Replacing Motor-Generator Sets with Modern Static DC Drives

by Jim Papez and Mark Kobiske

Learning Objectives

After reading this article, you should have learned about

- the drawbacks of motor-generator sets.
- the value of static DC drives.
- considerations when replacing a motor-generator set with a digital DC drive.
- input power considerations.
- the issue of power-line distortion.
- sizing criteria for transformers.
- output power considerations.
- ripple-filter recommendations and adjustments.
- car-controller considerations in a modernization with a DC drive.
- commissioning a DSD 412 DC elevator drive.
- verification of motor data and wiring.
- motor field board setup.
- recording motor data and encoder setup.
- grounding considerations.
- power-up verification and advanced diagnostics.

For many years, high-performance elevator systems utilized an extremely rugged, open-frame, brush-type DC motor to power the hoist.

The controlled DC power was generated via an AC motor operating from line power and driving a DC generator – a classic motor-generator set. This control configuration, known as a Ward Leonard system, basically regulates DC power to the hoist motor armature by controlling the generator field.

Although such MG systems performed satisfactorily for years, they were not without drawbacks. Some common concerns included:

- *High power consumption*: A motor and generator working together to generate DC power is inefficient. Additionally, an MG set creates a constant and significant power drain – even at idle speed when the elevator is not in motion.
- *High routine maintenance*: MG sets are often specified at minimum size and cost but must rotate at relatively high speeds to meet DC power requirements. As a result, frequent and costly maintenance is a necessity.
- *Excessive generator brush wear*: Brush wear is a continuing problem. Additionally, the large amount of carbon dust generated can spread throughout the machine room and cause failure of other electrical equipment.

Eventually, the cost and high maintenance required for MG sets rendered these impractical – even while the rugged, low-speed DC hoist motor kept operating as well as the day it was first installed.

Static DC Drives to the Rescue

At the same time, power electronics utilizing silicon-controlled rectifier (SCR) static switches to directly convert AC line power to DC were providing new solutions to some of the MG set problems. This advance virtually eliminated the need to provide rotating and high-maintenance components involved in the production of DC power.

Additionally, conversion efficiency was greatly improved, and idle losses were drastically reduced, resulting in much lower power consumption.

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Value: 1 contact hour

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Static components produced remarkable savings on maintenance, making MG set brush wear and carbon dust contamination things of the past. Crowded machine rooms also benefited from the comparatively small size of the static drive.

Today's Advanced, All-Digital Static DC Drives

Incorporation of modern, microprocessor-based controllers into today's all-digital elevator drives provides:

- ◆ Minimum installation and operating cost.
- ◆ High reliability.
- ◆ Exceptional performance to help reduce passenger waiting times and floor-to-floor times.
- ◆ All-digital control to ensure repeatability over time and consistent operation of all elevators in a group.

Digital DC drives have virtually eliminated problems experienced with the earlier analog versions. Analog DC drive problems included difficult adjustments caused by numerous potentiometer settings that were sensitive, often interactive and could not be replicated successfully on another car; component drift with age and environmental changes that affected car performance; and high part count with many more electrical connections that negatively impacted reliability.

Today's DC elevator drives are designed and field-qualified specifically for elevator applications. They have the high lift capacity demanded for minimum floor-to-floor times and can withstand the rigorous duty cycle associated with high-speed elevators.

In addition, modern software incorporates unique control algorithms to provide optimum performance and a broad spectrum of input/output capabilities for car control interface.

DC Drives as MG Set Replacements

Since the introduction of DC static drives, MG sets have essentially disappeared from use in new installations. This, in turn, has caused some manufacturers to exit the MG business, resulting in a severe shortage of replacement parts for existing MG set installations.

Thus, more and more MG sets are being replaced with all-digital DC drives as part of modernization programs or simply to reduce maintenance costs.

Application Considerations

Three major considerations must be met when replacing a MG set with a digital DC drive. Those considerations are:

- ◆ Input power;
- ◆ Output power; and
- ◆ Car control interface.

Input Power Considerations

Power Feed: Since it converts AC to DC directly, the DC drive will draw approximately 30% more amps from the line during car acceleration. Also, the requirement for peak acceleration amps is immediate, rather than built up gradually as with the MG set. The power line must be able to support these conditions without excessive voltage drop affecting equipment on the same feeder.

Input Voltage: MG sets convert line volts to armature volts via rotating components. Static DC drives do the AC to DC conversion directly via three-phase rectification. If the DC voltage required by a hoist motor is significantly lower than the line input voltage, the drive will lower the input power factor. A low power factor means a higher KVA requirement that needs to be supported by the power distribution equipment and wiring. Older buildings may not have this capability, and thus, an input transformer is recommended to make the voltage input to the drive comparable to motor armature voltage. As will be seen, there are other good reasons for using this transformer.

Power Line Distortion: Static switching draws square-wave current from the line and creates a notch when current is commutated from one switch to another. The result is a harmonic distortion on the power line. Potentially harmful effects are generally eliminated by use of an input isolation transformer with good secondary reactance.

SCR Switching (commutation): Two conditions must be met to provide proper operation: 1) the AC voltage must be equal to or greater than the DC voltage, and 2) at least 2-4% reactance on the input is needed. Both of these conditions can be met with an input transformer.

Transformer Sizing Criteria:

- ◆ Input primary voltage must match the line voltage.
- ◆ Output secondary voltage must equal or exceed DC armature voltage. If there is a potential for the line voltage to drop, then a 10-20% increase in secondary voltage is recommended as a safety factor.
- ◆ 5% voltage taps are recommended to allow for unforeseen field conditions, such as line voltage drop or the need to more closely match armature voltage for power factor or performance.
- ◆ Continuous (rated) secondary amps should equal or exceed 1.05 X 0.82 X full-load DC armature amps.
- ◆ Continuous (rated) KVA rating is secondary amps X secondary volts X 1.732.
- ◆ The transformer must not saturate when acceleration amps are substituted for full-load amps in the above formula.
- ◆ The secondary reactance should be at least 2-4%.

Output Power Considerations

These are somewhat more empirical, as they depend on both motor and hoistway conditions. Thus, some degree of application experience must be taken into consideration.

DC Motor Armature: Elevator motors almost always have armatures designed to minimize torque ripple and provide for a smooth ride. This is also the best motor for operation from a static DC drive. In the rare older hoist motor that may not have this armature design, torque ripple may be accentuated by the static DC drive. If that results in a performance issue, such as car vibration, then greater care in adjustment is needed. An increase in the size of the DC ripple filter may also be necessary to further reduce drive-generated voltage ripple.

DC Drive Output Voltage Ripple: Three-phase rectification produces a 360-Hz ripple on DC voltage. This ripple can excite the hoist motor and produce acoustical noise in the motor and mounting structure. That noise, in turn, is transmitted to the hoistway. Thus, some type of ripple filter in the DC line is normally desirable.

Ripple Filter Recommendations

A ripple filter added in the DC line from the static drive to the DC motor is normally recommended. The general criteria are:

- ◆ Filter inductance and resistance should be approximately equal to motor armature inductance and resistance.
- ◆ Adjustable capacitance and damping resistance should be included with the basic design criteria of roll-off starting at approximately 300 Hz and a tuned peak of approximately 100 Hz (Q of 1.2-1.5).
- ◆ The filter should be rated for continuous operation at full-load armature current and not saturate at acceleration current. Inductance needs to be constant from very low armature current through maximum acceleration current.
- ◆ The supplier of this filter must be familiar with its application.

Ripple Filter Adjustment: Most quality manufacturers provide application notes advising on how to measure the actual value of the filter and how to properly set up the DC drive with the filter.

Acoustical Noise Abatement: Typically, a static DC drive used in conjunction with the recommended ripple filter will achieve more than adequately quiet operation. Many times – almost always for geared machines – the addition of inductance alone will achieve the desired results. If it does, then the capacitors are performing no useful function and may be disconnected from the filter. Doing so now removes an unnecessary component from the power circuit, which in turn, improves reliability and reduces future maintenance of the filter circuit. In the rare circumstance that unacceptable noise is still present after the filter and drive are properly adjusted, mechanical dampening of hoistway components is required.

Practical Experience: Experience within the industry has shown that a ripple filter consisting of a 5mh inductor with sufficient range of adjustment in the capacitors and damping resistance is broadly effective. However,

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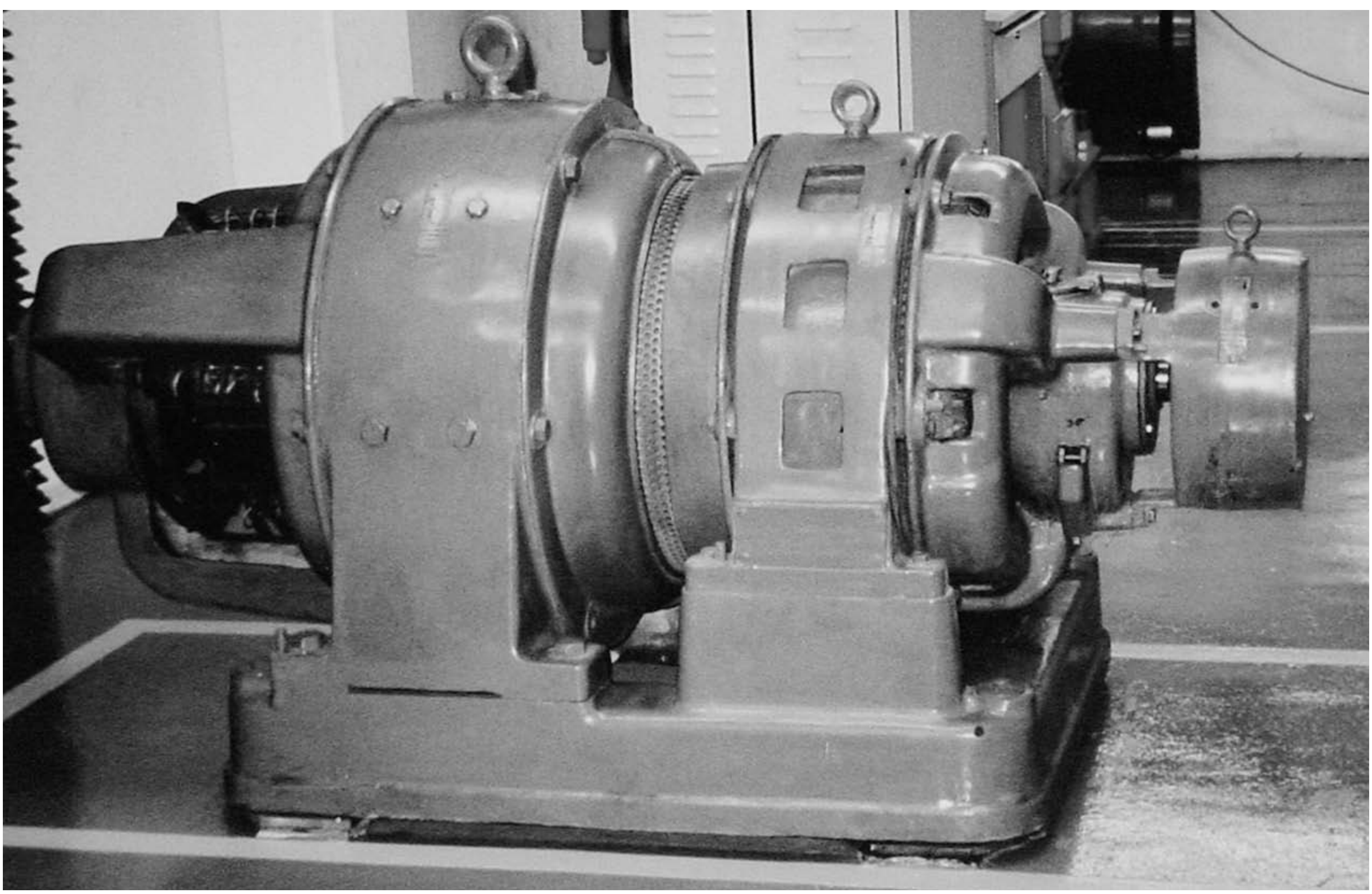

Vintage motor generator

some motors have very high armature inductance and, thus, may require a larger reactor, typically equivalent to the armature inductance, to obtain desired acoustical results. The elevator application engineer relies on his experience to make these judgement decisions initially. However, since noise is usually subjective, it may be necessary to have the building owner pass final judgement on acceptability.

Car Controller Considerations

In total modernization projects, a new car controller that includes the drive is usually provided. All interfaces with the drive are then either handled or specified by the car controller manufacturer. If simply replacing the MG set while retaining the existing car controller, then several issues must be considered:

◆ An electrical schematic, wiring diagram and operational sequence chart should be generated to ensure proper installation and operation.

◆ The compatibility of all signal and power supply ratings requires verification. In particular, low-level electronic signals interfacing with relays must be controlled via appropriately rated contacts.

◆ Older-style controls may not have had to consider the susceptibility to electrical noise of today's processor controls. Relay coil switching and contact arcing are significant noise generators that must be isolated from the electronics.

◆ A digital drive also generates electrical noise that must be isolated from existing electronic controls. Physical separation of products and wiring is the first step in successfully achieving that.

Conclusion

Today's all-digital static DC drives offer both the installer and building owner many benefits over older analog DC drives and Ward Leonard MG set controls. To realize these fully, especially when replacing MG sets, several factors beyond simple rating criteria must be considered. A general discussion of those has been presented here. However, since both elevators and buildings vary greatly in the details, an experienced elevator application engineer should be responsible for ensuring proper design and installation.

Commissioning of the Magnetek DSD 412 DC Elevator Drive

The Magnetek DSD 412 is one of the world's most widely used DC elevator drives. Its applications range from low-speed geared to high-speed gearless such as the Sky View observation deck at the Sears Tower. Whether fast or slow, geared or gearless, it is crucial to follow proper guidelines that will ensure years of trouble-free operation.

Verify Wiring

Wire sizes are required to comply with National Electrical Code (NEC), Underwriters Laboratories Inc. (UL), Canadian Standards Association (CSA) and other applicable codes for power-distribution safety.

◆ *Verify Wiring:* The wiring between the DSD 412 and the motor should be checked to determine that no insulation has been damaged during the installation. This check should be done at the drive end of the power wires. Disconnect the shunt field wires F1 and F2 from the field interface board (A3) terminal TB4. Attach the field wires temporarily to the load side of the armature contactor A1 and A2. Remove the wires from the armature interface board A2TB5-1 and A2TB5-2 and isolate them from the ground. With the power wiring now isolated from the drive, "megger" from the load side of the armature contactor to ground. If a problem is detected, the source of the ground fault must be determined and resolved prior to proceeding further.

◆ *Signal Wire:* Each signal wire located on the main control board TB1 must be checked for isolation

Pre-power checks

from ground. Verify that it is installed in the correct terminal and that the terminal is tight (3.5-in.-lb. maximum). All low-power, low-voltage wiring should be run separate from 120 VAC, three-phase AC, DC armature and field wires. These include:

Encoder wiring
Speed reference wiring
Pre-torque reference wiring
24-VDC logic inputs
Open collector outputs

To avoid noise pickup, shielded cable should always be used for these signals.

◆ *Control Wire:* The control wiring located on the power supply (A4) TB3-1 through TB3-8 should be checked to verify that connections are correct and tight.

Verify Motor Data

◆ *Field Coil Checks:* Prior to reattaching the F1 and F2 wires to A3 TB4-F2(-) and TB4-F1(+), record the resistance of the field coil. In most cases, the motor nameplate states the full field voltage or full field current. A quick calculation can verify which AC voltage must be applied to the field interface board (A3) to achieve full field current. The calculation below will provide the minimum acceptable level; however, typically the level could be in the range of 1.5 to 2.5 times *VAC(min). VAC(min) = VDC10.9 or (Full Field Current X Field Resistance)/0.9*. If the actual value for VAC drops below this point during the operation of the elevator motor, torque may be affected, which will result in higher-than-expected armature current.

◆ *Motor Field Board Setup:* The DSD 412 can operate motor fields in the range 0.2 to 40.0 ADC as standard. Connection on the field interface board for the motor field is TB4. Common connection point is F2(-). The maximum range of the motor field current determines which terminal F1(+) should be connected. For the drive to recognize the selected current range, "S1" must be set correctly. The figure below identifies the terminal locations and proper switch positions for "S1." In some models of the DSD 412, switch "S1" is a *rocker type*. A rocker switch is *closed* when it is pushed "in" on the top, and a rocker switch is *open* when it is pushed "in" on the bottom. Newer models of the DSD 412 will be *slide type* (see figure below). Move the slide actuator of "S1" or press the rocker switch actuator in as indicated to coordinate the position of "S1" with the ampere range connected at TB4. The AC voltage is the next consideration when approaching this part of the setup. Typically, the DSD 412 comes wired from the factory with the AC voltage derived from the L1 and L2. If the three-phase voltage fails to meet the criteria defined above, it will be necessary to supply an alternate AC voltage.

◆ *Setup of Alternate AC Voltage to the Motor Field Board (Optional):* If the three-phase voltage fails to meet the criteria defined above, it will be necessary to supply an alternate AC voltage. This is done by using a single-phase transformer. The DSD 412 factory wire should be moved from AC1 to L1A on TB1. Connect H1 on the transformer to L1A on TB1. Move the factory wire on AC2 to L2A on TB1. Connect H2 on the transformer to L2A on TB1. This will provide voltage to the primary side of the transformer. Connect X1 on the transformer to AC1 of TB1. Connect X2 on the transformer to AC2 of TB1. This completes the wiring of the alternate single-phase transformer. *Install semiconductor fuses between secondary of the transformer (X1, 2) and the TB1 (AC1, 2).*

Recording Motor Data

◆ *Record the Remaining Information from the Nameplate of the Motor:* Rated motor amps, rated armature voltage, rated motor RPM, full field current and weak field current. Record encoder pulses per revolution and rated car speed. These numbers will need to be entered into the DSD 412 drive as parameters later in the startup.

◆ *Input Isolation Transformer/ Control Transformer:* Transformer taps need to be set so the secondary voltage is equal to or exceeds the anticipated DC armature voltage at rated car speed. The control transformer, if used, should be checked to verify it is wired to provide 120 VAC on the secondary when the power is turned on.

◆ *Encoder Considerations:* The preferred method of mounting the encoder is inline with the motor armature; precision alignment is crucial to stability of the DSD 412 speed regulator. The body and shaft of the encoder should be electrically isolated from the motor frame to prevent electrical noise from causing interference. Digital encoders that operate with this product will require a shielded cable with three twisted pairs. The pairs should be made up of A and A-, B and B-, +5 VDC and common. The shield should be insulated from the encoder case and only connected at the drive end. The maximum frequency of the encoder at rated car speed should not exceed 300 kHZ.

Grounding

◆ *Grounding Considerations:* Ground bonding wire sizes are required to comply with NEC, UL, CSA and other applicable codes for safety. Provide ground bonding wires as indicated. Do not rely on metal conduit or building steel connections to perform this function. Drive enclosures should have an electrically bonded ground stud or bus bar contained

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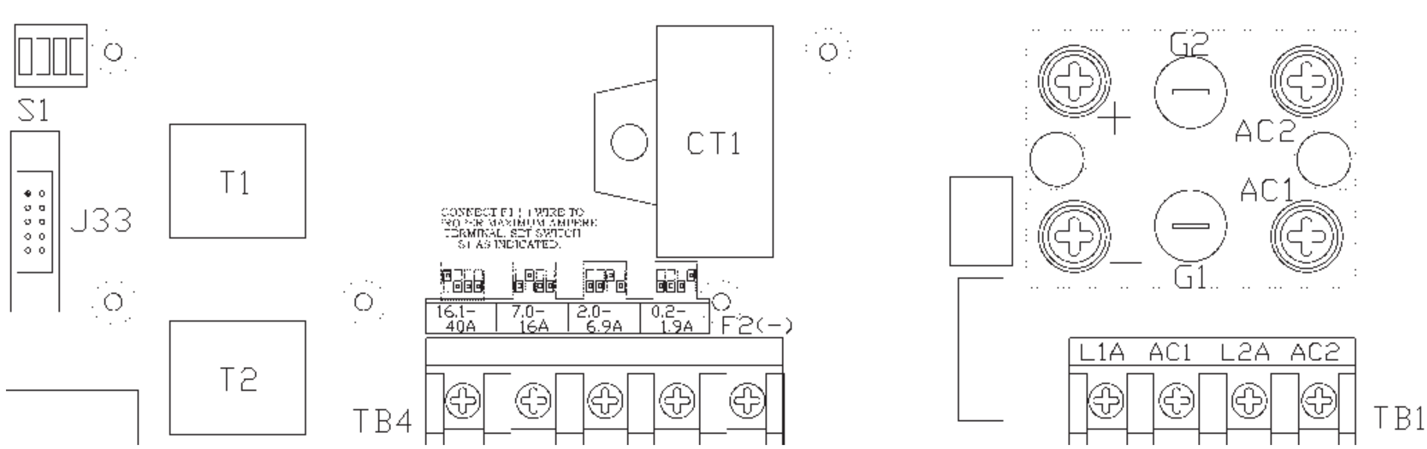

DSD 412 field interface board

within their construction. The following items should be connected to the enclosure ground point, *each with its own bonding wire*: DSD 412 drive ground lug, the sub panel (to which the DSD 412 is mounted), motor frame, isolation transformer frame and inductor frame of the armature ripple filter (if used). The secondary of the isolation transformer should remain ungrounded. The building ground should be tied to the enclosure ground point. On the DSD 412 drive, the low-voltage circuit common should be grounded by connecting A1TB1-44 to A1TB11.

Power Up

◆ *Apply the Control and Three-Phase Power:* Verify that the control voltage is between 103 VAC and 126 VAC. Check for balanced VAC from each phase to ground. Measure the voltage line to line. Verify that the voltage is in the range that was determined previously. Enter into the DSD 412 the motor parameters, line voltage and other specific parameters that will allow the elevator to operate as it was designed.

◆ *Advanced Diagnostics:* Prior to operating the motor, the DSD 412 has two automatic routines which need to be performed. To perform these tests, it is crucial that the DSD 412 has control of the armature contactor. Placing a jumper from TB3-3 to TB3-6 on the DSD 412 typically does this. *Once these tests are complete, the jumper must be removed*. The first of these tests is called "drive diagnostics" F998: this routine will verify the power components within the drive and some of the critical wiring. The second routine is called "self tune" F997: this step calculates critical motor parameters that are required for proper speed regulation. If either of these tests fail, the problem must be resolved prior to proceeding further.

◆ *Verifying Field Current:* The most critical step once the startup has reached this point is to verify functions to ensure that the controller is performing as expected. The motor field control on the controller can be easily verified to determine proper setup. Set up the elevator to run at zero speed. Do not lift the brake on the drive monitor function #612 (field current feedback). With an external monitoring device, such as an amp probe, measure the actual field current. Verify that these two readings match. If the only tool available is a digital volt-ohm meter, measure the voltage and calculate the actual field current: I = V shunt field/R shunt field (recorded previously).

◆ *Operating the Motor:* Set the expected car speed to 5% of rated speed, run the drive, and verify that the elevator is moving in the correct direction and at the correct speed. Repeat the check for the opposite direction. The Rated Car Speed can be monitored on function #600. Set the rated car speed to 100%. Make multi-floor runs. Monitor the armature voltage feedback on parameter #610. This number should be equal to or less than the AC line voltage feeding the drive. If the armature voltage is greater than the line voltage drive, then the motor needs to have less field current at top speed. This is done by a technique referred to as field weakening.

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Learning-Reinforcement Questions

Use the below learning-reinforcement questions to study for the Continuing Education Assessment Exam available online at www.elevatorbooks.com or on page 111 of this issue.

- What are the three main drawbacks of motor-generator sets?
- What are the four main values received when replacing motor-generator sets with DC drives?
- What are the most important things to consider when replacing motor-generator sets with DC drives?
- What is a ripple filter?
- How is the encoder mounted in a DSD 422 installation?
- Ground bonding wire must comply with which applicable codes?
- How is a jumper used in advanced diagnostics on the DSD 412?

ELEVATOR WORLD Continuing Education Assessment Examination Questions

Instructions:

- Read the article **"Replacing Motor-Generator Sets with Modern Static DC Drives,"** (page 85) including the sidebar **"Commissioning of the Magnetek DSD 412 DC Elevator Drive"** and study the learning-reinforcement questions.
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1. The Ward-Leonard system is a control configuration that generates:
   a. Controlled DC power via a DC motor operating from line power and driving a DC generator.
   b. Controlled DC power via an AC motor operating from line power and driving a DC generator.
   c. AC power via a DC motor operating from an AC generator.
   d. DC power via a DC motor operating from line power.

2. The following is a major drawback of MG systems:
   a. High power consumption.
   b. High routine maintenance.
   c. Excessive generator brush wear.
   d. All of the above.

3. Since the introduction of DC static drives, MG sets have essentially disappeared from use in new installations. This, in turn, has caused:
   a. A severe shortage of replacement parts for existing MG sets.
   b. An overage of replacement parts for existing MG sets.
   c. A manufacturing boom for replacement MG sets.
   d. None of the above.

4. Since it converts AC to DC directly, the DC drive will draw approximately _____ more amps from the line during car acceleration.
   a. 0%
   b. 10%
   c. 30%
   d. 90%

5. A _____ is added to the DC line from the static drive to the DC motor to reduce acoustical noise in the motor and mounting structure.
   a. Noise filter
   b. Ripple filter
   c. Output filter
   d. Capacitor filter

6. When replacing the MG set while retaining the existing car controller, the following should be generated to ensure proper installation and operation:
   a. An electrical schematic.
   b. A wiring diagram.
   c. An operational sequence chart.
   d. All of the above.

7. The wiring between the DSD 412 and the motor should be checked to determine that no insulation has been damaged during the installation. This check should be done at the:
   a. Motor end of the power wires.
   b. Drive end of the power wires.
   c. Midsection of the power wires.
   d. Exposed area of the power wires.

8. Encoder wiring, speed reference wiring, pre-torque reference wiring, 24 VDC login inputs and open collector outputs should be run _____ 120 VAC, three-phase AC, DC armature and field wires.
   a. Together with
   b. Separate from
   c. Directly underneath
   d. None of the above

9. In most cases, the _____ states the Full Field Voltage of Full Field Current.
   a. Motor nameplate
   b. Safety Handbook
   c. Main control board
   d. DC drive

10. The preferred method of mounting the encoder is ______ the motor armature.
    a. Perpendicular to
    b. Below
    c. In line with
    d. Above

ELEVATOR WORLD Continuing Education Reporting Form

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