An MCE Technical Publication

AC Motor Controls for Elevators

Motion Control Engineering, Incorporated

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Purpose

This technical publication is intended as a resource and guide for elevator consultants and contractors. Pertinent issues regarding proper application and installation of AC motors and drives are discussed. Information is based on our collective experience designing and manufacturing both controls and drives. Recommendations are the result of many years of experience analyzing and resolving customer problems.

Electrical noise, Radio Frequency Interference (RFI) and Electromagnetic Interference (EMI) are also addressed. Experience suggests that AC drives can generate noise that may affect radio-frequency-sensitive equipment in the building.
An understanding of these phenomena is required in order to select the best possible elevator drive system for a particular application.

Overview

The application of AC drive technology to various types of AC elevator motors requires a thorough understanding of the clear advantages and tradeoffs, in order to make the very best possible choices for AC drives and motors.

In addition, comparison of AC and DC motor and drive technology does not result in a clear-cut "winning" technology to be applied universally. Rather, each technology has unique advantages and disadvantages. The choice of either technology must take into account a wide variety of technical, environmental, and economic factors.

For new building construction, these issues can typically be addressed during the design phase. However, when modernizing elevator systems in existing buildings, thoughtful consideration is required. It is important to have a **basic understanding of the tradeoffs** that represent key determining factors in the motor and drive selection process.

In the discussion that follows, Variable Frequency AC drives are divided into two categories: **inverter drives** and **flux vector drives**.

Inverter drives are typically used for low speed, open loop (no encoder) applications. The simplest type of AC drive, inverter drives are non-regenerative – they do not have the ability to return regenerated energy back to the AC line when overhauling (empty car up or full load down). Regenerated energy must be dissipated across resistors in the form of heat.

Flux vector drives are typically used for high performance, closed loop (encoder required) applications with speeds above 150 fpm. **Standard flux vector** drives are also non-regenerative, requiring resistors for dissipating regenerated energy.

Motor Reuse or Replacement

GEARED APPLICATIONS – selection is job dependent:
Drive and motor selection are affected by the condition of the geared machine. When changing to a new machine, you may prefer to use an AC motor.

CAR SPEEDS TO 150 FPM (.75 m/s)

- **Existing**: Old AC motor
  Recommendation: Replace with New AC motor; use inverter drive

- **Existing**: DC motor in good condition
  Recommendation: Retain DC motor (especially above 40 HP)

- **Existing**: Old DC motor, below 40 HP
  Recommendation: Replace with New AC motor; use inverter drive (40 HP or above use Flux Vector Drive).

- **Existing**: Non-standard motor frame (hard-to-find/expensive replacement)
  Recommendation: Recondition (overhaul/rewind) existing AC motor

- **Existing**: Building has stringent RFI and EMI requirements
  Recommendation: Avoid changing to AC; however, when changing to AC, system may require grounding and additional filtering (anticipate costs).

CAR SPEEDS FROM 150 TO 450 FPM (.75 m/s to 2 m/sec)

- **Existing**: Old AC motor
  Recommendation: Replace with New AC motor; use flux vector drive.

- **Existing**: DC motor in good condition
  Recommendation: Retain DC motor (especially above 40 HP)

- **Existing**: Old DC motor, 40 HP or less
  Recommendation: Both DC and AC are good choices.
  Considerations: RFI and EMI requirements; lead time, staff training, etc. If this is your first conversion to AC there is an increased risk of making costly mistakes (ie: such as incorrect layout of equipment or wiring, no RFI filter, no drive isolation transformer).

- **Existing**: AC motor above 30 HP or...
  Helical gear machine or...
  Car speed above 300 fpm or...
  More than one car in the machine room

Recommendation: Considerable heat will be generated when overhauling. This heat must be removed from the machine room in order to keep the controller cabinet temperature below 104F degrees.

MOST GEARLESS APPLICATIONS – DC is still the best choice. Unless the DC motor is damaged or defective, replacing it with an AC motor will not result in improved performance. *Furthermore, see comments regarding delay on start under performance on page fourteen.* In gearless applications, since motors operate at low RPM, brush life and commutator maintenance are not significant issues.

There are two major concerns with AC gearless applications that will drive your decision making process.

HEAT

The primary concern is generation of very high heat output when overhauling which must be dissipated. For example, a 40 HP, 2:1 gearless AC with 50% counterweighting would produce 22KW of regenerated power in the form of heat.

COST

The alternative is to use a regenerative AC drive, which avoids the heat problem, but will cost one-and-one-half to two-and-one-half times as much as a non- regenerative drive (standard flux vector drive).

Retaining an Existing AC Motor

The following are considerations when retaining an existing AC motor. Note that newer AC motor designs are more efficient and draw less current than older single or two-speed motors. When reusing an existing AC motor, drives may have to be oversized (*extra cost*) in order to meet motor current requirement.

✓ **Accurate Nameplate Information.** Verify motor horsepower, voltage, full load current and full load RPM.

✓ **Actual Full Load Current**. Actual full load current is very important in order to accurately determine drive size. Particularly with older motors, nameplate data is sometimes inaccurate, illegible or missing. It is recommended that you measure motor current and RPM, with a full load, in order to calculate motor slip (see chart) and properly size the drive.

Drive Too Small

If the drive is not sized correctly, making a change in the field requires not only a drive change, but also changing the resistors in the dynamic braking circuit.

Drive Too Large

While a drive that is larger than necessary will not typically create problems, there is no reason to buy a larger drive than you need.

Calculating Motor Slip

Use the following tables to calculate motor slip (Fs) and slip percentage

Motor Rated Slip Frequency
Slip Frequency =
➢ Fs = F - (N x P) / 120
where...
- **Fs** = *Slip frequency (Hz)*
- **F** = *Motor rated frequency (Hz)*
- **N** = *Motor rated full load RPM*
- **P** = Number of poles

Slip Percentage
Once slip frequency (Fs) is calculated, slip percentage can be determined as follows:

➢ **Slip% = (Fs x 100) / F**
where...
- **F** = *Motor rated frequency in Hz*

Example

Here's how to calculate the slip frequency and slip percentage.

Obtain actual/nameplate motor RPM.

Motor Nameplate Data	
HP	20
Full Load RPM	**1170**
Volts	208
Phase	3
Hertz	60

Look up the Full Load RPM on the Synchronous RPM table to determine the number of poles (locate the closest higher RPM on the table to find the poles).

Synchronous RPM		
Poles	**60 Hz**	**50 Hz**
8	900	750
6	**1200**	**1000**
4	1800	1500

Then use the formula:
Fs = F - (N x P) / 120

➢ Fs = 60 - (1170 x 6) / 120 = 1.5
Calculate the slip percentage as follow:
Slip% = (Fs x 100) / F

➢ Slip% = (1.5 x 100) / 60 = 2.5
This is a low slip motor.

✓ **Slip requirements** - It is ***critical*** to know the exact slip of the motor in order to make the correct drive selection. Performance of vector drives, for instance, is optimized using low slip motors. You may encounter more adjustment difficulties when using a higher slip motor. There are some vector drives which simply will not operate properly with high slip motors.

Reusing an existing high slip motor may result in increased adjustment time (*cost*) and variations between UP vs DN speed (when using inverter drives).

Note: For gearless AC motors, calculating motor slip is <u>not</u> necessary because they are designed to work with modern flux vector drives.

Slip Requirements for new motors (based on current industry availability) to be used with Inverter & Flux Vector Drives.

INVERTER DRIVES (open loop)	**FLUX VECTOR DRIVES** (closed loop)
Motor slip should be **8% - 10%**. There may be minor variations in UP vs DN speed regulation, typical of inverter drives.	Motor slip should be **3% or less**.

In general, motors with **slip less than 5%** are considered **low slip** motors and motors with **slip more than 5%** are considered **high slip** motors. The correct motor slip factor will allow the drive to interact properly with the motor providing good performance. If motor slip is not accurately specified, the drive may not be able to control the motor properly.

Future development of drive technology may broaden the range of acceptable motor slip. For example, some drive manufacturers have developed "encoderless" vector drives, which can be thought of as a "missing link" between conventional inverter drives and true flux vector drives using encoders. These new drives are intended to provide performance superior to an inverter drive, but below that of a flux vector drive. If an encoderless vector drive is used, follow the drive manufacturer's recommendations for motor slip.

Note that the above information on motor slip is intended to be a guide. If a drive manufacturer claims to be able to handle specific motors, or recommends a particular slip range, their recommendations should be followed.

Using a New AC Motor

When replacing an existing AC or DC motor with a new AC motor, the following issues should be taken into consideration. A new motor can provide better performance and help reduce adjustment time (*hidden cost*). When buying a new motor be sure it is designed for AC drive applications (proper winding wire insulation).

WHEN BUYING A NEW MACHINE AND MOTOR...

✓ The object is to **select a motor which provides the required HP at contract speed** RPM required by the machine manufacturer. Machine designs typically cover three speed ranges:

- 750 - 900 RPM — Common
- 1050 - 1200 RPM — Most Common
- 1550 -1800 RPM — Less Common

✓ **Verify that the RPM required to run the machine at contract speed** matches the Full Load RPM of the motor (or is at least within 5% of the Full Load RPM of the motor). Use Full Load RPM data – *not synchronous RPM data* – to select an AC motor.

AC Drive Operating Characteristics

Below full load RPM	**Output produced in *constant torque mode***
Above full load RPM	**Output produced in *constant HP mode***

This means that, above full load RPM, AC motor output torque decreases. So the Full Load RPM of a new motor must be within 5% of the RPM required to run the machine at contract speed.

✓ **Verify correct slip:**

Inverter drives (open loop): Motor slip should be **8% - 10%**. There may be minor variations in UP vs DN speed regulation, typical of inverter drives. Future development of inverter drive technology may allow lower slip motors to be used.

Flux vector drives (closed loop): Motor slip should be **3% or less**.

✓ **Motor winding insulation** should be properly specified for AC drive applications.

WHEN BUYING A NEW MOTOR AND USING AN EXISTING MACHINE...

✓ **New motor Full Load RPM** should match existing motor RPM within 5%
Note: Verify the existing motor name plate full load RPM at contract speed.

✓ **Verify correct slip** as described above.

✓ **Motor should be designed** for AC drive applications (proper winding wire insulation).

Motor Drive Packages

Recognizing the challenge presented by matching the correct AC motor and drive, MCE offers motor and drive packages. These packages offer the convenience and security of manufacturer-matched components for greater assurance of project success.

Drives are factory programmed, based on new motor characteristics, in order to offer contractors a quicker, simplified installation process and improved system operation.

Input Line Impedance

“Stiffer” AC lines in AC drive applications may cause drive damage due to transients and surges. Drive manufacturers recommend 3% line impedance minimum. A “stiff” line is defined as one where voltage drop is less than 3% at the drive input when the drive draws rated input current.

Another example of the effects of line “stiffness” is when a VFAC drive (230V/460V, 25 HP or less) is connected to a large capacity transformer (600 KVA or greater, or more then 10 times drive KVA rating). In these cases, an additional AC line reactor is required in order to increase line impedance. The additional line reactor acts as a resistor, which limits charging current to the capacitor bank in the drive during AC line transients and surges, protecting the input bridge rectifier in the drive.

This problem is more critical when line frequency is 50Hz instead of 60HZ, because line impedance varies proportionately with frequency. A line reactor provides the additional benefit of reducing voltage harmonic distortion and increasing short circuit capability.

Some older drives used internal inductors to prevent input bridge damage. Unfortunately, contemporary drives no longer include inductors, which were sacrificed on the altar of competitive pricing.

Use of an isolation transformer provides the following benefits:

- Helps meet the 3% line impedance requirement
- Provides electrical isolation between the drive and power supply, reducing the effects of RFI
- Reduces harmonic distortion on the line

RFI/EMI Demons: The Need for Proper Grounding

All modern AC drives produce sufficient amounts of Radio Frequency Interference (RFI) to potentially affect the operation of equipment susceptible to this type of noise. The likelihood of encountering problems with RFI is increased in older buildings, where grounding is either inadequate or lacking altogether.

IGBT's as a Noise Source: Modern AC drives use power devices known as **Insulated Gate Bipolar Transistors**, or IGBTs. These devices make it possible to minimize annoying audible noise, using switching frequencies beyond the human audible range. Unfortunately, AC drives using IGBTs present a high potential for generating **Radio Frequency Interference**, or RFI.

The fast switching that characterizes these devices generates sharp-edged waveforms with high frequency components. The most likely complaint is **interference with AM band radios** in the 500-1600 kHz range. Noise-sensitive devices sharing the same power bus**,** including **computer** and **medical equipment,** could also be disrupted by interference.

HOW TO REDUCE THE EFFECT OF RFI AND EMI:

- ✓ Proper grounding, including correct ground conductor sizing
- ✓ Proper routing of field wiring
- ✓ Controller design and layout
- ✓ Use RFI filters
- ✓ Use drive isolation transformers
- ✓ Higher installation "standards of care"

GROUNDING

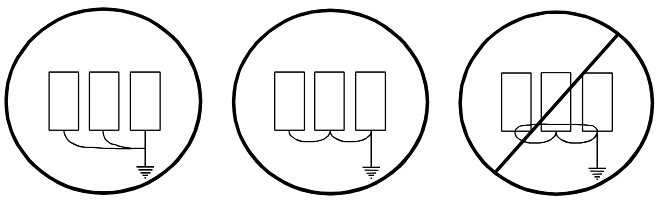
One contractor experienced multiple elevator system problems that were ultimately determined to result from the building's lack of good grounding. A solid earth ground was provided and many electrical noise problems were eliminated. Still, the elevator controller itself was being affected by undetermined sources of noise until proper grounding principles were applied (see Figure 1).

Proper Grounding Principles

- The ground wire to the equipment cabinet should be as large or larger than the primary AC power feeders for the controller. Ground wires should be as short as possible. Elevator system grounding should conform to all applicable codes.

- Direct, solid grounding must be provided in the machine room to properly ground the controller and motor. Indirect grounds may not provide proper grounding. Building structure grounds and water pipes can act as an antenna, radiating RFI noise. Improper grounding can render an RFI filter ineffective.

- Equipment cabinets should be grounded using a daisy chain or tree layout

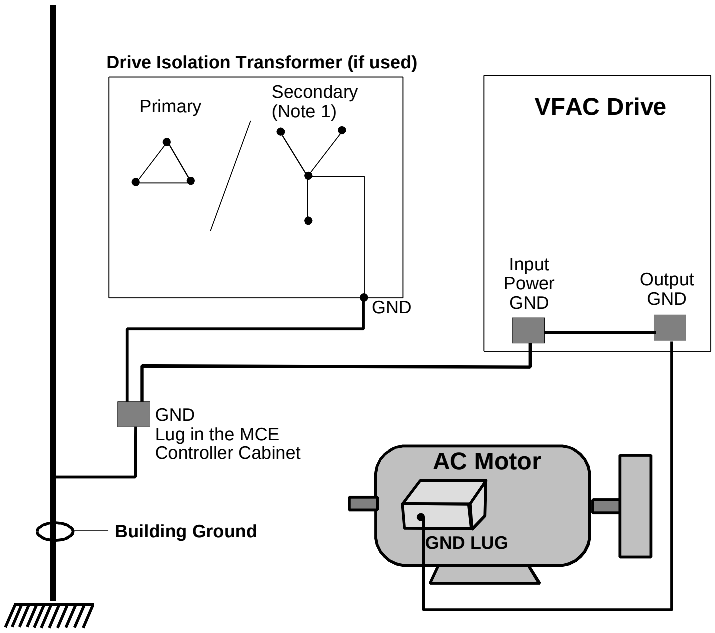


(a) Acceptable *(b) Acceptable* *(c) Not Acceptable*

- When routing filter wiring, avoid loops (as described above) which can render filters ineffective.

- Conduit containing AC power feeders <u>must not</u> be used for grounding.

Figure 1 (Grounding instructions)



Note 1: Grounding of the WYE secondary of the AC drive isolation transformer should be accomplished according to the drive manufacturer's recommendations.

WIRING THE CONTROLLER

Routing field wiring to the controller is a critical element in a quality installation. Use care to ensure that:

- ✓ Incoming power wiring (to the controller) and outgoing power wiring (to the motor) must be routed in <u>**separate**</u> grounded conduits.

- ✓ **Important:** ***Keep AC power leads separate from the control wires*.**
  AC motor wiring, both inside and outside the control enclosure, must be kept separate from <u>any</u> control wiring. This separation requirement includes routing of AC power feeders from the main line disconnect. <u>**No**</u> <u>**other conductors**</u> should be in the conduits for incoming AC power to the controller and outgoing power to the motor.

- ✓ Encoder wiring should be placed in a separate grounded conduit for flux vector applications.

PROPER LAYOUT

One contractor noticed that, when the controller cabinet door was opened, something affected operation of the controller's microcomputers. It was eventually discovered that the problem was caused by interference from the step down power/isolation transformer, located physically too close to the front of the controller. The ultimate remedy in this case was placement of a shield between the transformer and the controller. While other methods may have also worked, these difficulties are best avoided.

It is important to recognize that, in extreme cases, the **AC drive itself can be affected by electrical noise interference**. Elevator machine room equipment must be laid out correctly and wired properly.

RFI FILTERS

The use of RFI filters is **recommended** for all AC applications where a drive isolation transformer will not be used. **MCE**'s RFI filter should be specified when AC controls are ordered.

DRIVE ISOLATION TRANSFORMERS

For applications where RFI is critical (ie: hospitals, data processing centers, anywhere RFI-sensitive equipment is used), use of a drive isolation transformer is **recommended.** **MCE** can provide the isolation transformer, which should be specified when AC controls are ordered.

Marginally Sized Emergency Power Generators

Emergency power generator capacity must be sized **substantially larger** then the total power demand of elevator systems – for all static drive applications, AC or DC. Undersized generators can result in a variety of power-related problems.

Existing emergency power generators may be marginally sized – **at the theoretical minimum rating necessary to power elevators**. Under actual field conditions, static drives can place an excess burden on generators, resulting in poor elevator operation and frequent trip-off of either or both systems.

Compatibly problems result when the generating system is **unable to cope with the rapid changes in current demand** that typify static drives. These resulting frequency fluctuations can also cause trip-off of both systems.

Note that in general, natural gas generators – where regulation is a function of gas pressure – provide less satisfactory speed regulation (slower reaction to rapid changes in current demand) than better-regulated diesel-, turbine- and gasoline-driven generators.

EMERGENCY POWER CHECKLIST

- ✓ Selection of the proper elevator drive system includes a **thorough review of the various parameters of the existing** elevator control equipment, power distribution system, and emergency power generator. This examination should include: full load current, acceleration current, feeder size, emergency generator capacity and power source (natural gas, diesel, etc).

- ✓ **Obtain** the full load current, acceleration current, and so forth from static drive suppliers and manufacturers for proper sizing of emergency power generating capacity.

- ✓ **Discuss the issue of conversion to static drives** with the emergency power generator suppliers and manufacturers.

EMERGENCY GENERATOR SENSITIVITY TO HARMONICS

Static drives generate harmonic distortion that, in some instances, places an excessive burden on emergency generators. Emergency generators can be **sensitive to harmonics or other power line pollution** created by static drives.

- ✓ **Ask** the emergency power generator manufacturer **about system sensitivity** to harmonics and other noise.

EMERGENCY GENERATOR TOLERANCE FOR REGENERATED POWER

When emergency generators are being considered for an installation, their tolerance for regenerated power must be considered (i.e., the generator's ability to absorb energy being put back into the power lines by the AC or DC motor drive). Generally, the larger the elevator load is in proportion to the total load seen by the emergency generator, the greater is the risk of emergency generator problems associated with handling regenerated power from the elevators.

Where elevators comprise up to 25% of the total power consumption, as often is the case in larger buildings, regeneration is seldom a problem. However, when elevators make up a third or more of the total load, it may increasingly become an issue. The manufacturer of the emergency generator should be consulted to find how much, if any, regenerated power can be handled.

AC VS DC SCR DRIVE EFFICIENCY

Generally speaking, the most efficient drive type is the AC regenerative drive, which has unity power factor under all operating conditions. While it is sometimes claimed that AC drives are "more efficient" than DC SCR drives, this would only be true of AC regenerative drives. Comparison between AC non-regenerative drives and DC SCR drives is less clear cut.

A non-regenerative AC drive (by far the most common type) cannot return regenerated energy back to the AC line when overhauling. Instead, this regenerated energy must be dissipated across resistors in the form of heat. Therefore, to the extent that regeneration is occurring, the DC SCR drive in this case is <u>more</u> efficient due to the fact that all elevator DC SCR drives <u>are</u> regenerative, i.e., capable of returning power back to the power line.

Moreover, when the AC non-regenerative drive dissipates regenerated energy in the form of heat into the machine room environment, if air conditioning equipment is required to dissipate this heat energy, the power consumed by the air conditioning <u>further</u> adds to the loss in efficiency for the non-regenerative AC drive. However, this efficiency advantage of DC SCR drives over AC non-regenerative drives is somewhat tempered by the issue of power factor, which is highly variable for the DC SCR drive, and closer to unity for the AC non-regenerative drive.

Whether a system is geared or gearless, the amount of heat energy returned during regeneration increases in proportion to machine efficiency. The amount of regenerated power for a 30 HP geared machine, at 64% efficiency, could reach 9KW (or more) of regenerative power in the form of heat. With gearless machines, at 80%-90% efficiency, heat dissipation can easily exceed 16 KW of regenerative power for a 30 HP motor. A typical multi-car group will likely require a heat dissipation system in the machine room. When modernizing, cooling system capacity must be considered, the necessity of adding heat removal equipment determined, and future operating costs evaluated.

Hidden Costs

Use of AC drive technology represents the potential for encountering hidden costs that should be considered at time of purchase. Evaluate the following:

- ✓ Risk of improperly matched motor and drive
- ✓ Time required for system tuning and adjustment

Reliable, high quality performance should be delivered by an AC system once it is adjusted properly. However, these systems are less forgiving than DC SCR systems in a number of critical areas (as discussed in this publication). Proper care is required to protect a seemingly straightforward modernization project from substantial cost overruns.
AC applications require specialized expertise from both motor *and* control suppliers, along with good cooperation and coordination between the two.

Performance

A matched motor and drive pair will deliver the best ride quality. A byproduct of using the correct motor and drive is reduced adjustment time.

With regard to adjustment, AC systems should be able to achieve performance standards comparable to that of DC SCR systems, provided that the proper drive and motor are selected.

Recognize that AC drives have an inherent delay in starting, which may affect overall elevator performance time. Unlike DC applications, where the motor field is energized at all times, in AC applications, the motor is energized (via power contactor) on demand. Sufficient time must be allowed for magnetic flux to build within the motor before the brake can be lifted and the elevator car operated. Delay time may vary from 200 milliseconds to over one second, depending on motor characteristics. Therefore, all other factors being the same, the AC motor and drive must tolerate a delay on start which <u>does</u> <u>not</u> <u>exist</u> with DC motors and drives.

Failure to invest sufficient time and attention during the drive and motor selection stage of a project can result in longer adjustment time. **On occasion, it may simply not be possible to achieve required system performance**.

Heat Generation

Non-Regenerative AC Drives

In non-regenerative drives, commonly used with geared applications, overhauling energy is dissipated in the machine room through dynamic braking resistors. The amount of heat dissipated in the machine room is dependant on car speed, hoist motor horsepower, total car travel and duty factor. As any of the these factors increase, the amount of heat to be dissipated increases.

In general, if hoist motor horsepower increases above 30HP, and the elevator travel is over 100 feet, special considerations are required when sizing dynamic braking resistors. The question of how to remove this heat energy from the machine room must also be addressed.

Regenerative AC Drives

The ultimate solution to disbursing heat energy typically produced by a non-regenerative drive is to specify a regenerative VFAC drive. While relatively new to the elevator industry, these drives are quite suitable for gearless AC applications. Unfortunately, these drives presently cost more than twice what a comparable non-regenerative drive would cost.

Summary

In this publication, we have shown that the application of AC drive technology to various types of AC elevator motors must rely on a thorough understanding of the clear advantages and tradeoffs, in order to make the very best possible choices for AC drives and motors.

Our discussion has included examination of tradeoffs or possible drawbacks including the potential for increased harmonic distortion, radio frequency interference, and other issues that must be addressed in order to use AC technology successfully.

Comparison of AC and DC motor and drive technology does not result in a clear-cut "winning" technology to be applied universally. Rather, we have shown that each technology has unique advantages and disadvantages.

We have tried to arm the reader with as many facts as possible, given the limitations of the size of this document. As technology evolves, we will endeavor to continue to pass along as much information as possible to benefit our customers.

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