Load characterization for determination of conductor size, BCSC&GFPD, DS and overload ratings.

Based on NEC 2014.

Jose Urdaneta, [urdans@gmail.com](mailto:urdans@gmail.com)

July 2020

**Abbreviations:**

**BC**: branch circuit.

**BCSC**: branch-circuit selection current, could be provided, always >= RLC (440.2).

**BCSC&GFPD**: Branch-circuit short-circuit and ground-fault protective device.

**DS**: disconnect switch.

**FLA**: full-load amperes, marked in motors’ nameplate.

**FLC**: full-load current for motors, obtained in tables 430.247~430.250, based on motor horsepower.

**HRMC**: hermetic refrigerant motor-compressor.

**INOM**: nominal current of the load, provided or calculated from voltage, power, apparent power, pf, etc.

**LRC**: locked-rotor current (also known as LRA: locked-rotor amps).

**MCA**: minimum circuit ampacity, provided in nameplate.

**MOP**: maximum overcurrent protection rating, provided in nameplate (interpreted as BCSC&GFPC).

**NHSR rule**: next higher standard rating rule for BCSC&GFPD selection (NEC-240.4(B)).

**OP**: overload protection.

**OCPD**: overcurrent protection device, which includes the protection offered by an BCSC&GFPD and an OP. All fuses and breakers are OCPD. Motor loads require the separation of concepts where usually a breaker acts as a BCSC&GFPD and a fuse acts as an OP device.

**RLC**: rated load current, marked in hermetic motor-compressors.

**SCCR**: short-circuit current rating.

# General loads.

* 1. General:

These rules only apply to loads not listed in this document.

* 1. Conductor sizing (applies to all load types):

Account for conditions of use (ambient temperature, copper or aluminum, number of current-carrying conductors in the raceway, rooftop use, etc.).

Account for voltage drop, max 3%. This is a code recommendation and a good design criterion.

Account for continuousness (1.25\*INOM), unless BCSC&GFPD and enclosure are 100% rated.

Based on the biggest of MCA = 1.25\*Icont + Inon-cont or INOM when adjustment or correction factors have been applied (this is decided at the circuit level, for all the loads) .

* 1. BCSC&GFPD rating:

Must protect the conductor. Next higher standard rating rule (NHSR rule) can be used when permitted (240.4(B)&(C)).

Use 1.25\*INOM for continuous loads, unless OCDP and enclosure are 100% rated.

Use MCA.

If the load if a branch circuit, the BCSC&GFPD rating must be 15, 20, 30, 40 or 50Amps when the branch circuit feeds several outlets (several receptacles, lights, or combination of both). Dedicated branch circuits can have other ratings.

* 1. DS rating:

When required, not less than the ampacity of conductors.

* 1. Overload protection rating:

Provided by the BCSC&GFPD.

# General linear loads.

* 1. General:

Linear loads are rich in harmonics. Harmonics current of any frequency can flow through the neutral (in a 3-phase 4 wire circuit) producing heat. The triple harmonics in a 3-phase system cancels in the neutral only when they are in phase. This alignment in phase happens in 3-phase non-linear loads only. Single-phase non-linear loads fed from a 3-phase system, produce harmonics that are not in phase and they all add to the neutral current.

The difference between this load and the general load is that for 3-phase, 4-wire loads, the neutral must be sized bigger than the phase conductors. The load must indicate the neutral current.

* 1. Conductor sizing (applies to all load types):

Account for conditions of use (ambient temperature, copper or aluminum, number of current-carrying conductors in the raceway, rooftop use, etc.).

Account for voltage drop, max 3%.

Account for continuousness (1.25\*INOM), unless BCSC&GFPD and enclosure are 100% rated.

Based on INOM after A&C factors applied or MCA.

* 1. BCSC&GFPD rating:

Must protect the conductor. Use next higher standard rating rule (NHSR rule) when necessary (240.4(B)&(C)).

Use 1.25\*INOM for continuous loads, unless OCDP and enclosure are 100% rated.

Use 1.25\*Icont + Inon-cont for combination loads.

When a circuit feeds several outlets, use 15, 20, 30, 40 or 50Amps.

* 1. DS rating:

When required, not less than the ampacity of conductors.

* 1. Overload protection rating:

Provided by the BCSC&GFPD.

# Appliances (422).

* 1. General:

Appliances are marked with their voltage (VNOM) and current ratings (INOM), or voltage and watts.

If the appliance has a motor, it could be marked with MCA and MOP.

There are special requirements depending on the type of appliance and its use (dryer, washer, water heater tank)

A Storage-type water heater up to 120 gal is considered a continuous load.

* 1. Conductor sizing (422.10):

Motor operated:

Use MCA. If MCA not marked, treat it as a motor load (Determine the FLC based on horsepower).

Non-motor operated:

* INOM or 1.25\*INOM if continuous, unless OCDP and enclosure are 100% rated.
* For household ranges and cooking appliances of >=8.75KW, 40A minimum.
* For circuits combination of appliances and other loads in the same circuit, apply rule 210.23.
  1. BCSC&GFPD rating (422.11):
* (A) Max = MOP, if marked.
* (B) Max 50Amps for household-type appliances with surface heating elements.
* (C) Max 50Amps for infrared lamp commercial and industrial heating appliances.
* (D) Max 50Amps for open-coil or exposed sheathed-coil surface heating in commercial heating appliances.
* (E) For non-motor-operated appliances use MOP. If MOP not marked:
  + Max 20Amps for INOM<=13.3Amps
  + Max 1.5\*INOM if INOM>13.3Amps. Apply next higher standard rating rule (NHSR rule).
* (F)(1) Max 60Amps for non-household resistance-type electric heating appliances, where resistance rating is >48Amps each.
* (F)(2) Max 150Amps for commercial kitchen and cooking appliances not covered by (D) and elements are integral with cooking surface or contained in an enclosure or contained within an ASME-rated and stamped vessel.
* (F)(3) Max 150Amps for water heater and steam boilers with resistance-type immersion heating elements when contained in ASME-rated and stamped vessels, or when listed as instantaneous water heater or where installed in low-pressure water heater tanks or open-outlet water heater vessels.
* (G) Max = MOP for motor operated appliances.
  1. DS rating (460.8(C)):

Where required, not less than the ampacity of the conductors.

* 1. Overload protection rating:

For motor-operated appliances apply overload protection rules accordingly for motors (430) or air conditioning & refrigerant equipment (440).

# Fixed Electric Space-heating equipment (424).

* 1. General:

Includes heating cable, unit heaters, boilers, central systems, or other approved fixed electric space-heating equipment. If the equipment includes a hermetic refrigerant motor, apply the rule 440 also.

Considered as a continuous load.

INOM is the total current of the equipment or set of loads. It is provided or calculated.

MCA or minimum conductor size is marked on the equipment.

* 1. Conductor sizing (424.3):
* Use MCA or the marked size.
* Ampacity not less than the BCSC&GFPD for multioutlet.
* 1.25\*INOM.
  1. BCSC&GFPD rating (424.3, 424.22):
* 1.25\*INOM for stand-alone equipment, apply NHSR rule if required.
* 15, 20, 25 or 30Amps for circuit supplying outlets for space-heating equipment.
* Max 50Amps for non-dwelling unit fixed infrared heating equipment.
* Max 60Amps for resistance-type electric heating appliances, where resistance rating is >48Amps each.
  1. DS rating (460.8(C)):

1.25\*INOM.

* 1. Overload protection rating:

Provided by the BCSC&GFPD.

# Fixed Outdoor Electric Deicing and Snow-Melting Equipment (426).

* 1. General:

Cord-and-plug connected equipment to be installed as an appliance (422).

Considered as a continuous load.

INOM is provided or calculated.

* 1. Conductor sizing ():

1.25\*INOM.

* 1. BCSC&GFPD rating ():

1.25\*INOM.

* 1. DS rating (460.8(C)):

1.25\*INOM.

* 1. Overload protection rating:

Provided by the BCSC&GFPD.

# Fixed Electric Heating Equipment for Pipelines and Vessels (427).

* 1. General:

Cord-and-plug connected equipment to be installed as an appliance (422).

Considered as a continuous load.

INOM is provided or calculated.

* 1. Conductor sizing ():

1.25\*INOM.

* 1. BCSC&GFPD rating ():

1.25\*INOM.

* 1. DS rating (460.8(C)):

1.25\*INOM.

* 1. Overload protection rating:

Provided by the BCSC&GFPD.

# Motors (430).

* 1. General:

Motors are marked with voltage, horsepower, FLA, service factor, time rating (5, 15, 30 or 60 minutes or continuous), code letter or LRC (for >1/2hp), design letter (B, C or D), if it is thermally protected.

FLC is used for conductor ampacity, BCSC&GFPD and DS, and is determined from the motor horsepower, except for low speed (<1200rpm), high torque and multispeed motors.

For torque motors, use LRC for conductors, BCSC&GFPD, DS and overload.

For other motors use FLA directly.

Use FLA for separate overload protection.

Multimotor and combination-load equipment are additionally marked with MCA and MOP.

* 1. Conductor sizing: (review the bubbles)
* (430.22) Single motor, continuous duty: 1.25\*FLC.
  + DC motor rectifier supplied:
    - Feeding the rectifier: 1.25\*rated current of rectifier.
    - From rectifier to motor: 1.90\*FLC for half-wave, 1.50\*FLC for full wave rectification.
  + Multispeed motor:
    - Feeding the controller: highest FLA shown on motor nameplate.
    - From controller to motor: 1.25\*rated current of windings.
  + Wye-start, delta-run motor:
    - Feeding the controller: 1.25\*FLC.
    - From controller to motor: 0.72\*FLC.
  + Part-winding motor:
    - Feeding the controller: 1.25\*FLC.
    - From controller to motor: 0.625\*FLC.
  + For other than continuous duty, use table 430.22(E).
  + For small motors and conductors smaller than #14AWG apply rule (G)(1) & (G)(2)
* (430.23) Wound-rotor secondary:
  + Continuous duty, from controller to motor secondary: 1.25\*full-load current of secondary.
  + Non-continuous duty, use table 430.22(E), applied to full-load secondary current.
  + For resistor separated from controller, from controller to resistor, use table 430.23(C).
* (430.24) Several motors or a motors and other loads: 1.25\*FLC highest motor (or MCA if available), plus FLC of all other motors (or MCAs if available) + current of noncontinuous non-motor load, plus 1.25\*current of continuous non-motor loads.
* (430.25) Multimotor and combination-load equipment: use MCA provided.
  1. BCSC&GFPD rating (430.51, 430.52, 430.53, for voltage <=1000):
* Use MOP if marked.
* In accordance with table 430.52, using FLC. Do not use instantaneous trip circuit breaker unless it is part of a listed combination motor controller. Use NHSR rule if necessary.
* If the BCSC&GFPD is not sufficient for the motor to start:
  + For a nontime-delay fuse <=600Amps or class CC fuse, can be increased up to 4\*FLC.
  + For a time-delay (dual-element) fuse, can be increased up to 2.25\*FLC.
  + For an inverse-time circuit breaker, can be increased up to 4\*FLC (for FLC<=100Amps), or 3\*FLC for FLC>100Amps.
  + For a fuse rated between 601 and 6000Amps, can be increased up to 3\*FLC.
* For multispeed motor, use table 430.52 with the rating of smallest winding protected, or use table 430.52 with the rating of highest winding if each winding is overload protected, the conductors are sized per highest current winding, and the controller horsepower rating for each winding >= highest horsepower rating.
* For torque motors, use LRC.
* Review for motors and other loads scenario; also consider that there are two scenarios for sizing conductors: branch circuit conductors (430.50-430.58) and feeder conductors (430.61)
  1. DS rating (460.8(C)):

Min = 1.15\*FLC.

* 1. Overload protection rating:
* (430.32) Continuous duty motors:
  + Separate overload device: max values:
    - For service factor >1.15, use 1.25\*FLA (1.4\*FLA if motor does not start)
    - For temp. raise of <=40°C, use 1.25\*FLA (1.4\*FLA if motor does not start)
    - All other use 1.15\*FLA (1.3\*FLA if motor does not start)
  + Thermal protector (uses FLC, instead of FLA):
    - FLC<=9Amps, 1.7\*FLC
    - FLC>=9.1 and <=20Amps, 1.56\*FLC
    - FLC>20Amps, 1.4\*FLC
  + Integral with motor, part of the assembly.
  + Impedance-protected, for motors <=1hp.
* (430.33) Intermittent and similar duty: can be protected by the BCSC&GFPD which must be sized per table 430.52

# Air conditioning & refrigerant equipment (440).

* 1. General:
* These rules apply to A/C and refrigerating equipment that includes HRMC (aka motor-compressor), and are in addition to, or amend of, rule 430.
* A/C and refrigerant equipment not having an HRMC must be ruled by 422, 424 or 430, as applicable. For example, refrigerant compressors driven by motors, fan-coil units, furnaces with A/C coils, remote air-cooled condensers (with no HRMC), remote commercial refrigerator, etc. See 440.3.
* Room air conditioners, household refrigerators and freezers (not the commercial or the industrial ones), drinking water coolers and beverage dispensers are appliances and then, are ruled by 422.
* HRMC alone (no other loads in equipment) must be marked with voltage, phase, frequency, RLC, LRC (when more than 9A@115V, or more than 4.5A@230V), if “thermally protected” or if “thermally protected system” when furnished, and thermal protection rating when specified. For HRMC, LRC is the base for determining DS, BC conductors, controllers, BCSC&GFPD and separate OP. If BCSC is provided, use it instead of LRC, except for OP, for which always use LRC.
* HRMC in a multimotor and combination-load equipment, other than single phase 15-or-20A@120V or 15A@208-or-240V, and room A/C (treat them as appliances), must be marked with voltage, phase, frequency, MCA, BCSC&GFPD rating (MOP), SCCR (for the controller, not for 1-and-2-family dwellings, plug-connected equipment or equipment protected at 60A or less).
* BCSC must be provided for HRMC equipment that has built-in protection that permits continuous overload current. This is not an MCA.
  1. Conductor sizing:

Single motor-compressor (440.32): (this is not an equipment, only the motor, so there is no MCA).

Use 1.25\*BCSC, or 1.25\*RLC if BCSC is not provided.

Motor compressors and additional motor and non-motor loads (440.33 & 440.34): (this is not an equipment, is a set of motors feed from the same circuit, so there is no MCA).

Use 1.25\*Largest motor’s rating (BCSC for motor-compressors (or RLC if BCSC is not provided), RLC for other motors), plus the sum of BCSC of the other motor compressors (or the RLC if BCSC is not provided), plus the RLC of the other motors + INOM of the other loads. Use only the ratings of the motors and loads that operate at the same time (the worst-case scenario) and discard the smaller non-concurrent motors.

Multimotor and combination-load equipment: (this is an equipment with a marked MCA).

Use MCA.

* 1. BCSC&GFPD rating (440.21): Applies to A/C with HRMC. If A/C is nameplate reads “maximum fuse size”, fuses must be used. Values here are maximum.

Since 440.21 is in addition or amendatory of 240, NHSR rule can be applied but never go above MOP when provided.

Single motor-compressor(440.22(A)):

Use 1.75\*BCSC or 1.75\*RLC if BCSC not provided.

Use 2.25 in case BCSC&GFPD does not allow motor to start.

Minimum is 15 Amps.

Equipment with motor-compressor:

Always use MOP if provided, otherwise apply the following rules:

If a motor-compressor is the only load of the equipment:

Apply 440.22(A).

Equipment with motor-compressor (as the largest load) and other loads (440.22(B)(1)):

Use 440.22(A) rule to the largest motor-compressor, plus the sum of BCSC (or RLC if BCSC is not provided) of the other motor-compressors, plus INOM of other loads.

Equipment with motor-compressor (NOT as the largest load) and other loads (440.22(B)(2)):

* + Motor-compressor(s) and other motors:

Use the sum of BCSC (or RLC if BCSC is not provided) of the motor-compressors, plus value per table 430.52 for the highest motor, plus other motor load’s FLC, plus INOM of other non-motor loads.

* + Motor-compressor(s) and other non-motor loads:

Apply the rules for general loads.

* 1. DS rating (440.12):

Single motor or single motor equipment:

Min = 1.15\*BCSC or 1.15\*RLC if BCSC not provided.

Combination loads:

Per HP ratings:

RLC equivalent = Sum of all the motor RLC currents selected from table 430.251(A) or 430.251(B), plus all motor-compressor RLC, plus INOM of other loads. Then, determine the DS horse-power rating of this RLC equivalent from table 430.251(A) or 430.251(B).

Per FLC equivalent:

FLC equivalent = Sum of all the motor FLC currents selected from table 430.248 or 430.249 or 430.250, plus all motor-compressor BCSC (or RLC if BCSC not provided), plus INOM of other loads.

Minimum DS current rating = 1.25\* FLC equivalent.

* 1. Overload protection rating:

Not required if provided with integral thermal protection.

Max=1.4\*RLC for separated overload relay.

Max=1.25\*RLC for t-1 fuses and t-1 circuit breakers.

# Transformers (450)

* 1. General:

This does not apply to current transformers.

Applies also to transformer banks.

These rules are for residential and commercial transformers (V<=1000)

* 1. Conductor sizing: All conductors feeding the primary of a transformer are considered feeders, unless the rare case where there is no OCPD on the secondary side of the transformer. For voltage >600V, the feeder ampacity shall not be less than the transformer primary ampacity (NEC-215.2(B))
* When primary is fed from a tap (to comply with 240.21(B)(3) (total length of primary plus secondary not to exceed 25 ft):
  + Primary:

A good practice is to select the ampacity per the transformer INOMprim or 1.25\*INOMprim if the load is continuous. The ampacity of the primary conductor cannot be less than the maximum of these two values: (1) the ampacity from the previous formulae; (2) the ampacity of the load.

* + Any secondary:

The NHSR rule is not allowed (240.21(B)).

(This secondary conductor must end in an OCPD whose rating <= ampacity of secondary conductors.)

A good practice is to select the ampacity per the transformer INOMsec or 1.25\*INOMsec if the load is continuous. If ampacity is decided upon the load current, it must be increased if necessary, to comply with the previous formulae.

* When primary is fed from an OCPD:
  + Primary: not less than INOMprim or 1.25\*INOMprim if the transformer is feeding continuous loads.
  + Secondary: (Must end in an OCPD whose rating <= ampacity of the single secondary conductor and comply with 240.21(C)(2),(3),(4),(5)&(6)). The NHSR rule is not allowed. Complement this rule describing those references with words.
    - Single: INOMsec or 1.25\*INOMsec if load is continuous.
    - Any other secondary:
      * Ampacity>=Rating of equipment containing an OCPD, or ampacity>=rating of the OCPD at the end of the conductor.
  1. BCSC&GFPD rating:
* Regular transformers: in accordance with table 450.3(B) (only to protect the transformer). Apply NHSR rule if necessary.

The secondary protection for the transformer is optional, but it can be required for protection of secondary conductors. There are transformer configurations that allows omitting the protection of the secondary conductors (under certain rules, 240.21(C)(1)); except for that, protection of secondary conductors is always required, and can be installed within 10FT from the transformer (under conditions of 240.21(C)(2)), within 25FT (under conditions of 240.21(C)(3)) or outside (240.21(C)(4)) and others 240.21(C)(5) & (6). The NHSR rule does not apply for the protection of secondary conductors. If protection of the transformer secondary is installed at the secondary tap bars, the secondary conductors can be considered protected if their ampacity is coordinated with that protection rating (again, for that particular case, the NHSR rule can be applied). However, this type of installation is rare.

A good practice rule is to always provide secondary protection in a panel installed within 10ft from the transformer; do not apply the NHSR rule to that protection.

* For potential transformers installed indoors or enclosed, they must be protected with primary fuses. Protection of secondary conductors shall be as required for regular transformers.
* For autotransformers, use 1.25\*INOM(prim) and the NHSR rule applies only if INOM>=9Amps. Protection of secondary conductors shall be as required for regular transformers.
  1. DS rating (460.8(C)):

Above ampacity of conductors.

* 1. Overload protection rating:

Overload of transformer is provided by the overcurrent protection of the primary.

# Phase converters (455

* 1. General:

Two type, static and rotary.

Input INOM, output KVA or HP, voltages, etc. are provided.

* 1. Conductor sizing:
* For variable loads:

Min = 1.25\*Input INOM.

* For fixed loads:

2.5\*Sum of all 3-phase currents \* Vout/Vin

* 1. BCSC&GFPD rating:

Min = 1.25\*Input INOM.

The NHSR rule can be applied if necessary.

* 1. DS rating (460.8(C)):

Min = 1.15\*Input INOM \* Vout/Vin

* 1. Overload protection rating:

Not required, N/A.

# Capacitors (460), up to 1000V

* 1. General:

KVAR provided.

INOM provided or determined upon KVAR.

The tolerance could be provided.

* 1. Conductor sizing:

Account for condition of use and voltage drop.

Min = 1.35\*INOM.

If the capacitor connects directly to motor terminals or to a motor circuit, min >= 1/3\*FLA of the motor or >=1.35\*INOM whichever of the two is bigger.

* 1. BCSC&GFPD rating:

As low as practicable.

My own criteria: 1.10\*tolerance\*INOM.

* 1. DS rating (460.8(C)):

Min = 1.35\*INOM.

* 1. Overload protection rating:

Not required, N/A.

# Control and instrumentation circuit (727)

* 1. General:

Applicable to conductors used for instrumentation tray cable, where voltage<=150 and max current <= 5.

* 1. Conductor sizing:

Any size, generally small sizes, from #12AWG, 14, 16, 18, 20 and 22. Max ampacity allowed is 3A for #22AWG and 5A for all others.

* 1. BCSC&GFPD rating:

Max 5A for #20AWG and larger, and 3A for #22AWG.

* 1. DS rating (460.8(C)):

N/A.

* 1. Overload protection rating:

Provided by the BCSC&GFPD.

# Electric welders (630)

* 1. General:

.

* 1. Conductor sizing:

.

* 1. BCSC&GFPD rating:

.

* 1. DS rating (460.8(C)):

.

* 1. Overload protection rating:

.

# Fire Alarm System power loads

* 1. General:

.

* 1. Conductor sizing:

.

* 1. BCSC&GFPD rating:

.

* 1. DS rating (460.8(C)):

.

* 1. Overload protection rating:

.

1. **Household ranges and cooking appliances**
   1. General:

.

* 1. Conductor sizing:

.

* 1. BCSC&GFPD rating:

.

* 1. DS rating (460.8(C)):

.

* 1. Overload protection rating:

.

1. **Multi-outlet loads**
   1. General:

.

* 1. Conductor sizing:

.

* 1. BCSC&GFPD rating:

.

* 1. DS rating (460.8(C)):

.

* 1. Overload protection rating:

.

1. **.**
   1. General:

.

* 1. Conductor sizing:

.

* 1. BCSC&GFPD rating:

.

* 1. DS rating (460.8(C)):

.

* 1. Overload protection rating:

.

1. **.**
   1. General:

.

* 1. Conductor sizing:

.

* 1. BCSC&GFPD rating:

.

* 1. DS rating (460.8(C)):

.

* 1. Overload protection rating:

.

1. **.**
   1. General:

.

* 1. Conductor sizing:

.

* 1. BCSC&GFPD rating:

.

* 1. DS rating (460.8(C)):

.

* 1. Overload protection rating:

.