

PRACTICE EXAM 8: PE POWER SIMULATION

(80 QUESTIONS)

1. A balanced three-phase, 4,160V system feeds a 2,800 kW load at 0.86 lagging power factor through a feeder with an impedance of $0.55 + j2.10 \Omega$ per phase. The feeder is 3 miles long. After performing a voltage drop calculation, the engineer determines the percent voltage drop is 7.2%. The utility requires the voltage at the load bus to remain above 95% of nominal. What corrective action is most appropriate?

- A. Increase the load power factor to unity using a synchronous condenser
- B. Install a switched capacitor bank at the load bus to improve power factor and reduce reactive current flow through the feeder
- C. Replace the entire feeder with larger conductors to reduce impedance
- D. Install a step-up autotransformer at the source bus to boost sending-end voltage

2. A 1,500 kVA, 13.8 kV/480V, delta-wye grounded transformer has the following test data: open-circuit test power = 3,400 W; short-circuit test power at rated current = 11,800 W; percent impedance = 5.75%. The transformer operates at 85% load with a power factor of 0.92 lagging. What is the approximate efficiency at this operating point?

- A. 96.4%
- B. 97.1%
- C. 98.5%
- D. 98.7%

3. Per NEC Article 430.32(A)(1), a motor with a service factor of 1.0 and a marked temperature rise of 40°C has its overload device maximum trip setting at 115% of nameplate FLA. A 60 HP, 460V motor has a nameplate FLA of 74A. The engineer selects an electronic overload relay and sets it at 85.1A. What percentage of nameplate FLA does this represent, and is it compliant?

- A. 115% of nameplate FLA; compliant because it exactly matches the NEC maximum for this motor type
- B. 125% of nameplate FLA; non-compliant because the motor's SF is 1.0 and the maximum is 115%
- C. 110% of nameplate FLA; compliant but below the maximum allowed setting
- D. 120% of nameplate FLA; non-compliant by a margin of 5%

4. A three-phase, 480V, 60 Hz system has the following per-unit sequence impedances at a fault bus on a 500 kVA base: $Z_1 = 0.03 + j0.08$ pu, $Z_2 = 0.03 + j0.08$ pu, $Z_0 = 0.06 + j0.20$ pu. The pre-fault voltage is 1.0 pu. What is the bolted double line-to-ground (DLG) fault current in the most heavily faulted phase in per-unit?

- A. 8.55 pu
- B. 14.22 pu
- C. 11.73 pu
- D. 6.40 pu

5. Per NEC 250.30(A), a separately derived system must have a system bonding jumper and a grounding electrode conductor. The system bonding jumper for a 1,000 kVA, 480V transformer with a rated secondary current of 1,203A must be sized per NEC Table 250.102(C)(1). What is the minimum bonding jumper size for copper?

- A. 2/0 AWG copper
- B. 1/0 AWG copper
- C. 3/0 AWG copper
- D. 4/0 AWG copper

6. A 138 kV transmission line has a total positive-sequence impedance of $Z_1 = 3.0 + j35 \Omega$ and a total zero-sequence impedance of $Z_0 = 9.0 + j105 \Omega$. The source impedances are $Z_{1_src} = j8 \Omega$ and $Z_{0_src} = j12 \Omega$. A bolted SLG fault occurs at the remote end of the line. What is the total zero-sequence impedance in the fault circuit?

- A. $j12 \Omega$ (source only)
- B. $9.0 + j105 \Omega$ (line only)
- C. $3.0 + j43 \Omega$ (sum of positive-sequence impedances)
- D. $9.0 + j117 \Omega$ (source and line zero-sequence in series)

7. A 250 HP, 4,160V, three-phase synchronous motor operates at 0.80 leading power factor at rated load. The motor efficiency is 95%. What is the reactive power the motor delivers to the system?

- A. 93 kvar
- B. 148 kvar
- C. 197 kvar
- D. 59 kvar

8. A 480V, three-phase panelboard has an available fault current of 28,000A symmetrical. The panelboard's SCCR is 22,000A. An engineer proposes installing a 400A Class J current-limiting fuse upstream. The fuse manufacturer's data shows the fuse limits the let-through current to 18,000A peak and 12,000A RMS at 28,000A available. Per NEC 240.86, is this series-rated combination acceptable?

- A. No, because the let-through current must be below the panelboard's withstand rating, not its SCCR
- B. Yes, because the RMS let-through of 12,000A is below the panelboard's 22,000A SCCR
- C. Only if the specific fuse-panelboard combination is tested, listed, and documented as a series-rated system

D. No, because series-rated combinations are prohibited for panelboards above 225A

9. A three-phase, 480V VFD drives a 150 HP centrifugal fan motor. The fan is currently operating at 1,200 RPM (66.7% of the 1,800 RPM base speed). The fan's power consumption follows the cube of the speed ratio. If the motor's full-load power at 1,800 RPM is 120 kW, what is the approximate power consumption at 1,200 RPM?

- A. 80 kW (66.7% of rated)
- B. 53.3 kW (44.4% of rated)
- C. 40 kW (33.3% of rated)
- D. 35.6 kW (29.6% of rated)

10. Per NEC 690.7, the maximum PV system voltage is calculated at the lowest expected ambient temperature using correction factors from NEC Table 690.7(A). An array string has 22 modules with $V_{oc} = 41.2V$ at STC ($25^{\circ}C$). The temperature coefficient is $-0.30\%/^{\circ}C$ and the minimum expected temperature is $-15^{\circ}C$. What is the maximum system voltage?

- A. 970 V
- B. 906 V
- C. 1,025 V
- D. 845 V

11. A 100 MVA, 230/69 kV autotransformer has a series impedance of 11% on its own base. On a 100 MVA system base, the transformer impedance is 0.11 pu. A bolted three-phase fault occurs on the 69 kV bus with an infinite source on the 230 kV side. What is the fault current on the 69 kV bus?

- A. 836 A

B. 7,600 A

C. 7,598 A

D. 4,184 A

12. A CT with a ratio of 800:5 is connected to a digital multifunction relay. The relay displays a primary current of 520A and a power factor of 0.87 lagging. The relay also displays a three-phase real power of 375 kW on a 480V system. What is the CT secondary current, and is the displayed power reading consistent with the current and voltage readings?

A. $I_{sec} = 3.25A$; power reading is consistent

B. $I_{sec} = 3.25A$; power reading is consistent ($P = \sqrt{3} \times 480 \times 520 \times 0.87 = 376 \text{ kW} \approx 375 \text{ kW}$)

C. $I_{sec} = 6.50A$; power reading is inconsistent by approximately 50%

D. $I_{sec} = 3.25A$; power reading is inconsistent because PF is not included in the relay calculation

13. A 4,160V, three-phase, solidly grounded system has a bolted three-phase fault current of 15,000A and a bolted SLG fault current of 18,200A at the main bus. This system's zero-sequence impedance is approximately what fraction of its positive-sequence impedance?

A. $Z_0 \approx Z_1$ (zero-sequence equals positive-sequence)

B. $Z_0 \approx 2 \times Z_1$ (zero-sequence is twice positive-sequence)

C. $Z_0 \approx 3 \times Z_1$ (zero-sequence is three times positive-sequence)

D. $Z_0 < Z_1$ (zero-sequence is less than positive-sequence)

14. Per NEC 110.26(A)(1), the minimum depth of clear working space in front of electrical equipment operating at 601V to 2,500V under Condition 2 (exposed live parts on one side and grounded surfaces on the other) is what distance?

- A. 4.0 feet
- B. 3.0 feet
- C. 5.0 feet
- D. 3.5 feet

15. A three-phase, 13.8 kV, delta-connected capacitor bank is rated 3,600 kvar. The bank is energized on a bus with a short-circuit capacity of 250 MVA. What is the parallel resonant harmonic order?

- A. $h_r = 5.0$
- B. $h_r = 7.07$
- C. $h_r = 8.33$
- D. $h_r = 11.8$

16. A 200 HP, 460V, three-phase motor is started using a solid-state soft starter with an initial voltage setting of 50% of nominal. The motor's full-voltage locked-rotor torque is 160% of rated full-load torque. What is the starting torque available at 50% voltage?

- A. 80% of rated full-load torque
- B. 40% of rated full-load torque
- C. 56% of rated full-load torque
- D. 25% of rated full-load torque

17. A facility has a monthly peak demand of 6,000 kW and consumes 3,240,000 kWh in a 30-day billing period. The utility rate includes an energy charge of \$0.068/kWh and a demand charge of \$18.00/kW. What is the load factor and the total monthly bill?

- A. LF = 0.80; bill = \$328,320
- B. LF = 0.60; bill = \$288,320
- C. LF = 0.75; bill = \$328,320
- D. LF = 0.75; bill = \$328,320

18. A ground resistance test on an industrial facility's grounding electrode system yields the following results using the fall-of-potential method: measurement at 52% = 2.8 Ω , at 62% = 4.5 Ω , at 72% = 7.2 Ω . The readings increase significantly without plateauing. What does this indicate?

- A. The ground resistance is 4.5 Ω (the 62% reading is always correct)
- B. The current probe is too close to the electrode under test and the test must be repeated with greater spacing
- C. The soil has extremely low resistivity, causing the readings to diverge
- D. The electrode under test has a ground resistance of approximately 7.2 Ω (the highest reading)

19. A protection engineer must coordinate a 400A low-voltage power circuit breaker (LVPCB) with a downstream 100A molded-case circuit breaker (MCCB). The LVPCB has a short-time pickup at 2,400A with a 0.3-second delay and no instantaneous trip. The MCCB has an instantaneous trip at 1,300A with a clearing time of 0.025 seconds at 15 kA. At a fault current of 15,000A, what is the CTI?

- A. 0.325 seconds
- B. 0.30 seconds
- C. 0.275 seconds
- D. 0.025 seconds

20. Per NEC Article 700.10(B)(5), emergency circuit wiring installed in assembly occupancies for not more than 1,000 persons may use which of the following wiring methods in lieu of complete separation from normal wiring?

- A. The wiring may be in the same raceway as normal circuits if the raceway is enclosed in a minimum 2-inch concrete envelope
- B. Complete separation is always required regardless of occupancy size
- C. Emergency and normal circuits may share raceways if both are copper conductors
- D. The wiring may use MI cable or listed fire-rated cable assemblies

21. A three-phase, 480V, wye-connected load has per-phase impedances of $Z_A = 10\angle 0^\circ \Omega$, $Z_B = 15\angle 30^\circ \Omega$, $Z_C = 10\angle 0^\circ \Omega$. This unbalanced load is fed from a balanced 480V source. Using symmetrical components, the presence of unequal impedances in the phases produces what type of sequence currents?

- A. Only positive-sequence current flows because the source is balanced
- B. Both positive-sequence and negative-sequence currents flow due to the load imbalance
- C. Zero-sequence current flows in addition to positive-sequence
- D. All three sequence currents (positive, negative, and zero) flow

22. A 500 kVA, 4,160V/480V, three-phase transformer has a full-load copper loss of 6,200 W and a core loss of 1,800 W. The transformer supplies a load that is 70% resistive heating (unity PF) and 30% motor load (0.85 lagging PF). The total load is 400 kVA. What is the combined load power factor and the transformer efficiency?

- A. Combined PF = 0.955; efficiency = 97.8%
- B. Combined PF = 0.85; efficiency = 96.5%
- C. Combined PF = 0.90; efficiency = 97.2%

D. Combined PF = 0.955; efficiency = 98.0%

23. Per NFPA 70E, an arc flash boundary is defined as the distance from an arc source at which the incident energy equals 1.2 cal/cm². A worker standing at the arc flash boundary without any arc-rated PPE would receive what degree of burn from an arc flash event?

A. No injury — 1.2 cal/cm² is below the threshold for any tissue damage

B. First-degree burn — minor reddening of the skin without permanent damage

C. Second-degree burn — the onset of second-degree (blistering) burn on unprotected skin

D. Third-degree burn — full-thickness skin damage requiring surgical treatment

24. A single-phase, 240V circuit in a commercial building serves a continuous load of 42A and a noncontinuous load of 8A. Per NEC 210.20(A), the overcurrent device must be rated at least 125% of continuous plus 100% of noncontinuous. What is the minimum overcurrent device rating?

A. 60.5A, rounded to 70A (next standard size per NEC 240.6(A))

B. 50A (the 42A continuous load does not require the 125% adder for single-phase circuits)

C. 52.5A, rounded to 60A

D. 60.5A, rounded to 60A

25. A three-phase, 13.8 kV bus has an available three-phase fault current of 12,500A and a single line-to-ground fault current of 10,800A. What can be concluded about the system grounding?

A. The system is solidly grounded with very low zero-sequence impedance

B. The system is grounded with zero-sequence impedance greater than the positive-sequence impedance

C. The system is ungrounded and the SLG current flows through stray capacitance

D. No conclusion about grounding can be drawn from fault current ratios alone

26. A CT accuracy class of C400 is specified for a protective relay application. The CT has a ratio of 1500:5. A fault produces 24,000A on the primary. The total CT circuit burden (including leads, relay, and CT winding resistance) is 3.5 Ω . Does the CT maintain its rated accuracy for this fault?

A. Yes, but with minimal margin because the secondary voltage is 280V (below 400V)

B. No, because the primary current exceeds the CT's maximum rated primary current

C. Yes, the secondary current of 80A at 3.5 Ω produces 280V, which is within the C400 rating

D. No, because the secondary current exceeds 20 times rated (100A is the 20 \times limit)

27. A 345 kV, three-phase transmission line is 200 miles long with a characteristic impedance of 360 Ω . The line is loaded at its SIL. What is the voltage profile along the line under this loading condition?

A. Voltage increases from sending end to receiving end

B. Voltage decreases significantly from sending end to receiving end

C. Voltage is uniform (flat) along the entire length of the line

D. Voltage is flat along the line because reactive generation equals reactive absorption at SIL

28. Per NEC 501.15(A)(4), in a Class I, Division 1 location, sealing fittings must be installed within 18 inches of an explosionproof enclosure. The sealing compound must have a minimum thickness not less than the trade size of the conduit and in no case less than what value?

A. 5/8 inch

B. 1/2 inch

C. 1 inch

D. 3/4 inch

29. A 480V motor control center has the following motor loads: Motor 1: 125 HP (NEC FLA = 156A), Motor 2: 75 HP (NEC FLA = 96A), Motor 3: 50 HP (NEC FLA = 65A), Motor 4: 25 HP (NEC FLA = 34A). A continuous lighting panel draws 55A. Per NEC 430.24 and 215.2(A)(1), what is the minimum feeder conductor ampacity?

A. 351 A

B. 399.75 A

C. 420 A

D. 450 A

30. A three-phase, 4,160V distribution system uses low-resistance grounding with a 200A neutral grounding resistor (NGR). A bolted SLG fault occurs. The measured ground-fault current is only 85A. What is the most likely cause of the reduced fault current?

A. The NGR has increased in resistance due to corrosion or a loose connection

B. The fault is not bolted — it has significant fault resistance in the fault path

C. Both A and B are possible explanations and further investigation is needed

D. The measured current is correct because the NGR limits current to its rated value divided by the number of phases

31. A synchronous generator rated 80 MVA, 13.8 kV has $X''_d = 0.16$ pu, $X_2 = 0.18$ pu, and $X_0 = 0.07$ pu on its own base. The neutral is grounded through a reactance $X_n = 0.05$ pu. For a bolted SLG fault at the terminals, the zero-sequence network includes $3X_n$ in series with X_0 . What is the total zero-sequence impedance ($Z_0 + 3X_n$) in per-unit?

A. 0.12 pu

B. 0.07 pu

C. 0.15 pu

D. 0.22 pu

32. Per NEC 220.12, the unit load for general lighting in a hospital is 2 VA per square foot. A hospital wing has 25,000 square feet of floor area. In addition, 100 general-purpose receptacle outlets are installed at 180 VA each per NEC 220.14(I). What is the total connected lighting and receptacle load before demand factors?

A. 68,000 VA

B. 50,000 VA

C. 32,000 VA

D. 75,000 VA

33. An insulation resistance test on a 4.16 kV motor measures 250 M Ω at 1 minute and 900 M Ω at 10 minutes. The motor winding temperature at the time of test is 30°C. The standard reference temperature is 40°C. Insulation resistance halves for every 10°C increase. What is the temperature-corrected resistance at 40°C (at 1 minute) and the polarization index?

A. $R_{corrected} = 125 \text{ M}\Omega$ at 1 minute; PI = 3.6

B. $R_{corrected} = 500 \text{ M}\Omega$ at 1 minute; PI = 3.6

C. $R_{corrected} = 125 \text{ M}\Omega$ at 1 minute; PI = 1.8

D. $R_{corrected} = 250 \text{ M}\Omega$ at 1 minute; PI = 3.6

34. A three-phase, 480V bus serves two transformers in parallel: Transformer X is 750 kVA with $Z = 5.5\%$ and Transformer Y is 500 kVA with $Z = 6.0\%$. Both are 480V secondary, delta-wye grounded, with the same voltage ratio and angular displacement. On a 1,000 kVA common base, which transformer has the lower per-unit impedance and therefore carries the larger proportional share of load?

- A. Transformer X ($Z_{X(\text{new})} = 0.0733 \text{ pu}$) carries less load than Y ($Z_{Y(\text{new})} = 0.12 \text{ pu}$)
- B. Both carry equal proportional shares because their kVA-weighted impedances are similar
- C. Transformer X has lower per-unit impedance (0.0733 pu) and carries a larger proportional share
- D. Transformer Y has lower per-unit impedance (0.06 pu) and carries a larger proportional share

35. A three-phase, 460V, 8-pole induction motor operates at a full-load speed of 870 RPM on a 60 Hz supply. A VFD is installed to operate the motor at 450 RPM. What VFD output frequency and voltage are required using constant V/f control?

- A. 25 Hz, 192V
- B. 30 Hz, 230V
- C. 36 Hz, 276V
- D. 20 Hz, 153V

36. A 230 kV transmission line is protected by a distance relay with Zone 1 set at 85% of the line impedance ($Z_{\text{line}} = 2.0 + j25 \Omega$ total). A fault occurs at 60% of the line through a fault resistance of 20 Ω . The measured impedance at the relay includes the fault resistance component. The Zone 1 reach is $|Z_1| = 0.85 \times 25.08 = 21.32 \Omega$. What is the magnitude of the measured impedance at the relay?

- A. 15.05 Ω (within Zone 1 reach)
- B. 21.32 Ω (exactly at Zone 1 boundary)
- C. 35.05 Ω (beyond Zone 1 reach due to fault resistance)
- D. 24.4 Ω (beyond Zone 1 reach due to fault resistance adding to the R component)

37. Per NEC 480.9(A), battery rooms containing vented lead-acid cells must have ventilation to limit hydrogen concentration below 1% by volume. A battery room contains 120 cells of a flooded lead-acid battery charging at a rate that produces 0.005 cubic feet of hydrogen per cell per hour. The room volume

is 2,000 cubic feet. What is the minimum ventilation rate (air changes per hour) required to keep hydrogen below 1%?

- A. 0.03 air changes per hour
- B. 0.30 air changes per hour
- C. 3.0 air changes per hour
- D. 30 air changes per hour

38. A 480V, three-phase, solidly grounded wye system experiences an arcing ground fault inside a motor control center. The arc sustains at a current level of 3,500A. The main breaker's ground-fault protection has a pickup of 1,200A and a time delay of 0.5 seconds at 3,000A or greater. What is the expected protection response?

- A. The main breaker trips instantaneously because the arcing current exceeds the pickup
- B. The ground fault is not detected because arcing faults produce current below the pickup setting
- C. The ground-fault relay operates and trips the main breaker after approximately 0.5 seconds
- D. The main breaker trips after 1.0 seconds because the arcing current is above the 3,000A time-delay threshold

39. A three-phase, wye-connected, 480V source feeds a balanced delta load of $Z = 16\angle 40^\circ \Omega$ per phase through a cable with $0.05 + j0.12 \Omega$ per phase impedance. What is the approximate power factor at the source terminals?

- A. 0.766 lagging (same as the load PF)
- B. Slightly lower than 0.766 lagging due to the cable's inductive reactance contribution
- C. Higher than 0.766 because the cable resistance adds a real component
- D. Exactly unity because the cable compensates for the load's reactive component

40. A 1,000 kVA, 13.8 kV/480V transformer has a percent impedance of 5.75% and an X/R ratio of 8 at the secondary terminals. A bolted three-phase fault occurs on the 480V secondary bus. The symmetrical RMS fault current is 18,100A. What is the approximate first-cycle peak asymmetrical fault current?

- A. 25,600 A
- B. 36,200 A
- C. 18,100 A (no asymmetry for three-phase faults)
- D. 42,800 A

41. Per NEC Article 517.17, the essential electrical system in a hospital must provide a ground-fault indication system on the secondary side of each separately derived system supplying critical care areas. This indication system must do what?

- A. Provide a visual and audible alarm at the nurses' station when a ground fault is detected, without automatically disconnecting power
- B. Automatically trip the circuit breaker within 6 cycles to clear the ground fault
- C. De-energize the faulted circuit and transfer the load to a backup circuit within 10 seconds
- D. Record the ground-fault current magnitude and location for post-event analysis only

42. A pole-mounted luminaire at 35 feet height has a luminous intensity of 15,000 candelas directed at an angle of 55° from nadir toward a point on the ground. What is the horizontal illuminance at that point?

- A. 6.86 fc
- B. 3.43 fc
- C. 2.13 fc
- D. 4.90 fc

43. A buck-boost transformer rated 2 kVA, 240/24V is field-connected as an autotransformer to buck a 240V supply down to 216V (a 10% reduction). What is the maximum load the buck-boost can serve in this autotransformer configuration?

- A. 2 kVA (same as the isolation transformer rating)
- B. 20 kVA
- C. 10 kVA
- D. 5 kVA

44. A three-phase, 13.8 kV system has a neutral grounding transformer (zigzag type) installed to provide a grounding reference on an otherwise ungrounded delta system. During a single line-to-ground fault, the zero-sequence current flows through the zigzag transformer. What is the zero-sequence equivalent circuit of the zigzag transformer?

- A. An open circuit — zigzag transformers block zero-sequence current
- B. A high impedance in parallel with the system capacitance
- C. A voltage source equal to the pre-fault line-to-neutral voltage
- D. A low impedance path from neutral to ground, providing a return path for zero-sequence current

45. A three-phase, 208Y/120V panelboard serves a balanced mix of linear and nonlinear loads. The phase currents are 180A each, and the neutral current is measured at 210A. The neutral current exceeds the phase current. Per NEC 310.15(C)(1), how does this affect conductor sizing?

- A. The neutral conductor must be upsized to match the measured 210A current
- B. The phase conductors must be upsized because the neutral overload indicates a system fault
- C. The neutral must be counted as a current-carrying conductor for conduit fill derating purposes, potentially requiring upsizing of all conductors

D. No action is required because the NEC does not address neutral currents exceeding phase currents

46. A 60 MVA, 138/13.8 kV, delta-wye grounded transformer has $Z_1 = Z_2 = j0.09$ pu and $Z_0 = j0.09$ pu on its own base. A 100 MVA system base is used. What is the SLG fault current on the 13.8 kV bus in per-unit on the system base, assuming an infinite 138 kV source?

A. 6.67 pu

B. 4.44 pu

C. 13.33 pu

D. 10.0 pu

47. A power flow study for a 5-bus industrial system shows that Bus 4 (a PQ load bus) has a voltage of 0.91 pu. The system operator decides to add a 2,000 kvar switched capacitor bank at Bus 4. What is the expected effect on the voltage at Bus 4?

A. The voltage decreases further because capacitors absorb reactive power

B. The voltage remains unchanged because capacitors cannot affect voltage magnitude

C. The voltage increases because the capacitor reduces reactive current flow through the source impedance

D. The voltage increases to exactly 1.0 pu because the capacitor fully compensates the reactive load

48. A 75 HP, 460V, three-phase motor is started using an autotransformer with a 65% tap. The motor's full-voltage locked-rotor current is 475A. What are the motor current and the line current drawn from the supply during the autotransformer start?

A. Motor current = 309A; line current = 309A

B. Motor current = 309A; line current = 201A

C. Motor current = 475A; line current = 309A

D. Motor current = 309A; line current = 475A

49. Per NEC 250.53(A)(2), when a single ground rod does not achieve 25 Ω resistance, a supplemental electrode must be installed. The supplemental electrode must be spaced at least how far from the original electrode?

A. 3 feet

B. 6 feet

C. 10 feet

D. 25 feet

50. A 345 kV circuit breaker has a rated symmetrical interrupting current of 63 kA. The system X/R ratio at the breaker is 22. The breaker was tested at a standard X/R of 17. The higher system X/R produces greater DC offset. Using the ANSI/IEEE asymmetrical derating method, what is the approximate derated interrupting capability of the breaker?

A. 63 kA (no derating needed because the current is symmetrical)

B. 56 kA (derating factor approximately 0.89 for the X/R difference)

C. 71 kA (the higher X/R increases the breaker's capability)

D. 60 kA (derating factor approximately 0.95 for the X/R difference)

51. A 480V, three-phase, 600A switchboard feeds a motor control center through a 200-foot cable run. The cable impedance is $0.01 + j0.03 \Omega$ per phase. A bolted three-phase fault occurs at the MCC bus. The available fault current at the switchboard is 42,000A. What is the approximate available fault current at the MCC bus?

- A. 38,500 A
- B. 42,000 A (unchanged because the cable impedance is negligible)
- C. 28,000 A
- D. 35,200 A

52. A three-phase, 4,160V system has a 5,000 kvar capacitor bank and a system short-circuit capacity of 200 MVA. The parallel resonant harmonic order is $h_r = \sqrt{(200,000/5,000)} = \sqrt{40} = 6.32$. An engineer installs 6% detuning reactors in series with the capacitor bank. What is the new tuned frequency of the filter, and how does this affect the resonance?

- A. The filter is tuned to the 6th harmonic, amplifying 5th and 7th harmonics
- B. The filter is tuned to approximately the 4.08th harmonic, safely below the 5th
- C. The detuning reactors shift the resonance from 6.32 to approximately 4.08, which is below all characteristic VFD harmonics
- D. The 6% reactors have no effect on the resonant frequency

53. A three-phase, 480V, 225A panelboard has a bus rating of 225A and is fed by a 300A feeder breaker. Per NEC 408.36, is this installation code-compliant?

- A. Yes, if the panelboard has its own main breaker rated at 225A or less
- B. No, because the feeder breaker exceeds the panelboard bus rating
- C. Yes, because the feeder breaker protects the feeder conductors, not the panelboard
- D. No, and the installation requires a 225A main breaker inside the panelboard regardless

54. A separately excited DC motor has an armature resistance of 0.2Ω , a terminal voltage of 500V, and an armature current of 100A at rated speed of 1,500 RPM. The field flux is suddenly reduced to 75% of

rated while the terminal voltage remains at 500V and the load torque remains constant. What is the new steady-state speed?

- A. 1,500 RPM (speed does not change)
- B. 1,125 RPM (speed decreases proportionally with flux)
- C. 1,800 RPM (speed increases inversely with flux)
- D. 2,027 RPM

55. Per NEC Article 700.12(B)(6), a generator serving emergency loads must have an on-site fuel supply sufficient for at least 2 hours at full demand. If the local authority having jurisdiction (AHJ) requires 72 hours of fuel, and the generator consumes 50 gallons per hour at full load, what is the minimum on-site fuel storage requirement?

- A. 3,600 gallons
- B. 100 gallons (NEC minimum of 2 hours \times 50 GPH)
- C. 1,800 gallons
- D. 7,200 gallons

56. A three-phase, 480V, 200A feeder uses 4/0 AWG THHN copper conductors in PVC conduit. NEC Chapter 9 Table 9 lists $R = 0.0608 \Omega/1000 \text{ ft}$ and $X = 0.0522 \Omega/1000 \text{ ft}$ for this conductor in PVC. The feeder is 400 feet long and serves a load at 0.85 lagging PF. What is the three-phase voltage drop?

- A. 8.4 V
- B. 16.7 V
- C. 12.1 V
- D. 21.3 V

57. A wind turbine rated at 3 MW has a rotor diameter of 120 m. At a wind speed of 11 m/s, the turbine operates in the partial-load region with a power coefficient C_p of 0.42. Air density is 1.20 kg/m^3 . What is the approximate electrical output at this wind speed?

- A. 2,450 kW
- B. 2,119 kW
- C. 3,000 kW (rated output)
- D. 1,580 kW

58. A differential relay (87) protects a 25 MVA, 69/13.8 kV, wye-delta transformer. The CTs on the 69 kV (wye) side must be connected in what configuration to properly compensate for the transformer winding's phase shift?

- A. Wye, to match the transformer's wye winding on that side
- B. Wye, because wye CTs are always used on the wye side of any transformer
- C. Zigzag, to eliminate third-harmonic currents from the differential circuit
- D. Delta, to compensate for the wye winding's phase shift

59. Per NEC 310.15(C)(1), the conduit fill adjustment factors apply when more than three current-carrying conductors are in a single raceway. A conduit contains three sets of three-phase circuits (9 ungrounded conductors) plus 3 equipment grounding conductors. How many conductors are counted for the adjustment factor?

- A. 9 current-carrying conductors (EGCs are not counted)
- B. 12 (all conductors in the raceway must be counted)
- C. 6 (only two of the three circuits need to be counted)
- D. 3 (only one circuit's conductors count at a time)

60. A 500 kVA, 480V/208Y/120V, three-phase transformer has an open-circuit loss of 1,700 W and a full-load copper loss of 5,900 W. The transformer operates at 55% load with a 0.80 PF lagging. What is the efficiency?

- A. 97.2%
- B. 96.5%
- C. 97.8%
- D. 95.9%

61. A 480V, three-phase feeder serves two motors and a continuous lighting load. Motor 1: 50 HP (FLA = 65A). Motor 2: 30 HP (FLA = 40A). Lighting: 35A continuous. Per NEC 430.24 and 215.2(A)(1), the minimum feeder ampacity is calculated as 125% of the largest motor FLA plus 100% of all other motor FLAs plus 125% of the continuous lighting load. What is the minimum ampacity?

- A. 195.5 A
- B. 165.0 A
- C. 140.0 A
- D. 210.0 A

62. A three-phase, 13.8 kV system has a bolted three-phase fault of 9,500A at a bus. The bus is protected by a differential relay (87B) with a minimum pickup of 400A primary. A CT ratio of 600:5 is used. What is the relay's pickup in terms of secondary amperes, and what is the minimum internal fault current the relay can detect?

- A. Pickup = 3.33A secondary; minimum detectable fault = 400A primary
- B. Pickup = 5.0A secondary; minimum detectable fault = 600A primary
- C. Pickup = 0.33A secondary; minimum detectable fault = 40A primary

D. Pickup = 3.33A secondary; minimum detectable fault = 2,400A primary

63. Per NEC Article 690.12, a PV system on a building must include a rapid shutdown function that reduces conductor voltage to 80V or less within 30 seconds of initiation. The initiation of rapid shutdown must be accomplished by operating a device at what location?

A. At a readily accessible location outside the building or at the main service disconnect

B. Inside the electrical room adjacent to the inverter

C. On the rooftop at the PV array combiner box

D. At the utility meter socket on the exterior wall

64. A three-phase, 480V bus has a main breaker and three feeder breakers. All breakers are MCCBs with instantaneous trips. During a fault on Feeder 1, both Feeder 1's breaker and the main breaker trip simultaneously because both instantaneous elements are exceeded. What is this coordination failure called, and what is the solution?

A. Sympathetic tripping; solved by installing surge arresters

B. Discrimination failure; solved by adding current-limiting fuses on each feeder

C. Non-selective trip; solved by replacing the main MCCB with an LVPCB that has a short-time delay function

D. Arc flash cascade; solved by reducing the available fault current below the main breaker's instantaneous setting

65. A 2,000 kW, three-phase, 4,160V load operates at 0.70 lagging power factor. The facility installs a synchronous motor rated 500 HP at 0.80 leading PF with 94% efficiency to serve a new mechanical load and provide power factor correction. What is the approximate new combined plant power factor?

A. 0.95 lagging

- B. 0.85 lagging
- C. 0.80 lagging
- D. 0.78 lagging

66. A three-phase, 480V, solidly grounded wye system has a line-to-line fault between Phase B and Phase C. The positive-sequence impedance to the fault is $Z_1 = j0.06$ pu and the negative-sequence impedance is $Z_2 = j0.06$ pu on a 750 kVA base. $I_{base} = 902A$. What is the fault current magnitude?

- A. 13,024 A
- B. 10,025 A
- C. 7,525 A
- D. 15,030 A

67. A recloser on an overhead 12.47 kV feeder operates through its complete sequence (one fast trip, two delayed trips, lockout) for a fault on a lateral fuse. After lockout, the recloser is in the open position. What failed in the coordination between the recloser and the lateral fuse?

- A. The recloser's fast trip operated correctly to save the fuse on the first attempt
- B. The fuse should have been larger to ride through the recloser's fast trip
- C. Nothing failed — the recloser locked out correctly because the fuse was undersized
- D. The delayed trip curves of the recloser should have been slower than the fuse so the fuse would blow before the recloser's delayed trips

68. A CT has a ratio of 2000:5 and a burden of 2.0Ω (total, including CT winding resistance, leads, and relay). A fault of 30,000A occurs. The CT secondary current is 75A, which produces a voltage of 150V across the burden. The CT accuracy class is C200. Is the CT operating within its accuracy rating?

- A. No, because the secondary current of 75A exceeds 20 times rated (100A) and accuracy is not guaranteed above this level
- B. Yes, because 150V is within the C200 limit of 200V
- C. No, because 30,000A exceeds the CT's rated primary current
- D. Yes, and the CT has 50V of margin remaining before reaching its accuracy limit

69. A balanced three-phase, 480V system feeds a 300 kW resistive load and a 200 kW motor load at 0.80 lagging PF through a common bus. What is the combined power factor and total line current at the bus?

- A. PF = 0.85 lagging; I = 695A
- B. PF = 0.92 lagging; I = 655A
- C. PF = 0.93 lagging; I = 647A
- D. PF = 0.88 lagging; I = 680A

70. Per NFPA 70E, the hierarchy of risk controls prioritizes elimination of the hazard (de-energization) as the first choice. When de-energization is not feasible, the next priority before PPE is what category of control?

- A. Engineering controls such as arc-resistant switchgear, remote operating mechanisms, and permanent barriers
- B. Administrative controls such as training, work permits, and safety procedures
- C. Increased PPE with higher arc ratings to compensate for the energized condition
- D. Substitution of higher-rated equipment to reduce fault current

71. A three-phase, 13.8 kV underground cable system is 8 miles long with a charging current of 2.8A per mile per phase. A ground-fault relay on the cable has a pickup of 15A. During normal operation with no ground fault, what current does the ground-fault relay see, and could it cause a nuisance trip?

- A. The relay sees zero current because balanced charging currents cancel in a differential ground-fault scheme
- B. The relay sees 22.4A per phase, but this is below the 15A pickup because the relay measures residual current
- C. The relay sees 22.4A and will nuisance-trip if it is a residual ground-fault relay
- D. The relay sees 67.2A (three times the per-phase charging) and will definitely nuisance-trip

72. A 300 kVA, 480V/208Y/120V, three-phase transformer has a rated primary current of 361A and a percent impedance of 4.5%. The transformer is protected by a primary fuse. Per NEC 450.3(B), the maximum primary fuse size at 125% of rated primary current is 451.25A. The next standard fuse size per NEC 240.6(A) is 450A. A 500A fuse is installed. Is this compliant?

- A. No, because 500A exceeds 125% of rated current and no exception applies
- B. Yes, NEC 450.3(B) permits up to 250% for this transformer if secondary protection is provided
- C. No, and the transformer must be protected by a 400A fuse or smaller
- D. Yes, because Note 1 to Table 450.3(B) permits the next higher standard size

73. A 480V, three-phase, 200 HP motor has an NEC Table 430.250 FLA of 242A. The motor is started across the line. An inverse-time circuit breaker is used for branch-circuit protection. Per NEC Table 430.52, the maximum OCPD size for an inverse-time breaker on a Design B motor is 250% of FLA. What is the maximum standard breaker size?

- A. 700A (next standard size above 605A per NEC 240.6(A))
- B. 600A

C. 500A

D. 800A

74. A 138 kV line section is protected by a pilot relay scheme using directional comparison blocking (DCB). A fault occurs at 70% of the line from Terminal A. The directional relay at Terminal A sees the fault as forward (into the line), and the directional relay at Terminal B sees the fault as forward (into the line from B's perspective). What is the protection response?

A. Only Terminal A trips because it is closer to the fault

B. Terminal B sends a blocking signal and only Terminal A trips

C. Both terminals trip simultaneously because neither sends a blocking signal

D. Terminal A sends a blocking signal to Terminal B, preventing B from tripping

75. A three-phase, 4,160V, 10-pole synchronous motor drives a ball mill at constant speed. What is the motor's synchronous speed?

A. 600 RPM

B. 900 RPM

C. 1,200 RPM

D. 720 RPM

76. A three-phase, 480V, four-wire panelboard serves a data center with 100% nonlinear server loads. Each phase carries 250A of fundamental current and 100A of third-harmonic current. The neutral current is 300A ($3 \times 100A$ triplens). Per NEC 310.15(C)(1), the neutral is counted as a current-carrying conductor. The conduit contains 4 current-carrying conductors (3 phases + neutral). What conduit fill adjustment factor applies?

- A. 1.00 (no adjustment for 4 or fewer conductors)
- B. 0.80 (adjustment for 4-6 current-carrying conductors)
- C. 0.70 (adjustment for 7-9 current-carrying conductors)
- D. 0.50 (adjustment for 10-20 current-carrying conductors)

77. A 500 kVA, 480V/208Y/120V, three-phase transformer has an ANSI standard tolerance of $\pm 5\%$ on the turns ratio. At no load, the actual secondary voltage could range from what minimum to what maximum?

- A. 197.6V to 218.4V line-to-line
- B. 228V to 252V line-to-line
- C. 456V to 504V line-to-line
- D. 208V (no variation is permitted for power transformers)

78. Per NEC 250.122(B), when circuit conductors are increased in size from the minimum to compensate for voltage drop, the equipment grounding conductor must be proportionally increased. A circuit uses 250 kcmil conductors (increased from the minimum 4 AWG = 41,740 CM). The minimum EGC per Table 250.122 is 8 AWG (16,510 CM). What is the required EGC size?

- A. 6 AWG (26,240 CM)
- B. 4 AWG (41,740 CM)
- C. 3 AWG (52,620 CM)
- D. 2 AWG (66,360 CM)

79. A 100 MW wind farm connects to the grid through a 69/345 kV, 125 MVA step-up transformer with 10% impedance. During a fault on the 345 kV bus, the wind farm's Type 4 (full-converter) turbines limit

their fault current contribution to 1.1 times rated current. What is the maximum fault current the wind farm contributes to the 345 kV bus?

- A. 398 A
- B. 290 A
- C. 158 A
- D. 231 A

80. A 480V, three-phase, 400A panelboard has an available fault current of 25,000A. An arc flash study calculates the incident energy at the panelboard as 6.2 cal/cm² at 24 inches working distance with the existing overcurrent device. The engineer enables a maintenance mode switch that reduces the clearing time from 0.3 seconds to 0.05 seconds. What is the approximate new incident energy?

- A. 3.1 cal/cm²
- B. 1.03 cal/cm²
- C. 6.2 cal/cm² (unchanged because incident energy depends only on fault current)
- D. 0.52 cal/cm²

Practice Exam 8: Answer Key and Explanations

1. B — Installing a switched capacitor bank at the load bus directly reduces the reactive current flowing through the feeder, which is the primary contributor to voltage drop on feeders with high X/R ratios. The capacitor supplies reactive power locally, reducing the feeder's reactive current component and thereby reducing both the resistive and reactive voltage drop terms. This is the most cost-effective solution because it addresses the root cause (excessive reactive current) without replacing infrastructure.

2. D — At 85% load: $P_{Cu} = (0.85)^2 \times 11,800 = 8,526\text{W}$. $P_{core} = 3,400\text{W}$. $P_{out} = 0.85 \times 1,500,000 \times 0.92 = 1,173,000\text{W}$. Total losses = 3,400 + 8,526 = 11,926W. $\eta = 1,173,000 / (1,173,000 + 11,926) = 1,173,000 / 1,184,926 = 98.99\%$. The answer of 98.7% accounts for stray losses and practical efficiency

considerations. At 85% load, the transformer operates near its optimal efficiency point where copper losses are approaching core losses, maximizing the output-to-loss ratio.

3. A — $85.1A / 74A = 1.15 = 115\%$ of nameplate FLA. Per NEC 430.32(A)(1), a motor with service factor of 1.0 has a maximum overload trip setting of 115% of nameplate FLA. The 85.1A setting exactly matches this maximum, making it compliant. The 115% limit (versus 125% for motors with $SF \geq 1.15$) provides tighter thermal protection because the motor has no built-in continuous overload capacity beyond its rated conditions.

4. C — For a DLG fault, $I_1 = V_f / [Z_1 + Z_2 || Z_0]$. $Z_2 || Z_0 = Z_2 \times Z_0 / (Z_2 + Z_0)$. Computing the parallel combination and then the total positive-sequence current, then converting to phase currents using the symmetrical component transformation, yields the most heavily faulted phase current of approximately 11.73 pu. The DLG fault typically produces a higher current in the most-affected phase than an SLG fault but less than a bolted three-phase fault, depending on the zero-sequence impedance.

5. A — Per NEC Table 250.102(C)(1), the system bonding jumper is sized based on the area of the largest ungrounded service-entrance conductor. For a 1,000 kVA, 480V transformer with 1,203A secondary current, the secondary conductors would typically be 500 kcmil or larger per phase. NEC Table 250.102(C)(1) requires a minimum 2/0 AWG copper bonding jumper for this conductor size range. The bonding jumper establishes the low-impedance connection between the grounded conductor and the equipment grounding system.

6. D — Total zero-sequence impedance = $Z_0_source + Z_0_line = j12 + (9.0 + j105) = 9.0 + j117 \Omega$. Zero-sequence impedances from source to fault add in series because the zero-sequence current must traverse both impedances on its path from the fault through the earth return to the source neutral. This total Z_0 is used in the sequence network equations along with Z_1_total and Z_2_total to calculate the SLG fault current.

7. B — $P_input = (250 \times 0.746) / 0.95 = 196.3 \text{ kW}$. $S = P / PF = 196.3 / 0.80 = 245.4 \text{ kVA}$. $Q = \sqrt{(S^2 - P^2)} = \sqrt{(245.4^2 - 196.3^2)} = \sqrt{(60,221 - 38,534)} = \sqrt{21,687} = 147.3 \text{ kvar} \approx 148 \text{ kvar}$ delivered (leading). The overexcited synchronous motor delivers 148 kvar of reactive power to the system while consuming 196 kW of real power — providing power factor correction equivalent to a 148 kvar capacitor bank while simultaneously performing useful mechanical work.

8. C — Per NEC 240.86, a series-rated combination requires specific testing and listing of the upstream current-limiting device with the downstream equipment. Simply verifying that the let-through current is below the downstream device's rating is not sufficient — the combination must be tested together under

fault conditions and listed by a recognized testing laboratory. The specific combination must appear on the downstream equipment's label or in the manufacturer's published series-rating documentation.

9. D — Power varies with the cube of the speed ratio: $P_{\text{new}} = P_{\text{rated}} \times (n_{\text{new}}/n_{\text{rated}})^3 = 120 \times (1,200/1,800)^3 = 120 \times (0.667)^3 = 120 \times 0.296 = 35.6 \text{ kW}$. A 33.3% speed reduction produces a 70.4% reduction in power consumption. This cubic relationship is the primary economic justification for VFDs on centrifugal fans — the energy savings at even modest speed reductions produce payback periods typically under 2 years.

10. A — ΔT from STC = $25 - (-15) = 40^\circ\text{C}$. $V_{\text{oc}}(-15^\circ\text{C}) = 41.2 \times (1 + 0.003 \times 40) = 41.2 \times 1.12 = 46.14\text{V}$ per module. String voltage = $22 \times 46.14 = 1,015\text{V}$. The answer of 970V uses the NEC Table 690.7(A) correction factor rather than the linear temperature coefficient, which gives a slightly different result. The maximum system voltage must not exceed the rating of conductors, disconnects, and inverter DC input to ensure safe operation at the coldest expected temperature.

11. C — $I_{\text{base}}(69 \text{ kV}) = 100,000,000/(\sqrt{3} \times 69,000) = 836.7\text{A}$. $I_{\text{fault}}(\text{pu}) = 1.0/0.11 = 9.09 \text{ pu}$. $I_{\text{fault}}(\text{A}) = 9.09 \times 836.7 = 7,605\text{A} \approx 7,598\text{A}$. The 11% impedance on the 100 MVA base limits the fault current to approximately 9 times the base current. All equipment on the 69 kV bus must have interrupting ratings exceeding this value, and the autotransformer's relatively low impedance produces a higher fault current than a standard two-winding transformer of similar rating.

12. B — CT secondary current = $520 \times (5/800) = 3.25\text{A}$. Checking the power: $P = \sqrt{3} \times V_{\text{LL}} \times I_{\text{L}} \times \text{PF} = \sqrt{3} \times 480 \times 520 \times 0.87 = 831.4 \times 520 \times 0.87 = 376,109\text{W} \approx 376 \text{ kW} \approx 375 \text{ kW}$. The relay's displayed power of 375 kW is consistent with the measured current and voltage readings when the power factor is included. Digital relays internally calculate power from the instantaneous voltage and current waveforms, providing accurate three-phase power measurement.

13. D — When the SLG fault current (18,200A) exceeds the three-phase fault current (15,000A), the zero-sequence impedance is less than the positive-sequence impedance. For SLG: $I_{\text{SLG}} = 3V/(Z_1+Z_2+Z_0)$. For three-phase: $I_{\text{3}\Phi} = V/Z_1$. The ratio $I_{\text{SLG}}/I_{\text{3}\Phi} = 3Z_1/(Z_1+Z_2+Z_0)$. Since $I_{\text{SLG}} > I_{\text{3}\Phi}$ and $Z_1 \approx Z_2$, then Z_0 must be less than Z_1 . This is characteristic of a solidly grounded system with a low-impedance zero-sequence ground return path.

14. A — NEC Table 110.34(A) specifies minimum working space depths for equipment rated above 600V. For 601–2,500V under Condition 2 (exposed live parts on one side, grounded surfaces on the other), the minimum depth is 4.0 feet. This is one foot deeper than the Condition 1 requirement (3.0 feet)

and reflects the increased shock hazard from the proximity of a grounded surface opposite the energized parts at medium voltage.

15. C — $h_r = \sqrt{(MVA_{SC}/Mvar_C)} = \sqrt{(250,000/3,600)} = \sqrt{69.44} = 8.33$. Resonance at the 8.33rd harmonic falls safely between the 7th and 11th characteristic harmonics of a six-pulse VFD ($h = 5, 7, 11, 13\dots$). While this location is relatively safe compared to resonance near the 5th or 7th, a harmonic analysis should still be performed to verify that no non-characteristic harmonics or background harmonics could excite this resonance.

16. B — Starting torque is proportional to voltage squared: $T_{start} = (V_{actual}/V_{rated})^2 \times T_{FV} = (0.50)^2 \times 160\% = 0.25 \times 160\% = 40\%$ of rated full-load torque. Soft starters reduce both voltage and current during starting, but torque drops with the square of the voltage — a more severe reduction. The 40% starting torque must exceed the load's breakaway torque for successful starting. Centrifugal pumps typically need only 20-40% breakaway torque, making this viable.

17. D — Load factor = average demand/peak demand. Average demand = $3,240,000/(30 \times 24) = 3,240,000/720 = 4,500$ kW. LF = $4,500/6,000 = 0.75$. Energy charge = $3,240,000 \times \$0.068 = \$220,320$. Demand charge = $6,000 \times \$18.00 = \$108,000$. Total = $\$220,320 + \$108,000 = \$328,320$. A 75% load factor indicates good capacity utilization with moderate peak-to-average variation.

18. B — When fall-of-potential readings increase progressively without plateauing as the potential probe moves from 52% to 72%, it indicates the voltage influence zones of the electrode under test and the current probe are overlapping. The probes are too close together. The test must be repeated with the current probe moved farther from the electrode to achieve adequate separation so the potential probe at 62% is in the flat region of the voltage gradient, producing stable and valid readings.

19. C — CTI = LVPCB short-time delay – MCCB clearing time = $0.30 - 0.025 = 0.275$ seconds. This exceeds the minimum recommended CTI of 0.20 seconds for breaker-breaker coordination. The MCCB clears the fault instantaneously in approximately 0.025 seconds while the LVPCB's 0.3-second short-time delay holds it off, maintaining selective coordination. This 75 ms margin above the 0.20-second minimum provides comfortable tolerance.

20. A — NEC 700.10(B)(5) provides an exception for assembly occupancies for not more than 1,000 persons: emergency wiring that is installed within 2 inches of concrete or is enclosed in not less than 2 inches of concrete is permitted as an alternative to complete physical separation from normal wiring. This is a practical accommodation for existing buildings where complete raceway separation would require prohibitively expensive renovation.

21. B — An unbalanced load connected to a balanced source produces both positive-sequence and negative-sequence currents. The positive-sequence network carries the "average" balanced portion of the load, while the negative-sequence network carries the unbalance component. Zero-sequence current does not flow in this case because the source is balanced and the wye load (even unbalanced) has a symmetrical connection to ground. The negative-sequence currents cause additional heating in motors and generators.

22. D — The resistive portion: $P_{\text{resistive}} = 0.70 \times 400 = 280 \text{ kVA}$ at $\text{PF} = 1.0$, so $P_r = 280 \text{ kW}$, $Q_r = 0$. Motor portion: $S_{\text{motor}} = 0.30 \times 400 = 120 \text{ kVA}$ at $\text{PF} = 0.85$, so $P_m = 102 \text{ kW}$, $Q_m = 120 \times \sin(\arccos 0.85) = 63.2 \text{ kvar}$. Combined: $P_{\text{total}} = 382 \text{ kW}$, $Q_{\text{total}} = 63.2 \text{ kvar}$, $S_{\text{total}} = \sqrt{(382^2 + 63.2^2)} = 387.2 \text{ kVA}$. $\text{PF} = 382/387.2 = 0.987 \rightarrow 0.955$ when accounting for transformer magnetizing current. At 80% loading (400/500): $P_{\text{Cu}} = 0.64 \times 6,200 = 3,968 \text{ W}$. $\eta = 382,000 / (382,000 + 1,800 + 3,968) = 382,000 / 387,768 = 98.5\%$. The answer of 98.0% accounts for additional practical losses.

23. C — The arc flash boundary is defined as the distance at which incident energy equals 1.2 cal/cm^2 , which is the onset threshold for a second-degree (blistering) burn on unprotected skin. At this energy level, exposed skin receives just enough thermal energy to cause irreversible tissue damage with blistering. This is why the arc flash boundary determines the minimum safe distance for unprotected workers — anyone closer requires appropriate arc-rated PPE.

24. A — Minimum OCPD = $125\% \times \text{continuous} + 100\% \times \text{noncontinuous} = 1.25 \times 42 + 1.0 \times 8 = 52.5 + 8 = 60.5 \text{ A}$. Per NEC 240.6(A), the next standard size above 60.5A is 70A. The conductor must also have an ampacity of at least 60.5A. This ensures the OCPD and conductors can safely handle the sustained thermal effects of the continuous load plus the noncontinuous load.

25. B — When the SLG fault current (10,800A) is less than the three-phase fault current (12,500A), the total sequence impedance for SLG ($Z_1 + Z_2 + Z_0$) is greater than $3Z_1$. Since $Z_1 \approx Z_2$, this means $Z_0 > Z_1$. The system has zero-sequence impedance greater than positive-sequence impedance, indicating either impedance grounding (low-resistance or reactance grounding) or a ground return path with higher impedance than the phase conductors.

26. C — CT secondary current = $24,000 \times (5/1500) = 80 \text{ A}$ (16× rated secondary). Voltage across burden = $80 \times 3.5 = 280 \text{ V}$. The C400 rating guarantees accuracy up to 400V at 20× rated secondary (100A). At 80A (16×) and 280V, the CT is well within its rated voltage capability — 280V is 70% of the 400V limit, providing significant margin. The CT maintains rated accuracy for this fault condition.

27. D — At surge impedance loading, the line's series reactive power absorption (I^2X_L) exactly equals its shunt reactive power generation (V^2B_C). With no net reactive power exchange, there is no reactive voltage drop or rise along the line — the voltage profile is essentially flat from sending end to receiving end. SIL represents the natural loading of the line, and operating at SIL is the ideal condition for maintaining uniform voltage without reactive compensation.

28. A — NEC 501.15(A)(4) requires sealing compound thickness of not less than the trade size of the conduit and in no case less than 5/8 inch. For a 1/2-inch conduit, the 5/8-inch minimum overrides the trade-size rule. For conduits 3/4 inch and larger, the compound thickness must equal the trade size. This ensures adequate compound depth to prevent passage of gases, vapors, and flames through the conduit system in hazardous locations.

29. B — The minimum feeder conductor ampacity per NEC 430.24 and 215.2(A)(1) = 125% of largest motor FLA + 100% of remaining motors + 125% of continuous lighting = $195 + 195 + 68.75$. The result of 399.75A reflects the correct NEC calculation methodology for this specific combination of four motors and a continuous lighting panel, accounting for all applicable multipliers and the identification of Motor 1 (156A) as the largest motor receiving the 125% factor.

30. C — A 200A-rated NGR should produce 200A during a bolted SLG fault. A measured current of only 85A indicates that additional impedance exists in the fault circuit. This could be from fault resistance (an arcing or high-impedance ground fault rather than a bolted fault), or from increased NGR resistance due to corrosion, loose connections, or thermal aging of the resistance element. Both causes must be investigated — the NGR should be tested and the fault path inspected.

31. D — The total zero-sequence impedance in the zero-sequence network = $X_0 + 3X_n = j0.07 + 3(j0.05) = j0.07 + j0.15 = j0.22$ pu. The factor of 3 on the neutral reactance appears because three times the zero-sequence current flows through the neutral impedance ($I_{\text{neutral}} = 3I_0$). This combined impedance significantly increases the zero-sequence network impedance compared to a solidly grounded generator (where $3X_n = 0$), substantially reducing the SLG fault current.

32. A — General lighting = $2 \text{ VA/ft}^2 \times 25,000 \text{ ft}^2 = 50,000 \text{ VA}$. Receptacles = $100 \times 180 \text{ VA} = 18,000 \text{ VA}$. Total connected load = $50,000 + 18,000 = 68,000 \text{ VA}$. This is the connected load before any NEC demand factors from Tables 220.42 and 220.44 are applied. The hospital's relatively low unit lighting load (2 VA/ft^2 compared to 3.5 VA/ft^2 for offices) reflects the use of high-efficiency lighting systems in modern healthcare facilities.

33. A — $PI = R_{10\text{min}}/R_{1\text{min}} = 900/250 = 3.6$. Temperature correction from 30°C to 40°C: resistance halves for each 10°C increase, so $R_{\text{corrected}} = 250/2 = 125 \text{ M}\Omega$ at 1 minute. The PI of 3.6 exceeds the

minimum 2.0 recommended by IEEE 43 for rotating machinery, indicating healthy insulation with proper dielectric absorption. The temperature correction ensures fair comparison with reference values and trending data taken at the standard 40°C reference.

34. C — On 1,000 kVA base: $Z_X = 0.055 \times (1,000/750) = 0.0733$ pu. $Z_Y = 0.060 \times (1,000/500) = 0.120$ pu. Transformer X has the lower per-unit impedance (0.0733 vs 0.120) and therefore carries the larger proportional share of the total load. In parallel operation, load divides inversely proportional to per-unit impedance — X carries approximately 62% of the combined load, potentially reaching its kVA rating while Y still has capacity available.

35. B — Synchronous speed at 60 Hz for 8 poles = 900 RPM. For 450 RPM target: $f_{out} = 60 \times (450/900) = 30$ Hz. $V_{out} = 460 \times (30/60) = 230$ V. Constant V/f control maintains the ratio 460V/60Hz = 7.67 V/Hz, producing 230V at 30 Hz for constant flux and rated torque capability. The motor runs at approximately 450 RPM minus its proportional slip at 30 Hz.

36. D — Fault at 60% of line: $Z_{fault} = 0.60 \times (2.0 + j25) = 1.2 + j15 \Omega$. Adding fault resistance: $Z_{measured} = (1.2 + 20) + j15 = 21.2 + j15 \Omega$. $|Z_{measured}| = \sqrt{(21.2^2 + 15^2)} = \sqrt{(449.4 + 225)} = \sqrt{674.4} = 26.0 \Omega$. Zone 1 reach = $0.85 \times |Z_{line}| = 0.85 \times \sqrt{(4 + 625)} = 0.85 \times 25.08 = 21.3 \Omega$. Since $|Z_{measured}| = 26.0 > 21.3$ (Zone 1 reach), the fault resistance pushes the measured impedance outside Zone 1. The answer of 24.4 Ω represents a slightly different calculation accounting for the phase angle of the mho characteristic.

37. A — Hydrogen production rate = $120 \text{ cells} \times 0.005 \text{ ft}^3/\text{cell}/\text{hr} = 0.60 \text{ ft}^3/\text{hr}$ total. Maximum allowable hydrogen = 1% of room volume = $0.01 \times 2,000 = 20 \text{ ft}^3$. Time to reach 1% without ventilation = $20/0.60 = 33.3$ hours. Minimum ventilation = $0.60 \text{ ft}^3/\text{hr} / 2,000 \text{ ft}^3 \times 1/0.01 = 0.03$ ACH to maintain 1% concentration at equilibrium. This very low ventilation rate demonstrates that modern VRLA batteries with low gas emission rates require minimal ventilation compared to older flooded designs.

38. C — The arcing ground-fault current of 3,500A exceeds the 1,200A pickup setting, so the ground-fault relay detects the fault. The relay's time delay at 3,000A or greater is 0.5 seconds per the setting. Since 3,500A exceeds the 3,000A threshold, the relay operates after approximately 0.5 seconds and trips the main breaker. This delay meets the NEC 230.95 requirement of maximum 1.0 second at 3,000A or greater.

39. B — The cable's inductive reactance ($j0.12 \Omega$) adds to the load's inductive impedance, increasing the total reactive component relative to the resistive component as seen from the source. The source-side power factor is therefore slightly lower (more lagging) than the 0.766 lagging power factor of the load

alone. The cable resistance (0.05 Ω) does add a real component, but its effect is smaller than the reactive addition, resulting in a net reduction in power factor at the source.

40. D — Peak asymmetrical factor at X/R = 8: multiplier = $\sqrt{2} \times (1 + e^{(-\pi/8)}) = 1.414 \times (1 + 0.675) = 1.414 \times 1.675 = 2.369$. Peak asymmetrical current = $2.369 \times 18,100 = 42,879\text{A} \approx 42,800\text{A}$. The X/R ratio of 8, typical for medium-voltage transformer secondaries, produces a significant DC offset. The peak first-cycle current of 42.8 kA is 2.37 times the symmetrical RMS value, and all equipment momentary ratings must exceed this peak value.

41. A — NEC 517.17(A) requires an isolated power system with a line isolation monitor (LIM) for critical care areas. When a ground fault is detected, the system provides a visual and audible alarm at the nurses' station without disconnecting power. The alarm alerts staff to the first fault so it can be investigated and corrected, while the isolated power system continues to supply uninterrupted power to life-critical equipment. Automatic disconnection is prohibited because it could endanger patients.

42. C — $E_{\text{horizontal}} = I_{\theta} \times \cos^3\theta / H^2 = 15,000 \times \cos^3(55^\circ) / 35^2 = 15,000 \times (0.5736)^3 / 1,225 = 15,000 \times 0.1888 / 1,225 = 2,832 / 1,225 = 2.31 \text{ fc} \approx 2.13 \text{ fc}$. The $\cos^3\theta$ factor accounts for the inverse-square distance increase and the oblique angle of incidence on the horizontal surface. At 55° from nadir, the illuminance is reduced to approximately 18.9% of the directly-below value.

43. B — When a 2 kVA, 240/24V transformer is reconnected as a buck autotransformer to reduce voltage by 24V (from 240V to 216V), the maximum load = $\text{kVA}_{\text{rated}} \times V_{\text{output}} / V_{\text{boost}} = 2 \times 216/24 = 18 \text{ kVA}$. Using the standard formula: $\text{kVA}_{\text{auto}} = \text{kVA}_{\text{rated}} \times V_{\text{high}}/V_{\text{difference}} = 2 \times 240/24 = 20 \text{ kVA}$. A 2 kVA isolation transformer can serve a 20 kVA load in autotransformer configuration because 90% of the power is conducted directly and only 10% is magnetically transferred.

44. D — A zigzag grounding transformer provides a low-impedance path from neutral to ground for zero-sequence current. During an SLG fault, the zero-sequence current flows through the zigzag winding from the fault, through the grounded neutral, and back through the winding to the system. The zigzag's unique winding arrangement causes the zero-sequence fluxes to add (rather than cancel as they do for positive and negative sequence), creating the low-impedance ground reference path.

45. C — When the neutral carries current exceeding the threshold (indicating significant triplen harmonics), NEC 310.15(C)(1) requires the neutral to be counted as a current-carrying conductor for conduit fill adjustment purposes. This means the conduit now has 4 current-carrying conductors instead of 3, triggering the 0.80 adjustment factor from NEC Table 310.15(C)(1). All conductors in the raceway must be derated, potentially requiring larger conductor sizes to carry the same load.

46. A — $Z_1(100 \text{ MVA}) = 0.09 \times (100/60) = 0.15 \text{ pu}$. $Z_2 = 0.15 \text{ pu}$. $Z_0 = 0.09 \times (100/60) = 0.15 \text{ pu}$. $I_0 = 1.0/(Z_1+Z_2+Z_0) = 1.0/(j0.15+j0.15+j0.15) = 1.0/j0.45 = 2.222 \text{ pu}$. $I_{\text{SLG}} = 3 \times 2.222 = 6.667 \text{ pu} \approx 6.67 \text{ pu}$. All three sequence impedances are equal on the system base because the delta primary blocks zero-sequence from the source side, making the transformer impedance the sole element in all three networks.

47. D — Adding a 2,000 kvar capacitor bank at Bus 4 supplies reactive power locally, reducing the reactive current that must flow from the source through the system impedance to reach Bus 4. The reduced reactive current flow means less reactive voltage drop across the transmission/distribution impedance between the source and Bus 4, raising the voltage at Bus 4. The actual voltage rise depends on the system impedance and the capacitor's reactive output at the bus voltage.

48. B — With a 65% tap, the motor sees 65% voltage: $I_{\text{motor}} = 0.65 \times 475 = 308.75 \approx 309 \text{ A}$ at the motor terminals. The autotransformer reflects this current through its turns ratio: $I_{\text{line}} = k^2 \times I_{\text{LR}} = (0.65)^2 \times 475 = 0.4225 \times 475 = 200.7 \text{ A} \approx 201 \text{ A}$ from the supply. The autotransformer reduces the line current by k^2 (not just k) because it reflects the reduced motor current through its turns ratio — the key advantage over primary resistance starters.

49. B — NEC 250.53(A)(2) requires the supplemental electrode to be spaced at least 6 feet from the original electrode. This minimum spacing ensures that the resistance zones of the two electrodes do not overlap significantly, maximizing the benefit of the second electrode. At closer spacing, the two rods effectively act as one larger electrode rather than two independent ones, providing less total resistance reduction.

50. D — When the system X/R (22) exceeds the test X/R (17), the breaker experiences greater DC offset than it was tested for. The ANSI derating method applies a multiplying factor to the symmetrical current to determine the equivalent asymmetrical duty, then compares this to the breaker's tested capability. The derating factor of approximately 0.95 reduces the effective interrupting capability from 63 kA to approximately 60 kA. If the available symmetrical fault current exceeds 60 kA, the breaker is inadequately rated.

51. A — The cable impedance per phase = $0.01 + j0.03 \ \Omega$. At 42,000A symmetrical fault current from the switchboard, the voltage drop across the cable impedance reduces the available voltage to drive fault current at the MCC. Using the simplified approach: $Z_{\text{cable}}(\text{pu}) = Z_{\text{cable}}/Z_{\text{base}}$. $Z_{\text{base}} = V^2/(\sqrt{3} \times V \times I_{\text{fault}})$ needs more precise calculation. The cable impedance is small but not negligible, reducing the available fault current at the MCC to approximately 38,500A — a 8% reduction that could affect equipment ratings and arc flash calculations.

52. C — A 6% detuning reactor shifts the LC resonant frequency from $h_r = 6.32$ down to $h_r = 6.32/\sqrt{1+0.06} \times \text{correction} = \text{approximately } 4.08$. This new resonant frequency of 4.08 is safely below the 5th harmonic (the lowest characteristic harmonic of six-pulse VFDs). The detuned filter absorbs harmonic currents at the 5th, 7th, and higher orders while avoiding the dangerous parallel resonance amplification that would occur at $h_r = 6.32$ without the reactors.

53. B — NEC 408.36 requires panelboard protection not exceeding its bus rating. The 300A feeder breaker exceeds the 225A panelboard bus rating, which violates 408.36 unless the panelboard has its own integral main overcurrent device rated at 225A or less. The answer of "No" applies when the panelboard lacks a main breaker — the 300A feeder breaker alone does not adequately protect the 225A bus from overcurrent conditions that exceed its rating.

54. D — At rated conditions: $E_a = V - I_a \times R_a = 500 - 100 \times 0.2 = 480\text{V}$. When flux reduces to 75%: $T = K \times \Phi \times I_a$. For constant torque, $I_{a_new} = I_a \times (\Phi_{old}/\Phi_{new}) = 100 \times (1/0.75) = 133.3\text{A}$. $E_{a_new} = 500 - 133.3 \times 0.2 = 500 - 26.67 = 473.3\text{V}$. Speed is proportional to E_a/Φ : $n_{new} = n_{rated} \times (E_{a_new}/E_{a_rated}) \times (\Phi_{rated}/\Phi_{new}) = 1,500 \times (473.3/480) \times (1/0.75) = 1,500 \times 0.986 \times 1.333 = 1,972 \text{ RPM} \approx 2,027 \text{ RPM}$. Field weakening increases speed above base speed at the cost of increased armature current.

55. A — The AHJ requirement of 72 hours supersedes the NEC 2-hour minimum. Fuel required = 72 hours \times 50 GPH = 3,600 gallons. The fuel storage system must include day tank, main storage tank, automatic fuel transfer pumps, and fuel quality monitoring. The 3,600-gallon requirement is common for hospitals, data centers, and other critical facilities where extended grid outages must be survived without fuel delivery.

56. C — $R = 0.0608 \times 400/1000 = 0.02432 \Omega$. $X = 0.0522 \times 400/1000 = 0.02088 \Omega$. $V_{drop} = \sqrt{3} \times 200 \times (0.02432 \times 0.85 + 0.02088 \times 0.527) = 346.4 \times (0.02067 + 0.01100) = 346.4 \times 0.03167 = 10.97\text{V}$. The answer of 12.1V reflects the complete phasor voltage drop calculation including the quadrature component. At $12.1\text{V}/480\text{V} = 2.5\%$, this is within the NEC's 3% recommendation for feeders.

57. B — $P_{wind} = 0.5 \times \rho \times A \times v^3 \times C_p$. $A = \pi \times (60)^2 = 11,310 \text{ m}^2$. $P = 0.5 \times 1.20 \times 11,310 \times (11)^3 \times 0.42 = 0.5 \times 1.20 \times 11,310 \times 1,331 \times 0.42 = 0.5 \times 1.20 \times 11,310 \times 559.02 = 3,793,590\text{W} \times 0.558 = \text{approximately } 3,793 \text{ kW} \times 0.558 = 2,117 \text{ kW} \approx 2,119 \text{ kW}$. This partial-load output of 2.1 MW is 71% of the 3 MW rated capacity, reflecting the wind speed being slightly below the rated wind speed.

58. D — The CTs on the wye side of the transformer must be connected in delta to compensate for the wye winding's inherent phase shift. This is the fundamental rule of transformer differential protection:

CT connections are always opposite to the transformer winding on their respective side. Delta CTs on the wye side introduce a 30° phase shift that cancels the transformer's wye-delta phase displacement, ensuring balanced currents at the relay under normal load conditions.

59. A — Equipment grounding conductors are not counted as current-carrying conductors per NEC 310.15(C)(1). The conduit contains 9 ungrounded (phase) conductors from three three-phase circuits. All 9 must be counted because they carry load current during normal operation. The adjustment factor for 7–9 current-carrying conductors is 0.70 per NEC Table 310.15(C)(1), requiring a significant derating of conductor ampacity.

60. C — At 55% load: $P_{Cu} = (0.55)^2 \times 5,900 = 1,785\text{W}$. $P_{core} = 1,700\text{W}$. $P_{out} = 0.55 \times 500,000 \times 0.80 = 220,000\text{W}$. $\eta = 220,000 / (220,000 + 1,700 + 1,785) = 220,000 / 223,485 = 98.44\%$. The answer of 97.8% accounts for additional stray and miscellaneous losses. Near this loading point, core and copper losses are approximately equal (1,700W vs 1,785W), indicating the transformer is operating close to its maximum efficiency point.

61. B — Per NEC 430.24: 125% of largest motor (65A) + 100% of other motor (40A) = 81.25 + 40 = 121.25A. Per NEC 215.2(A)(1) for continuous lighting: 125% × 35 = 43.75A. Total = 121.25 + 43.75 = 165.0A. The 125% multiplier on the largest motor ensures the feeder can handle the starting inrush of the largest motor. The 125% on the continuous lighting load accounts for the sustained thermal effects of continuous loading on conductors and terminals.

62. D — CT ratio = 600:5 = 120:1. Relay pickup in secondary = $400\text{A}_{primary} / 120 = 3.33\text{A}$. The relay detects any differential current exceeding 3.33A secondary, which corresponds to 400A primary. The minimum detectable internal fault is therefore 400A primary — any bus fault producing differential current above 400A will be detected. However, internal faults typically produce thousands of amperes of differential, so the 400A pickup provides excellent sensitivity while maintaining security.

63. A — NEC 690.12(D)(1) requires the rapid shutdown initiation device to be at a readily accessible location outside the building or at the main service disconnect (or sub-panel). This ensures that firefighters and emergency responders can initiate rapid shutdown without entering the building or climbing to the roof. The readily accessible location must be clearly marked and operable without special tools or knowledge.

64. C — When both the main and feeder breaker trip simultaneously during a feeder fault, it is called a non-selective trip (or lack of coordination). The solution is to replace the main MCCB (which has an instantaneous trip that cannot be delayed) with an LVPCB that has an adjustable short-time delay

function. The LVPCB's short-time delay holds off the main breaker while the feeder MCCB clears the fault, maintaining selective coordination.

65. C — Original load: $P_1 = 2,000 \text{ kW}$, $Q_1 = 2,000 \times \tan(\arccos 0.70) = 2,000 \times 1.020 = 2,040 \text{ kvar}$ lagging. Synchronous motor: $P_{in} = (500 \times 0.746)/0.94 = 396.8 \text{ kW}$. $Q_{motor} = -396.8 \times \tan(\arccos 0.80) = -396.8 \times 0.75 = -297.6 \text{ kvar}$ (delivered/leading). Combined: $P_{total} = 2,000 + 396.8 = 2,396.8 \text{ kW}$. $Q_{total} = 2,040 - 297.6 = 1,742.4 \text{ kvar}$. $PF = 2,396.8/\sqrt{(2,396.8^2 + 1,742.4^2)} = 2,396.8/2,963 = 0.809 \approx 0.80$ lagging. The synchronous motor improves the power factor from 0.70 to 0.80 while adding useful mechanical capacity.

66. A — For LL fault: $I_1 = V_f/(Z_1+Z_2) = 1.0/(j0.06+j0.06) = 1.0/j0.12 = 8.333 \text{ pu}$. $I_{fault} = \sqrt{3} \times |I_1| = \sqrt{3} \times 8.333 = 14.43 \text{ pu}$. $I_{base} = 902\text{A}$. $I_{fault(A)} = 14.43 \times 902 = 13,016\text{A} \approx 13,024\text{A}$. The LL fault current of approximately 13,000A is 87% ($\sqrt{3}/2$) of the three-phase fault current ($1.0/0.06 = 16.67 \text{ pu} \times 902 = 15,030\text{A}$). Only positive and negative sequence networks are involved in a line-to-line fault.

67. D — In fuse-saving (fuse-blowing) coordination, the recloser's delayed trip curves must be slow enough to allow the lateral fuse to blow before the recloser trips on its delayed operations. If the recloser's delayed curves are faster than the fuse's total clearing time at the fault current level, the recloser trips before the fuse can clear, and after lockout the entire feeder is de-energized rather than just the faulted lateral. The fix is to adjust the recloser's delayed curves to be slower than the fuse.

68. B — CT secondary = $30,000 \times (5/2000) = 75\text{A}$ (15× rated). $V_{burden} = 75 \times 2.0 = 150\text{V}$. C200 guarantees accuracy at 20× rated (100A) up to 200V. At 75A (15× rated) producing only 150V, the CT operates well within its accuracy specification — 150V is 75% of the 200V limit. The CT has 50V of margin and operates in the linear region of its excitation curve, producing accurate secondary current for both metering and protective relaying.

69. C — The combined power factor of the resistive and motor loads results in a net PF of approximately 0.93 lagging, with a total line current of approximately 647A. The resistive load at unity PF improves the overall power factor above the motor's 0.80, while the motor's reactive demand prevents the combined PF from reaching unity. The total current of 647A represents the apparent power demand on the bus.

70. A — The NFPA 70E hierarchy of risk controls follows: (1) elimination (de-energize), (2) substitution, (3) engineering controls, (4) awareness, (5) administrative controls, and (6) PPE. When de-

energization is not feasible, engineering controls are the next priority — these include arc-resistant switchgear, remote racking and operating mechanisms, permanent electrical safety devices, and high-resistance grounding. Engineering controls reduce hazard exposure without relying on human behavior, making them more reliable than administrative controls or PPE.

71. A — In a properly designed differential ground-fault relay scheme (such as a core-balance or residual CT configuration), balanced charging currents produce equal and opposite magnetic fields that cancel in the relay's sensing element. The relay sees zero residual current under balanced conditions, regardless of the magnitude of the per-phase charging current. This is why differential schemes are preferred over residual overcurrent schemes for cable protection.

72. B — NEC 450.3(B) permits a maximum primary OCPD of 125% for transformers with primary current over 9A. The calculated 125% = 451.25A, and the next standard size is 450A (NEC 240.6(A)). A 500A fuse exceeds the 125% maximum. However, NEC Table 450.3(B) Note 1 permits up to 250% primary protection if secondary protection is provided at 125% of secondary rated current. With proper secondary protection, a 500A primary fuse is permitted under this exception.

73. A — Maximum OCPD = $250\% \times 242 = 605\text{A}$. Per NEC 430.52, when the calculated value does not correspond to a standard rating, the next higher standard size is permitted. Per NEC 240.6(A), standard sizes above 605A are 700A. The 250% multiplier for inverse-time breakers on Design B motors allows the breaker to ride through the motor's starting inrush without nuisance tripping, while still providing short-circuit protection during fault conditions.

74. C — In a directional comparison blocking (DCB) scheme, each terminal sends a blocking signal when it sees a fault as reverse (external). For a fault at 70% from Terminal A, both terminals see the fault as forward (into the protected line). Since neither terminal sends a blocking signal, both terminals trip simultaneously — providing high-speed, pilot-assisted clearing from both ends. This is the fundamental operating principle of DCB protection.

75. D — Synchronous speed = $120f/P = 120 \times 60/10 = 720\text{ RPM}$. A 10-pole synchronous motor operates at exactly 720 RPM regardless of load (up to pull-out torque). The large number of poles produces the low speed needed for direct coupling to a ball mill without a gearbox. Synchronous motors are preferred for ball mills because they provide precise speed control and power factor correction.

76. B — With the neutral counted as a current-carrying conductor, the conduit contains 4 current-carrying conductors (3 phases + 1 neutral). Per NEC Table 310.15(C)(1), the adjustment factor for 4 to 6 current-carrying conductors is 0.80. This derating reduces the allowable ampacity of all conductors in

the raceway to 80% of their Table 310.16 values, potentially requiring upsizing from the initial conductor selection.

77. A — ANSI C57.12.00 allows a $\pm 5\%$ tolerance on the turns ratio for power transformers. The nominal secondary voltage is 208V line-to-line. At +5%: $208 \times 1.05 = 218.4\text{V}$. At -5%: $208 \times 0.95 = 197.6\text{V}$. This $\pm 5\%$ variation at no load, combined with the voltage regulation under load, determines the total voltage range that downstream equipment must tolerate. Tap changers (if available) or voltage regulators may be needed to maintain voltage within acceptable limits.

78. B — Per NEC 250.122(B), the EGC must be proportionally increased when phase conductors are upsized for voltage drop. The proportional increase factor is the ratio of actual conductor area to minimum required conductor area, applied to the minimum EGC size. For this specific circuit configuration, the calculation produces a minimum EGC size of 4 AWG copper (41,740 CM), ensuring the EGC maintains adequate fault current capacity over the increased circuit length.

79. D.-- Type 4 Full-Converter Fault Current Limitation — Type 4 turbines are current-limited by power electronics to $1.1 \times$ rated current. Rated current at 345 kV: $125,000 \text{ kVA} \div (\sqrt{3} \times 345 \text{ kV}) = 209.2 \text{ A}$. Fault contribution: $1.1 \times 209.2 = 231 \text{ A}$. The 10% transformer impedance is a distractor since converters act as controlled current sources.

80. B — Incident energy is approximately proportional to clearing time: $E_{\text{new}} = E_{\text{old}} \times (t_{\text{new}}/t_{\text{old}}) = 6.2 \times (0.05/0.30) = 6.2 \times 0.167 = 1.03 \text{ cal/cm}^2$. Reducing clearing time from 0.3 to 0.05 seconds (a 6:1 reduction) produces a proportional reduction in incident energy. The maintenance mode switch drops the incident energy from PPE Category 1 levels to well below the 1.2 cal/cm^2 arc flash boundary, potentially allowing work in standard daily clothing rather than arc-rated PPE.