

Module 1.4 — Branch Circuits, Feeders & Panelboards

The panelboard is the hub. The 125% rule with worked feeder examples, the 3-phase panel, a step-by-step install from the NEMA and Schneider instructions, the service bond, MWBCs, and GFCI.

Why this module. Raceway, conductors, and terminations all come together at the **panelboard**, the hub where feeders come in and branch circuits go out. This is where 3-phase power gets divided, where the building's most important safety rule (the neutral-ground bond) lives, and where one wrong move creates a real hazard: a double bond, an overloaded phase, an open shared neutral, or an undersized breaker on a continuous load. This version adds the full install from the NEMA panelboard instructions and the Schneider NQ bulletin, worked feeder and balancing examples, the pre-energize test, and the energize sequence.

Part A — Branch Circuits vs. Feeders, and the 125% Rule

- A **feeder** runs between pieces of distribution equipment, for example from a switchboard to a panel. A **branch circuit** is the final wiring from the last breaker to the load.
- A **continuous load** is one that runs 3 hours or more, like office lighting.

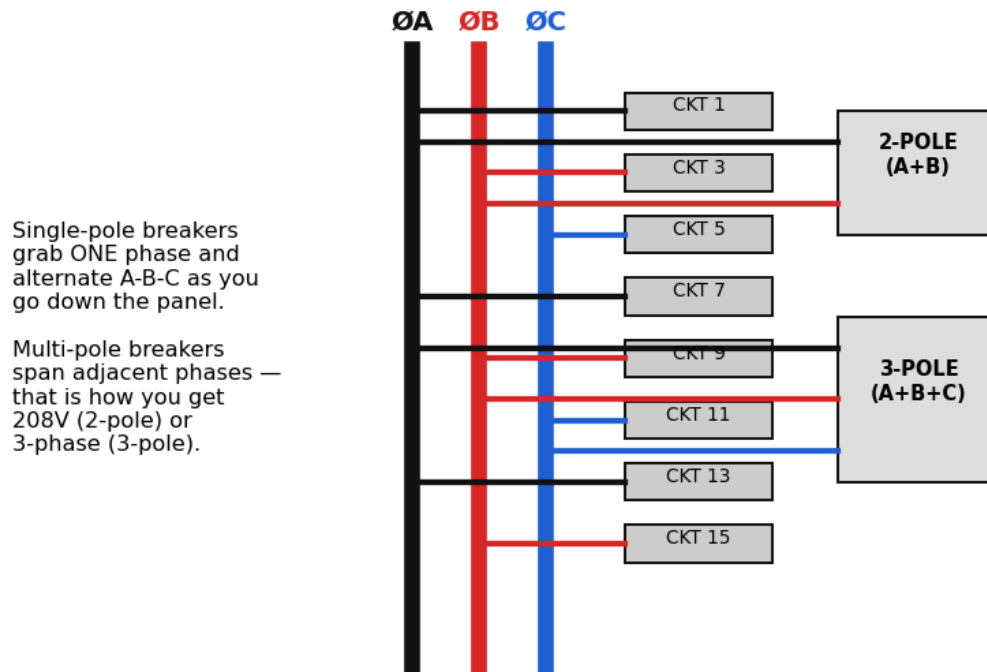
Rule	NEC 2026	What it says
Branch conductor size	210.19(A)(1)	Ampacity "not less than the noncontinuous load plus 125 percent of the continuous load"
Branch breaker size	210.20(A)	Rating "not less than the noncontinuous load plus 125 percent of the continuous load"
Feeder conductor size	215.4(A)(1) (215.2 in 2023)	Same 125 percent rule. A neutral not connected to a breaker may be sized at 100 percent
Feeder breaker size	215.5 (215.3 in 2023)	Same 125 percent rule
Feeder ground	215.6	The feeder "shall include or provide an equipment grounding conductor"
Small conductors	240.4(D)	14 AWG copper max 15 A, 12 AWG max 20 A, 10 AWG max 30 A, after any correction factors
Next size up	240.4(B)	If the conductor ampacity falls between standard breaker sizes, the next higher standard size is allowed up to 800 A
Receptacle load	120.14(I) (220.14(I) in 2023)	180 VA for each single or multiple receptacle on one yoke

Standard breaker sizes (Table 240.6(A)) include 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, and 400 A.

- **Worked example 1, a branch circuit.** 277 V lighting at **16 A continuous**. Breaker at least $16 \times 1.25 = \mathbf{20\ A}$. 12 AWG THHN is 25 A at 75°C, but 240.4(D) caps it at a 20 A breaker, so 12 AWG on a 20 A breaker works. Turned around, the most continuous load a 20 A breaker can carry is $20 \div 1.25 = 16\ \text{A}$, which is 4,432 VA at 277 V.
- **Worked example 2, a feeder to a 208Y/120 V panel.** 40,000 VA of continuous lighting and 20,000 VA of noncontinuous receptacle load after demand factors.
 1. Line current: $60,000 \div (208 \times 1.732) = 166.5\ \text{A}$. The continuous part is 111.0 A and the noncontinuous part 55.5 A.
 2. Breaker (215.5): $55.5 + 1.25 \times 111.0 = 194.3\ \text{A}$, so a **200 A** breaker.
 3. Phase conductors (215.4(A)(1)): at least 194.3 A at 75°C. **3/0 copper** is 200 A at 75°C.
 4. Neutral: 100 percent of 166.5 A, so 2/0 copper (175 A), unless most of the load is nonlinear. Then the neutral is a current-carrying conductor (310.15(E)(1)) and you run it full size.
 5. Ground: size it from Table 250.122 for a 200 A breaker.
 6. Panel: rated at least 200 A (408.36), for example a 225 A panel with a 200 A main.
- **Worked example 3, derating.** Six 12 AWG THHN hots in one EMT: $30\ \text{A}\ (90^\circ\text{C}) \times 0.80 = 24\ \text{A}$, still fine on a 20 A breaker. With 10 to 20 in one pipe: $30 \times 0.50 = 15\ \text{A}$, and the 12 AWG becomes a 15 A conductor.

Part B — The 3-Phase Panelboard

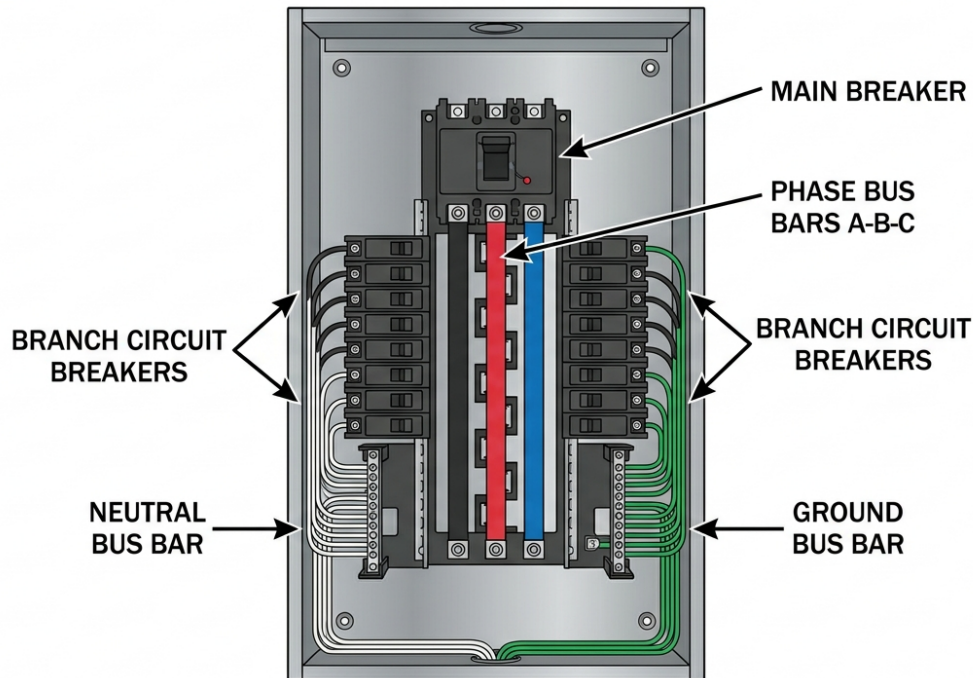
HOW BREAKERS LAND ON THE 3-PHASE BUS



Single-pole breakers grab one phase and alternate A-B-C; multi-pole span adjacent phases for 208V or 3-phase.

- **1-pole** = one phase (120 or 277 V to neutral). **2-pole** = two phases (208 or 480 V). **3-pole** = all three.
- **Main breaker vs. MLO.** A main-lugs-only (MLO) panel has no main breaker of its own and is protected by the breaker upstream.
- **Bus arrangement** (NEC 2026 408.10(E)(1), 408.3(E)(1) in 2023): A, B, C "from front to back, top to bottom, or left to right, as viewed from the front." On a high-leg delta, B is the high leg, orange, with a caution label (Module 1.0B).

COMMERCIAL PANELBOARD



Main breaker, A-B-C phase bus, branch breakers, neutral bus (white), ground bus (green).

NEC 2026	Rule
408.14 (408.30 in 2023)	Panel current rating "not less than the minimum calculated load"
408.36	"Protected by an OCPD having a rating not greater than that of the panelboard," inside the panel or upstream. A backfed plug-in main breaker must be "secured in place by an additional fastener"
408.6	Short-circuit rating not less than the available fault current. Fault current and the date of the calculation field-marked on the enclosure
408.7	Unused breaker openings "closed using identified closures" (filler plates)
408.54	A physical means prevents installing more breakers than the panel is listed for
408.40	Ground bar "bonded to the cabinet and panelboard frame." Grounds go on the neutral bar only where that is permitted (the service)
408.41	Each neutral lands in "an individual terminal that is not also used for another conductor"

Use the panel maker's breakers. The Schneider NQ bulletin: "Use only Square D brand circuit breakers and accessories." Breakers from another maker go in only if they are UL-classified for that panel and the panel is on their compatibility list (NEC 110.3(B)). On a 240 V delta panel, do not use breakers rated 120 V or 120/240 V, and "two-pole CAFI circuit breakers cannot be used on three-phase systems."

Balancing a panel schedule

A 1-pole 120 V load sits 100 percent on its phase. A 2-pole 208 V load counts half on each of its two phases. A 3-pole load counts one-third on each phase.

Load	VA	A	B	C
3-pole unit, 10,000 VA	10,000	3,333	3,333	3,333
2-pole 4,160 VA on A-B	4,160	2,080	2,080	—
9 receptacle circuits × 1,440 VA (8 × 180): 2 on A, 3 on B, 4 on C	12,960	2,880	4,320	5,760
6 lighting circuits × 1,500 VA, 2 per phase	9,000	3,000	3,000	3,000
Phase total	36,120	11,293	12,733	12,093
Amps (VA ÷ 120)		94.1	106.1	100.8

Worked example 4. The imbalance by the method in Module 1.0B is $(12,733 - 11,293) \div 12,733 = \mathbf{11.3 \text{ percent}}$, over the 10 percent trigger, so move circuits. Notice the shortcut of total VA ÷ 360 gives 100.3 A and hides the 106.1 A on B. Always size and check on the heaviest phase. The federal design standard says "phase loading on panelboards shall be balanced as much as practical by the type of loads."

Part C — STEP-BY-STEP: Installing & Landing a Panelboard

Steps follow NEMA PB 1.1 (General Instructions for Proper Installation, Operation, and Maintenance of Panelboards) and the Schneider NQ/NQM instruction bulletin 80043-712-06. Schneider: "Refer to the torque information label provided on the panelboard before tightening."

1. **Receive and inspect.** Store the panel "in a clean, dry place." Check for shipping damage and that the interior is "the correct one for installation in the cabinet."
2. **Check the location.** Away from flammables, not over 40°C (104°F), no dripping water. In damp or wet places leave a ¼-inch air space behind the cabinet. Lay out the working space before you mount: 30 inches wide or the width of the panel, 6½ feet of headroom, doors open 90 degrees, and depth from Table 110.26(A)(1) (3 feet at 0–150 V to ground; 3, 3½, or 4 feet at 151–600 V depending on what is across from it). No storage in it (110.26(B)). Full layout steps are in Module 1.1.
3. **Mount the cabinet** plumb and level with a 4-foot level, on wedge anchors or strut. NEC 2026 110.13(A): no wooden plugs in masonry or concrete. A flush cabinet in a noncombustible wall may be set back no more than ¼ inch from the finished surface (312.5). In a wood wall it sits flush or proud.
4. **Open the knockouts** the NEMA way: "Remove knockouts, ONE AT A TIME, alternating INWARD and OUTWARD." Push the center slug in with a screwdriver against the point farthest from the tie, then the rings one at a time. Raceways entering the bottom may rise no more than 3 inches above the bottom of the enclosure (408.5). Land each raceway with

a connector, locknut, and insulated bushing. Close every unused opening (110.12(A), 408.7).

5. **Set the interior.** Surface mount: deadfront off, interior on the studs, then "Tighten the Keps nuts against the interior side rails until the rails are against the back of the enclosure." Flush mount: use the four elevating screws in the side rails and "Adjust the screws so that the lip of the deadfront is approximately 0.25 inches (6.35 mm) from the wall line," then tighten the Keps nuts. Clean any plaster or paint off the contacts. Do not use spray cleaners.
6. **Neutral: bond or isolate** (Part D). Schneider: "The neutral bonding strap/cable should be used only when the panelboard is installed as service entrance equipment." Install the ground bar kit at "the ground symbol stamped into the back wall." One kit covers 1 to 42 circuits. Use two for 54 to 84.
7. **Land the feeder.** Strip without nicking. For aluminum, clean off the oxide and apply anti-oxidant. Check that the conductor temperature rating suits the lugs. Torque to the label with a calibrated tool (NEC 2026 110.14(D)). For neutrals 3 AWG and larger, NQ panels have an oversized neutral kit.
8. **Install the breakers** with the power off, breaker OFF, deadfront off. "Snap the wire terminal end of the circuit breaker onto the mounting rail." Plug-on QO breakers: "Push inward until the plug-on jaws fully engage." Bolt-on QOB breakers: center on the hole, engage the screw, and torque per the interior diagram. A backfed main must be bolt-on.
9. **Land the branch circuits.** Hot to its breaker at the breaker's torque. Each neutral in its own terminal (408.41). Each ground on the ground bar. Group the conductors of each multiwire circuit together. Where two voltage systems exist, post the color code (210.5(C) (2)). Alternate A-B-C as you go so the phases stay balanced.
10. **Install a filler plate** in every unused breaker space. Schneider: "Install a filler plate in all branch circuit breaker spaces not used."
11. **Fill out the circuit directory** (408.4(A)): "legible and permanent," on or inside the door, "specific to the purpose or use of each circuit including spare positions." Write "Lights, Room 102," not "lights."
12. **Mark the labels:** available fault current and date and the panel's short-circuit rating (408.6), the arc-flash label (110.16), and the high-leg caution label if it applies.

Square D QO/QOB wire-binding screw	Torque
10-30 A, 1-, 2-, and 3-pole	36 lb-in
35-70 A 1- and 2-pole; 40-60 A 3-pole	45 lb-in
70-100 A 3-pole; 80-125 A 2-pole	50 lb-in
150-200 A 3-pole; QOB-VH 150 A	250 lb-in
QO tandem	25 lb-in

Schneider Electric FAQ FA128927. NQ neutral bonding strap screws: 10-32 at 10-12 lb-in, ¼-20 at 25-30 lb-in. The label on the breaker governs.

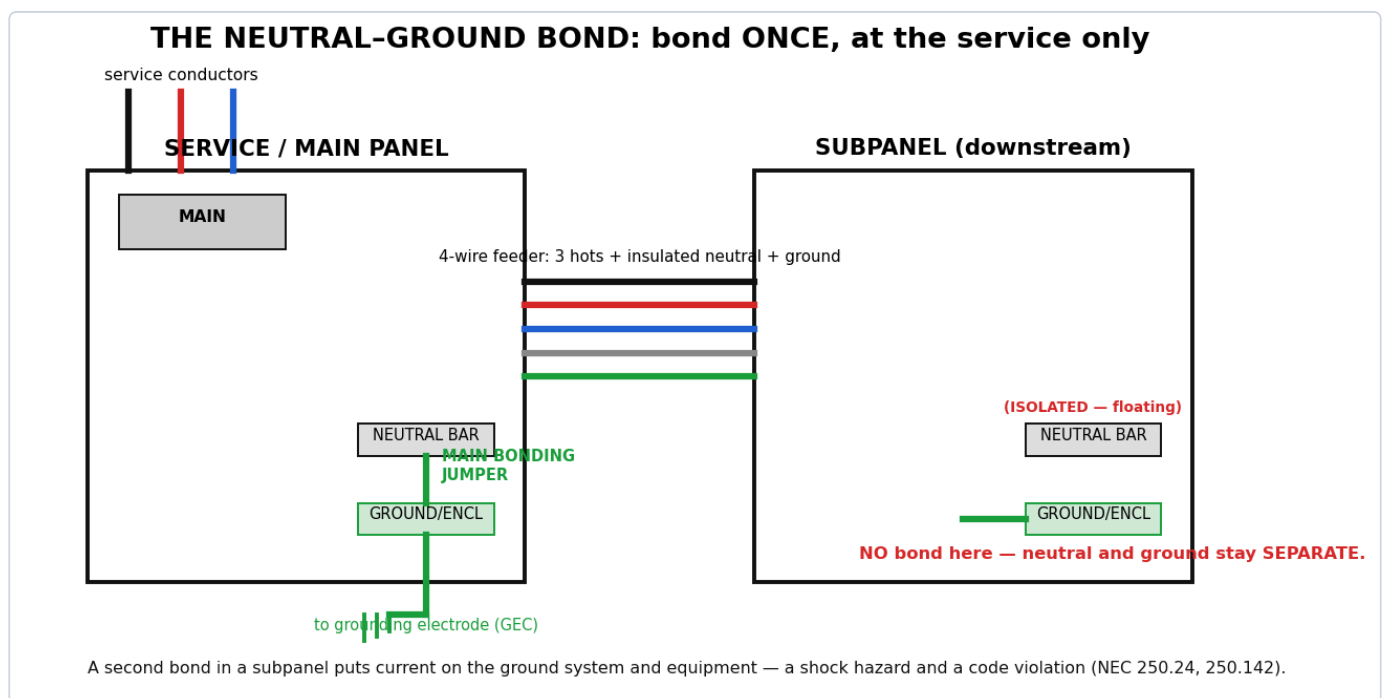
Pre-energize test and energize sequence (NEMA PB 1.1)

1. Check every accessible connection for torque. Remove shipping blocks. "Manually exercise all switches, circuit breakers."
2. Insulation-resistance test phase to ground and phase to phase, with the breakers open and then closed. NEMA: "If the resistance reads less than 1 megohm while testing with the branch circuit devices in the open position, the system may be unsafe."
3. On a service panel, "make certain that the neutral ... is properly bonded." Remove all foreign material. Fillers in every space.
4. Energize with a qualified person, and with no load: "There should be no load on the panelboard when it is energized."
5. "Energize the main devices, then the feeder devices, and then the branch-circuit devices. Turn the devices on with a firm positive motion."
6. Check line-to-line and line-to-neutral voltages and phase rotation before you release any 3-phase loads.

Maintenance

NEMA PB 1.1 calls for inspection yearly or after any severe fault. Brush or vacuum the dust; "Do not use a blower or compressed air." Discoloration or pitting means a loose or overheated joint; de-energize and repair it per the manufacturer. Re-test insulation after a fault, a parts change, or moisture. Do not re-torque connections that look and scan fine (Module 1.3).

Part D — STEP-BY-STEP: The Service Bond (and never in a subpanel)



Bond once, at the service. Subpanels get a 4-wire feed with an ISOLATED neutral and a separately-bonded ground.

NEC 2026	Rule
250.24(A)(1)	The grounding electrode conductor lands "to the terminal or bus to which the grounded service conductor is connected at the service disconnecting means"
250.24(B)	On the load side of the service, the neutral "shall not be connected to normally non-current-carrying metal parts of equipment, to equipment grounding conductor(s), or be reconnected to ground"
250.24(C)	"An unspliced main bonding jumper shall be used" at the service disconnect
250.28	A screw main bonding jumper is "identified with a green finish"
250.30(A)(1)	A transformer secondary gets its own system bonding jumper, the same one-bond logic
250.142(B)	Load side: neutrals "shall not be connected to non-current-carrying metal parts of equipment"

At the service

1. Install the main bonding jumper (the green screw or the strap) tying the neutral bar to the enclosure, at the bulletin's torque.
2. Land the grounding electrode conductor on the neutral bus, or on the ground bar the bonding jumper lands on.

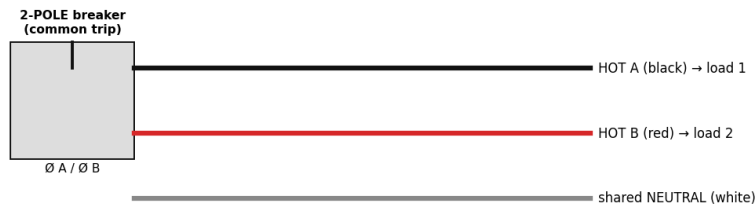
At a subpanel

1. Leave the bonding strap or screw in the bag. The **neutral bar floats** (isolated from the can).
2. Install a separate ground bar bonded to the enclosure. NEMA: the ground bar "is not connected to the neutral bar except at service equipment ... or at separately derived systems."
3. Feed it **4-wire**: three hots, an insulated neutral, and a ground.
4. Check after energizing: with load on, clamp the feeder ground conductor. Steady current on the ground means a neutral is bonded to ground somewhere downstream.

Never bond neutral to ground in a subpanel. The Navy electrician manual: a load-side bond "would be extremely hazardous if the neutral became loosened or disconnected ... any line-to-neutral load would energize all metal components connected to the neutral." A second bond also puts normal current on the ground system and the conduit.

Part E — Multiwire Branch Circuits (MWBC)

MULTIWIRE BRANCH CIRCUIT (MWBC) — shared neutral



The two hots must be on DIFFERENT phases so the neutral carries only the DIFFERENCE, not the sum. A common-trip 2-pole breaker (or handle tie) is required (NEC 210.4) so both hots de-energize together.

Hots on different phases share a neutral that carries only the difference.

A multiwire branch circuit is two or three hots sharing one neutral.

- **210.4(A):** all conductors "shall originate from the equipment containing the overcurrent protective device."
- **210.4(B):** "a means that will simultaneously disconnect all ungrounded conductors at the point where the branch circuit originates." A multi-pole breaker, or single-pole breakers "with identified handle ties" where the circuit serves only line-to-neutral loads (240.15(B)(1)). A handle tie gives common switching. A true 2- or 3-pole breaker also trips all poles together on a fault.
- **210.4(C):** it "shall supply only line-to-neutral loads," unless the breaker opens all hots together.
- **210.4(D):** group the conductors of each MWBC together in the panel (per 200.6(B), 200.4(B) in 2023).

Worked example 5, the shared neutral. Using the neutral formula from Module 1.0B on a wye: 16 A on A and 10 A on B gives $\sqrt{(16^2 + 10^2 - 16 \times 10)} = \mathbf{14\ A}$ on the neutral. Three balanced phases give about 0 A. Put both hots on the **same** phase by mistake and the neutral carries the sum, **26 A**, on a wire sized for 20.

Two MWBC rules you never break. (1) Hots on **different phases**. (2) Never open a shared neutral under load. An open neutral puts the full 208 or 240 V across loads in series, and something burns up.

Part F — GFCI & Required Protection

NEC 2026 210.8(B), other than dwelling units: all 125 through 250 V receptacles on single-phase circuits of 150 V or less to ground and 50 A or less, and on three-phase circuits of 150 V or less to ground and 100 A or less, need GFCI protection in these locations:

1. Bathrooms	2. Kitchens	3. Sink or food-prep areas	4. Buffet serving areas
5. Rooftops	6. Outdoors	7. Within 6 ft of a sink	8. Indoor damp locations
9. Indoor wet locations	10. Locker rooms with showers	11. Garages and service bays	12. Crawl spaces
13. Unfinished basements	14. Within 6 ft of pools and tubs	15. Laundry areas	16. Within 6 ft of a tub or shower

- **Required service receptacle (210.63):** a 125 V, 15 or 20 A receptacle within 25 feet of HVAC equipment on the same level, and one in the same room as indoor switchboards, panelboards, and motor control centers.
- **AFCI (210.12(D))** in commercial buildings applies to hotel and motel guest rooms, nursing-home sleeping rooms, and sleeping quarters in fire, police, and ambulance stations. An ordinary office, store, or warehouse panel needs no AFCI breakers.

Common mistakes

Mistake	Rule
Two neutrals under one screw	408.41. Servicing one circuit opens the other's neutral
Grounds on a subpanel neutral bar	408.40
Bonding strap left in a subpanel	250.24(B), 250.142(B)
Other-brand breakers	110.3(B); the panel's listing
No directory, or "spare" written on a live circuit	408.4(A)
Derating not applied	Table 310.15(C)(1), then 240.4(D)
Torque by feel	110.14(D)
Empty spaces with no fillers	408.7
MLO panel with no upstream breaker at or below its rating; plug-in backfed main with no retainer	408.36
Energizing under load; cleaning with compressed air	NEMA PB 1.1

Inspection checklist before the cover goes on

- Working space clear and to size. Cabinet plumb, secured, flush within ¼ inch.
- Every raceway bushed. Every unused opening closed. Every unused space filled.
- Bond only at the service. Subpanel neutral floating, ground bar bonded, 4-wire feed.
- One neutral per terminal. Grounds on the ground bar. MWBCs grouped with common disconnect.
- Every lug and breaker torqued to its label and marked.

- Directory complete and specific. Fault-current, arc-flash, and high-leg labels on.
- Insulation test above 1 megohm. Phases balanced within about 10 percent.

Safety. Schneider: "Turn off all power supplying this equipment before working on or inside equipment." "Always use a properly rated voltage sensing device to confirm power is off." "Replace all devices, doors, and covers before turning on power." Follow the NFPA 70E (2024) Article 120 steps to an electrically safe work condition: identify all sources, open the disconnects, look to confirm, release stored energy, lock and tag, then test each phase conductor at each point of work, phase to phase and phase to ground, with a meter proved on a known source before and after. A non-contact tester is not acceptable for this test.

NEC 2026 Checkpoints (2023 number in parentheses where it moved)

- **210.19, 210.20(A)** 125% [quoted] • **215.4(A)(1)** (215.2), **215.5** (215.3), **215.6** feeders • **240.4(B), (D)**, Table 240.6(A).
- **120.14(I)** (220.14(I)) receptacle load • Article 120 (Article 220) load calculations.
- **408.4, 408.6, 408.7, 408.10(E)** (408.3(E)), **408.14** (408.30), **408.36, 408.40, 408.41, 408.54**.
- **250.24, 250.28, 250.30, 250.142** bonding • **210.4** MWBC • **210.8(B), 210.12(D), 210.63** • **110.26** working space.

Hands-On Field Exercise

- **Mount and land** a 3-phase panelboard by the NEMA steps: knockouts one at a time, interior set, feeder, neutral, ground, then six branch circuits balanced A-B-C. Torque every lug to its label, install fillers, and fill out the directory.
- Work the 200 A feeder example and size the breaker and wire for a **16 A continuous** load (20 A).
- Balance a panel schedule on paper and find the heaviest phase.
- Set the **main bonding jumper** at a service. Confirm a subpanel's neutral is isolated and the feed is 4-wire.
- Wire a 2-pole **MWBC** (different phases, common trip). Measure the neutral current balanced and unbalanced, and compare to the formula.
- Megger a panel before energizing, then energize it in the NEMA order with no load.

Sources used in this module (public documents)

- NFPA 70, National Electrical Code 2026 (free read-only access at [nfpa.org](https://www.nfpa.org)).
- NEMA PB 1.1, General Instructions for Proper Installation, Operation, and Maintenance of Panelboards Rated 600 Volts or Less.
- Schneider Electric Instruction Bulletin 80043-712-06, NQ/NQM Panelboards; Schneider FAQ FA128927, QO breaker torque: [se.com](https://www.se.com)
- UFC 3-520-01 Interior Electrical Systems: [wbdg.org](https://www.wbdg.org)
- NAVEDTRA 14027 Construction Electrician Intermediate, Chapters 5 and 7.

- OSHA 29 CFR 1910.303(g) and 1926.417: [osha.gov](https://www.osha.gov). NFPA 70E, 2024 edition.

Next: Module 1.5 — Distribution, Switchboards & Transformers.