Quick Topics

In This Section

Over time, several "universal" issues affecting elevator installation and/or modernization have repeatedly been of concern. This section contains technical "white" papers addressing several of these issues, including:

- Drive System Considerations
- Motor Generator vs. Static Drives: A look at when it might be appropriate to stay with motor generator drives rather than switching to static drives.
- AC Motor Controls for Elevators: A review of pertinent issues regarding proper application and installation of AC motors and drives.
- Harmonic Analysis and Comparison: A discussion of harmonic analysis and comparison of DC and AC static drives.
- AC Inverter Drives & RFI: A review of the generation of electrical noise and effects of RFI in AC static drives.
- Modernization Performance Charts

Drive System Considerations

This introductory information is a preface to the separate white papers in this section, providing information about why they were written, including:

- Purpose
- Overview
- Communication is Vital
- Drive Technology

Purpose

This Technical Publication discusses drive system considerations for selection of elevator drives and possible side effects associated with static drives.

Motion Control Engineering manufactures elevator control systems using motor generator and DC-SCR or AC static drives. MCE's experience as a control system supplier suggests the need to improve industry understanding regarding the application of elevator control drive systems.

Overview

Many modernization projects use static drives successfully (either DC-SCR or AC inverter type). On the other hand, a few projects have presented significant difficulties from which much can be learned.

As an elevator control system supplier, MCE has become aware of problems that result from the use of static drives. These situations underscore the need to share experiences and maintain an open dialogue between elevator control suppliers, consultants, contractors and other interested parties.

Communication is Vital

Sometimes, neither consultants, contractors nor control suppliers alone recognize a potential problem. Communication is vital to the successful installation of static drives and it is, of course, preferable to address as many issues as possible up front. Mutual recognition of potential issues is the key to a successful project. This is particularly true for modernization.

Occasionally, a problem comes as a total surprise. The result is chaos -- especially for the end user, who cannot understand how knowledgeable elevator industry people could have failed to foresee the difficulty. Some specification writers have attempted to address issues in advance by specifying that, "The contractor and/or control supplier shall be responsible for everything that may occur as the result of the application of static drives." This is not a reasonable solution.

To best serve the customer and the industry, it is necessary to establish a continuous dialogue. There are issues that can be recognized up front and potential difficulties prevented. Consultants, contractors and control suppliers working as a team can research, evaluate and resolve issues.

An example of an issue not properly identified and adequately addressed is the case where elevators were converted to DC-SCR static drives. During the completion stages of the project it was discovered that the existing building power supply was inadequate. What can an owner or, for that matter, a supplier do when they have no prior knowledge of this type of job specific condition?

The contractor, consultants and others directly familiar with a project should recognize the need for power system evaluation. Everyone involved with a modernization project should remember that existing elevators frequently do not run at contract speed. Further, static drives may affect AC power distribution systems differently than original DC or AC elevator controls.

Drive Technology

Modern drive technology includes motor generator drives using static field control, DC-SCR static drives and AC static drives. These state-of-the-art drives raise additional issues for consideration.

Old relay technology had little or no effect on the AC line. This equipment generated little or no noise, and operated well with emergency power generators.

Static drives present issues for new construction and retrofitting (modernization) of existing systems. Static drives are preferred, in most cases, over motor generator drives. For new construction, the static drive option can be evaluated and used as the basis for design of the elevator machine room and the AC power distribution system. For modernization projects, it is important to recognize the potential for damaging effects from static drives, including:

- Degraded performance of emergency power generators
- Additional heating and induction motor power losses
- Audible noise
- Interference with sensitive medical equipment
- Interference with computers
- Interference with radio and television equipment

Noise is generated as a result of static drive switching and the way these devices draw current from the AC line. Static drives use switching devices, including SCRs, transistors, and IGBTs, that switch very rapidly, producing Radio Frequency Interference (RFI). Static drives also produce current distortion (harmonic distortion) on the AC line.

Types of noise include:

- Audible Noise - Airborne
- Physical Noise - Structure conducted
- Electrical Noise - Radiated or conducted
  - Radiated Noise from wires connected to a drive becomes an issue when the magnitude creates RFI that interferes with radio receivers and other devices.
  - Conducted Noise transmitted from the drive through electrical conductors can result in harmonic distortion, line notching, and other disturbances.

While static drives have some unfriendly characteristics, their overall performance makes them highly desirable. When the implications are understood, static drives frequently provide the best total solution for elevator control.

Conclusion

The MCE Technical Publication series is intended to be an informative catalyst for ongoing dialogue and sharing of information between consultants, elevator contractors, owners and other interested parties. MCE Technical Publications are available on our website at www.mceinc.com.

Don Alley, Chief Engineer
MCE R&D Staff
January 1996

Note

It is MCE's philosophy to share information with interested parties. To this end MCE grants unlimited reproduction rights, with proper attribution, to NAVTP and/or NAEC to further engineering and technical excellence within the elevator industry.

Static Drives vs. Motor Generators

Purpose

This Technical Publication examines variables that help determine the suitability of static drives vs. motor generators for any given project.

Motion Control Engineering, Inc. experience with various drive configurations suggests the need for review of drive considerations by consultants and contractors prior to the selection of a drive system for any project, whether new installation or modernization.

Overview

Many elevator control specifications require the use of static drives. Nonetheless, experience shows that there are applications where motor generator control systems may be a better choice (in fact they may be the only choice). It is important to have a basic understanding of the variables that influence drive selection.

Introduction

Selecting an elevator drive requires examination of the adequacy of the power distribution system and possible interference with other devices sharing the power line. After all variables have been considered, select the drive type (and if necessary, appropriate isolation and filtering devices) to satisfy the needs of the specific application.

For elevator systems, static drives are preferred over motor generator sets. Nonetheless, after thorough evaluation, motor generator drives may be the most appropriate choice for a particular project. In this bulletin, we evaluate the merits of both choices and look at some situations in which it might be better to specify motor generator drives in lieu of static drives. Issues to consider before selecting static drives include:

- Power consumption
- Maintenance
- Emergency power generators
- Shared power feeders
- Equipment sensitive to harmonics
- Marginal AC feeders
- Gearless motors with straight slots

Power Consumption

One of the advantages of solid state drives is that they are more efficient than motor generator sets. There are three elements that contribute to an elevator systems use of power.

1. **The power used by the MG set when running idle.** Many are not aware of the fact that a motor generator draws about 35% to 40% of full load current when idling. In other words, if the generator is running while the car is stopped, as much as 40% of full load current may be drawn to keep the generator running. This current is used for overcoming friction and providing magnetization current for the MG set. Power used to run a generator at idle may translate to about 12% of the power used by the elevator when running on full load. Note that the generator will be running idle well over 50% of the time, and sometimes as much as 70% of the time (any time the elevator is stopped at a floor and the generator is running).
2. **MG sets are less efficient than SCR drives.** A motor-generators two rotating elements operate with 72% to 81% efficiency. A static drive used in conjunction with a line transformer operates with 95% to 97% rectifier-transformer efficiency. By substituting a solid state DC drive for a motor-generator set, drive efficiency can be improved from 18% to 33%.
3. **The power factor.** At leveling speeds, SCR drives have a poorer power factor than MG sets. On the other hand, MGs running with no load have a fairly poor power factor as well. Utility rates may or may not penalize for poor power factor. Therefore, some of the effect of the power savings of static drives may be lost as the result of power factor.

Various elevator companies claim anywhere from 15% to 25% power savings using SCR drives. From the above, one can see that the actual savings depends on many elements. However, one could state conservatively that a 15% power savings is likely when substituting SCR drives for MG sets.

Maintainability

Another advantage of solid state drives is ease of maintenance. Motor generators are high speed rotating equipment. They need periodic lubrication and bearing and brush replacement. Additionally, brush wear produces carbon dust that can contaminate the machine room. Elimination of MG sets removes associated maintenance demands. These are two of the strongest arguments in favor of using static drives instead of motor generators.

Marginally Sized Emergency Generators

For static drive applications, the emergency power generator must be sized substantially larger then the total power demand required by elevators. Undersized generators can result in interaction between the two systems causing trip-off of either the emergency generator or the static drive.

Some emergency generators are sized so marginally that they are at the theoretical minimum rating necessary to provide power for the elevators. In actual field conditions, static drives can place an excessive burden on these generators, resulting in poor elevator operation, trip-off of generators, trip-off of elevators and other irregularities.

Compatibility problems result from a generators inability to cope with the rapid changes in current demand that are typical of static drives. Consequences include frequency fluctuations that can trip either system.

The first step to ensure selection of the proper elevator drive system is to review existing elevator control equipment, the power distribution system, and emergency power generation. This examination should include full load current, acceleration current, running current, feeder size, emergency generator capacity and power source (natural gas, diesel, etc.).

Ask static drive suppliers to provide the AC equivalents for full load current, acceleration current, running current, and so forth. Discuss the issue of conversion to static drives with the manufacturer of the emergency generators. Note that natural gas generators, where regulation is a function of gas pressure, are more likely to present a problem than diesel generators. As a rule of thumb, you could expect anywhere up to about 30% more current drawn by SCR drives than MG sets, depending on the efficiency of both the existing MG set and the new SCR drive.

A notable experience with static drives and emergency power regulation is an instance where the emergency generator would run empty cars, but would lift fully loaded cars only 10 of 22 floors. Regulation had to be readjusted to remedy the problem. When writing specifications you may wish to require the generator maintenance company representative be present during final testing.

Emergency Generators Sensitive 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 generator manufacturer about sensitivity to harmonics and other noise.

Emergency Generators Sensitive to Power Factor

At low elevator speeds, SCR static drives have a poorer power factor than motor generator control systems (at high speed they are similar). KVA ratings for feeder transformers and wire sizing must be adequate. If emergency generators are sensitive to poor power factor, SCR drives are not recommended. Find out about power factor sensitivity from the emergency generator manufacturer.

Shared Power Distribution Systems

MG sets may be the best choice if equipment sharing the same power feeders is sensitive to harmonics and other line noise created by static drives. This can happen in hospitals, financial centers, airports, government agencies or other similar buildings where electronic devices (computers, scanners, data transmission equipment, and radio-TV transmission equipment) are present. In some cases, RFI generated by certain types of static drives, especially VFAC drives, may cause interference.

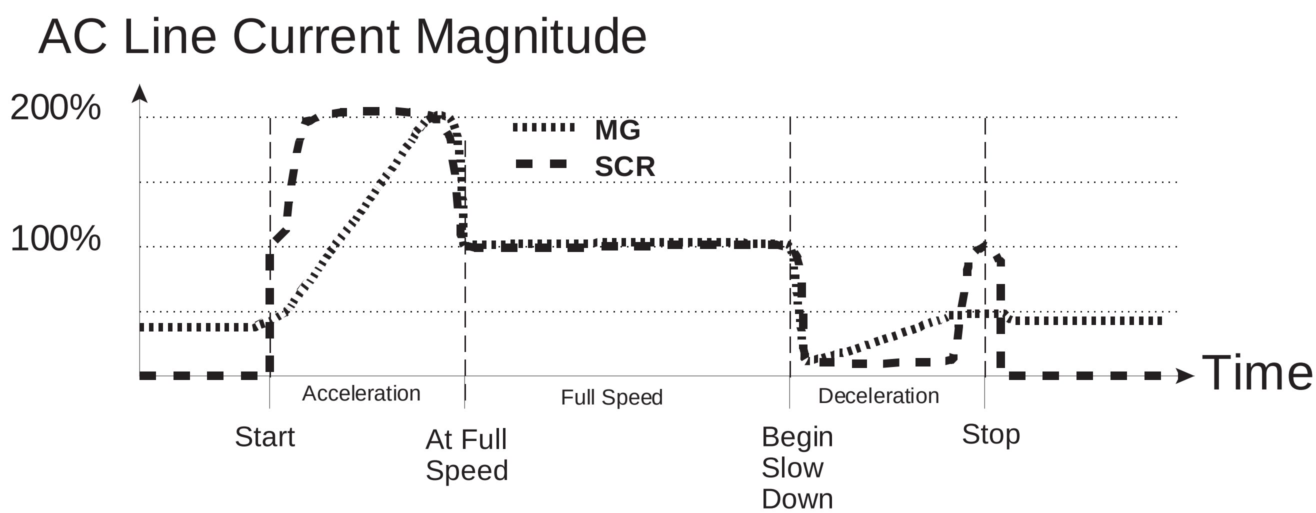
Marginal AC Power Distribution

Static drives draw current from the power distribution system differently then motor generator systems. It is extremely important to note that, in many modernizations where static drives are to be used, the existing elevators may not really be running at contract speed. As a result, power distribution systems may appear to be adequate but, after modernization, the power system may actually be marginal or even insufficient to run the elevators at contract speed. Here again, thoughtful evaluation of job site conditions is required, and motor generator systems may be preferred.

AC Line Current Magnitude Graphs for Motor Generator vs. SCR

The curves in the following graph illustrate the difference between the way current is taken from the AC line by these two types of devices. The respective AC line current magnitudes, at full speed, are very similar; however, you can see that there are substantial differences during acceleration and deceleration. The motor generator system current magnitude during acceleration has a gradually increasing curve which rises to maximum current to achieve full speed. The SCR drive has an immediate response, drawing maximum current throughout acceleration until full speed is achieved. The SCR drive is more efficient overall, but the brief extra current loads on acceleration and deceleration can create problems when the power distribution system or emergency generator is inadequate.

Figure 17.1 AC Line Current Magnitude — Motor Generator vs SCR



Current Requirements for SCR Drives

A good approximation for calculating the AC equivalent currents for SCR drive applications is:

$$0.82 \times \frac{\text{DC Full Load Amps x Armature Voltage}}{\text{Line Voltage}}$$

The AC equivalent current being taken from the elevator power supply is the sum of the current calculated above (SCR drive current), plus the AC current required for the controller, door operator, brake, and motor field. For maximum accuracy when determining AC line equivalents, it is best to use field data obtained during operation of the elevator at full load and full speed.

Note

Full load current typically drawn by SCR drives may be about 30% greater than that of the drive motor for the matching motor generator set.

Gearless Machines

When the hoist motor is an old gearless type with “straight slots” (motor armature slots relative to the edges of the motor field poles), torque pulsations may be created during high current conditions. This effect is subdued with MG sets, but accentuated with SCR drives of any kind.

When retaining this type of hoist motor it is best to modernize using motor generator controls. Motors with straight slots are often GE or Westinghouse gearless machines dating to 1930 or earlier. A knowledgeable elevator man can usually identify “straight slots” in gearless motors by visual inspection.

Conclusion

Selecting the best elevator control drive for a particular application is not an exact science. However, as you have seen, consideration of factors discussed here can increase the likelihood of success. With proper evaluation, the transition from motor generator controls to static drives is, in most cases, not only desirable but appropriate.

MCE’s Technical Publication series is intended to be an informative catalyst for ongoing dialogue and sharing of information between consultants, elevator contractors, owners and other interested parties. MCE Technical Publications are available on our web site at www.mceinc.com.

Don Alley, Chief Engineer
MCE R&D Staff
February 1996

AC Motor Controls for Elevators

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 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. 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 drives, 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 (i.e.: 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. 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.

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. 17

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 not necessary because they are designed to work with modern flux vector drives.

Calculating Slip

First, check the Motor Nameplate Data and note Full Load RPM. Find the entry in the following Synchronous RPM table (under 60Hz or 50Hz as appropriate) that matches your noted Full Load RPM. (If the exact number is not in the table, use the next higher entry.) Note the corresponding number of poles listed.

Table 17.1 Determining Number of Motor Poles

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

Use the number of poles and data from the motor name plate to calculate slip frequency:

First, calculate motor slip frequency using the formula: 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.

Next, calculate slip percentage using the formula:

Next, calculate slip percentage using the formula: Slip% = (Fs X 100) / F
Where: F = Motor rated frequency (Hz)
Fs= Slip frequency

Example Checking the motor name plate tells you it is a 60Hz motor with Full Load RPM of 1170:

1. Check the Synchronous RPM table. 1170 is not listed under 60Hz, so you use 1200 and note that the motor has 6 poles.
2. Calculate Slip Frequency: 60 - ((1170 x 6) / 120) = 1.5
3. Calculate Slip Percentage: (1.5 x 100) / F = 2.5
4. At a Slip Percentage of 2.5, this is a low slip motor.

Slip Requirements for New Motors

(Based on current industry availability for motors to be used with Inverter & Flux Vector Drives.)

- 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.
- Flux Vector Drives: (closed loop) 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

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 – <u>not</u> synchronous RPM data – to select an AC motor.

AC Drive Operating Characteristics

<u>Below</u> full load RPM	Output produced in <u>constant torque mode</u>
<u>Above</u> full load RPM	Output produced in <u>constant HP mode</u>

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.

Insulation

- 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 drive and power supply, reducing effects of RFI
- Reduces harmonic distortion on the line

RFI / EMI Demons: The Need for Proper Grounding

AC drives produce Radio Frequency Interference (RFI) and can potentially affect operation of equipment susceptible to this type of noise. The likelihood of encountering problems with RFI increases in older buildings where grounding is frequently inadequate.

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 hearing 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 a 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.

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.
- 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.

17

Figure 17.2 Correct Grounding

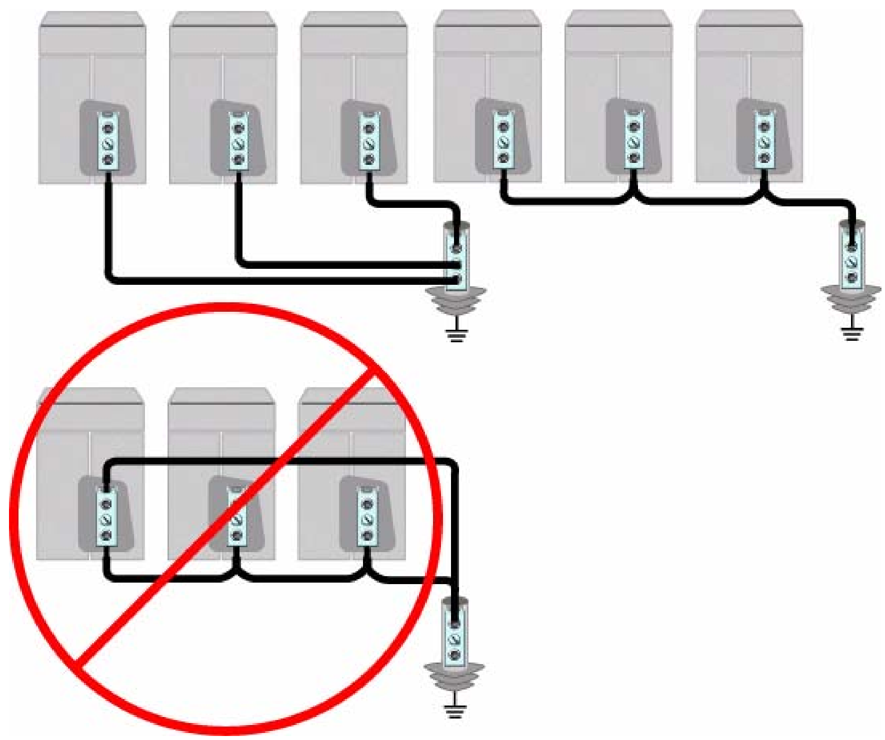
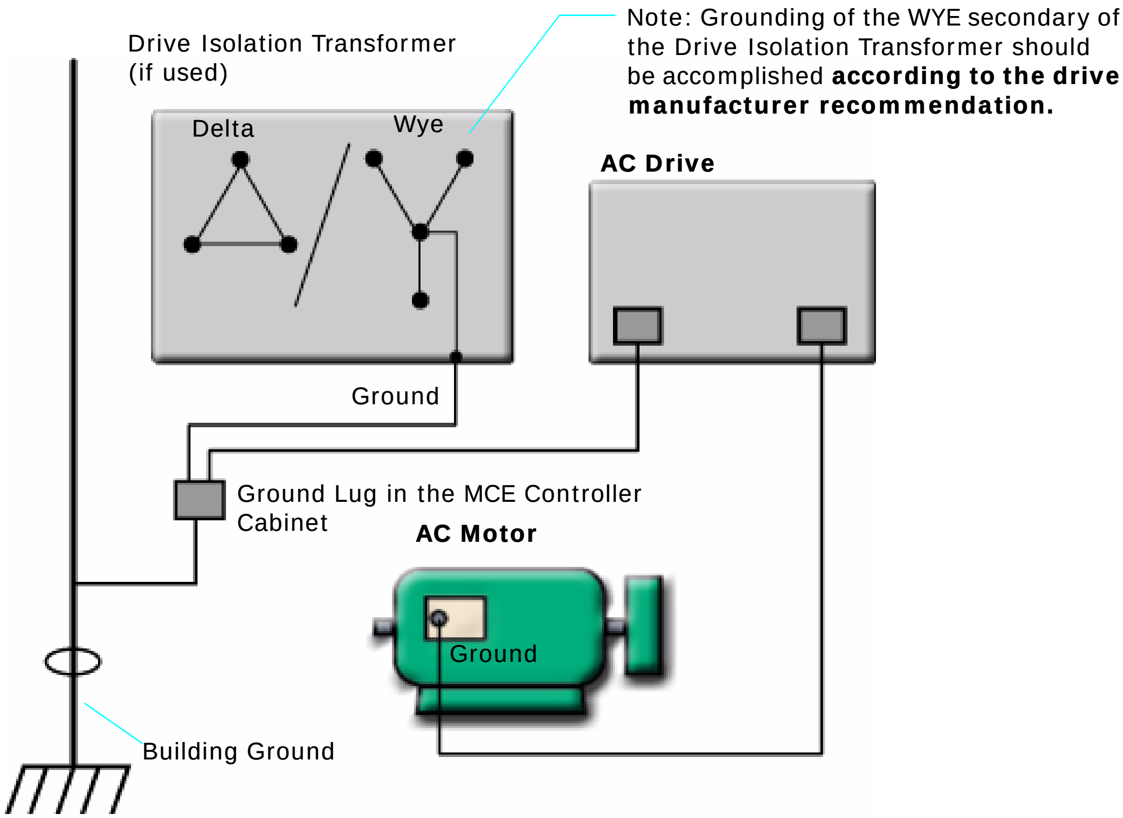


Figure 17.3 Transformer, Drive, and Motor Ground



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 separate grounded conduits.
- Important: Keep AC power leads separate from control wires.
- AC motor wiring, both inside and outside the control enclosure, must be kept separate from any control wiring. This separation requirement includes routing AC power feeders from the main line disconnect. No other conductors 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 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 placing 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 (i.e.: 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. The 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 the risk of emergency generator problems associated with handling regenerated power from the elevators.

Where elevators comprise up to 25% of 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.

MCE R&D Staff
March 1999

Harmonic Analysis and Comparison

- SYSTEM 12 - 12 Pulse SCR Elevator Drive
- Conventional Six Pulse Elevator Drive
- Flux Vector VFAC Elevator Drive
- Includes Supplemental Jobsite Analysis

Purpose

This Technical Publication reports analysis and comparison of AC line harmonic distortion produced by three modern static drive types.

Motion Control Engineering, Inc. SYSTEM 12 using 12-pulse DC SCR drive technology is compared to a conventional 6-pulse DC SCR drive and the typical "quiet" variable frequency AC inverter or flux vector drive. Testing was conducted under "controlled" test tower conditions. This research study presents a true comparison of drive-generated AC power line distortion (harmonic distortion).

Elevator Test Tower Research Overview

Most of today's elevator control specifications require the use of static drives. Increased use and experience with static drives has focused attention on the potential for AC power supply distortion and other problems. In many cases AC power line distortion does not become a major factor. Nevertheless, it is important that everyone dealing with static drives have a basic understanding of the nature of AC line distortion.

Power supply distortion caused by static drives can result in:

1. Degraded emergency power generator performance
2. Induction motor heating
3. Power losses in transformers
4. Objectionable audible noise
5. Interference with sensitive medical equipment, computers, radios and television equipment

AC power supply distortion caused by elevator equipment is an issue for consultants, architecture/engineering firms, contractors and building owners.

This study concludes that use of MCE's SYSTEM 12 drive results in significantly less AC line distortion than most other types of static drives. 17

Tested Drives

Three types of static drives were evaluated for generation of harmonic distortion. They are the types in most frequent use today.

1. MCE's SYSTEM 12 using 12-pulse DC SCR drive technology for DC motors.
2. A conventional 6-pulse DC SCR drive for DC motors.
3. A variable frequency (VFAC) drive for AC motors. The tested unit is a "quiet" type utilizing "IGBT" devices.

Testing Methodology

The geared elevator installed in the test tower at MCE's Research & Development Center in Rancho Cordova (Sacramento) California was used for the tests.

The same AC power supply, drive isolation transformer, machine and elevator were used for all tests. An Imperial 20 HP DC motor was used for the DC drive tests. An Imperial 20 HP AC motor was used for the AC drive test.

It is our judgement that this methodology represents the most equitable possible arrangement for comparison of the three types of static drives.

The test tower elevator operates at 350 fpm with a 20 HP motor and a 480 VAC 3-phase power supply. The drive isolation transformer was a 27-KVA unit reconfigurable for conventional SCR or SYSTEM 12 operation. No line filter was used in any of the three drive tests. A Fluke Model 41 Power Harmonics Analyzer was used for all measurements and computations. Data was downloaded to a printer.

General comments regarding the tests:

It was decided to measure worst-case conditions for the drives. Results were evaluated during *full load acceleration in the up direction*. Up acceleration for the VFAC unit was not as great as for the DC SCR drives so the current levels were correspondingly lower. Nevertheless, the waveforms and results for all the tested drives are considered to be typical, accurately representing each drive type.

Drive Characteristics

1. MCE's SYSTEM 12, with 12-pulse DC SCR technology for elevator control applications, is a unique 12-pulse 4-quadrant, fully regenerative DC SCR drive utilizing 19 SCRs. Test results reflect the benefits of this advanced technology.
2. The conventional 6-pulse DC SCR drive was a Baldor Sweo 6-pulse 4-quadrant, fully regenerative DC SCR drive. This drive is typical of DC SCR drives generally available in the U.S. for elevator control applications. Test results are applicable to drives such as Magnetek DSD412, GE DC300E, Reliance, Emerson and others.
3. The VFAC drive evaluated was a Saftronics (Yaskawa) Flux Vector type. In regard to production of AC line harmonic distortion, the Yaskawa is considered to be typical of VFAC drives, either conventional or flux vector types. This is the case because the power supply is simply a 3-phase, six rectifier bridge feeding a capacitor bank, typical of VFAC designs presently available.

   The single exception to universal applicability of test data is a commercially available VFAC drive claiming very low levels of harmonic distortion. As far as can be determined, these product claims are accurate; however, cost is approximately two times that of any competitive drive. Thus, these drives are not considered a viable alternative to the drives examined in this study.

   Furthermore, this particular drive type, along with most other AC drives, radiates RFI (Radio Frequency Interference) in far greater amounts and across a much wider and higher band of frequencies than either 6-pulse or 12-pulse DC SCR drives. As a result, sophisticated containment strategies and careful installation practices are required to keep radiation in check.

Evaluating the Tables

Two pages of data from the Harmonic Analyzer are presented for each of the three drive types studied. The first page shows the voltage and current waveforms along with graphs showing relative magnitudes for voltage and current harmonics. The second page presents a tabular summary of the measurements taken.

The tables contain a considerable amount of information. To compare the AC line distortion generated by each of the three drives, pay particular attention to:

1. The Total Harmonic Distortion (THD Rms) values for both voltage and, especially, current -- the Voltage Total Harmonic Distortion and the Current Total Harmonic Distortion.
2. The Current Magnitude (IMag) column which shows the actual magnitude,in amperes, for each harmonic.

THD Rms measurements for current represent the total amount of current the drive is drawing from, or putting back into, the AC line at frequencies other than the main fundamental frequency of 60 Hz. These *current harmonics* originating from the drive are the “junk” that distorts the AC power line. They can be the cause of AC line problems.

THD Rms measurements for voltage represent the *voltage distortion or the amount of deviation* from a perfect 60 Hz sine wave. Voltage Total Harmonic Distortion is the result, or the effect of the current harmonics that the drive is producing.

There are a number of important facts to consider regarding current and voltage harmonics:

1. Identical current harmonic magnitudes (Current Total Harmonic Distortion) will not have the same effect on all AC power lines in terms of the amount of voltage harmonics produced (Voltage Total Harmonic Distortion).

   If the AC line is “stiff,” i.e., not easily affected, you can put a lot of current distortion on the line and voltage distortion measurements may be nominal. If the AC line is “soft” (as with a marginally sized power supply or a small emergency power generator), very moderate amounts of current distortion can generate considerable Voltage Total Harmonic Distortion, which can have serious consequences.
2. The Voltage Total Harmonic Distortion measured on the AC line is not only the result of elevator static drives. Residual base-line values can be measured by turning the drive off and recording harmonic distortion from other sources. When the static drive is on, measurements will reflect the total distortion including the base-line values plus the contribution of the elevator drive(s).

Evaluating the Data

The shape of the voltage and current waveforms provides meaningful information for evaluation of the various types of static drives. The ideal shape for both waveforms is a perfect sine wave. In all cases the voltage waveform is a close approximation of a sine wave. It is the current waveform that most clearly illustrates the effect of harmonic distortion generated by static drives.

The harmonic components generated by static drives can be calculated using the following formula:

$$H = nP \pm 1$$

where n = 1,2,3....etc. and

P = the pulse number of the diode or SCR bridge

Yaskawa Flux Vector VFAC Drive

The voltage waveform for the VFAC drive has a noticeable flattening at the top and bottom. The VFAC drive visibly distorted the voltage sine wave, which is not easy to do — the AC line for the MCE test tower elevator is very stiff.

Examination of the shape of the current waveform reveals the real story insofar as line distortion being generated by the VFAC drive is concerned. The waveform depicts how the VFAC drive draws current from the AC line. The current sine wave is obviously distorted. The VFAC is clearly the worst of all three drive types, a surprise considering the previously acknowledged superiority of AC technology in the elevator industry. The tests were repeated numerous times to verify that these figures were correct. Review of published literature corroborates findings -- suggesting that test results are typical.

Consider the bar graphs showing the relative magnitude of current harmonics. The fifth harmonic is nearly half the magnitude of the first harmonic. The first harmonic is actually the 60 Hz fundamental -- in the hypothetical ideal power system it would be the only bar illustrated.

Turning your attention to the data tables, the most important thing to note is the Current Total Harmonic Distortion (THD Rms under the Current column) at 44.3%. The current magnitude (IMag) column shows the largest harmonic (fifth) as a percentage of the 60 Hz fundamental, or 12.1 amps/28.4 amps = 42.6%. The VFAC drive demonstrates a propensity to generate harmonic distortion.

Conventional 6-Pulse DC SCR Drive

The voltage waveform doesn't provide much information because it is very close to a sine wave. This is confirmed by measured Voltage Total Harmonic Distortion of 2.6% (THD Rms under the Voltage column). Also note voltage harmonics are almost invisible on the bar graphs.

Examining the current waveform you can see that it is an improvement over the VFAC drive, but it is still only a rough approximation of a sine wave. Current harmonic distortion is apparent.

Contents MCE Web

For a 6-pulse DC SCR drive, the main harmonics are five, seven, eleven, thirteen and so forth. These are the same significant harmonics as those in the VFAC drive. This is explained by the fact that the typical VFAC drive can be considered a 6-pulse system.

Looking at the data table it is important to note that Current Total Harmonic Distortion is 25.9% (THD Rms under the Current column). This is a significant improvement over the VFAC drive's numbers. The current magnitude (IMag) column shows the largest harmonic (fifth) as a percentage of the 60 Hz fundamental, or 10.6 amps/45.5 amps = 23.3%. Again, a significant improvement over the VFAC drive.

12-Pulse DC SCR Drive (MCE System 12)

As expected, the voltage waveform doesn't reveal much information because it so closely approximates a sine wave. The Voltage Total Harmonic Distortion confirms this, measured at only 2.6%, equal to the 6-pulse DC SCR drive.

The bar graph illustrating voltage harmonics appears identical to the 6-pulse DC SCR drive, but this is misleading. The AC line is very stiff and hard to effect. Further, the graph represents residual distortion on the line, not the effect of the 12-pulse DC SCR drive.

The System 12 current waveform more closely resembles that of an ideal sine wave than either waveforms for the 6-pulse DC SCR or VFAC drives. The 12-pulse waveform shows significant improvement over the other two drive types.

When the current harmonics are examined, one can see they are greatly reduced in comparison to the other drive types. The significant harmonics for the 12-pulse drive are 11, 13, 23, 25 and so forth.

Finally, checking the data table, the Current Total Harmonic Distortion is only 13.5% (THD Rms under the Current column). This represents meaningful improvement over both the VFAC and 6-pulse DC SCR drives. The current magnitude (IMag) column shows the largest harmonic (11th) as a percentage of the 60 Hz fundamental, or 4.9 amps/44.3 amps = 11.1%.

The 12-pulse drive offers a factor of two improvement in Total Harmonic Distortion when compared to the typical 6-pulse DC SCR drive and a factor of four improvement when compared to the typical VFAC drive.

Conclusion

The purpose of this technical publication is to provide an awareness of the potential for adverse AC line distortion when elevators are controlled by static drives. It has been demonstrated how different types of static drives compare to the state-of-the-art in 12-pulse DC SCR technology.

Data indicates that non-regenerative VFAC drives present the biggest challenge insofar as AC line distortion is concerned. VFAC drives are also a potential source of RFI noise. Careful consideration is required when selecting these drives for a particular application.

This study shows that the conventional 6-pulse DC SCR drive definitely is not as clean as a 12-pulse DC SCR drive. In cases where there is any concern about AC line distortion use of the 12-pulse DC SCR drive is advisable.

Examination of the data supports the conclusion that MCE's System 12 using 12-pulse technology is the most effective method for minimizing AC line distortion.

The advantages of the 12-pulse drive are grounded in solid theory. The reader may wish to review, "Application of 12-Pulse Converters -- reducing electrical interference and audible noise from DC-motor drives" which appeared in the February 1992 issue of Elevator World magazine. Additional advantages of 12-pulse DC SCR drives are discussed in this article.

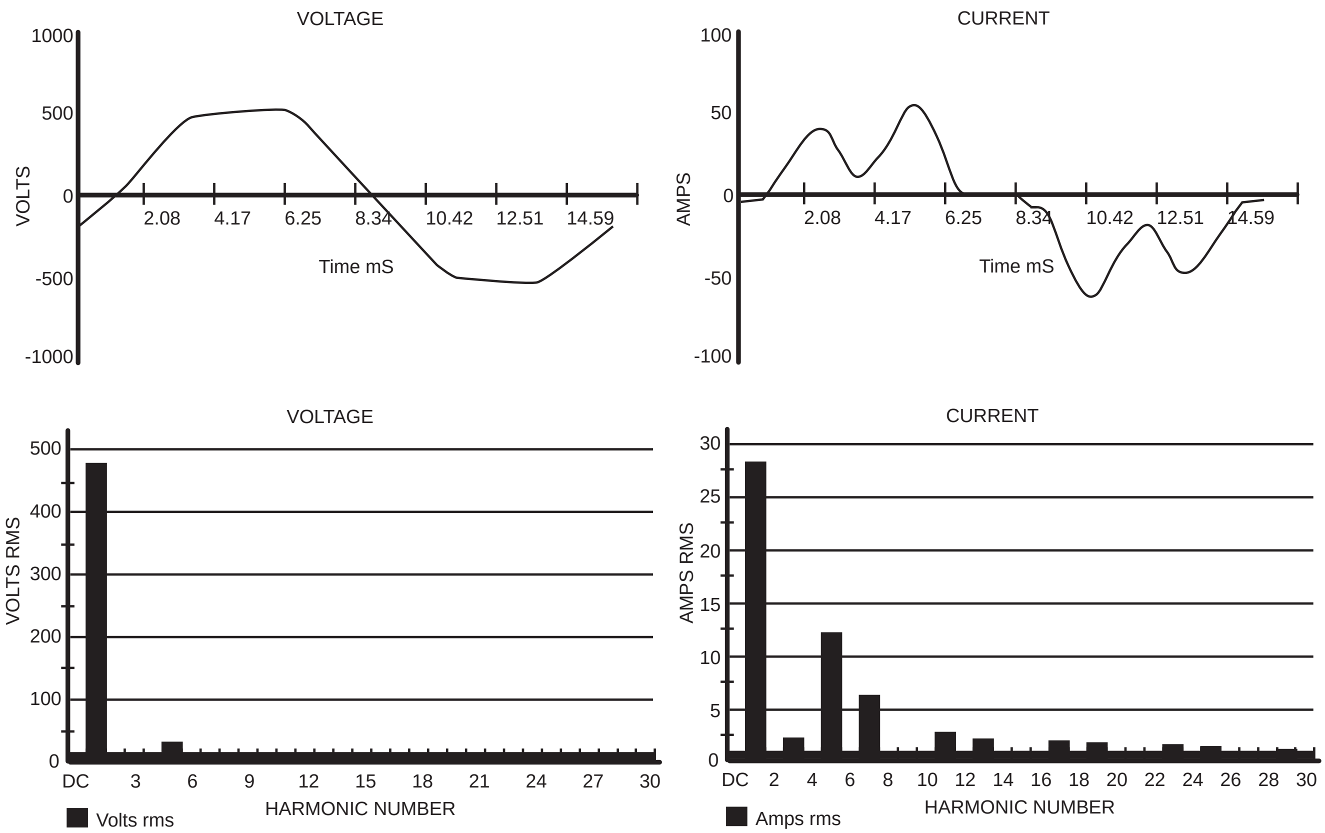
Static drive technology continually changes. As improved applications become available the nature of AC line pollution problems will also change. It is the hope of the authors that MCE's series of Technical Publications is informative and a catalyst for ongoing dialogue and sharing of information between consultants, elevator contractors, owners and other interested parties. MCE Technical Publications are available on our website at www.mceinc.com.

Don Alley, Chief Engineer
MCE R&D Staff
August 1994

Yaskawa Flux Vector VFAC Drive

MCE test tower data; 350 fpm, 20 HP AC motor, full load up acceleration. Ideal voltage and current should be illustrated as perfect sine waves. Fifth an seventh current harmonics are severe. The voltage waveform peaks are “flattened” unlike either SCR drive.

Figure 17.4 Yaskawa Flux Vector VFAC Drive



17

Yaskawa Flux Vector VFAC Drive

MCE test tower data; 350 fpm, 20HP AC motor, full load up acceleration. Data is considered to be typical for most VFAC drives. RMS Current Total Harmonic Distortion (THD Rms) or 44.3%. Current magnitude (Imag) of the largest harmonic (fifth) as a percentage of the 60 Hz fundamental, or 12.1 amps/28.4 amps = 42.6%.

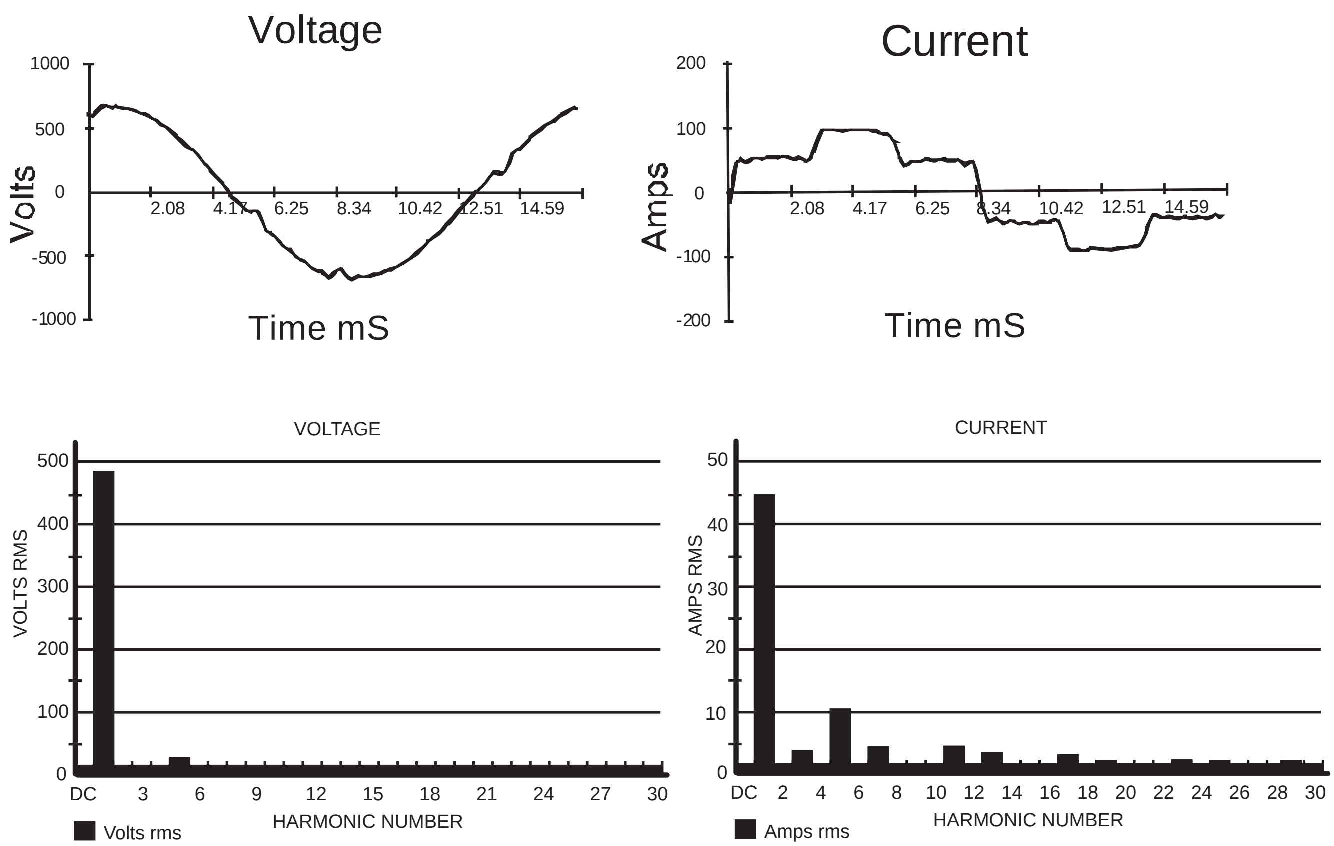
Readings - 11/02/94 08:43:50							
Summary Information							Recorded Information
				Voltage	Current		
Frequency	60.0		RMS	473	31.7		V RMS
Power			Peak	652	59.3		A RMS
KW	13.3		DC Offset	-2	-0.4		V Peak
KVA	15.0		Crest	1.38	1.87		A Peak
KVAR	2.8		THD Rms	3.8	44.3		V THD-F%
Peak KW	38.8		THD Fund	3.8	49.4		A THD-F%
Phase	12° lead		HRMS	18	14.0		K Watts
Total PF	0.89		KFactor		7.9		KVAR
DPF	0.98						TPF
							DPF
							Frequency

Harmonic Distortion								
	Freq.	V Mag	%V RMS	V Phase	I Mag	% I RMS	I Phase	Power (KW)
DC	0.0	2	0.4	0	0.4	1.2	0	0.0
1	60.0	473	100.3	-12	28.4	90.6	0	13.1
2	119.9	0	0.1	-154	0.4	1.3	65	0.0
3	179.9	1	0.2	-75	1.9	6.0	158	0.0
4	239.8	0	0.0	-11	0.1	0.4	-125	0.0
5	299.8	18	3.8	154	12.1	38.7	-158	0.1
6	359.8	0	0.0	172	0.1	0.2	89	0.0
7	419.7	1	0.2	-141	6.1	19.6	9	0.0
8	479.7	0	0.0	72	0.1	0.2	-84	0.0
9	539.7	0	0.0	-41	0.2	0.5	-11	0.0
10	599.6	0	0.0	-146	0.1	0.2	47	0.0
11	659.6	2	0.3	59	2.2	7.1	133	0.0
12	719.5	0	0.0	46	0.0	0.0	-95	0.0
13	799.5	1	0.2	120	1.2	3.9	-106	0.0
14	839.5	0	0.0	5	0.0	0.1	150	0.0
15	899.4	0	0.0	164	0.1	0.2	-128	0.0
16	959.4	0	0.0	42	0.0	0.0	-165	0.0
17	1019.3	1	0.2	-38	1.0	3.1	27	0.0
18	1079.3	0	0.0	39	0.0	0.0	-32	0.0
19	1139.3	1	0.1	-1	0.5	1.7	131	0.0
20	1199.2	0	0.0	92	0.0	0.1	44	0.0
21	1259.3	0	0.0	53	0.1	0.2	46	0.0
22	1319.2	0	0.0	17	0.0	0.1	-176	0.0
23	1379.1	1	0.1	-143	0.5	1.7	-83	0.0
24	1439.1	0	0.0	41	0.0	0.0	81	0.0
25	1499.0	1	0.1	-120	0.3	0.9	7	0.0
26	1559.0	0	0.0	134	0.0	0.1	-54	0.0
27	1619.0	0	0.0	-144	0.1	0.2	-37	0.0
28	1678.9	0	0.0	155	0.0	0.0	-70	0.0
29	1738.9	1	0.1	89	0.4	1.1	169	0.0
30	1798.8	0	0.0	113	0.0	0.0	59	0.0
31	1858.8	0	0.1	136	0.2	0.7	-119	0.0

Conventional 6-Pulse DC SCR Drive

Data taken from MCE test tower; 350 fpm, 20 HP DC motor, full load up acceleration. Ideal voltage and current should be illustrated as perfect sine waves. Note that the largest current harmonics are the fifth and seventh. This data is typical and would be identical for a 6-pulse SCR drive of any manufacturer.

Figure 17.5 Conventional 6-Pulse DC SCR Drive



17

Conventional 6-Pulse DC SCR Drive

Data from MCE test tower, 350 fpm, 20HP DC motor, full load up acceleration. Note particularly the RMS Current Total Harmonic Distortion (THD RMS of 25.9%). Also note the current magnitude (Imag) of the largest (fifth) as a percentage of the 60 Hz fundamental, or 10.6 amps/45.5 amps = 23.3%.

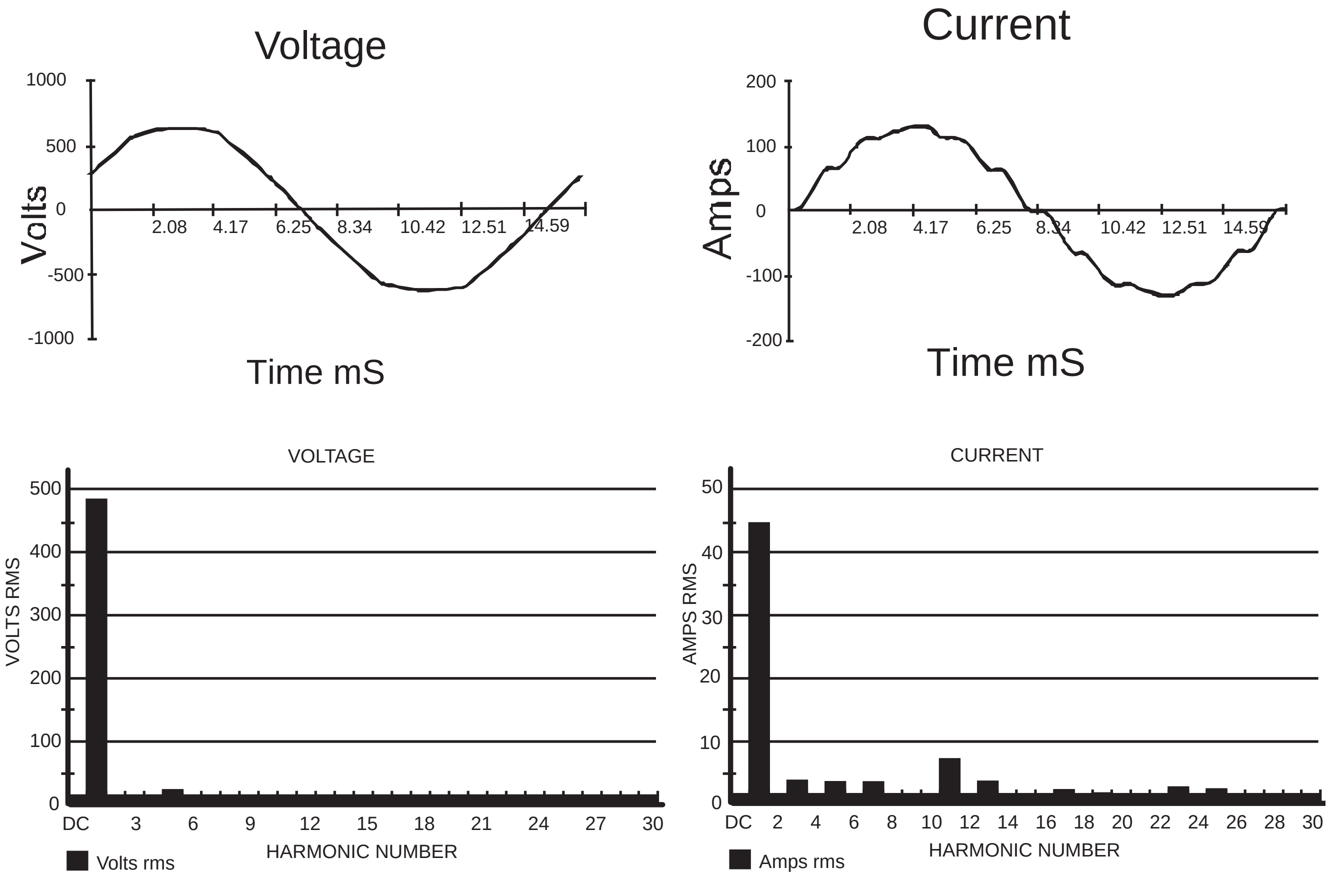
Readings - 09/22/94 16:12:57							
Summary Information							Recorded Information
				Voltage	Current		
Frequency	60.0		RMS	484	47.3		V RMS
Power			Peak	695	65.9		A RMS
KW	16.8		DC Offset	-2	-0.3		V Peak
KVA	22.9		Crest	1.44	1.39		A Peak
KVAR	14.4		THD Rms	2.6	25.9		V THD-F%
Peak KW	46.8		THD Fund	2.6	26.9		A THD-F%
Phase	41° lag		HRMS	12	12.2		K Watts
Total PF	0.74		KFactor		5.1		KVAR
DPF	0.76						TPF
							DPF
							Frequency

Harmonic Distortion						
	Freq.	V Mag	%V RMS	V Phase	I Mag	% I RMS
DC	0.0	2	0.3	0	0.3	0.6
1	60.0	484	100.3	41	45.5	96.9
2	119.9	0	0.1	65	0.7	1.5
3	179.9	1	0.1	56	2.0	4.2
4	239.8	0	0.0	-105	0.1	0.1
5	299.8	11	2.4	130	10.6	22.5
6	359.8	0	0.0	-95	0.1	0.2
7	419.7	2	0.5	49	3.1	6.5
8	479.7	0	0.0	-39	0.1	0.3
9	539.7	0	0.0	142	0.4	0.8
10	599.6	0	0.0	30	0.1	0.3
11	659.6	2	0.5	-90	3.3	7.0
12	719.5	0	0.0	-13	0.2	0.3
13	799.5	2	0.3	-138	2.1	4.5
14	839.5	0	0.0	23	0.1	0.1
15	899.4	0	0.1	-98	0.4	0.8
16	959.4	0	0.0	84	0.0	0.1
17	1019.3	1	0.3	108	1.7	3.6
18	1079.3	0	0.0	94	0.1	0.1
19	1139.3	1	0.3	39	1.4	3.0
20	1199.2	0	0.0	-49	0.0	0.1
21	1259.3	0	0.0	70	0.3	0.7
22	1319.2	0	0.0	0	0.1	0.2
23	1379.1	1	0.3	-84	1.1	2.3
24	1439.1	0	0.0	-40	0.1	0.2
25	1499.0	1	0.3	-146	1.0	2.2
26	1559.0	0	0.0	-47	0.1	0.1
27	1619.0	0	0.0	-136	0.3	0.6
28	1678.9	0	0.0	41	0.0	0.1
29	1738.9	1	0.2	86	0.7	1.4
30	1798.8	0	0.0	96	0.0	0.1
31	1858.8	1	0.2	34	0.7	1.5

12-Pulse SCR Drive (MCE System 12)

Data taken from MCE test tower; 350 fpm, 20 HP DC motor, full load up acceleration. Ideal voltage and current should be illustrated as perfect sine waves. Note that the largest current harmonics are the eleventh and thirteenth.

Figure 17.6 MCE 12-Pulse SCR Drive



17

12-Pulse DC SCR Drive (MCE SYSTEM 12)

Data taken from MCE test tower, 350 fpm, 20 HP DC motor, full load up acceleration. Note particularly the RMS Current Total Harmonic Distortion (THD RMS of 13.5%. Also note the current magnitude (Imag) of the largest (eleventh) as a percentage of the 60 Hz fundamental, or 4.9 amps/45.3 amps = 11.1%.

Readings - 08/25/94 11:40:17							
Summary Information							Recorded Information
				Voltage	Current		
Frequency	60.0		RMS	487	44.7		V RMS
Power			Peak	699	65.1		A RMS
KW	17.8		DC Offset	-2	-0.3		V Peak
KVA	21.8		Crest	1.43	1.46		A Peak
KVAR	12.0		THD Rms	2.6	13.5		V THD-F%
Peak KW	45.1		THD Fund	2.6	13.6		A THD-F%
Phase	34^{o} lag		HRMS	13	6.0		K Watts
Total PF	0.82		KFactor		3.5		KVAR
DPF	0.83						TPF
							DPF
							Frequency

Harmonic Distortion						
	Frequency	V Mag	%V RMS	V Phase	I Mag	% I RMS
DC	0.0	2	0.4	0	0.3	0.7
1	60.0	487	100.3	34	44.3	99.8
2	119.9	1	0.1	-107	0.1	0.1
3	179.9	1	0.2	70	1.8	4.1
4	239.8	0	0.1	-75	0.1	0.1
5	299.8	12	2.4	86	1.3	2.9
6	359.8	0	0.0	67	0.0	0.0
7	419.7	1	0.3	15	1.4	3.2
8	479.7	0	0.0	138	0.0	0.1
9	539.7	0	0.0	-140	0.4	0.9
10	599.6	0	0.0	165	0.1	0.1
11	659.6	3	0.7	105	4.9	11.1
12	719.5	0	0.0	-97	0.1	0.2
13	799.5	2	0.3	-3	1.5	3.3
14	839.5	0	0.0	-59	0.0	0.1
15	899.4	0	0.0	-25	0.1	0.2
16	959.4	0	0.0	141	0.0	0.1
17	1019.3	1	0.1	-57	0.5	1.2
18	1079.3	0	0.0	-158	0.0	0.0
19	1139.3	0	0.1	12	0.4	0.8
20	1199.2	0	0.0	171	0.0	0.0
21	1259.3	0	0.0	8	0.1	0.3
22	1319.2	0	0.0	26	0.0	0.1
23	1379.1	2	0.3	-84	1.4	3.0
24	1439.1	0	0.0	-10	0.1	0.2
25	1499.0	1	0.3	-146	0.8	1.8
26	1559.0	0	0.0	169	0.0	0.1
27	1619.0	0	0.0	-65	0.0	0.0
28	1678.9	0	0.0	-128	0.0	0.1
29	1738.9	0	0.1	157	0.2	0.4
30	1798.8	0	0.0	-94	0.0	0.0
31	1858.8	0	0.1	-115	0.1	0.3

Supplemental Job Site Analysis

Purpose

Supplemental jobsite analysis was undertaken to compare the results of the Test Tower study with actual jobsite measurements. The general discussions of the Test Tower Research are applicable to this supplemental study.

Tested Drives

Two types of static drives were evaluated at the jobsite. They are the Magnatek 6-pulse DC SCR drive and MCE's ***SYSTEM 12*** using 12-pulse DC SCR drive. The job sites are as follows:

1. 1) International Towers Building -- 700 fpm; 2500 lb capacity; Magnatek 6-pulse drive; General Dynamics ED machine; 35.4 HP; 115 amp/260 volt armature; 480 AC line voltage.
2. 2)Plaza Building -- 500 fpm; 3000 lb capacity; MCE ***SYSTEM 12***; Otis 131HT machine; 32 HP; 177 amp/150 volt armature; 480 AC line voltage.

Testing Methodology

The gearless elevators were tested using a Fluke Model 41 Power Harmonics Analyzer for all measurements and computations. Data was take from the primary side of the isolation transformers and downloaded to a printer. It was decided to measure worst-case conditions for the drives, which in the absence of test weights, is during empty car acceleration in the down direction.

Evaluating the Data

Conventional 6-Pulse DC SCR Drive - International Towers Building

The voltage waveform doesn't provide much information because it is very close to a sine wave. This is confirmed by measured Voltage Total Harmonic Distortion of 4.1% (THD Rms under the Voltage column). Note that voltage harmonics are insignificant on the bar graphs.

For a 6-pulse DC SCR drive, the main harmonics are five, seven, eleven, thirteen and so forth. Looking at the data table it is important to note that Current Total Harmonic Distortion is 26.9% (THD Rms under the Current column). The current magnitude (Imag) column shows the largest harmonic (fifth) as a percentage of the 60 Hz fundamental, or 13.7 amps/64.7 amps = 21.2%.

12-Pulse DC SCR Drive - Plaza Building

As expected, the 12-pulse voltage waveform doesn't reveal any more information than the 6-Pulse voltage waveform because it also closely approximates a sine wave. The Voltage Total Harmonic Distortion confirms this, measured at only 2.5% lower than that of the

6-pulse DC SCR drive.

The SYSTEM 12 current waveform more closely resembles that of an ideal sine wave than the waveform for the 6-pulse DC SCR. When the current harmonics are examined, one can see they are greatly reduced in comparison to the 6-pulse drive. The significant harmonics for the 12-pulse drive are 11, 13, 23, 25 and so forth.

Finally, checking the data table, the Current Total Harmonic Distortion is **only 6.5%** (THD Rms under the Current column). This represents meaningful improvement over the 6-pulse DC SCR drive. The current magnitude (Imag) column shows the largest harmonic (11th) as a percentage of the 60 Hz fundamental, or 4.7 amps/93.3 amps = 5.0%.

The Plaza Building SYSTEM 12 drive offers a factor of four improvement in Total Harmonic Distortion when compared to the International Towers Building 6-pulse DC SCR drive.

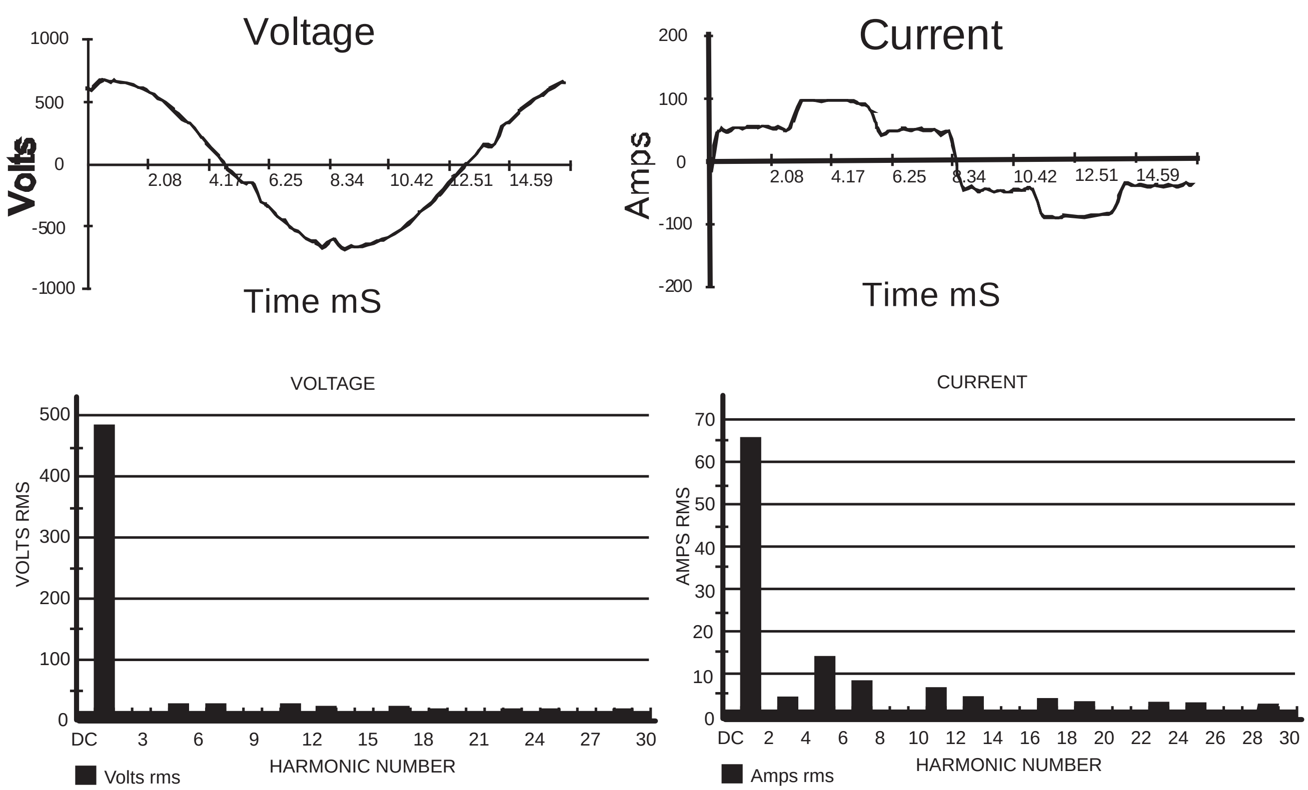
Conclusion

The supplemental analysis further validates the hypotheses of the Test Tower Research in that a 12-pulse SCR drive produces substantially less harmonic distortion than other static drives typically used. It must be noted that levels of Harmonic Distortion will vary from installation to installation as the result of job-specific variables (current drawn, car direction and loading, line stiffness, other static drives sharing the line, baseline distortion).

Conventional 6-Pulse DC SCR Drive

Data taken from International Tower Building; 700 fpm, 5.4 HP DC motor, empty car down acceleration. Ideal voltage and current should be illustrated as perfect sine waves. Note that the largest current harmonics are the fifth and seventh. This data is typical and would be identical for any 6-pulse SCR drive of any manufacturer.

Figure 17.7 Conventional 6-Pulse DC SCR Drive



17

Conventional 6-Pulse DC SCR Drive

Data taken from International Tower Building – 700 fpm, 35.4 HP DC motor, empty car down acceleration. Note particularly the RMS Current Total Harmonic Distortion (THD RMS of 26.9%. Also note the current magnitude (Imag) of the largest (fifth) as a percentage of the 60 Hz fundamental, or 13.7/64.7 amps = 21.2%.

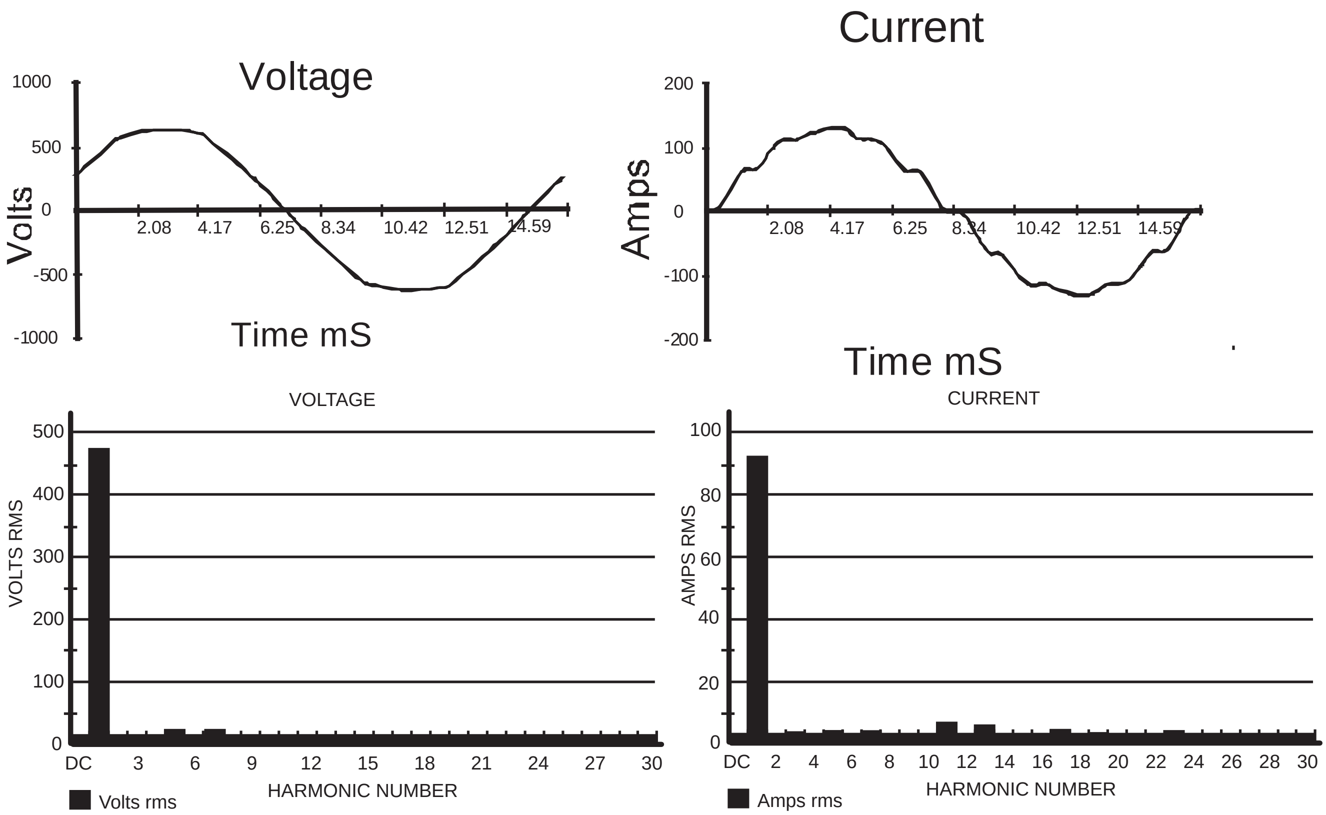
Readings - 11/03/95 15:59:14							
Summary Information							Recorded Information
				Voltage	Current		
Frequency	60.0		RMS	484	67.2		V RMS
Power			Peak	692	97.9		A RMS
KW	7.1		DC Offset	-1	-0.3		V Peak
KVA	32.5		Crest	1.43	1.46		A Peak
KVAR	30.5		THD Rms	4.1	26.9		V THD-F%
Peak KW	39.4		THD Fund	4.1	27.9		A THD-F%
Phase	77° lag		HRMS	20	18.1		K Watts
Total PF	0.22		KFactor		7.5		KVAR
DPF	0.22						TPF
							DPF
							Frequency

Harmonic Distortion								
	Freq.	V Mag	%V RMS	V Phase	I Mag	% I RMS	I Phase	Power (KW)
DC	0.0	1	0.3	0	0.3	0.5	0	0.0
1	60.0	484	100.2	77	64.7	96.7	0	6.8
2	119.9	0	0.1	-68	0.3	0.5	94	0.0
3	179.9	1	0.2	-127	1.4	2.1	-51	0.0
4	239.8	0	0.0	-27	0.2	0.3	46	0.0
5	299.8	10	2.0	-175	13.7	20.5	-11	-0.1
6	359.8	1	0.1	-37	0.1	0.1	98	0.0
7	419.7	7	1.4	-94	7.5	11.2	-14	0.0
8	479.7	0	0.0	-31	0.2	0.3	82	0.0
9	539.7	1	0.2	101	0.4	0.6	-164	0.0
10	599.6	0	0.0	-15	0.2	0.3	49	0.0
11	659.6	7	1.4	-147	5.6	8.3	-21	0.0
12	719.5	0	0.0	-56	0.1	0.1	56	0.0
13	799.5	5	1.1	-104	4.1	6.1	-32	0.0
14	839.5	0	0.0	-61	0.2	0.3	70	0.0
15	899.4	1	0.1	0	0.2	0.3	110	0.0
16	959.4	0	0.1	-46	0.2	0.3	39	0.0
17	1019.3	7	1.4	-164	3.4	5.1	-38	0.0
18	1079.3	0	0.0	-63	0.1	0.1	29	0.0
19	1139.3	5	1.0	-108	2.6	3.8	-42	0.0
20	1199.2	0	0.1	-51	0.2	0.3	60	0.0
21	1259.3	0	0.1	-108	0.1	0.1	-12	0.0
22	1319.2	0	0.1	-58	0.2	0.3	15	0.0
23	1379.1	6	1.2	179	2.3	3.4	-53	0.0
24	1439.1	0	0.1	-59	0.1	0.1	37	0.0
25	1499.0	5	1.1	-117	2.0	2.9	-53	0.0
26	1559.0	0	0.1	-77	0.2	0.3	37	0.0
27	1619.0	0	0.1	150	0.1	0.1	-116	0.0
28	1678.9	0	0.1	-71	0.2	0.3	0	0.0
29	1738.9	5	1.0	169	1.6	2.4	-64	0.0
30	1798.8	0	0.1	-87	0.1	0.1	-2	0.0
31	1858.8	5	1.0	-136	1.6	2.4	-71	0.0

12-Pulse SCR Drive (MCE System 12*)*

Data taken from the Plaza Building; 500 fpm, 32 HP DC motor, empty car down acceleration. Ideal voltage and current should be illustrated as perfect sine waves. Note that the largest current harmonics are the eleventh and thirteenth.

Figure 17.8 12-Pulse SCR Drive (MCE System 12)



17

Contents MCE Web

12-Pulse DC SCR Drive (MCE System 12)

Data taken from Plaza Building, 500 fpm, 32 HP DC motor, empty car down acceleration. Note particularly the RMS Current Total Harmonic Distortion (THD RMS of 13.5%. Also note the current magnitude (Imag) of the largest (eleventh) as a percentage of the 60 Hz fundamental, or 4.7 amps/93.5 amps = 5.0%.

Readings - 11/06/95 15:31:22							
Summary Information							Recorded Information
				Voltage	Current		
Frequency	60.0		RMS	469	93.7		V RMS
Power			Peak	645	135.3		A RMS
KW	39		DC Offset	-2	-0.4		V Peak
KVA	44		Crest	1.38	1.44		A Peak
KVAR	20		THD Rms	2.5	6.5		V THD-F%
Peak KW	85		THD Fund	2.5	6.6		A THD-F%
Phase	27° lag		HRMS	12	6.1		K Watts
Total PF	0.89		KFactor		1.6		KVAR
DPF	0.89						TPF
							DPF
							Frequency

Harmonic Distortion								
	Freq.	V Mag	%V RMS	V Phase	I Mag	% I RMS	I Phs	Power (KW)
DC	0.0	2	0.3	0	0.4	0.4	0	0.0
1	60.0	469	100.3	27	93.5	100.1	0	6.8
2	119.9	0	0.1	-115	0.2	0.2	143	0.0
3	179.9	1	0.3	122	0.5	0.5	-167	0.0
4	239.8	0	0.1	-41	0.1	0.2	77	0.0
5	299.8	8	1.7	-37	1.0	1.1	-160	-0.1
6	359.8	0	0.0	18	0.0	0.0	32	0.0
7	419.7	7	1.6	-168	1.0	1.1	137	0.0
8	479.7	0	0.0	124	0.1	0.2	-91	0.0
9	539.7	1	0.1	-18	0.1	0.1	59	0.0
10	599.6	0	0.0	158	0.2	0.2	-148	0.0
11	659.6	3	0.6	131	4.7	5.0	171	0.0
12	719.5	0	0.0	-112	0.1	0.1	124	0.0
13	799.5	2	0.4	17	3.5	3.7	179	0.0
14	839.5	0	0.0	-79	0.1	0.1	42	0.0
15	899.4	0	0.1	102	0.1	0.2	84	0.0
16	959.4	0	0.0	-5	0.1	0.1	-69	0.0
17	1019.3	2	0.4	-46	0.3	0.4	-60	0.0
18	1079.3	0	0.0	89	0.0	0.0	-169	0.0
19	1139.3	1	0.2	128	0.2	0.2	4	0.0
20	1199.2	0	0.0	107	0.0	0.0	-138	0.0
21	1259.3	0	0.1	-101	0.1	0.1	153	0.0
22	1319.2	0	0.0	-46	0.0	0.0	136	0.0
23	1379.1	1	0.3	98	0.7	0.7	-179	0.0
24	1439.1	0	0.0	-146	0.0	0.0	84	0.0
25	1499.0	1	0.2	-84	0.4	0.4	97	0.0
26	1559.0	0	0.0	-79	0.1	0.1	-55	0.0
27	1619.0	0	0.1	32	0.0	0.0	-51	0.0
28	1678.9	0	0.0	0	0.0	0.0	-97	0.0
29	1738.9	1	0.2	-120	0.3	0.3	-19	0.0
30	1798.8	0	0.0	-165	0.0	0.0	-158	0.0
31	1858.8	1	0.1	51	0.1	0.1	-33	0.0

AC Inverter Drives Electrical Noise & RFI

Purpose

This Technical Publication discusses electrical noise and Radio Frequency Interference (RFI) created by AC Inverter drives and possible effects on other equipment.

Motion Control Engineering, Inc. experience with AC inverter drives suggests that they can generate noise that may affect radio frequency sensitive equipment in the building. This phenomenon needs to be understood and considered prior to selection of an elevator drive system.

Overview

It is generally believed that AC inverter drives are the ideal technology providing maximum power savings, reduced motors cost and lower maintenance costs. AC inverter drives have tradeoffs that need to be recognized and understood. These tradeoffs (potential drawbacks) include greater harmonic distortion, radio frequency interference and other idiosyncrasies that can make typically used AC drives unfriendly.

In most instances, new construction design can address these issues; however, elevator modernization in existing buildings requires thoughtful consideration. It is important to have a basic understanding of the tradeoffs that are determining factors in the drive selection process.

Static Drives

MCE Technical Publications “Harmonic Analysis & Comparison” and “Motor Generator vs SCR” explored considerations for drive selection for a particular elevator control application. Issues addressed in these publications apply to all static drives, including the typical AC inverter drive.

Radio Frequency Interference “RFI”

AC inverter drives can produce sufficient amounts of Radio Frequency noise (RFI) that affect the operation of equipment susceptible to Radio Frequency noise. This is particularly true in older buildings when grounding is lacking or otherwise inadequate.

One example of a substantial RFI problem is a brick apartment complex, built in the mid 20's, where the elevator contractor was in the process of modernizing existing AC elevator equipment. After the first cars were modernized (new controllers included RFI filtering devices), the building superintendent complained that he was unable to listen to his favorite radio station because of interference from the elevators. He stated that the vintage AC elevator controls caused no problems; however, the state-of-the-art static drives generated disruptive RFI.

The building manager, considering the complaint unfounded, suggested that the superintendent select a different radio station. The superintendent reported the incident to the FCC. Subsequently, the contractor received an FCC notice to immediately respond and resolve the problem.

At the building the complaint was verified using an inexpensive AC plug in radio and the superintendent's portable battery operated radio equipped with all the latest technology. In the elevator machine room the AC radio was tuned to the AM band and, as expected, there was a considerable amount of interference. At roof level the battery operated radio, tuned to the same frequencies, performed slightly better; however, a considerable amount of interference was evidenced.

In an apartment on the fourth floor, located in the middle of the building, both radios demonstrated a similar level of interference. Conditions were found to be the same in an apartment on the first floor. Outside, in the courtyard which is surrounded by many buildings, AM band station signals were very strong and free of interference.

Simply stepping back inside at the first floor entrance the interference returned. Using the battery operated radio, as the elevator ran one could hear interference during both acceleration and deceleration.

The conclusion, later confirmed by the drive manufacturer, was that the building, without a solid earth ground, was acting as an antenna. Grounding of the elevator drive system and motor was occurring through water pipes and whatever other steel may have been present in this brick building.

The drive manufacturer did additional research to identify some probable causes. The contractor needed to provide a proper earth ground, ground the controller and the motor to this proper earth ground, and use insulated bushings to isolate other devices from the controller and motor to prevent grounding to or through the water piping system. These recommendations are, generally, requirements of the National Electrical Code, but they are sometimes overlooked. An additional suggestion would have been to try an isolation transformer. The drive manufacturer subsequently confirmed the transformer may not have helped in absence of a proper earth ground.

This is one example of how RF noise pollution can unintentionally be propagated throughout a building. Improper grounding conditions make this possible. Nonetheless, grounding alone may not be the cause of some RFI problems. Certain incorrect installation and wiring practices can also create serious RFI problems.

IGBTs

All modern AC Inverter drives use power devices known as Insulated Gate Bipolar Transistors (IGBTs). These devices make it possible to minimize annoying audible noise by using switching frequencies beyond the audible range. Unfortunately, AC inverter drives using IGBTs, present a high potential for generating RFI -- Radio Frequency Interference.

Fast switching in these devices generates sharp-edged waveforms with high frequency components that generate more RFI. The most likely complaint is interference with AM band radios 500-1600 Khz. Nonetheless, sensitive computers, medical equipment and other noise-sensitive devices sharing the same power buss could experience serious interference.

In extreme cases, the AC inverter drive itself can experience electrical noise interference. If elevator machine room equipment is not correctly laid out and properly wired, the electrical noise propagated by the elevator drive system can interfere with the elevator controller.

An example is the building lacking a solid grounding system where the elevator system experienced multiple problems. A solid earth ground was provided to eliminate many electrical noise problems, yet the elevator controller itself was being affected by undetermined sources of noise.

The routing of the contractor's field wiring into the controller was examined and several deficiencies were found and corrected. It was subsequently determined that the step down power/isolation transformer required by this particular application was physically located too close to the front of the controller. With the controller door open, the transformer created interference that affected the control microcomputers. The remedy was placement of a shield between the transformer and the controller, although other methods may have also worked.

Reducing / Preventing Electrical Noise

Electrical noise, whether it is conducted or radiated, can create unusual phenomenon that are difficult to evaluate. To avoid the effects of electrical noise pollution, consider:

- Proper grounding including correct ground conductor sizing
- Contractors routing of field wiring
- Controller and motor isolation to prevent indirect grounds
- Controller design and layout
- RFI filters
- Isolation transformers
- Higher standards of care by the installing contractor

Warnings from Manufacturers

MCE

Motion Control Engineering warns, in job specific manuals, "For proper operation of the AC inverter drive unit in your controller, you must make sure that a direct solid ground is provided in the machine room to properly ground the controller and the motor.

Indirect grounds such as building structure or water pipe may not provide proper grounding and could act as an antenna to radiate RFI noise, thus disturbing sensitive equipment in the building.

Improper grounding may also render any RFI filter and isolation transformer ineffective."

SAFTRONICS

When experiencing RFI problems with AC inverter drives, Saftronics has stated that the first step is to verify the existence of a proper grounding system. All too often, old commercial or residential construction relied on "indirect" grounding methods in which the building ground was accomplished via steel water pipes or conduit instead of through solid, properly sized conductors. This poor practice increases the likelihood that common mode noise will be propagated throughout the facility.

Conclusion

The phenomenon of AC static drive noise generation can adversely effect many devices including the controller itself. Nonetheless, AC static drives offer technology that, in numerous circumstances, can provide more benefits than alternative drives. Awareness of the circumstances that allow AC static drives to interfere with other devices and proper design considerations will greatly reduce the effects of these phenomenon.

While this publication addresses AC inverter drives, it is desirable to continually explore issues relating to emerging AC drive technology.

MCE's Technical Publication series is intended to be an informative catalyst for ongoing dialogue and sharing of information between consultants, elevator contractors, owners and other interested parties. MCE Technical Publications are available on our website at www.mceinc.com.

Don Alley, Chief Engineer
MCE R&D Staff
January 1996

Elevator Modernization Performance Charts

Elevator Performance Data for Representative Buildings Before and After Modernization with MCE's M3 Group System Elevator Dispatching

Purpose

This Technical Publication illustrates the dramatic elevator performance improvement realized using MCE's M3 Group System. Each page summarizes actual project data.

Overview

These studies document system performance improvement by comparing average waiting time, before and after modernization, for a variety of projects.

Impressive reductions in hall call waiting time have been documented *up to 83%*.

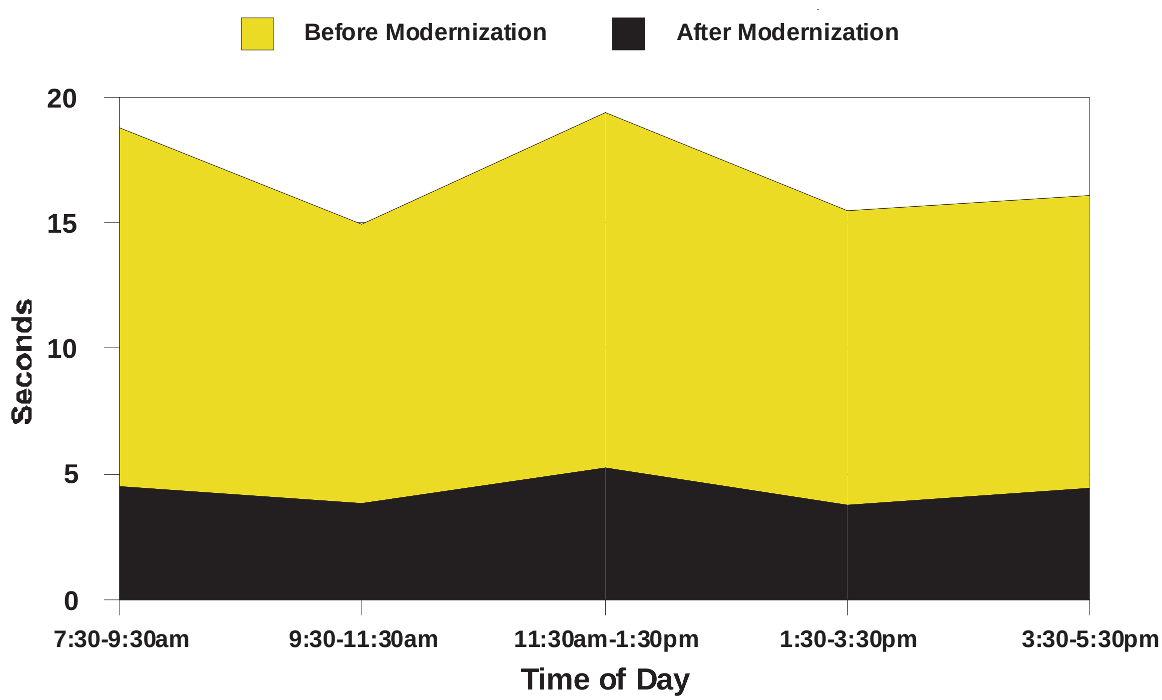
While every building is different, the following collection of individual site studies is useful as a generalized predictive model for successful elevator system improvement — as measured by reduced average waiting time — applicable to similar buildings.

The actual performance improvement resulting from a particular scope of work is obviously based on many factors including: the type of building occupancy, current population and rate of growth, the efficiency and condition of existing elevator control and dispatching equipment, and the extent of modernization undertaken.

Chase Manhattan Bank
Worldwide Headquarters — Low Rise
Manhattan, New York USA

75%
Reduction
in Hall Call
Wait Time

Average Waiting Time



Equipment
Existing:
Otis gearless
Modernized with:
MCE IMC-SCR 12-pulse controls
MCE M3 Group Dispatcher

Traffic Study Detail
Pre-Modernization:
7/25/94 — Delta Traffic Analysis System
Post-Modernization:
1/27/97 — MCE CMS Traffic Analysis Reporting

Project Profile

Cars:	**8**
Floors:	**11**
Stops:	**10**
Speed:	**500 fpm**
Capacity:	**3,500 lbs**
Type:	**office building single tenant**

Statistics

	BEFORE	AFTER
Calls	3,712	4,443
Population	3,200	5,000+

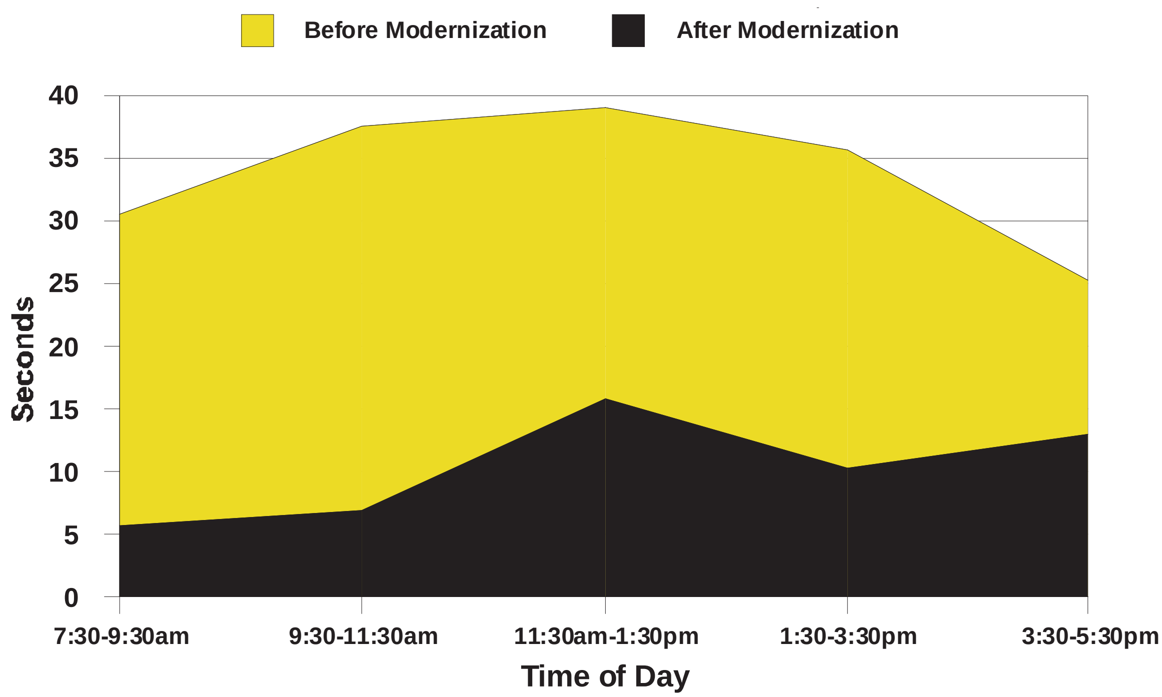
Rev 5/26/98

Chase Manhattan Bank

Worldwide Headquarters — High Rise
Manhattan, New York USA

70%
Reduction in Hall Call Wait Time

Average Waiting Time



Equipment

Existing:
Otis gearless
Modernized with:
MCE IMC-SCR 12-pulse controls
MCE M3 Group Dispatcher

Traffic Study Detail

Pre-Modernization:
7/25/94 — Delta Traffic Analysis System
Post-Modernization:
1/27/97 — MCE CMS Traffic Analysis Reporting

Project Profile

Cars:	**8**
Floors:	**52**
Stops:	**21**
Speed:	**1,200 fpm**
Capacity:	**3,500 lbs**
Type:	**office building single tenant**

Statistics

	BEFORE	AFTER
Calls	3,130	2,496
Population	3,200	5,000+

17

MCE

Rev 5/26/98

CNN Center - North Tower

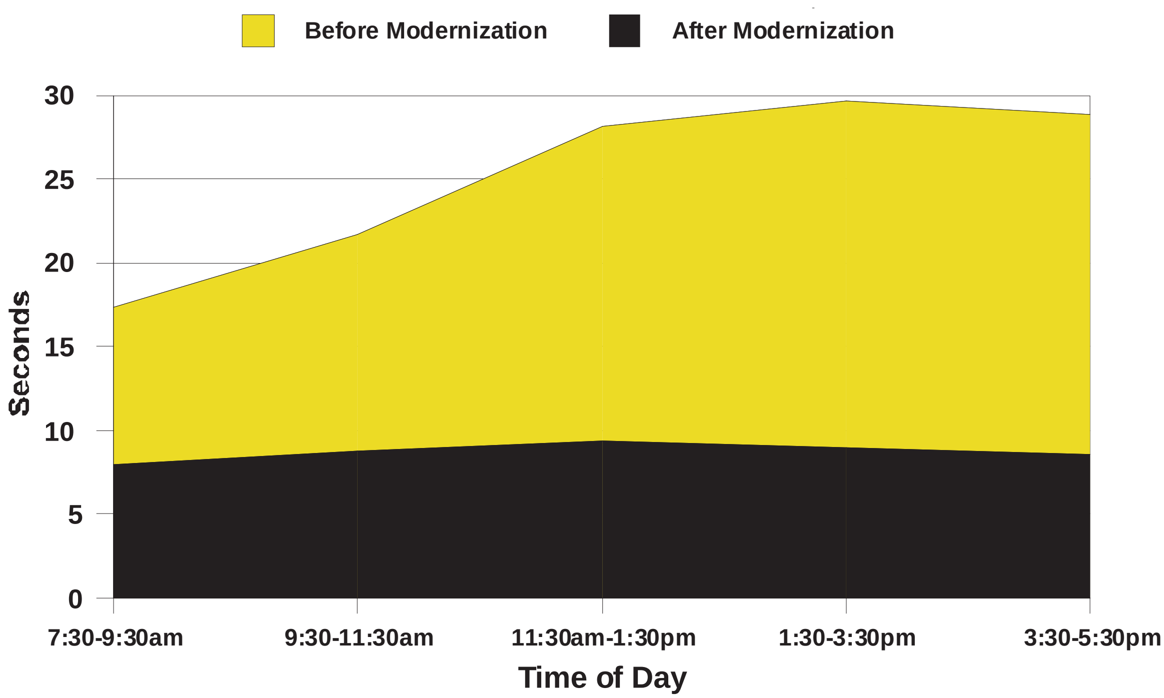
One CNN Center

Atlanta, Georgia USA

65%

Reduction in Hall Call Wait Time

Average Waiting Time



Equipment

Existing:

Westinghouse gearless

Modernized with:

MCE IMC-SCR 12-Pulse Controls

MCE M3 Group Dispatcher

Traffic Study Detail

Pre-Modernization:

6/29/95 — EPTi Traffic Analysis System

Post-Modernization:

4/9/96 — MCE Traffic Analysis Reporting

Project Profile

Cars:	**4**
Floors:	**12**
Stops:	**12**
Speed:	**500 fpm**
Capacity:	**3,000 lbs**
Type:	**office building multiple tenant**

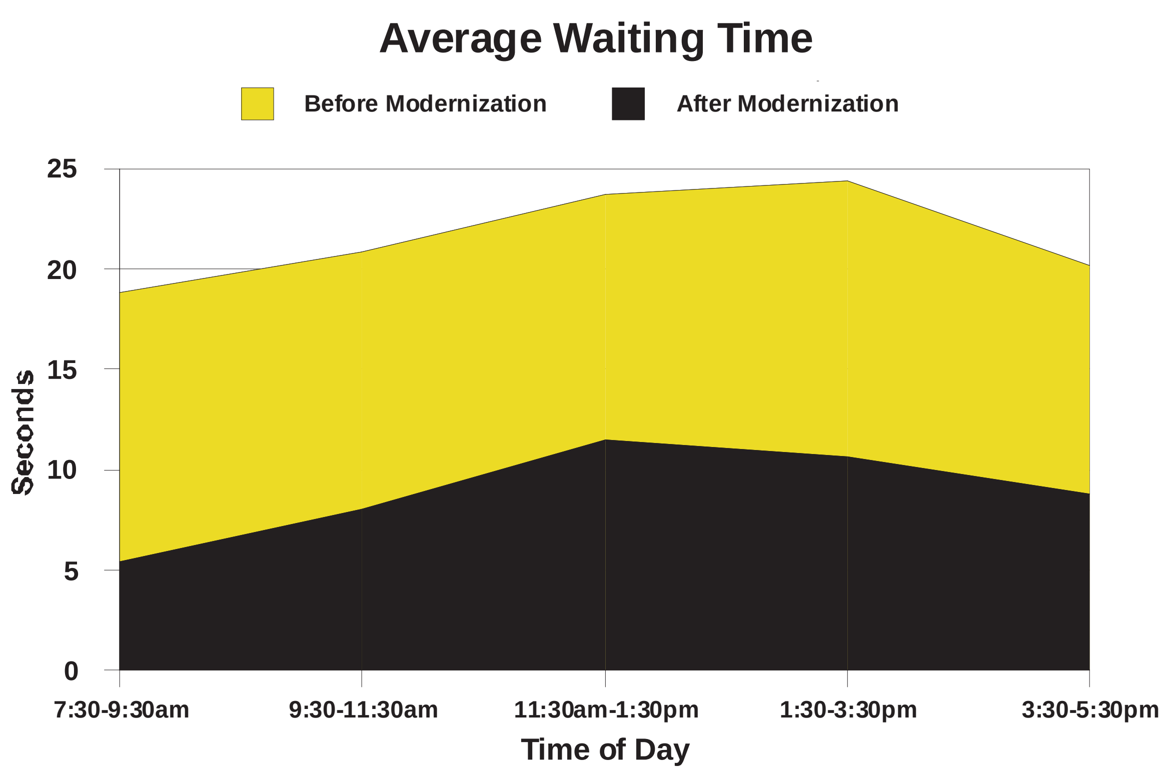
Statistics

	BEFORE	AFTER
Calls	2,413	3,258

Rev 9/10/98

Dupont Plaza
Office Building
Miami, FL USA

59%
Reduction
in Hall Call
Wait Time



Equipment
Existing:
Otis gearless
Modernized with:
MCE IOS Intelligent Overlay System
MCE M3 Group Dispatcher

Traffic Study Detail
Pre-Modernization:
11/18/91 — Digimetrix Traffic Analysis System
Post-Modernization:
8/5/92 — MCE CMS Traffic Analysis Reporting

Project Profile

Cars:	**3**
Floors:	**12**
Stops:	**12**
Speed:	**700 fpm**
Type:	**office building multiple tenant**

Statistics

	BEFORE	AFTER
Calls	1,712	1,739

17

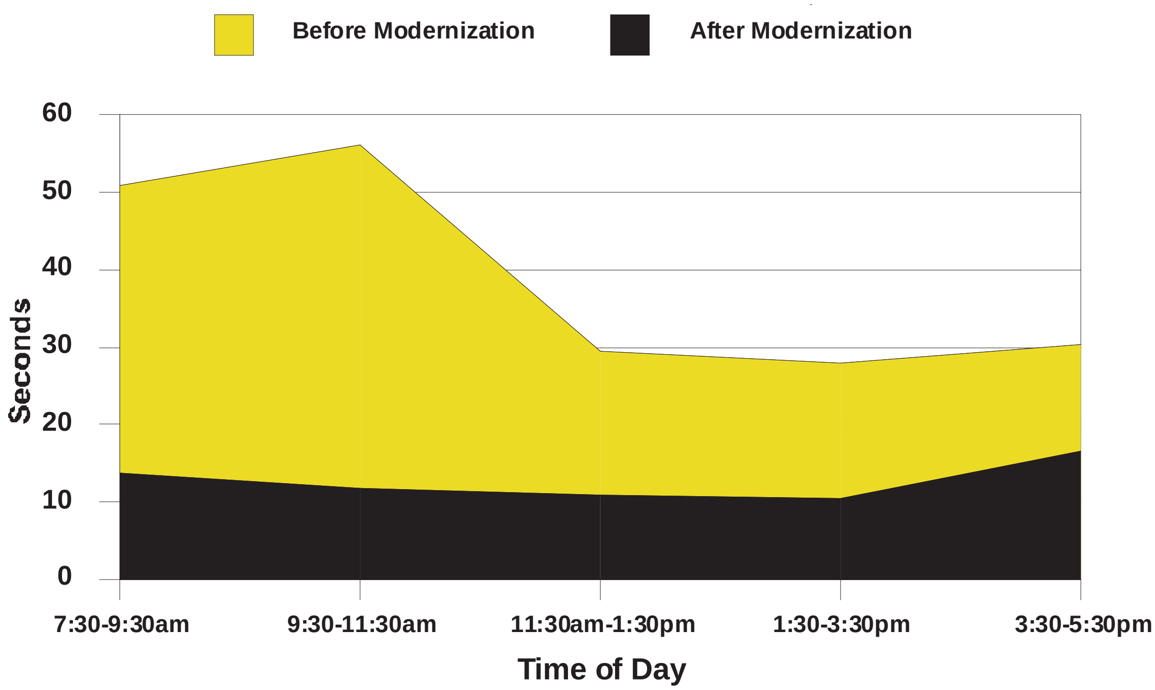
MCE

Rev 5/26/98

Holiday Inn
750 Kearny Street
San Fransisco, CA USA

68%
Reduction
in Hall Call
Wait Time

Average Waiting Time



Equipment
Existing:
Otis gearless
Modernized with:
MCE IMC-SCR 12-pulse controls
MCE M3 Group Dispatcher

Traffic Study Detail
Pre-Modernization:
10/29/96 — Digimetrix Traffic Analysis System
Post-Modernization:
5/4/98 — MCE CMS Traffic Analysis Reporting

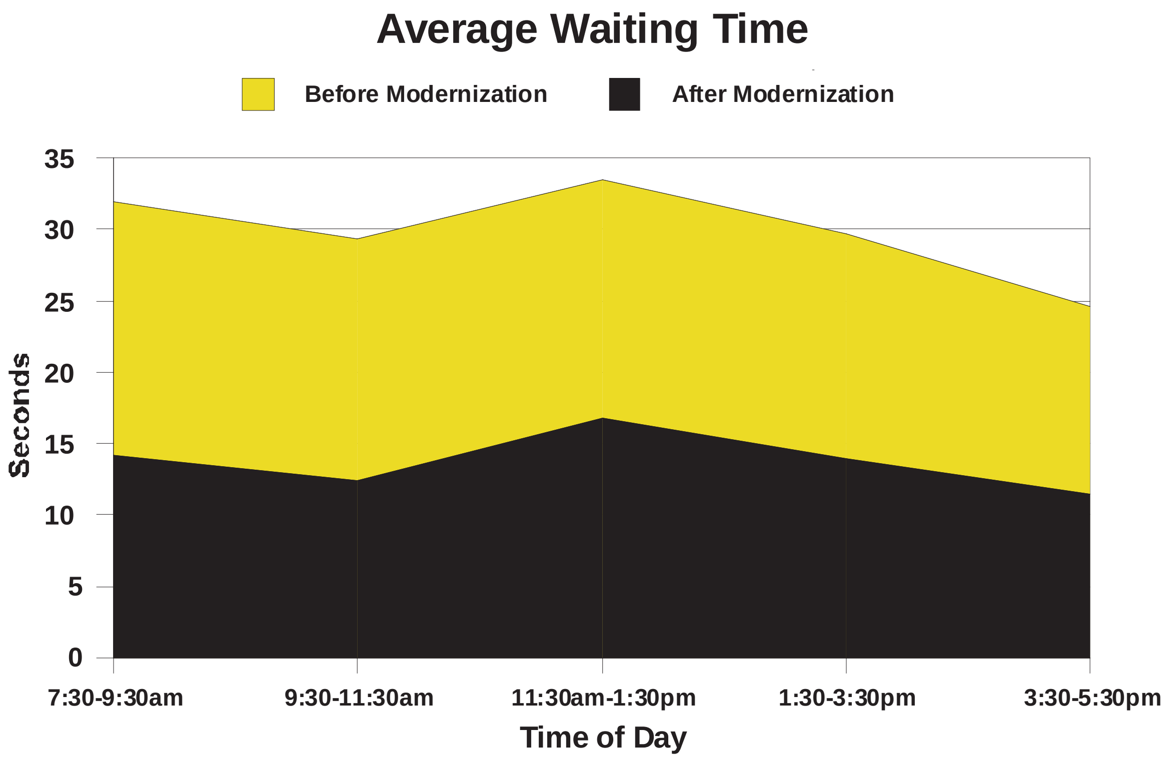
Project Profile
Cars:	**4**
Floors:	**31**
Stops:	**31**
Speed:	**700 fpm**
Capacity:	**2,500**
Type:	**hotel**

Statistics
	BEFORE	AFTER
Calls	3,925	3,590

Rev 5/26/98

Office Building 9
744 P Street — Low Rise
Sacramento, California USA

54%
Reduction in Hall Call Wait Time



Equipment
Existing:
Otis gearless
Modernized with:
MCE IMC-MG Controls
MCE M3 Group Dispatcher

Traffic Study Detail
Pre-Modernization:
5/8/97 — EPTi Traffic Analysis System
Post-Modernization:
9/11/98 — MCE Traffic Analysis Reporting

Project Profile

Cars:	**3**
Floors:	**11**
Stops:	**11**
Speed:	**500 fpm**
Capacity:	**3,500 lbs**
Type:	**office building multiple tenant**

Statistics

	BEFORE	AFTER
Calls	1,852	1,995

MCE

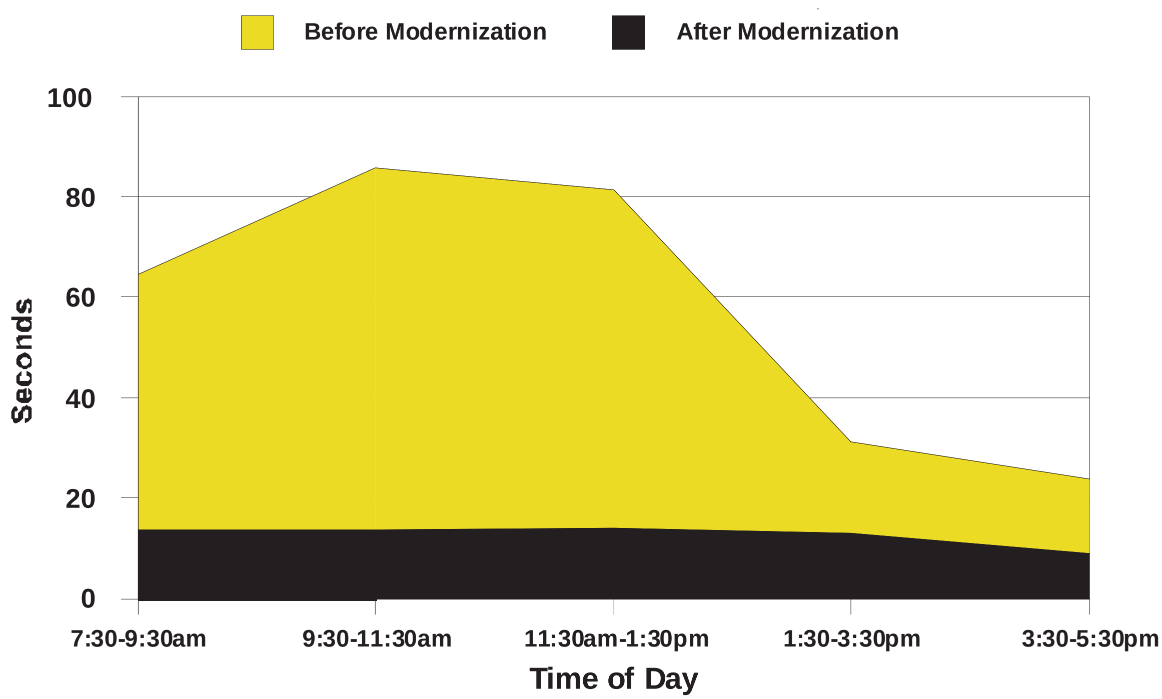
Rev 9/17/98

Office Building 9

744 P Street — High Rise
Sacramento, California USA

78%
Reduction in Hall Call Wait Time

Average Waiting Time



Equipment

Existing:
Otis gearless
Modernized with:
MCE IMC-MG Controls
MCE M3 Group Dispatcher

Traffic Study Detail

Pre-Modernization:
5/20/97 — EPTi Traffic Analysis System
Post-Modernization:
9/4/98 — MCE Traffic Analysis Reporting

Project Profile

Cars:	**3**
Floors:	**18**
Stops:	**11**
Speed:	**1,000 fpm**
Capacity:	**3,500 lbs**
Type:	**office building multiple tenant**

Statistics

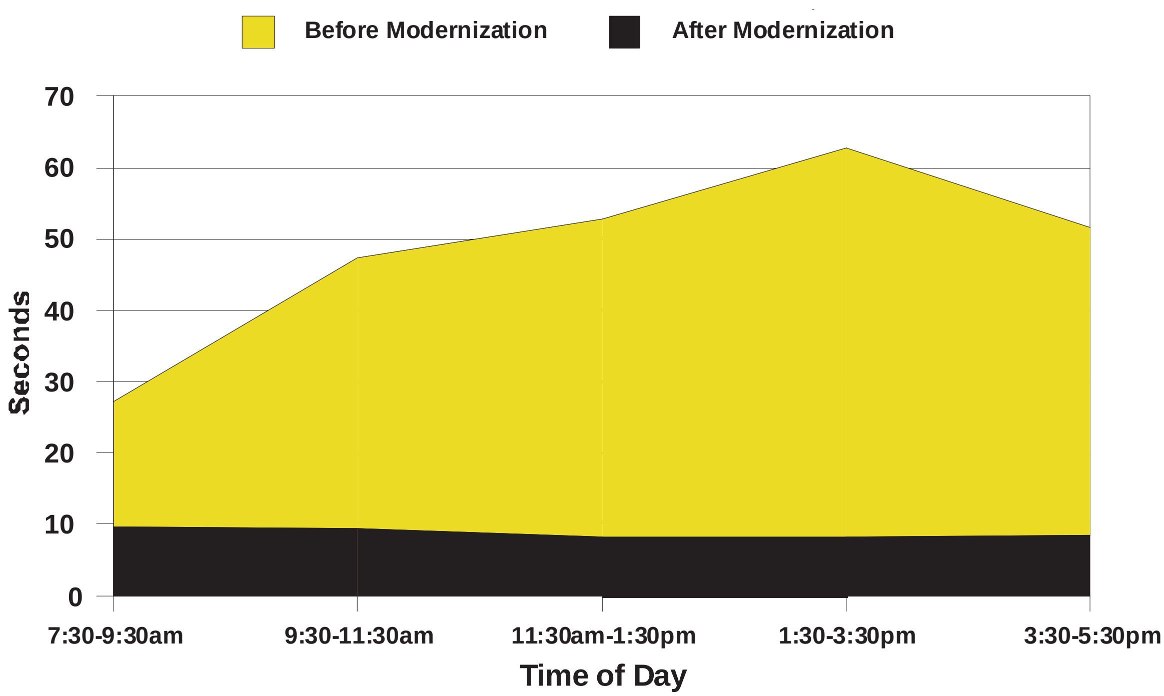
	BEFORE	AFTER
Calls	1,607	1,792

Rev 9/10/98

Rutledge Building
Senate Street
Columbia, South Carolina, USA

83%
Reduction in Hall Call Wait Time

Average Waiting Time



Equipment
Existing:
Otis gearless
Modernized with:
MCE IMC-SCR 12-Pulse Controls
MCE M3 Group Dispatcher

Traffic Study Detail
Pre-Modernization:
5/10/95 — EPTi Traffic Analysis Reporting
Post-Modernization:
9/24/98 — MCE CMS Traffic Analysis Reporting

Project Profile

Cars:	**4**
Floors:	**13**
Stops:	**13**
Speed:	**500 fpm**
Capacity:	**3,000 lbs**
Type:	**office building single tenant**

Statistics

	BEFORE	AFTER
Calls	1,900	2,536
Population	600	600

MCE

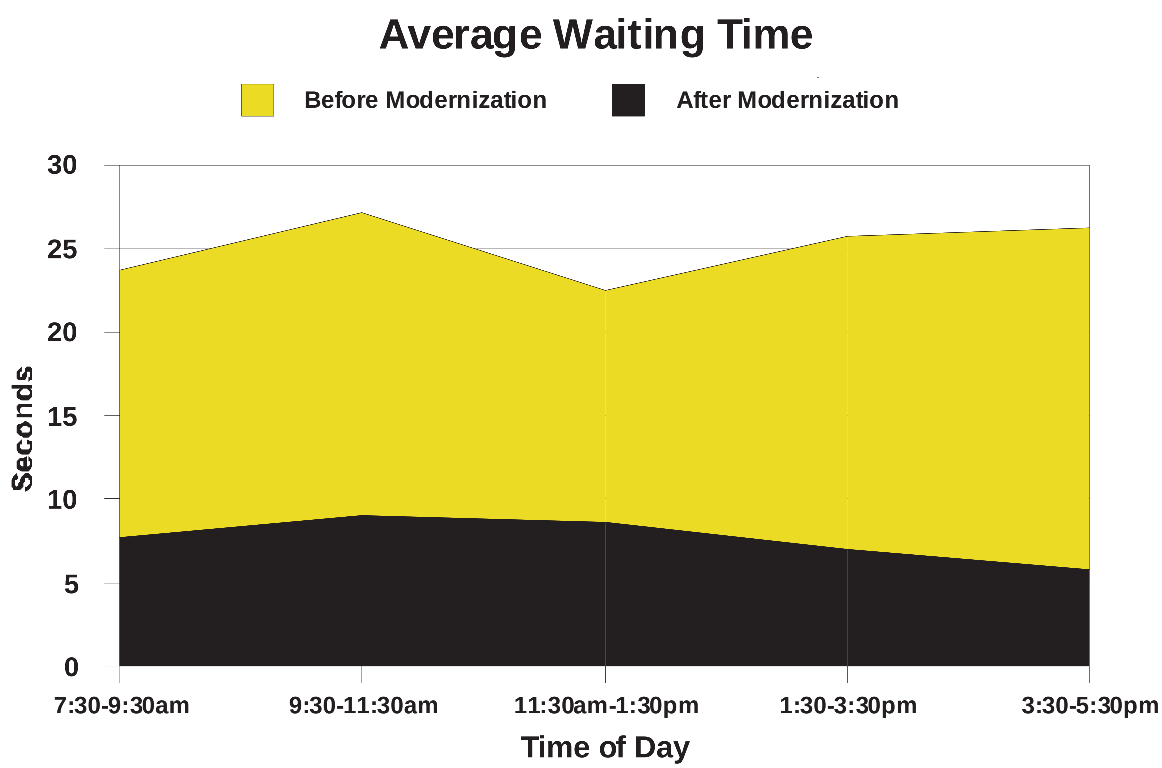
Rev 11/05/98

University of Minnesota

Moos Tower

Minneapolis, MN USA

70%
Reduction
in Hall Call
Wait Time



Equipment

Existing:
Westinghouse gearless
Modernized with:
MCE IMC-SCR 12-pulse controls
MCE M3 Group Dispatcher

Traffic Study Detail

Pre-Modernization:
3/19/96 — Digimetrix Traffic Analysis System
Post-Modernization:
3/18/97 — Digimetrix Traffic Analysis System

Project Profile

Cars:	**6**
Floors:	**19**
Stops:	**18**
Speed:	**700 fpm**
Capacity:	**4,000 lbs**
Type:	**medical school**

Statistics

	BEFORE	AFTER
Calls	2,203	3,422

Rev 5/26/98