1

Doug Smith, MCP/CBO

- Inspector/Plan Reviewer for over 19 years
- 19 ICC certifications
- Certified Master Code Professional and CBO
- Taught electrical and solar PV classes for over 13 years
- Performed thousands of electrical and solar reviews
- Serve on *NEC* CMP 10 representing IAEI.
- Currently serve as an STP Member for the following UL standards:
  - UL 1703 (61730) – Flat-Plate PV Modules and Panels
  - UL 1741 - Inverters, Converters, Controllers, and Int. equip…
  - UL 2703 – PV Mounting Systems/Clamps/Gnd. Lugs
  - UL 6703 – Connectors for Use in PV Systems
  - UL 9540 - Energy Storage Systems and Equipment

2

Course Objective/Intent

- The objective of this presentation is to explain some of the core *NEC* requirements of Articles 225, 230, 240, and 250. This presentation is based on the 2020 *NEC*.
- The intent of this information is to be used as a guide only. This presentation is not intended to indicate any change in any code or local requirements by inference or omission. All diagrams are for illustration purposes only and actual wiring and installation may vary. This presentation is not intended to indicate if one piece or particular brand of equipment is better than another. Also, efficiency and ideal design considerations are not addressed herein. All codes and manufacture requirements must always be followed when designing, installing, and inspecting electrical systems and equipment.

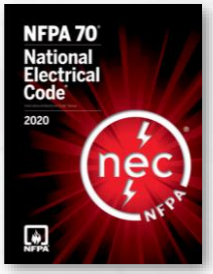
3

Topics to be covered:

- Article 225:
  - Number of supplies to a bld
  - Location of disconnects
  - Rating of disconnects
- Article 230:
  - Numbers of services
  - Overhead services
  - Clearances
  - Service entrance conductors
  - Surge protection
  - Number of service disconnects
  - Ground fault protection of equipment
- Article 240:
  - General OCPD requirements
  - Feeder taps
  - Secondary conductors for transformers
  - Basic transformer requirements
  - Location of OCPDs
  - Series rating of equipment
- Article 250
  - Key grounding and bonding requirements
  - Fault current pathway
  - Grounding of services
  - Separately derived systems
  - Grounding electrodes
  - GEC & EGC requirements

4

NEC Article 225
Outdoor Feeders & Branch Circuits



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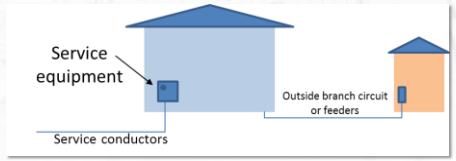
5

225.30 Number of Supplies to a Building

- Where a building or structure is served by a branch circuit or feeder on the load side of a service disconnect, there must only be one feeder or branch circuit that supplies such building or structure, unless permitted per (A) through (F):



6

225.30 Number of Supplies to a Building (continued)

- **(A)** Additional feeders or branch circuits (more than one) are permitted to supply the following:
  - Fire pumps
  - Emergency systems
  - Legally required standby systems
  - Optional standby systems
  - Parallel power production systems
  - Systems designed for connection to multiple sources of supply for enhanced reliability
  - Electric vehicle charging/power transfer systems which are listed, labeled, and identified for more than a single branch circuit or feeder
  - Docking facilities and piers

7

225.30 Number of Supplies to a Building (continued)

(B) Common Supply Equipment.

- There are allowed to be up to 6 sets of feeders that feed a separate building but each set of such feeders must originate in the same panelboard. Also, at the separate building (termination point) each set of feeders must have its own disconnect and the disconnects must be grouped together at the separate building.

8

225.30 Number of Supplies to a Building (continued)

- **(C)** Additional feeders or branch circuits are permitted by special permission for either of the following:
  - Multiple-occupancy buildings where there is no space for supply equipment which is accessible to all occupants of the building served.
  - A single building that is large enough to make more than one supply necessary.

9

9

225.30 Number of Supplies to a Building (continued)

- **(D)** Additional feeders or branch circuits are permitted when the supply capacity is required to be over 2,000A.

Capacity Required > 2,000A

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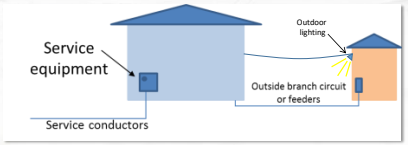
225.30 Number of Supplies to a Building (continued)

- **(E)** Additional feeders or branch circuits are permitted to supply systems of different voltages, frequencies, phases, or for different uses such as control of outside lighting from multiple locations.



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225.30 Number of Supplies to a Building (continued)

- **(F)** Additional feeders or branch circuits shall be permitted to supply buildings or structures that are under a single management and where documented safe switching procedures are established and maintained for disconnection.

12

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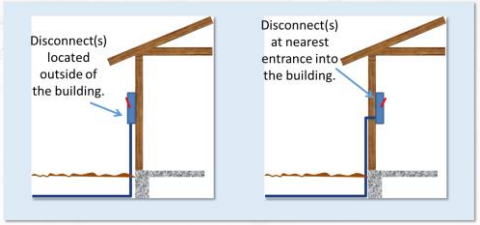
225.32 Location of Disconnect

- The disconnecting means is required to be installed at a readily accessible location either outside of the building or at the nearest point of entrance of the conductors in the building.



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13

225.32 Location of Disconnect (continued)

- **Exception #1:** Where the installation is under single management and there are documented safe switching procedures, and where the installation is monitored by qualified individuals, then the disconnecting means is allowed to be located elsewhere on the premises.
- **Exception #2:** Buildings falling under the provisions of Article 685 are permitted to have the disconnecting means located elsewhere on the premises. (integrated electrical systems are those where orderly shutdown of equipment is necessary in order to minimize personnel hazard and damage to equipment)

14

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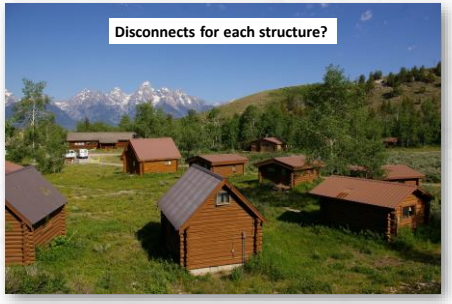
225.32 Location of Disconnect (continued)



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225.32 Location of Disconnect (continued)

- **Exception #3:** Towers or [light poles] are permitted to have the disconnecting means be located elsewhere on the premise.

16

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225.32 Location of Disconnect (continued)

- **Exception #4:** Poles or other structures used only for the support of signs, the disconnecting means is permitted to be located elsewhere on the premise. (and such signs are in compliance with Article 600)

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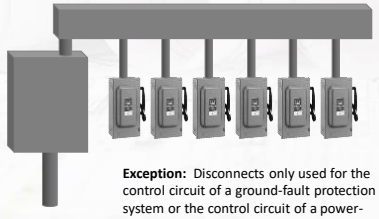
225.33 Max # of Disconnects

- There shall not be more than 6 disconnects per supply to a building or structure.



Exception: Disconnects only used for the control circuit of a ground-fault protection system or the control circuit of a power-operated system, shall not be considered as one of the supply disconnecting means.

18

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225.34 Grouping of Disconnects

- **(A)** The two to six disconnects per supply to a building or structure must be grouped together in the same location on (or within) each structure.
  - Exception: One of the six disconnects is permitted to be located remote from the others when serving a water pump for a fire protection system.
- Each disconnect must also be marked to indicate the load it serves.

19

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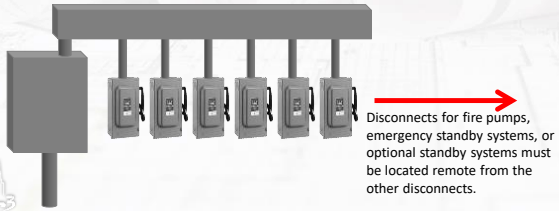
225.34 Grouping of Disconnects (continued)

- **(B)** Disconnecting means for fire pumps, for emergency standby systems, or optional standby systems must be located remote from the other supply disconnects for a building or structure.



Disconnects for fire pumps, emergency standby systems, or optional standby systems must be located remote from the other disconnects.

20

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225.38 Disconnect Construction (continued)

- **(C)** Where the disconnect does not disconnect the grounded conductor, other means must be provided to be able to disconnect the supply grounded conductor from the building's grounded conductor.

Disconnecting means for the grounded conductor is permitted to be accomplished by using a terminal or bus with pressure connectors.

21

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225.39 Rating of Disconnect

- A branch circuit or feeder disconnect must have an ampacity not less than the calculated load to be supplied as determined per Parts I and II of Article 220 for branch circuits, and Part III or IV of Article 220 for feeders.
- Where there is more than one disconnect for the disconnecting means of a branch circuit or feeders supplying a building, it is permitted to combine the ratings of such disconnects for determining the total rating of the disconnect.
- In no case can the rating of the disconnect be lower than items 225.39 (A) through (D).

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225.39 Rating of Disconnect (continued)

- **(A)** One-Circuit Installations- Limited loads of a single branch circuit shall have not less than 15 amp.
- **(B)** Two-Circuit Installations- For not more than two 2-wire branch circuits, not less than 30 amp.
- **(C)** One Family Dwellings- Not less than 100 amp, three wire.
- **(D)** All Others- All others shall have at least a 60 amp.

See also *NEC* 230.79 for similar requirements for services.

23

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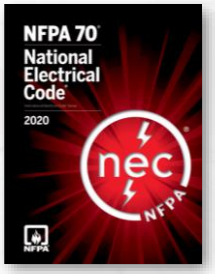
NEC Article 230
Services



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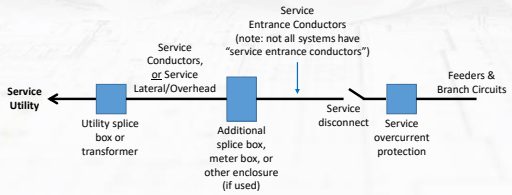
230.1 – Scope

- Article 230 contains provisions for the protection and installation of service conductors and service equipment. (see also service diagram in the NEC)



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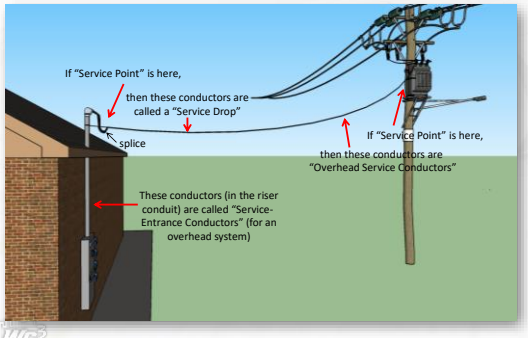
Definitions



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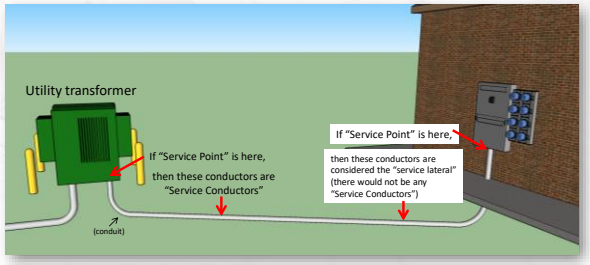
Definitions



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230.2 – Number of Services

- A building or structure is only allowed to have a single (one) service, unless permitted by 230.2(A) through (D).
  - Underground sets of conductors that are 1/0 AWG or larger which are ran to the same location and are connected together at their supply end, but not connected together at their load end, are considered to be supplying only one service (for applying the requirements of 230.40).

Single Service
(both sets of service wires originate from same location)

28

28

230.2 – Number of Services (continued)

- (A) Additional services are allowed for the following:
  - Fire pumps
  - Emergency systems
  - Legally required standby systems
  - Optional standby systems
  - Parallel power production systems (Such as Solar PV!)
  - Other systems which are designed for enhanced reliability and connected to multiple sources of supply

29

29

230.2 – Number of Services (continued)

- **(B)** Additional services are permitted by special permission for either of the following:
  - Buildings which contain multiple occupancies where there isn't sufficient space for service equipment that would be accessible to all occupants.
  - A building which is sufficiently large enough to justify having more than one service.

Largest Mall in the World - Dubai

30

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230.2 – Number of Services (continued)

- (C) Additional services are allowed under any of the following situations:
  - Where the required service capacity is required to be over 2,000A at a supply voltage of less than 1000V.
  - Where a single phase system is to be installed and is required to be a capacity which is greater than what a utility normally installs.
  - By special permission.

31

31

230.2 – Number of Services (continued)

- **(D)** Additional services are allowed for systems at different voltages, frequencies, or phases, or for different uses such as different rate schedules from the utility.
- **(E)** Where there is more than one service feeding a building or structure, a permanent plaque or directory is required to be provided at each service disconnect specifying where all other services are located *(this requirement also applies to main feeders or branch circuits supplying a building – see presentation on NEC Article 225)*.

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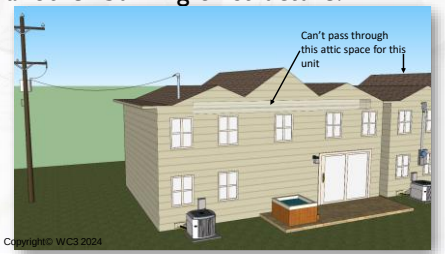
230.3 Supply to a Building

- The service conductors supplying a building are not allowed to pass through the interior of another building or structure.



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230.6 Conductors Considered Outside the Building

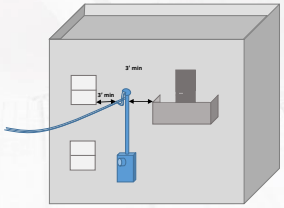
- Conductors are considered outside of a building per any of the following conditions:
  - Where installed under concrete that is min. 2" thick
  - Where installed in conduit which is encased in concrete a minimum of 2" thick
  - Where installed in a vault that meets the construction requirements of Part III of Article 450.
  - Where installed in conduit buried not less than 18" deeper than a building's footings or lowest portion of a structure
  - Where installed in rigid metal conduit (RMC) or intermediate metal conduit (IMC) used for an overhead service and only passing through the eave of another building, (per 230.24).

34

34

230.9 Clearances on Buildings (overhead)

- Overhead service conductor clearances must be as per noted in 230.9(A) through (C).
- **(A)** Service conductors must have a clearance of not less than 3 feet from openable windows, doors, porches, balconies, ladders, stairs, fire escapes, etc.
  - Exception: Conductors installed over the top of a window are not required to meet the 3 foot clearance.



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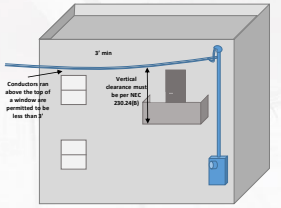
230.9 Clearances on Buildings (continued)

- **(B)** Conductors over or within 3 feet horizontally of a platform or surface from when the conductors could be reached, must meet the vertical clearances as required per NEC 230.24(B).



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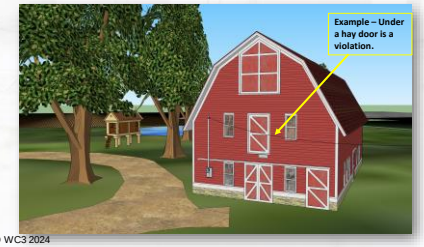
230.9 Clearances on Buildings (continued)

- **(C)** Overhead service conductors are not allowed to be installed under openings where materials may be moved and cannot block entrance to such openings.



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230.10 Vegetation Supporting Service Wires

- Trees and other vegetation are not allowed to be used for supporting overhead service conductors.

 38

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230.22 Insulation

- All individual overhead service conductors must be insulated or covered.
  - Exception: The grounded conductor that is part of a multiconductor cable is permitted to be bare.

 39

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230.24 Clearances (for overhead systems)

- Overhead service wires must not be readily accessible and must also comply with 230.24(A) through (E).
- **(A)** Service conductors must have a vertical clearance of not less than **8 feet** (8.5 ft in the 2023 *NEC*) above a roof. Such 8 feet clearance must be maintained for not less than 3 feet horizontally from the edge of the roof.

40

230.24(A) continued

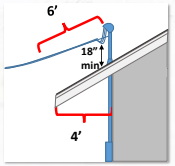
- **Exception #1:** If a roof is subject to pedestrian or vehicular traffic, then the clearance above the roof must be in accordance with 230.24(B).

- **Exception #2:** If the roof has a slope of 4/12 or more and the voltage between any of the conductors does not exceed 300V, then the clearance above the roof is permitted to be reduced to 3 feet (instead of 8 feet).

41

230.24(A) continued

- **Exception #3:** A clearance reduction is permitted down to 18" above the roof where not more than 6 feet of wire does not pass over the roof overhang more than 4 feet horizontally, and such service wires terminate at a through the roof conduit or other approved support. Also, the voltage between conductors cannot exceed 300V.



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42

230.24(A) continued

- **Exception #4:** The requirement for maintaining an 8 foot vertical clearance for up to 3 feet horizontally from the edge of a roof is not required where the final span of the overhead service wires are attached to the side of a building.

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230.24(A) continued

- **Exception #5:** Where a roof is guarded or isolated, a vertical clearance of 3 feet is permitted (if the voltage between service wires does not exceed 300V).

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230.24(B) Vertical Clearances

- **(B)** The vertical clearance for overhead service conductors must be in accordance with the following:
  - A minimum of 10' above sidewalks or other areas where there could be pedestrian traffic (and the voltage to ground of the service wires does not exceed 150V).
  - A minimum of 12' over a residential property or driveway, and for commercial areas not subject to vehicular traffic (and the voltage to ground does not exceed 300V).
  - A minimum of 15' for areas noted for a 12' clearance, but the voltage to ground exceeds 300V.
  - A minimum of 18' over public streets, alleys, roads, or other areas subject to truck traffic.

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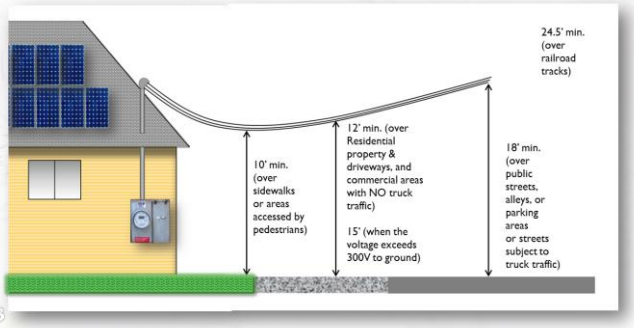
230.24(B) Vertical Clearances (cont.)



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230.24 (continued)

- **(C)** For overhead service wire clearance to building openings, see *NEC* 230.9.
- **(D)** For clearances over a swimming pool, see *NEC* 680.9.
- **(E)** Service wire clearance from communication wires must be in accordance with *NEC* 800.44(A)(4).

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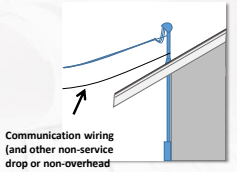
230.28 Service Masts

- Only service drop or overhead service conductors are allowed to be attached to service mast.
- Service masts must also be installed per the requirements of 230.28(A) and (B).



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230.28 Service Masts (continued)

- **(A)** A service mast must have adequate strength to support overhead service wires, or have braces or guy wires installed.

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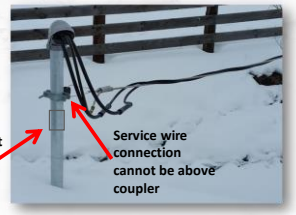
230.28 Service Masts (continued)

- **(B)** Service wires must not be attached to the upper portion of a mast where such mast has been essentially spliced with separate pieces of conduit (paraphrased).



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230.54 Overhead Service Locations (summary)

- **(A) and (B)** All overhead service wires must be provided with a service head as the wires enter the conduit.
- **(E)** The service head must have conductors enter through separate openings. overhead service wires must be provided with a service head as the wires enter the conduit.

Service Head

51

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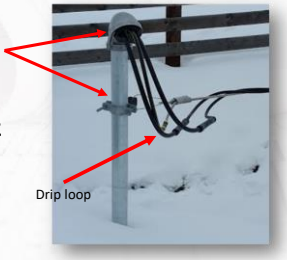
230.54 Overhead Service Locations (continued)

- **(C)** Service head must be above the point of attachment.
- **(F)** Drip loops must be provided to keep water from entering the weather head.



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230.40 Service Entrance Conductor Sets

- Each individual service drop, set of overhead service conductors, service lateral, or underground service conductors are allowed to serve only <u>one</u> set of service-entrance conductors.
  - **Exception #1:** A building with multiple occupancies is permitted to have a set of service-entrance conductors for each service when in compliance with 230.2 as long as signage is provided as required per 230.2(E).

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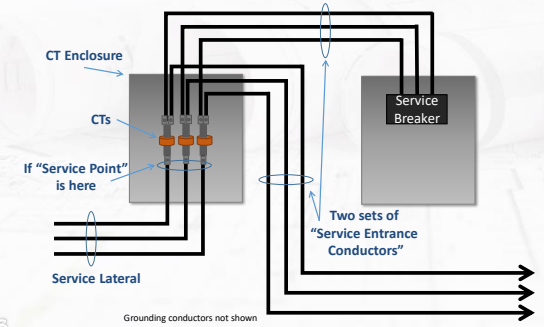
Example of multiple service entrance conductors



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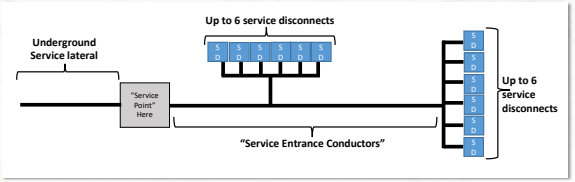
230.40 Service Entrance Conductor Sets (continued)

- **Exception #2:** Where two to six service disconnects (in separate enclosures) are grouped together in the same location, one set of service entrance conductors are permitted to serve each set of such disconnects.



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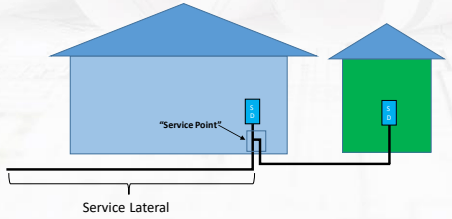
230.40 Service Entrance Conductor Sets (continued)

- **Exception #3:** A single service drop, set of overhead service conductors, set of underground service conductors, or service lateral is permitted to serve multiple service entrance conductors for a dwelling unit and its accessory structures (one for each structure).



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230.40 Service Entrance Conductor Sets (continued)

- **Exception #4:** Buildings containing two-family dwellings, multi-family dwellings, and multiple occupancies are permitted to have another set of service entrance conductors feed circuits noted in 210.25 (such as common area and common load circuits).

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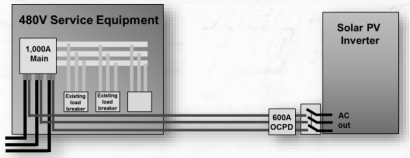
230.40 Service Entrance Conductor Sets (continued)

- **Exception #5:** A set of service entrance conductors which are connected to the supply side of a service disconnect are also permitted to supply systems covered by 230.82(5) (such as fire pumps, or sprinkler systems) or 230.82(6) (such as solar photovoltaic or fuel cell systems).



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Splices and Taps

230.46 – Splices and Taps

- Effective January 1, 2023 any pressure connectors and devices for splicing or taps onto service conductors must be marked "suitable for use on the line side of the service equipment," or equivalent wording.
- Devices to have an 'SR' rating – see UL ZMVV product IQ.

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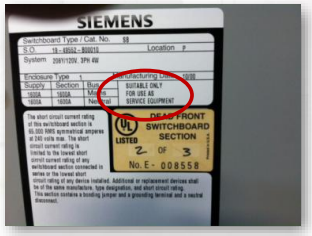
230.66 Marking

- Service equipment must be marked suitable for use as service equipment (see exceptions).



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Surge Protection (new for 2020 *NEC*)

***NEC* 230.67**

- Services supplying a dwelling unit are required to have surge protection (SPD) installed.
- The required SPD must be part of the service or be located next to it.
  - Exception: If an SPD is provided at each next level distribution equipment downstream, then the service is not required to have the SPD.
- A Type 1 or Type 2 SPD is required.
- This requirement applies for new or replaced services.

61

61

Barriers (new for 2020 *NEC*)

230.62(C) – Barriers (for service equipment)

- Barriers will be required in service equipment so that no uninsulated ungrounded busbars or terminals are exposed to accidental contact while someone is servicing load terminations.

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62

Barriers (for switchgear)

The line-side terminals and busbars in this service equipment would require barriers to protect someone from coming in contact with live parts while servicing load terminations [*NEC* 230.62(C)].

63

63

Max # of Service Disconnects (new for 2020 *NEC*)

230.71 – Max Number of Service Disconnects:

- (A) Each service equipment is only allowed to have one disconnect, unless 230.71(B) is met. (This goes along with *NEC* 230.62(C))
- For the purposes of 230.71, the following shall not be considered as a service disconnecting means:
  - Power monitoring equipment
  - Surge-protective device(s)
  - Control circuit of the ground-fault protection system
  - Power-operable service disconnecting means

64

64

Max # of Service Disconnects (Continued)

230.71(B):

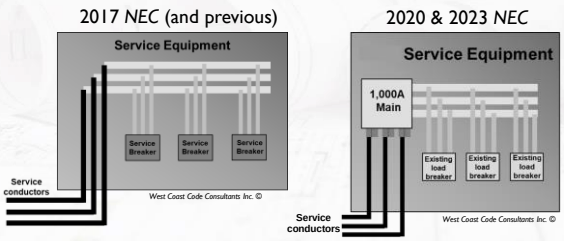
- (B) Two to six service disconnects are allowed for a service (or for each set of service-entrance conductors per *NEC* 230.40). Such disconnecting means is permitted to be any of the following:
  - Separate enclosures which each have a main disconnect.
  - Panelboards which each having a main disconnect.
  - Switchboards where each separate vertical section has a main disconnect (and barriers separating each section).
  - Switchgear or metering centers where each disconnect is in a separate compartment.

Note: *NEC* 230.72(A) still requires the two to six disconnects to be grouped.

65

65

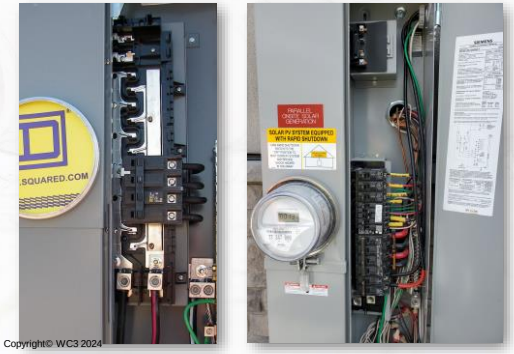
Max # of Service Disconnects (continued)



66

66

Service panels no longer allowed (for new installs) per the 2020 *NEC*



67

67

Service panels no longer allowed (for new installs) per the 2020 *NEC*

68

68

Service panels no longer allowed (for new installs) per the 2020 *NEC*



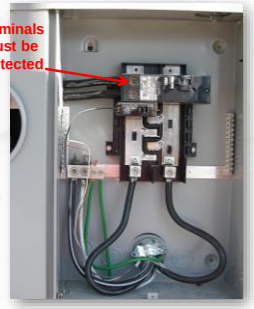
69

Service panels no longer allowed (for new installs) per the 2020 *NEC*


70

Examples of Service Panels that Will Work (for new installs) per the 2020 *NEC*





71

Metering Equipment

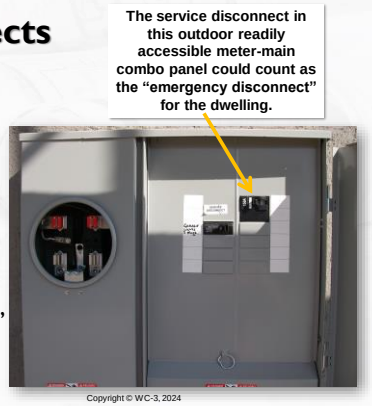
If this service equipment did not have an overall main service disconnect, then each of the downstream breakers (shown in this image) would be considered as service disconnects and each would be required to be in its own compartment [*NEC* 230.71(B)(4)].

72

Emergency Disconnects

230.85 – Emergency Disconnects

- New services for one- and two-family dwelling units are required to have an emergency disconnect located at a readily accessible location on the outside of the dwelling. If more than one emergency disconnect is provided, they must be grouped. (see also signage requirements)



73

73

230.82 Equipment Connected to the Supply Side of Service Disconnect (summary)

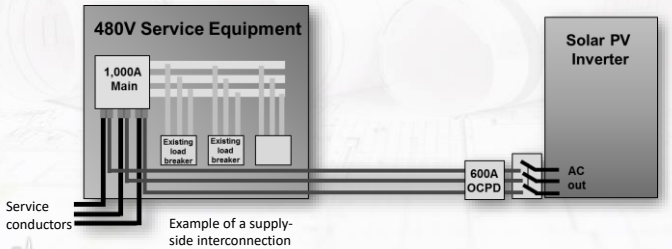
Only the following equipment is allowed to be connected to the supply side of the service disconnect:

- Cable limiters (or other current-limiting devices)
- Meters and meter enclosures (if properly grounded per NEC 250)
- Meter disconnect switches (which are rated per the calculated available fault current)
- Instrument transformers, load management devices, surge protective devices, etc.
- Taps feeding load management devices, standby power systems, fire pumps, and fire and sprinkler alarms.
- Solar PV systems, fuel cell systems (or other types of interconnected power production sources), but the disconnect must be listed as suitable for use as service equipment.
- Emergency disconnects (see also 230.85)
- (see others noted under *NEC* 230.82)

74

74

230.82 Equipment Connected to the Supply Side of Service Disconnect (continued)



75

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230.95 Ground-Fault Protection of Equipment

- Each service disconnect rated 1,000A or more fed by a solidly grounded wye electrical service of 150V to ground but not exceeding 1,000V phase to phase, are required to have ground fault protection of equipment to be provided for such disconnect. (see exception)
- The most common type of system that requires such protection is a 480/277V system (however, others could apply).
- Such protection is **not** required for 240/120V or 208/120V systems.

76

76

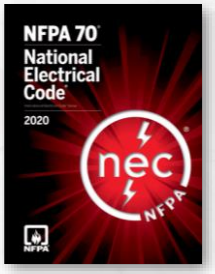
230.95 Ground-Fault Protection of Equipment (continued)

- **(A)** The maximum setting of the GFPE device cannot exceed 1200A, and such device must cause all ungrounded (hot) conductors to be simultaneously disconnected.
- **(C)** The GFPE device must be performance tested when first installed on site (a factory test is NOT sufficient for this test), and the test must be conducted in accordance with the manufacture's instructions.
  - A written record of such test must be provided to the AHJ.

77

77

NEC Article 240
Overcurrent Protection



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78

78

240.4 Protection of Conductors

- All conductors except for flexible cords, flexible cables, and flexible wires, must have overcurrent protection according to their ampacity, unless otherwise permitted or required per *NEC* 240.4 (A) – (G).

79

79

240.4 Protection of Conductors (continued)

- **(A) Power Loss Hazard.** Overload protection is not required when the interruption of the circuit would create a hazard, like a fire pump. However, still need short-circuit protection.

80

80

240.4 Protection of Conductors

- **(B) Overcurrent protection devices rated 800A or less:** It is permissible to use the next higher standard overcurrent device rating (above the ampacity of the conductors being protected) as long as 1, 2 and 3 are followed:
  - **(1)** The circuit conductors being protected are not part of a branch circuit which supplies more than one receptacle for cord-and-plug connected portable equipment.
  - **(2)** The ampacity of the conductors does not correspond with a standard amp rating of a fuse or breaker.
  - **(3)** The next higher ampacity rating of the fuse or breaker is not over 800A.

81

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240.6(A) Standard Amp Ratings

- Standard ampere ratings of fuses and breakers (inverters time type) are: 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000 amperes.
- Additional standard ampere ratings of fuses are 1, 3, 6, 10, and 601.

82

82

240.4 Protection of Conductors (continued)

- **(D) Small Conductors:** Unless otherwise permitted by 240.4(E) or (G), overcurrent devices must not exceed that which is noted per ***NEC* 240.4(D)(1)** through **(D)(7)** (after any ampacity correction or adjustment factors have been applied to the conductors).

83

83

240.4 Protection of Conductors

(D)(3) through (D)(7) Small Conductors Continued.

3. **14 AWG Copper** - 15 amps
4. **12 AWG Aluminum/Copper-Clad -** 15 amps
5. **12 AWG Copper -** 20 amps
6. **10 AWG Aluminum/Copper-Clad -** 25 amps
7. **10 AWG Copper –** 30 amps

84

84

NEC Table 310.16 [previously 310.15(B)(16)]

Table 310.15(B)(16) (formerly Table 310.16) Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)*

Size AWG or kcmil	Temperature Rating of Conductor [See Table 310.104(A).] 60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, USE, ZW	90°C (194°F) Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	60°C (140°F) Types TW, UF	75°C (167°F) Types RHW, THHW, THW, THWN, XHHW, USE	90°C (194°F) Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Size AWG or kcmil
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18**	—	—	14	—	—	—	—
16**	—	—	18	—	—	—	—
14**	15	20	25	15	20	25	12**
12**	20	25	30	20	25	30	10**
10**	30	35	40	25	30	35	8
8	40	50	55	35	40	45	6
6	55	65	75	40	50	55	4
4	70	85	95	55	65	75	3
3	85	100	115	65	75	85	2
2	95	115	130	75	90	100	1
1	110	130	145	85	100	115	1/0
1/0	125	150	170	100	120	135	2/0
2/0	145	175	195	115	135	150	3/0
3/0	165	200	225	130	155	175	4/0
4/0	195	230	260	150	180	205	250
250	215	255	290	170	205	230	300
300	240	285	320	195	230	260	350
350	260	310	350	210	250	280	400
400	280	335	380	225	270	305	500
500	320	380	430	260	310	350	600
600	350	420	475	285	340	385	700
700	385	460	520	315	375	425	750
750	400	475	535	320	385	435	800
800	410	490	555	330	395	445	900
900	435	520	585	355	425	480	1000
1000	455	545	615	375	445	500	1250
1250	495	590	665	405	485	545	1500
1500	525	625	705	435	520	585	1750
1750	545	650	735	455	545	615	2000
2000	555	665	750	470	560	630	

*Refer to 310.15(B)(2) for the ampacity correction factors where the ambient temperature is other than 30°C (86°F).
**Refer to 240.4(D) for conductor overcurrent protection limitations.

NFPA 70 – *National Electrical Code*

85

85

240.9 Thermal Devices

- **Thermal Devices.** These types of devices are permitted to protect motor branch-circuit conductors from overload if they meet *NEC* 430.40.
- But other than for motors, thermal relays and similar devices that are not designed to open short circuits or ground faults, cannot be used to protect conductors against overcurrent due to short circuits.

86

86

240.10 Supplementary Overcurrent Protection

- Supplementary overcurrent protection cannot substitute required branch circuit overcurrent protection.

87

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240.21 Feeder Tap Rules of the NEC

88

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Definitions

- **Feeder:** "All circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device."

NFPA 70 National Electrical Code©

89

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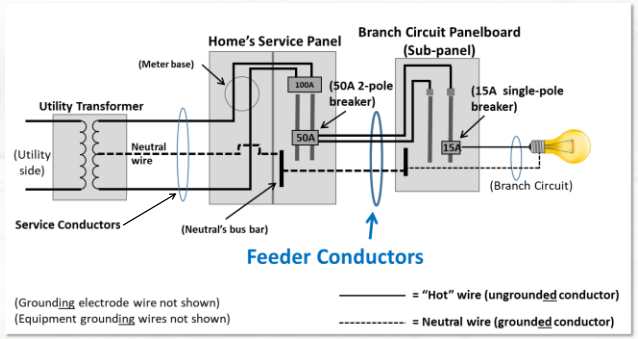
Feeder Conductor (example)



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90

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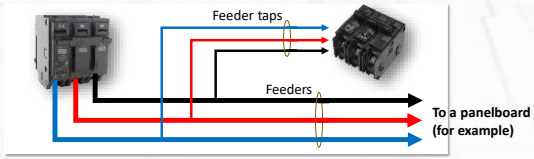
Definitions

- **Tap Conductor:** "A conductor, other than a service conductor, that has overcurrent protection ahead of its point of supply that exceeds the value permitted for similar conductors that are protected as described elsewhere in 240.4." NFPA 70 National Electrical Code©



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91

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Definitions

- **Overcurrent:** "Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault." NFPA 70 National Electrical Code©

Overload
Short Circuit
Ground Fault
} = Overcurrent

92

92

Definitions

- **Overload:** "Operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload." NFPA 70 *National Electrical Code*©

Short Circuit
Ground Fault
} NOT an Overload

93

93

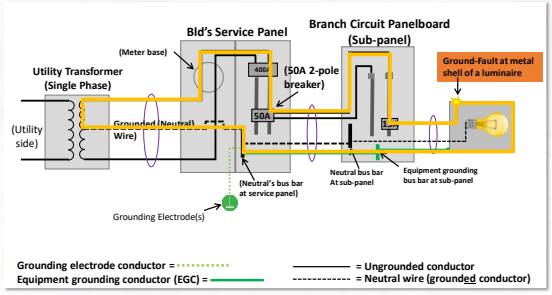
Definitions

- **Short Circuit** (added to the 2023 *NEC*): "An abnormal connection (including an arc) of relatively low impedance, whether made accidentally or intentionally, between two or more points of different potential." NFPA 70 *National Electrical Code*©
- **Ground Fault:** "An unintentional, electrically conductive connection between an ungrounded conductor of an electrical circuit and the normally non–current-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth." NFPA 70 *National Electrical Code*©

94

94

Example of a ground-fault current path:



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95

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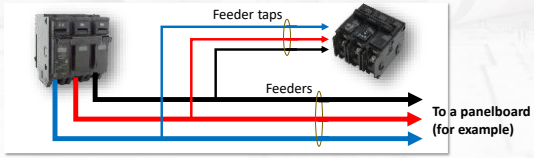
Feeder Taps

- If following the rules of 240.21(B), tap conductors are considered to be protected against overcurrent.



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96

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Are these feeder taps???

97

97

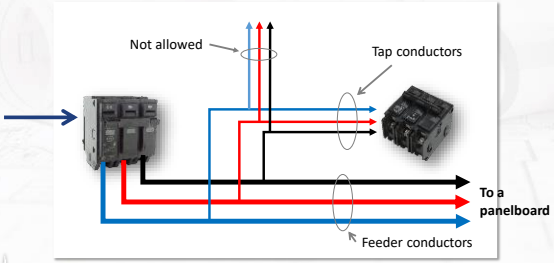
240.21 Location in Circuit (commonly called the "tap rules")

- Overcurrent protection for ungrounded conductors must be located at the point they receive their supply, except for conditions noted in *NEC* 240.21(A) through (H).
- The conductors noted in (A) through (H) cannot supply another conductor except through an overcurrent protective device (per 240.4).

98

98

Can't tap tap conductors!



99

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240.21(B) Feeder Taps

- **(B) Feeder Taps –** Conductors are allowed to be tapped without having overcurrent protection at the point where the tap is made, per items (B)(1) through (B)(5).
- Taps are allowed to be made at any point on the load side of the feeder OCPD.
- Overcurrent protection for feeder taps cannot use the "next up rating" of 240.4(B).

100

100

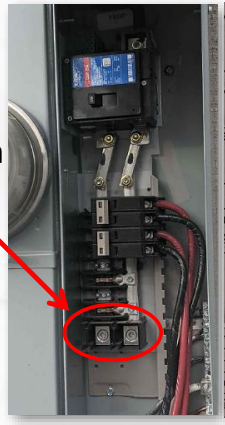
240.4(B) OCPDs Rated 800A or Less

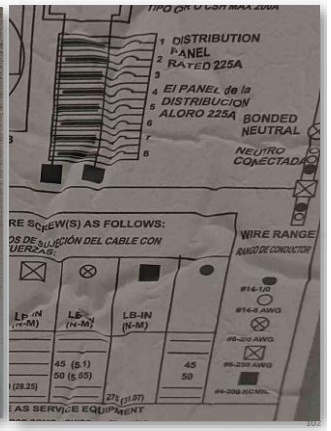
- **(B) OCPDs rated 800A or less:** It is permissible to use the next higher standard overcurrent device rating (above the ampacity of the conductors being protected) as long as 1, 2 and 3 are followed:
  - **(1)** The circuit conductors being protected are not part of a branch circuit which supplies more than one receptacle for cord-and-plug connected portable equipment.
  - **(2)** The ampacity of the conductors does not correspond with a standard amp rating of a fuse or breaker.
  - **(3)** The next higher ampacity rating of the fuse or breaker is not over 800A.

101

101

Can feed-through lugs in a panelboard be tapped?





102

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240.21(B)(1) Feeder Taps

- **(B)(1) Taps not over 10 feet in length –** Length of the tap conductors does not exceed 10 feet and the tap conductors comply with **all** of the following (1 through 4):
  - **(1)** The ampacity of the tap conductor is:
    - Not less than the calculated loads that the tap conductors serve,
    - Not less than the rating of the equipment OR overcurrent protection device which the tap conductors terminate to.

Exception to 240.21(B)(1)(b) are SPD(s) installed per manufacturer instructions

103

103

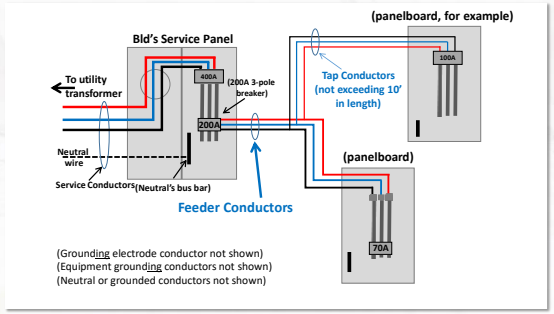
240.21(B)(1) Feeder Taps (continued)

- **(2)** The tap conductors cannot extend past the switchboard, switchgear, panelboard, disconnecting means, or control devices that they supply.
- **(3)** Other than at the point where the taps are made, the tap conductors must be installed in a raceway extending to the equipment they supply.

104

104

Tap Conductors (up to 10' long)



105

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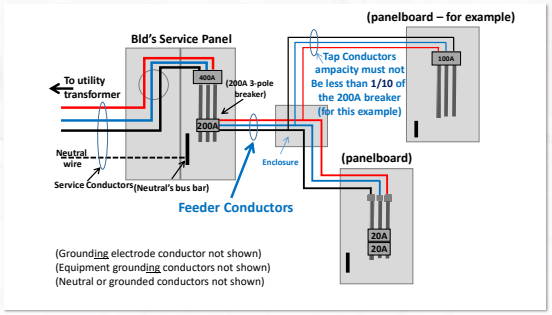
240.21(B)(1) Feeder Taps (continued)

- **(4)** If the tap conductors leave the enclosure or vault where the tap is made, then the ampacity of the tap conductors cannot be less than 1/10 of the rating of the overcurrent device which protects the feeders that the tap wires are tapping.

106

106

Ampacity of Tap Conductors (up to 10' long)



107

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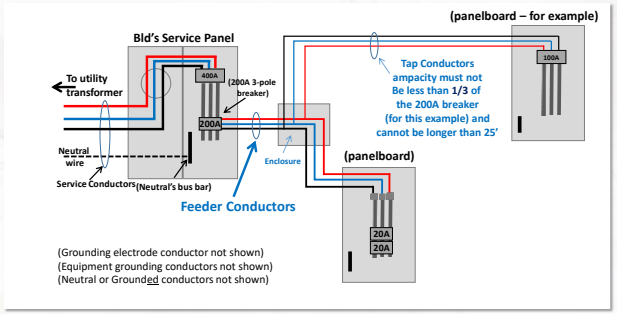
240.21(B)(2) Feeder Taps

- **(B)(2) Taps up to (but not over) 25 feet long.** Where the tap conductors do not exceed 25,' then all of the following applies:
  - **(1)** The ampacity of the tap conductors is not less than 1/3 of the rating of the upstream overcurrent device protecting the feeder conductors which are being tapped.
  - **(2)** The end of the tap conductors must terminate at a single breaker of set of fuses rated not more than the ampacity of the tap conductors.
  - **(3)** The tap conductors must be protected from physical damage by being installed within an approved raceway or by other approved means (as allowed per the AHJ).

108

108

Ampacity of Tap Conductors (up to 25' long)



109

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240.21(B)(5) Outside Feeder Taps (of unlimited length)

- **(B)(5)** Where tap conductors are located outside of a building or structure, except at the point of load termination, must comply with all of the following:
  - **(1)** The tap conductors are required to be protected from damage in an "approved manner"
  - **(2)** The end of the tap conductors terminate to a single breaker or set of fuses (OCPD) which are rated not more than the ampacity of the tap conductors

110

110

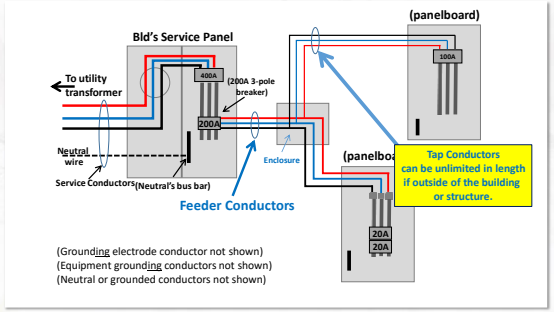
240.21(B)(5) Outside Feeder Taps (of unlimited length) Continued…

- **(3)** The OCPD must be an integral part of the disconnect itself or it must be located immediately adjacent to the disconnect.
- **(4)** The disconnect for the tap conductors must be installed at a readily accessible location per one of the following options:
  - Be outside of a building or a structure
  - Be inside the building or structure at the nearest point of entrance of the tap conductors into the building or structure
  - Or where the wiring is installed per *NEC* 230.6 (conductors considered outside of the building), the disconnect must be located at the nearest point of entrance of the tap conductors into the building or structure

111

111

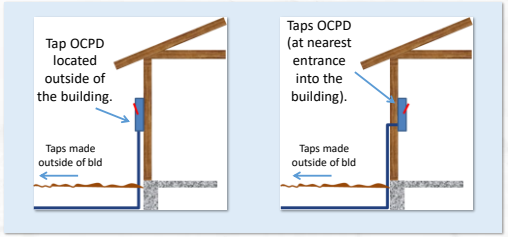
Tap Conductors Outdoors (unlimited length)



112

112

Example of tap OCPD location per *NEC* 240.21(B)(5):

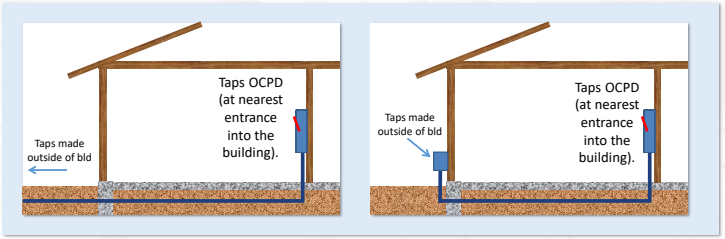


The tap conductor's OCPD must be readily accessible and can be located outside of the building or inside at nearest point of entry into the building.

113

113

Example of tap OCPD location per *NEC* 240.21(B)(5):



114

114

NEC 230.6 (conductors outside of a bld)

The following conductors are considered to be outside of a building:

- Under 2" or more thick concrete
- In a raceway that is encased in 2" of concrete or brick
- In a vault meeting Part III of Article 450
- In conduit buried at least 18" deep under a building
- RMC or IMC conduit through an eave (for overhead services)

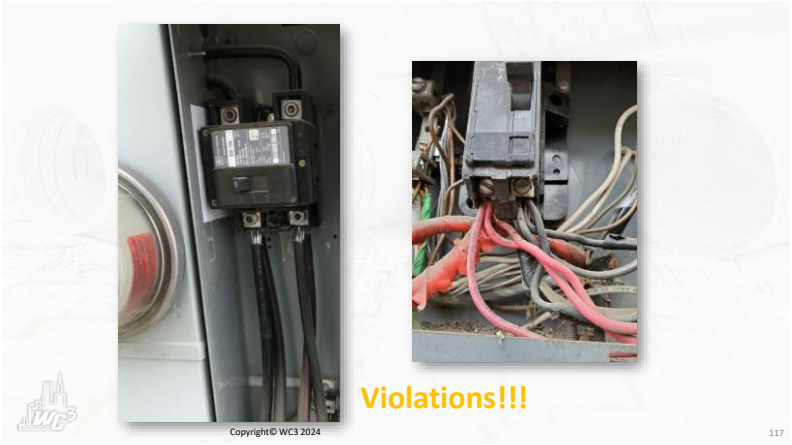
115

115

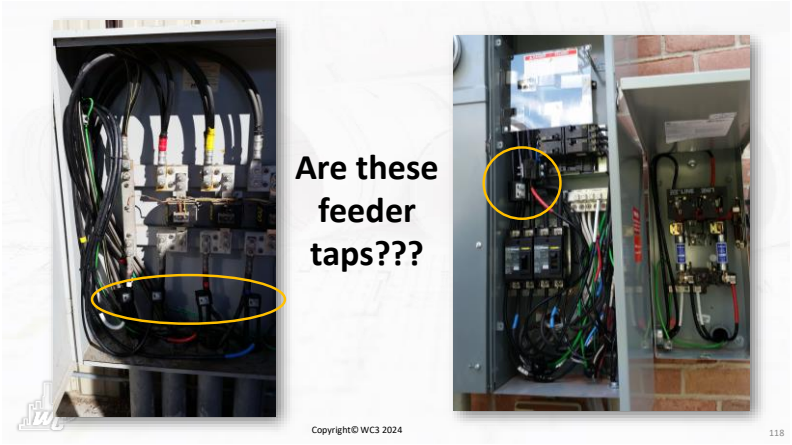
Violations?

116

116



117



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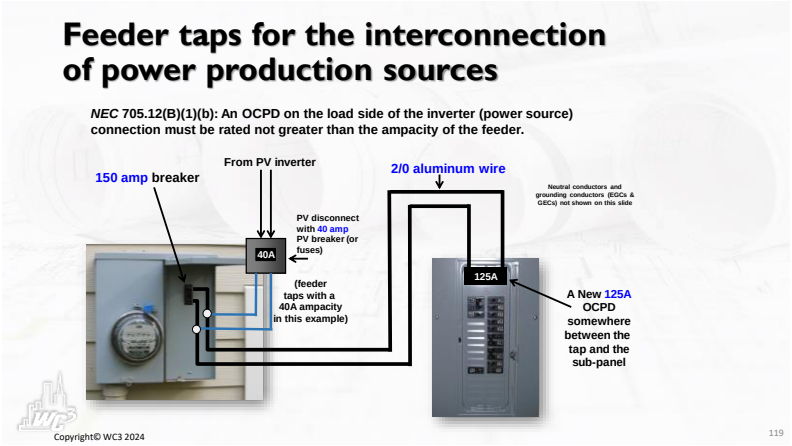

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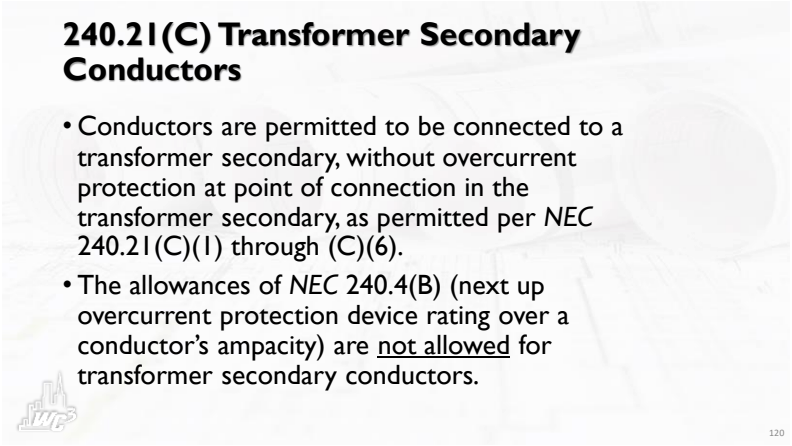
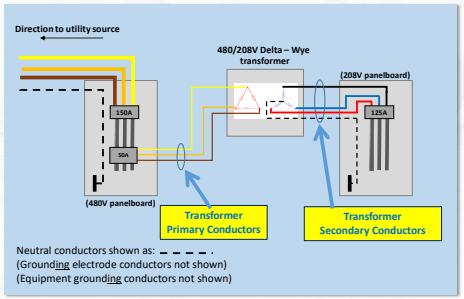


120

Example of Transformer Primary and Secondary Conductors



 121

121

Example of Transformer Primary and Secondary Conductors

 122

122

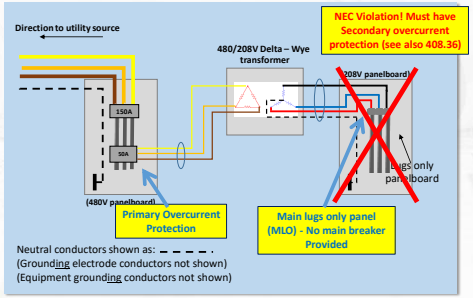
240.21(C)(1) Protection by Primary Overcurrent Device

- The overcurrent protection device on the primary side of a transformer is permitted to be the overcurrent protection for the secondary conductors of a single-phase transformer having a 2-wire (single-voltage) secondary, or a three-phase delta-delta connected transformer having a 3-wire (single voltage) secondary. (these situations are rare!!)
- The above noted overcurrent protection must also be in accordance with *NEC* 450.3 and the rating of the primary overcurrent protection is not allowed to exceed "the value of the secondary-to-primary transformer voltage ratio multiplied by the secondary conductor ampacity."
- Single-phase (other than 2-wire) and multiphase (other than delta-delta 3-wire) transformer secondary conductors must have secondary overcurrent protection! (these situations are very common!!)

123

123

Example of Transformer Primary and Secondary Conductors



 124

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240.21(C)(2) Transformer Secondary Conductors (not over 10' long)

- Secondary conductors not over 10 ft. in length must comply with all of items 1 through 4:
  - **(1)** The ampacity of the secondary conductors are not less than:
    - the total calculated loads that such conductors serve,
    - and not less than the rating of the equipment and overcurrent protection device which the secondary conductors terminate to.
  - **(2)** The secondary conductors do not extend past the switchboard, switchgear, panelboard, disconnect, or control devices they serve.

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240.21(C)(2) Transformer Secondary Conductors (not over 10' long) Continued

- **(3)** The secondary conductors must installed in conduit extending to the equipment they supply.
- **(4)** Where the secondary conductors leave the enclosure or vault where the supply connection is made, the secondary conductors must have an ampacity that is not less than the value of the primary-to-secondary voltage ratio multiplied by 1/10 of the rating of the transformers primary overcurrent device.

126

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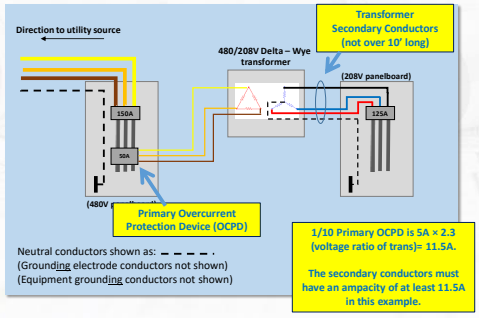
Example of Transformer Primary and Secondary Conductors



127

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240.21(C)(4) Transformer Secondary Conductors Outdoors

- **(C)(4)** Where secondary conductors are located outside of a building or structure, except at the point of load termination, all of the following applies:
  - **(1)** The secondary conductors must be protected from damage (in a manner approved by the AHJ).
  - **(2)** The end of the secondary conductors must connect to a single breaker or set of fuses rated not more than the ampacity of the secondary conductors.

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240.21(C)(4) Transformer Secondary Conductors Outdoors (continued)

- **(3)** The overcurrent device for the conductors is integral of the disconnect (or be located adjacent to it).
- **(4)** The disconnect for the secondary conductors must be readily accessible and must be installed per one of the following:
  - Be outside of the building or structure
  - Be located inside the building at the nearest entrance of the secondary conductors
  - Or if where installed per *NEC* 230.6 (conductors considered outside a building) be installed at the nearest point of entrance of the secondary conductors in the building.

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240.21(C)(6) Transformer Secondary Conductors (not over 25' long)

- **(C)(6)** Transformer secondary conductors not exceeding 25 feet in length must comply with all of the following:
  - **(1)** The secondary conductors must have an ampacity that is not less than the value of the primary-to-secondary voltage ratio multiplied by 1/3 of the rating of the transformers primary overcurrent device.
  - **(2)** The end of the secondary conductors connect to a single circuit breaker or set of fuses rated not more than the ampacity of the secondary conductors.
  - **(3)** The secondary conductors are protected from physical damage by being installed within a conduit, approved raceway, enclosure, or by other approved means per the AHJ.

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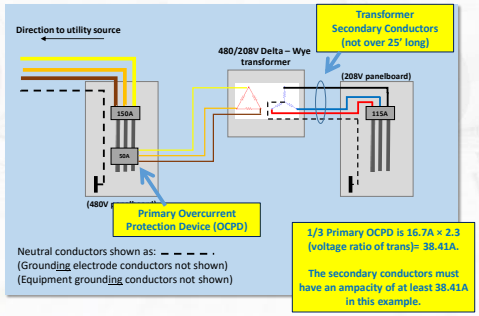
Example of Transformer Primary and Secondary Conductors



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450.3 Overcurrent Protection

- *NEC* Table **450.3(B)** notes overcurrent protection requirements for transformers <u>less than 1000 Volts</u>.

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NEC Table 450.3(B)

Table 450.3(B) Maximum Rating or Setting of Overcurrent Protection for Transformers 1000 Volts and Less (as a Percentage of Transformer-Rated Current)

	Primary Protection			Secondary Protection (See Note 2)	
Protection Method	Currents of 9 Amperes or More	Currents Less Than 9 Amperes	Currents Less Than 2 Amperes	Currents of 9 Amperes or More	Currents Less Than 9 Amperes
Primary only Protection	125% (See Note 1)	167%	300%	Not Required	Not Required
Primary and secondary protection	250% (See Note 3)	250% (See Note 3)	250% (See Note 3)	125% (See Note 1)	167%

Notes:

1. Where 125% of this current does not correspond to a standard rating of a fuse or nonadjustable circuit breaker, a higher rating that does not exceed the next higher standard rating shall be permitted.
2. Where secondary overcurrent protection is required, the secondary overcurrent device shall be permitted to consist of not more than six circuit breakers or six sets of fuses grouped in one location. Where multiple overcurrent devices are utilized, the total of all the device ratings shall not exceed the allowed value of a single overcurrent device.
3. A transformer equipped with coordinated thermal overload protection by the manufacturer and arranged to interrupt the primary current shall be permitted to have primary overcurrent protection rated or set at a current value that is not more than six times the rated current of the transformer for transformers having not more than 6% impedance and not more than four times the rated current of the transformer for transformers having more than 6% but not more than 10% impedance.

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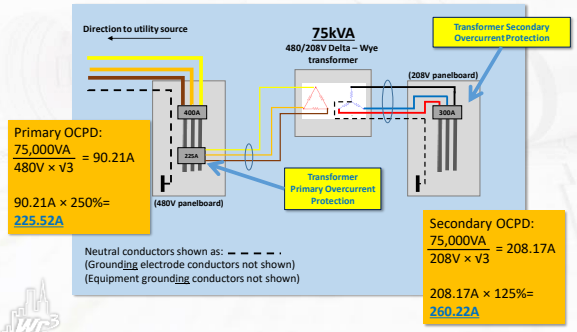
Example of Transformer Primary and Secondary Overcurrent Protection



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450.13 Accessibility (of transformers)

- **(B)** Transformers and are allowed to be installed where not in the open (ie. such as in 'hollow' spaces), as long as they're dry-type transformers which are rated 1,000 volts (or less) and rated **not more than 50 kVA**.
- However, the transformer cannot be permanently closed in by structure and they must still meet the ventilation and signage requirements of *NEC* 450.9.
- The transformer must also be separated from combustible materials per *NEC* 450.21(A).

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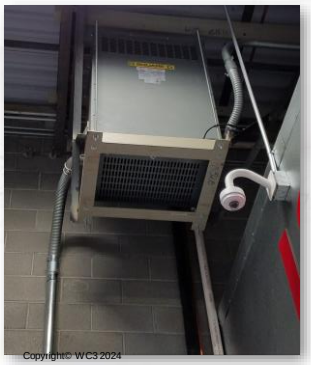
450.13 Accessibility (continued)



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450.14 Disconnecting Means

- Transformers are required to have a disconnecting means located within sight of the transformer.
- However, the disconnect can be located remote from the transformer as long as the disconnecting means is lockable (per *NEC* 110.25), and the location of such disconnect is field marked on the transformer.

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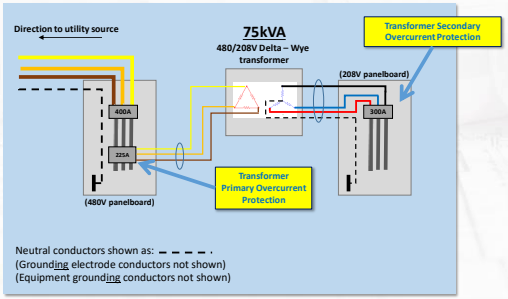
Example of Disconnects for a Transformer



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240.24 Location of Overcurrent Devices

(A) Overcurrent devices (switches with fuses, and breakers) must be readily accessible.

- The center of the breakers or switches handles can't be over 6 feet 7 inches above the floor or working platform.
  - For busways, see 368.17(C).
  - Supplemental OCPDs are not required to be readily accessible (per 240.10).
  - OCPDs noted in 225.40 and 230.92 are permitted to be located in accordance with those sections.
  - OCPDs located adjacent to the equipment they supply are permitted to have access provided by portable means.
  - See exception for industrial control panels using a tool for access.

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240.24 Location on Premises (continued)

- **(C) Not exposed to Physical Damage** – Overcurrent devices must located where not subject to physical damage.

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240.24 Location on Premises (continued)

- **(D) Not in Vicinity of Easily Ignitable Material** – Overcurrent devices should not be located in areas with flammable materials, such as in a clothes closet.

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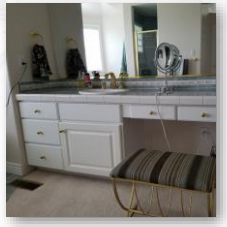
240.24 Location on Premises (continued)

- **(E) Not Located in a Bathroom** – Overcurrent devices (not counting supplementary overcurrent devices) cannot be located in bathrooms of dormitories, dwelling units, and guest rooms.



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240.24 Location on Premises

- **(F) Not Located Over Steps** – overcurrent protection cannot be located over any steps of a stairway.

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240.81 Circuit Breaker Indicating

- Circuit breakers must clearly indicate whether they are in the open (off) or closed (on) position.
- When circuit breakers are operated vertically instead of horizontally, the up position of the handle must be the on position.

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110.9 Interrupting Rating

- Equipment which is intended to interrupt current at fault levels is required to have an interrupting rating sufficient for the maximum amount of fault current that it could be susceptible to.

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110.10 (Available Fault Current)

- All devices, total impedance, equipment short circuit ratings, and other characteristics of a circuit must be as such that will allow circuit overcurrent protective devices to safely clear a fault without being damaged.
- A fault could be assumed to be between two or more circuit conductors or between any circuit conductor and the equipment grounding conductor.

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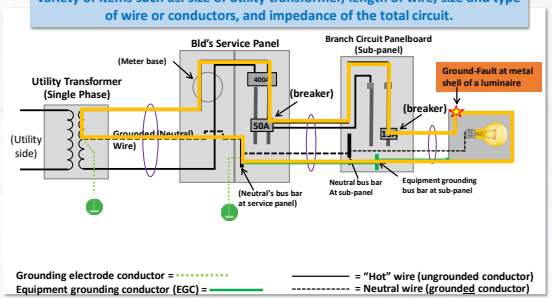
Fault Current

The amount of fault current that could flow on a faulted circuit depends on a variety of items such as: size of utility transformer, length of wire, size and type of wire or conductors, and impedance of the total circuit.



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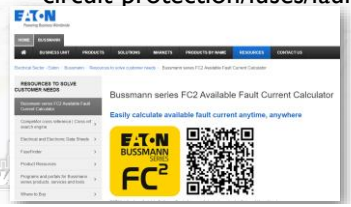
147

Download: Bussman Series FC2 Available Fault Current Calculator

- Search "FC2 Eaton" on your mobile device for the app, or visit:
- https://www.eaton.com/us/en-us/products/electrical-circuit-protection/fuses/fault-current-calculator.html



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240.86 Series Ratings

- Where a circuit breaker is installed on a circuit which has a calculated fault current that is more than the fault current rating of the breaker, and such breaker is on the load side of an approved breaker (overcurrent protective device) which has an acceptable higher rating, the circuit breaker must meet the requirements of (A) or (B), and (C) (see following slides for such requirements).

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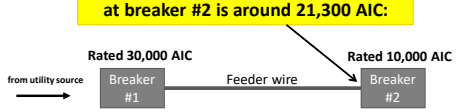
Example of Series Rating

Example. if the calculated fault current at breaker #2 is around 21,300 AIC:



Since the calculated fault current at breaker #2 exceeds 10,000A, then a series rating would be required or breaker #2 would need to be replaced with a 22,000 AIC rated breaker.

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240.86 Series Ratings (continued)

(A) Existing installations and designed under engineering supervision.

- The series rated combination devices must be selected by a licensed professional engineer who deals primarily with the design or maintenance of electrical installations.
- The selection of the devices must be documented and stamped by such engineer.
- The series combination rating must be field marked on the new equipment.

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240.86 Series Ratings (continued)

(B) For series combinations, the line-side overcurrent device and the load-side overcurrent protection device are required to be tested and marked to be used as combination series rated devices.

- The informational note (on page106 of the 2020 *NEC*) says to also see 110.22(B) for signage requirements for a series combination systems. The signage is required to state the following:

"CAUTION-SERIES COMBINATION SYSTEM RATED___ AMPERES. IDENTIFIED REPLACEMENT COMPONENTS REQUIRED."

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240.86 Series Ratings (continued)

(C) When motors can contribute to a fault:

- Series ratings cannot be used where both of the following applies:
  - When motors are essentially connected somewhere between the load-side of the higher rated OCPD and the line-side of the lower rated OCPD, and
  - The combined full-load currents (FLA amps) of the motors exceed 1% of the fault current interrupting rating of the lower-rated circuit breaker.

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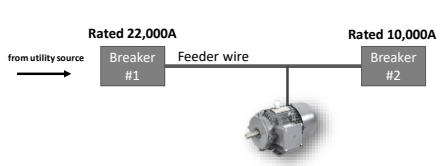
Example of Series Rating

Example of motor contribution to a fault:



In this example the full-load amps of the motor cannot exceed 1% of the fault-current rating of breaker #2, which is 100A.

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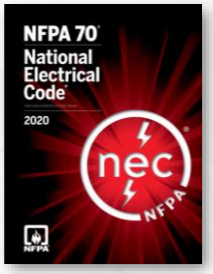
NEC Article 250
Grounding & Bonding



NFPA 70 *National Electrical Code*©

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250.6 Objectionable Current

- **(A)** The grounding and bonding of electrical systems must be installed to prevent objectionable current.
- **(B)** The following actions may be taken to stop objectionable current as long as requirements of *NEC* 250.4 are met:
  - Disconnect one or more, but not all, grounding connections.
  - Change location of grounding connections.
  - Interrupt the continuity of the conductive path causing the objectionable current.
  - Take other suitable approved action.

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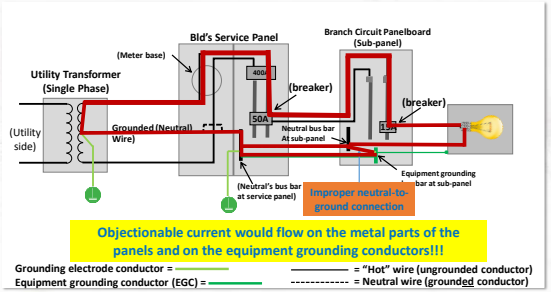
Objectionable Current (example)



157

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250.8 Connection of Grounding and Bonding Equipment

Permitted methods of grounding and bonding connections:

1. Listed pressure connectors.
2. Terminal bars.
3. Pressure connecters listed for bonding and grounding.
4. Exothermic welding process. **(Soldering Not Allowed)**
5. Machine screw with at least 2 threads or nut.
6. Thread forming machine screws with at least 2 threads.
7. Connections that are part of a listed assembly.
8. Other listed means.

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250.8 Connection of Grounding and Bonding Equipment continued

1. Listed pressure connectors.

2. Terminal bars.

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250.8 Connection of Grounding and Bonding Equipment continued

4. Exothermic welding process. **(Soldering Not Allowed)**

5. Machine screw with at least 2 threads or nut.

6. Thread forming machine screws with at least 2 threads.

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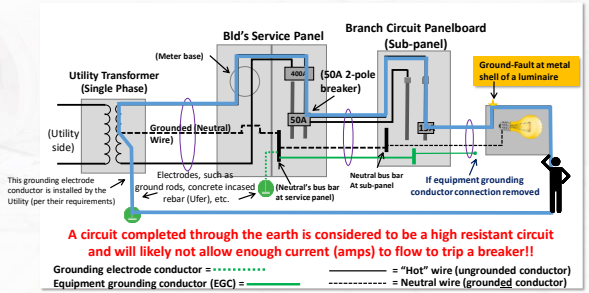
Electrical Continuity of Metal Parts To The EGC Is VERY Important!!



The earth is NOT considered an effective ground fault pathway!

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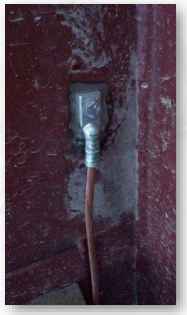
250.12 Clean Surfaces

- Nonconductive coatings must be removed and cleaned for bonding.



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250.20 AC Systems to be Grounded

- **(B)** AC systems of 50 to 1,000 volts that supply wiring systems must be grounded under any of the following conditions:
  - Whenever the system can be grounded so the maximum voltage between an ungrounded conductor and ground would not exceed 150 volts.
  - Where the system is a 3-phase, 4-wire, wye connected system.
  - Where the system is a 3-phase, 4-wire delta connected transformer with the center of one of the windings is used as a circuit conductor.

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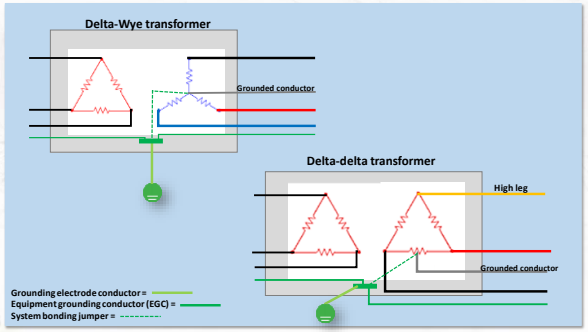
Examples of Grounded AC Systems



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250.26 Conductors to Be Grounded for AC Systems

The following conductors for AC systems are to be grounded:

- 1 - One conductor of a single-phase, 2 wire system
- 2 - The neutral conductor of a single-phase, 3 wire system.
- 3 - The neutral conductor of a 3 phase system having one wire common to all phases.
- 4 - One phase conductor where one phase is grounded.
- 5 - The neutral conductor of a 3 phase system where the center of one of the windings is grounded.

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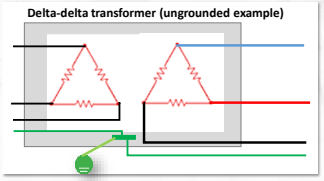
250.21(B) AC Systems NOT Required to be Grounded

- Ungrounded systems noted in 250.21(A) which operate at over 120 volts but not over 1,000 volts, are required to have ground detectors.
- The ground detection sensing equipment must be connected as "close as practicable" to where the system receives its supply.
- Ungrounded systems must have signage per *NEC* 250.21(C).



Grounding electrode conductor =
Equipment grounding conductor (EGC) =

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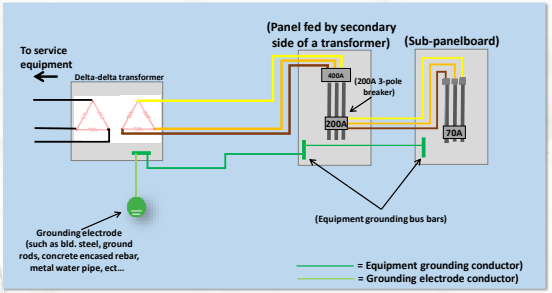
Ungrounded System (example)



Ungrounded systems are very limited per the *NEC*! See 250.21 and 250.22.

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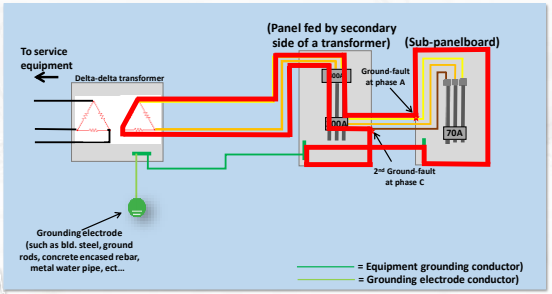
Double ground-fault scenario



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110.15 High-Leg Marking

- For a 4-wire (3 ungrounded conductors and one neutral), delta connected system where the midpoint of one of the phase winding is grounded, the conductor(s) or the busbar(s) having the higher phase voltage-to-ground are required to be durably marked with a finish that is orange in color (or by other effective means).
- The above noted identification is required to be made at each point in the system where a connection is made.

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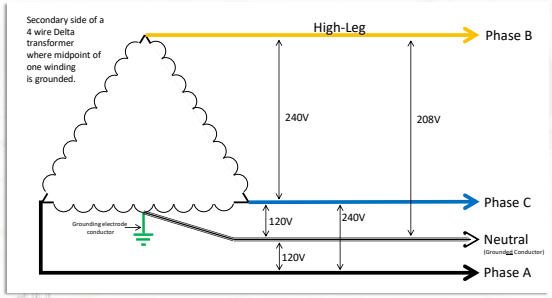
High-Leg Marking



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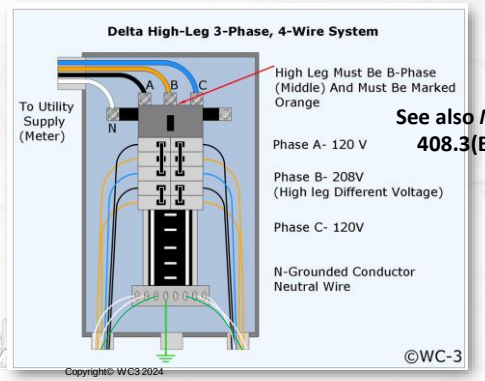
High-Leg Marking



See also *NEC* 408.3(E)

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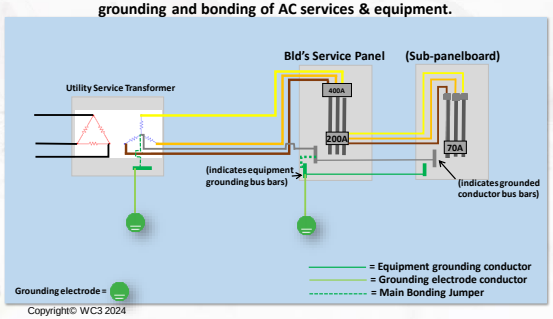
250.24 System Grounding Connections (Summary)

See *NEC* 250.24(A) through (E) for general requirements regarding grounding and bonding of AC services & equipment.



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250.28 Main/System Bonding Jumpers

- **(A)** Main bonding jumpers and system bonding jumpers must be made of copper or other corrosion-resistant material. They must be a wire, bus, screw, or a similar suitable conductor.
- **(B)** When a main bonding jumper or system bonding jumper is a screw, it must have a green finish and must be visible when installed.

Examples of main bonding jumpers:

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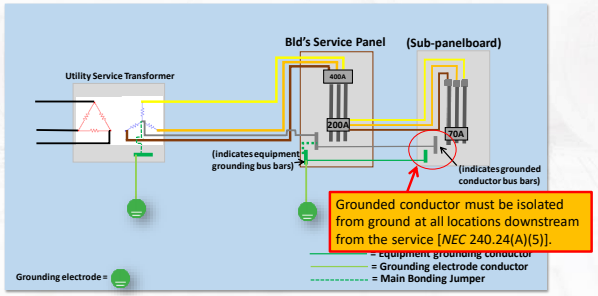
250.24 System Grounding Connections (continued)



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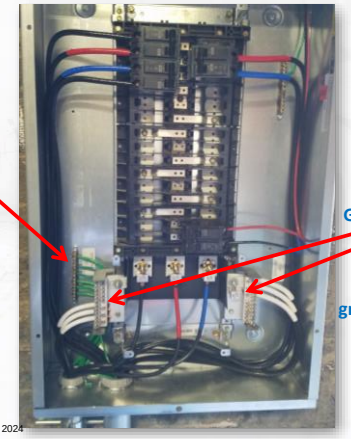
Typical 3-phase panelboard



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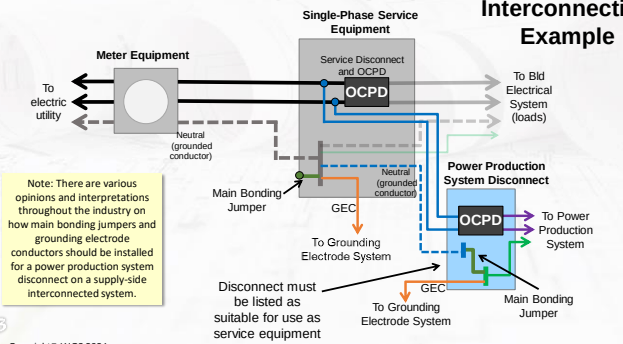
Section 250.25 of the 2020 & 2023 *NEC* (example)

Supply-Side Interconnection Example



Note: There are various opinions and interpretations throughout the industry on how main bonding jumpers and grounding electrode conductors should be installed for a power production system disconnect on a supply-side interconnected system.

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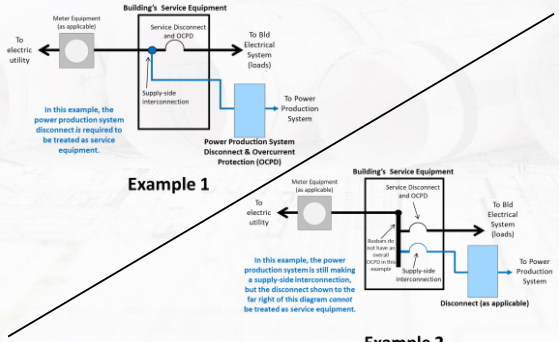
Supply (Line) side connection continued…



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250.30(A) Grounded Separately Derived System

- **(A)(1)** says that there must be provided an un-spliced **system bonding jumper** that connects the terminal bars of the grounded conductor(s) to the terminal bars of the grounding electrode conductor(s) and equipment grounding conductor(s).
  - Such connection must be made within the enclosure of the separately derived system or be made within the enclosure of the first disconnect/overcurrent protection device.

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Definitions

- **Separately Derived System:** "An electrical source, other than a service, having no direct connection(s) to circuit conductors of any other electrical source other than those established by grounding and bonding connections."

NFPA 70, *National Electrical Code©*

Transformers are typically considered as separately derived systems

A generator would be considered as a separately derived system if all ungrounded ("hot") conductors and the neutral conductor for the generator are switched at a transfer switch.

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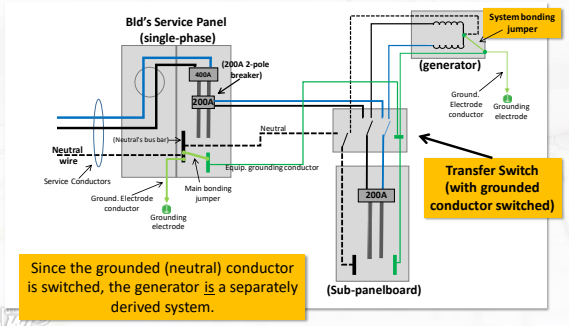
Example of a generator that is a separately derived system:



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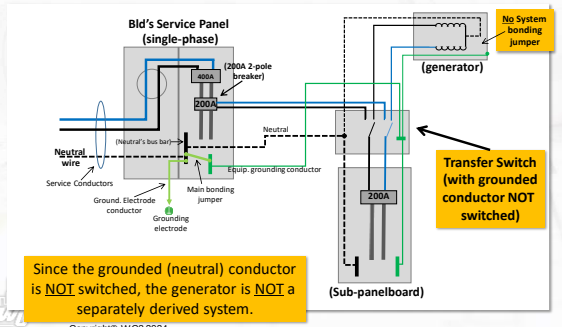
Example of a generator that's NOT a separately derived system:



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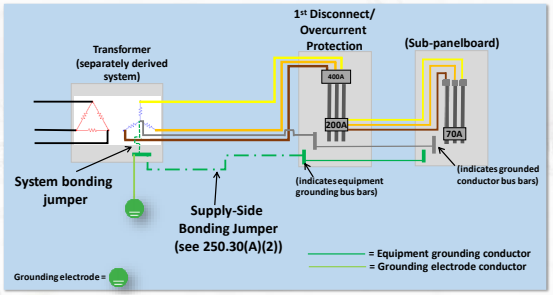
System Bonding Jumper Location



 183

183

250.30(A) Grounded Separately Derived System (continued)

- **(A)(6)(a)** A common grounding electrode conductor is permitted for multiple separately derived systems.
  - Such common electrode conductor must not be smaller than 3/0 copper (or 250 kcmil aluminum)
  - Or the common electrode conductor can be the metal water pipe or the metal frame of the building if it/they meet the requirements of 250.68(C)(1) or (C)(2) respectively (see 250.30(A)(6)(a), items 1 through 3).
  - The electrode conductor taps from each separately derived system are sized per Table 250.66 based on the size of the derived conductors (ie. the transformer's secondary conductors).

184

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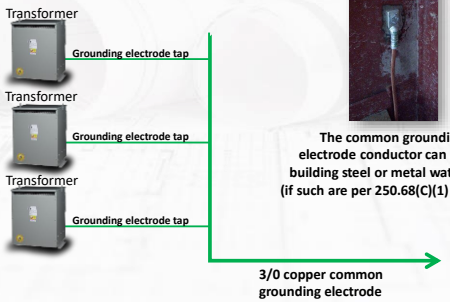
Common Grounding Electrode Conductor (example)



The common grounding electrode conductor can be the building steel or metal water pipe (if such are per 250.68(C)(1) or (C)(2))

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250.30(A) Grounded Separately Derived System (continued)

- **250.30(A)(6)(c)** says that the grounding electrode tap connections to the common grounding electrode conductor must be made at an accessible point per one of the following methods:
  - A connector listed for bonding and grounding
  - Listed connections to a busbar not smaller than ¼" by 2" (and be large enough to accommodate all the required connections to it)
  - Or by an exothermic welding process.

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250.32 Buildings/Structures Supplied by Feeders or Branch Circuits

- **(B)(1)** An equipment grounding conductor must be provided with the feeder or branch circuit conductors supplying the building or structure and be sized per *NEC* Table 250.122. (see exception for existing installations)
- **(B)(2)** If the building or structure is supplied by a separately derived system and the overcurrent protection for the feeders supplying the building is located at the building, then the requirements of 250.30(A) would apply. (paraphrased)

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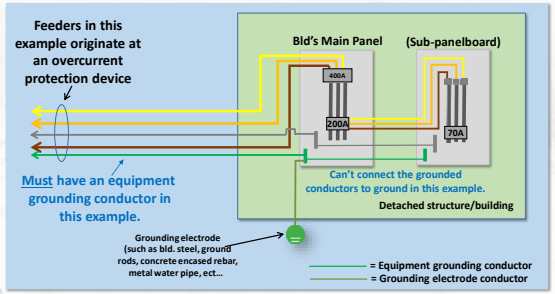
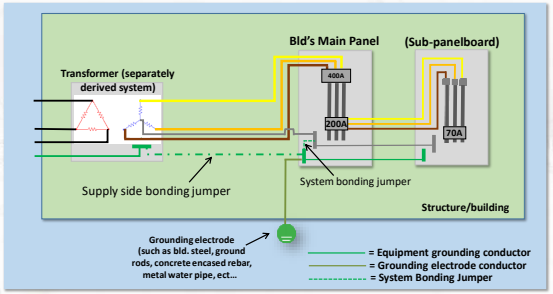
Detached structure fed by a set of feeders (example)



188

188

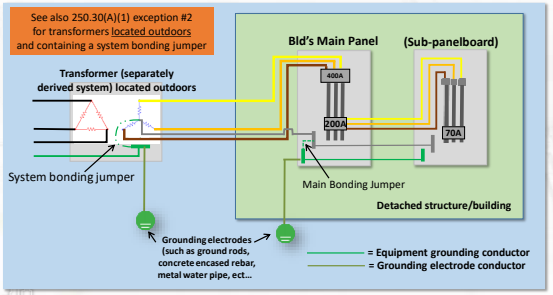
Transformer within the building (example)



189

189

Detached structure fed by a transformer located outdoors (example)



190

190

250.50 Grounding Electrode System

- At least one grounding electrode noted per 250.50(A)(1) through (A)(7) must be provided for a grounded system.
- All grounding electrodes that are present at each building or structure must be bonded together to form the grounding electrode system
  - Existing concrete-encased electrodes are not required to be connected to the electrode system when such reinforcement is not accessible – see this exception under *NEC* 250.50.

191

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250.52 Grounding Electrodes

- **(A)(1)** A grounding electrode conductor must connect to a metal underground water pipe that is in contact with the earth for at least 10 feet.
- Such connection must be made within 5 feet of where the metal water pipe enters the bld. (see 250.68(C)).
- Such connection also cannot rely on water meters or filtering devices for continuity to the water pipe (see 250.53(D)(1)).

192

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250.52 Grounding Electrodes (continued)

- **(A)(2)** The metal frame of a building or structure is to be considered as an electrode when it meets the following:
- There's at least one structural member that is in direct contact with the earth vertically for at least 10 feet (with or without concrete encasement).

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250.52 Grounding Electrodes (continued)

- **(A)(3)** A concrete-encased electrode (with min. of 2" concrete cover) must be at least 20 feet worth of either of the following:
- Bare steel reinforcing bars or rods of not less than ½ in diameter for not less than 20' feet in length, or multiple sections of rebar tied together which forms at least 20' of length in contact with the earth.
- Minimum #4 AWG bare copper wire.

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250.52 Grounding Electrodes (continued)

- **(A)(4)** A ground ring is an electrode that is at least #2 AWG bare copper that is buried at least 30" deep (see 250.53(F)) and has at least 20 feet in contact with the earth.

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250.52 Grounding Electrodes (continued)

- **(A)(5)** says that rod and pipe electrodes must be at least 8 feet in length.
  - Pipe or conduit electrodes must be at least ¾" in diameter (trade size) and must have the outer surface be galvanized or be metal coated for corrosion protection.
  - Rod type electrodes must be either stainless-steel and copper, or be zinc coated steel and such rods must be at least 5/8" in diameter.

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250.52 Grounding Electrodes (continued)

- **(A)(6)** says that other listed grounding electrodes are permitted.

This ½" ground rod is listed as an electrode

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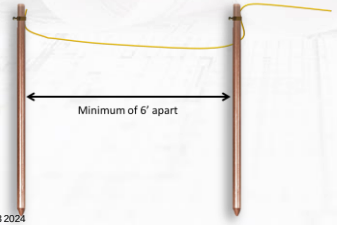
250.53 Installation of Grounding Electrodes (continued)

- **(A)(3)** Supplemental electrodes for this section must be located at least 6 feet from the other electrode (see also 250.53(B) which says that any electrodes must be at least 6' apart).

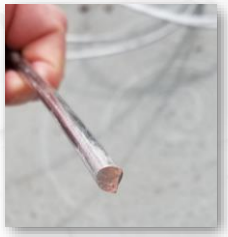


198

198

250.64(A) Aluminum or Copper-Clad Aluminum Conductors

- Bare aluminum or copper-clad aluminum grounding electrode conductors cannot be installed in direct contact with masonry or the earth and cannot be installed in any corrosive locations.
- If they're installed outside the building, then they must not be terminated within 18 inches of the earth.



Above example is not copper-clad aluminum, but rather is tin-plated copper wire.

199

199

250.64(B) Securing and Protecting the GEC

- GECs of #6 AWG (or larger) solid copper are permitted to be installed exposed along the surface of the building as long as it is free from exposure to damage.
- GECs that are smaller than #6 AWG must be protected in appropriate conduit or enclosures (see 250.64(B)).

Violations?

200

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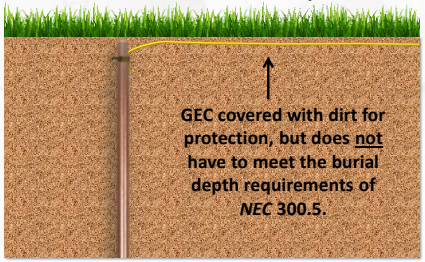
250.64(B) Securing and Protecting the GEC (continued)

Per 250.64(B)(4), GEC's do not have to meet the burial requirements of *NEC* 300.5, however the wire still must be protected from damage.



201

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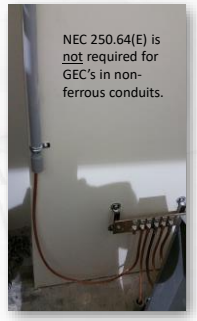
NEC 250.64(E)

- *Any* GECs installed in ferrous metal (contains iron) enclosures or conduit must be made electrically continuous by bonding each end of the metal enclosure and/or conduit(s) to the GEC wire.

Examples of bond bushings that can be used at each end of a ferrous metal conduit for bonding a GEC to the ends of the conduit.



202

202

250.66 Size of Grounding Electrode Conductors for AC Systems

- Grounding electrode conductors must be sized per Table 250.66 based on the largest ungrounded service conductor for the service (or based on the largest ungrounded transformer secondary conductors, if the GEC is for a transformer).
- GECs do not have to be larger than that noted per 250.66(A) through (C).
  - (A) #6 copper when sole connection to rod, pipe, or plate electrodes.
  - (B) #4 copper when sole connection to concrete-encased electrodes.
  - (C) #2 copper when sole connection to ground rings (or not smaller than the size of the ground ring conductor).

203

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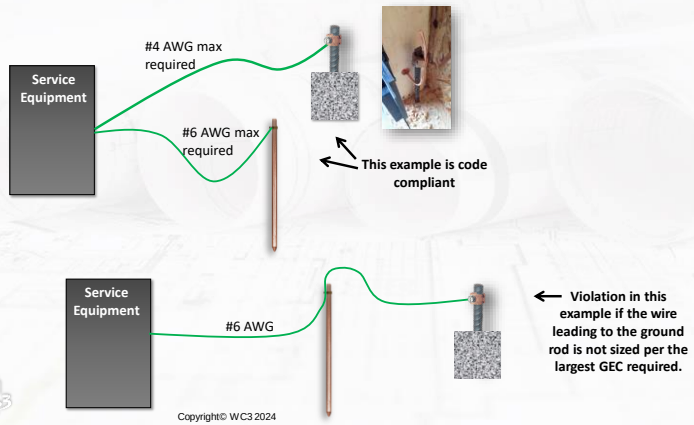

204

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NEC Table 250.66

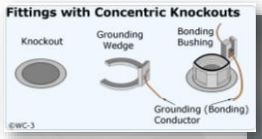
Size of largest ungrounded conductor or equivalent area for parallel conductors		Size of grounding electrode conductor	
Copper	Aluminum	Copper	Aluminum
#2 or smaller	1/0 or smaller	8	6
#1 or 1/0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250 kcmil	4	2
Over 3/0 through 350 kcmil	Over 250 kcmil through 500 kcmil	2	1/0
Over 350 kcmil through 600 kcmil	Over 500 kcmil through 900 kcmil	1/0	3/0
Over 600 kcmil through 1100 kcmil	Over 900 kcmil through 1750 kcmil	2/0	4/0
Over 1100 kcmil	Over 1750 kcmil	3/0	250 kcmil

See also notes to *NEC* Table 250.66

205

205

Bonding at Service Equipment



4 bolt threaded conduit hubs need not have additional bonding (*NEC* 250.92(B)(2)).

See also *NEC* 250.97 for similar requirements for bonding of electrical enclosures and conduit containing wiring having a voltage of over 250V to ground.

Metal conduit must be provided with a **supply-side bonding jumper** (or a listed conduit bonding fitting that makes such jumper Unnecessary).

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250.122 Size of Equipment Grounding Conductors

- Equipment grounding conductors (EGC) of the wire type must not be smaller than what is required per Table 250.122 based on the largest overcurrent device rating protecting the circuit conductors the EGC serves.
- An EGC is not required to be larger than the ungrounded circuit conductors that the EGC serves.

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NEC Table 250.122

Size of equipment grounding conductor

Rating of OCPD protecting the circuit	Copper	Aluminum
15	14	12
20	12	10
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250 kcmil
1600	4/0	350 kcmil
2000	250 kcmil	400 kcmil
2500	350 kcmil	600 kcmil
3000	400 kcmil	600 kcmil
4000	500 kcmil	750 kcmil
5000	700 kcmil	1200 kcmil
6000	800 kcmil	1200 kcmil

208

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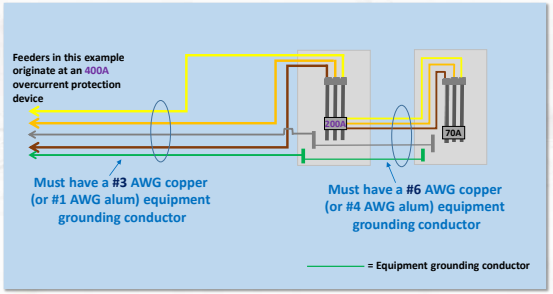
Size of equipment grounding conductors (example)



209

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250.122(B) Increased In Size

- Whenever the ungrounded feeder or branch circuit conductors are increased in size (from that of their minimum size), any wire-type equipment grounding conductors installed for the circuit must be proportionately be increased in size (according to the circular mil area of the ungrounded conductors).

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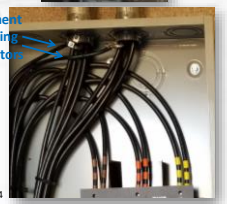
250.122(F) Conductors in Parallel

- In general, if there are parallel sets of conductors in the same conduit, raceway, or cable tray, then only one full size equipment grounding conductor needs to be provided therein.
- If parallel sets of conductors are installed in separate raceways or conduit, then there must be a full size equipment grounding conductor provided in each raceway or conduit.



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Questions?

The End

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