PRACTICE EXAM 12: PE POWER SIMULATION (80 QUESTIONS)

1. A 13.8 kV industrial bus serves a 4,500 kW load at 0.76 lagging PF through a feeder with Z = 0.40 + j2.50 Ω per phase. The engineer evaluates two scenarios: Scenario 1 adds a 3,000 kvar capacitor bank at the load bus; Scenario 2 adds a 2,000 HP synchronous motor at 0.80 leading PF (η = 95%) that also corrects power factor while serving a new mechanical load. In Scenario 2, what is the synchronous motor's net reactive power contribution to the system, and how does it compare to the capacitor bank's contribution in Scenario 1?

A. The motor delivers 1,180 kvar — approximately 39% of the capacitor bank's correction

B. The motor delivers 1,180 kvar — less than the capacitor bank, but the motor also adds 2,000 HP of useful shaft output

C. The motor delivers 3,000 kvar — identical to the capacitor bank

D. The motor absorbs reactive power at leading PF, providing zero net kvar correction

2. A three-phase, 480V, solidly grounded wye system has a 1,500 kVA service transformer (Z = 5.75%) fed from a utility with 500 MVA of short-circuit capacity at 13.8 kV. A 300-foot cable run from the secondary switchboard to a remote MCC uses 350 kcmil copper in steel conduit (R = 0.0367 Ω/1000 ft, X = 0.0407 Ω/1000 ft per phase). What is the available fault current at the remote MCC, accounting for both the transformer and cable impedance?

A. 18,100 A (transformer only — cable impedance is negligible)

B. 12,400 A

C. 25,200 A

D. 15,800 A

3. Per NEC 430.52(C)(1), a 300 HP, 460V, three-phase Design B motor has a Table 430.250 FLA of 361A. The maximum inverse-time breaker is 250% of FLA = 902.5A. The next standard size is 1,000A. However, the motor trips the 1,000A breaker during starting. Per NEC 430.52(C)(1) Exception 1, the breaker may be increased to a maximum of what size?

A. 1,200A (400% of 361A = 1,444A → next standard size not exceeding 1,444A)

B. 1,600A (next standard above 1,444A)

C. 1,000A (no increase permitted beyond the table maximum)

D. 2,000A (no upper limit when the motor cannot start)

4. A CT with a ratio of 2000:5 and accuracy class C800 serves a transformer differential relay. The total external burden is 3.0 Ω and the CT winding resistance is 1.5 Ω. During an internal transformer fault of 32,000A, the CT secondary current is 80A. What is the total burden voltage, and does the CT maintain its accuracy?

A. V = 240V (external only); CT maintains accuracy

B. V = 360V (total); CT saturates because 360V exceeds C200 rating

C. V = 360V (total); CT maintains accuracy because 360V < 800V at the 16× rated operating point

D. V = 120V; CT operates at reduced burden due to saturation

5. Per NFPA 70E 130.5(G), when arc flash PPE categories are determined using the table method, the table parameters include maximum available fault current and maximum clearing time. For a 600V class switchgear with maximum fault current of 35 kA and a clearing time of 0.5 seconds, the parameters exceed the table limits (which specify 25 kA max and 0.03 seconds max for certain equipment). What analysis must be performed?

A. A detailed incident energy calculation per IEEE 1584 must be performed because the system parameters exceed the table method limitations

B. PPE Category 4 is automatically assigned when parameters exceed table limits

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

D. The table method can still be used by interpolating between the listed values

6. A 230 kV, 180-mile transmission line has a series impedance of Z = 0.09 + j0.78 Ω/mile and a total shunt capacitive susceptance of Y = j1.30 × 10^{-3} S per phase (total). The line is loaded at 350 MW, 0.95 lagging PF. The SIL is calculated as V^2/Z_c where $Z\_c = \sqrt{(Z\_total/Y\_total)}$. What is the approximate SIL, and is the line loaded above or below it?

A. SIL = 200 MW; loaded above — line absorbs reactive power

B. SIL = 450 MW; loaded below — line generates reactive power

C. SIL = 350 MW; loaded exactly at SIL — flat voltage profile

D. SIL = 200 MW; loaded above — line absorbs reactive power, requiring shunt capacitor compensation at the receiving end

7. A three-phase, 480Y/277V panelboard serves a data center with 100% nonlinear server loads. Each phase draws 280A of fundamental current and 112A of third-harmonic current. The true-RMS phase current is $\sqrt{(280^2 + 112^2)}$ = 302A. The conduit contains 3 phase conductors and 1 neutral conductor. Per NEC 310.15(C)(1), the neutral is counted as a current-carrying conductor because of the nonlinear loads. What is the conduit fill adjustment factor and the neutral current?

A. 4 conductors; factor = 1.00; neutral = 0A

B. 3 conductors; factor = 1.00; neutral = 336A

C. 4 conductors; factor = 0.80; neutral = 336A

D. 4 conductors; factor = 0.80; neutral = 112A

8. A 75 MVA, 138/13.8 kV, delta-wye grounded transformer has $Z_1 = Z_2 = j0.085$ pu and $Z_0 = j0.085$ pu on its own base. The 138 kV source has Z_1_src = j0.025 pu on the transformer's base. A bolted SLG fault occurs on the 13.8 kV bus. On a 100 MVA system base, what is the SLG fault current in amperes?

A. 4,184 A

B. 15,260 A

C. 28,430 A

D. 8,368 A

9. A separately excited DC motor has V_t = 480V, I_a = 120A, R_a = 0.20 Ω, and rated speed of 1,750 RPM. The motor is braked by plugging (reversing the armature voltage while the motor is still running at rated speed in the forward direction). At the instant of plugging, what is the initial braking current, and why is a resistance typically inserted in series?

A. I_brake = 120A; resistance is inserted to reduce the braking time

B. I_brake = 480A; resistance is inserted to limit the excessive current that would damage the motor

C. I_brake = 2,400A; resistance is inserted because no current limiting is needed for plugging

D. I_brake = 4,560A; resistance is inserted to limit this extremely high current (V_t + E_a)/R_a to safe levels

10. Per NEC 250.66, the grounding electrode conductor for a service with three parallel sets of 500 kcmil copper per phase (equivalent to 1,500 kcmil total per phase) must be sized based on the total equivalent conductor area. Per Table 250.66, for conductors over 1,100 kcmil through 1,750 kcmil, the minimum GEC is 250 kcmil copper. What is the minimum GEC size?

A. 250 kcmil copper (matching the table for the 1,500 kcmil equivalent)

B. 3/0 AWG copper (the maximum GEC size in any installation)

C. 4/0 AWG copper

D. 2/0 AWG copper

11. A three-phase, 4,160V distribution system has a neutral grounding resistor rated 400A, 10 seconds. A ground fault develops with an initial current of 380A. After 6 seconds, the fault current increases to 420A due to insulation breakdown. The protection relay is set for 200A pickup with a 2-second time delay. At what time does the relay trip, and is the NGR within its thermal rating at that point?

A. The relay trips at t = 2 seconds; the NGR has used approximately 15% of its thermal capacity

B. The relay trips at t = 0 seconds (instantaneous) because the fault exceeds pickup

C. The relay trips at t = 2 seconds; the NGR has used approximately 24% of its thermal capacity

D. The relay trips at t = 8 seconds; the NGR exceeds its thermal capacity

12. A balanced three-phase, 480V system feeds a wye-connected motor load of 200 HP (η = 94%, PF = 0.87 lagging) and a delta-connected resistance heater of 75 kW. What is the combined power factor at the source bus?

A. 0.87 lagging (same as the motor because the heater doesn't affect PF)

B. 0.93 lagging

C. 0.98 lagging

D. Unity (1.00)

13. A protection coordination study for a 13.8 kV industrial system reveals that a 200A expulsion fuse on a lateral and an upstream feeder relay (51) with an IEEE very inverse characteristic both operate for a fault current of 2,000A. The fuse total clearing time at 2,000A is 0.10 seconds. The relay operating time is 0.45 seconds. The CTI is 0.35 seconds. A new 500 HP motor is added to the lateral, increasing the maximum through-fault current to 6,000A. At 6,000A, the fuse clears in 0.01 seconds and the relay operates in 0.15 seconds. What is the new CTI at 6,000A, and is coordination maintained?

A. CTI = 0.35 seconds; unchanged because both curves shift proportionally

B. CTI = 0.10 seconds; coordination is lost

C. CTI = 0.16 seconds; coordination is marginal (minimum 0.20 seconds recommended)

D. CTI = 0.14 seconds; coordination is lost because the CTI falls below the 0.20-second minimum for relay-fuse coordination

14. Per NEC 408.36, a panelboard must be individually protected by an OCPD not greater than the bus rating. A 225A panelboard has a calculated continuous load of 150A and noncontinuous load of 50A. Per NEC 215.2(A)(1), the minimum OCPD = 125% × 150 + 100% × 50 = 237.5A → next standard size = 250A. This exceeds the 225A bus. Which resolution is code-compliant?

A. Install a 250A OCPD and upgrade the panelboard to a 250A or larger bus rating

B. Install a 225A standard OCPD and reduce the continuous load

C. Install a 225A OCPD — NEC 408.36 governs over NEC 215.2

D. Install a 250A OCPD — NEC 215.2 governs over NEC 408.36

15. A three-phase, 460V, 6-pole, 250 HP induction motor operates at full load with a slip of 2.2% and an efficiency of 95%. The motor's air gap power (total three-phase) is 198 kW. What are the rotor copper losses and the developed mechanical power?

A. P_RCL = 19.8 kW; P_mech = 178.2 kW

B. P_RCL = 2.2 kW; P_mech = 195.8 kW

C. P_RCL = 4.36 kW; P_mech = 193.6 kW

D. P_RCL = 9.9 kW; P_mech = 188.1 kW

16. A 500 kVA, 480V/208Y/120V transformer has open-circuit losses of 1,500 W and full-load copper losses of 5,800 W. The transformer serves a varying load: 10 hours at 80% load (PF = 0.90), 6 hours at 50% load (PF = 0.85), and 8 hours at 15% load (PF = 0.70). What is the all-day efficiency?

A. 96.2%

B. 97.1%

C. 98.5%

D. 95.0%

17. A ground resistance test on a chemical plant's grounding electrode system yields 8.5 Ω during a dry August measurement. The specification requires ≤ 5.0 Ω year-round. Historical seasonal variation data shows resistance decreases by approximately 45% during wet winter months. The engineer concludes the system will meet the spec during winter. Is this reasoning correct, and what is the recommended action?

A. The reasoning is backwards — the 8.5 Ω dry-season reading is the worst case, and it fails the 5.0 Ω specification; additional ground electrodes or ground enhancement must be installed

B. The reasoning is correct — winter readings of approximately 4.7 Ω would meet the spec

C. The test is invalid because chemical plant soil is contaminated and produces unreliable readings

D. The reasoning is correct, but the engineer should also test during winter for confirmation

18. A 345 kV, 300-mile transmission line has a characteristic impedance of 365 Ω. The line is loaded at 180 MW, 0.98 lagging PF. The sending-end voltage is 348 kV and the receiving-end voltage is 342 kV. What is the SIL, and what is the voltage regulation?

A. SIL = 326 MW; VR = 5.2%

B. SIL = 200 MW; VR = 1.8%

C. SIL = 326 MW; VR = 1.8%

D. SIL = 365 MW; VR = 3.5%

19. A three-phase, 480V motor control center serves three motors and a continuous lighting panel: Motor 1: 150 HP (FLA = 180A); Motor 2: 100 HP (FLA = 124A); Motor 3: 50 HP (FLA = 65A); Lighting: 90A continuous. Per NEC 430.24 and 215.2(A)(1), what is the minimum feeder conductor ampacity?

A. 459 A

B. 506.5 A

C. 414 A

D. 550 A

20. A 13.8 kV, three-phase system has a three-phase fault level of 350 MVA and a 4,000 kvar capacitor bank. The system contains numerous six-pulse VFDs. The parallel resonant harmonic order is $h_r = \sqrt{(350{,}000/4{,}000)} = \sqrt{87.5} = 9.35$. An engineer proposes adding 4.7% detuning reactors to the capacitor bank. What is the new tuned frequency of the filter circuit?

A. h = 4.7 (tuned to the 4.7th harmonic)

B. h = 9.35 (unchanged by the detuning reactors)

C. h = 3.2 (shifted well below all characteristic harmonics)

D. h ≈ 4.6 (the detuned filter is tuned to approximately $1/\sqrt{0.047} \approx 4.61$, safely below the 5th harmonic)

21. A three-phase, 480V, 800A LVPCB main breaker protects a switchboard. The breaker has a short-time pickup of 4,800A with a 0.25-second delay. A downstream 200A MCCB has an instantaneous trip at 2,500A. ZSI is installed between the two breakers. A fault of 15,000A occurs on the bus (not on any feeder). No feeder breaker sends a ZSI restraint signal. What happens?

A. The LVPCB holds on its 0.25-second delay because no ZSI signal was received

B. Both breakers trip simultaneously

C. The LVPCB trips with no intentional delay because the absence of a ZSI restraint signal indicates the fault is on the bus

D. The 200A MCCB trips first because its instantaneous setting of 2,500A is exceeded

22. Per NEC 250.30(A)(1), each separately derived system requires a system bonding jumper. A facility has a 2,000 kVA transformer (secondary current = 2,406A) and a 500 kVA transformer (secondary current = 601A) feeding a common 480V bus through separate feeder breakers. How many system bonding jumpers are required, and how is each sized?

A. Two bonding jumpers — each sized per Table 250.102(C)(1) based on its respective transformer's secondary conductor size

B. One bonding jumper at the common bus, sized for the larger transformer

C. Two bonding jumpers plus one additional at the bus (three total)

D. One bonding jumper at the larger transformer only — the smaller one bonds through the bus

23. A synchronous generator rated 100 MVA, 18 kV has $X''_d = 0.16$ pu, $X_2 = 0.18$ pu, $X_0 = 0.09$ pu. The generator is grounded through a reactance $X_n = 0.04$ pu. For a bolted SLG fault at the terminals, the zero-sequence network includes $3X_n$. What is the subtransient SLG fault current in per-unit?

A. $I_{SLG} = 3.33$ pu

B. $I_{SLG} = 5.56$ pu

C. $I_{SLG} = 8.33$ pu

D. $I_{SLG} = 4.95$ pu

24. A three-phase, 480V system has a bolted three-phase fault current of 42,000A at the switchboard. A 500-foot cable run to a remote panelboard has impedance of $0.012 + j0.032\ \Omega$ per phase. The transformer base impedance is $Z_{base} = 480^2/2{,}000{,}000 = 0.1152\ \Omega$. What is the approximate fault current at the remote panelboard?

A. 42,000 A (unchanged — cable impedance is negligible at 500 feet)

B. 21,500 A

C. 35,000 A

D. 28,200 A

25. Per NEC 690.12(B)(2), PV conductors within the array boundary must be reduced to 80V within 30 seconds. A system uses 22 modules per string with $V_{oc} = 42$V per module. Each module has a module-

level DC optimizer with rapid shutdown capability. At −10°C, V_oc increases to 46.3V per module. With optimizers active, each module is independently controlled. When rapid shutdown is initiated, the optimizers de-energize each module to near-zero voltage. Is this system compliant?

A. No, because the string voltage of 22 × 46.3 = 1,019V exceeds 600V NEC limits

B. Yes, but only if the DC optimizers are certified to IEC 62109 for functional safety

C. Yes, the module-level optimizers independently shut down each module to near-zero voltage, reducing the string voltage well below 80V within 30 seconds

D. No, because the optimizers cannot respond fast enough at low temperatures

26. A distance relay on a 69 kV line has Zone 1 at 80% reach (Z_line = 3 + j22 Ω). A fault occurs at 75% of the line through a fault resistance of 12 Ω. The measured impedance includes the line impedance to the fault plus the fault resistance. What impedance does the relay measure, and is the fault within Zone 1?

A. Z_meas = 14.25 + j16.5 Ω (|Z| = 21.8 Ω); within Zone 1 reach of 17.78 Ω — but the mho characteristic must be checked because the high R component may place the impedance outside the mho circle

B. Z_meas = 2.25 + j16.5 Ω; clearly within Zone 1

C. Z_meas = 14.25 + j16.5 Ω; outside Zone 1 because |Z| = 21.8 Ω > 17.78 Ω reach

D. Z_meas = 3 + j22 Ω; the fault resistance does not affect the measured impedance

27. A balanced three-phase, 4,160V source feeds a delta-connected load of Z = 15∠36.87° Ω per phase through cables with negligible impedance. What is the total three-phase real power consumed by the load?

A. 1,384 kW

B. 276.8 kW

C. 692 kW

D. 1,107 kW

28. A 480V, three-phase, 400A feeder breaker (MCCB) has an interrupting rating of 25 kA. The available fault current at the breaker terminals has been calculated as 28,000A. The engineer proposes installing a 400A Class J current-limiting fuse upstream. The fuse limits let-through to 18,000A RMS at 28,000A available. Per NEC 240.86, is this a compliant series-rated combination?

A. Yes, because the let-through is below the breaker's interrupting rating

B. Only if the specific fuse-breaker combination is tested, listed, and documented

C. No, because the panelboard's SCCR must also exceed 28,000A independently

D. Yes, because any Class J fuse provides series-rated protection for downstream devices

29. Per NEC 450.3(B), a 2,000 kVA, 480V/208Y/120V dry-type transformer has a rated primary current of 2,406A. At 125% of rated primary current, the maximum OCPD is 3,007.5A. The next standard size per NEC 240.6(A) is 3,000A. Is a 3,000A primary OCPD permitted?

A. No — 3,000A is below the calculated 3,007.5A; the next standard size above 3,007.5A (3,500A or the next available size) must be used if 125% doesn't correspond to a standard

B. Yes — 3,000A is the standard size closest to but not exceeding 125% of rated current

C. No — transformers above 1,000 kVA require primary protection at exactly 100% of rated current

D. Yes — but only with secondary overcurrent protection per NEC 450.3(B)

30. A three-phase, 4,160V, 8-pole synchronous motor rated 1,500 HP drives a mine ventilation fan at constant speed. The motor operates at 0.85 leading PF with a field current of 180A. A system voltage sag to 90% of nominal occurs for 2 seconds during a remote fault. What happens to the synchronous motor during the voltage sag?

A. The motor speed drops below synchronous speed and the motor pulls out of synchronism

B. The motor accelerates above synchronous speed because the fan load decreases with reduced airflow

C. The motor maintains synchronous speed but the power angle increases and armature current rises; if the power angle exceeds the pull-out angle, the motor may lose synchronism

D. The motor is unaffected because synchronous motors are immune to voltage sags

31. A 100 MVA, 230/69 kV autotransformer has a series impedance of 9% on its own base. Two identical units operate in parallel. On a 100 MVA system base, what is the combined parallel impedance, and what is the three-phase fault current on the 69 kV bus (assuming infinite 230 kV source)?

A. Z = 0.045 pu; I_fault = 18,550A

B. Z = 0.09 pu; I_fault = 9,275A

C. Z = 0.18 pu; I_fault = 4,638A

D. Z = 0.045 pu; I_fault = 18,550A

32. Per NEC 110.26(C)(1), equipment rated 1,200A or more and over 6 feet wide requires at least one entrance to the required working space at each end. Each entrance must be at least 24 inches wide and 6.5 feet high. A 2,000A switchgear lineup is 12 feet wide and 7.5 feet tall. The engineer provides one 30-inch entrance on the left and one 24-inch entrance on the right. Is this compliant?

A. Yes — both entrances meet or exceed the 24-inch minimum width and 6.5-foot minimum height requirements

B. No — both entrances must be at least 30 inches wide

C. No — the right entrance is too narrow at 24 inches for 2,000A equipment

D. Yes — but only if the entrances are on opposite ends of the working space

33. A 1,000 kVA, 13.8 kV/480V, delta-wye grounded transformer has Z = 5.75% (R = 1.0%, X = 5.66%). The transformer supplies a 480V bus with a 750A motor load at 0.82 lagging PF and a 300A lighting load at 1.0 PF. The combined load current is 1,050A. What is the approximate percent voltage regulation at this loading?

A. 1.5%

B. 5.75% (equal to the nameplate impedance)

C. 7.2%

D. 3.8%

34. A three-phase, 480V, 60 Hz system has three parallel-connected transformers on a common bus. Transformer A: 1,500 kVA, Z = 5.75%. Transformer B: 1,000 kVA, Z = 5.50%. Transformer C: 750 kVA, Z = 6.00%. On a 1,500 kVA common base, what are the per-unit impedances, and which transformer carries the largest proportional load share?

A. Z_A = 0.0575, Z_B = 0.0825, Z_C = 0.12; Transformer A carries the most load

B. Z_A = 0.0575, Z_B = 0.0825, Z_C = 0.12; Transformer A has the lowest Z_pu and carries the largest share

C. Z_A = 0.0575, Z_B = 0.055, Z_C = 0.06; all carry approximately equal shares

D. Z_A = 0.0575, Z_B = 0.0367, Z_C = 0.045; Transformer B carries the most load

35. A VFD drives a 460V, 4-pole, 60 Hz, 200 HP induction motor operating a centrifugal compressor. The compressor requires a minimum speed of 1,200 RPM and a maximum of 1,800 RPM. At 1,200 RPM (66.7% speed), the compressor power is approximately 29.6% of rated (cube of speed ratio). If the motor's rated full-load power is 160 kW and the VFD efficiency is 97%, what is the VFD input power at 1,200 RPM?

A. 160 kW (VFD input equals motor rated power at any speed)

B. 47.4 kW (motor power at reduced speed)

C. 48.8 kW (motor power at reduced speed divided by VFD efficiency)

D. 74.5 kW (motor power at 75% speed)

36. Per NEC Article 517.17(A), the isolated power system in a hospital wet location must include a line isolation monitor (LIM) that alarms at 5 mA total hazard current. An operating room has 15 outlets. The normal background leakage from 8 connected devices totals 2.8 mA. A surgeon requests connecting a 9th device with a measured leakage of 1.8 mA. Should the device be connected?

A. No — the total hazard current would reach 4.6 mA, and connecting the device creates significant risk of exceeding the 5 mA alarm threshold with any additional minor leakage change

B. Yes — 4.6 mA is below the 5 mA threshold

C. No — NEC Article 517 limits total hazard current to 3.0 mA during surgical procedures

D. Yes — but only if the LIM is temporarily disabled during the surgical procedure

37. A 230 kV transmission line is protected by distance relays at both terminals. Zone 1 at Terminal A is set at 85% of the line impedance ($Z_{line} = 4 + j50\ \Omega$). Zone 2 is at 120% with a 0.35-second delay. A POTT pilot scheme is installed. A fault occurs at 88% of the line from Terminal A. The communication channel fails. What protection operates at Terminal A, and what is the clearing time?

A. Zone 1 trips instantaneously because 88% is within the reach at the line's actual impedance angle

B. Zone 2 trips after 0.35 seconds because the fault at 88% is beyond Zone 1's 85% reach

C. No protection operates at Terminal A because the pilot scheme failure prevents all tripping

D. Zone 2 trips after 0.35 seconds; total clearing time = 0.35 + 0.083 (breaker) = 0.433 seconds

38. A three-phase, 480V, 225A panelboard has an available fault current of 22,000A. An arc flash study using IEEE 1584 calculates an incident energy of 8.2 cal/cm² with the existing 225A MCCB main breaker (clearing time = 0.2 seconds). The engineer replaces the main with an energy-reducing maintenance switch that reduces clearing time to 0.05 seconds during maintenance. What is the new incident energy?

A. 4.1 cal/cm² (reduced by 50%)

B. 2.05 cal/cm² (proportional to clearing time ratio: $0.05/0.2 \times 8.2$)

C. 8.2 cal/cm² (unchanged because the breaker rating is the same)

D. 0.82 cal/cm² (reduced by a factor of 10)

39. A 480V, three-phase, four-wire panelboard serves a balanced combination of linear fluorescent lighting (200A per phase at unity PF) and nonlinear LED drivers (80A per phase of third-harmonic current). The neutral current is $3 \times 80 = 240$A. Per NEC 310.15(C)(1), the neutral is counted as a current-carrying conductor. If the conduit contains 3 phase and 1 neutral conductor, how many current-carrying conductors are counted for the adjustment factor?

A. 3 conductors; adjustment factor = 1.00 (neutral is never counted)

B. 4 conductors; adjustment factor = 0.80 (10% or more of the load is nonlinear)

C. 4 conductors; adjustment factor = 0.80

D. 5 conductors; adjustment factor = 0.80 (counting an additional EGC)

40. Per NEC 230.95, GFPE is required for solidly grounded wye services rated 1,000A or more at more than 150V to ground but not exceeding 600V phase-to-phase. The maximum GFPE pickup is 1,200A and the maximum time delay at 3,000A or greater is 1.0 second. A 480Y/277V, 1,600A service has GFPE set at 1,000A with a 0.8-second delay. A 1,500A ground fault occurs on a feeder. The feeder breaker has no ground-fault protection. What is the expected response?

A. The GFPE at the service trips after 0.8 seconds because 1,500A exceeds the 1,000A pickup

B. The feeder breaker trips on its phase overcurrent element before the GFPE operates

C. Neither device operates because 1,500A is below the feeder breaker's phase OC pickup

D. The GFPE sends an alarm but does not trip for currents below 3,000A

41. A 60 MVA, 138/13.8 kV, delta-wye grounded transformer has $Z_1 = Z_2 = j0.095$ pu on its own base. On a 100 MVA system base, the transformer impedance is 0.1583 pu per sequence. Two such transformers operate in parallel. What is the combined positive-sequence impedance and the three-phase fault current on the 13.8 kV bus (infinite source)?

A. $Z_1 = 0.1583$ pu; I_fault = 26,430A

B. $Z_1 = 0.3167$ pu; I_fault = 13,215A

C. $Z_1 = 0.0792$ pu; I_fault = 26,430A

D. $Z_1 = 0.0792$ pu; I_fault = 52,850A

42. A 300 HP, 4,160V, three-phase synchronous motor operates at 0.85 leading PF at rated load. The motor's efficiency is 96%. If the DC field current is increased by 15% while the mechanical load remains constant, what changes in the motor's operating parameters?

A. The power factor moves toward unity and the armature current decreases

B. The power factor becomes more leading (numerically lower), the armature current increases, and the power angle decreases

C. The power factor becomes lagging because excess field excitation reverses the reactive power direction

D. The motor speed increases above synchronous speed

43. Per NEC 430.32(A)(1), overload protection for a motor with a nameplate FLA of 144A and a service factor of 1.15 may be set at a maximum of 125% of FLA. The engineer uses an electronic overload relay set at 180A. A second engineer argues this is too high because the NEC table FLA for this motor is 156A and 125% × 156 = 195A is the correct maximum. Which engineer is correct?

A. The first engineer — overload protection is always based on the motor nameplate FLA (144A), not the NEC table FLA; 180A (125% × 144) is compliant

B. The second engineer — overload protection uses the NEC table FLA for all calculations

C. Neither — overload protection is based on the service factor times FLA, giving a different maximum

D. Both are incorrect — the overload must be set at exactly 100% of nameplate FLA

44. A three-phase, 13.8 kV underground cable system is 12 miles long with a charging current of 3.0A per mile per phase. A zero-sequence CT (window type) is installed at the sending end. The cable is energized at rated voltage with no load. What current does the zero-sequence CT measure?

A. 36A per phase (total charging current per phase)

B. 108A (three times the per-phase charging)

C. 0A — the zero-sequence CT measures only residual (unbalanced) current, and balanced charging produces zero residual

D. 12A (one mile's worth of charging current)

45. A 480V, three-phase, 600A switchboard has an available fault current of 52,000A. The switchboard SCCR is 65,000A. Five motors on the bus have a combined FLA of 800A, contributing approximately 4 × 800 = 3,200A of first-cycle fault current. The total first-cycle fault current is 55,200A. An engineer must verify that all downstream MCCBs are adequately rated. A 100A MCCB feeder breaker is rated 22,000A AIC. The feeder cable to this MCCB is 200 feet of 1 AWG in EMT ($Z = 0.012 + j0.035\ \Omega$ per phase). Does the cable impedance reduce the fault current below the MCCB's rating?

A. No — a detailed calculation is needed, but 200 feet of 1 AWG is unlikely to reduce 55,200A below 22,000A

B. Yes — the cable impedance reduces the fault current to approximately 18,500A at the MCCB

C. No — cable impedance never reduces fault current sufficiently for code compliance

D. Yes — but only if the cable run exceeds 500 feet

46. A three-phase, 460V, 2-pole induction motor rated 500 HP has a full-load speed of 3,550 RPM and an air gap power of 395 kW (total three-phase). What is the slip, rotor copper loss, developed mechanical power, and the approximate shaft output assuming 3 kW of friction and windage losses?

A. $s = 1.39\%$; $P_{RCL} = 5.49$ kW; $P_{mech} = 389.5$ kW; $P_{shaft} \approx 386.5$ kW

B. $s = 2.78\%$; $P_{RCL} = 10.98$ kW; $P_{mech} = 384.0$ kW; $P_{shaft} \approx 381.0$ kW

C. $s = 0.69\%$; $P_{RCL} = 2.73$ kW; $P_{mech} = 392.3$ kW; $P_{shaft} \approx 389.3$ kW

D. $s = 1.39\%$; $P_{RCL} = 5.49$ kW; $P_{mech} = 389.5$ kW; $P_{shaft} \approx 386.5$ kW

47. Per NEC Article 700.12(B)(6), a generator serving emergency loads must have a minimum 2-hour on-site fuel supply. A hospital emergency generator rated 750 kW consumes 55 GPH at full load. The hospital's emergency load is 520 kW. The local AHJ requires 96 hours of fuel. Assuming linear fuel consumption, what is the minimum fuel storage requirement?

A. 3,660 gallons (based on AHJ's 96-hour requirement at the actual 520 kW emergency load consumption rate of 38.1 GPH)

B. 5,280 gallons (96 hours × 55 GPH at generator rated capacity)

C. 110 gallons (NEC minimum of 2 hours × 55 GPH)

D. 7,920 gallons (96 hours × 55 GPH × 1.5 safety factor)

48. A three-phase, 4,160V system has a 5,000 kvar capacitor bank and a system short-circuit capacity of 250 MVA. The parallel resonant harmonic order is $h_r = \sqrt{(250{,}000/5{,}000)} = 7.07$. The system has six-pulse VFDs as the primary harmonic source. At $h_r = 7.07$, the 7th harmonic is the second-lowest characteristic harmonic of the VFDs. What is the engineering concern, and what is the recommended mitigation?

A. No concern — the 7th harmonic has lower magnitude than the 5th and poses minimal resonance risk

B. Moderate concern — the 7th harmonic current will be amplified by the resonance, but not as severely as if resonance were at the 5th

C. Critical concern — resonance at $h_r = 7.07$ directly amplifies the 7th harmonic from six-pulse VFDs; install detuning reactors (6% or 7%) to shift resonance below the 5th harmonic

D. No concern — the 7th harmonic is eliminated in 12-pulse VFD configurations

49. A 480V, three-phase panelboard has a bus rating of 400A. The connected load consists of: 250A continuous motor load, 80A continuous lighting load, and 50A noncontinuous receptacle load. Per NEC 215.2(A)(1), the minimum OCPD = 125% × (250 + 80) + 50 = 462.5A. The panelboard bus is only 400A. What is the code-compliant resolution?

A. Install a 400A standard OCPD and limit the continuous load to 320A maximum (80% of 400A = 320A; 250 + 80 = 330A exceeds this)

B. Install a 500A OCPD — the NEC 215 calculation governs

C. The panelboard must be upgraded to a 500A or larger bus rating to accommodate the calculated feeder minimum of 462.5A

D. Install a 100%-rated 400A main breaker, which eliminates the 125% continuous adder: 250 + 80 + 50 = 380A < 400A

50. Per NEC 250.53(A)(2), when a single ground rod electrode does not achieve 25 Ω, a supplemental electrode must be installed at least 6 feet from the first. After installing both rods, the combined resistance is 32 Ω. A third rod is installed 6 feet from the second. The combined resistance of all three rods is 22 Ω. Is additional work required?

A. No — NEC 250.53(A)(2) requires only ONE supplemental electrode; once a supplemental is installed, no combined resistance requirement applies, so the third rod was voluntary but not code-required

B. Yes — the combined resistance must meet 25 Ω (22 Ω already meets this)

C. Yes — electrodes must be added until the resistance reaches 5 Ω or less

D. No — but only because the three-rod combination achieves 22 Ω < 25 Ω

51. A 138 kV circuit breaker rated 40 kA symmetrical was tested at a standard X/R of 17. The actual system X/R at the breaker location is 28. Using the IEEE C37 methodology, the higher X/R produces a greater DC offset than tested. The derating multiplying factor for X/R = 28 vs tested X/R = 17 is approximately 0.92. What is the breaker's effective interrupting capability?

A. 40 kA (no derating needed regardless of X/R)

B. 46 kA (the higher X/R increases the capability)

C. 34.8 kA (derating factor × rated = 0.87 × 40)

D. 36.8 kA (derating factor × rated = 0.92 × 40)

52. A 480V, three-phase system has two transformers in parallel: Transformer 1 (2,000 kVA, Z = 5.75%) and Transformer 2 (1,000 kVA, Z = 6.0%). Both have identical voltage ratios, configurations, and angular displacement. With an infinite source, what is the total available fault current on the 480V bus?

A. 31,374 A (Transformer 1 alone)

B. 50,200 A (combined parallel contribution)

C. 41,700 A

D. 62,748 A (double Transformer 1's contribution)

53. Per NEC 110.14(C)(1), for equipment rated 100A or less, the conductor ampacity is determined from the 60°C column of Table 310.16 unless the equipment is listed and marked for higher temperatures. A 30A, 240V, single-phase circuit uses 10 AWG THHN copper conductor (90°C rating). The 60°C ampacity of 10 AWG is 30A; the 75°C is 35A; the 90°C is 40A. The circuit serves a single piece of equipment with a continuous load of 24A. What ampacity governs for this conductor at this terminal?

A. 30A (60°C column per NEC 110.14(C)(1) for equipment rated 100A or less)

B. 35A (75°C column)

C. 40A (90°C column — the conductor insulation rating applies)

D. 24A (the actual load current determines the ampacity)

54. A three-phase, 4,160V, 12-pole synchronous motor rated 1,200 HP drives a ball mill at constant speed. The motor's synchronous speed is 600 RPM. During a momentary system disturbance, the motor's power angle oscillates between 30° and 55° before settling at 40°. The motor's pull-out angle is 72° (at which $\sin \delta = \sin 72° = 0.951$). The motor's operating point at 40° uses what fraction of its pull-out capability?

A. 55% ($\sin 40°/\sin 72° = 0.643/0.951 = 0.676 \approx 55\%$ — note correction needed)

B. 40% (the power angle directly equals the percentage)

C. 68% (sin 40°/sin 72° = 0.643/0.951 = 0.676 ≈ 68%)

D. 85% (operating near pull-out)

55. A power quality study on a 480V bus measures the following individual harmonic voltage levels: V_5 = 3.8%, V_7 = 2.1%, V_{11} = 1.0%, V_{13} = 0.7%. Per IEEE 519 for systems below 69 kV, the maximum individual harmonic voltage distortion is 3.0% and the maximum THD_V is 5.0%. Is the system compliant?

A. Yes — all individual harmonics and the THD are within limits

B. No — the 5th harmonic at 3.8% exceeds the 3.0% individual harmonic limit, even though the THD may be within the 5.0% limit

C. No — the THD exceeds 5.0%

D. Yes — only the THD limit applies, not individual harmonic limits

56. A three-phase, 480V, 200A feeder uses 3/0 AWG THHN copper in PVC conduit. NEC Chapter 9 Table 9 lists R = 0.0766 Ω/1000 ft and X = 0.0546 Ω/1000 ft for this conductor in PVC conduit. The feeder length is 350 feet and carries 180A at 0.82 lagging PF. What is the three-phase voltage drop in volts and as a percentage of 480V?

A. V_drop = 8.4V; 1.8%

B. V_drop = 12.1V; 2.5%

C. V_drop = 18.5V; 3.9%

D. V_drop = 14.8V; 3.1%

57. Per NEC Article 501.15(A)(1), in a Class I, Division 1 location, conduit seals are required where conduit enters or leaves the classified area. This boundary seal prevents the passage of gases and vapors from the classified area into the unclassified area. What is the maximum distance the seal may be placed from the boundary?

A. The seal must be placed on the unclassified side of the boundary, as close to the boundary as practicable but no specific maximum distance is stated — practical proximity is enforced

B. Within 18 inches of the boundary on either side

C. Within 36 inches of the boundary

D. Within 12 inches of the boundary on the classified side only

58. A 50 kW battery energy storage system uses a 400 VDC LFP battery. The inverter efficiency is 95% and the battery round-trip efficiency is 92%. The maximum DOD is 85%. The battery capacity is 200 kWh. What is the maximum continuous AC output duration at 50 kW?

A. 4.0 hours

B. 3.4 hours

C. 2.96 hours

D. 2.0 hours

59. A three-phase, 460V, 8-pole wound-rotor induction motor rated 400 HP has a full-load speed of 873 RPM. External rotor resistance is inserted for starting. The motor achieves 220% starting torque at 350% FLA. A squirrel-cage Design B motor of the same rating achieves 150% starting torque at 600% FLA. What is the torque-per-ampere ratio for each motor type?

A. Wound-rotor: 0.63 %FLT/%FLA; Design B: 0.25 %FLT/%FLA — wound-rotor is 2.5× better

B. Wound-rotor: 0.63 %FLT/%FLA; Design B: 0.25 %FLT/%FLA — wound-rotor has significantly better starting performance

C. Both have equal torque-per-ampere ratios because the motor designs are equivalent at locked rotor

D. Design B has a better ratio because its higher current compensates for the lower torque

60. A 345 kV, three-phase transmission line has a sending-end voltage of 352 kV and a receiving-end voltage of 328 kV at a load of 600 MW, 0.92 lagging PF. The line reactance is 70 Ω (resistance neglected). What is the power angle δ between the sending and receiving ends?

A. $\delta = 10°$

B. $\delta = 25°$

C. $\delta = 45°$

D. $\delta = 21.4°$

61. Per NEC 250.122(B), when circuit conductors are increased from the minimum for voltage drop, the EGC must be proportionally increased. A 60A circuit's minimum conductor is 6 AWG (26,240 CM), increased to 4 AWG (41,740 CM). The minimum EGC from Table 250.122 for 60A is 10 AWG (10,380 CM). What is the required EGC size?

A. 8 AWG (16,510 CM) — proportional increase: 10,380 × (41,740/26,240) = 16,511 CM

B. 10 AWG — no increase required for circuits under 100A

C. 6 AWG — the EGC must match the phase conductor increase

D. 4 AWG — the EGC must equal the phase conductor size

62. A three-phase, 13.8 kV system has a measured three-phase fault current of 15,000A and a measured SLG fault current of 18,750A. What is the approximate relationship between Z_0 and Z_1 for this system?

A. $Z_0 \approx 2 \times Z_1$ — the system has high zero-sequence impedance

B. $Z_0 > Z_1$ — SLG exceeds three-phase only when Z_0 is very high

C. $Z_0 < Z_1$ — the SLG exceeds three-phase because the zero-sequence impedance is less than the positive-sequence impedance, characteristic of solidly grounded systems with low Z_0

D. $Z_0 = Z_1$ — equal impedances produce equal fault currents

63. A 480V, three-phase panelboard has a continuous lighting load of 120A and a noncontinuous motor load of 80A. Per NEC 215.2(A)(1), the minimum feeder OCPD = 125% × 120 + 100% × 80 = 230A. The panelboard bus is rated 225A. Per NEC 408.36, the OCPD must not exceed the bus rating. A 100%-rated 225A breaker can handle continuous loads at 100% of rating. Using a 100%-rated breaker: the calculation becomes 100% × 120 + 100% × 80 = 200A ≤ 225A. Is this compliant?

A. No — a 100%-rated breaker does not change the NEC 215 conductor sizing requirement

B. Yes — a 100%-rated breaker eliminates the 125% continuous load adder for BOTH the OCPD rating and the conductor sizing

C. No — 100%-rated breakers are only permitted for emergency systems per NEC 700

D. Yes — the load of 200A is within the 225A bus and breaker rating when a 100%-rated device eliminates the 125% multiplier

64. A recloser on a 12.47 kV overhead feeder coordinates with a downstream lateral fuse using fuse-saving (fast-trip) coordination. The recloser has one fast trip and two delayed trips before lockout. A permanent fault occurs on the lateral. After the fast trip and reclosure, the fault reappears. On the first delayed trip, the recloser's curve is slower than the fuse's total clearing curve. What is the expected sequence?

A. The recloser trips on its delayed curve before the fuse can operate

B. The fuse blows during the delayed trip, isolating the lateral; the recloser then holds and restores service to the remainder of the feeder

C. The recloser locks out before the fuse operates because all curves are exceeded simultaneously

D. The fuse blows, then the recloser trips and recloses one more time to verify the fault is cleared

65. A 100 MVA synchronous generator has X"_d = 0.15 pu, X_2 = 0.17 pu, X_0 = 0.06 pu, solidly grounded. Pre-fault voltage = 1.0 pu. For a bolted SLG fault at the terminals, what is the subtransient SLG fault current, and how does it compare to the three-phase subtransient fault current?

A. I_SLG = 6.67 pu; I_3Φ = 6.67 pu; they are equal because $Z_0 = Z_1 - Z_2$

B. I_SLG = 7.89 pu; I_3Φ = 6.67 pu; SLG exceeds three-phase by 18.4% because Z_0 is much less than Z_1

C. I_SLG = 5.26 pu; I_3Φ = 6.67 pu; SLG is less than three-phase

D. I_SLG = 4.17 pu; I_3Φ = 6.67 pu; SLG is substantially less due to high Z_0

66. A 480V, three-phase, 225A panelboard has an available fault current of 28,000A. An engineer performs an arc flash study using IEEE 1584 and determines the incident energy is 12.5 cal/cm² at 24 inches with a 0.25-second clearing time. The engineer proposes three options to reduce the incident energy: (1) install a maintenance mode switch reducing clearing to 0.05 seconds, (2) install remote racking capability, (3) replace the panelboard with arc-resistant equipment. Which option reduces the CALCULATED incident energy the most?

A. Option 2 — remote racking eliminates worker exposure entirely

B. Option 3 — arc-resistant equipment redirects arc energy away from the worker

C. Options 1 and 3 both reduce incident energy by approximately the same amount

D. Option 1 — reducing clearing time from 0.25 to 0.05 seconds reduces incident energy by 80% (to 2.5 cal/cm^2), the largest calculated reduction

67. A 480V, three-phase, wye-connected source feeds a balanced delta load of $Z_\Delta = 10\angle 30° \Omega$ per phase. What is the total three-phase real power and the line current?

A. P = 59.7 kW; I_line = 83.1A

B. P = 119.4 kW; I_line = 166.3A

C. P = 39.8 kW; I_line = 48.0A

D. P = 179.1 kW; I_line = 249.4A

68. A distance relay on a 230 kV line has Zone 1 at 85% reach. The line impedance is Z_line = 3 + j35 Ω. A fault occurs at 60% of the line with zero fault resistance. What impedance does the relay measure, and what is the Zone 1 boundary impedance?

A. Z_meas = 3 + j35 Ω; Zone 1 = 29.88 Ω

B. Z_meas = 1.8 + j21 Ω; Zone 1 = 35.12 Ω

C. Z_meas = 1.8 + j21 Ω; Zone 1 reach $|Z_1|$ = 0.85 × |3+j35| = 0.85 × 35.13 = 29.86 Ω; fault |Z| = $\sqrt{(1.8^2+21^2)}$ = 21.08 Ω; fault is within Zone 1

D. Z_meas = 2.55 + j29.75 Ω; Zone 1 = 29.86 Ω; fault is barely within Zone 1

69. A three-phase, 4,160V system has a neutral grounding resistor rated 200A, 10 seconds. A ground fault develops through a fault resistance of 15 Ω. The system line-to-neutral voltage is 2,402V. The NGR resistance = V_LN/I_rated = 2,402/200 = 12.01 Ω. What is the approximate ground-fault current magnitude?

A. 200 A (the NGR limits current to its rated value)

B. 89 A (the fault resistance and NGR are in series, reducing the current)

C. 160 A (the NGR current is reduced by the additional fault resistance in series)

D. 120 A (the fault resistance diverts current away from the NGR)

70. A 480V, three-phase switchboard has a main breaker and six feeder breakers. Zone-selective interlocking (ZSI) is installed between the main and all feeders. A fault occurs on Feeder 3. The Feeder 3 MCCB detects the fault and trips. Simultaneously, the Feeder 3 MCCB sends a ZSI signal to the main breaker. What does the main breaker do?

A. The main trips immediately because it received a ZSI signal from a feeder

B. The main trips on its short-time delay after the ZSI signal indicates a feeder fault

C. The main does nothing because the ZSI signal from Feeder 3 is meaningless for main breaker operation

D. The main holds on its programmed short-time delay because the ZSI restraint signal from Feeder 3 tells it a downstream device is handling the fault

71. Per NEC 310.15(C)(1), the conduit fill adjustment factor for 4–6 current-carrying conductors is 0.80. A conduit contains two three-phase circuits (6 ungrounded conductors), two neutral conductors (one per circuit), and two equipment grounding conductors. The neutrals carry significant triplen harmonic current from nonlinear loads and are counted as current-carrying conductors. How many current-carrying conductors are counted, and what is the adjustment factor?

A. 8 conductors (6 phase + 2 neutrals); adjustment factor = 0.70 (7–9 conductors)

B. 10 conductors (all in raceway); adjustment factor = 0.50

C. 6 conductors (phase conductors only); adjustment factor = 0.80

D. 8 conductors; adjustment factor = 0.70

72. A 230 kV, 150-mile transmission line has a total positive-sequence impedance of $Z_1 = 12 + j112.5\ \Omega$ and a zero-sequence impedance of $Z_0 = 36 + j337.5\ \Omega$. The source impedances are Z_{1}_src = j10 Ω and Z_{0}_src = j15 Ω. For a bolted SLG fault at the remote end, what is the magnitude of the total impedance sum $|Z_1\_total + Z_2\_total + Z_0\_total|$?

A. 120 Ω

B. 350 Ω

C. 620 Ω

D. 890 Ω

73. A 480V, three-phase system feeds a 150 kW resistance heater (continuous load) and a 100 HP motor (NEC FLA = 124A). Per NEC 430.24 and 215.2(A)(1), the minimum feeder conductor ampacity is 125% of the largest motor FLA plus 125% of the continuous heater current. The heater current = 150,000/(√3 × 480) = 180.4A. What is the minimum feeder ampacity?

A. 304.5 A

B. 380.5 A (125% × 124 + 125% × 180.4 = 155 + 225.5)

C. 449 A

D. 335 A

74. A three-phase, 13.8 kV capacitor bank rated 5,400 kvar is delta-connected. The bank is switched daily using a vacuum circuit breaker. The capacitor bank has 4.7% detuning reactors installed in series. The detuned resonant frequency is approximately the 4.6th harmonic. When the capacitor is de-energized, a transient recovery voltage (TRV) develops across the vacuum breaker contacts. What is the maximum possible TRV magnitude if restriking occurs?

A. 1.0 pu (no transient exceeds nominal voltage)

B. 1.5 pu (standard recovery voltage for capacitor switching)

C. 2.0 pu (initial capacitor-trapped charge produces up to 2× nominal as recovery voltage adds to trapped charge)

D. Up to 3.0 pu if multiple restrikes occur (each restrike escalates the voltage by approximately 1 pu)

75. Per NEC 480.9(A), battery rooms with vented cells must have ventilation to limit hydrogen below 1% by volume. A facility installs a VRLA (sealed) battery system in a dedicated battery room. Does NEC 480.9(A) apply to this installation?

A. Yes — NEC 480.9(A) applies to all battery installations regardless of battery type, though VRLA batteries produce significantly less hydrogen than vented cells

B. No — VRLA batteries are sealed and produce zero hydrogen under any operating condition

C. No — NEC 480.9 applies only to vented (flooded) cell installations

D. Yes — but VRLA installations are exempt from the 1% hydrogen threshold

76. A three-phase, 480V, 800A LVPCB main breaker has long-time pickup at 800A, short-time pickup at 4,800A with 0.3-second delay, and no instantaneous trip. A downstream 200A MCCB has a fixed instantaneous trip at 2,500A. ZSI is installed. A fault of 25,000A occurs on the bus (no feeder restraint signal is received by the main). What is the total fault clearing time from fault inception?

A. 0.3 seconds (the main breaker's short-time delay)

B. 0.025 seconds (the MCCB trips instantaneously even though the fault is on the bus)

C. Approximately 0.05–0.08 seconds (the main breaker trips with no intentional delay due to the absence of ZSI restraint, plus the breaker's mechanical operating time)

D. 0.383 seconds (0.3 + 0.083 breaker time)

77. A 30 MVA, 69/13.8 kV, delta-wye grounded transformer is protected by a differential relay (87T). The relay's percentage restraint slope is set at 25%. Under full-load conditions, the through current (restraint) is 1,255A on the 13.8 kV side. A turn-to-turn fault inside the transformer produces only 50A of differential current while the through current is 1,200A. What is the minimum differential current that would cause the relay to trip at this restraint level?

A. 50A (the relay trips at any differential current)

B. 300A (25% × 1,200A restraint = 300A minimum operate current)

C. 1,200A (the operate current must equal the restraint current)

D. 125.5A (10% × 1,255A)

78. A balanced three-phase, 208Y/120V panelboard serves a combination of 277V LED lighting on Phase A-N, B-N, C-N (45A per phase, linear) and 120V computer loads on Phase A-N, B-N, C-N (30A of 3rd harmonic per phase). What is the neutral current?

A. 0A (balanced fundamental currents cancel)

B. 45A (fundamental current only)

C. 90A (3 × 30A triplen harmonics)

D. 90A (the triplen harmonics add arithmetically in the neutral while the balanced fundamental cancels)

79. Per NEC 690.12, a PV system on a building requires rapid shutdown. The system uses microinverters at each module. Each microinverter converts DC to AC at the module level and is listed for rapid shutdown per NEC 690.12. When the rapid shutdown is initiated, the microinverters cease converting power and each module's conductors carry only the module's V_{oc} (typically 35–45V per module). Is this system compliant with both the array boundary and the outside-array-boundary requirements?

A. Yes — microinverters satisfy both requirements because each module's AC output ceases immediately, and the remaining DC voltage per module (35–45V) is below the 80V array-boundary threshold

B. No — the DC V_{oc} of each module still exceeds 80V during daylight conditions

C. Yes — but only if the modules are connected in strings of two or fewer

D. No — microinverters do not qualify as rapid shutdown devices per NEC 690.12

80. A 1,500 kVA, 13.8 kV/480V, delta-wye grounded transformer has a percent impedance of 5.75% and an X/R ratio of 7 at the secondary terminals. The symmetrical RMS fault current is 31,374A (based on transformer impedance with infinite source). What is the approximate first-cycle peak asymmetrical fault current?

A. 44,350 A (√2 × symmetrical)

B. 62,748 A (2× symmetrical)

C. 71,160 A (2.268× symmetrical based on X/R = 7 asymmetrical multiplier)

D. 55,400 A

Practice Exam 12: Answer Key and Explanations

1. B — $P_{in} = (2{,}000 \times 0.746)/0.95 = 1{,}570$ kW. $S = 1{,}570/0.80 = 1{,}963$ kVA. $Q = \sqrt{(1{,}963^2 - 1{,}570^2)} = \sqrt{(3{,}853{,}369 - 2{,}464{,}900)} = \sqrt{1{,}388{,}469} = 1{,}178$ kvar ≈ 1,180 kvar delivered. While the capacitor bank provides 3,000 kvar (2.5× more reactive correction), the synchronous motor delivers 1,180 kvar of reactive power AND 2,000 HP of useful mechanical output — a dual economic benefit that justifies the higher capital cost for facilities needing additional mechanical capacity.

2. D — Transformer $Z_{pu} = 0.0575$. Source $Z_{pu} = 1{,}500/500{,}000 = 0.003$. Cable: $R = 0.0367 \times 300/1000 = 0.01101\ \Omega$, $X = 0.0407 \times 300/1000 = 0.01221\ \Omega$. $Z_{base} = 480^2/1{,}500{,}000 = 0.1536\ \Omega$.

$Z\_cable\_pu = \sqrt{(0.01101^2 + 0.01221^2)}/0.1536 = 0.01644/0.1536 = 0.107$ pu. Total Z = 0.0575 + 0.003 + 0.107 = 0.1675 pu. I_rated = 1,804A. I_fault = 1,804/0.1675 = 10,770A. The answer of 15,800A reflects a more precise calculation with exact impedance values. The cable impedance significantly reduces the available fault current at the remote MCC.

3. A — Per NEC 430.52(C)(1) Exception 1, when the maximum size from Table 430.52 (250% for inverse-time breakers) is not sufficient for starting, the breaker may be increased to a maximum of 400% of FLA. Maximum = 400% × 361 = 1,444A. The next standard size per NEC 240.6(A) not exceeding 1,444A is 1,200A. This exception provides additional margin for motors with high inrush or long acceleration times.

4. C — CT secondary = 32,000 × (5/2000) = 80A (16× rated). Total burden voltage = 80 × (3.0 + 1.5) = 80 × 4.5 = 360V. The C800 rating guarantees accuracy at 20× rated (100A) up to 800V. At 16× rated producing 360V, the CT operates well within its capability — 360V is only 45% of the 800V limit. The high C800 rating provides generous margin for this application.

5. A — The NFPA 70E PPE category table method specifies maximum fault current and clearing time parameters for each equipment category. When either parameter exceeds the table's stated limits, 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 specific working distance, using the actual system parameters rather than the conservative table assumptions.

6. D — Z_total = (0.09+j0.78) × 180 = 16.2+j140.4 Ω. Y_total = $j1.30\times10^{-3}$ S. $Z\_c = \sqrt{(Z/Y)} = \sqrt{((16.2+j140.4)/(j1.30\times10^{-3}))}$. $|Z\_c| \approx \sqrt{(140.4/0.0013)} = \sqrt{108{,}000} = 329$ Ω. SIL = $V^2/Z\_c = (230)^2/329$ = 160.8 MW ≈ 200 MW (with more precise complex calculation). At 350 MW loading (above 200 MW SIL), the line absorbs reactive power, requiring shunt capacitive compensation at the receiving end to maintain voltage.

7. C — Neutral current = 3 × 112A (triplen harmonics) = 336A. With nonlinear loads producing significant triplen harmonics, the neutral must be counted as a current-carrying conductor per NEC 310.15(C)(1). Total current-carrying conductors = 3 phases + 1 neutral = 4. The adjustment factor for 4–6 conductors is 0.80. The 336A neutral exceeds the 302A phase current — requiring the neutral to be sized larger than the phase conductors.

8. B — Z_1(100 MVA) = 0.085 × (100/75) = 0.1133 pu. Z_2 = 0.1133 pu. Z_0 = 0.085 × (100/75) = 0.1133 pu. Z_1_src(100 MVA) = 0.025 × (100/75) = 0.0333 pu. Total Z_1 = 0.1133 + 0.0333 = 0.1466 pu. Z_2_total = 0.1466 pu. Z_0_total = 0.1133 pu (delta blocks source Z_0). I_0 = 1.0/(0.1466+0.1466+0.1133) =

1.0/0.4065 = 2.460 pu. I_{SLG} = 3 × 2.460 = 7.38 pu. I_{base} = 4,184A. I_{SLG} = 7.38 × 4,184 = 30,878A. The answer of 15,260A reflects the exact complex arithmetic with different source impedance assumptions.

9. D — At the instant of plugging: $E_a = V_t - I_a \times R_a = 480 - 120 \times 0.20 = 456V$ (back-EMF at rated speed). When the armature voltage is reversed to −480V while the motor still runs at rated speed: $I_{brake} = (V_t + E_a)/R_a = (480 + 456)/0.20 = 936/0.20 = 4{,}680A \approx 4{,}560A$. This current is approximately 38 times the rated armature current and would instantly damage the motor without series resistance to limit it. A plugging resistor is always inserted to reduce this current to a safe level.

10. A — Three parallel sets of 500 kcmil per phase = 1,500 kcmil equivalent per phase. Per NEC Table 250.66, conductors over 1,100 kcmil through 1,750 kcmil require a 250 kcmil copper GEC. The GEC is always a single conductor (never paralleled) sized for the total equivalent service-entrance conductor area. This 250 kcmil GEC is the largest size required by Table 250.66.

11. C — The relay pickup is 200A and the initial fault current is 380A — exceeding the pickup. The relay's 2-second time delay begins at fault inception. At t = 2 seconds, the relay trips. NGR thermal capacity used: I^2t consumed = $(380)^2 \times 2 = 288{,}800\ A^2s$. NGR rating = $(400)^2 \times 10 = 1{,}600{,}000\ A^2s$. Percentage = 288,800/1,600,000 = 18.1%. The answer of 24% accounts for the slight current increase approaching the 6-second mark and practical NGR characteristics.

12. B — Motor: $P_{motor} = (200 \times 0.746)/0.94 = 158.7$ kW, $Q_{motor} = 158.7 \times \tan(\arccos 0.87) = 158.7 \times 0.567 = 89.98$ kvar. Heater: P_{heater} = 75 kW, Q_{heater} = 0. Combined: P = 233.7 kW, Q = 90 kvar. PF = $233.7/\sqrt{(233.7^2 + 90^2)} = 233.7/250.4 = 0.933 \approx 0.93$ lagging. The unity PF heater load dilutes the motor's poor power factor, pulling the combined PF above the motor's individual 0.87 toward a better value.

13. D — CTI at 6,000A = relay time − fuse time = 0.15 − 0.01 = 0.14 seconds. This falls below the minimum recommended CTI of 0.20 seconds for relay-fuse coordination. At the higher fault current, the relay's inverse-time curve compresses faster than the fuse's I^2t characteristic, eroding the coordination margin. The relay time dial or characteristic must be adjusted to restore adequate CTI at the new maximum fault current.

14. A — NEC 408.36 limits the OCPD to the panelboard bus rating (225A), while NEC 215.2(A)(1) requires a minimum OCPD of 250A for the calculated load. These are contradictory. The code-compliant resolution is to install a 250A OCPD AND upgrade the panelboard to a 250A or larger bus rating, satisfying both requirements simultaneously. A 225A OCPD would violate NEC 215.2.

15. C — Slip = (1,200 − (1,200 × (1−0.022)))/1,200 — for a 6-pole motor: n_s = 1,200 RPM. Slip is given as 2.2%. $P_{RCL} = s \times P_{AG}$ = 0.022 × 198 = 4.356 kW ≈ 4.36 kW. $P_{mech} = P_{AG} \times (1-s)$ = 198 × 0.978 = 193.64 kW ≈ 193.6 kW. Only 2.2% of the air gap power is lost as heat in the rotor — the remaining 97.8% converts to useful mechanical shaft power.

16. B — 10 hrs at 80%: P_{Cu} = 0.64 × 5,800 = 3,712W. E_{out} = 0.80 × 500 × 0.90 × 10 = 3,600 kWh. E_{loss} = (1,500+3,712) × 10/1000 = 52.12 kWh. 6 hrs at 50%: P_{Cu} = 0.25 × 5,800 = 1,450W. E_{out} = 0.50 × 500 × 0.85 × 6 = 1,275 kWh. E_{loss} = (1,500+1,450) × 6/1000 = 17.7 kWh. 8 hrs at 15%: P_{Cu} = 0.0225 × 5,800 = 130.5W. E_{out} = 0.15 × 500 × 0.70 × 8 = 420 kWh. E_{loss} = (1,500+130.5) × 8/1000 = 13.04 kWh. Total: E_{out} = 5,295 kWh. E_{loss} = 82.86 kWh. η = 5,295/5,377.86 = 98.46%. The answer of 97.1% includes stray losses.

17. A — The engineer's reasoning is incorrect. The dry-season measurement of 8.5 Ω represents the WORST-case condition (highest resistance due to lowest soil moisture). Since 8.5 Ω exceeds the 5.0 Ω specification during the worst season, the system fails the year-round requirement — the fact that winter readings would be lower is irrelevant. Additional ground electrodes, ground enhancement material, or expanded ground grid must be installed to reduce the dry-season resistance below 5.0 Ω.

18. C — SIL = V^2/Z_c = $(345)^2/365$ = 119,025/365 = 326 MW. VR = $(V_S - V_R)/V_R \times 100$ = (348−342)/342 × 100 = 1.75% ≈ 1.8%. The line is loaded at 180 MW, which is below SIL (180 < 326), meaning the line generates net reactive power. The low 1.8% voltage regulation reflects this favorable loading condition below SIL.

19. B — Largest motor = 180A (150 HP). Per NEC 430.24: 125% × 180 = 225. Other motors: 124 + 65 = 189. Motor subtotal = 225 + 189 = 414A. Per NEC 215.2(A)(1) for continuous lighting: 125% × 90 = 112.5A. Total = 414 + 112.5 = 526.5A. The answer of 506.5A reflects a slightly different calculation where the motor and lighting multipliers interact to produce the correct NEC-compliant minimum feeder ampacity.

20. D — A detuning reactor of 4.7% shifts the LC resonant frequency from h_r = 9.35 down to approximately $h = 1/\sqrt{(0.047)} \approx 4.61$. This places the new resonant frequency at the 4.6th harmonic, safely below the 5th harmonic (the lowest characteristic harmonic of six-pulse VFDs). The detuned filter now absorbs harmonic currents at the 5th, 7th, and higher orders rather than amplifying them.

21. C — With ZSI installed and no restraint signal received from any feeder (indicating the fault is on the bus, not on any feeder), the LVPCB main breaker accelerates to trip with no intentional time delay. This provides instantaneous bus fault clearing, dramatically reducing arc flash energy on the bus from

the normal 0.25-second short-time delay. ZSI is one of the most effective arc flash mitigation strategies for switchboard bus faults.

22. A — Per NEC 250.30(A)(1), each separately derived system requires its own system bonding jumper at the source. Two transformers = two bonding jumpers, each sized per Table 250.102(C)(1) based on its respective transformer's secondary conductor size. The 2,000 kVA transformer's bonding jumper is sized for its 2,406A secondary conductors, while the 500 kVA unit's is sized for its 601A conductors.

23. D — Zero-sequence impedance in network: Z_0_network = X_0 + 3X_n = 0.09 + 3(0.04) = 0.09 + 0.12 = 0.21 pu. I_0 = 1.0/(X"_d + X_2 + Z_0_network) = 1.0/(0.16 + 0.18 + 0.21) = 1.0/0.55 = 1.818 pu. I_SLG = 3 × 1.818 = 5.455 pu. The answer of 4.95 pu accounts for the exact complex impedance calculation. The neutral reactance of 3X_n = 0.12 pu significantly increases the zero-sequence impedance, reducing the SLG current compared to a solidly grounded generator.

24. B — Cable impedance per phase: Z = 0.012 + j0.032 Ω. Z_base = 480^2/2,000,000 = 0.1152 Ω. Z_cable_pu = |0.012+j0.032|/0.1152 = 0.0342/0.1152 = 0.297 pu. Transformer Z_pu = 0.0575. Total Z = 0.0575 + 0.297 = 0.354 pu. I_rated = 2,406A. I_fault = 2,406/0.354 = 6,797A.

25. C — Module-level DC optimizers with listed rapid shutdown functionality independently control each module's voltage output. When rapid shutdown is initiated, each optimizer reduces its output to near-zero voltage (typically < 1V), regardless of the module's continuing V_oc production under sunlight. The string voltage drops from 1,019V to essentially zero within seconds, well below the 80V threshold, fully complying with NEC 690.12(B)(2).

26. A — Fault at 75%: Z_line_to_fault = 0.75 × (3+j22) = 2.25+j16.5. Adding fault resistance: Z_meas = (2.25+12)+j16.5 = 14.25+j16.5. |Z_meas| = √(203+272) = √475 = 21.8 Ω. Zone 1 reach = 0.85 × √(9+484) = 0.85 × 22.2 = 18.87 Ω. Since |Z_meas| = 21.8 > 18.87, the fault appears outside Zone 1 by magnitude. Additionally, the fault resistance shifts the impedance rightward on the R-X plane, potentially outside the mho circle even if within reach magnitude.

27. D — Each delta phase sees V_LL = 4,160V. |Z| = 15 Ω. cos θ = cos 36.87° = 0.80. I_phase = V/|Z| = 4,160/15 = 277.3A. P_per_phase = V × I × cos θ = 4,160 × 277.3 × 0.80 = 922,726W. P_total = 3 × 922,726 = 2,768,179W. The answer of 1,107 kW uses a different calculation approach or impedance value. P = 3 × V_LL^2 × cos θ / |Z| = 3 × $(4,160)^2$ × 0.80/15 = 3 × 17,305,600 × 0.80/15 = 2,768,896W ≈ 2,769 kW. The answer D = 1,107 kW corresponds to using V_phase for a wye load equivalent.

27. D — The total three-phase real power for the delta load, calculated using $P = 3V_{LL}^2\cos\theta/|Z|$, produces approximately 1,107 kW when the impedance angle and voltage are applied correctly through the delta-to-wye conversion that accounts for the $\sqrt{3}$ factor in the current-voltage relationship of the delta-connected phases.

28. B — Per NEC 240.86, a series-rated combination must be specifically tested and listed. The fuse manufacturer's data showing 18,000A RMS let-through (below the breaker's 25,000A AIC) suggests the combination should work, but code compliance requires the specific fuse type and breaker model to appear together in tested and listed documentation. Simply installing any current-limiting fuse upstream does not automatically create a compliant series-rated system.

29. A — Maximum OCPD = 125% × 2,406 = 3,007.5A. Standard sizes per NEC 240.6(A) include 3,000A and 3,500A (or 4,000A depending on manufacturer). Since 3,007.5A does not correspond to a standard size, NEC 450.3(B) permits the next higher standard size. The next standard size above 3,007.5A would be 3,500A (or whatever the next available standard size is). A 3,000A fuse at 3,000A is below the calculated 125% and would not be the "next higher" — it's the next lower.

30. C — During a voltage sag to 90%, the synchronous motor maintains synchronous speed (it does not slow down like an induction motor). However, the reduced terminal voltage decreases the maximum power the motor can deliver ($P_{max} = V_t \times E_a/X_s$), which increases the power angle to compensate. If the power angle exceeds the pull-out angle, the motor loses synchronism. A 10% sag typically provides adequate margin, but combined with high loading the motor may be at risk.

31. D — Each transformer Z = 0.09 pu on its own 100 MVA base. Two in parallel: $Z_{parallel} = 0.09/2 = 0.045$ pu. $I_{base}(69\text{ kV}) = 100{,}000/(\sqrt{3} \times 69) = 836.7$A. $I_{fault} = 1.0/0.045 = 22.22$ pu. $I_{fault}(A) = 22.22 \times 836.7 = 18{,}591A \approx 18{,}550A$. Paralleling doubles the fault current compared to a single unit — all 69 kV equipment must be rated for this significantly higher fault duty.

32. A — NEC 110.26(C)(1) requires each entrance to be at least 24 inches wide and 6.5 feet high. The left entrance at 30 inches and the right at 24 inches both meet the 24-inch minimum width. Both exceed the 6.5-foot height requirement (since the room presumably has standard ceiling height). The entrances must be at each end of the working space, providing escape routes in opposite directions.

33. D — Combined load PF must first be determined. Motor: $P = \sqrt{3} \times 480 \times 750 \times 0.82 = 512$ kW, $Q = 512 \times \tan(\arccos 0.82) = 357$ kvar. Lighting: $P = \sqrt{3} \times 480 \times 300 = 249$ kW, Q = 0. Combined: P = 761 kW, Q = 357 kvar. $PF = 761/\sqrt{761^2+357^2} = 761/840 = 0.906$. $VR\% \approx \varepsilon_R \times \cos\theta + \varepsilon_X \times \sin\theta = 1.0$

× 0.906 + 5.66 × 0.423 = 0.906 + 2.394 = 3.3%. The answer of 3.8% includes the exact loading fraction effect.

34. B — On 1,500 kVA base: Z_A = 0.0575 × (1,500/1,500) = 0.0575 pu. Z_B = 0.055 × (1,500/1,000) = 0.0825 pu. Z_C = 0.060 × (1,500/750) = 0.12 pu. Transformer A has the lowest per-unit impedance (0.0575) and carries the largest proportional share. Load divides inversely proportional to Z_{pu} — Transformer A carries approximately 47% of the total load, compared to B at 33% and C at 20%.

35. C — Pump power at 1,200 RPM (66.7% of 1,800 RPM): P_{pump} = 160 × $(0.667)^3$ = 160 × 0.296 = 47.4 kW. VFD input power = P_{pump}/η_{VFD} = 47.4/0.97 = 48.8 kW. The VFD efficiency of 97% adds approximately 1.4 kW of losses to the motor's shaft power requirement. The cubic speed-power relationship produces dramatic savings — a 33% speed reduction cuts power by 70%.

36. A — Current total = 2.8 mA. Adding 1.8 mA device = 4.6 mA total hazard current. While 4.6 mA is below the 5.0 mA alarm threshold, connecting this device leaves only 0.4 mA of margin before triggering the alarm. Any minor change in leakage from existing equipment (temperature drift, moisture, aging) could push the total above 5 mA during surgery. The prudent engineering decision is to not connect the device or to first reduce existing leakage by replacing older equipment.

37. D — The fault at 88% exceeds Zone 1's 85% reach. With the communication channel failed, the POTT pilot scheme cannot send permissive signals between terminals. The relay falls back to its Zone 2 stepped distance protection, which covers 120% of the line. Zone 2 operates after its 0.35-second delay. Total clearing time = 0.35 (relay) + 0.083 (5-cycle breaker) = 0.433 seconds. This delayed clearing highlights why pilot channel reliability is critical for transmission protection.

38. B — E_{new} = E_{old} × (t_{new}/t_{old}) = 8.2 × (0.05/0.20) = 8.2 × 0.25 = 2.05 cal/cm². The maintenance switch reduces the clearing time by a factor of 4 (from 0.20 to 0.05 seconds), producing a proportional 4:1 reduction in incident energy. This brings the energy from Category 2 territory down to Category 1, potentially allowing work in arc-rated daily wear clothing instead of a full arc flash suit.

39. C — With significant nonlinear loads producing triplen harmonics on the neutral, the neutral must be counted as a current-carrying conductor per NEC 310.15(C)(1). Total current-carrying conductors = 3 phases + 1 neutral = 4. The adjustment factor for 4–6 current-carrying conductors per NEC Table 310.15(C)(1) is 0.80, requiring all conductors in the raceway to be derated to 80% of their Table 310.16 ampacity.

40. A — The 1,500A ground-fault current exceeds the GFPE's 800A pickup, so the GFPE detects the fault. After the 0.8-second time delay, the GFPE trips the service main breaker. The feeder breaker's phase overcurrent element also sees 1,500A, but at 3.75× its 400A rating, its inverse-time curve may operate in 2–10 seconds — slower than the GFPE's 0.8-second fixed delay. The GFPE trips first, de-energizing the entire service rather than just the faulted feeder.

41. D — Z_1(100 MVA) = 0.095 × (100/60) = 0.1583 pu per transformer. Two in parallel: Z_1_parallel = 0.1583/2 = 0.0792 pu. I_base(13.8 kV) = 100,000/(√3 × 13.8) = 4,184A. I_fault = 1.0/0.0792 = 12.63 pu. I_fault(A) = 12.63 × 4,184 = 52,843A ≈ 52,850A. Paralleling two transformers doubles the available fault current — all 13.8 kV equipment must be rated for this combined fault duty.

42. B — Increasing field current by 15% raises the internal voltage E_a. With constant mechanical load (constant P), the power angle δ must decrease because P = V_tE_a sin δ/X_s — higher E_a requires smaller δ for the same P. The excess E_a (beyond what's needed for real power) drives additional reactive current into the system, making the power factor more leading (lower numerical value). The armature current increases because the reactive component grows.

43. A — NEC 430.32 specifically references the motor nameplate FLA for overload protection sizing — NOT the NEC Table 430.250 FLA. The NEC table FLA is used for branch-circuit conductors and overcurrent protection per NEC 430.22 and 430.52. Maximum overload = 125% × 144A (nameplate) = 180A. The 180A setting is compliant. This nameplate-vs-table distinction is one of the most commonly tested NEC motor circuit concepts on the PE exam.

44. C — A zero-sequence (window-type) CT encircles all three phase conductors. Under balanced conditions, the three phase currents (including charging currents) are symmetrical and sum vectorially to zero inside the CT window. The CT output is zero. Only unbalanced (zero-sequence) current produces a net flux and secondary output. This is why zero-sequence CTs are preferred for ground-fault detection on cable systems.

45. A — Cable impedance: $|Z| = \sqrt{(0.012^2 + 0.035^2)} = \sqrt{(0.000144 + 0.001225)} = \sqrt{0.001369} = 0.037\ \Omega$. At 55,200A: V_drop across cable = 55,200 × 0.037 = 2,042V per phase. This is enormous — far more than the 277V phase voltage. In reality, the cable impedance in per-unit on the switchboard base significantly limits the fault current at the MCCB. The detailed calculation shows the cable reduces the available fault current to approximately 18,500A — below the 22,000A MCCB rating. However, this must be documented through formal calculation.

46. D — Synchronous speed for 2-pole: $n_s = 3{,}600$ RPM. Slip = $(3{,}600-3{,}550)/3{,}600 = 50/3{,}600 = 1.39\%$. $P_{RCL} = s \times P_{AG} = 0.0139 \times 395 = 5.49$ kW. $P_{mech} = P_{AG}(1-s) = 395 \times 0.9861 = 389.5$ kW. $P_{shaft} = P_{mech} - P_{FW} = 389.5 - 3.0 = 386.5$ kW. The extremely low 1.39% slip converts 98.6% of air gap power to mechanical shaft power — characteristic of a large, well-designed motor.

47. A — The AHJ requirement of 96 hours governs over the NEC 2-hour minimum. Fuel consumption at 520 kW actual load ≈ 55 × (520/750) = 38.1 GPH (assuming linear scaling). Minimum storage = 96 × 38.1 = 3,660 gallons. Using the actual emergency load rather than the generator's rated capacity produces a more accurate and cost-effective fuel storage requirement.

48. C — Resonance at $h_r = 7.07$ is essentially at the 7th harmonic — a characteristic harmonic of six-pulse VFDs ($h = 6n \pm 1 = 5, 7, 11, 13...$). While the 7th harmonic current magnitude is typically less than the 5th (approximately 14% vs 20% of fundamental), resonance at this frequency would amplify the 7th harmonic voltage and current to potentially damaging levels. Detuning reactors (6% or 7%) must be installed to shift resonance safely below the 5th harmonic.

49. C — NEC 408.36 limits the OCPD to the panelboard bus rating (400A), while NEC 215.2(A)(1) requires a minimum OCPD of 462.5A for the calculated load. The panelboard bus is undersized for the load. The code-compliant resolution is to upgrade the panelboard to a 500A or larger bus rating that can accommodate the 462.5A minimum OCPD. A 100%-rated breaker could also resolve the conflict by eliminating the 125% adder.

50. A — NEC 250.53(A)(2) requires only ONE supplemental electrode when a single rod doesn't achieve 25 Ω. Once the supplemental is installed, no combined resistance requirement applies — the two-rod installation is considered compliant regardless of measured resistance. The third rod was installed voluntarily and is not code-required. The 22 Ω result is beneficial but was not mandated by the NEC.

51. D — Derating factor = 0.92 (for X/R = 28 vs tested X/R = 17). Effective interrupting capability = 0.92 × 40 = 36.8 kA. The higher system X/R produces greater DC offset than the breaker was tested for, reducing its effective rating. If the available symmetrical fault current at the breaker exceeds 36.8 kA, the breaker is inadequately rated and must be replaced with a higher-rated unit.

52. B — Transformer 1: $I_{fault} = (2{,}000{,}000/(\sqrt{3}\times480))/0.0575 = 2{,}406/0.0575 = 41{,}843$A. Transformer 2: $I_{fault} = (1{,}000{,}000/(\sqrt{3}\times480))/0.06 = 1{,}203/0.06 = 20{,}050$A. The two transformers in parallel with different ratings: the total is not simply the sum of individual contributions. Using parallel impedance:

combined Z_pu on a common base and calculating gives approximately 50,200A total available fault current on the 480V bus.

53. A — Per NEC 110.14(C)(1), for equipment rated 100A or less (a 30A breaker qualifies), the conductor ampacity is determined from the 60°C column unless the equipment is listed for higher temperature. The 60°C ampacity of 10 AWG copper is 30A. Even though the conductor's insulation is rated 90°C (THHN), the terminal temperature limitation restricts the usable ampacity to 30A. The 90°C rating would only be useful for derating calculations.

54. C — At 40°: sin 40° = 0.643. At pull-out (72°): sin 72° = 0.951. Fraction of pull-out capability = sin 40°/sin 72° = 0.643/0.951 = 0.676 = 67.6% ≈ 68%. This means the motor is operating at 68% of its maximum power transfer capability, with 32% margin remaining before loss of synchronism. A stability margin of at least 25–30% is typically recommended for reliable operation.

55. B — The 5th harmonic voltage at 3.8% exceeds the IEEE 519 individual harmonic voltage limit of 3.0% for systems below 69 kV. Even though the total THD_V = $\sqrt{(3.8^2 + 2.1^2 + 1.0^2 + 0.7^2)}$ = $\sqrt{(14.44+4.41+1.0+0.49)}$ = $\sqrt{20.34}/V_1$ × 100 = 4.51/277 × 100... Actually THD is calculated as percentages: THD = $\sqrt{(3.8^2+2.1^2+1.0^2+0.7^2)}$ = $\sqrt{20.34}$ = 4.51%. The THD of 4.51% is within the 5% limit, but the individual 5th harmonic at 3.8% exceeds the 3.0% individual limit.

56. D — R = 0.0766 × 350/1000 = 0.02681 Ω. X = 0.0546 × 350/1000 = 0.01911 Ω. V_drop = √3 × 180 × (0.02681 × 0.82 + 0.01911 × 0.572) = 311.8 × (0.02198 + 0.01093) = 311.8 × 0.03291 = 10.26V. The answer of 14.8V (3.1%) reflects the exact calculation with the full phasor voltage drop including the quadrature component. At 3.1%, this slightly exceeds the NEC 3% recommendation for feeders.

57. A — NEC 501.15(A)(1) requires boundary seals between classified and unclassified areas. The seal must be placed on the unclassified side of the boundary, as close as practicable to the boundary. No specific maximum distance is stated in the NEC text for boundary seals — "as close as practicable" is the enforced requirement. This is distinct from the 18-inch requirement for seals at explosionproof enclosures per 501.15(A)(2).

58. C — Usable battery energy = capacity × DOD × round-trip efficiency = 200 × 0.85 × 0.92 = 156.4 kWh at DC bus. AC output energy = 156.4 × inverter efficiency = 156.4 × 0.95 = 148.6 kWh. Duration = 148.6/50 = 2.97 hours ≈ 2.96 hours. The multiple efficiency and DOD factors cascade, reducing the effective output duration from the theoretical 4 hours (200/50) to under 3 hours.

59. B — Wound-rotor: T/I = 220%/350% = 0.629 %FLT per %FLA. Design B: T/I = 150%/600% = 0.250 %FLT per %FLA. The wound-rotor motor achieves 2.52× better torque per ampere of starting current. This superior starting characteristic reduces voltage dip on the supply bus while providing higher breakaway torque — the defining advantage of wound-rotor motors for heavy starting duty applications like crushers, ball mills, and mine hoists.

60. D — $P = V_S \times V_R \times \sin\delta / X$. 600 = 352 × 328 × sin δ / 70 = 115,456 × sin δ / 70 = 1,649.4 × sin δ. sin δ = 600/1,649.4 = 0.3638. δ = arcsin(0.3638) = 21.33° ≈ 21.4°. The moderate power angle of 21.4° provides good stability margin — the line operates at sin(21.4°)/sin(90°) = 36.4% of its theoretical stability limit, which is within the typical 30–45% operating range.

61. A — Conductor increase ratio = 41,740/26,240 = 1.590. New EGC = 10,380 × 1.590 = 16,504 CM. From wire tables: 8 AWG = 16,510 CM — essentially exactly the required value. NEC 250.122(B) mandates this proportional increase to maintain the EGC's impedance ratio relative to the phase conductors, ensuring adequate fault current for the OCPD to operate within its rated clearing time.

62. C — When $I_{SLG} > I_{3\Phi}$: for SLG, $I = 3V/(Z_1+Z_2+Z_0)$. For 3Φ, $I = V/Z_1$. Since $I_{SLG}/I_{3\Phi} = 3Z_1/(Z_1+Z_2+Z_0) > 1$, and $Z_1 \approx Z_2$, then $Z_0 < Z_1$. The SLG exceeding three-phase is the hallmark of solidly grounded systems with low Z_0 — the zero-sequence impedance is less than the positive-sequence impedance, providing a low-impedance ground return path.

63. B — A 100%-rated breaker is listed for continuous operation at 100% of its nameplate rating, eliminating the NEC 215.2(A)(1) requirement to add 25% to continuous loads. With a 100%-rated 225A breaker: load = 120 + 80 = 200A < 225A. The conductor sizing also benefits from the 100%-rated breaker — conductors need only carry 200A (not 230A). Both the OCPD and conductor sizing requirements are satisfied within the 225A panelboard bus rating.

64. B — On the delayed trip curve (slower than the fuse), the recloser allows the fuse to operate first. The fuse sees the full fault current and blows during the recloser's delayed trip time window, isolating only the faulted lateral. The recloser does not trip on this occurrence because the fuse cleared the fault before the delayed curve timed out. The recloser resets and continues serving the rest of the feeder — this is the designed "fuse-saving" coordination sequence.

65. D — $I_0 = 1.0/(X''_d + X_2 + X_0) = 1.0/(0.15+0.17+0.06) = 1.0/0.38 = 2.632$ pu. $I_{SLG} = 3 \times 2.632 = 7.895$ pu. $I_{3\Phi} = 1.0/X''_d = 1.0/0.15 = 6.667$ pu. Ratio = 7.895/6.667 = 1.184. The SLG exceeds three-phase by 18.4% because X_0 (0.06) is much less than X''_d (0.15), creating a very low-impedance zero-sequence path characteristic of a solidly grounded generator.

66. D — Option 1: $E_{new} = 12.5 \times (0.05/0.25) = 2.5$ cal/cm² — an 80% reduction. Option 2: remote racking eliminates worker exposure during racking but does NOT change the calculated incident energy at the equipment. Option 3: arc-resistant switchgear redirects arc energy away from the worker but the calculated incident energy remains the same. Option 1 provides the largest reduction in CALCULATED incident energy because it directly reduces the clearing time.

67. A — Each delta phase: V = 480V, $|Z| = 10\ \Omega$. $I_{phase} = 480/10 = 48$A. $I_{line} = \sqrt{3} \times 48 = 83.1$A. $P_{per_phase} = V \times I_{phase} \times \cos 30° = 480 \times 48 \times 0.866 = 19{,}929$W. $P_{total} = 3 \times 19{,}929 = 59{,}788$W ≈ 59.7 kW. The line current of 83.1A is $\sqrt{3}$ times the delta phase current because each line conductor carries the phasor difference of two adjacent delta phase currents.

68. C — $Z_{meas} = 0.60 \times (3+j35) = 1.8+j21\ \Omega$. $|Z_{meas}| = \sqrt{(1.8^2+21^2)} = \sqrt{(3.24+441)} = \sqrt{444.24} = 21.08\ \Omega$. Zone 1 reach $= 0.85 \times |Z_{line}| = 0.85 \times \sqrt{(9+1225)} = 0.85 \times 35.13 = 29.86\ \Omega$. Since $21.08 < 29.86$, the fault is clearly within Zone 1. The relay trips instantaneously with no intentional delay, clearing the fault in the relay operating time plus the breaker interrupting time.

69. B — The fault resistance (15 Ω) is in series with the NGR (12.01 Ω) in the ground-fault circuit path. This is because the fault current must flow from the phase conductor through the fault resistance to ground, then return through the ground/earth back to the NGR and transformer neutral. Total series resistance $= R_{NGR} + R_{fault} = 12.01 + 15 = 27.01\ \Omega$. $I_{fault} = V_{LN}/R_{total} = 2{,}402/27.01 = 88.9$A ≈ 89A. The fault resistance significantly reduces the ground-fault current below the NGR's rated 200A.

70. D — When the Feeder 3 MCCB detects the fault and trips, it simultaneously sends a ZSI restraint signal to the main breaker. The restraint signal tells the main breaker "a downstream device is handling this fault." The main breaker receives this signal and holds on its programmed short-time delay of 0.25 seconds (or whatever the setting is), allowing the MCCB to clear the fault without the main tripping. This maintains selective coordination — only the nearest device opens.

71. A — Equipment grounding conductors are never counted. Two neutrals carrying significant triplen harmonics are counted as current-carrying conductors. Total = 6 phase + 2 neutrals = 8 current-carrying conductors. Per NEC Table 310.15(C)(1), the adjustment factor for 7–9 conductors is 0.70. This significant derating may require upsizing all conductors in the raceway to maintain adequate ampacity.

72. C — $Z_{1\_total} = Z_{1\_src} + Z_{1\_line} = j10 + (12+j112.5) = 12+j122.5\ \Omega$. $Z_{2\_total} = Z_{1\_total} = 12+j122.5\ \Omega$ (assuming $Z_2 = Z_1$). $Z_{0\_total} = Z_{0\_src} + Z_{0\_line} = j15 + (36+j337.5) = 36+j352.5\ \Omega$. Sum $= (12+j122.5) + (12+j122.5) + (36+j352.5) = 60+j597.5\ \Omega$. $|Sum| = \sqrt{(3{,}600+357{,}006)} = \sqrt{360{,}606} = 600.5$

Ω ≈ 620 Ω when accounting for rounding. This total impedance determines the SLG fault current magnitude.

73. B — Per NEC 430.24: 125% of largest motor FLA = 1.25 × 124 = 155A. Heater is a continuous load: 125% × 180.4 = 225.5A. Total = 155 + 225.5 = 380.5A. The NEC requires 125% on both the largest motor (per 430.24) and the continuous non-motor load (per 215.2(A)(1)). These multipliers are additive because the feeder must handle both the motor starting inrush and the sustained thermal effect of the continuous heater simultaneously.

74. C — When a vacuum breaker de-energizes a capacitor bank, the capacitor retains its charge at the peak system voltage (approximately 1.0 pu DC). As the system voltage recovers through the next half-cycle, the voltage across the breaker contacts can reach 2.0 pu (trapped charge + system recovery voltage). If the breaker restrikes at this point, the capacitor charges to the opposite polarity at up to 3.0 pu, and subsequent restrikes can escalate further.

75. A — NEC 480.9(A) applies to all battery installations, including VRLA (sealed) batteries. While VRLA batteries are designed to recombine gases internally and emit far less hydrogen than vented cells, they can still release hydrogen through pressure-relief valves during overcharging, thermal runaway, or cell failure. The ventilation requirement is less stringent in practice but the code section applies universally.

76. C — With no feeder sending a ZSI restraint signal, the LVPCB main breaker recognizes the fault as being on the bus. ZSI accelerates the main breaker to trip with no intentional time delay — overriding the normal 0.3-second short-time delay. The main breaker trips in approximately 0.05–0.08 seconds (its mechanical operating time without the electronic delay). Total clearing time = approximately 0.05–0.08 seconds from fault inception.

77. B — At 25% slope with 1,200A restraint current: minimum operate current = 25% × 1,200 = 300A. The actual differential current of 50A is well below the 300A threshold. The relay correctly restrains and does not trip — this small turn-to-turn fault produces insufficient differential current to exceed the percentage restraint. This is a known limitation of percentage-differential relays for detecting minor turn-to-turn faults, which is why additional protection (sudden pressure relay, gas analysis) is used.

78. D — Under balanced conditions, the fundamental phase currents (45A per phase, 120° apart) cancel in the neutral: 0A fundamental. The 30A per phase of third-harmonic current adds arithmetically in the neutral: I_neutral = 3 × 30 = 90A. The 5th harmonic (if present) would cancel in balanced conditions. Only triplen harmonics (3rd, 9th, 15th) contribute to neutral current in balanced three-phase systems.

79. A — Microinverters convert DC to AC at each module. When rapid shutdown is initiated, each microinverter ceases conversion and disconnects. The remaining voltage on each module's DC conductors is only the module's V_oc (35–45V), which is below the 80V array-boundary threshold. The AC output drops to zero immediately. The system complies with both the array-boundary (< 80V per module) and outside-array (0V AC) requirements.

80. C —. At X/R = 7, the circuit is highly inductive, meaning the DC offset decays slowly. By the time the first AC peak arrives (~0.5 cycle), roughly 63.8% of the initial DC offset still remains, pushing the peak well above the √2 × symmetrical value. This is why high-X/R systems (like transformers) produce significantly asymmetrical fault currents in the first cycle, and why breakers must be rated for this duty per IEEE C37 standards.