Bulletin 4-3-11
Sizing of neutral conductors
Rules 4-004, 4-018, 6-302, 6-308,10-210 b)

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Scope

1) Minimum size of service neutral for single dwellings
2) Unbalanced loads and size of neutral

1) Minimum size of service neutral for single dwellings

Rule 6-308 1) requires the use of an insulated neutral conductor in a consumer service raceway and subrule 2) permits the use of bare neutral conductors for busways or overhead applications, as per Rule 6-302, when it forms part of an assembly of a busway or neutral supported cable.

Rule 6-308 2) permits the use of a bare neutral conductor in a consumer's service subject to the restrictions of the rule. A bare neutral having sufficient ampacity to carry the unbalanced load is permitted by Rule 4-018 1). When installed in a raceway, the insulated neutral conductor size shall be as per Rule 4-018 3). This means that the neutral is sized on the basis of unbalanced load.

As per Rule 4-018 3) b), the neutral conductor size shall be not less than the minimum size of grounded conductor required by Rule 10-210 b) that is the same as the bonding conductor sized as per Rule 10-616, . A service neutral also serves as a low impedance fault return path to the utility source where a bonding conductor is not provided.

The minimum size of the service neutral is based on the allowable ampacity of the ungrounded circuit conductors (corrected or adjusted in accordance with Rules 4-004 and 4-006), not the ampere rating of the electrical service as per Rule 10-616 2).

Service conductors for single dwellings and feeder conductors supplying single dwelling units of row housing of apartment and similar buildings are permitted to be sized in accordance with Rule 4-004 26) and Table 39. Based on Rule 4-004 26), service conductors are permitted to be sized in accordance with Table 39 if they have a 90 °C insulation rating and the maximum calculated load or demonstrated load does not exceed the 75 °C ampacity of the conductor. Hence, the service neutral is permitted to be sized based on 75 °C ampacity of the ungrounded service conductors.

The following is an example of determining the minimum size of a service neutral conductor for single dwellings based on Table 16:

For 200 A service		
Size of ungrounded Conductor	**The minimum size of a service neutral**	
Copper, AWG	**Copper, AWG**	**Aluminum, AWG**
2/0 (Table 39) 3/0	6 6	4 4
Aluminum, AWG or kcmil	**Aluminum, WG**	**Copper, AWG**
4/0 (Table 39) 250	4 2	6 4

The minimum size of the neutral conductor can never be less than the minimum size required by the terminating lugs of the equipment that the neutral is connected to.

In addition, bare neutral conductors must be insulated where passing through a meter base and in service switches where there is danger of inadvertent contact with live parts.

2) Unbalanced loads and size of neutral

Rule 4-018 states that the neutral conductor shall have sufficient ampacity to carry the unbalanced load. The unbalanced load may be comprised of two components: unbalancing in the phase loading and unbalancing by the harmonics produced from non-linear loads.

For example, Rule 4-018 2) a) does not allow any reduction in the neutral size for that portion of a load consisting of electric discharge lighting. Electric discharge lighting includes fluorescent and high intensity discharge lighting (e.g. Metal Halide). The Code does not permit a reduction in neutral size for this type of load recognizing the difficulty in balancing the phase loading of electric discharge lighting together with the harmonic current produced by these types of non-linear loads.

Also, Rule 4-018 2) b) does not allow any reduction in the neutral size for that portion of a load consisting of non-linear loads supplied from a three-phase, four-wire system. The Appendix B Note to Rule 4-018 2) specifies that examples of these types of loads are dimmers, computers, microprocessors, and most other electronic loads such as variable frequency drives, and uninterruptable power supply systems.

The neutral conductor provides a return path for the current carried by the individual phase conductors of a three-phase system. The 60 Hz phase currents will cancel each other when they return through the common neutral and it will carry only any imbalance between these currents.

Any triplen harmonic currents produced by non-linear loads at frequencies other than 60 Hz do not cancel each other and will combine in a common neutral. This can result in the neutral conductor carrying a much higher current than predicted when considering only the 60 Hz phase current imbalance. If a reduced neutral is installed based only on the maximum 60 Hz imbalance and some of the load consists of non-linear harmonic producing loads, then there is a possibility the reduced neutral may be overloaded by the triplen harmonic currents resulting in overheating.

It is essential that the neutral conductor be sized to handle both the 60 Hz unbalanced load currents and the triplen harmonic current generated by connected non-linear loads.

In the case of existing installations where there may be harmonic concerns, the size of neutral conductor should be recalculated considering the total unbalanced current including both unbalanced load current and zero sequence harmonic currents.