it comes to propagating EMC noise. Consult the Hardware Manual or User’s Manual for more details on EMC lead length limitations.

As a final clarification, motor lead length limitations listed in the Hardware Manual or User's Manual should NOT be interpreted as a statement concerning permissible motor lead lengths with respect to the impact of voltage reflection on the motor. This is a separate issue which is discussed in the next section.

Winding insulation

AC drives generate voltage outputs that change hundreds of volts in 400 nanoseconds or less. Due to a phenomenon called voltage reflection this can lead to peak motor winding voltages that reach 1500 V peak or more. If the motor's insulation isn't designed to handle these peak voltages the windings can rapidly deteriorate and fail.

This phenomenon is a function of motor lead length. It is generally agreed that motor lead length distances from 5 to 30 ft typically aren't a problem. Beyond 30 ft voltage reflection should be taken into account. Below 5 ft extremely high dv/dt needs to be taken into account.

The easiest way to deal with this issue is to specify an inverter duty motor that is designed to comply with NEMA MG1, Part 31, section 31.4.4.2. This specification ensures that the motor's insulation can meet both the peak voltage stress and high dv/dt stress that an AC drive can create.

If a motor that doesn't meet this specification will be utilized, then a dv/dt output filter should be installed between the drive and motor to help protect the motor windings. Again, this is usually not necessary if the motor lead lengths fall within the 5 to 30 foot window mentioned above.

Dynamic brake protection hardware

A dynamic brake chopper connected across a drive's DC bus can be applied in conjunction with dynamic brake resistor to dissipate regenerative motor energy. If the drive to which the chopper is connected has only a simple diode input structure, then external circuitry is required to provide protection for the chopper and resistor. The necessary hardware and circuit wiring is documented in the drive's Hardware Manual or User's Manual. It is the responsibility of the user to order and install the necessary equipment.

Multiple motors on a single drive

All drives provide short circuit, ground fault, and motor overload protection for a single motor. However, when a single drive is used to supply multiple motors then additional external hardware is also required.

Motor overload protection is always required for each individual motor. If more than three motors will be supplied by a single drive or if the supplied motors are of different sizes then individual short circuit and ground fault protection will also need to be added. Often a separate distribution panel is needed to supply multiple motors connected to a single drive. The end user or system supplier is responsible for designing, purchasing, assembling, and installing all additional equipment required to implement a multiple motor system.

Meeting EMC requirements

All ABB drives have been designed to meet IEC EMC requirements when the recommended EMC filters are installed. The needed EMC filters may or may not be optional depending on the specific drive involved. In all cases it must be understood that meeting the EMC standard at the installed system level relies heavily on the use of recommended cabling and installation practices. ABB can assist in recommending what needs to be done to increase the likelihood of achieving a compliant EMC installation; however, ultimately this responsibility lies with the system installer.

Power cable termination

For various reasons, both input and output power cables may need to be increased in size from ‘normal’ cable size. In some instances paralleled power cables may also be needed or desired. In these cases a check should be made to ensure that the standard terminations provided on the drive are compatible with the intended cable sizing and number of cables. ABB Application Engineering should be contacted for suggestions if an incompatibility is found.

Mechanical Installation

General

When mounting a drive its general location, orientation, and clearances from other equipment should all be considered. Flange mounting or vibration mounting necessitate additional considerations.

Location

Ideally drives should be located in a clean, vibration free, 100 m altitude, 60% relative humidity, 20º C (68º F) ambient temperature environment. Drives can tolerate environments that deviate significantly from these ideals. However, these characteristics represent the 'sweet spot' that will maximize drive life and drive reliability. It is always a good idea to keep this 'sweet spot' in mind when making decisions concerning where a drive will be located.

Mounting orientation

Drives are designed for vertical mounting. Mounting in any other orientation may jeopardize proper cooling. Even with a forced cooled drive it can't be assumed that orienting the drive in a non-vertical manner will be acceptable. Although this will usually cool power components properly, it can lead to overheating of control electronics. Always contact ABB Application Engineering for assistance if a non-standard mounting configuration is being considered.

Clearance requirements

Drive spacing requirements vary. Always consult the Hardware Manual or User's Manual for specific details. Usually this information is contained in a section entitled Mechanical Installation. In some cases the information may be contained in a Technical Data or Dimensional Drawing section. Failing to meet minimum spacing requirements can lead to improper cooling, drive tripping, and / or reduced drive life.

In addition to following minimum clearance recommendations, it is equally important to ensure that other heat producing components don't radiate or blow directly on a drive. In general, air internal to a cabinet should be sufficiently circulated so that no components (drive or other) are exposed to hot spot heating. If necessary, consider adding internal cabinet circulating fans (see "Cooling" section).

Flange mounting

Flange mounting kits are optionally available for many drives and drive modules. These kits include cutout and drilling templates in addition to full installation instructions. Flange mounting provides the ability to dissipate a significant portion of drive power losses external to the drive cabinet. In many instances, this allows the control section of the cabinet to be designed without ventilation. Typically, cabinets designed for flange mounting can meet Type 12 enclosure criteria. With the addition of special hoods, Type 3R designs are also possible.

If the flange mounting documentation provides a specific method for calculating what portion of the drive's losses will be dissipated externally, use the provided calculation method. If the documentation doesn't provide a calculation method, use this method to estimate the total losses inside the cabinet.

Assume a control related heat loss of 50 watts whenever the drive control power is on. Then, estimated heat loss inside enclosure = rated power loss * 0.10 + 50 W.

The Cooling section of this document explains how to estimate the temperature rise in the non-ventilated section of a cabinet.

Vibration mounting

Standard drives are designed to meet normal levels of shock and vibration as typically seen in industrial applications. Design shock and vibration levels are documented in the Technical Data section of the Hardware Manual or User's Manual. Normally international standard IEC 60068-2 applies.

In some drive instances, additional shock and vibration standards also apply. For example, the ACH550 drive is seismic certified per ICC-ES AC156. ABB has some shock mounting hardware that has been designed for marine service. This may also be usable in other applications. When special shock and vibration requirements are specified, contact ABB Application Engineering for assistance.

Cooling

Providing adequate drive cooling is a critical step in achieving a good drive installation.

Wall mounted drives and factory assembled cabinet drives include fully designed and tested cooling systems. The only responsibility of the installer is to ensure that a sufficient supply of clean cooling air is available and that the cooling air is within a temperature range compatible with the selected drive. Typically this will mean air with a temperature between 0º C (32º F) and 40º C (104º F). However, some drives accept air down to -15º C (5º F). Cabinet drives may include space heaters to comply with minimum temperature requirements. In some cases, drives may have been de-rated to operate at 50º C (122º F).

Type 12 drives and cabinet drives with filters can tolerate air with higher levels of pollutants. However, even filtered drives have practical limitations on air contaminates. A drive that needs its filters cleaned every 8 hours will probably not be considered a practical solution. Likewise, many chemical contaminants can't be tolerated even by filtered drives.

Stepping beyond wall mounted and factory assembled drives into the custom assembly of drives into cabinets involves significant additional complexity. Whoever assemblies drives into a cabinet assumes responsibility for:

- component power loss calculations
- internal cabinet temperature calculation
- required air volume calculation (if applicable)
- air flow design (if applicable)
- air conditioner / heat exchanger selection (if applicable)

Both non-ventilated and ventilated cabinet designs are possible; however, non-ventilated designs are quite limited in terms of the power losses that can be handled without resorting to adding an air conditioner or heat exchanger.

Both non-ventilated and ventilated cabinet requirements will be discussed; however, first, estimation of power losses will be covered since this is pertinent to all cabinet types.

Estimating power losses

Ensuring adequate cooling requires knowledge of the level of power losses present during normal operation of the drive equipment. The Hardware Manual and User's Manual document drive losses for rated normal duty current operation. Actual operation at a lower current output level reduces power losses.

Reduced output losses can be estimated with the formula:

$$L_{est} = L_{rated} \cdot \left(0.1 + 0.9 \cdot \left(\frac{I_{act}}{I_{2N}} \right)^{1.6} \right)$$

where :

L_{est} = estimated loss

L_{rated} = rated drive losses (see manual)

I_{act} = actual current

I_{2N} = rated normal duty current

For example, assume that a 30 Hp, 480 VAC drive has a rated normal duty current of 42 A. The drive's manual lists rated drive losses as 610 W. The motor connected to the drive has a nameplate current rating of 36 A. Estimated losses are:

$$L_{est} = L_{rated} \cdot \left(0.1 + 0.9 \cdot \left(\frac{I_{act}}{I_{2N}} \right)^{1.6} \right) = 610 \cdot \left(0.1 + 0.9 \cdot \left(\frac{36}{42} \right)^{1.6} \right) = 490 \text{ watts}$$

Estimates likewise need to be made for any auxiliary equipment mounted inside the cabinet containing the drive. The sum of all estimated drive losses plus auxiliary equipment losses, constitute the total power loss the needs to be considered in the cooling design.

Many applications have cyclical loading. This also means that the drive losses are cyclical in nature. In general, for total application cycle times of 5 minutes or less, simple averaging of power losses can be applied:

$$L_{est} = \frac{L_1 \cdot t_1 + L_2 \cdot t_2 + \ldots + L_n \cdot t_n}{t_1 + t_2 + \ldots + t_n}$$

where:

$$t_1 + t_2 + \ldots + t_n \le 5 \text{ minutes}$$

Any portion of an application duty cycle that runs for 30 minutes or more should be treated as continuous. Thus, the cooling design should be based on the power losses present during the 30 minute or greater period that has the highest power losses.

Duty cycles that are greater than 5 minutes in length but do not include individual power loss segments of 30 minutes or more are more difficult to estimate because thermal time constants need to be taken into account. Such cases either require a formal thermal analysis or need to rely on empirical testing to determine their cooling requirements. Such cases are beyond the scope of this discussion.

Non-ventilated enclosures

Non-ventilated enclosures provide the obvious advantage of not being sensitive to air borne contaminants. However, the level of internal power loss that can be handled is typically small. Often, a successful design hinges on ensuring that the maximum internal enclosure temperature won't exceed the maximum permitted operating temperature of the enclosed drive.

The temperature rise in a non-ventilated enclosure is a function of:

- total internal enclosure power loss
- enclosure surface area

A small amount of power loss can lead to what is often a surprisingly high internal temperature rise. For example, assume a totally enclosed cabinet measuring 20" x 16" x 10" (H x W x D) is used to house a small 2 Hp, 240 VAC drive which has total losses of 90 W. This enclosure will experience a temperature rise of 22º C (39º F). If the drive ambient can't exceed 40º C for the drive to maintain its rated output current, then the ambient temperature can't exceed 18º C (65º F). This is likely not what a user would expect (or want). This simple example shows how important it is to perform a proper cooling analysis.

The temperature rise in a non-ventilated enclosure can be estimated using the formula:

$$\Delta T = \frac{C_m \cdot L_{est}}{2 \cdot H \cdot W + 2 \cdot W \cdot D + 2 \cdot D \cdot H}$$

where:

ΔT = temperature rise (°C)

C_m = enclosure material constant,

= 330 for painted enclosure,

= 420 for stainless steel or bare aluminum enclosure

L_{est} = estimated internal losses (W)

H = enclosure height (in)

W = enclosure width (in)

D = enclosure depth (in)

Mechanical Installation

Looking at this issue from a different perspective, the power loss that can be tolerated by a non-ventilated enclosure is a function of:

- maximum ambient temperature
- maximum drive cooling air temperature
- enclosure surface area

The power losses that a non-ventilated enclosure design can handle can be estimated using the formula:

$$L_{\max} = \frac{(2 \cdot H \cdot W + 2 \cdot W \cdot D + 2 \cdot D \cdot H) \cdot (T_{\max} - T_{amb})}{C_m}$$

where:

$L_{\max}$ = maximum tolerable loss (W)

H = enclosure height (in)

W = enclosure width (in)

D = enclosure depth (in)

$T_{\max}$ = maximum drive cooling air temperature (^{o}C)

T_{amb} = ambient temperature (^{o}C)

C_m = enclosure material constant,

= 330 for painted enclosure,

= 420 for stainless steel or bare aluminum enclosure

Ventilated enclosures

Utilizing a ventilated enclosure greatly enhances the enclosure's ability to tolerate larger internal power losses. The power loss that can be tolerated by a ventilated enclosure is a function of:

- maximum ambient temperature
- maximum drive cooling air temperature
- air volume passed through the enclosure

The volume of air flow required by a ventilated enclosure can be estimated using the formula:

$$V_{air} = \frac{1.75 \cdot L_{est}}{T_{\max} - T_{amb}}$$

where:

V_{air} = required air volume (CFM)

L_{est} = estimated internal losses (W)

$T_{\max}$ = maximum drive cooling air temperature (^{o}C)

T_{amb} = ambient temperature (^{o}C)

Select a fan (or fans) capable of supplying this volume of air flow or more. If the enclosure design includes air filters to keep out air borne contaminates, make sure that the fan selection takes the filter pressure drops into account. It is common for fan air volumes to drop to 50% or less when operating at a pressure of 0.5 inches of water. In some cases it may be necessary to include both intake and exhaust fans to properly compensate for air filter pressure drops.

For application of less than ~800 total drive horsepower and less than ~10 drives in one enclosure, some very simple estimations may be made in lieu of the more advanced calculations presented above.

1. Sum all the rated airflows of the LV Drives in the enclosure
2. Select enclosure fan(s) to meet the calculated cfm above
3. Calculate the total area of the exhaust area for the fan(s) and then double that for the appropriate filter area intake

This simple strategy ensures adequate air flow through the enclosure and minimal back pressure through the air intake filters.

Of almost equal importance to ensuring adequate air volume is the issue of ensuring an effective air flow pattern. Although effective cooling is especially critical for some equipment (e.g. drives), typically all components need cooling. As such, the enclosure's internal air flow must ensure that all components get their required share of the total air flow. This may mean that air baffles need to be strategically placed to direct and divide the air flow as needed. Care should be taken to ensure that no air 'dead spots' or 'hot spots' occur.

An important factor in achieving effective air flow is the selection of the air intake and air exhaust locations. Typically it is best to have air intakes occur at a lower point on the cabinet and air exhaust occur at a higher point on the cabinet. This helps ensure that hot air doesn't end up getting trapped near the top of the enclosure. It is also better to have a design that pulls air across the full width of the cabinet so that a 'hot side' doesn't develop.

Heat exchangers / air conditioners

In some applications the severity of air borne contaminants (particle or chemical) renders air filters unacceptable. If internal enclosure losses are very low, simply using a non-ventilated enclosure can resolve the issue. But, in most cases, internal losses will necessitate an impractically large enclosure to achieve a sufficient cooling surface area. Often, moderate sized drives can be successfully applied by utilizing flange mounting to dissipate the majority of drive losses external to the enclosure, and then relying on the enclosure's surface area to only dissipate the remainder of the internal losses. However, in the case of large drives, or multiple drives in the same cabinet, a point is reached where internal power losses can only be handled through using a heat exchanger or air conditioner.

The design of enclosures with heat exchangers or air conditioners is beyond the scope of this document. Such designs are best implemented by designers who work with this equipment on a regular basis. ABB recommends contacting a drive integrator with expertise in this area.

⚠ For temperature controlled equipment rooms or enclosures the target air temperature should not be below 20º C (68º F). Excessive cooling and large temperature differential increases the potential for formation of condensation. The recommended range for controlled air temperature in an enclosure is 20º C (68º F) to 30º C (86º F).

Electrical Installation

Overload, short circuit, and ground fault protection

All drives include overload and short circuit protection. Most drives also include ground fault protection. These circuits are designed to trip the drive and stop drive output whenever a problem is detected. However, these protection circuits don’t provide short circuit or ground fault protection for problems which may occur internal to the drive, on the drives DC Bus or for problems in the feeder circuit to the drive. For this reason separate external circuit interruption equipment is required that provides short circuit and ground fault protection in accordance with National Electrical Code (NEC).

Although most cabinet drives include protection fuses to provide short circuit and ground fault protection for the drive, most wall mount and panel mount drives do not. Even when this protection is provided, it only protects the drive. It doesn’t protect the feeder circuit to the drive.

The installer must always provide external short circuit and ground fault protection per the NEC to protect the feeder to the drive. If the drive doesn’t include internal fuse protection, then the short circuit and ground fault protection supplied by the installer must also meet the protection requirements as stipulated for the drive.

The Hardware Manuals and User’s Manuals include tables that list recommended protective fuses versus drive size. Presently, only fuses (not circuit breakers) are recommended. If desired, a circuit breaker may be installed in series with the recommended fuses to serve as a disconnect and overload protection.

ABB documentation calls out 600V, UL class T, fast acting fuses (Bussmann JJS). Any 600V, fast acting, current limiting fuse which provides similar time-current and peak let-through characteristics is an acceptable alternative. This includes UL class CC, J, and L fuses which don't provide time-delay (Bussmann KTK-R, JKS, DFJ, and KTU). True high speed semiconductor fuses are also acceptable (Bussmann 170M…). Other vendors equivalent fuses are fully acceptable.

Grounding issues

It is important to recognize the difference between equipment grounding and network grounding. Equipment grounding (also referred to as equipment bonding) is primarily associated with personnel safety. Indeed it is common practice for the terms "equipment ground" and "safety ground" to be used interchangeably. The fundamental goal of equipment grounding is to keep all equipment at a common potential. Network grounding, on the other hand, is intended to limit phase to ground voltages to known predefined levels. The type of network grounding implemented is a conscious decision made by the person responsible for the electrical characteristics of the network (e.g. a plant electrical engineer). The drive installation factors with respect to equipment grounding and network grounding will be discussed separately.

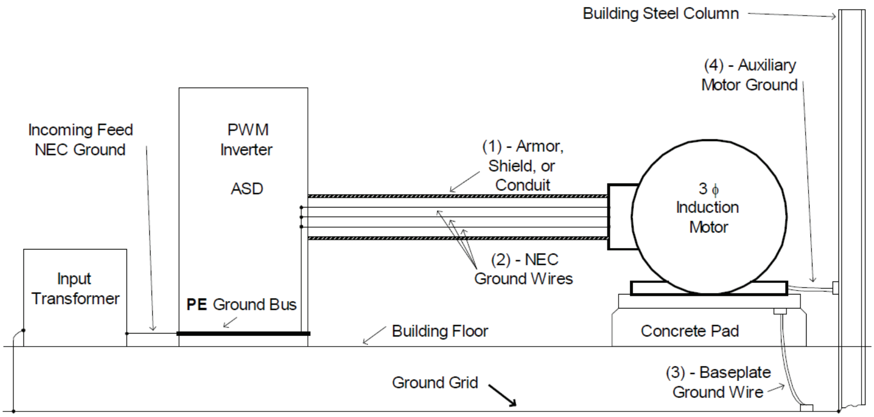


Figure 11. Electrical Diagram of System Grounding

Electrical Installation

Equipment ground

The primary goal of equipment grounding is to keep all frame structures (drives, motors, enclosures, etc.) at a common potential. This is done to ensure personnel safety. Regardless or what equipment a user may touch, he will be safe provided the potential of all equipment is the same.

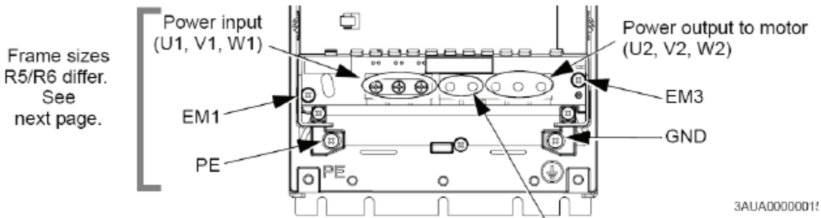
Equipment grounding should be implemented in accordance with NEC sections 250.110 through 250.126. These NEC sections clarify what needs to be bonded together, what materials and techniques can be utilized to do this, and what minimum size conductors must be applied. Compliance with these code sections will ensure a safe installation.

For safety purposes the potentials of concern occur at the utility frequency (normally 60 Hz). However, drives also produce high frequency outputs. Equipment grounding (bonding) plays a very important role in keeping these high frequencies flowing through preferred paths. This is especially true between the drive output and its connected motor. Special cabling and wiring practices are required to implement equipment grounding in a manner that optimally controls high frequency currents. See the “Cable and wiring” section for complete details.

Network ground

The type of network ground present determines the maximum voltage level the drive will likely experience from each of its input power phases to ground. These voltage levels are important because internal EMC filters can be damaged if the voltage to ground becomes excessive. An ungrounded system may also put excessive stress on internal MOV protection.

The Hardware Manual or User's Manual should be consulted to determine what, if any, special steps may be required during drive setup to handle the type of network grounding present. In some cases, one or more grounding screws must be removed. In some cases, screws may need to be installed in order to fully activate internal EMC filters. None of the described screws impact personal safety with respect to equipment grounding. For example, Figure 12 shows an excerpt from the ACS550 User's Manual that documents how to handle EM1 and EM3 screws.



Optional braking

Frame size	Terminal labels	Brake options
R1, R2	BRK+, BRK-	Brake resistor
R3, R4	UDC+, UDC-	• Braking unit • Chopper and resistor

WARNING! For IT systems and corner grounded TN systems, disconnect the internal EMC filter by removing:
- On ACS550-01: screws EM1 and EM3
- On ACS550-U1: screw EM1 (drive is shipped with EM3 already removed).

See *IT systems* on page *268* and *Corner grounded TN systems* on page *267*.

Figure 12. EMC Filter Connections – Ungrounded Power Network

Dynamic brake protection

A drive installation that includes a dynamic braking resistor needs external circuitry to protect its DB resistor and brake chopper. This protection equipment is necessitated because DB resistors are normally not rated for continuous operation and, thus, aren't protected by the drive's standard overload protection. In addition, a failure of the brake chopper will likely lead to uncontrolled current flow into the brake resistor.

Drives which deactivate their input bridge SCRs to provide brake chopper protection represent an exception to this external hardware requirement. The ACS800 frame R5 to R8 drives for example, have the ability to internally interrupt chopper faults. All other drives require external circuitry. The necessary hardware and circuit wiring are documented in the Hardware Manual or User's Manual.

Multiple motors on a single drive

All drives provide short circuit, ground fault, and motor overload protection for a single motor. However, if a single drive is used to supply multiple motors then additional external hardware is also required.

In multiple motor configurations, separate motor overload protection is always required for each individual motor. Figure 13 shows a simple two motor configuration. When selecting an electronic overload always check that it is recommended for use with AC variable frequency drives. Conventional thermal motor overloads are typically compatible.

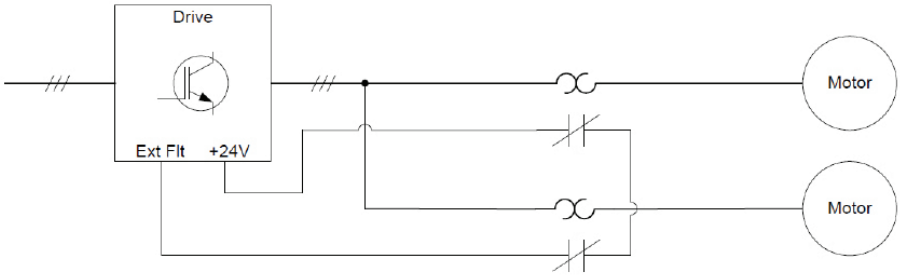


Figure 13. Simple Multiple Motor Connection

If more than three identical motors are supplied by a single drive, or if two or more motors of different sizes are supplied by a single drive, then in addition to individual overloads, individual short circuit and ground fault protection must also be supplied. In some cases, properly selected fuses can provide overload, short circuit, and ground fault protection in a single device set.

The end user or system supplier is responsible for designing, purchasing, assembling and installing all additional equipment required to implement a multiple motor system.

For more information on multiple motor configurations and requirements when applied to AC drives, contact ABB Application Engineering for assistance.

Cabling and wiring – Power

Cabling and wiring of an AC drive presents both similarities and differences as compared to the cabling and wiring of traditional power equipment. Power cables are sized normally. They are subject to the same de-rating based on number of cables present and ambient temperature. On the other hand, special cable types are recommended and special termination procedures apply. Special recommendations concerning separation and routing of control wiring and power cables also apply. Unique aspects will be discussed for each of the wiring of cabling areas impacted.

Drive power input

Drive input power cabling is usually handled with a conventional power cable type. The exception to this is an installation that must meet IEC EMC requirements. In this case, a cable type similar to that recommended for the drive to motor cable should be used (see “Drive power output / motor”).

Cables should be sized in compliance with sections 430.6 and 430.21 through 430.25 of the NEC. In most cases, cables will need an ampacity equal to 125% of the drives normal duty current rating as indicated on the drive nameplate.

If cables are very long they may need to be increased in size to reduce their voltage drop. In general, cable voltage drops exceeding 3% under rated load conditions should be avoided.

Cables may also need to be increased in size due to code required conductor quantity adjustment factors (NEC Table 310.15(B)(2)(a)) or code required ambient temperature de-rates (NEC Table 310.16 Correction Factors). Parallel conductors are often applied at higher current levels. Conductor quantity de-rating is likely to apply.

A ground conductor should always accompany the three power phases. If conduit or another form of raceway is relied upon to provide the equipment ground, make sure it's well bonded throughout its entire path. NEC Table 250.122 clarifies the minimum equipment grounding conductor size that applies.
When parallel conductors are utilized they should be kept the same length. Best practice is to keep three phase groups together. For example, if 3, three conductor plus ground cables are to be paralleled to achieve necessary ampacity, then each cable should contain an A phase, B phase, and C phase plus ground.

Input cables to multiple drives may be run in the same conduit.

Always double check all terminations to ensure proper tightness. The Hardware Manual or User's Manual lists recommended tightening torque for all power connections.

Drive power output / motor

The pulse width modulated (PWM) nature of an AC drive's output places unique requirements upon the cabling from the drive output to its associated motor(s). Besides needing to handle normal power level currents and voltages, the cable must (1) provide a low impedance high frequency current return path from the motor back to the drive, and (2) provide high frequency shielding qualities not normally required from a power cable.

The PWM output of an AC drive effectively creates a rapidly changing common mode voltage to ground. The motor cable and motor windings which carry this common mode voltage inherently include parasitic capacitance to ground. The combination of common mode voltage to ground and capacitance to ground causes high frequency currents to be injected into the cable and motor ground (I = C*dv/dt). If these currents end up flowing in the general building ground system, they can cause problems with sensitive electronics that shares the same system ground. For this reason, it is very important that as much of the high frequency current as possible flows back to the AC drive via the ground path provided by the drive output cable. Achieving this puts special requirements on the cable that connects the drive to the motor. Figure 14 emphasizes the important role played by the motor cable. A properly armored / shielded motor cable is shown carrying 90% of the high frequency ground currents directly back to the drive. Only 10% of the high frequency ground currents flow through the general system ground.

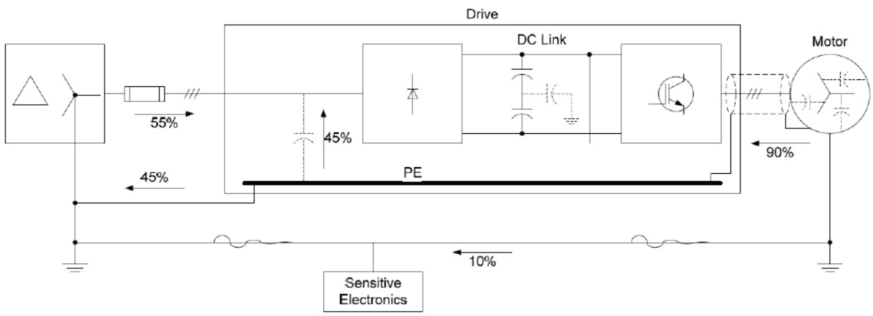


Figure 14. Motor Cable Connection & Proper Grounding

Achieving this desired high frequency current flow requires that the motor cable be implemented with either:

- continuous corrugated aluminum armored MC cable
- power shielded cable
- a fully bonded steel conduit (360º electrical contact joints)

The primary functionality that is desired from all of these cabling solutions is to provide a low impedance grounding path back to the drive. This is achieved through the large surface area coaxial geometry provided by either the armor, shield, or conduit.

In addition to the armor or shield that is recommended, ABB also recommends using a cable with three symmetrical grounds on all cables where the main phase conductors are 8 AWG or larger. This symmetry helps ensure that no low frequency ground voltage differences are induced in the cable ground conductor. Figure 15 shows a cable with the described construction. It includes three 250 MCM power phases and three 4 AWG ground wires. Figure 15 shows a side view of the same cable with the armor insulation removed from the last 1½ inches as would be done prior to installing a metal clad fitting.

Figure 15. Continuous Corrugated Armored Cable

Proper termination of the motor cable is of equally high importance. Both armored cable and shielded cable solutions should be terminated using a metal-clad cable fitting on both the drive and motor ends. The cable supplier should be relied upon to recommend the best fitting for the cable type and size being utilized. Figure 16 shows an example of the typical fitting assembled to a cable. Also note the triple ground wires previously discussed.

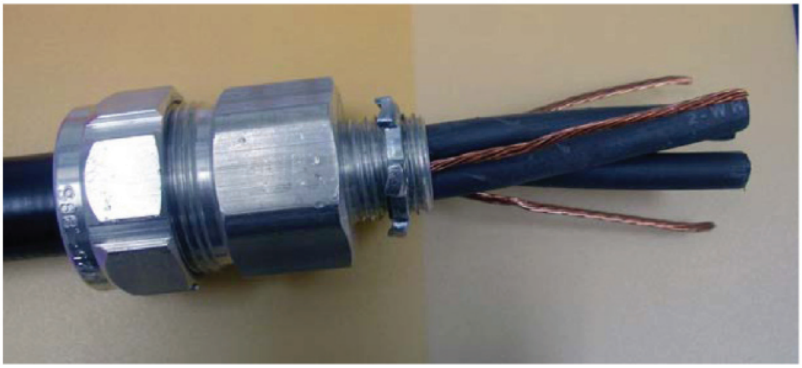


Figure 16. Metal-Clad Cable Fitting

Motor cables should be sized in compliance with sections 430.6 and 430.21 through 430.25 of the NEC. In most cases, cables will need an ampacity equal to 125% of the drives normal duty current rating as indicated on the drive nameplate.

If cables are very long they may need to be increased in size to reduce their voltage drop. In general, cable voltage drops exceeding 3% under rated load conditions should be avoided.

Cables may also need to be increased in size due to code required conductor quantity adjustment factors (NEC Table 310.15(B)(2)(a)) or code required ambient temperature de-rates (NEC Table 310.16 Correction Factors). Parallel conductors are often applied at higher current levels. Conductor quantity de-rating is likely to apply.

For best results, when using conduit, each drive output should be run in a separate conduit. If separate conduits are not practical, as a minimum, drive outputs that differ by more than a power ratio of 10 (largest motor power / smallest motor power > 10) must be run in separate conduits. Also be aware that if common output conduits are utilized, it may be necessary to turn off drive earth fault protection to stop drives from experiencing false earth faults.

Always double check all terminations to ensure proper tightness. The Hardware Manual or User's Manual lists recommended tightening torque for all power connections.

Dynamic brake resistor

Power cabling to a dynamic brake resistor should be accomplished using the same type armored, shielded, or conduit cabling applied to the motor output wiring. The dynamic brake cable should be sized the same as the motor cable.

The maximum permitted distance between the brake chopper and the resistor that it supplies is 10 m (33 ft). Braking resistor wiring should not be combined with any other cabling.

Always double check all terminations to ensure proper tightness. The Hardware Manual or User's Manual lists recommended tightening torque for all power connections.

Shield Termination

All cable armor, cable shielding or steel conduit associated with power wiring must be grounded at both ends. This should be done in a manner which provides continuous 360 degree electrical continuity around the periphery of the armor, shield, or conduit. Tight bonding is required to ensure that a low impedance path is provided for high frequency ground return currents. This step is critical to providing an installation that minimizes the likelihood of experiencing electrical noise interference from the AC drive. It is, likewise, very important in minimizing the occurrence of high frequency motor bearing current damage.

Cabling and wiring – Control

Cable type

Different control signals require different cable types. Belden cable types are provided for reference. Cable types from other vendors that provide similar construction and electrical characteristics are fully acceptable.

120 VAC control should utilize standard 600 VAC single conductor wire (e.g. THHN/THWN) or multi-conductor tray cable.

24 VDC (or 12 VDC) control should utilize multi-conductor twisted pair control cable. An overall shield is recommended but not required. Twisted pairs should include the control signal and its associated supply common. Representative 18 AWG unshielded Belden types include 9740, 9156, 8690, 9157, 9159, 8691, and 9161 (1, 2, 3, 4, 5, 6, and 8 pair respectively). Representative 18 AWG shielded Belden types include 9318, 9552, 9553, 9554, 9556, and 9559 (1, 2, 3, 4, 6, and 9 pair respectively).

Analog signals (0 – 10 VDC or 0 – 20 ma) should utilize individually shielded multi-conductor twisted pair control cable. Representative 18 AWG individually shielded Belden types include 9318, 9368, 9369, 9388, 9389, and 9390 (1, 2, 3, 4, 6, and 9 pair respectively). Encoder signals should utilize low capacitance individually shielded twisted pair cable. Representative 24 AWG shielded Belden types include 9729, 9730, and 9728 (2, 3, and 4, pair respectively).

Fieldbus signals should utilize the cable as recommended in the fieldbus manual covering each specific protocol product offering.

Routing and separation

Control signals should never be run in a conduit or multi-conductor cable that contains power wiring of any kind. Likewise, 120 VAC control should be kept in a separate conduit or multi-conductor cable from both power wiring and all other control (24 VDC, analog, encoder, or fieldbus). Thus, three separate conduit or cable runs are typically required: power, 120 VAC control, and all other control.

The minimum recommended spacing between control and power wiring is 20 cm (8 in). This spacing recommendation is particularly important where long parallel runs of power wiring and control wiring occur. If, due to physical constraints, this minimum spacing can't be maintained, then power wiring and control wiring should be oriented to cross each other perpendicularly (at 90 degrees with respect to one another).

Shield termination

Any control wiring that utilizes shielded cable should only be grounded at the drive end. Termination points are provided on the drive to facilitate this. Never ground a control cable shield at both the drive and its source.

Control signal problems

The high level, high frequency, common mode voltage that AC drives create can interfere with sensitive electronics such as transducer sensors and fieldbus communications. In particular since field sensing devices often share a common ground plane with the frames of motors powered by AC drives, these sensing devices are often at risk. Control grounding or isolation practice plays an important role in preventing possible issues. Ground potential problems and ground loop problems represent related, but separate, aspects of this issue.

Ground potential problems occur because, when high frequencies are present, it is difficult to ensure that ground planes located a significant distance > 6m (> 20 ft) from one another remain at the same potential. In turn, these potential differences can cause electronic circuitry to malfunction whenever an input voltage exceeds an input device's common mode voltage rating.

Ground loop problems occur because the same described differences in ground potential can also cause currents to flow in any conductors that link the different ground potentials. This can either directly impact current signals (e.g. 4- 20 ma sensor outputs) or can indirectly induce noise in voltage signals (e.g. 0 – 10 VDC sensor outputs).

Practices intended to minimize both ground potential and ground loop problems are the same. These recommendations include all of the following.

If possible, control signals should float with respect to the local ground plane. Thus, if they are supplied by a local power supply, the output of the supply should not be grounded. Whenever possible, devices should be fed from the 24 VDC auxiliary power output of the drive.

When practical, sensors should be mounted in a manner that isolates their case body from ground. This helps reduce capacitive coupling to ground.

The shield of the control cable associated with the sensor should only be connected at the drive end. It should not be connected on the sensor source end.

If control signals must be grounded at their source, then inclusion of a signal isolator module just in front of the drive's analog input may be necessary. Appropriate space and mounting provisions should be considered in advance.

Meeting EMC requirements

Drives that are being exported to Europe often need to meet EMC requirements. When this is the case, ABB document "Technical Guide No. 3, EMC Compliant Installation and Configuration for a Power Drive System" should be referenced.

EMC compliant installations should always call out EMC filters in the drive. The selection between a 2nd environment (EN 61800-3 C3) or 1st environment (EN 61800-3 C2) filter depends on the application. Shielded cable should be used both for the drive motor output cable and the drive power input cable.

US installations seeking to minimize external electrical noise and minimize common mode currents in the general system ground should follow a similar approach. Figure 17 shows a general one line diagram where all connections have been optimized to minimize noise and common mode current in all external paths.

This configuration minimizes electromagnetic interference (EMI) both for conducted noise and radiated noise. In most applications it is the former that represents the most significant problem.

Note that when EMI / RFI filters are applied, the power source feeding the drive must be symmetrically grounded. Normally, a transformer with a center point grounded wye secondary is utilized. This is what is shown in Figure 17.

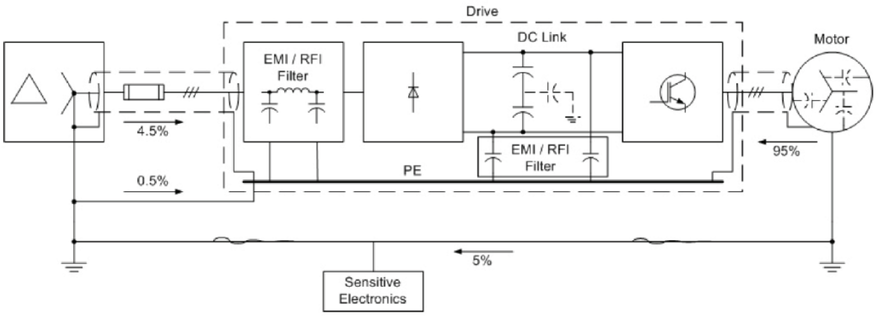


Figure 17. Optimized Connections to Minimize Electrical Noise

Index

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