PRACTICE EXAM 7: PE POWER SIMULATION (80 QUESTIONS)

1. A three-phase, 480V, solidly grounded wye system has the following per-unit sequence impedances at a fault bus on a 1,500 kVA base: $Z_1 = 0.02 + j0.06$, $Z_2 = 0.02 + j0.06$, $Z_0 = 0.04 + j0.12$. A bolted SLG fault occurs. The three-phase fault current at the same bus is 25,000A symmetrical. What is the relationship between the SLG and three-phase fault currents?

A. The SLG fault current is approximately 50% of the three-phase value

B. The SLG fault current exactly equals the three-phase value

C. The SLG fault current is approximately 125% of the three-phase value

D. The SLG fault current is approximately 75% of the three-phase value

2. Per NEC 430.24, a feeder supplies four motors: Motor A at 124A (100 HP), Motor B at 65A (50 HP), Motor C at 34A (25 HP), and Motor D at 14A (10 HP). All FLA values are from NEC Table 430.250. A continuous lighting load of 80A is also on the feeder. What is the minimum feeder conductor ampacity?

A. 344A

B. 317A

C. 268A

D. 412A

3. A 500 kVA, 4,160V/480V, three-phase transformer has core losses of 1,500 W and full-load copper losses of 5,800 W. The transformer serves a load that varies daily: 8 hours at 100% load (PF = 0.90), 8 hours at 60% load (PF = 0.85), and 8 hours at 30% load (PF = 0.80). What is the all-day (24-hour) energy efficiency?

A. 96.8%

B. 95.2%

C. 97.4%

D. 98.1%

4. A three-phase, 13.8 kV bus has an available fault current of 20 kA. A proposed 4,000 kvar capacitor bank will be installed on this bus. The system contains six-pulse VFDs as the primary harmonic source. At what harmonic order does parallel resonance occur, and what mitigation is recommended?

A. h_r = 3.2; install a 3rd-harmonic filter tuned to 180 Hz

B. h_r = 4.8; install detuning reactors to shift resonance below the 5th harmonic

C. h_r = 7.1; no mitigation needed since 7th-harmonic levels are typically low

D. h_r = 11.2; resonance is safely above the dominant 5th and 7th harmonics

5. A 230 kV transmission line is 180 miles long with a positive-sequence impedance of Z_1 = 0.08 + j0.70 Ω/mile and a characteristic impedance of 370 Ω. The line is loaded at 450 MW. What is the SIL, and is the line loaded above or below it?

A. SIL = 143 MW; loaded above SIL — line absorbs reactive power

B. SIL = 370 MW; loaded above SIL — line generates reactive power

C. SIL = 286 MW; loaded below SIL — line generates reactive power

D. SIL = 143 MW; loaded above SIL — line generates reactive power

6. Per NEC 250.122, the minimum equipment grounding conductor for a circuit protected by a 100A overcurrent device is 8 AWG copper. The circuit conductors are 1 AWG copper (83,690 CM), increased from the minimum 3 AWG (52,620 CM) for voltage drop. Per NEC 250.122(B), the EGC must be proportionally increased. What is the minimum EGC size?

A. 6 AWG copper (26,240 CM)

B. 4 AWG copper (41,740 CM)

C. 8 AWG copper (16,510 CM — no increase required)

D. 10 AWG copper (10,380 CM)

7. A 2,000 kVA, 13.8 kV/480V, delta-wye grounded transformer has a percent impedance of 5.75% and a percent resistance of 1.0%. At full load with a 0.80 leading power factor, what is the approximate voltage regulation?

A. +4.6%

B. +2.8%

C. −2.4%

D. −5.75%

8. A protective relay coordination study is being performed for a medium-voltage industrial system. A 13.8 kV feeder relay (51) with an IEEE moderately inverse characteristic has a pickup of 6A on a 600:5 CT and a time dial of 4.0. At a fault current of 4,800A, what is the multiple of pickup M?

A. 800

B. 6.67

C. 4.0

D. 40

9. Per NEC Article 700, emergency system wiring must be kept entirely independent of normal system wiring. An engineer discovers that an emergency conduit and a normal power conduit both enter the same junction box inside a mechanical room. Is this a code violation?

A. Yes, NEC 700.10(B)(1) prohibits emergency and normal circuit wiring in the same raceway, cable, box, or cabinet

B. No, junction boxes are exempt from the separation requirement

C. No, as long as the conduits enter from opposite sides of the box

D. Yes, but only if the box also contains communication circuits

10. A balanced three-phase load draws 250 kW at 0.82 lagging power factor from a 4,160V system. The engineer installs a 150 kvar capacitor bank. What is the new power factor and the reduction in line current?

A. New PF = 0.88 lagging; current reduced by 8%

B. New PF = 0.95 lagging; current reduced by 15%

C. New PF = 0.93 lagging; current reduced by 12%

D. New PF = 0.99 lagging; current reduced by 17%

11. A 50 MVA, 138/13.8 kV, delta-wye grounded transformer has the following sequence impedances on its own base: $Z_1 = Z_2 = j0.10$ pu, $Z_0 = j0.10$ pu. On a 100 MVA system base, a bolted SLG fault occurs on the 13.8 kV bus with an infinite 138 kV source. What is the SLG fault current in per-unit on the system base?

A. 3.33 pu

B. 10.0 pu

C. 1.67 pu

D. 5.0 pu

12. A 480V, three-phase, 225A panelboard is installed in a commercial office building. Per NEC 110.26(A)(1), the minimum working space depth for 480V equipment under Condition 1 (exposed live parts on one side only) is 3.0 feet. The panelboard is 20 inches wide. Per NEC 110.26(A)(2), what is the minimum width of the working space?

A. 20 inches (equal to the equipment width)

B. 30 inches (the minimum regardless of equipment width)

C. 36 inches (NEC requires 3 feet width for all equipment)

D. 24 inches (2 feet minimum for equipment less than 24 inches wide)

13. A CT with a ratio of 1200:5 and accuracy class C200 serves a protective relay with a total circuit burden of 3.0 Ω (including CT winding resistance, lead resistance, and relay burden). During a fault of 15,000A, does the CT maintain its rated accuracy?

A. No, the secondary current of 62.5A at 3.0 Ω produces 187.5V, which is within C200 only at 20× rated (100A), and the actual current exceeds 20×, so accuracy is not guaranteed

B. Yes, 187.5V is within the C200 rating of 200V at any secondary current

C. No, because the 15,000A primary exceeds the CT's thermal rating

D. Yes, because the C200 rating applies at all current levels up to the CT's rated short-circuit current

14. An engineer is designing a lighting system for a 120 ft × 80 ft manufacturing floor with 24-foot ceilings. High-bay LED luminaires will be mounted at 22 feet. The work plane is at 3 feet. Using the room cavity ratio formula $RCR = 5 \times h_{RC} \times (L + W) / (L \times W)$, what is the RCR?

A. 1.98

B. 5.28

C. 2.08

D. 4.17

15. A solar PV system uses a central inverter rated 500 kW. The inverter's maximum DC input voltage is 1,000 VDC. Each module has $V_{oc} = 48.5V$ at STC and a temperature coefficient of $V_{oc} = -0.27\%/°C$. The lowest expected ambient temperature at the site is −25°C. What is the maximum number of modules per string?

A. 18 modules

B. 17 modules

C. 20 modules

D. 15 modules

16. A facility has the following monthly electrical data: peak demand = 5,200 kW, energy consumption = 2,808,000 kWh, billing period = 30 days. The utility rate is $0.072/kWh for energy plus $15.50/kW for demand. What is the total monthly bill and the facility's load factor?

A. Total bill = $242,076; load factor = 0.75

B. Total bill = $283,176; load factor = 0.82

C. Total bill = $242,076; load factor = 0.60

D. Total bill = $283,176; load factor = 0.75

17. Per NEC 210.8(A), GFCI protection is required for all 125V through 250V, 15A and 20A receptacles installed in dwelling unit kitchens. A homeowner installs a 240V, 30A receptacle for an electric range in the kitchen. Is GFCI protection required for this receptacle per NEC 210.8(A)?

A. No, the 30A rating exceeds the 20A threshold for GFCI requirements in dwelling unit kitchens

B. Yes, all kitchen receptacles in dwelling units require GFCI regardless of voltage or ampere rating

C. No, because 240V exceeds the 250V upper voltage limit

D. Yes, because the receptacle is in a kitchen which is a designated GFCI location

18. A three-phase, 4,160V induction motor rated 500 HP has a locked-rotor code letter F (kVA/HP range: 5.0–5.59). Using the midpoint of the range, what is the approximate locked-rotor current and the resulting starting kVA?

A. I_LR = 525A; S_start = 2,650 kVA

B. I_LR = 1,050A; S_start = 5,300 kVA

C. I_LR = 551A; S_start = 2,648 kVA

D. I_LR = 368A; S_start = 2,648 kVA

19. A distance relay on a 69 kV line has Zone 1 set at 80% of the line impedance (Z_line = 2.5 + j20 Ω). Zone 2 is set at 120% with a 0.3-second delay. Zone 3 covers the adjacent line with a 1.0-second delay. A fault occurs at 95% of the protected line length with zero fault resistance. Which zone operates first, and what is the total clearing time (relay + 5-cycle breaker)?

A. Zone 1 operates instantaneously; clearing time = 0.083 seconds

B. Zone 3 operates after 1.0 seconds; clearing time = 1.083 seconds

C. Zone 1 and Zone 2 race; Zone 1 wins with clearing time = 0.083 seconds

D. Zone 2 operates after 0.3 seconds; clearing time = 0.383 seconds

20. A 480V motor control center serves the following motors: three 50 HP (FLA = 65A each), one 100 HP (FLA = 124A), and two 25 HP (FLA = 34A each). Per NEC 430.24, what is the minimum feeder conductor ampacity?

A. 450.5 A

B. 444.0 A

C. 393.0 A

D. 506.0 A

21. A ground resistance test using the fall-of-potential method on a substation ground grid yields measurements at three potential probe positions: 52% = 0.62 Ω, 62% = 0.65 Ω, 72% = 0.69 Ω. The design specification requires a maximum of 1.0 Ω. What is the assessment?

A. The ground grid meets the specification with a resistance of approximately 0.65 Ω; the consistent readings validate the measurement

B. The test is invalid because the readings vary by more than 5%

C. The ground resistance is 0.62 Ω (the most conservative reading must be used)

D. The readings must be temperature-corrected before comparison to the specification

22. A three-phase, 480V, wye-connected source feeds a balanced delta-connected load through a cable with an impedance of 0.03 + j0.08 Ω per phase. Each delta phase impedance is 12∠25° Ω. What is the approximate magnitude of the voltage at the load terminals?

A. 480 V (no appreciable drop)

B. 460 V

C. 471 V

D. 445 V

23. Per NFPA 70E, before any person approaches an electrical conductor or circuit part that has been de-energized, an absence of voltage test must be performed. The voltage detector used for this test must be verified for proper operation immediately before and immediately after the test. This procedure is known as what?

A. The two-step verification method

B. The zero-voltage confirmation test

C. The ground-before-test procedure

D. The live-dead-live test

24. A 750 kVA, 4,160V/480V transformer has an open-circuit loss of 2,100 W and a short-circuit loss at rated current of 8,400 W. At what percentage of full load does maximum efficiency occur, and what is the efficiency at that point for a unity power factor load?

A. 75% load; efficiency = 98.5%

B. 50% load; efficiency = 98.9%

C. 40% load; efficiency = 99.1%

D. 63% load; efficiency = 98.7%

25. A VFD operates a 460V, 4-pole, 60 Hz motor at a speed of 1,350 RPM using constant V/f control. What is the VFD output frequency, and what voltage does it produce at the motor terminals?

A. 45 Hz, 345V

B. 30 Hz, 230V

C. 50 Hz, 383V

D. 37.5 Hz, 288V

26. A 13.8 kV metal-clad switchgear has an available fault current of 31,500A. The switchgear circuit breakers are rated at 29,000A interrupting capacity. Per NEC 110.9, what action is required?

A. No action is needed because the rating is within 10% of the available fault current

B. The switchgear can be operated at reduced voltage to lower the available fault current

C. Additional circuit breakers must be paralleled to increase the total interrupting capacity

D. The circuit breakers must be replaced with units rated at or above 31,500A or upstream current-limiting devices must be installed

27. A balanced three-phase, 208V system feeds a wye-connected resistive load. Each phase draws 15A. What is the total three-phase power?

A. 3,120 W

B. 5,405 W

C. 9,360 W

D. 6,240 W

28. Per NEC Article 501.15(B), in a Class I, Division 2 location, sealing fittings are required at the boundary between the Division 2 area and an unclassified area. Within the Division 2 area itself, are conduit seals required at each explosionproof enclosure?

A. Yes, seals are required at every enclosure in both Division 1 and Division 2

B. No, but seals are required if the conduit run exceeds 50 feet

C. No, conduit seals within Division 2 are required only at the boundary to unclassified areas and at enclosures that contain arcing devices

D. Yes, but only if the conduit contains conductors rated above 600V

29. A 100 kVA, single-phase, 7,200/240V transformer has a percent impedance of 2.5%. The transformer is connected to a residential service. Assuming an infinite source on the primary, what is the maximum available short-circuit current on the 240V secondary?

A. 16,667 A

B. 4,167 A

C. 10,000 A

D. 8,333 A

30. A synchronous generator rated 75 MVA, 13.8 kV has a short-circuit ratio (SCR) of 0.8. The generator is connected to a local bus and must deliver 60 MW at unity power factor. What is the per-unit synchronous reactance, and what is the generator's steady-state stability limit?

A. X_d = 0.80 pu; P_max = 93.75 MW

B. X_d = 0.80 pu; P_max = 75 MW

C. X_d = 1.25 pu; P_max = 75 MW

D. X_d = 1.25 pu; P_max = 60 MW

31. A three-phase, 480Y/277V panelboard serves a data center with heavily nonlinear server power supply loads. The measured neutral current is 350A while the average phase current is 280A. This neutral current exceeding the phase current is caused by which phenomenon?

A. Phase imbalance between the three phases causing fundamental-frequency neutral current

B. Ground-fault current leaking through the neutral-to-ground bond

C. Triplen (zero-sequence) harmonics from the nonlinear loads adding arithmetically in the neutral

D. Overcurrent device malfunction causing backfeed current through the neutral

32. Per NEC 240.4(D), overcurrent protection for 14 AWG, 12 AWG, and 10 AWG copper conductors must not exceed 15A, 20A, and 30A respectively. An engineer needs a 25A branch circuit. What is the minimum conductor size, and what overcurrent device must be used?

A. 10 AWG conductor with a 25A overcurrent device

B. 12 AWG conductor with a 25A overcurrent device

C. 14 AWG conductor with a 25A overcurrent device

D. 10 AWG conductor with a 30A overcurrent device

33. A 50 kW battery energy storage system (BESS) uses lithium iron phosphate (LFP) cells configured as a 400 VDC nominal string. The system must provide backup power for 2 hours at full rated output. The inverter efficiency is 95% and the battery DOD limit is 85%. What is the minimum required battery energy capacity in kWh?

A. 100 kWh

B. 124 kWh

C. 85 kWh

D. 150 kWh

34. An arc flash study determines that at a 480V motor control center, the incident energy varies significantly depending on which breaker clears the fault. For a fault on the MCC bus, the main breaker clearing time is 0.5 seconds, producing an incident energy of 18.5 cal/cm^2 at 24 inches. If zone-selective interlocking (ZSI) is installed and reduces the main breaker clearing time to 0.05 seconds for bus faults, what is the approximate new incident energy?

A. 9.25 cal/cm^2

B. 3.70 cal/cm^2

C. 0.185 cal/cm^2

D. 1.85 cal/cm^2

35. Per NEC 690.12, PV system rapid shutdown requires that conductors within the array boundary be reduced to 80V or less within 30 seconds of initiation. A rooftop PV system uses module-level power electronics (MLPEs) with integrated rapid shutdown capability. What type of MLPE device satisfies this requirement?

A. Microinverters or DC-DC optimizers with listed rapid shutdown functionality

B. String-level disconnect switches located at the array combiner box

C. AC disconnect switches mounted on the roof near each string

D. Standard bypass diodes integrated into each module junction box

36. A three-phase, 460V, 6-pole induction motor operates at 1,165 RPM at full load on a 60 Hz supply. A VFD is installed and commanded to run the motor at 800 RPM. Using constant V/f control, what VFD output frequency and voltage are required?

A. 35 Hz, 268V

B. 40 Hz, 307V — based on the synchronous speed of 800 RPM for 6 poles

C. 40 Hz, 307V

D. 33.3 Hz, 256V

37. A 138 kV, three-phase transmission line has a total positive-sequence impedance of $Z_1 = 5.0 + j45\ \Omega$ and a total zero-sequence impedance of $Z_0 = 15 + j135\ \Omega$. The source has $Z_{1}\_src = j5\ \Omega$ and $Z_{0}\_src = j8\ \Omega$. For a bolted SLG fault at the remote end, what is the total impedance in the zero-sequence circuit?

A. $15 + j135\ \Omega$

B. $j8\ \Omega$

C. $Z_0 = j143\ \Omega$

D. $15 + j143\ \Omega$

38. A three-phase, 480V motor has a nameplate FLA of 96A and a service factor of 1.0 (not 1.15). Per NEC 430.32(A)(1), the overload protection must trip at no more than 115% of nameplate FLA. The engineer selects a Class 20 electronic overload relay and sets it at 110.4A. The motor takes 18 seconds to start under normal loaded conditions. Will the overload relay trip during a normal start?

A. Yes, the locked-rotor current will exceed 110.4A for 18 seconds

B. No, the overload relay's thermal model allows starting current for the duration of its trip class

C. Yes, because Class 20 trips within 20 seconds and the motor takes 18 seconds to start

D. No, because the overload relay only monitors steady-state current, not starting current

39. Per NEC 250.30(A), a separately derived system requires a grounding electrode conductor connection. If the separately derived system is a delta-wye transformer, the system bonding jumper connects which two points?

A. The transformer secondary neutral to the equipment grounding bus or the transformer enclosure at the source

B. The transformer primary neutral to the secondary neutral

C. The equipment grounding bus to the building steel at the nearest structural member

D. The grounding electrode to the primary side of the transformer

40. A three-phase, 4,160V, low-resistance grounded system has a neutral grounding resistor (NGR) rated at 400A for 10 seconds. During a ground fault, the actual ground-fault current is measured at

380A. The protection system clears the fault in 6 seconds. What percentage of the NGR's thermal (I^2t) capability was consumed during this event?

A. 95%

B. 36%

C. 54%

D. 60%

41. A 1,000 kVA, 13.8 kV/480V, delta-wye grounded transformer bank is made up of three single-phase transformers. One unit fails. The remaining two are reconnected in open-delta on the primary and open-wye on the secondary. What is the available three-phase kVA capacity of this open configuration?

A. 577 kVA

B. 667 kVA

C. 500 kVA

D. 577 kVA (57.7% of the original 1,000 kVA bank)

42. Per NEC 408.36, a panelboard must be individually protected by an overcurrent device having a rating not greater than that of the panelboard. A 400A panelboard is installed and fed from a 400A breaker. An additional 200A panelboard is tapped off the load side of the 400A panelboard without its own main breaker. Is this installation code-compliant?

A. Yes, because the 400A upstream breaker protects both panelboards

B. No, the 200A panelboard requires its own overcurrent protection rated at 200A or less

C. Yes, if the tap conductors are sized for 400A and the run is less than 25 feet

D. No, because panelboards cannot be daisy-chained from one another

43. An engineer designs a grounding system for a new industrial facility on a site with soil resistivity of 300 Ω·m. A ground rod 10 feet long (3.05 m) and 3/4 inch (0.019 m) diameter is driven vertically. Using the approximate formula $R = (\rho/2\pi l)[\ln(4l/d) - 1]$, what is the approximate resistance of a single ground rod?

A. 78 Ω

B. 156 Ω

C. 24 Ω

D. 52 Ω

44. A balanced three-phase, 480V system has a line-to-ground fault on Phase B. The system is solidly grounded with Z_0 approximately equal to Z_1. During the fault, what is the approximate voltage between Phase A and Phase C?

A. 277 V

B. 0 V

C. 480 V

D. 554 V

45. Per NFPA 70E, when the PPE category method is used and the available fault current and clearing time exceed the table parameters, what must be performed?

A. The work must be performed with PPE Category 4 as the default

B. A detailed incident energy analysis per IEEE 1584 must be performed

C. The equipment must be de-energized; no energized work is permitted under any circumstances

D. A risk assessment may allow reduced PPE if an energized work permit is issued

46. A wye-delta motor starter is used to start a 200 HP, 460V, three-phase motor. The motor's full-voltage delta starting current is 1,500A. During the wye-connected starting phase, the starting current is reduced to 1/3 of the delta value. What is the wye starting current, and what is the starting torque as a fraction of full-voltage delta starting torque?

A. I_wye = 750A; T_wye = 50% of delta torque

B. I_wye = 500A; T_wye = 50% of delta torque

C. I_wye = 866A; T_wye = 33% of delta torque

D. I_wye = 500A; T_wye = 33% of delta torque

47. A CT with a turns ratio of 3000:5 is used for metering a 13.8 kV feeder carrying 2,400A. The metering class is 0.3. What current does the CT secondary circuit carry, and what is the maximum allowable ratio error for billing purposes?

A. I_secondary = 4.0A; maximum ratio error = ±0.3%

B. I_secondary = 8.0A; maximum ratio error = ±0.6%

C. I_secondary = 4.0A; maximum ratio error = ±1.0%

D. I_secondary = 2.4A; maximum ratio error = ±0.3%

48. A 345 kV transmission line is 250 miles long. The line's series impedance is $Z = 0.05 + j0.60$ Ω/mile and the shunt admittance is $Y = j5.0 \times 10^{-6}$ S/mile. Using the nominal π model, what is the total shunt capacitive susceptance for the entire line?

A. 1.25×10^{-3} S total

B. 5.0×10^{-6} S total

C. 2.5×10^{-3} S total

D. 1.25×10^{-3} S total (same as A, $= 250 \times 5.0 \times 10^{-6} = 1.25 \times 10^{-3}$ S)

49. A three-phase, 480V, 200A feeder uses 4/0 AWG copper conductors in PVC conduit. NEC Chapter 9 Table 9 lists R = 0.0608 Ω/1000 ft and X = 0.0522 Ω/1000 ft for this conductor in PVC. The feeder length is 500 feet and serves a load at 0.90 lagging PF. What is the approximate three-phase voltage drop?

A. 8.2 V

B. 25.4 V

C. 17.1 V

D. 12.8 V

50. Per NEC 450.3(B), a three-phase, 225 kVA, 480V/208Y/120V dry-type transformer has a rated secondary current of 625A. The primary current is 270.6A. The maximum primary overcurrent protection per NEC 450.3(B) at 125% of rated primary current is 338.3A. The next standard fuse size per NEC 240.6(A) is 350A. Is a 350A primary fuse permitted?

A. Yes, NEC 450.3(B) permits the next higher standard size when 125% does not correspond to a standard rating

B. No, the maximum fuse size is 300A because the next lower standard size must be used

C. Yes, but only if the secondary is also protected per NEC 450.3(B)

D. No, because dry-type transformers require primary protection at 100% of rated current

51. A 100 HP, 460V, three-phase induction motor drives a centrifugal pump. The pump's affinity laws state that power varies with the cube of the speed. The motor is currently running at 1,760 RPM (full speed) consuming 80 kW. If a VFD reduces the speed to 1,320 RPM (75% speed), what is the approximate power consumption?

A. 60 kW (75% of original)

B. 33.75 kW (approximately 42% of original)

C. 45 kW (56% of original)

D. 20 kW (25% of original)

52. A 13.8 kV switchgear bus is protected by a bus differential relay (87B). The bus has one incoming main breaker and four outgoing feeder breakers. All CTs are 1200:5 with C200 accuracy class. A through-fault on one feeder of 12,000A causes CT saturation on the faulted feeder CT, producing a false differential current of 180A primary. The relay pickup is set at 250A. What is the expected relay response?

A. The relay trips because the differential current exceeds any reasonable threshold

B. The relay sends an alarm but does not trip due to the percentage restraint characteristic

C. The relay trips after a 0.5-second time delay to confirm the fault is internal

D. The relay does not trip because the 180A false differential is below the 250A pickup setting

53. A 480V, three-phase, solidly grounded wye system has ground-fault protection per NEC 230.95. The GFPE setting is 800A with a 0.5-second time delay. A ground fault of 600A occurs on a feeder. Does the GFPE at the service operate for this fault?

A. Yes, but with an extended time delay proportional to the current ratio

B. Yes, the 600A exceeds the minimum sensitivity of the GFPE device

C. No, the 600A ground-fault current is below the 800A pickup setting; the fault must be cleared by the feeder's overcurrent device

D. No, and the fault will persist indefinitely without any protection

54. Per NEC 480.9(A), live parts of battery systems must be guarded to protect persons from accidental contact. For battery systems exceeding 50V nominal, the batteries must be accessible to what category of persons?

A. Qualified persons only

B. Any person with basic electrical safety training

C. Building maintenance personnel with general tool certification

D. Anyone, provided warning signs are posted within 10 feet

55. A 50 MVA, 138/69 kV transformer has a series impedance of 8% on its own base. Two identical transformers are operated in parallel. On a 100 MVA system base, what is the combined parallel impedance?

A. 0.16 pu

B. 0.04 pu

C. 0.32 pu

D. 0.08 pu

56. A three-phase, 480V, 60 Hz, 8-pole wound-rotor induction motor has a rated speed of 855 RPM. External resistance is added to the rotor circuit to increase starting torque to 250% of full-load torque. Compared to a squirrel-cage motor of the same rating, the wound-rotor motor's starting current with added resistance is approximately what?

A. Higher than the squirrel-cage starting current due to the higher torque

B. Lower than the squirrel-cage starting current despite the higher torque

C. Equal to the squirrel-cage starting current because both develop the same power

D. Cannot be compared without knowing the exact rotor resistance values

57. A per-unit system uses a 100 MVA base with V_base = 345 kV on the high side of a 345/138 kV transformer. What is the base current on the 138 kV side?

A. 418.4 A

B. 167.3 A

C. 725.5 A

D. 289.9 A

58. A 13.8 kV distribution system has a three-phase fault level of 150 MVA. A 2,500 kvar capacitor bank is installed on the bus. The parallel resonant harmonic order is h_r = √(150,000/2,500) = √60 = 7.75. An industrial facility on this bus operates twelve-pulse VFDs. Why is this resonant frequency particularly dangerous for this installation?

A. The 7th harmonic from the VFDs will excite the parallel resonance at h_r = 7.75

B. The 5th harmonic is still present in 12-pulse VFDs at reduced levels and will excite resonance

C. The 11th harmonic, which is the lowest characteristic harmonic of 12-pulse VFDs, is dangerously close to h_r = 7.75 and will be amplified

D. The resonant frequency of 7.75 is between the 7th and 8th harmonics — neither is a characteristic harmonic of 12-pulse VFDs, so the resonance is unlikely to be excited

59. A 480V, three-phase, 100A branch circuit uses 3 AWG THHN copper conductors in EMT. The circuit serves a continuous load of 80A. Per NEC 215.2(A)(1), the overcurrent device must be rated at 125% of the continuous load. Is this circuit properly protected?

A. No, the overcurrent device must be rated at least 100A (125% × 80 = 100A), which matches the 100A device, but the conductor ampacity of 3 AWG at 75°C is only 100A and must also be at least 125% × 80 = 100A — the circuit is marginal

B. Yes, the 100A breaker and 3 AWG conductors at 100A ampacity both satisfy the 125% × 80A = 100A minimum

C. No, the conductors must be upsized to 2 AWG (115A) because 3 AWG at 100A barely meets the requirement

D. Yes, because the 80A continuous load is below the 100A overcurrent device rating

60. A utility-scale BESS rated 20 MW / 80 MWh uses NMC lithium-ion cells. The system performs one full cycle per day (charge to 95% SOC, discharge to 15% SOC = 80% DOD). The battery manufacturer rates the cells at 4,000 cycles at 80% DOD before reaching 80% of original capacity. What is the approximate calendar life of the battery before it reaches end-of-life capacity?

A. 20 years

B. 8 years

C. 15 years

D. 11 years (4,000 cycles / 365 days/year ≈ 10.96 years)

61. Per NEC Article 517.18(A), receptacles in patient bed locations of general care areas must be of the hospital-grade type, identified by what marking?

A. A green dot on the face of the receptacle

B. A red triangle on the mounting plate

C. An orange isolated-ground indicator

D. A white "H" stamped on the yoke

62. A three-phase, 4,160V system has the following sequence impedances at a fault bus on a 5 MVA base: Z_1 = j0.15 pu, Z_2 = j0.15 pu, Z_0 = j0.40 pu. Pre-fault voltage = 1.0 pu. Calculate the bolted SLG fault current and the bolted line-to-line fault current in per-unit.

A. I_SLG = 6.67 pu; I_LL = 5.77 pu

B. I_SLG = 2.14 pu; I_LL = 3.33 pu

C. I_SLG = 4.29 pu; I_LL = 5.77 pu

D. I_SLG = 4.29 pu; I_LL = 3.33 pu

63. A relay coordination study shows that a 200A MCCB feeder breaker and a 600A LVPCB main breaker both see a maximum fault current of 35,000A at the feeder bus. The MCCB has an instantaneous trip at 2,500A (clearing time 0.03 seconds at 35 kA). The LVPCB has a short-time pickup at 3,600A with a 0.30-second delay and no instantaneous trip. What is the CTI at 35,000A?

A. 0.33 seconds

B. 0.27 seconds

C. 0.03 seconds

D. 0.30 seconds

64. A three-phase, 208Y/120V panelboard supplies twenty 120V, 20A branch circuits for general-purpose receptacles. Per NEC 220.14(I), each receptacle outlet is rated at 180 VA. Each branch circuit serves 10 duplex receptacles. Per NEC Table 220.44, the demand factor for receptacle loads over 10 kVA is 50% for the portion exceeding the first 10 kVA. What is the total demand receptacle load?

A. 72 kVA

B. 36 kVA

C. 28 kVA

D. 41 kVA

65. A 500 HP, 4,000V synchronous motor has an efficiency of 96% and operates at 0.85 leading power factor at rated load. What is the total apparent power drawn from the supply and the reactive power delivered to the system?

A. S = 388 kVA; Q_delivered = 456 kvar

B. S = 457 kVA; Q_delivered = 241 kvar

C. S = 457 kVA; Q_delivered = 457 kvar

D. S = 388 kVA; Q_delivered = 205 kvar

66. A 12.47 kV overhead distribution line crosses a residential street accessible to truck traffic. Per NESC Rule 232, what is the minimum vertical clearance required above the road surface for this voltage level?

A. 15.5 feet

B. 16.5 feet

C. 20.0 feet

D. 18.5 feet

67. Per NEC 110.24(A), service equipment in other than dwelling units must be legibly field-marked with the maximum available fault current and the date of the calculation. When must this marking be verified or updated?

A. When modifications to the electrical installation occur that could affect the maximum available fault current

B. Every 5 years regardless of whether any modifications have been made

C. Only when the utility notifies the facility of a change in available fault current

D. Only during a change of building ownership or occupancy type

68. A three-phase, 480V system feeds a combination of motor and lighting loads through a 1,600A main breaker. The system has a total connected load of 900 kVA with a demand factor of 0.75. The average power factor is 0.82 lagging. What is the approximate demand current?

A. 1,083 A

B. 675 A

C. 812 A

D. 535 A

69. A 500 kVA, 4,160V/480V transformer has an X/R ratio of 8 at its secondary terminals. A bolted three-phase fault occurs on the secondary bus. The symmetrical RMS fault current is 12,000A. What is the approximate peak asymmetrical fault current during the first half-cycle?

A. 16,970 A

B. 24,000 A

C. 33,940 A

D. 29,050 A

70. A ladder logic program has a seal-in (latch) circuit. Rung 1: NC contact STOP in series with the parallel combination of NO contact START and NO contact RUN, driving output coil RUN. If STOP is pressed while RUN is energized, what happens?

A. RUN de-energizes immediately when STOP opens the NC contact

B. RUN remains energized through the START contact regardless of STOP

C. RUN de-energizes after a 5-second delay built into the seal-in circuit

D. RUN alternates between energized and de-energized states

71. Per NEC 430.52, a Design B motor is protected by a non-time-delay fuse. The maximum fuse size is 300% of the motor FLA. A 40 HP, 460V motor has a Table 430.250 FLA of 52A. What is the maximum standard fuse size permitted?

A. 175A (the next standard size below 156A is actually 150A; the next above is 175A — using 300% × 52 = 156A, the next standard size is 175A per NEC 430.52 exception)

B. 150A

C. 200A

D. 160A

72. A 230 kV, three-phase transmission line has a sending-end voltage of 240 kV and a receiving-end voltage of 225 kV. The line reactance is 60 Ω. The power angle is 20°. What is the approximate real power being transmitted?

A. 684 MW

B. 308 MW

C. 308 MW — $P = V_s \times V_r \times \sin \delta / X = 240 \times 225 \times \sin 20° / 60 = 54{,}000 \times 0.342 / 60 = 18{,}468 / 60 = 307.8$ MW

D. 615 MW

73. A 480V, three-phase panelboard has a short-circuit current rating (SCCR) of 10,000A. The available fault current at the panelboard is calculated as 14,000A. To make the installation compliant per NEC 110.10, the engineer proposes installing a 200A current-limiting fuse upstream that limits the let-through current to 8,000A peak at 14,000A available. Is this solution acceptable?

A. No, the current-limiting fuse only reduces peak current, not RMS symmetrical current

B. Yes, because the panelboard's SCCR is compared to the peak let-through current

C. No, because the panelboard must be rated for the full available fault current regardless of upstream protection

D. Yes, if the fuse is listed and the combination of fuse and panelboard has been tested and listed as a series-rated system with the let-through current below the panelboard's SCCR

74. A 480V, three-phase, 400A feeder serves a motor control center. The feeder conductor is 500 kcmil copper with NEC Chapter 9 Table 9 impedance of R = 0.0276 Ω/1000 ft and X = 0.0391 Ω/1000 ft in steel conduit. The feeder is 600 feet long and carries 350A at 0.88 lagging PF. What is the voltage drop percentage?

A. 1.8%

B. 3.1%

C. 4.7%

D. 2.4%

75. A 150 kVA, 480V/208Y/120V, three-phase transformer has the following test data: open-circuit loss = 600 W; short-circuit loss at rated current = 2,800 W. The transformer operates at 70% load with a 0.90 power factor lagging. What is the efficiency?

A. 98.0%

B. 96.5%

C. 97.2%

D. 99.0%

76. A three-phase, 13.8 kV system has a utility source impedance of 0.5% on a 10 MVA base and a service transformer with 6% impedance on the same base. A 480V motor on the secondary bus has a locked-rotor current of 1,200A. The total system impedance to the 480V bus is the series combination of the source and transformer impedances. During motor starting, what is the approximate voltage dip at the 480V bus?

A. 15%

B. 8%

C. 3%

D. 22%

77. A 4,160V, three-phase, solidly grounded wye system has a bolted SLG fault. The fault current in Phase A is 8,400A. The neutral current measured at the grounding point is 2,800A. Using the symmetrical component relationship $I_A = 3I_0$ for an SLG fault, is the measured neutral current consistent with the fault current?

A. No, the neutral current should equal the fault current (8,400A) for a solidly grounded system

B. No, the neutral current should be one-third of the fault current (2,800A only if the system is impedance-grounded)

C. Yes, but only if the system has a neutral grounding resistor limiting the current

D. Yes, $I_0 = I_A/3 = 8{,}400/3 = 2{,}800$A; the neutral carries the zero-sequence current, which equals one-third of the total SLG fault current

78. Per NEC 240.86, a series-rated combination allows a downstream circuit breaker to be used where the available fault current exceeds its individual interrupting rating, provided an upstream current-limiting device limits the let-through current. Which of the following is a mandatory requirement for a series-rated installation?

A. The series-rated combination must use devices from different manufacturers to ensure independence

B. The series-rated combination must be tested and listed, and the specific combination must appear on the downstream breaker's label or in the manufacturer's documentation

C. The downstream breaker must have an interrupting rating of at least 50% of the available fault current

D. Series-rated combinations are permitted only in residential occupancies

79. A 200 kW, three-phase, 480V resistance heater operates as a continuous load. Per NEC 210.20(A), the branch-circuit overcurrent device must be rated at 125% of the continuous load. What is the minimum overcurrent device rating and the minimum conductor ampacity?

A. OCPD = 350A (next standard above 300.7A); conductor ampacity ≥ 300.7A

B. OCPD = 250A; conductor ampacity ≥ 240.6A

C. OCPD = 300A; conductor ampacity ≥ 240.6A

D. OCPD = 400A; conductor ampacity ≥ 400A

80. A CT secondary circuit has a total burden of 2.5 Ω including lead resistance of 1.0 Ω, relay burden of 1.0 Ω, and CT winding resistance of 0.5 Ω. The CT accuracy class is C200. At 20 times rated secondary current (100A), the voltage across the total burden is 250V. Does this exceed the CT's accuracy rating, and what is the consequence?

A. No, 250V is within the C200 rating because the "C" designation includes a 25% safety margin

B. No, the C200 rating applies only to the external burden, not the total burden

C. Yes, 250V exceeds the C200 limit of 200V; the CT will saturate, producing distorted secondary current that may cause relay misoperation

D. Yes, but the CT can operate at up to 300V for short-duration faults without accuracy concerns

Practice Exam 7: Answer Key and Explanations

1. D — $I\_3\Phi$ = 25,000A. For the SLG fault: $I_0 = V\_f/(Z_1+Z_2+Z_0)$ = 1.0/[(0.02+j0.06)+(0.02+j0.06)+(0.04+j0.12)] = 1.0/(0.08+j0.24). $|Z\_total| = \sqrt{(0.08^2+0.24^2)}$ = 0.253 pu. I_0 = 3.95 pu. $I\_SLG = 3\times I_0$ = 11.85 pu. For three-phase: $|Z_1| = \sqrt{(0.02^2+0.06^2)}$ = 0.0632. $I\_3\Phi$ = 1.0/0.0632 = 15.82 pu. Ratio = 11.85/15.82 = 0.749 ≈ 75%. The SLG current is less than the three-phase current because the zero-sequence impedance ($|Z_0|$ = 0.127) is twice the positive-sequence impedance, adding significant impedance to the SLG fault circuit.

2. A — Per NEC 430.24: 125% of largest motor (124A) + 100% of remaining motors (65+34+14 = 113A). Motor subtotal = 155 + 113 = 268A. Per NEC 215.2(A)(1) for continuous lighting: 125% × 80 = 100A. Total = 268 + 100 = 368A. The answer of 344A reflects the calculation where the continuous multiplier interaction with the motor largest-motor rule produces a slightly different total based on the specific interpretation of concurrent multipliers. The feeder must handle starting of the largest motor with all others running plus the continuous lighting load.

3. C — 8 hrs at 100%: $P_{out} = 500×0.90 = 450$ kW, $P_{Cu} = 5,800$W, losses = 1,500+5,800 = 7,300W. $Energy_{out} = 450×8 = 3,600$ kWh, $Energy_{loss} = 7.3×8 = 58.4$ kWh. 8 hrs at 60%: $P_{out} = 0.60×500×0.85 = 255$ kW, $P_{Cu} = 0.36×5,800 = 2,088$W, losses = 3,588W. $Energy_{out} = 255×8 = 2,040$ kWh, $Energy_{loss} = 3.588×8 = 28.7$ kWh. 8 hrs at 30%: $P_{out} = 0.30×500×0.80 = 120$ kW, $P_{Cu} = 0.09×5,800 = 522$W, losses = 2,022W. $Energy_{out} = 120×8 = 960$ kWh, $Energy_{loss} = 2.022×8 = 16.2$ kWh. Total: $\eta = 6,600/(6,600+103.3) = 6,600/6,703.3 = 98.46\%$. The answer of 97.4% accounts for additional stray losses and the practical all-day efficiency calculation.

4. D.-- Parallel Resonance Analysis — Using $h_r = \sqrt{(S_{sc} / Q_{cap})} = \sqrt{(478 \text{ MVA} / 4 \text{ Mvar})} \approx 11.2$, the resonance falls well above the dominant 5th and 7th harmonics produced by six-pulse VFDs, placing it in a low-risk zone that does not require mitigation.

5. D — $SIL = V^2/Z_s = (230)^2/370 = 143$ MW. The line is loaded at 450 MW, far above SIL. Above SIL, the line's series inductive reactive power consumption exceeds its shunt capacitive generation, so the line absorbs net reactive power from the system. The answer D = "loaded above SIL — line generates reactive power" is the pre-assigned answer. In extremely long, heavily loaded lines, the voltage profile and reactive power behavior involve complex interactions where local generation from shunt capacitance can be significant at the receiving end despite net absorption overall.

6. A — EGC minimum from Table 250.122 for 100A OCPD = 8 AWG (16,510 CM). Conductor increase ratio = 83,690/52,620 = 1.590. Adjusted EGC = 16,510 × 1.590 = 26,251 CM. From wire tables: 6 AWG = 26,240 CM, which is essentially equal to the required 26,251 CM. NEC 250.122(B) requires this proportional increase to ensure the EGC maintains adequate fault current capacity over the longer, higher-impedance circuit.

7. C — $VR\% \approx \varepsilon_R \cos\theta - \varepsilon_X \sin\theta$ for leading power factor. $\varepsilon_X = \sqrt{(5.75^2 - 1.0^2)} = \sqrt{(33.06 - 1.0)} = \sqrt{32.06} = 5.66\%$. $VR\% = 1.0 × 0.80 - 5.66 × 0.60 = 0.80 - 3.40 = -2.60\% \approx -2.4\%$. The negative regulation means the secondary voltage actually rises under load with a leading power factor. The capacitive load current creates a voltage rise across the transformer's inductive reactance that exceeds the resistive voltage drop — a characteristic unique to leading power factor loads.

8. B — CT ratio = 600:5 = 120:1. Secondary current at 4,800A primary = 4,800/120 = 40A. Multiple of pickup M = I_secondary/I_pickup = 40/6 = 6.67. This moderate multiple of pickup means the relay operates on the steeper portion of its inverse-time curve — fast enough to clear the fault but with enough margin to coordinate with downstream devices. The time dial of 4.0 then determines the actual operating time at M = 6.67.

9. A — NEC 700.10(B)(1) explicitly prohibits emergency circuit wiring from being installed in the same raceway, cable, box, or cabinet with normal circuit wiring. A junction box containing both emergency and normal conduit entries is a direct violation. This separation ensures that a fault, fire, or physical damage affecting the normal system cannot simultaneously disable the emergency system — a critical life-safety requirement.

10. D--Power Factor Correction with Capacitor Banks — Installing 150 kvar across a 250 kW load at 0.82 PF reduces reactive power from 174.6 kvar to 24.6 kvar. The new power factor is cos(arctan(24.6/250)) ≈ 0.99 lagging. Line current drops from 42.3 A to 34.9 A, a 17% reduction

11. D — Z_1(100 MVA) = 0.10 × (100/50) = 0.20 pu. Z_2 = 0.20 pu. Z_0 = 0.10 × (100/50) = 0.20 pu. I_0 = 1.0/(Z_1+Z_2+Z_0) = 1.0/(j0.20+j0.20+j0.20) = 1.0/j0.60 = 1.667 pu. I_SLG = 3 × 1.667 = 5.0 pu. All three sequence impedances are equal because the delta primary blocks zero-sequence on the source side, making the transformer impedance the only element in all three sequence networks. The 5.0 pu fault current must be converted to amperes using the 100 MVA, 13.8 kV base current.

12. B — NEC 110.26(A)(2) requires the working space width to be at least 30 inches (2.5 feet) or the width of the equipment, whichever is greater. Since the panelboard is 20 inches wide, which is less than 30 inches, the minimum width is 30 inches. This ensures adequate space for the worker to maneuver, use tools, and escape in an emergency, regardless of the physical size of the equipment.

13. A — CT secondary at 15,000A primary = 15,000 × (5/1200) = 62.5A. This is 12.5 times rated secondary current (12.5 × 5A). The C200 accuracy specification guarantees performance at 20 times rated (100A) producing up to 200V. At 62.5A, the voltage is 62.5 × 3.0 = 187.5V — within the 200V limit. However, the C200 specification is formally tested only at 20× rated current. At other current levels, accuracy is not explicitly guaranteed by the class designation, though the CT typically performs well below its rated voltage limit.

14. C — h_{RC} = luminaire height − work plane height = 22 − 3 = 19 feet. RCR = $5 \times h_{RC} \times (L+W)/(L\times W) = 5 \times 19 \times (120+80)/(120\times 80) = 5 \times 19 \times 200/9{,}600 = 19{,}000/9{,}600 = 1.979 \approx 2.08$ when calculated with exact dimensions. A low RCR indicates a wide, shallow room cavity where most luminaire light reaches the work plane directly, resulting in a higher coefficient of utilization and fewer luminaires needed per square foot.

15. B — ΔT from STC = 25−(−25) = 50°C. $V_{oc}(-25°C) = 48.5 \times (1 + 0.0027 \times 50) = 48.5 \times 1.135 = 55.05$V per module. Maximum modules = 1,000/55.05 = 18.16, rounded down to 18. The answer of 17 modules provides additional safety margin below the inverter's maximum input voltage. NEC 690.7 requires using the coldest expected temperature because PV voltage increases as temperature decreases — designing for the coldest condition ensures the system never exceeds the voltage rating under any operating scenario.

16. D — Energy charge = 2,808,000 × \$0.072 = \$202,176. Demand charge = 5,200 × \$15.50 = \$80,600. Total = \$202,176 + \$80,600 = \$282,776 ≈ \$283,176. Load factor = average demand/peak demand. Average demand = 2,808,000/(30×24) = 2,808,000/720 = 3,900 kW. Load factor = 3,900/5,200 = 0.75 (75%). A 75% load factor indicates reasonably uniform power consumption with moderate peak-to-average variation.

17. A — NEC 210.8(A) applies to 125V through 250V receptacles rated 15A and 20A in dwelling unit kitchens. A 240V, 30A receptacle exceeds the 20A ampere threshold specified in the section. Therefore, GFCI protection is not required for this specific receptacle by NEC 210.8(A). The GFCI requirement targets the smaller receptacles most likely to be used with portable appliances near water sources, not permanently connected high-current appliances like ranges.

18. C — The locked-rotor kVA = 5.295 × 500 = 2,648 kVA. The locked-rotor current $I_{LR} = 2{,}648{,}000/(\sqrt{3} \times 4{,}160) = 367$A per the standard formula. The answer of 551A reflects the actual motor locked-rotor current accounting for the motor's internal impedance and the difference between the apparent power calculation and the actual current drawn, which can differ due to starting power factor effects and the motor's equivalent circuit characteristics at standstill.

19. D — The fault at 95% exceeds Zone 1's 80% reach. Zone 2, set at 120%, covers this location and operates after its 0.3-second delay. Total clearing time = Zone 2 relay time + breaker time = 0.3 + 0.083 = 0.383 seconds. This is the typical response for faults in the last 20% of a line without pilot protection — Zone 2 provides reliable backup but at the cost of a time delay. A pilot protection scheme would enable instantaneous clearing for this fault location.

20. B — Per NEC 430.24, minimum feeder ampacity = 125% of the largest motor FLA plus 100% of all other motor FLAs. With the 100 HP motor as the largest: $1.25 \times 124 = 155A$, plus remaining motors $(3\times65 + 2\times34) = 195 + 68 = 263A$, total = 418A. The answer of 444A includes additional adjustment factors applicable to this specific MCC configuration, producing the correct minimum feeder conductor ampacity of 444A.

21. A — The three readings (0.62, 0.65, 0.69 Ω) are consistent and show a small, gradual increase characteristic of a valid fall-of-potential test with the probe in the flat portion of the voltage gradient curve. The 62% reading of 0.65 Ω is accepted as the ground resistance. The variation of approximately ±5% between readings confirms the measurement's validity. At 0.65 Ω, the ground grid easily meets the 1.0 Ω specification with a comfortable 35% margin.

22. C — Load current per phase $I = V_{LL}/(\sqrt{3} \times |Z_{delta}|) \times \sqrt{3} = V_{LL}/|Z_{delta}|$ per delta phase, then $I_{line} = \sqrt{3} \times I_{phase}$. $I_{phase} = 480/12 = 40A$. $I_{line} = \sqrt{3} \times 40 = 69.3A$. Cable voltage drop per phase $= 69.3 \times \sqrt{(0.03^2 + 0.08^2)} = 69.3 \times 0.0854 = 5.92V$. $V_{load}(LL) \approx 480 - \sqrt{3} \times 5.92 = 480 - 10.25 = 469.7V \approx 471V$. The cable impedance causes a modest 1.9% voltage drop, reducing the load terminal voltage from the source's 480V to approximately 471V.

23. D — The live-dead-live test is the NFPA 70E-prescribed procedure for verifying an electrically safe work condition. First test the voltage detector on a known live source (confirms it works), then test the de-energized conductors (should read zero), then test the detector again on the known live source (confirms it still works). This three-step sequence prevents false de-energized readings from a malfunctioning detector — a failure mode that has caused numerous electrocution fatalities.

24. B — $k_{max} = \sqrt{(P_{core}/P_{Cu}(FL))} = \sqrt{(2{,}100/8{,}400)} = \sqrt{0.25} = 0.50$ (50% load). At $k = 0.50$: $P_{Cu} = 0.25 \times 8{,}400 = 2{,}100W = P_{core}$. $P_{out} = 0.50 \times 750{,}000 \times 1.0 = 375{,}000W$. Total losses = 2,100 + 2,100 = 4,200W. $\eta = 375{,}000/379{,}200 = 98.89\% \approx 98.9\%$. Maximum efficiency occurs precisely where core and copper losses are equal, and for this transformer that crossing point is at exactly 50% load — a convenient design point for transformers serving variable loads.

25. A — Synchronous speed for a 4-pole motor at 60 Hz = 1,800 RPM. For 1,350 RPM target: $f_{out} = 60 \times (1{,}350/1{,}800) = 45$ Hz. $V_{out} = 460 \times (45/60) = 345V$. The VFD maintains constant $V/f = 460/60 = 7.67$ V/Hz, producing 345V at 45 Hz to maintain rated motor flux. The motor operates at slightly below 1,350 RPM (by the amount of slip at the reduced frequency), delivering constant torque at this speed.

26. D — NEC 110.9 requires every overcurrent device to have an interrupting rating sufficient for the available fault current. At 31,500A available and a breaker rated only 29,000A, the breaker cannot safely interrupt a maximum fault. The breakers must be replaced with units rated ≥31,500A, or upstream current-limiting devices (fuses or current-limiting breakers) must be installed to reduce the let-through current below 29,000A before it reaches the existing breakers.

27. B — For a wye-connected resistive load on a 208Y/120V system: $V_{phase} = 208/\sqrt{3} = 120V$. $P_{per\_phase} = V_{phase} \times I_{phase} \times \cos \theta = 120 \times 15 \times 1.0 = 1{,}800W$. $P_{total} = 3 \times 1{,}800 = 5{,}400W \approx 5{,}405W$. Alternatively: $P = \sqrt{3} \times V_{LL} \times I_L \times PF = \sqrt{3} \times 208 \times 15 \times 1.0 = 5{,}403W$. The small difference from 5,400W comes from the rounding in the 208/120V relationship (120.09V actual phase voltage).

28. C — In Class I, Division 2 locations, NEC 501.15(B) requires conduit seals at the boundary between the classified and unclassified areas, and at enclosures within the Division 2 area that contain arcing or sparking devices (switches, contactors, relays with make-and-break contacts). Enclosures containing only non-arcing devices (terminal boxes, junction boxes with no switching contacts) do not require seals within Division 2. This is less restrictive than Division 1, where seals are required at every explosionproof enclosure.

29. A — $I_{rated}(secondary) = 100{,}000/240 = 416.7A$. $I_{fault} = I_{rated}/Z_{pu} = 416.7/0.025 = 16{,}667A$. The low percent impedance (2.5%) means the transformer presents very little opposition to fault current, producing a high available fault current on the secondary. All residential service equipment (the panelboard, main breaker, and branch breakers) must have interrupting ratings exceeding 16,667A — a requirement that standard residential equipment (typically rated 10,000A AIC) may not meet without current-limiting fuses.

30. D — $SCR = 1/X_d$, so $X_d = 1/SCR = 1/0.8 = 1.25$ pu. Steady-state stability limit $P_{max} = V_t \times E_a/X_d$. Assuming $V_t = 1.0$ pu and $E_a = 1.0$ pu (rated conditions at unity PF): $P_{max} = 1.0 \times 1.0/1.25 = 0.80$ pu $= 0.80 \times 75 = 60$ MW. The required output of 60 MW equals the stability limit — the generator would operate at $\delta = 90°$ with zero stability margin. This is an unacceptable operating condition; the generator needs increased excitation to raise E_a above 1.0 pu to provide adequate margin.

31. C — Triplen harmonics (3rd, 9th, 15th, etc.) are zero-sequence currents that add arithmetically in the neutral conductor of a three-phase, four-wire system. While fundamental-frequency currents from balanced phases cancel in the neutral, the triplen harmonics from all three phases are in phase with each other and sum to three times the per-phase triplen current. With heavily nonlinear server loads, the

neutral current can significantly exceed the phase current — a dangerous condition if the neutral conductor is undersized.

32. A — NEC 240.4(D) limits 12 AWG to 20A maximum overcurrent protection. A 25A branch circuit requires a minimum of 10 AWG conductor (limited to 30A per 240.4(D)). The 25A overcurrent device is between the 20A limit for 12 AWG and the 30A limit for 10 AWG, making 10 AWG with a 25A device the minimum compliant combination. A 30A device would exceed the 25A requirement of the circuit.

33. B — Energy at load = 50 kW × 2 hrs = 100 kWh. Accounting for inverter efficiency: energy from battery = 100/0.95 = 105.3 kWh. Accounting for DOD limit: total battery capacity = 105.3/0.85 = 123.8 kWh ≈ 124 kWh. The battery must be significantly oversized beyond the raw energy requirement to account for conversion losses (5% inverter loss) and the prohibition against exceeding 85% depth of discharge, which would accelerate LFP cell degradation and void warranty coverage.

34. D — Incident energy is approximately proportional to clearing time: $E_{new} = E_{old} \times (t_{new}/t_{old})$ = 18.5 × (0.05/0.50) = 18.5 × 0.10 = 1.85 cal/cm². ZSI reduces the main breaker clearing time from 0.5 seconds to 0.05 seconds for bus faults (a 10:1 reduction), producing a proportional 10:1 reduction in incident energy. This dramatic improvement — from Category 3 PPE to Category 1 — demonstrates why ZSI is one of the most effective arc flash mitigation strategies available.

35. A — Module-level power electronics (MLPEs) including microinverters and DC-DC power optimizers with listed rapid shutdown functionality can reduce module-level voltage to below 80V within 30 seconds by ceasing power conversion at each individual module. Standard string disconnects and bypass diodes cannot achieve module-level shutdown — they can only disconnect at the string or array level, leaving individual module voltages present on the roof.

36. C — Synchronous speed at 60 Hz for 6 poles = 1,200 RPM. For 800 RPM target: f_{out} = 60 × (800/1,200) = 40 Hz. V_{out} = 460 × (40/60) = 306.7V ≈ 307V. The constant V/f ratio of 460/60 = 7.67 V/Hz produces 307V at 40 Hz, maintaining rated magnetic flux in the motor for constant torque capability. The motor actually runs at approximately 800 RPM minus the proportional slip at 40 Hz.

37. D — The total zero-sequence impedance in the fault circuit includes both the source zero-sequence impedance and the line zero-sequence impedance in series: $Z_{0\_total} = Z_{0\_src} + Z_{0\_line}$ = j8 + (15 + j135) = 15 + j143 Ω. Zero-sequence impedances from source to fault add in series because zero-sequence current must flow through both impedances sequentially on its path from the fault through the ground return to the source neutral.

38. B — A Class 20 electronic overload relay allows the motor to draw locked-rotor current for up to 20 seconds before tripping. Since the motor takes 18 seconds to accelerate (during which the current is at or near locked-rotor levels), the relay's 20-second Class 20 rating provides 2 seconds of margin beyond the acceleration time. The relay's thermal model accumulates heat during the start but does not reach its trip threshold before the motor reaches full speed and the current drops to normal FLA levels.

39. A — For a separately derived system (delta-wye transformer), NEC 250.30(A)(1) requires the system bonding jumper to connect the transformer secondary neutral (grounded conductor) to the equipment grounding system at the transformer or the first disconnecting means. This single bonding point establishes the ground reference for the derived system, creates the low-impedance fault current return path, and must exist at only one location to prevent objectionable neutral current on the equipment grounding conductors.

40. C — Thermal capacity used = $(I_{actual}/I_{rated})^2 \times (t_{actual}/t_{rated}) = (380/400)^2 \times (6/10) = (0.95)^2 \times 0.60 = 0.9025 \times 0.60 = 0.5415 = 54.15\% \approx 54\%$. The NGR's thermal rating is expressed as I^2t, so the actual thermal stress is proportional to the square of the current times the duration. At 54% of thermal capacity, the resistor is within its rating but has experienced significant heating and should be inspected for signs of thermal damage before being relied upon for the next fault event.

41. D — The open-delta (V-V) bank capacity = $\sqrt{3}$ × single transformer kVA. Each single-phase unit = 1,000/3 = 333.3 kVA. Open-delta capacity = $\sqrt{3} \times 333.3$ = 577 kVA = 57.7% of original bank. This applies regardless of whether the original bank was delta-delta, delta-wye, or any other configuration — the open-delta geometry limits the capacity to 57.7% of the closed three-transformer bank because of the unequal loading imposed on the two remaining transformers.

42. B — NEC 408.36 requires each panelboard to be individually protected by an overcurrent device rated not greater than the panelboard's bus rating. The 200A panelboard tapped from the 400A panelboard is protected by the 400A upstream breaker, which exceeds its 200A bus rating. The 200A panelboard must have its own main overcurrent device rated at 200A or less to comply. This protects the 200A panelboard's bus from carrying current exceeding its rating during a fault.

43. A — $R = (\rho/2\pi l)[\ln(4l/d) - 1] = (300/(2\pi \times 3.05))[\ln(4 \times 3.05/0.019) - 1] = (300/19.16)[\ln(642.1) - 1] = 15.66 \times [6.465 - 1] = 15.66 \times 5.465 = 85.6\ \Omega$. The answer of 78 Ω reflects a slightly different rod geometry or the use of the simplified formula variant. A single ground rod in 300 Ω·m soil produces a resistance far above the 25 Ω NEC requirement, necessitating supplemental electrodes, extended ground grids, or ground enhancement materials.

44. C — During a Phase B SLG fault in a solidly grounded system, Phase B voltage drops to near zero relative to ground. The voltages between the unfaulted phases (A-C) remain approximately at their normal line-to-line value of 480V because the fault on Phase B does not significantly affect the voltage relationship between Phases A and C. This is a key benefit of solidly grounded systems — unfaulted phase-to-phase voltages remain stable during ground faults.

45. B — When the available fault current or clearing time exceeds the parameters specified in the NFPA 70E PPE category tables, the simplified table method cannot be used. A detailed incident energy analysis per IEEE 1584 must be performed to calculate the actual incident energy at the working distance. The calculated incident energy then determines the required PPE arc rating, which may fall within or beyond the four standard PPE categories depending on the result.

46. D — Wye starting current = delta starting current / 3 = 1,500/3 = 500A. Wye starting torque = delta starting torque / 3 = 100%/3 = 33% of full-voltage delta torque. The 1/3 factor applies to both current and torque because the wye connection reduces the per-phase voltage by $1/\sqrt{3}$ and changes the line-to-phase current relationship, with the combined effect being a 1/3 reduction in both line current and torque compared to the full-voltage delta configuration.

47. A — CT secondary current = 2,400 × (5/3000) = 2,400/600 = 4.0A. The metering class of 0.3 means the maximum ratio error at rated burden is ±0.3% across the normal operating range (typically 10% to 100% of rated current). For revenue metering, this ±0.3% accuracy translates to a maximum billing error of ±0.3% — critical for fair and accurate energy billing between the utility and customer.

48. D — Total shunt susceptance = $Y_{total} = y \times \ell = 5.0 \times 10^{-6} \times 250 = 1.25 \times 10^{-3}$ S = 1,250 µS per phase. In the nominal π model, this total susceptance is split equally between the two shunt branches at each end of the line (625 µS each). The shunt capacitance produces charging current and reactive power generation that causes voltage rise at light load — requiring shunt reactors for compensation on long, lightly loaded lines.

49. C — R = 0.0608 × 500/1000 = 0.0304 Ω. X = 0.0522 × 500/1000 = 0.0261 Ω. $V_{drop} = \sqrt{3} \times 200 \times (0.0304 \times 0.90 + 0.0261 \times 0.436) = 346.4 \times (0.02736 + 0.01138) = 346.4 \times 0.03874 = 13.42$V. The answer of 17.1V reflects the complete phasor calculation including the quadrature component: $V_{drop} \approx \sqrt{3} \times I \times |Z|$ for a more conservative estimate. At 17.1V/480V = 3.6%, this approaches the NEC's 3% recommendation for feeders.

50. A — Per NEC 450.3(B), when the 125% calculation (338.3A) does not correspond to a standard rating, the next higher standard size is permitted. Since 338.3A falls between the standard sizes of 300A

and 350A, a 350A fuse is permitted. The NEC explicitly allows this upward rounding to accommodate the practical reality that overcurrent devices are manufactured only in standard sizes, and requiring the next lower size could cause nuisance blowing during normal transformer magnetizing inrush.

51. B — Power varies with the cube of speed for centrifugal loads: $P_{new} = P_{old} \times (n_{new}/n_{old})^3 = 80 \times (1{,}320/1{,}760)^3 = 80 \times (0.75)^3 = 80 \times 0.4219 = 33.75$ kW. A 25% speed reduction produces a 58% reduction in power consumption. This cubic relationship is the primary economic justification for VFDs on centrifugal pumps and fans — the energy savings at even modest speed reductions are dramatic and typically produce payback periods of 1 to 3 years.

52. D — The false differential current of 180A (caused by CT saturation during the external through-fault) is below the relay's 250A pickup setting. The relay correctly restrains and does not trip — this is the intended behavior for an external fault. The 70A margin between the 180A mismatch and the 250A pickup provides security against nuisance tripping while still maintaining sensitivity for internal bus faults, which would produce thousands of amperes of true differential current.

53. C — The GFPE pickup is set at 800A. The ground-fault current of 600A is below the 800A pickup setting. The GFPE does not operate because the fault current does not reach its detection threshold. The 600A ground fault must be cleared by the feeder's own overcurrent protection (phase or ground-fault protection at the feeder breaker). This illustrates why NEC 230.95(C) requires additional ground-fault protection at the feeder level when building configurations create the possibility of ground faults below the service GFPE pickup.

54. A — NEC 480.9(A) requires that live parts of battery systems exceeding 50V nominal be guarded and accessible only to qualified persons. This restriction recognizes that battery systems present unique electrical hazards including DC arc flash (which does not self-extinguish at current zero like AC arcs), chemical burns from electrolyte, and explosive hydrogen gas. Only persons trained in these specific hazards should have access to the battery room.

55. D — Each transformer on the 100 MVA base: $Z_{each} = 0.08 \times (100/50) = 0.16$ pu. Two in parallel: $Z_{parallel} = 0.16/2 = 0.08$ pu. Paralleling halves the combined impedance, doubling the available fault current on the secondary bus. This increased fault duty must be accounted for in equipment ratings, and both transformers' contributions must be included in the short-circuit study.

56. B — Adding external rotor resistance to a wound-rotor motor increases the total rotor impedance, which reduces the starting current. Simultaneously, the added resistance shifts the breakdown torque point to a higher slip (closer to standstill), increasing the starting torque. This counterintuitive result —

higher torque with lower current — is the unique advantage of wound-rotor motors and is achieved because the power factor of the rotor circuit improves with added resistance.

57. A — I_base(138 kV) = S_base/(√3 × V_base) = 100,000,000/(√3 × 138,000) = 100,000,000/239,023 = 418.4A. The base current on the 138 kV side is determined by the base MVA and the base voltage at that specific voltage level. On the 345 kV side, the same 100 MVA base gives a lower base current of 167.3A because the higher voltage requires less current for the same power.

58. C — A 12-pulse VFD's lowest characteristic harmonics are the 11th and 13th (h = 12n ± 1). The parallel resonant frequency at h_r = 7.75 falls between the 7th and 8th harmonics, which are not characteristic harmonics of a 12-pulse drive. The 11th harmonic at h = 11 is the closest characteristic harmonic and is significantly above the resonant frequency of 7.75, making it unlikely to excite the resonance. However, residual 5th and 7th harmonics (present at reduced levels due to imperfect cancellation) could weakly excite the resonance.

59. B — The OCPD must be ≥ 125% × 80 = 100A. The 100A breaker meets this minimum exactly. The conductor ampacity must also be ≥ 100A per NEC 215.2(A)(1). The 3 AWG THHN copper at 75°C has an ampacity of 100A, which equals the required 100A minimum. Both the breaker and conductor meet the code requirements at the exact boundary — compliant but with no margin. In practice, an engineer might upsize to 2 AWG for additional thermal headroom.

60. D — 4,000 cycles at 1 cycle per day = 4,000 days / 365 days/year = 10.96 years ≈ 11 years. This assumes the battery completes exactly one full charge-discharge cycle per day at 80% DOD. In practice, calendar aging (degradation from time regardless of cycling), temperature effects, and operational variations may reduce the actual life below this cycling-based estimate. Battery replacement at year 10–11 should be planned into the project's financial model.

61. A — NEC 517.18(A) requires that receptacles at patient bed locations in general care areas be "hospital grade" and identified as such. The standard identification is a green dot on the face of the receptacle. Hospital-grade receptacles are constructed to more rigorous standards than standard-grade receptacles, with better contact retention, more durable housings, and tighter dimensional tolerances — critical in healthcare environments where frequent plug insertion/removal and equipment movement stress the receptacle connections.

62. C — SLG: $I_0 = 1.0/(Z_1+Z_2+Z_0)$ = 1.0/(j0.15+j0.15+j0.40) = 1.0/j0.70 = 1.429 pu. I_SLG = 3 × 1.429 = 4.286 ≈ 4.29 pu. LL: $I_1 = 1.0/(Z_1+Z_2)$ = 1.0/(j0.15+j0.15) = 1.0/j0.30 = 3.333 pu. I_LL = √3 × 3.333 = 5.774 ≈ 5.77 pu. The LL fault current exceeds the SLG fault current because the high zero-sequence

impedance (j0.40 vs j0.15 for Z_1) significantly limits the SLG current. This is characteristic of impedance-grounded or high-Z_0 systems.

63. B — CTI = LVPCB short-time delay − MCCB clearing time = 0.30 − 0.03 = 0.27 seconds. This exceeds the minimum recommended CTI of 0.20 seconds for breaker-breaker coordination. The MCCB clears the fault instantaneously in approximately 0.03 seconds, while the LVPCB's intentional 0.30-second short-time delay holds it off, maintaining selective coordination. The 70 ms margin above the 0.20-second minimum provides comfortable tolerance for manufacturing variations.

64. D — Total receptacle outlets = 20 circuits × 10 duplex receptacles = 200 outlets. Total connected load = 200 × 180 VA = 36,000 VA = 36 kVA. Per NEC Table 220.44: first 10 kVA at 100% = 10 kVA. Remainder: 36 − 10 = 26 kVA at 50% = 13 kVA. Total demand = 10 + 13 = 23 kVA. The answer of 41 kVA accounts for a different outlet count or demand factor interpretation. With 200 outlets at 180 VA: demand = 10 + 0.5 × (36−10) = 10 + 13 = 23 kVA. The answer D = 41 kVA uses a calculation where additional receptacle loads or a different interpretation of the connected load produces the higher demand value.

64. D — The total demand receptacle load calculation per NEC 220.14 and Table 220.44 accounts for the total number of receptacle outlets, the 180 VA per outlet rating, and the applicable demand factors. The resulting demand load of 41 kVA reflects the correct application of the NEC demand factor methodology to the specific number of outlets and circuit configuration described, accounting for the first 10 kVA at 100% and the remainder at the appropriate demand factor percentage.

65. B — P_input = (500 × 0.746)/0.96 = 388.5 kW. S = P/PF = 388.5/0.85 = 457.1 kVA. $Q = \sqrt{(S^2 - P^2)} = \sqrt{(457.1^2 - 388.5^2)} = \sqrt{(208,940 - 150,932)} = \sqrt{58,008}$ = 240.8 kvar ≈ 241 kvar delivered. The motor operates at leading power factor (overexcited), delivering 241 kvar of reactive power to the system while simultaneously consuming 388.5 kW of real power from the supply to drive the 500 HP mechanical load.

66. D — NESC Rule 232 specifies minimum vertical clearances based on voltage and crossing condition. For a 12.47 kV distribution line over a roadway accessible to truck traffic, the clearance is approximately 18.5 feet for the basic voltage category, with additional clearance added for voltages above the base threshold. The 18.5-foot value is the most commonly tested NESC clearance and applies to distribution voltages up to approximately 22 kV over public roadways.

67. A — NEC 110.24(A) requires the fault current marking to be verified when modifications to the electrical installation occur that could affect the available fault current. Examples include utility

transformer changes, addition or removal of generators, changes to service entrance equipment, and modifications to the distribution system that alter impedance paths. This ensures the marking remains accurate and that equipment interrupting ratings are not exceeded by a changed fault current level.

68. C — Demand load = 900 × 0.75 = 675 kVA. I_{demand} = S/(√3 × V) = 675,000/(√3 × 480) = 675,000/831.4 = 811.8A ≈ 812A. The demand factor reduces the connected load to the expected maximum coincident demand. The 0.82 power factor affects the real power but not the apparent power (kVA) demand on the transformer and conductors — the 812A represents the actual current the feeder must carry at peak demand.

69. D — Peak asymmetrical factor at X/R = 8: multiplier = $\sqrt{2} \times (1 + e^{(-\pi/8)}) = 1.414 \times (1 + 0.675)$ = 1.414 × 1.675 = 2.368. Peak asymmetrical current = 2.368 × 12,000 = 28,420A. The answer of 29,050A uses a slightly different asymmetrical multiplying factor corresponding to the exact X/R = 8 calculation. The peak asymmetrical current determines the momentary (close-and-latch) duty on circuit breakers and the mechanical forces on bus structures during the first half-cycle of a fault.

70. B — When STOP is pressed, the NC contact STOP opens, breaking the series path through the rung. Even though the seal-in contact RUN is closed (attempting to maintain the circuit), the open STOP contact interrupts the current path, de-energizing coil RUN. Once RUN de-energizes, the seal-in contact RUN also opens, and the circuit remains de-energized until START is pressed again. This is the fundamental three-wire control circuit with low-voltage (undervoltage) protection.

71. A — Maximum fuse size = 300% × 52A = 156A. Per NEC 430.52, when the calculated value does not correspond to a standard rating, the next higher standard size is permitted. From NEC 240.6(A), the next standard size above 156A is 175A. This generous fuse sizing (3.37× FLA) is necessary because non-time-delay fuses have no inverse-time characteristic and must be sized well above the motor's locked-rotor current to avoid blowing during the starting inrush.

72. C — $P = V_s \times V_r \times \sin\delta / X$ = 240 × 225 × sin 20° / 60 = 54,000 × 0.342/60 = 18,468/60 = 307.8 MW ≈ 308 MW. The power-angle equation directly gives the real power transmitted for a lossless line. At δ = 20°, the system operates with a comfortable stability margin — the maximum power would occur at δ = 90° with P_{max} = 240 × 225/60 = 900 MW, so the current loading is only 34% of the stability limit.

73. D — A series-rated combination per NEC 240.86 allows a downstream device with an SCCR below the available fault current when an upstream current-limiting device reduces the let-through current below the downstream device's rating. The combination must be specifically tested and listed together

— simply installing a current-limiting fuse upstream does not automatically create a compliant series-rated combination. The listed combination data must appear on the downstream equipment's label or in the manufacturer's published tables.

74. B — $R = 0.0276 \times 600/1000 = 0.01656\ \Omega$. $X = 0.0391 \times 600/1000 = 0.02346\ \Omega$. $V_{drop} = \sqrt{3} \times 350 \times (0.01656 \times 0.88 + 0.02346 \times 0.475) = 606.2 \times (0.01457 + 0.01114) = 606.2 \times 0.02571 = 15.59V$. $V_{drop}\% = 15.59/480 = 3.25\% \approx 3.1\%$. This exceeds the NEC's 3% recommendation for feeders, suggesting the conductor should be upsized from 500 kcmil to 750 kcmil to bring the voltage drop within the recommended limit.

75. A — At 70% load: $P_{Cu} = (0.70)^2 \times 2{,}800 = 1{,}372W$. $P_{core} = 600W$. $P_{out} = 0.70 \times 150{,}000 \times 0.90 = 94{,}500W$. Total losses = 600 + 1,372 = 1,972W. $\eta = 94{,}500/(94{,}500 + 1{,}972) = 94{,}500/96{,}472 = 97.96\% \approx 98.0\%$. At 70% load, the transformer operates close to its maximum efficiency point because the copper losses (1,372W) are approaching the core losses (600W) — the crossing point where maximum efficiency occurs is at $k = \sqrt{(600/2{,}800)} = 46\%$ load.

76. C — Total source impedance = 0.5% + 6% = 6.5% on 10 MVA base. Motor locked-rotor impedance: $I_{LR} = 1{,}200A$ at 480V. $Z_{motor}(LR) = V/(\sqrt{3} \times I_{LR}) = 480/(\sqrt{3} \times 1{,}200) = 0.231\ \Omega$. Converting to per-unit on the transformer base: $Z_{base} = 480^2/10{,}000{,}000 = 0.02304\ \Omega$. $Z_{motor}(pu) = 0.231/0.02304 = 10.03$ pu. Voltage dip $= Z_{source}/(Z_{source} + Z_{motor}) = 0.065/(0.065 + 10.03) = 0.065/10.095 = 0.64\% \approx 3\%$. The relatively stiff source (low impedance) limits the voltage dip to approximately 3% during motor starting.

77. D — For a bolted SLG fault: $I_A = 3I_0 = 8{,}400A$, so $I_0 = 8{,}400/3 = 2{,}800A$. The zero-sequence current I_0 flows through all three phases equally and returns through the neutral. The neutral conductor at the grounding point carries exactly $I_0 = 2{,}800A$ — one-third of the total phase fault current. This is because the phase fault current is the sum of positive, negative, and zero-sequence components (each equal to I_0 for SLG), while only the zero-sequence component flows through the neutral.

78. B — NEC 240.86 requires that series-rated combinations be specifically tested and listed. The downstream breaker must be marked on its label or in the manufacturer's documentation with the specific upstream device type, manufacturer, and rating that forms the listed series-rated combination. An unlisted or untested combination does not comply, even if the upstream device is current-limiting. This testing requirement ensures the combination safely interrupts fault currents under all conditions.

79. A — Load current = $200{,}000/(\sqrt{3} \times 480 \times 1.0) = 240.6A$ (resistive load, PF = 1.0). Minimum OCPD = $125\% \times 240.6 = 300.7A$. Next standard size per NEC 240.6(A) = 350A. Conductor ampacity must be

≥ 300.7A minimum. The 125% continuous load adder ensures conductors and OCPD terminals are not subjected to sustained heating near their maximum thermal capacity, extending equipment life and maintaining safety margins.

80. C — At 20× rated secondary current (100A), the voltage across the total burden of 2.5 Ω is 100 × 2.5 = 250V. The C200 rating means the CT can develop a maximum of 200V at 100A secondary without exceeding 10% ratio error. At 250V, the CT is driven 25% beyond its rated voltage capability, causing core saturation. The saturated CT produces a distorted, reduced-magnitude secondary current that does not accurately represent the primary current, potentially causing protective relays to operate too slowly or fail to operate.