CADMUS

PV & Utility Interconnections

An Independent Contractor to: nyserda Energy. Innovation. Solutions.

Solar Photovoltaic Installation Best Practices

Presented: May 6, 2014
Revised May 15, 2014

Presented by:
The Cadmus Group

About Cadmus

- Energy and environmental consulting firm
- Completed hundreds of solar inspections and design reviews
- Owner's Agent on ~50 municipal solar projects
- Staff includes
  - PE's
  - Licensed electricians
  - NABCEP certified installers

Outline

- Residential Systems
  - Load Side Connections
  - Supply Side Connections
- Commercial Systems
  - Load Side Connections
  - Supply Side Connections
- Additional Notes
- References

Guide to Compliant PV interconnections

- As of the date of this writing, in the State of NY, the 2008 version of the NEC is in effect. Therefore all code references in this document will be relevant to the 2008 NEC.

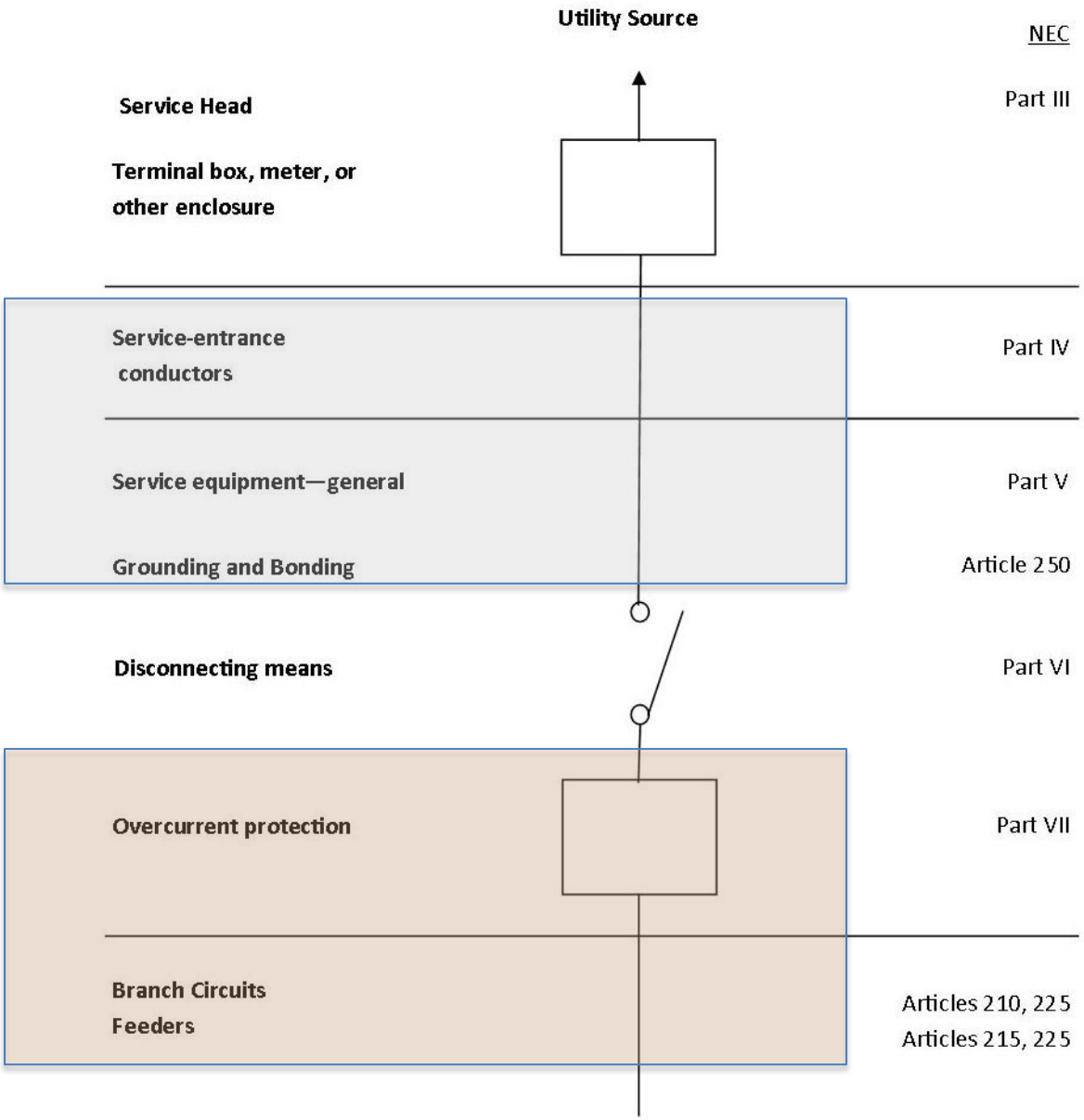
Before we get too far…

- MLC – Main Load Center
- MB – Main Breaker
- MLO – Main Lugs Only
- OCPD – Over Current Protection Device
- PV – Photovoltaic
- VAC – Volts, Alternating Current
- A – Amps
- N-G – Neutral to Ground
- GEC – Grounding Electrode Conductor
- EGC – Equipment Grounding Conductor




Supply Side Connections

Load Side Connections

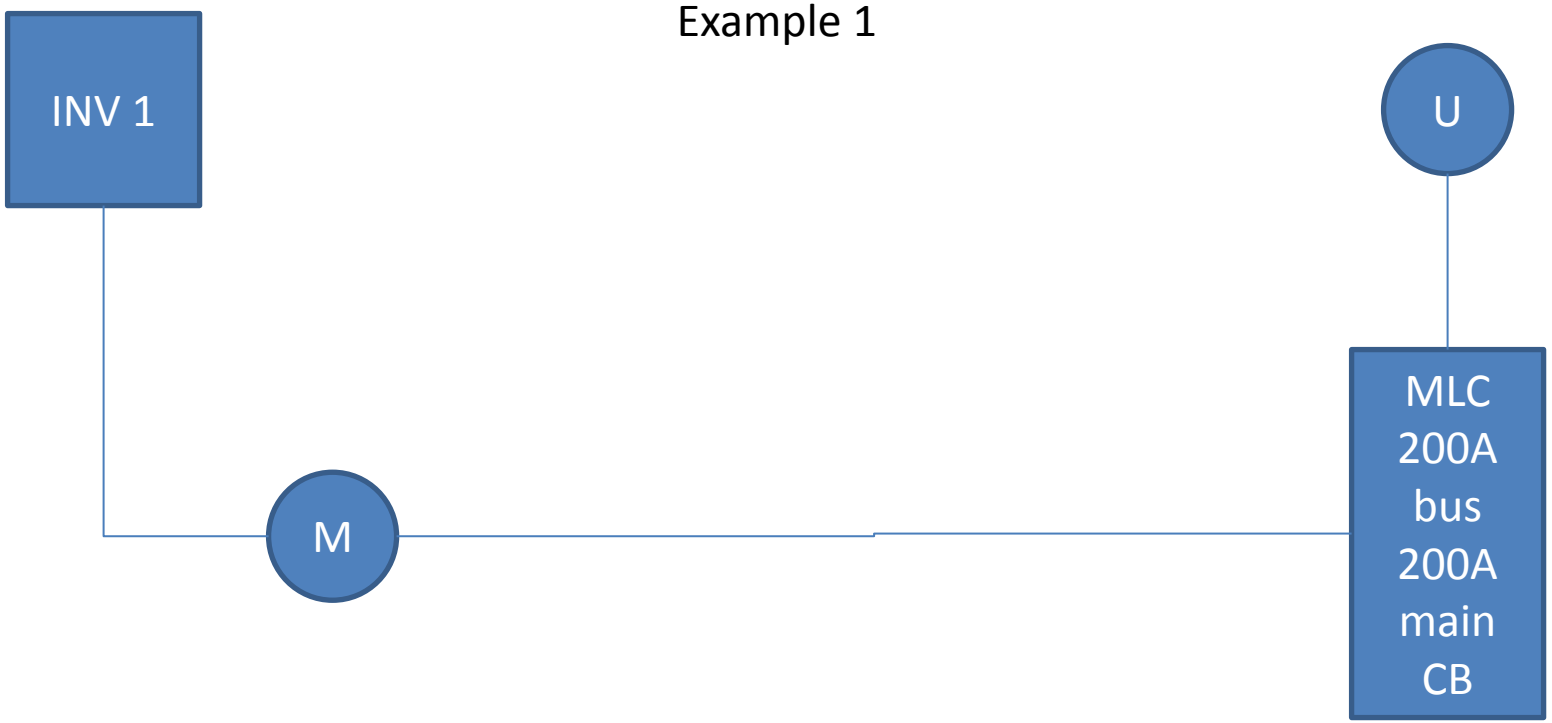


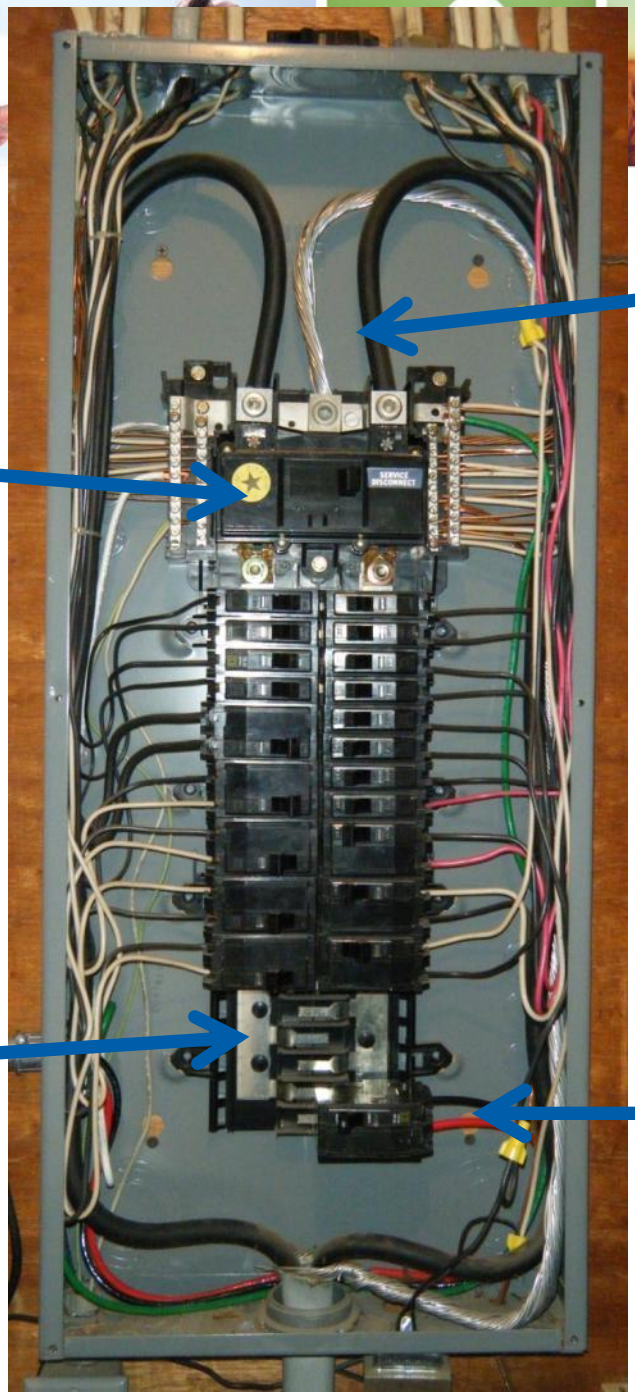
Residential Load Side Connection – 690.64(B)

- Backfed breaker in the MLC
- Any point downstream of the first service disconnect (main breaker or dwelling service disconnect)
- If greater than 100% of bus bar rating, must be located at opposite end from utility feed
- Each inverter must have its own OCPD (no paralleling outputs)




Example 1




Service conductors
Main breaker
Bus bars
Backfed breaker

- 690.64(B)2; sum of ampere ratings of OCPDs in circuits supplying power to a busbar or conductor shall not exceed 120% of the rating of the busbar or conductor.
- 690.64(B)7; unless the panelboard is rated not less than the sum of the ampere ratings of all overcurrent devices supplying it, a connection in a panelboard shall be positioned at the opposite (load) end from the input feeder location or main circuit location

120% Calculation Examples

- Main Load Center (MLC) bus bar rating = 200A
  Main Breaker (MB) in main load center rating = 200A
  MLC * 1.2 = 240A
  240A – MB = 40A
  40A maximum breaker size allowable for this example
- Practically speaking this limits backfed current to 32A (40A/1.25=32A)
- Must be located at opposite end of bus bars from MB




Main Breaker

PV system backfed breaker

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Backfed breaker

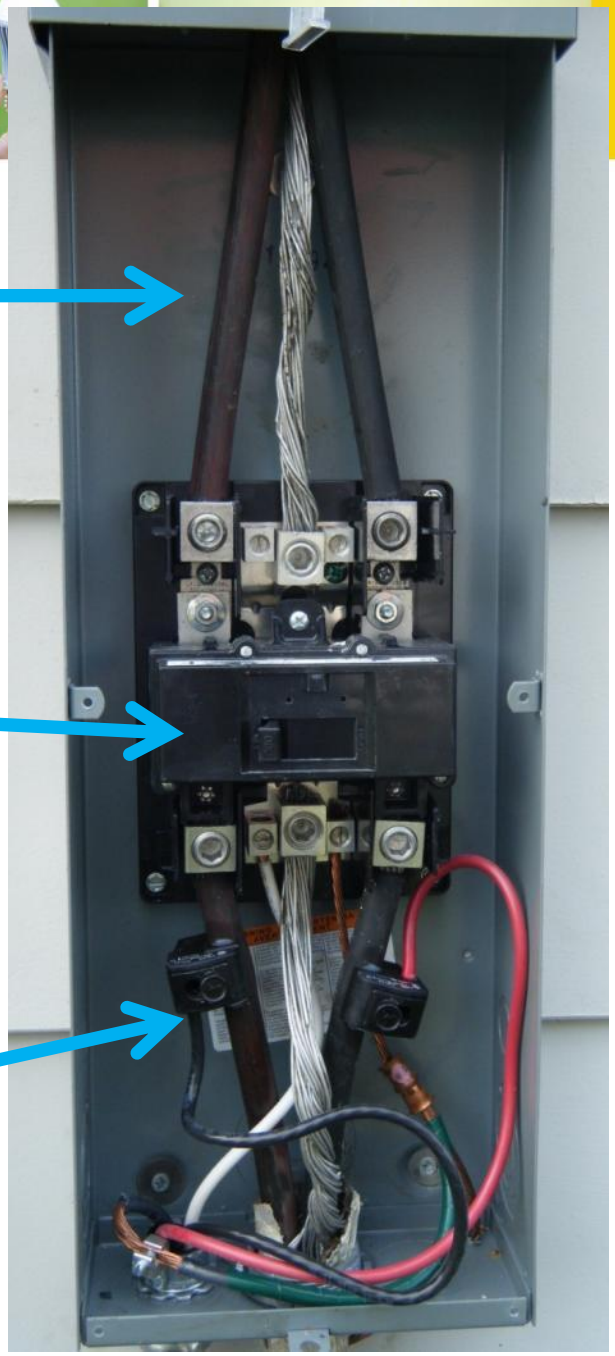


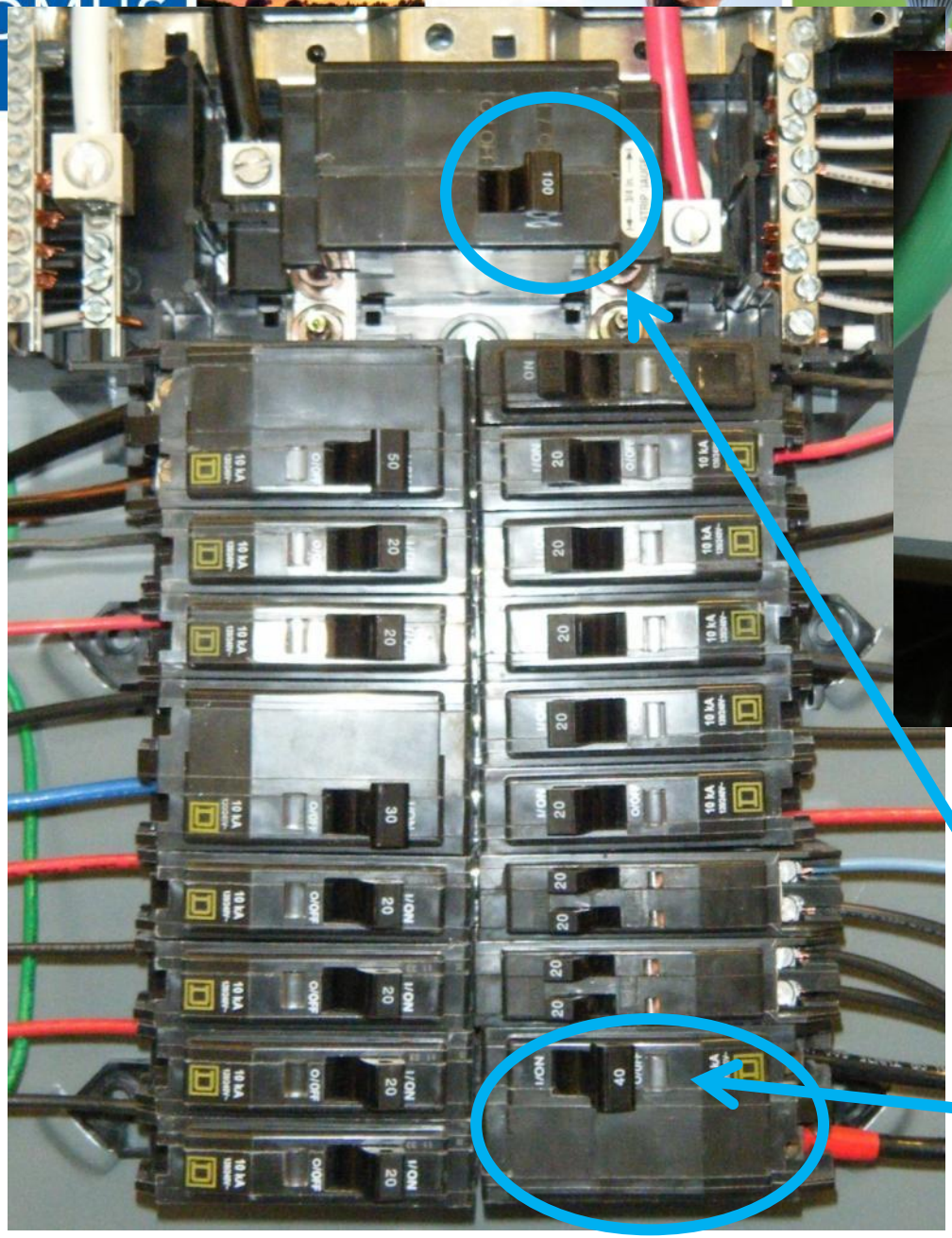

Backfed breaker

Service Entrance Conductors

Main Service disconnect-OCPD

Load side conductors tapped for PV




100A bus bars
100A Main breaker
40A PV backfeed




Combining Inverter Outputs

- Sometimes multiple inverters can be combined in a subpanel, allowing a compliant backfeed in an MLC which would not be possible when each inverter had its own breaker in the MLC.
- With microinverters, it may be the only practical way to install a PV interconnection.

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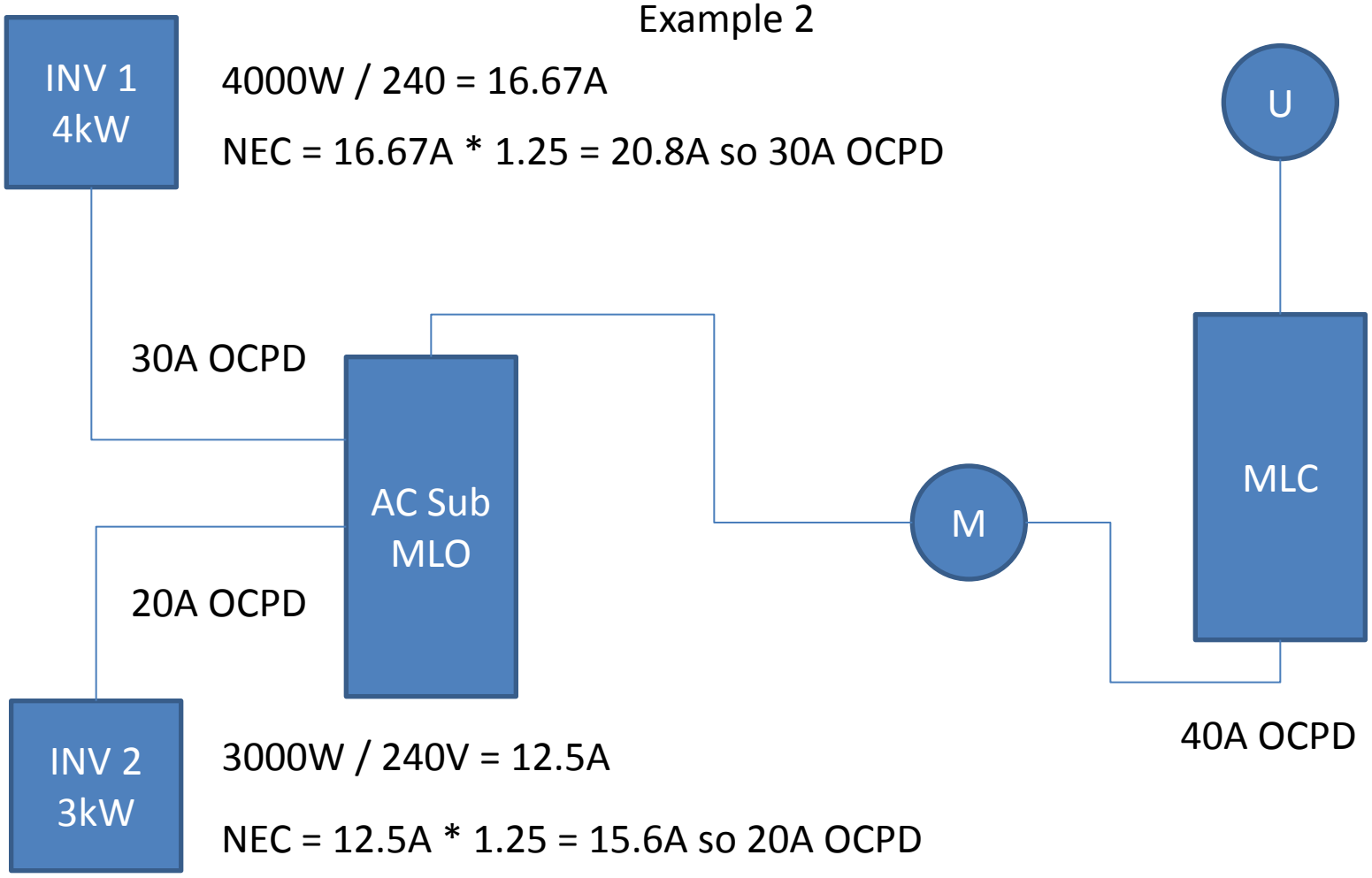
Example 2



16.67A +12.5A = 29.17A * 1.25 = 36.47A so 40A OCPD in MLC

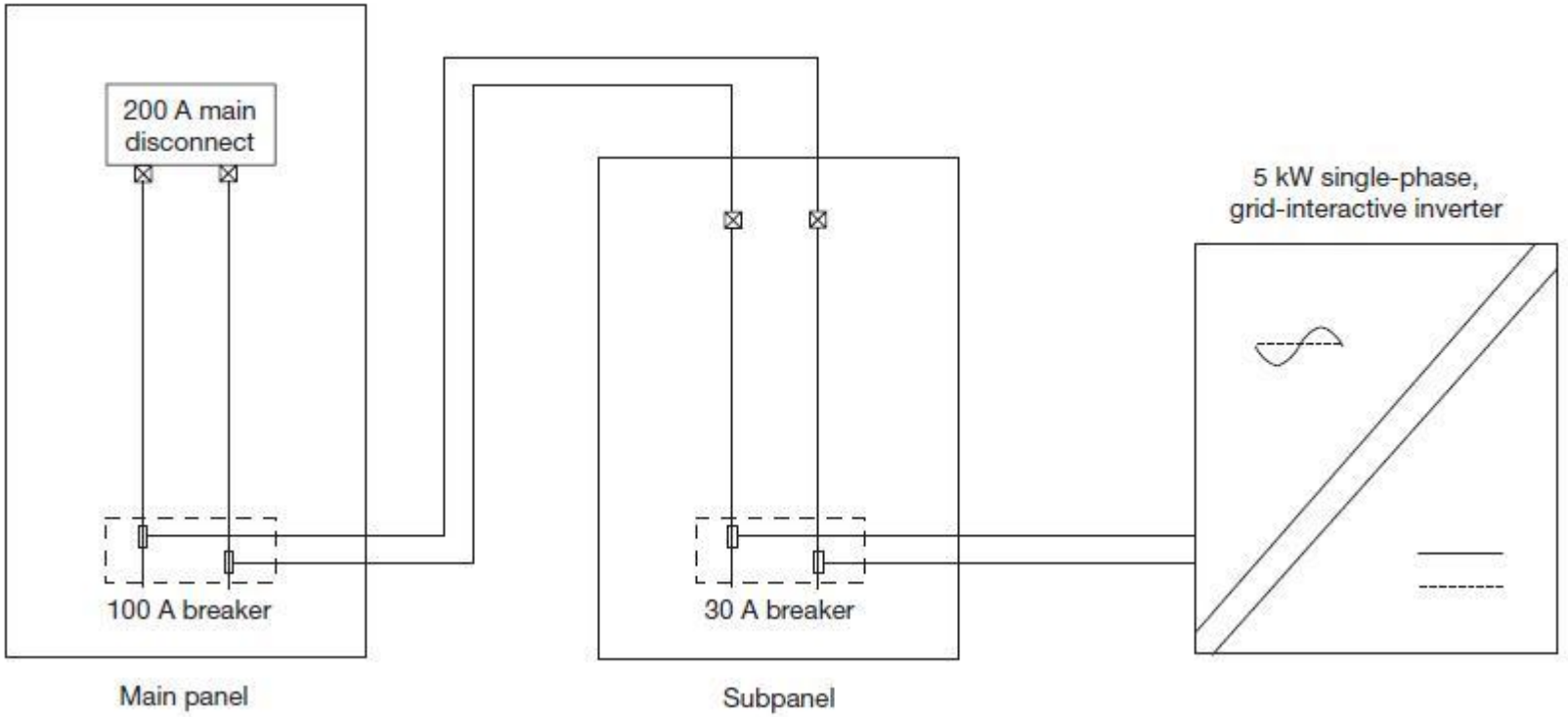
Downsizing Main Breaker

- Another option is when the service is oversized for the loads, it may be possible to downsize the main breaker, increasing the available backfeed amount.
- MLC bus bar rating = 100A
  MB in main load center rating = 100A
  MLC * 1.2 = 120A
  120A – MB = 20A
  reduce MB to 90A then 30A is possible

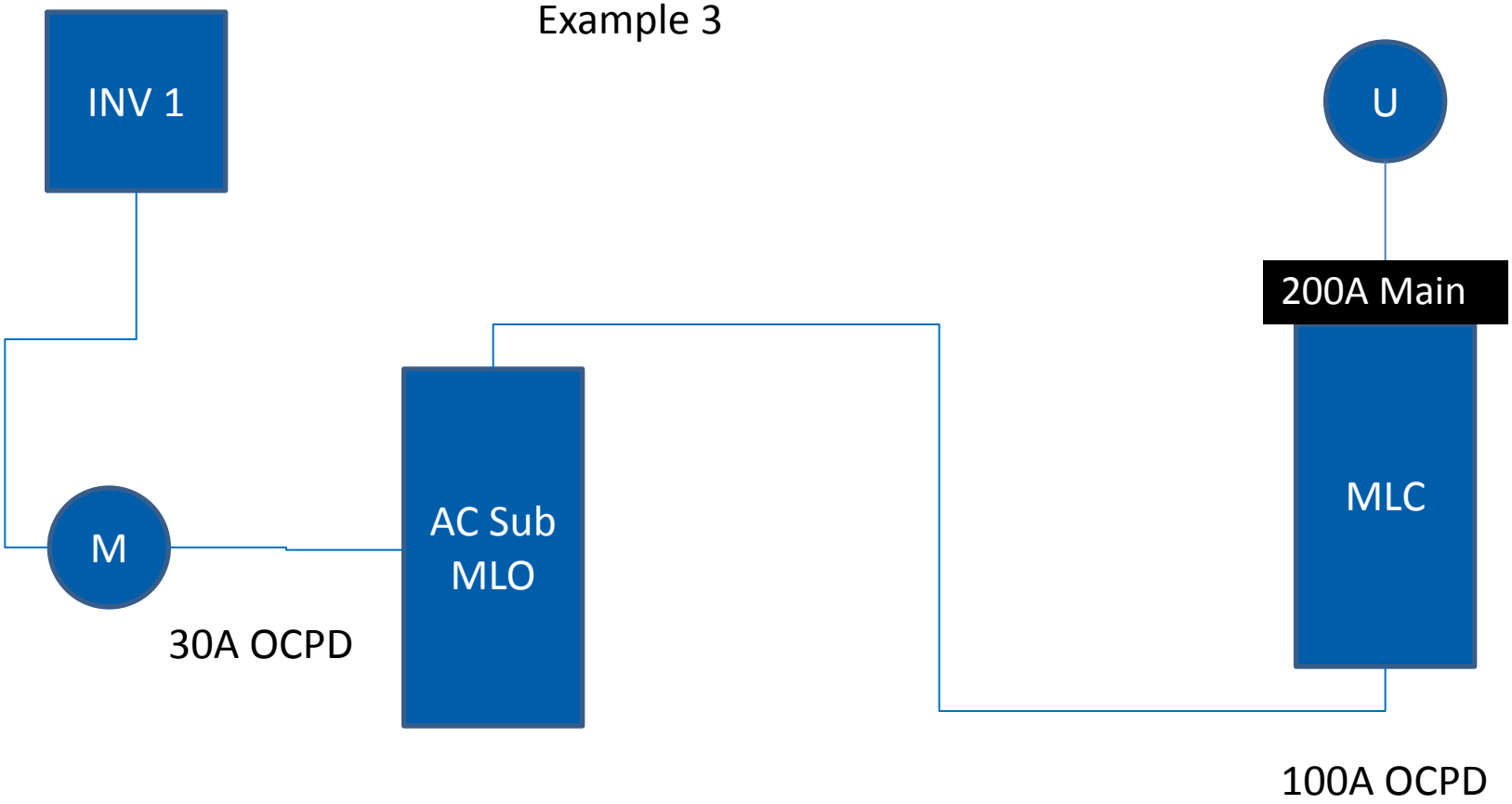
Backfed Breaker in a Subpanel

- Bus bars, conductors and breaker in MLC must all meet ampacity requirements of 690.64(B)2
- Backfed breaker in MLC must be at opposite end of bus bars from main breaker per 690.64(B)7
- Tapping a feeder is also a possibility, however this also requires that the 120% rules be followed and calculations be performed on all conductors and busbars upstream of the tap location. Additionally, busbars downstream from a tap must be protected by a main breaker, unless the sum of the OCPD's supplying power to that busbar are less than the rating of that busbar.





200 A main disconnect
100 A breaker
Main panel
30 A breaker
Subpanel
5 kW single-phase, grid-interactive inverter

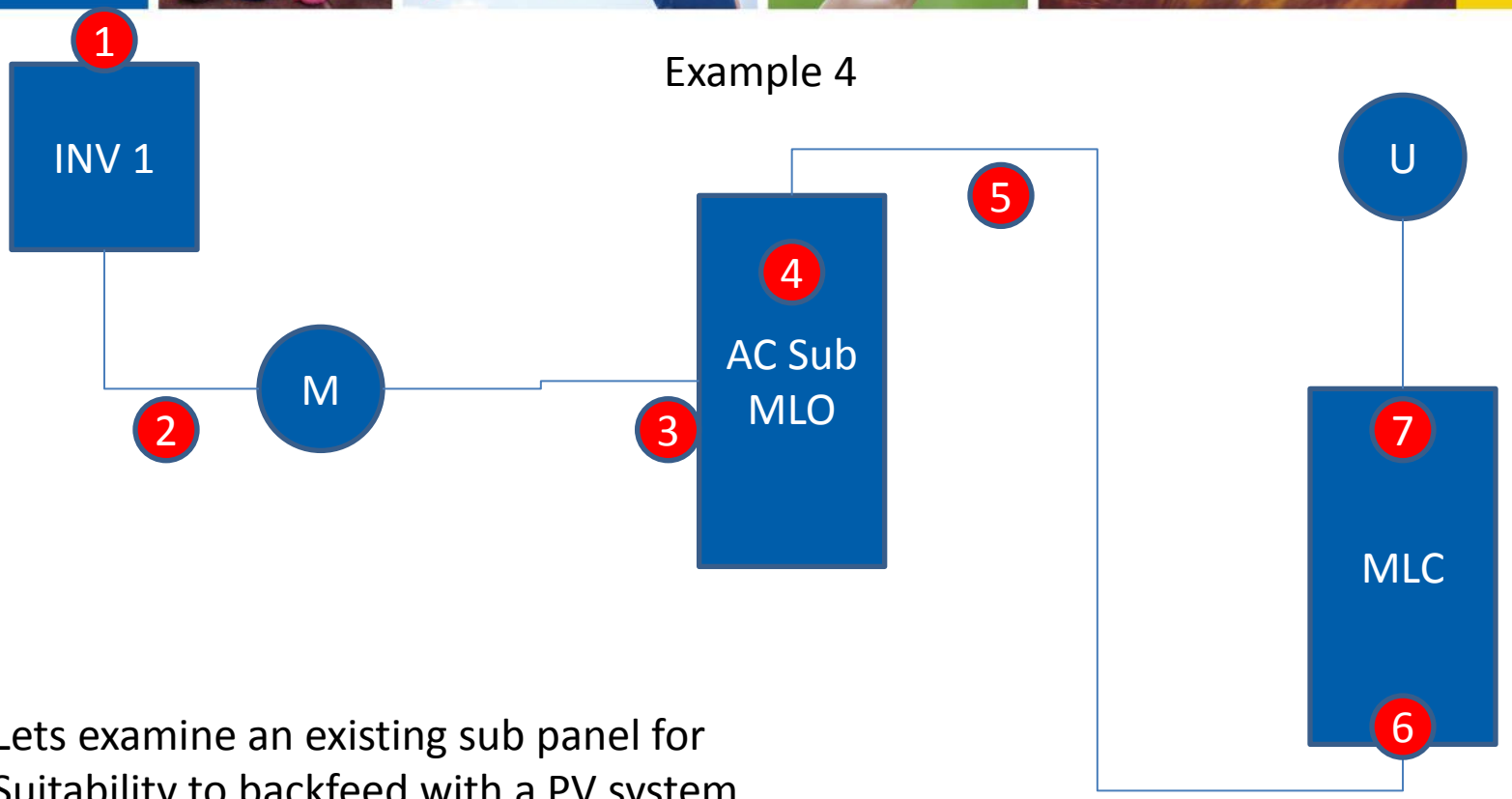
Example 3



(30A + 100A) / 1.2 = 108.33A

MLO must be 125A panel and have 110A conductors to MLC

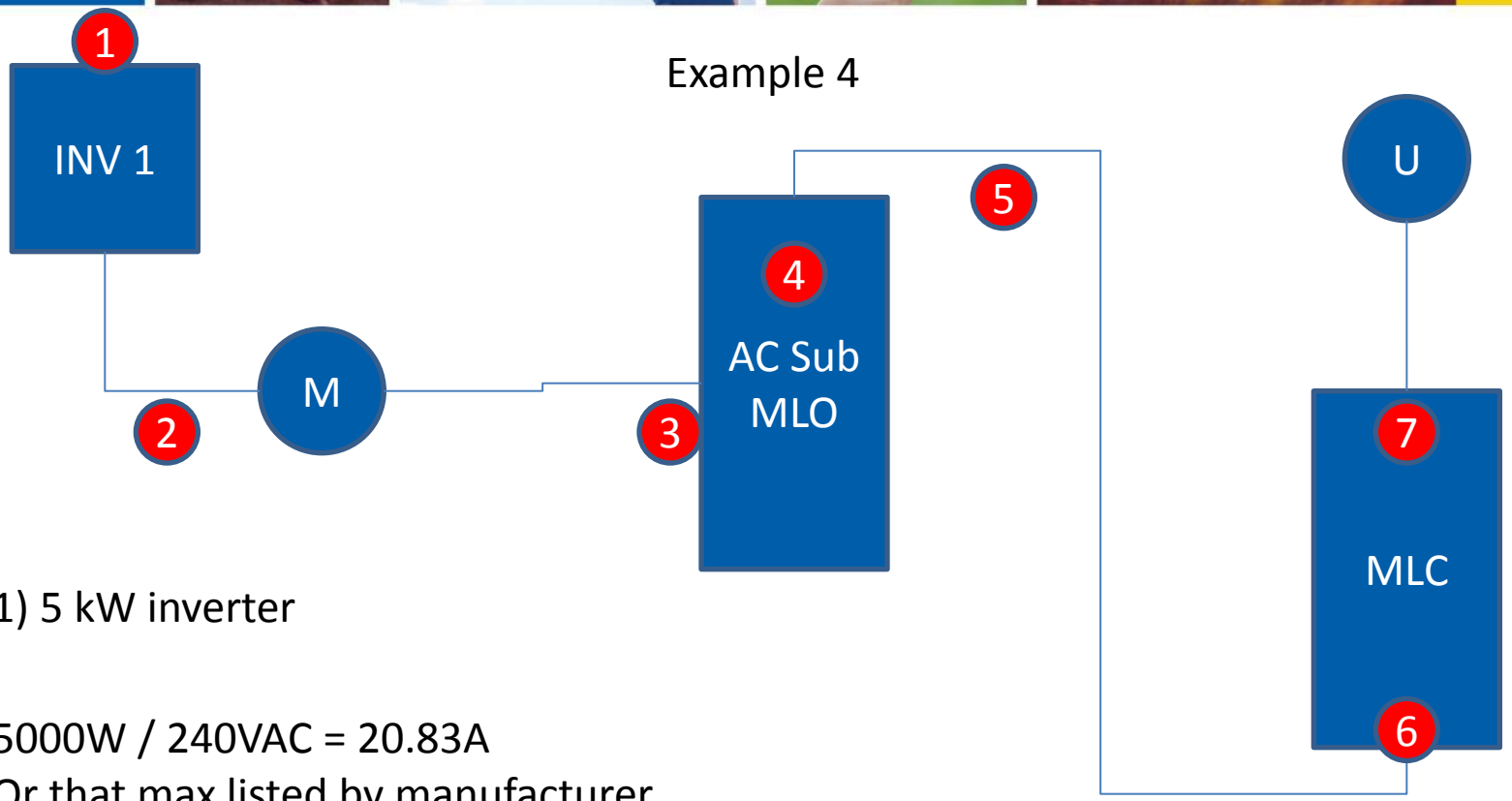
Example 4



Lets examine an existing sub panel for Suitability to backfeed with a PV system.

1)
2)
3)
4)
5)
6) 60A OCPD
7) 200A main/200A bus

Example 4

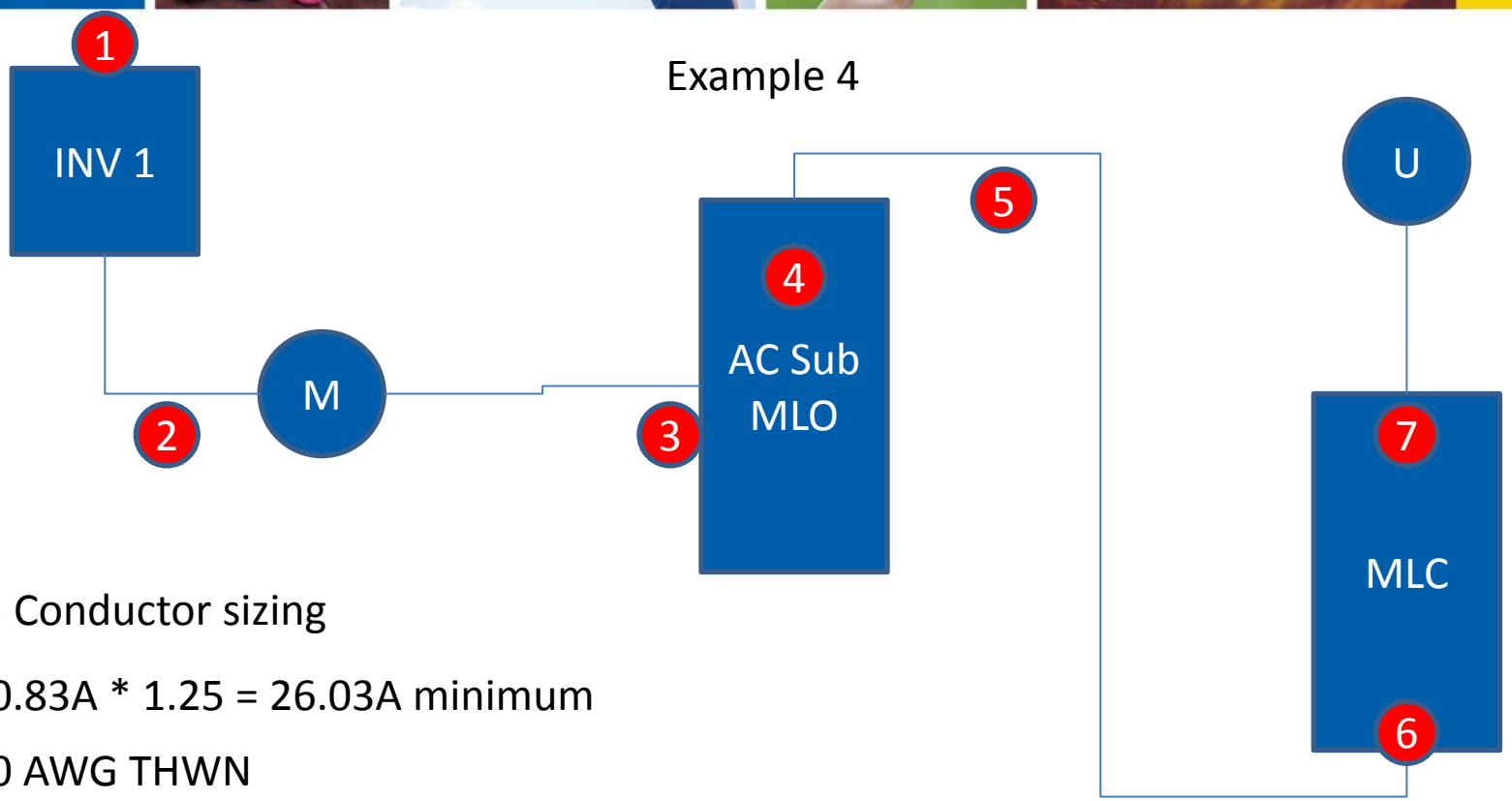


1) 5 kW inverter

5000W / 240VAC = 20.83A
Or that max listed by manufacturer

1) 5000W inverter
2)
3)
4)
5)
6) 60A OCPD
7) 200A main/200A bus

Example 4



2) Conductor sizing

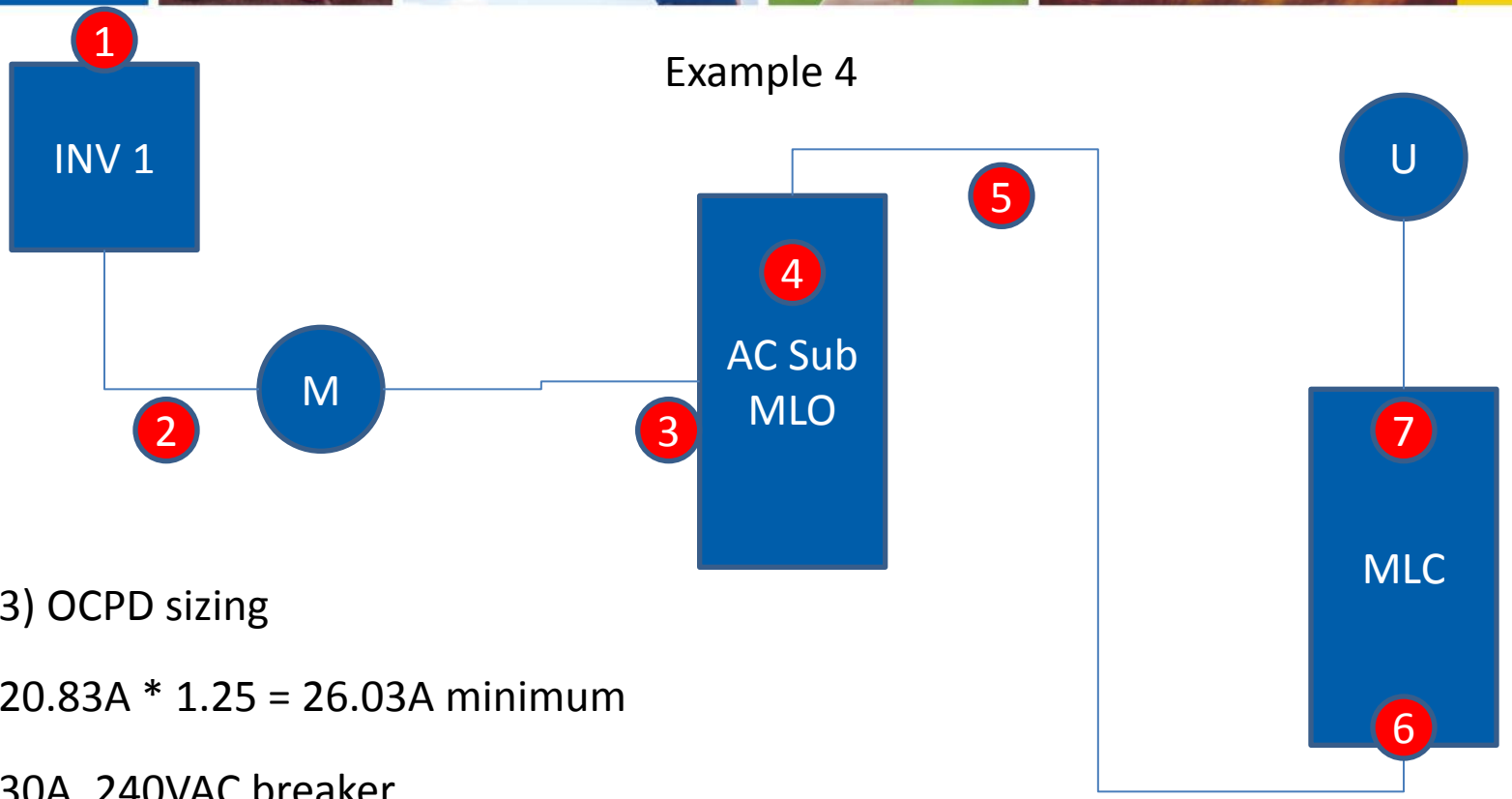
20.83A * 1.25 = 26.03A minimum

10 AWG THWN

1) 5000W inverter
2) 10 AWG THWN
3)
4)
5)
6) 60A OCPD
7) 200A main/200A bus




Example 4



3) OCPD sizing

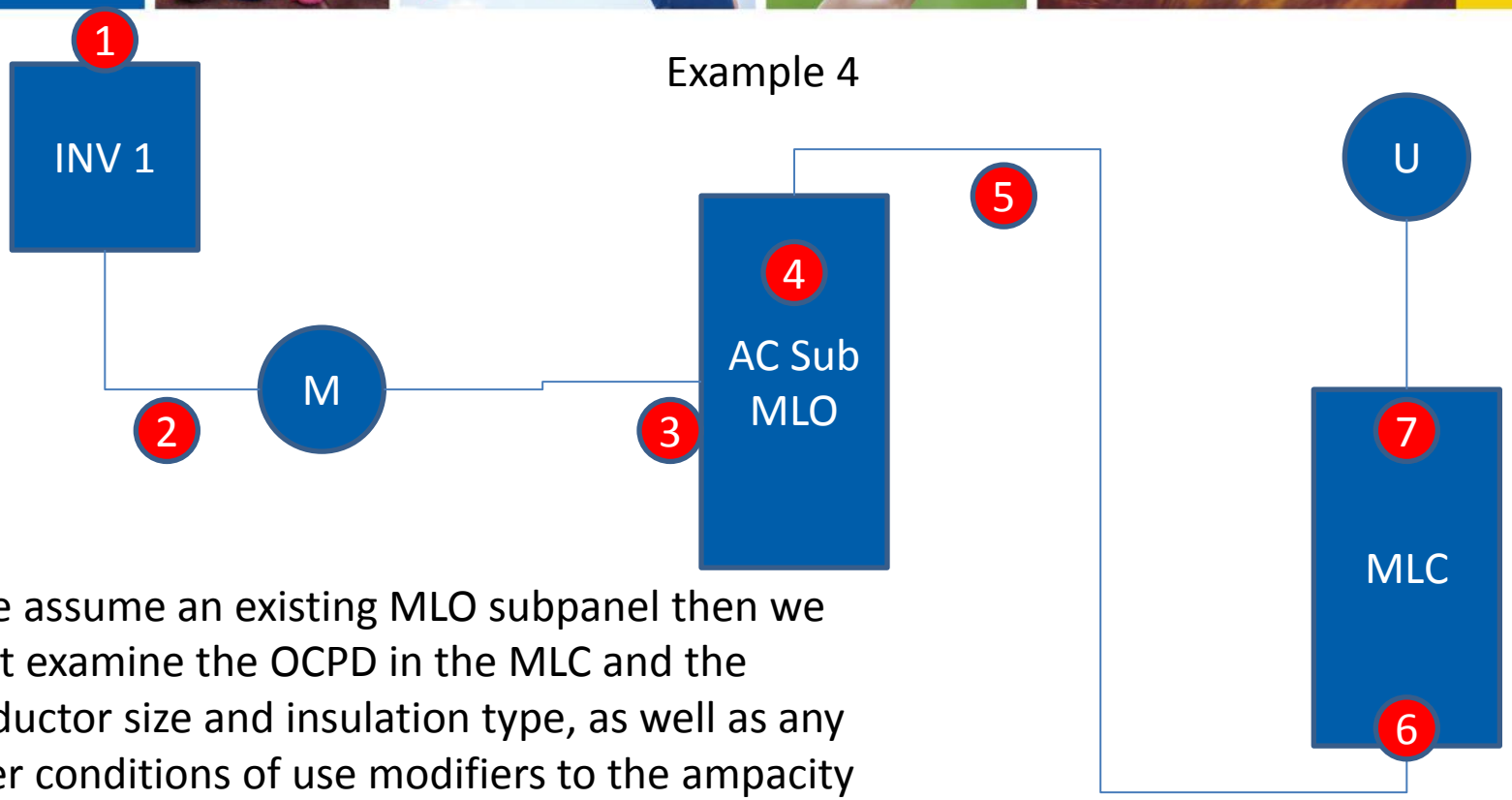
20.83A * 1.25 = 26.03A minimum

30A, 240VAC breaker

1) 5000W inverter
2) 10 AWG THWN
3) 30A OCPD
4)
5)
6) 60A OCPD
7) 200A main/200A bus




Example 4



If we assume an existing MLO subpanel then we must examine the OCPD in the MLC and the conductor size and insulation type, as well as any other conditions of use modifiers to the ampacity of the run between the MLC and the subpanel.

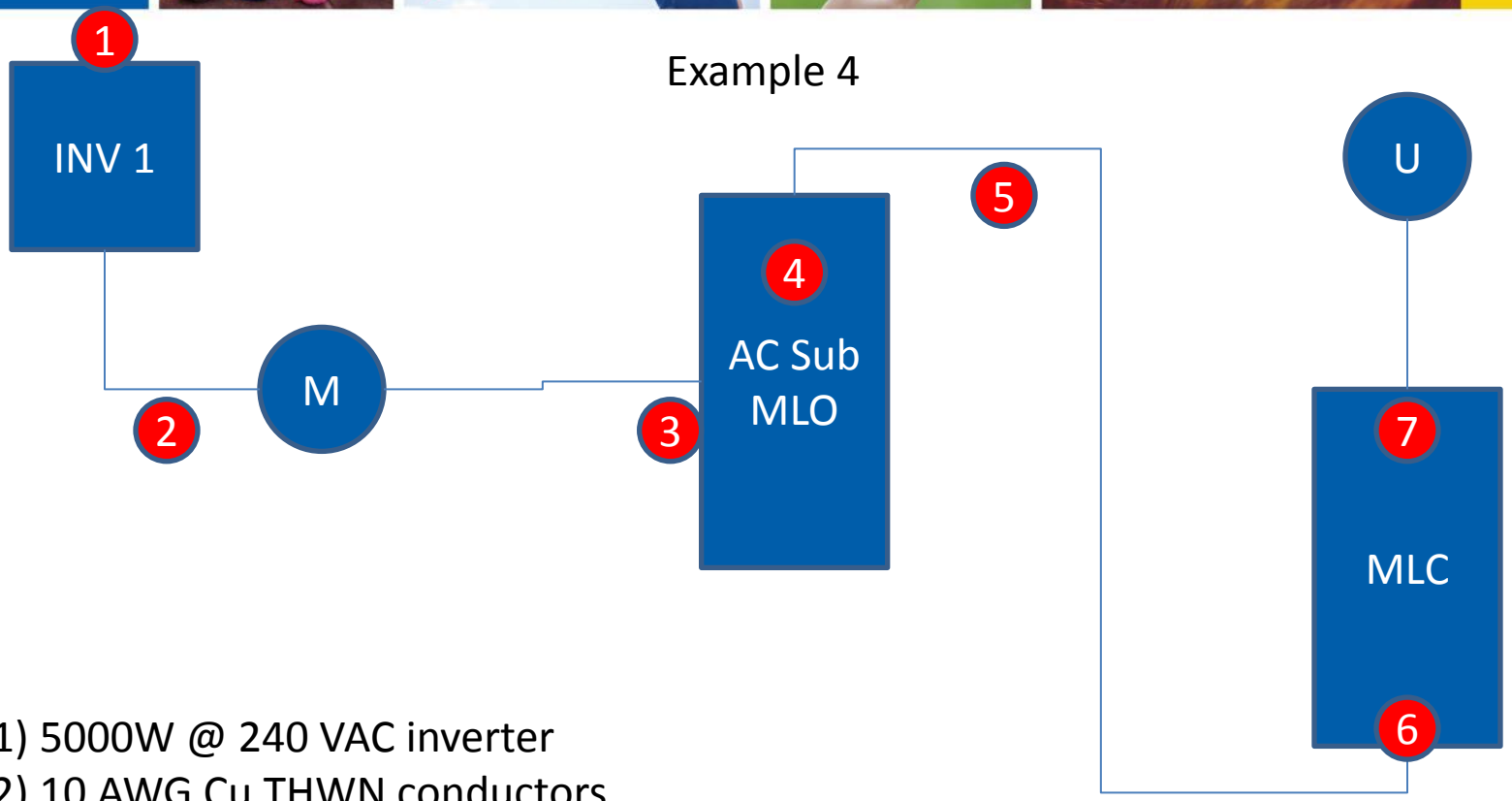
Assume existing 60A OCPD in the MLC (6)
30A + 60A = 90A

90A / 1.2 = 75A

100A subpanel is minimum necessary

1) 5000W inverter
2) 10 AWG THWN
3) 30A OCPD
4) 100A MLO subpanel
5)
6) 60A OCPD
7) 200A main/200A bus

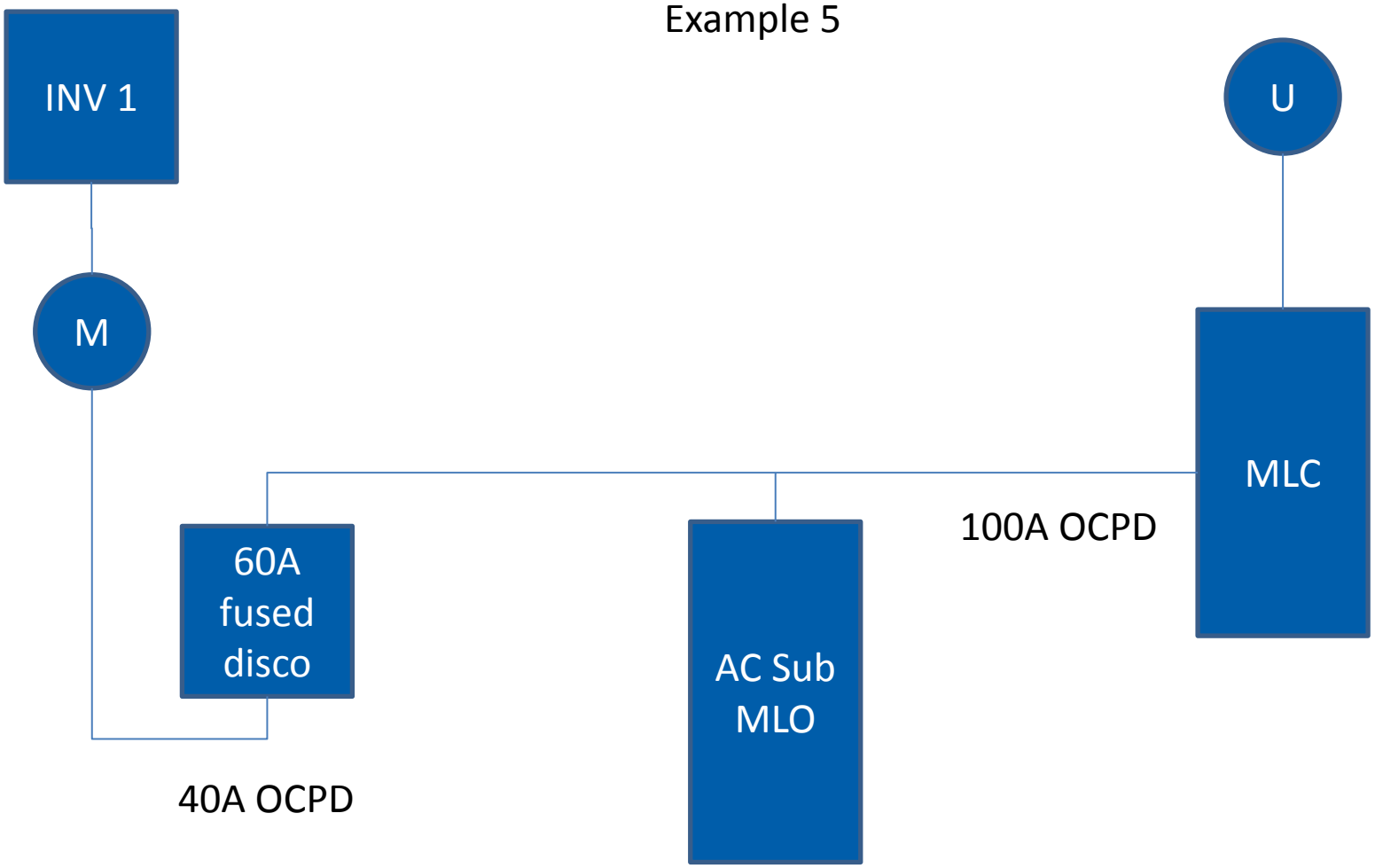
Example 4



1) 5000W @ 240 VAC inverter
2) 10 AWG Cu THWN conductors
3) 30 A OCPD
4) 100 A subpanel with MLO
5) 3 AWG Al XHHW conductors
6) 60 A OCPD in main panel at farthest point from main breaker along bus bar
7) 200A main with 200A bus bars




Example 5



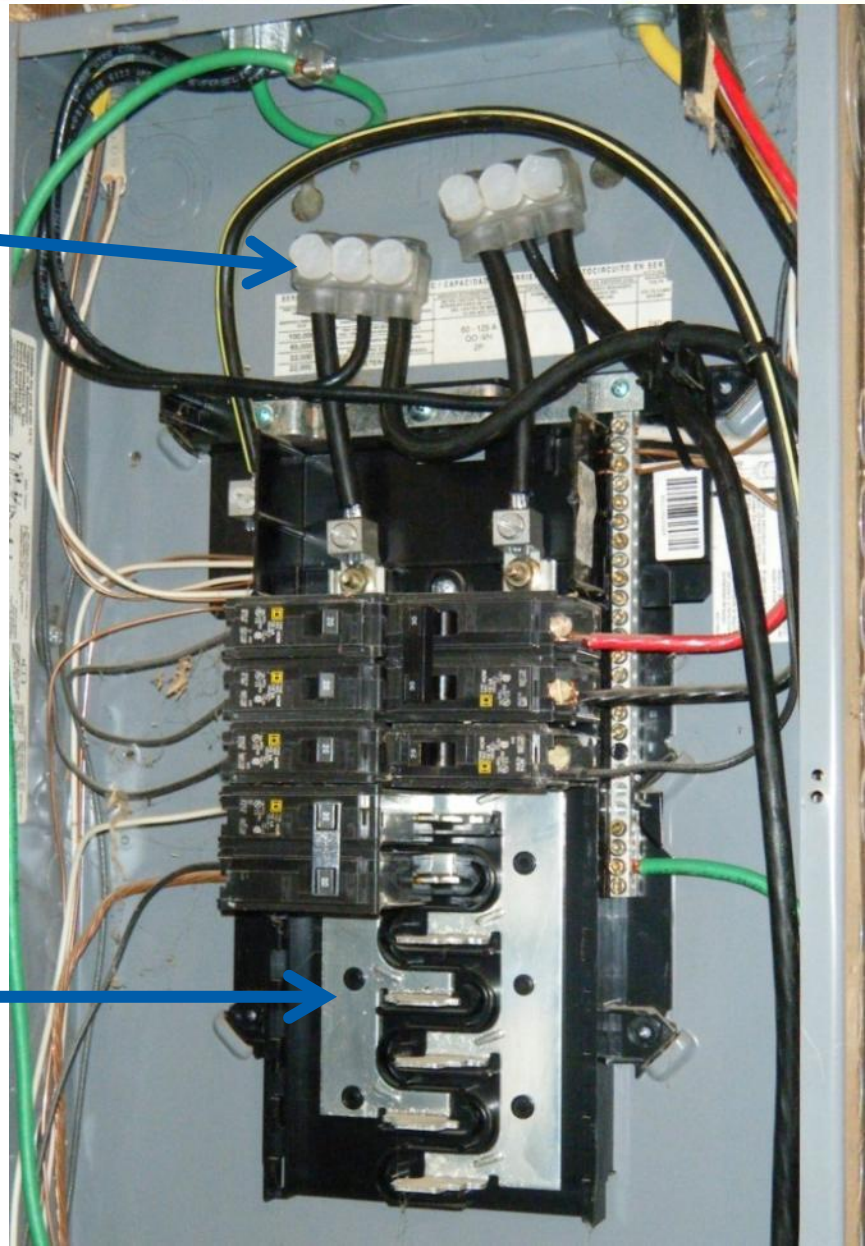
(40A + 100A) / 1.2 = 116.7A

MLO must be 125A panel and have 120A (Al) or 130A (Cu) conductors to MLC




Load side tap on feeder from Main Load Center

150A bus bars






Microinverters

- Follow same rules as larger string inverters when selecting OCPD and subpanels
- Reduces Wiring
- Common practice to combine EGC with GEC
  - Must abide by all GEC rules when choosing this; minimum conductor sizing and splicing, bonding to conduit or enclosures



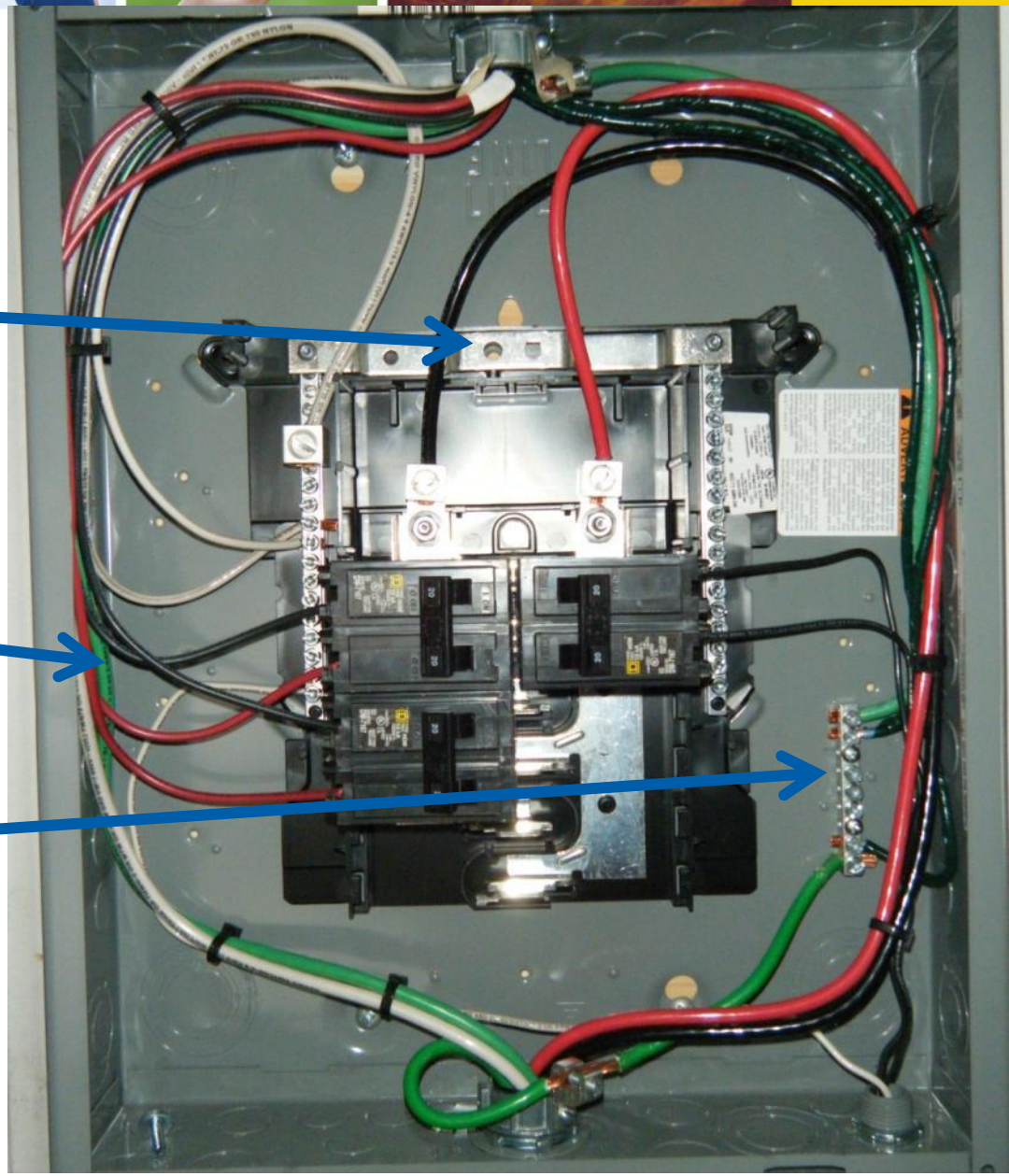

100A MLO subpanel with 2 microinverter strings

Isolated neutral conductors

No N-G bond in panel

GEC unbroken

EGC on appropriate terminal block

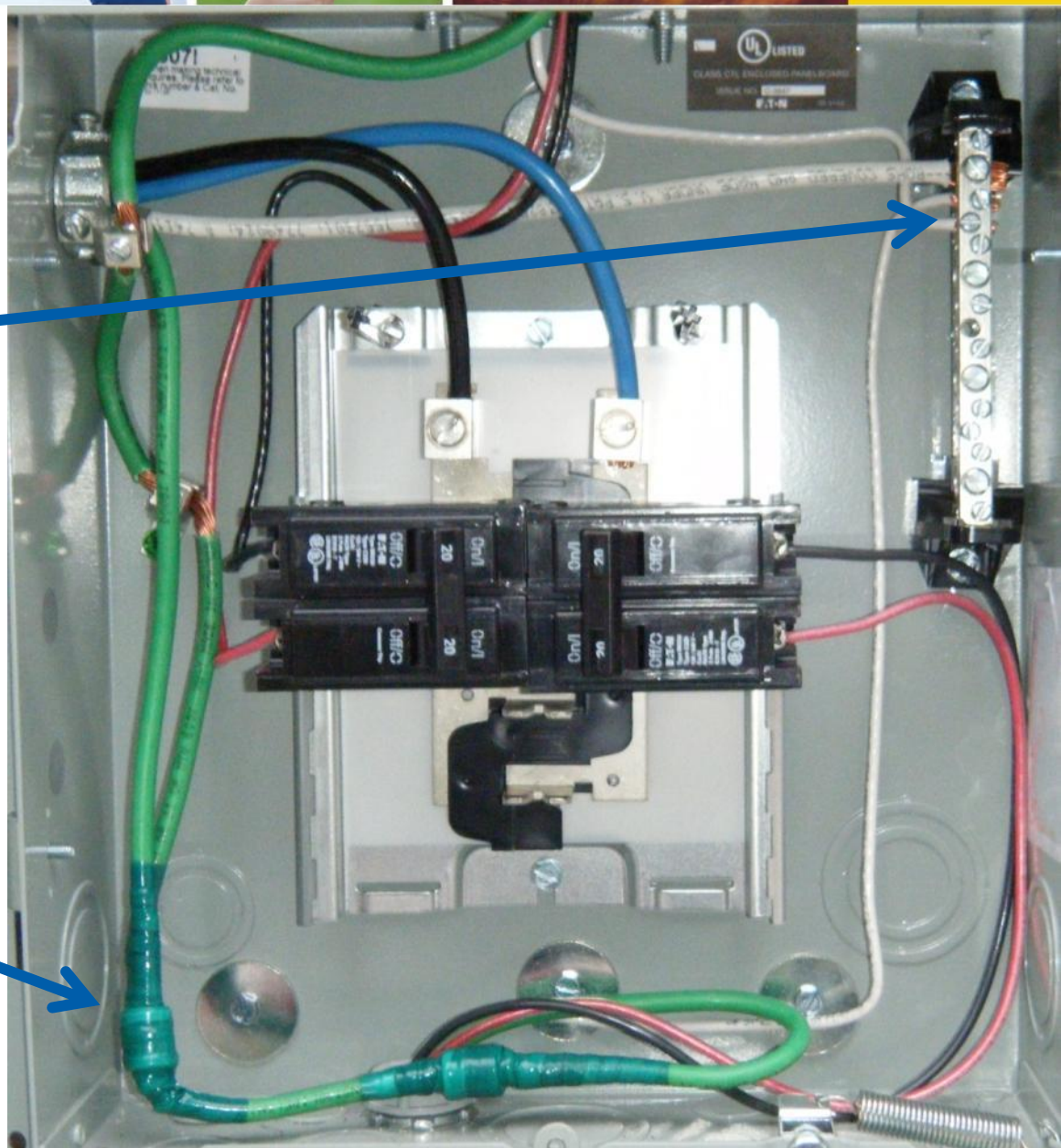





125A MLO subpanel with 2 microinverter strings

Isolated Neutrals

Combined EGC/GEC irreversably spliced



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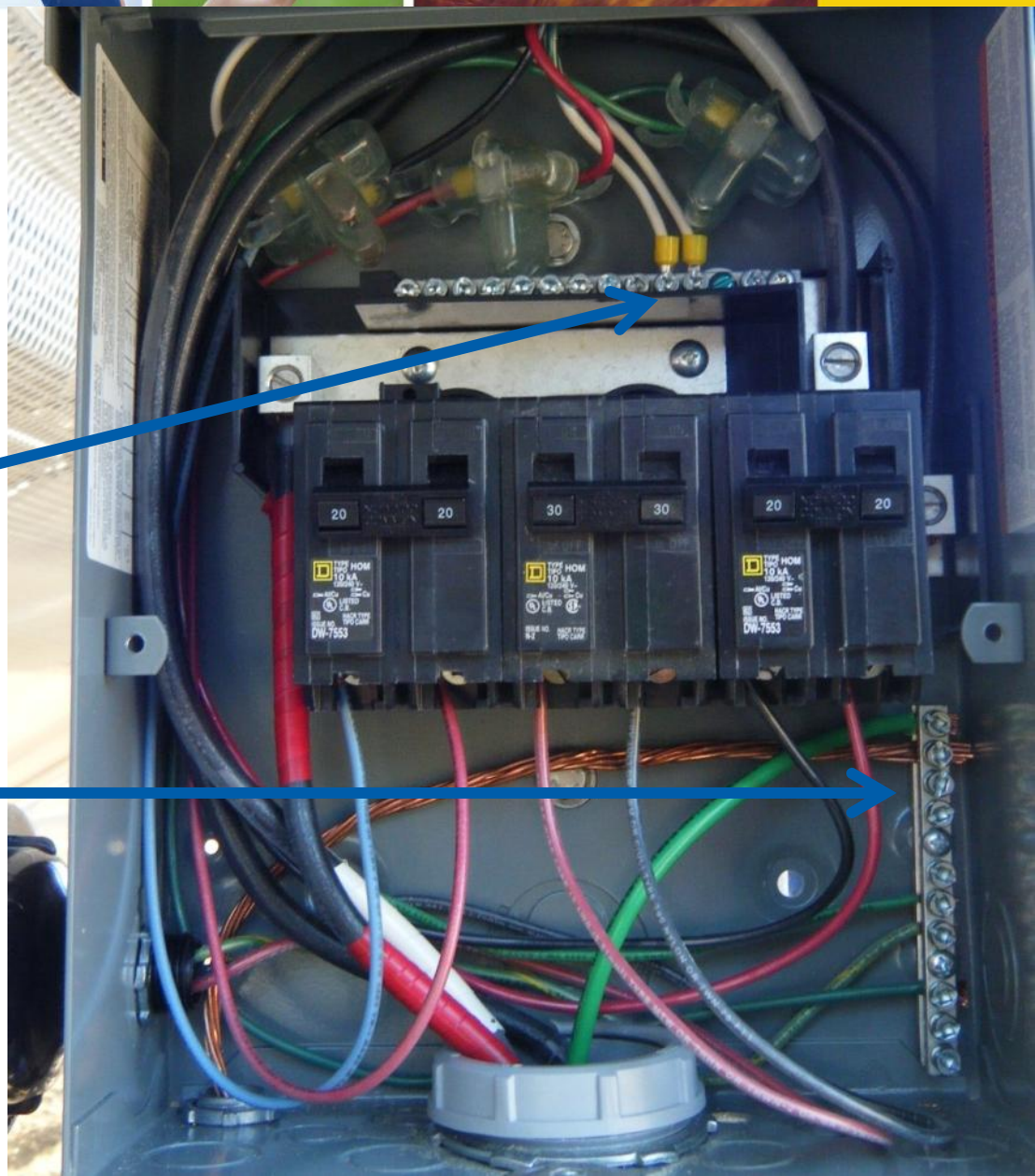
100A MLO panel with 2 microinverter circuits

Improper N-G bond

Combined EGC/GEC – broken - violation

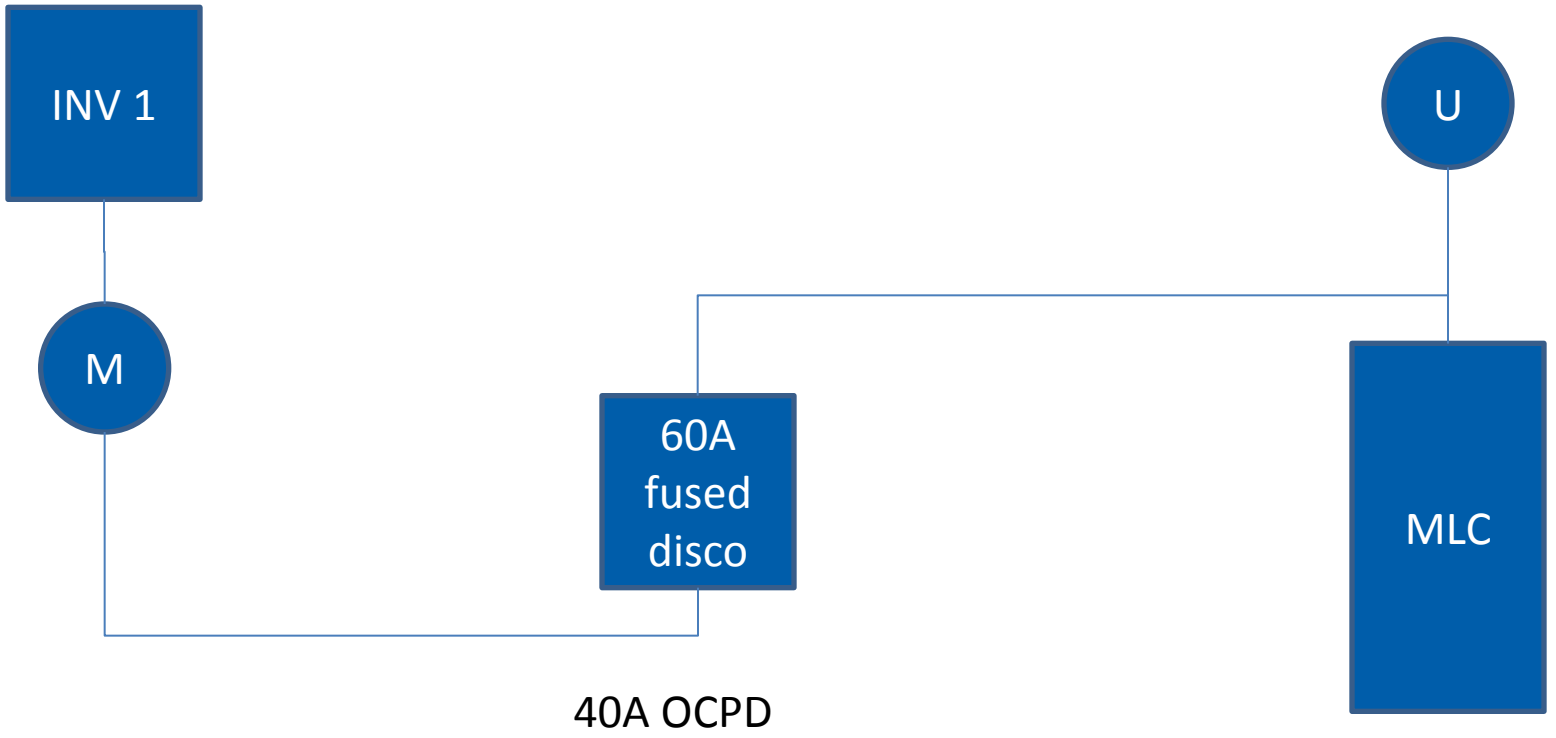


Reminders

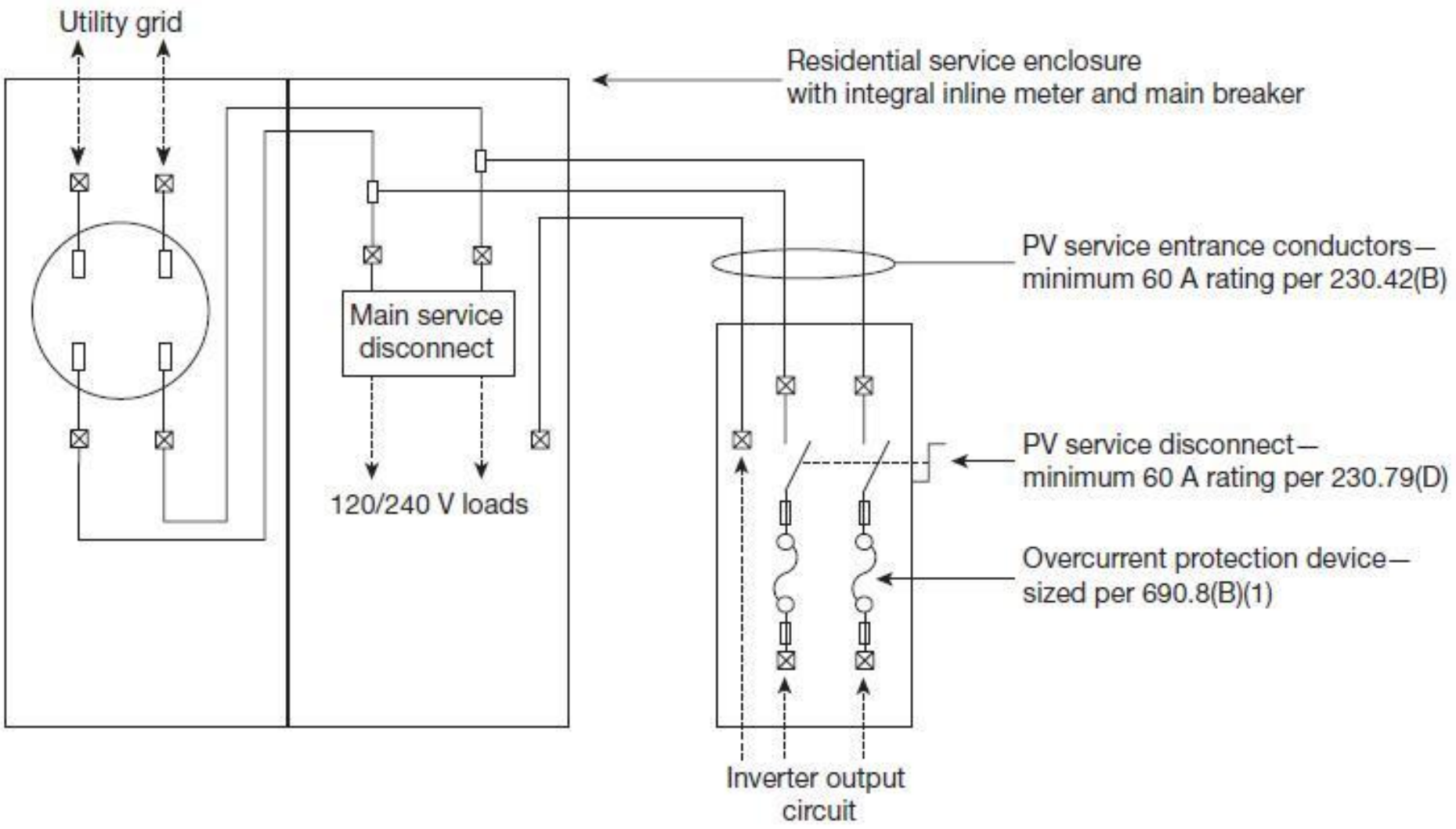
- Any breakers with terminals marked “line” and “load” may not be backfed per 690.64(B)5
- Backfed breaker does not require fastening per 690.64(6)
- Labeling per 690.14(C)2, 690.54, 690.56, 690.64(B)4 & 7, 705.10
- Be sure to update any circuit directories in breaker panels per 408.4

Residential Supply Side Connection

Example 5







Utility grid
Residential service enclosure
with integral inline meter and main breaker
PV service entrance conductors—
minimum 60 A rating per 230.42(B)
Main service
disconnect
120/240 V loads
PV service disconnect—
minimum 60 A rating per 230.79(D)
Overcurrent protection device—
sized per 690.8(B)(1)
Inverter output
circuit

Supply Side Connection – 690.64(A)

- Allowable per 230.46 and 230.82(6)
- 60A minimum PV service entrance conductors per 230.42(B)
- 60A minimum PV service disconnect per 230.79(D)
- Must be protected per 230.50(A) & (B)
- Remember clearance requirements per 110.26

- Article 230.90(A) says OCPD shall not exceed the rating of the existing service entrance conductors.
- Over Current Protective Device (OCPD) to cover inverter output conductor per 690.8(B)1
- Protection against physical damage per 230.50 - remember these conductors will have no OCP all the way back to the primary side of the utility transformer
- Take care to meet 110.9 requirements

- Article 230.70(A)1 – service disconnecting means shall be installed at a readily accessible location either outside of a building or structure or inside nearest the point of entrance of the service conductors.
- Conductors and conduits should be as short as possible
- Article 230 applies - Adding new service equipment in parallel with existing equipment




- Article 240 tap rules do not apply to inverter connections since the tap rules were developed only for circuits with one source. “10-foot tap rule” does not apply
- 250.24 rules apply to this new service equipment

  A) each service shall have a GEC connected to the grounded service conductor (Neutral)
- Must have N-G bond and originate new GEC.
- GEC to be irreversibly spliced to existing AC GEC, or new GE connected to existing GE

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Insulation piercing taps

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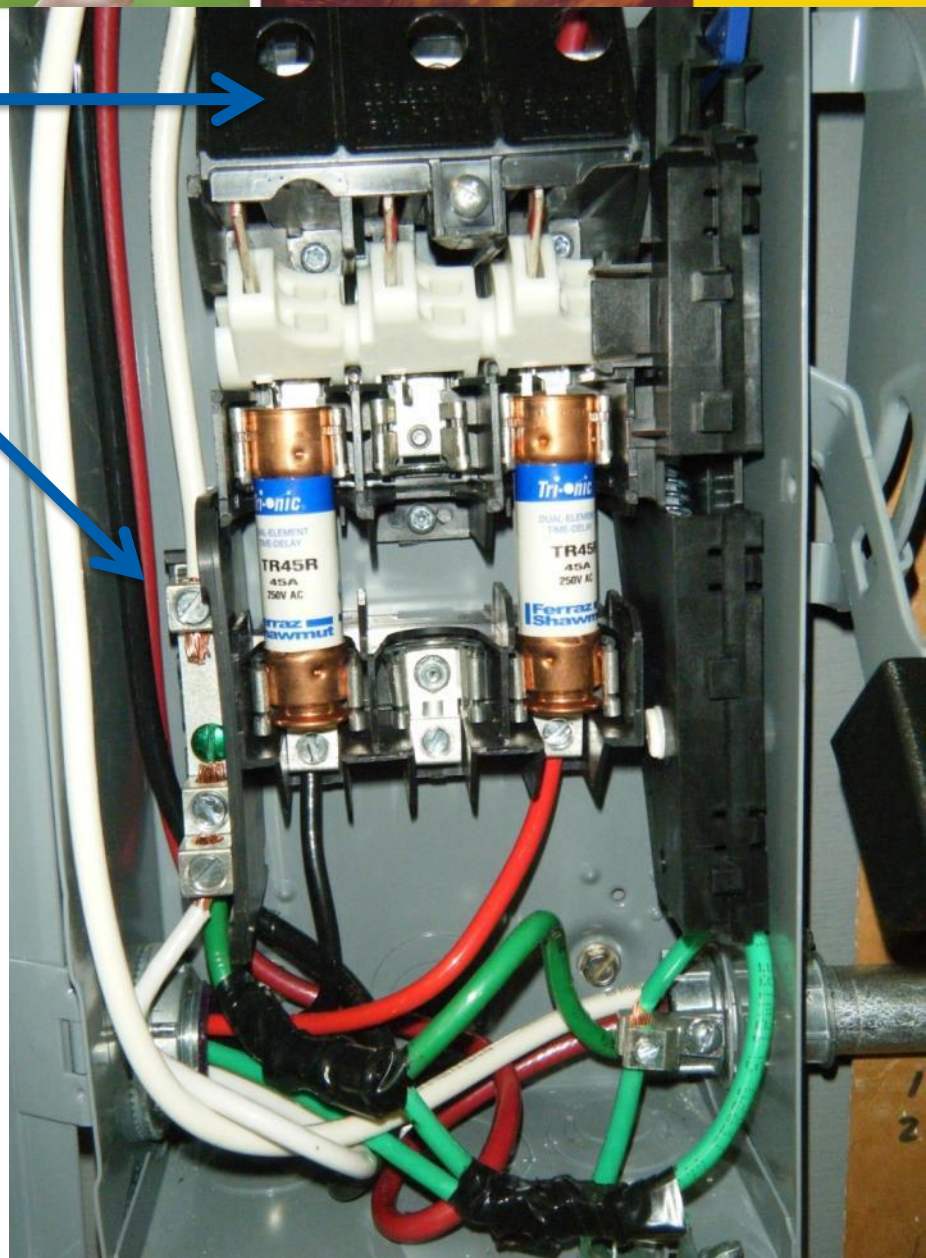
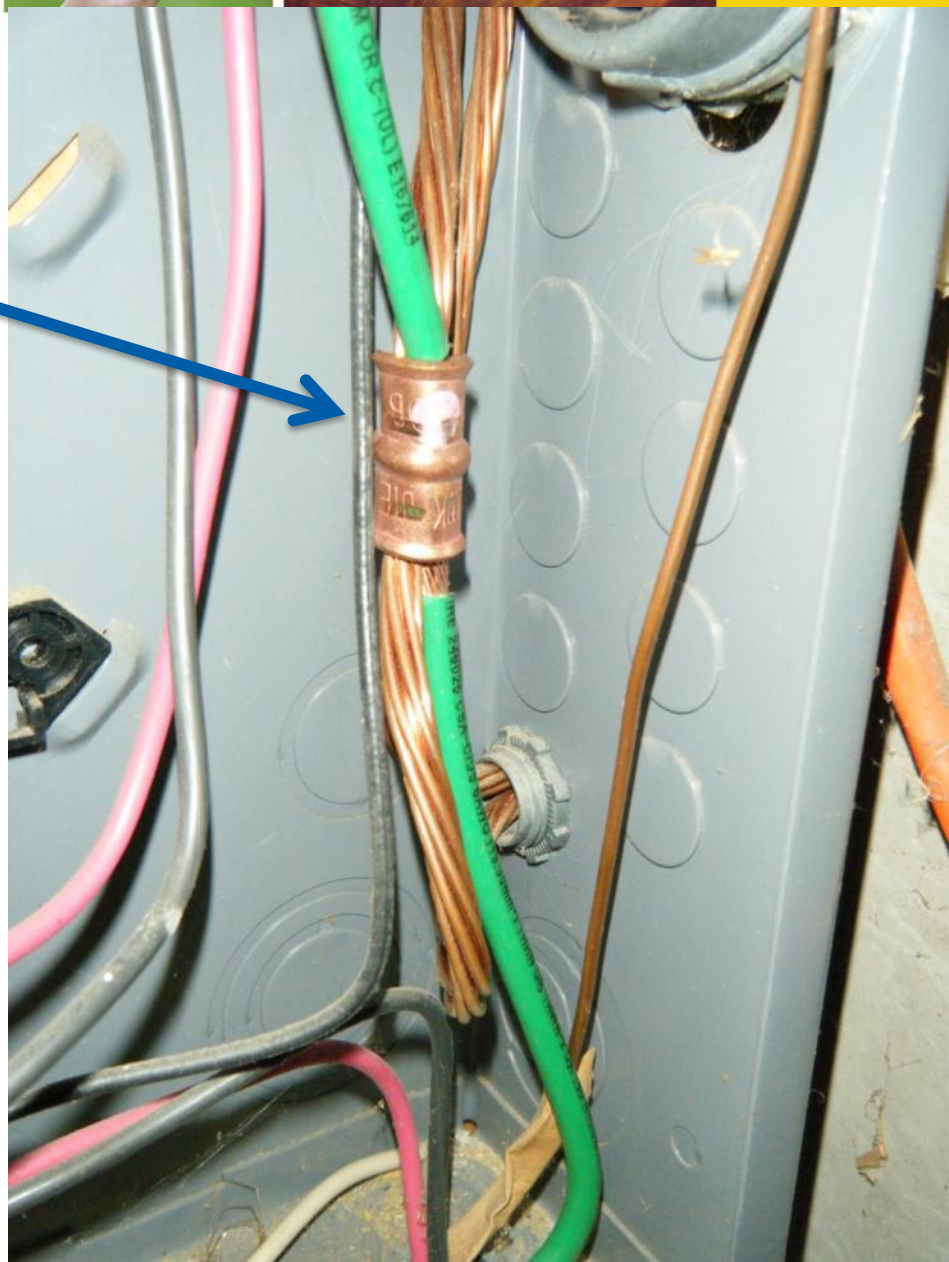
Utility conductors connect to LINE terminals

Neutral bonded to ground per rules for new service equipment






Compression connection creates an irreversible splice



Neutral to Ground (N-G) bond

- Installing a Supply Side Connection is essentially paralleling the existing main load center and its rules for wiring a new service.
- Article 230 Services & 250 Grounding & Bonding
- N-G bond performed in the new Service Equipment per 250.24
- Originate a new GEC
- Consider possible fault currents on added conductors

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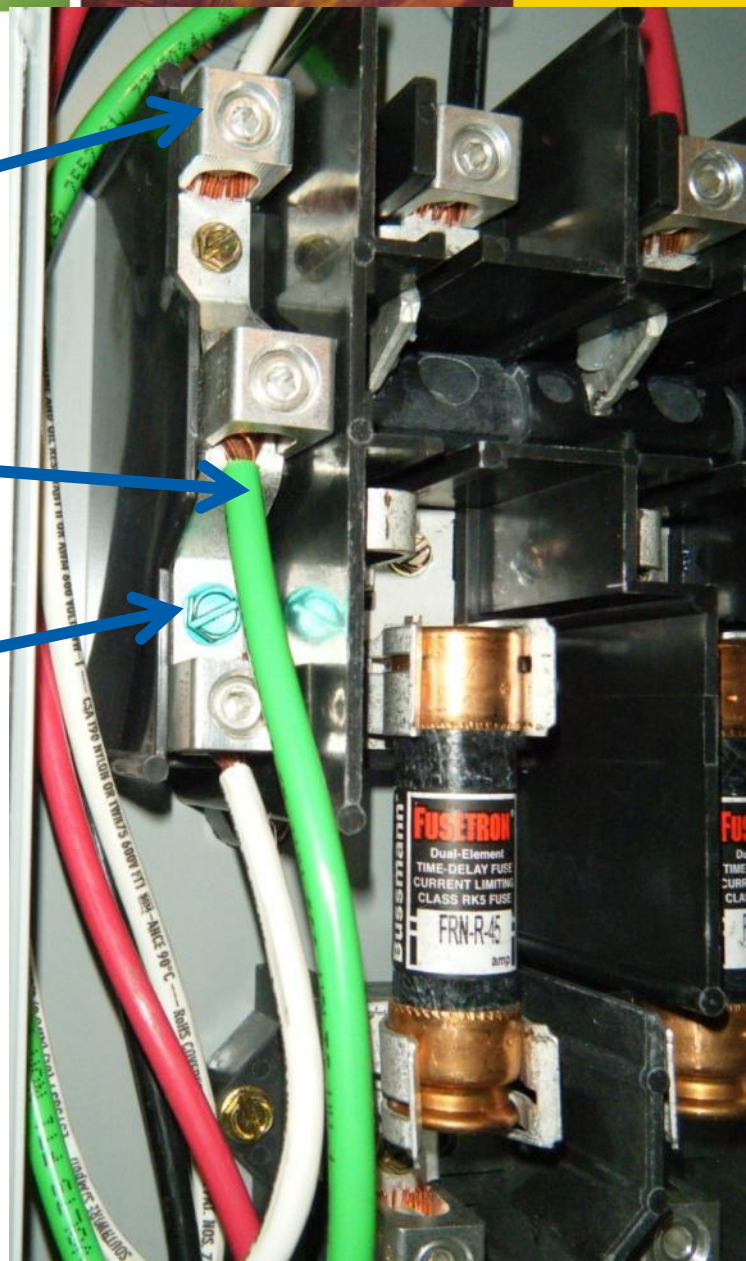
Neutral connected to manufacturer provided terminal block

New GEC originated – continuing on to GE

Bonding screw installed correctly creating code required N-G bond in new service equipment





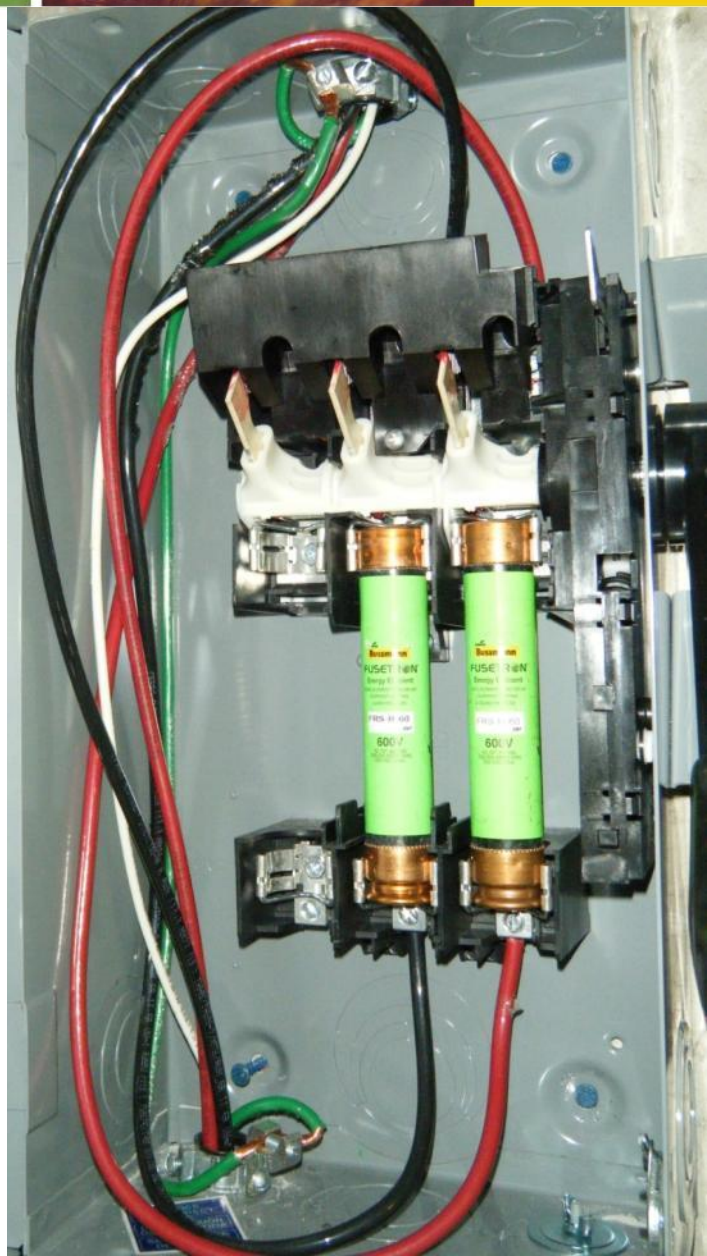

Supply Side connection service equipment

Many common violations are visible in this picture

Missing properly installed EGC

Missing N-G bond

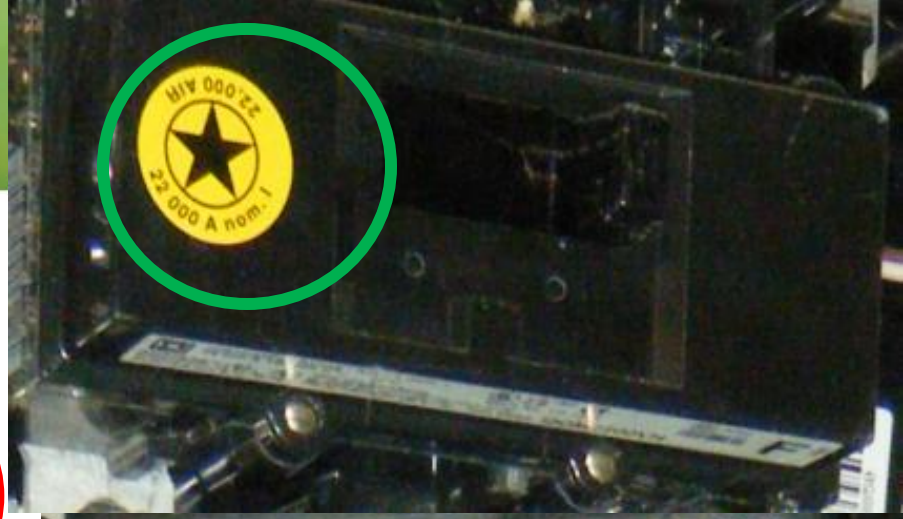
Missing new GEC



Ampere Interrupt Capability (AIC) of new service disconnect

- Also referred to as AI Rating (AIR) of device
- Short circuit current values can be obtained from the utility providing electrical service to the location, or at a minimum, you can match the rating of the existing main breaker to meet 110.9 & 110.10
- Branch circuit breakers are typically only rated to 10 kAIC. Most main breakers you will see in main load centers are rated to 20 kAIC or more.


I/ON
40
10 kA
120/240V~


22,000 AIR
22 000 A nom.

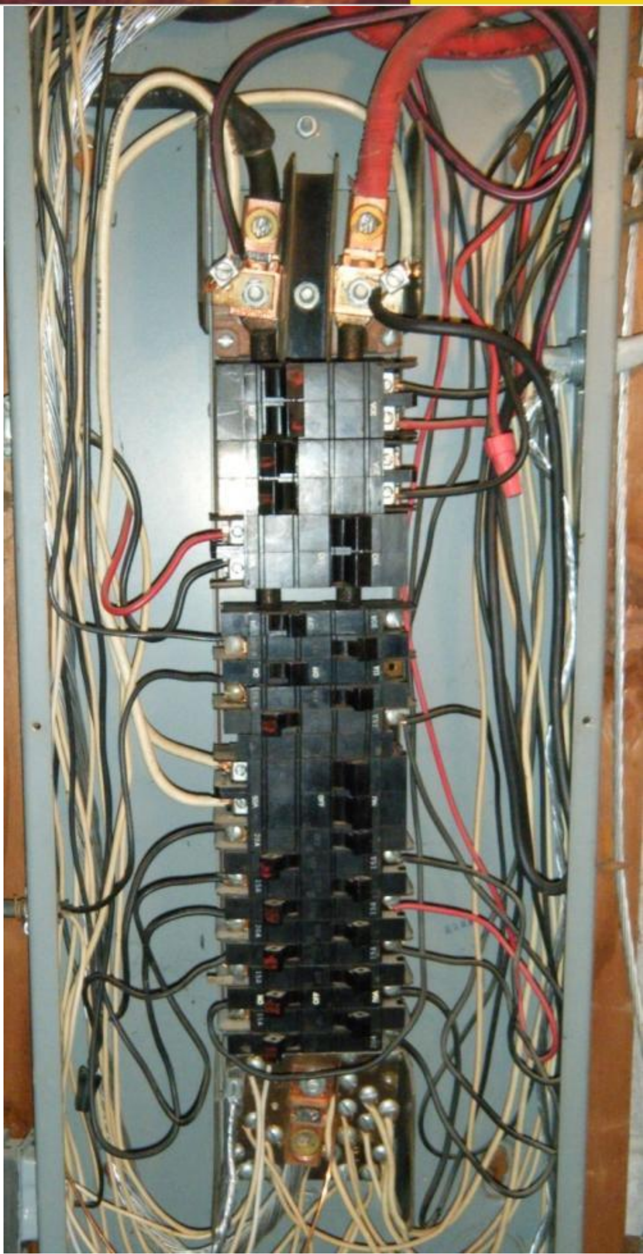

SIEMENS
TYPE EQ8695
CIRCUIT BREAKER
2 POLE UNIT
LISTED
120/240V~
HACR Type
40°C
Interrupting Rating 22,000 Amperes RMS
Symmetrical
120/240V~
Torque 250 lb-
Wire Range - 1-3
kcmil CU-Al
USE ONLY IN LISTED ENCLOSURES
SIEMENS INDUSTRY, INC.
NORCROSS, GA USA
ASSEMBLED IN MEXICO
200A

Unusual

- There are always surprises out there waiting to be found
- Split bus – now explicitly disallowed under PON 2112 rev 12.
- Fuses as main OCPD
- Farm service


MAIN DISCONNECT
MAIN DISCONNECT
MAIN DISCONNECT
MAIN DISCONNECT
MAIN DISCONNECT
MAIN DISCONNECT


MAIN DISCONNECT
30A
ON
MAIN DISCONNECT
ON
OFF
30A
MAIN DISCONNECT
30A
OFF



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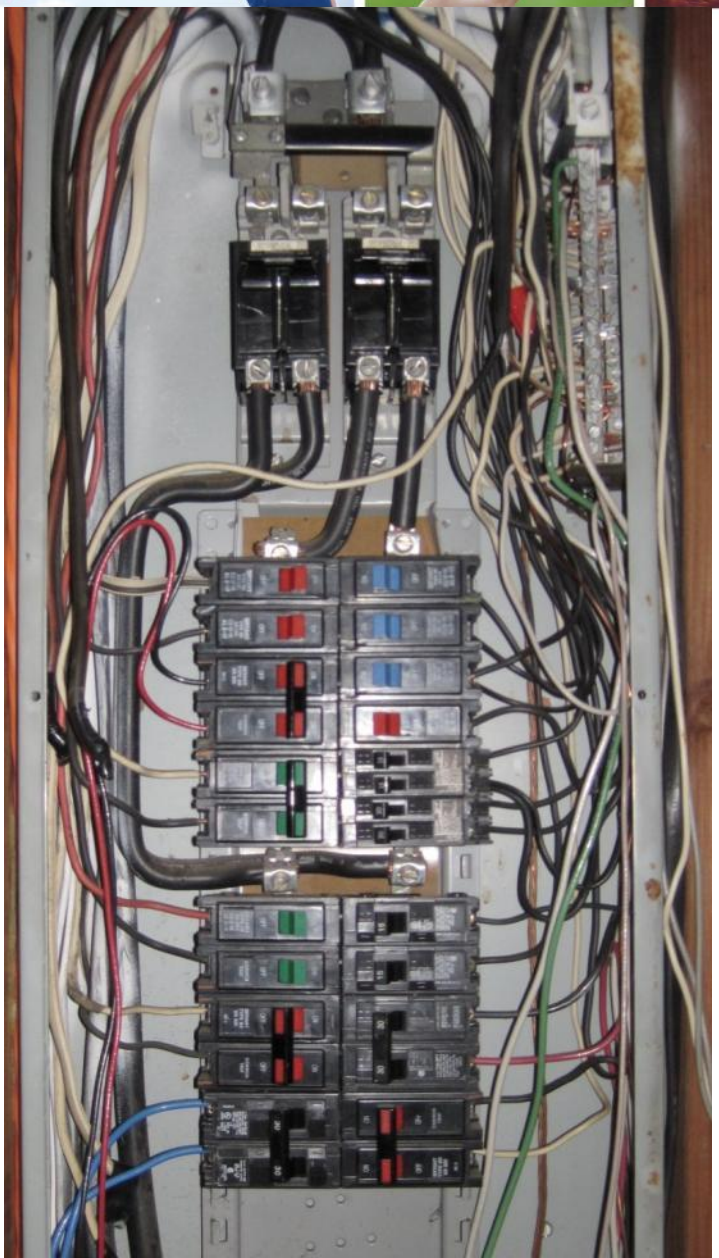

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Reminders

- Do not try to reinvent the wheel
  - Use manufacturer listed ground kit
  - Install at manufacturer designated location
  - Maintain the device UL listing
  - Seal any unused openings to maintain NEMA rating
  - Use proper fittings
- Utility AC to LINE side of disconnect
- Labeling per 225.37, 230.2(E), 690.14(C)2, 690.54, 690.56, 705.10

Commercial PV Systems
Load Side Connections

- Typically done via a backfed breaker
- Ensure main breaker is not a Ground Fault (GF) breaker (most are if over 1000 A (230.95); unless it has been identified and listed for backfeeding)
- Only backfeed a GF breaker on its LINE side per 690.64(B)3
- Ensure main manufacturer is OK to backfeed
- Any breakers with terminals marked “LINE” and “LOAD” may not be backfed per 690.64(B)5

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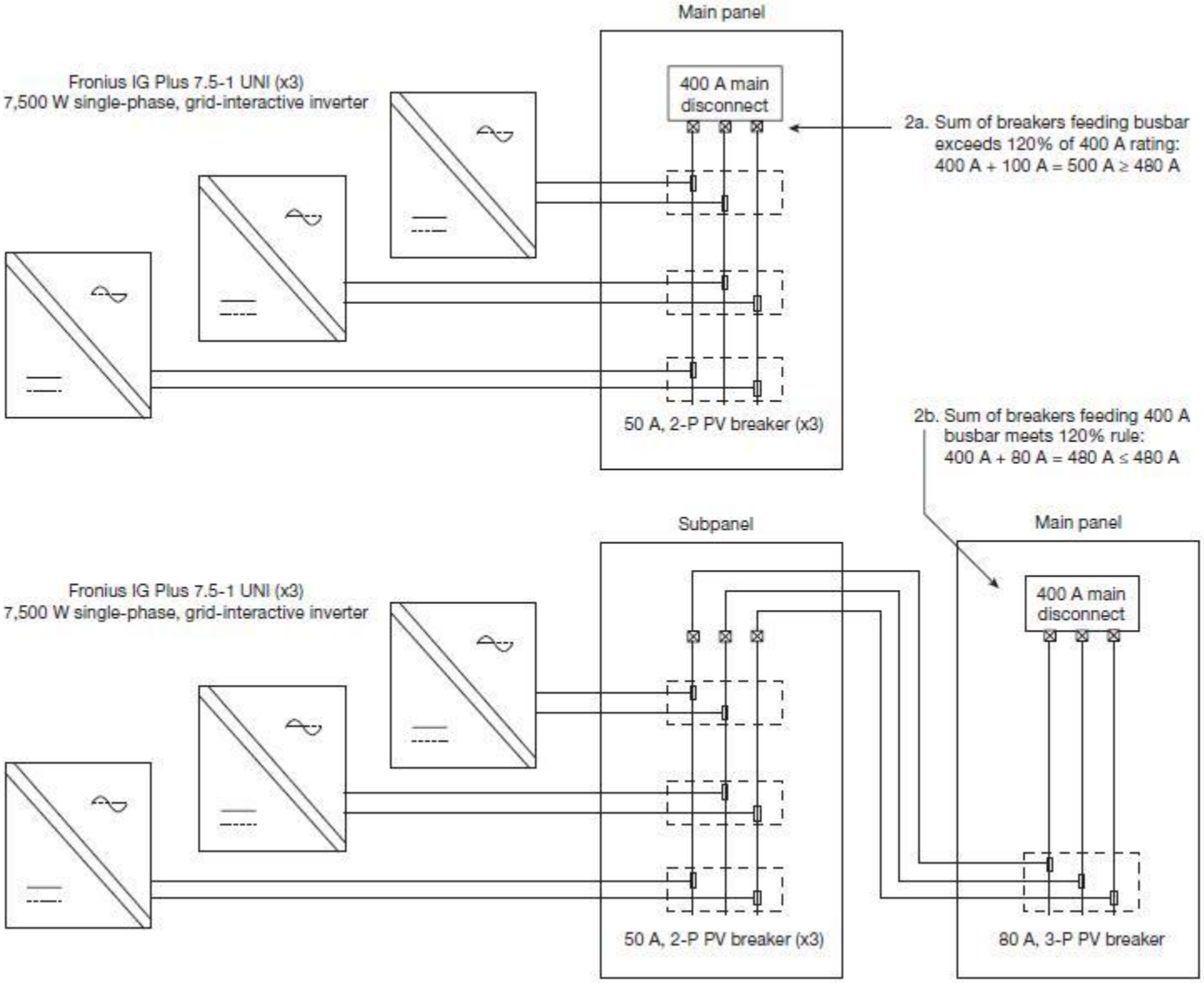
Center fed panelboards

- Backfeeding a center fed busbar
- Cannot exceed busbar rating
- No 120% allowance permissable
- Utility OCPD + PV OCPD < bus bar rating

Subpanel

- Again using a subpanel may allow you to combine larger PV systems than trying to use individual breakers in a MLC
- 120% rules as covered in previous residential section do apply to busbars and conductors





Main panel
Fronius IG Plus 7.5-1 UNI (x3)
7,500 W single-phase, grid-interactive inverter
400 A main disconnect
2a. Sum of breakers feeding busbar exceeds 120% of 400 A rating:
400 A + 100 A = 500 A ≥ 480 A
50 A, 2-P PV breaker (x3)
2b. Sum of breakers feeding 400 A busbar meets 120% rule:
400 A + 80 A = 480 A ≤ 480 A
Subpanel
Main panel
Fronius IG Plus 7.5-1 UNI (x3)
7,500 W single-phase, grid-interactive inverter
400 A main disconnect
50 A, 2-P PV breaker (x3)
80 A, 3-P PV breaker

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PANELBOARD / PANNEAU DE DISTRIBUTION / TABLERO DE ALUMBRADO / DISTRIBUCION
NF
225
20 A

Feeders

- It may be possible to tap a feeder in a commercial application that would save conduit, copper and labor costs to the project.
- Evaluation of tie in points must contain all the above points for suitability.

Commercial PV Systems
Supply Side Connections

- Verify AIC required for disco
- Be sure to accurately identify where the utility meters the service. If current transformer (CT) metering is used, be sure the PV system will be connected on the appropriate side of the CT's.
- Some main breakers and disconnects have provisions for additional conductors. Be sure which side of the breaker you are connecting to and apply the 120% rules when on the LOAD side.

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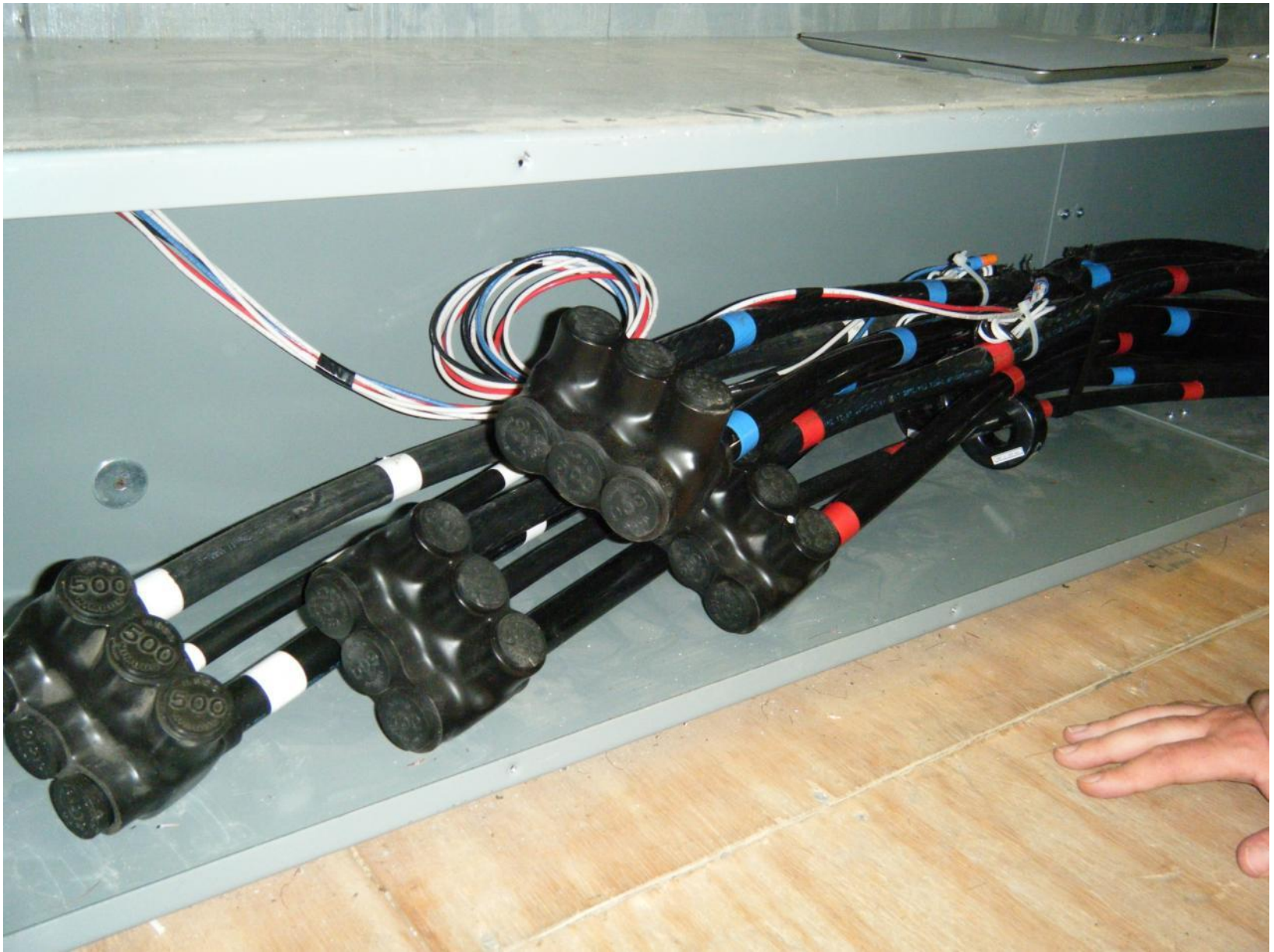

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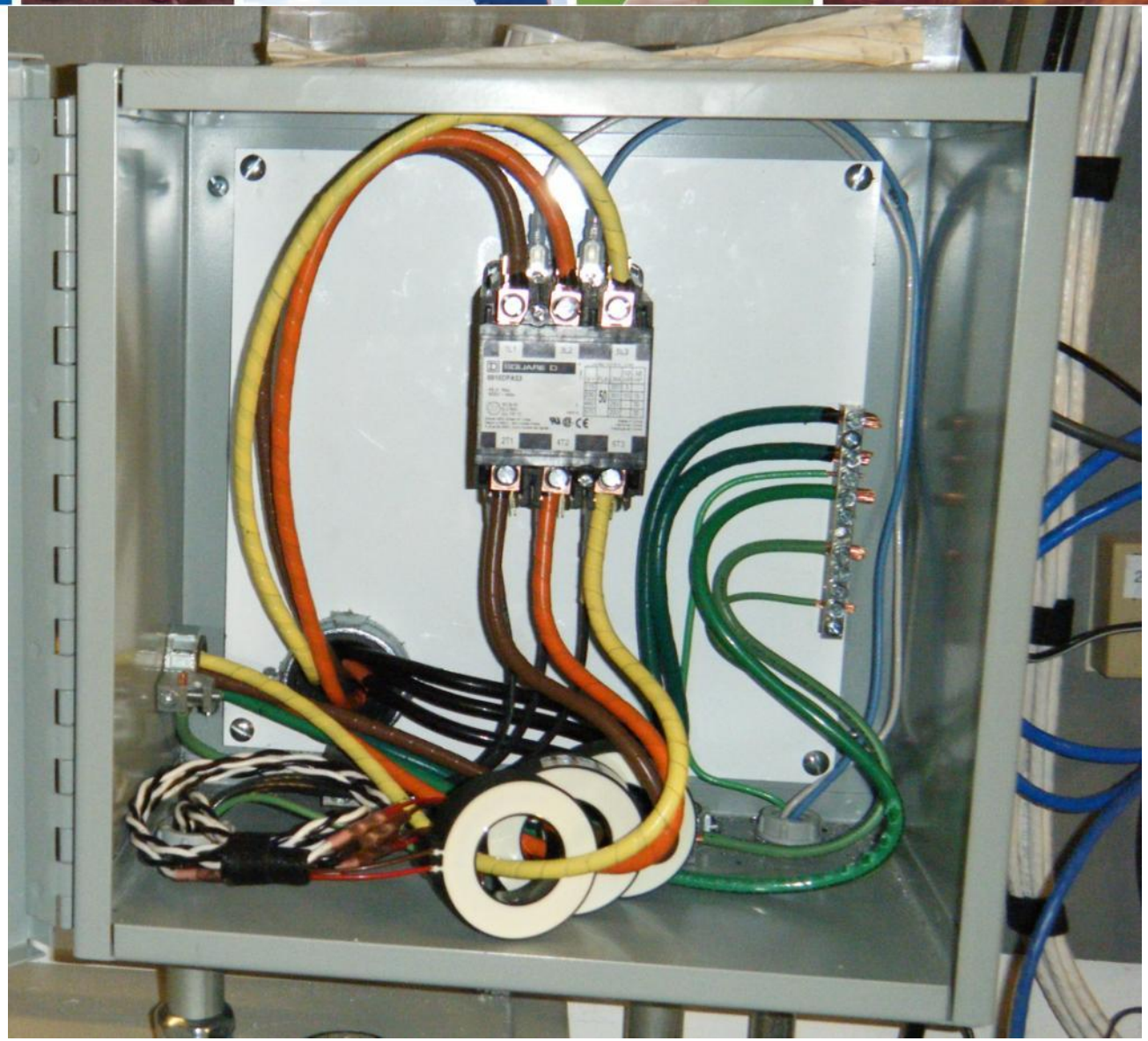
Possible points for LOAD side connection




Look for generator transfer switches

Transfer switches typically indicate the presence of a generator.

If a generator is upstream from your intended point of interconnection, you will have to interconnect ahead of it to avoid the possibility of damage during its operation.



Reminders

- Labeling per 225.37, 230.2(E), 690.14(C)2, 690.54, 690.56, 705.10

Additional Notes

- If GEC is run inside ferrous conduit, it must be bonded to each end of the conduit to prevent choking of its ampacity during a fault event per 250.64(E).
- If EGC and GEC are combined as a single conductor, it must be continuous or irreversibly spliced per 250.61(C)1
- As always, bear in mind conductor coloring requirements for grounded conductors (and AWG limits for taping for identification) per 200.6(A)&(B), and grounding conductors per 250.119.

Notes – Cont.

- Additional complications arise when backup generators are introduced into the system. It is important to not design a system that can backfeed a generator during operation, and destroy the generator. Systems whole house generators will need to have the PV point of interconnection before the Automatic or Manual Transfer Switch, or be provided with relaying to prevent PV system operation during generator operation.
- Correct labeling of additional sources of power are also required for safety and code compliance per 690.54.

REFERENCES

- NFPA 70 2008
- Solar Pro Magazine, June & July 2009 article "Can We Land?", Ryan LeBlanc and Tarn Yates
- IAEI News, January-February 2010, "Supply Side PV Utility Connections", John Wiles
- Home Power Magazine, Feb/March 2006, "Making the Utility Connection", John Wiles

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Thank You!