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8. Electrical Power Distribution

This chapter covers Section 130.5, which covers energy efficiency requirements for electrical systems. It is addressed primarily to electrical engineers and to enforcement agency personnel responsible for electrical plan checking and inspection.

This chapter is new to the 2013 version of the Nonresidential Compliance Manual. It been developed because the Standards themselves have been restructured to create a new section (Section 130.5) for electrical power system requirements, distinct from lighting control system requirements (Sections 130.1 through 130.4).

In deliberations concerning the 2013 standard, the Commission determined that important emerging issues of circuit metering and disaggregation, plug load (receptacle) controls, demand response systems, and energy management and control systems (EMCS) were cost effective provisions that would either save energy directly, or serve the invaluable purpose of allowing cost effective energy use monitoring for management purposes. In addition, the Standard was changed to make voltage drop limits mandatory that had previously been recommended but not required by the California Electrical Code (Title 24 Part 3).

8.1 Overview

All the requirements in Section 130.5 are mandatory, and therefore are not included in the energy budget for the whole building performance method.

8.1.1 Scope

The requirements for electrical power distribution systems apply to all non-residential buildings. The intention is to save energy and to allow future systems for power use monitoring and control to be added when expected changes in the marketplace occur.

A. New Construction and Additions

This Section applies to all new structures, and to some additions and alterations to existing structures.

For additions to existing structures, electrical circuits and Energy Management Control Systems (EMCSs) must in general meet the requirements of Section 130.5 if they:

- Serve a lighting system
- Serve an altered space-conditioning system or water heating system
- Serve an addition to an outdoor lighting system

See Section 141.0(a) of the Code for a list of exceptions

B. Existing Construction

For alterations to existing spaces, electrical circuits and EMCSs that have been altered must in general meet the requirements of Section 130.5 only if:

- Serve lighting, space conditioning or water heating systems
- Are newly installed components of an existing system

See Section 8.7 (Additions and Alterations), for a list of exceptions.

However, the requirements of Section 130.5 are invoked when any of the following occur:

- Additional feeder(s), panelboard(s), major load(s), and/or motor control center(s) are added.
- A new service and/or main switchboard or panelboard is installed.
- A building is re-purposed and new panelboards and feeders are installed.

C. Acceptance Testing, Commissioning, and Installation Certificates

The requirements of Section 130.5 are not subject to acceptance testing or commissioning.

8.1.2 Summary of Requirements

The requirements of Section 130.5 are organized as follows:

A. Service Metering

Each electrical service shall have metering that will allow the building Owner to get useful information for managing the use of electrical power. The requirements increase as the size of the service increases. For smaller services, the building owner must be able to manually read the energy use (kWh) meter and to reset the readout to allow for period measurements, without of course affecting revenue measurements. As service size increases, the meter must also allow for demand measurements so that the building owner or operator can gain a better understanding of how and when the building uses electrical power. If the building is equipped with an Energy Management and Control System (EMCS) that provides these measurements, then the manual system is not required.

B. Disaggregation of Electrical Circuits

Above a minimum threshold that varies by load type, electrical power systems must be designed and built such that the total load of specific building load types can be measured. For instance, lighting loads must be able to be measured independently of HVAC loads. The intent is to have a single feeder or breaker with each type of load (such as lighting) on it, such that a meter could be placed on the feeder to report energy use by that load type.

Note that this is a wiring requirement only, and the providing of meters is optional.

C. Voltage Drop

This section makes the National Electrical Code/California Electrical Code suggestion of voltage regulation mandatory, limiting branch circuit voltage drop to 3% at design load and to 2% in feeders at design load.

D. Circuit Controls for 120-Volt Receptacles

This section adds minimum requirements for switching of 120-volt receptacles in non-residential applications. The primary reason is to permit simple control of furniture mounted task lights and other plug loads. There are a number of exceptions and exemptions to this requirement as not all receptacles require control.

E. Demand Response Controls and Equipment

Section 130.1(f) requires nonresidential buildings over 10,000 sf to have a demand responsive lighting system. The provisions of new Section 130.5 (e) require that demand responsive loads be equipped with controls that can receive at least one demand response signal and respond.

F. Energy Management Control System (EMCS)

For buildings employing Energy Management Control Systems, some of the above requirements are modified provided that the EMCS provides them.

8.2 Service Metering

Projects are required to provide an electric meter that permits the building owner or manager to read the instantaneous power in kilowatts being used by the building, and to be able to reset and measure energy use in kilowatt-hours over a period of his own choosing. If this is possible from the utility company's revenue service meter, then an additional meter does not need to be provided.

For larger buildings and electrical systems (greater than 250 kVA, which is 700 amps at 120/208 volts three phase and over 1000 amps at 120/240 volts single phase), the meter must also record the historical peak demand in kilowatts.

For much larger systems (greater than 1000 kVA, which is over 2700 amps at 120/208 volts three phase and over 4000 amps at 120/240 volts single phase, the meter must also be able to report the kWh for a fixed rate period.

Table 130.5-A (see page 13 below) repeats these requirements in table form.

8.2.1 What is the “Electrical Service”?

The word service originates in Article 110 of Title 24 Part 3, the California Electrical Code. The Code intends that the service is where electric power enters a building or other structure. For safety and security, there are number of specific requirements for the service, such as where they must be located, how many disconnecting devices may be used, and how they must be labeled, as described in Article 230 of the Code.

The Electrical Code defines service as, “The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served”. To many people, this indicates that the service is where a utility company provides power to the building or structure. In fact, most buildings¹ are served directly by the electric utility company, and the service includes a revenue meter. The requirements of Section 130.5(A) refer to this service and to this meter.

But not all buildings are connected directly to the utility company and not all services have revenue-measuring meters. For example, a college campus might purchase bulk power from an electric utility company, to save energy costs. The revenue meter is located where the electric utility company connects to the customer's power distribution system. From this point on to the campus' buildings, the customer owns the electrical system and becomes the serving utility for the purposes of the Code.

¹ Sometimes, a building may in turn serve an adjacent power user, such as a garage or pumping station, but these are technically not services.

It is the intent of Section 130.5(A) that the service to every building or structure be metered so that its energy use can be monitored. For most buildings, the utility revenue meter can meet this requirement if it includes the read-out provisions indicated in Table 130.5-A. However, if a customer's power distribution system serves a number of buildings, then a customer-owned meter meeting the requirements of Table 130.5-A must be provided for each building. Note that this meter does not need to "revenue grade," which typically means 0.2% accuracy; less accurate metering is acceptable, as the point of this metering is to help the owner determine building energy use for management and planning purposes.

Sometimes buildings are not connected to a utility company at all. Power may be obtained from a generating system such as a diesel generator, wind turbine, or photovoltaic system without a grid tie. In each case, the generating system becomes the serving utility. As above, metering is not required to be revenue grade, but it is required to permit energy use management.

8.2.2 Buildings with Multiple Services

In rare cases, a building may have more than one service. These may include:

- a) Fire pump service(s)
- b) Emergency generating system(s)
- c) Legally required standby generating system(s)
- d) Optional standby generating system(s)
- e) Parallel power production systems
- f) Systems designed for connection to multiple sources of supply for the purpose of enhanced reliability
- g) Multiple-occupancy buildings where there is no available space for service equipment accessible to all occupants
- h) A single building or other structure sufficiently large to make two or more services necessary, including buildings where the capacity requirements are in excess of 2000 amperes at a supply voltage of 600 volts or less, or where the load requirements of a single-phase installation are greater than the serving agency normally supplies through one service

As the intent of Section 130.5 is to allow general energy use measurement for management purposes, metering is only required for those services that regularly provide electric power to the building or structure. In general, this includes e) through h). For instance, a photovoltaic system regularly provides power and is (e) a parallel power system.

Some projects with emergency power or standby power sources use them for peak-load shaving. If the building is designed to do this, metering on these services is also recommended, as they also constitute a parallel power system. However, if the alternative power source is only used for emergency conditions, metering is not required (although it is strongly recommended).

8.2.3 Practical Considerations

Metering of electrical power involves three key components:

- Current transformers (CTs), usually 2 or 3, which are typically in the shape of a doughnut and the power wire being measured goes through the doughnut hole'; and,
- Voltage measurement, phase to phase and/or phase to neutral, with isolation transformers in some instances; and,
- A meter to which the voltage wires and output of the CTs are connected.

The simple residential meter has everything in a single box. Most people are familiar with the electromechanical residential and small commercial meter shown in Figure 8-1.



Figure 8-1 – A Self Contained Residential or Small Commercial Electromechanical Meter

The electromechanical meter shown above is obsolete. Most new meters are electronic, and over time, most old meters will be replaced with an electronic meter. Meters with electronic data collection, analysis and communications ability are commonly called “smart meters”. Modern “smart” utility meters generally have all of the required features of this mandatory requirement, and more. The question is whether the building owner can access the information. The utility company owns the meter and there is no clear requirement for them to offer access to the data. If data access is provided, the mandatory requirement is met with the utility meter.



Figure 8-2 – A modern electronic utility revenue meter (GE)

It may be desirable add a separate meter so that the building owner can have access to all of the data he needs. Adding a meter includes adding CTs, which will require room in a cabinet separate from the utility company CTs.



Figure 8-3 – Solid Core CTs Various Sizes (MES)

Solid core CTs require pulling a de-energized cable through the hole.



Figure 8-4 – A Residential Grade Split Core CT (Efergy)

A split core CT can be installed on an existing wire without de-energizing. This is a residential and light commercial grade CT with plug connection to a digital energy meter

The accuracy of metering is an issue. In general, “revenue grade” metering requires high accuracy CT’s and metering equipment. Energy-management metering CT’s can be less accurate without affecting their role and purpose.



Figure 8-5 – An Electronic Energy Meter with Mandatory Metering and Digital Output Costing Less than \$200 (Akvim)

The meter itself can be located remotely from the CT's, making it easier to read. Most electronic meters have a digital output that permits remote reading using specific hardware and software. Many can be read using a web browser and a password if the meter is connected to the Internet or building Ethernet.

8.2.4 Summary

- A meter that can be read by the building owner or occupant must be provided. This applies to any electrical service and is invoked any time that any section of the Standard applies and a permit is obtained.
- It must allow the building owner or occupant to view instantaneous power (kW) and have a manually resettable cumulative energy measurement (kWh) permitting periodic review of total electric energy use.
- Larger services will require additional capabilities identified in Table 130.5-A.
- Modern electronic utility meters “smart meters” usually meet the requirements as long as the data is accessible to the building owner or occupant.
- The cost of high performance meters is low and metering separate from the utility meter for energy monitoring, energy management, power quality measurement and other features not provided by the utility may be desirable.

Table 8-1 - Required Disaggregation of Electrical Loads

Table 130.5-A Minimum requirements for metering of electrical load

Meter Type	Services rated 50 kVA or less	Services rated more than 50kVA and less than 250 kVA	Services rated more than 250 kVA and less than 1000kVA	Services rated more than 1000kVA
Instantaneous (at the time) kW demand	Required	Required	Required	Required
Historical peak demand (kW)	Not required	Not required	Required	Required
Resettable kWh	Required	Required	Required	Required
kWh per rate period	Not required	Not required	Not required	Required

8.3 Disaggregation of Electrical Circuits

This section of the Standard requires buildings to be wired in a manner that separates loads by types onto independent feeders and risers through the building. This will require separate feeders and panels for lighting, plug and equipment loads, HVAC loads, etc. The requirements are contained in Table 130.5-B, reproduced below.

“Disaggregation” means in this case to break down the total electrical use in the building into groups that permit power and energy use measurements to be taken, to enable management to determine where energy is being used. For instance, lighting energy use quantities and patterns can be studied and excess use or waste can be targeted for improvements.

Note that this requirement does not require any metering. By placing all load of a particular type on one feeder, a portable power measurement and analysis device can be temporarily attached to its feeder, measurements can be made, and then the device can be moved to another feeder.

In the examples, note that the manner in which disaggregation occurs does not require specific wiring; for instance, a single feeder can provide lighting and plug load power as long as the panelboard has a split bus allowing measurement of one and then the other. However, this can only be used in a smaller building as the all lighting must be able to be measured at one point.

This requirement is for new buildings and for major additions or renovations. It is invoked whenever the service is modified as with a new switchboard, or when sections are added or new feeders pulled. In an existing building that is being altered, this requirement is not invoked as long as the existing service switchboard, existing feeders and existing panelboards remain essentially “as-is.”

As an alternative to disaggregation, current transformers can be added to individual branch circuits or loads throughout the building, and a permanent measurement system can be installed. In this case disaggregated wiring would not be required as long as the

metering system permitted the equivalent disaggregated measurements. See Exception 1 to Section 130.5(b).

8.3.1 Disaggregation increases as loads get larger

The requirement is progressive. Disaggregation is not required until the service reaches 50 kVA, which is 60 amps at 277/480 volts three phase, 150 amps at 120/208 volts, three phase and 200 amps at 120/240 volts single phase. For most small buildings or separately metered portions of a building, such as a store in a mall, this requirement will not apply.

Once the service to the building reaches 50 kVA, the requirements are applied to some groups regardless of actual load, and to other groups when the group reaches a threshold value of 25 kVA (100 amps at 240 volts single phase, 70 amps at 120/208 volts three phase, and 30 amps at 277/480 volts three phase).

For services rated 250 kVA and above, lighting and plug loads are required to be disaggregated “*by floor, type or area.*” So in a single-story building, all the lighting loads could be fed from a single panel, and all the plug loads could be fed from another panel (or alternatively, both types of load could be fed from one panel with a split bus).

In a large single-story building it would be useful, but not mandatory, to split each type of load into sub-panels that serve particular areas or particular types of light fixture, so these could be metered with the same CT.

In a multi-story building, a simple way to comply would be to install a separate lighting panel and a separate plug-load panel for each floor of the building. However, it would be equally acceptable and more useful to divide the load according to which area of the building it serves (office, warehouse, corridors etc.), or by the type of light fixture (metal halide vs. fluorescent, dimmable vs. fixed output, etc.). So, for instance, both the first and second floor office lights could be fed from the same panel, while the warehouse lights would be fed from a second panel. Dividing the load by area or by type instead of by floor is more likely to yield useful information when the loads are analyzed in an energy audit.

- Practical Considerations

These requirements were developed with a reasonably practical eye. In a small building or service, disaggregation is not required at all. The minimum threshold of 50-kVA service means that almost all projects less than 5,000 sf will not be required to comply. Slightly larger projects will be able to comply by using carefully laid-out panelboards. The standard envisions the use of conventional panelboards, motor control centers, through wired panels, and other standard wiring methods. It also envisions a new generation of creative solutions such as split bus panels, with separate bus and breaker sections for lighting and receptacles/equipment. Likewise, clever wiring methods will also emerge, such as connecting all HVAC units to a single feeder from the service, using a combination of through feeds and taps. In other words, with minor changes in how power is distributed in a building, the requirement can be met with little or no added cost.

In larger buildings, this mandatory requirement will make separate risers for lighting, receptacles/equipment, and HVAC necessary. Single large loads or groups of loads, such as an elevator machine room, chiller or commercial kitchen, will have a separate feeder and panelboard or motor control center anyway; in many buildings these requirements are already met at least in part.

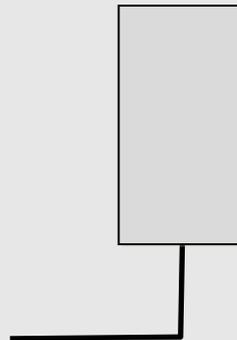
For buildings with a single large service greater than 50 kVA, such as retail malls, offices and apartment buildings that have submetered distribution to completely demised tenants, the requirements apply as follows:

- Common areas of the building must be disaggregated
- Individual submetered services must be disaggregated if the submetered service is 50 kVA or greater, with the exception of residential units, in which disaggregation is not required.

In remodeled or renovated buildings, the total electrical load is expected to be reduced as Title 24 lighting power requirements, HVAC requirements, insulation and glazing requirements, etc. will necessarily cause the original building to use less energy, and to a certain extent a building can be enlarged without increasing the service or existing feeders and panels. As long as the only changes to the electrical system involve changes to branch breakers and branch circuits, this mandatory requirement is not invoked.

Example 8-1

Single panel with service less than 50 kVA, which is less than 60A @ 277/480v 3φ, 135A @ 120/208v 3φ, or 200A @ 120/240v 1φ

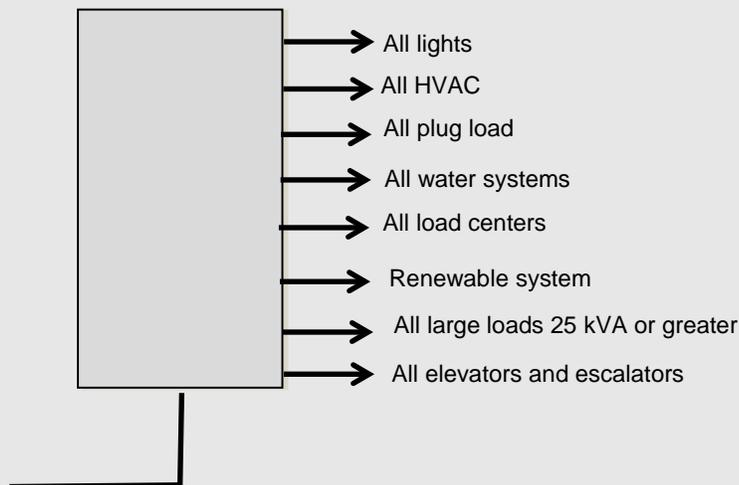


No requirements for disaggregated wiring

Example 8-2

Basic Requirements for Disaggregated Wiring.

Service panel with service less than 250 kVA, which is less than 300A @ 277/480v 3φ, 690A @ 120/208v 3φ, or 1000A @ 120/240v 1φ



This would be typical of a small school or office building (~25,000 to 50,000 sf), small retail or grocery store (~10,000 to 20,000 sf), etc.

Each feeder serves a breaker panel, load center, or load or load group with its own disconnect and subdistribution.

Notes

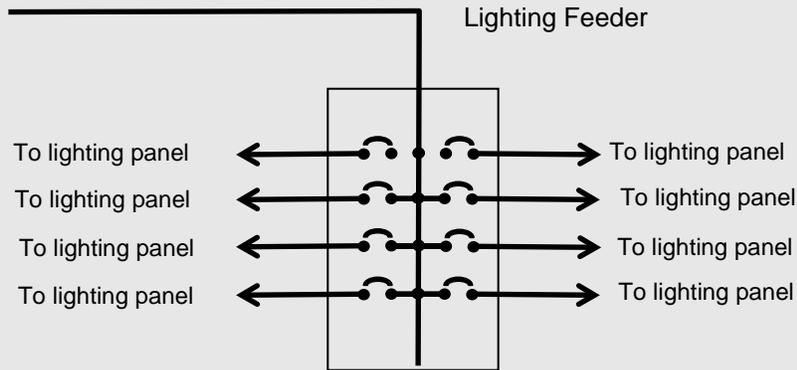
Large loads smaller than 25 kVA can be connected to load centers or plug load groups.

Load centers can be used to aggregate many small equipment loads such as commercial or industrial equipment, computer server rooms, commercial kitchens, retail refrigeration, etc.

A single multi-pole breaker can be used to feed all branch circuit loads of one type, such as all lighting loads, in smaller buildings.

Example 8-3

Using a distribution panel to subfeed branch circuit panelboards. Can be used for lighting, HVAC, plug loads, or any other group of load types.

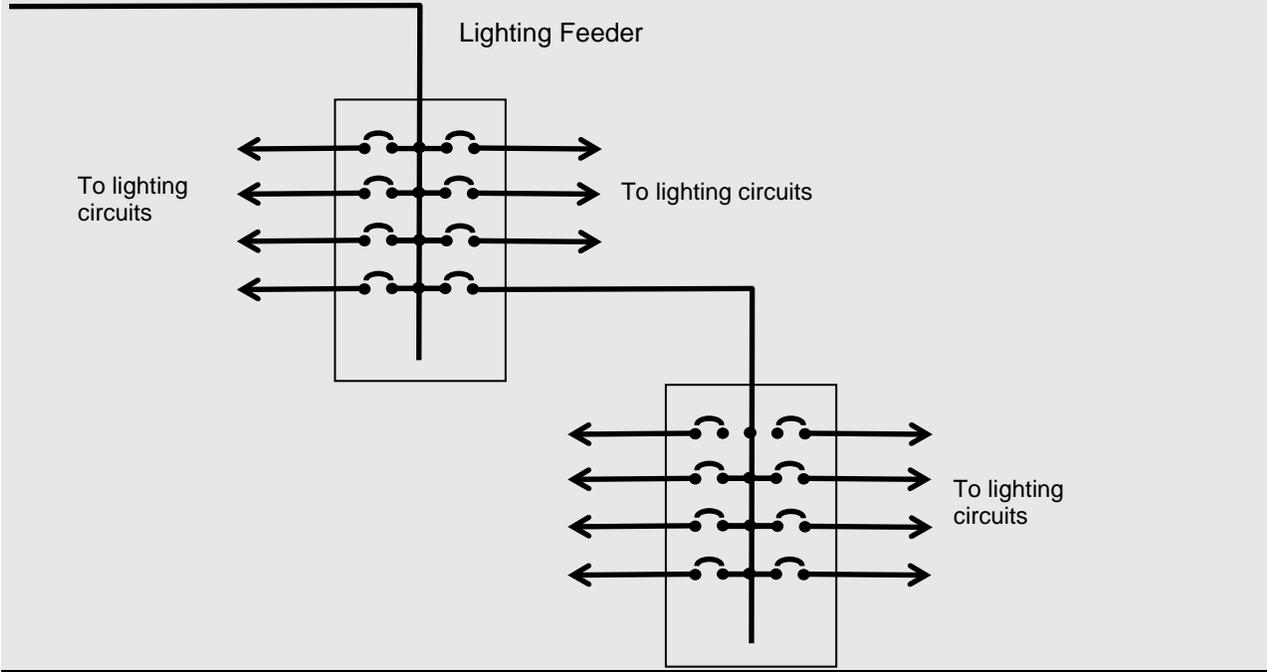


Example 8-4

Combined lighting panel with subfeed to other lighting panel(s).

A larger first lighting panel (e.g. 400 amps) could subfeed three 100-amp panels, or 6 60-amp panels, and serve local branch circuits, too.

Can be used for lighting, HVAC, plug loads, or any other group of load types.



Example 8-5

Using a split bus panel to feed two groups of branch circuits. Can be used for lighting, HVAC, plug loads, or any other group of load types. Limited to use in smaller projects where only one panel is needed for each load type.

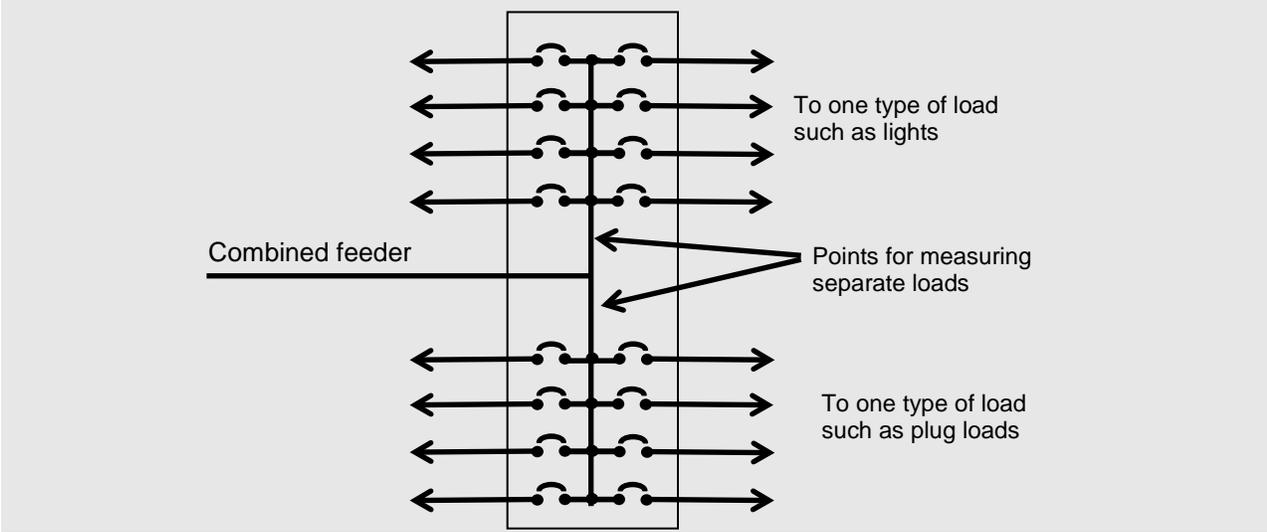


Table 8-2 - Required Disaggregation of Electrical Loads

Table 130.5-B from the Standards				
Load Type	Services rated 50 kVA or less	Services rated more than 50kVA and less than 250 kVA	Services rated more than 250 kVA and less than 1000kVA	Services rated more than 1000kVA
Lighting including exit and egress lighting and exterior lighting	Not required	All lighting in aggregate	All lighting disaggregated by floor, type or area	All lighting disaggregated by floor, type or area
HVAC systems and components including chillers, fans, heaters, furnaces, package units, cooling towers, and circulation pumps associated with HVAC	Not required	All HVAC in aggregate	All HVAC in aggregate and each HVAC load rated at least 50 kVA	All HVAC in aggregate and each HVAC load rated at least 50kVA
Domestic and service water system pumps and related systems and components	Not required	All loads in aggregate	All loads in aggregate	All loads in aggregate
Plug load including appliances rated less than 25 kVA	Not required	All plug load in aggregate Groups of plug loads exceeding 25 kVA connected load in an area less than 5000 sf	All plug load separated by floor, type or area Groups of plug loads exceeding 25 kVA connected load in an area less than 5000 sf	All plug load separated by floor, type or area All groups of plug loads exceeding 25 kVA connected load in an area less than 5000 sf
Elevators, escalators, moving walks, and transit systems	Not required	All loads in aggregate	All loads in aggregate	All loads in aggregate
Other individual non-HVAC loads or appliances rated 25kVA or greater	Not required	All	Each	Each
Industrial and commercial load centers 25 kVA or greater including theatrical lighting installations and commercial kitchens	Not required	All	Each	Each
Renewable power source (net or total)	Each group	Each group	Each group	Each group
Loads associated with renewable power source	Not required	All loads in aggregate	All loads in aggregate	All loads in aggregate
Charging stations for electric vehicles	All loads in aggregate	All loads in aggregate	All loads in aggregate	All loads in aggregate

8.4 Voltage Drop

This is a new Section. It makes the recommended voltage drop limits from the California Electrical Code (Title 24 Part 3) mandatory. Specifically:

- The voltage drop in feeders is limited to 2% of design load; and
- The voltage drop in branch circuits is limited to 3% of design load.

Emergency power circuits are exempt.

8.4.1 Purpose of this Requirement

Voltage drop represents energy loss as heat in the electrical conductors. The loss is called “ I^2R ” (I-squared-R) loss, meaning that the loss is directly proportional to the conduction resistance and proportional to the amps **squared**. Because of I^2R loss, it is advantageous to distribute utilization power at the highest practical voltage to reduce current to each load. This basic consideration will continue to promote 277/480-volt systems wherever practical. But with the growth of 120-volt utilization loads, many projects will consider 120/208-volt or 120/240-volt systems to avoid subtransformers and the added costs of having two power systems.

Once the distribution and utilization voltage(s) are determined, feeders and branch circuits are designed. Per code, the wire size or gauge is primarily based on “ampacity,” the number of amps for which the wire is rated in the application.² Voltage drop limits may cause increased cable diameter (gauge), particularly for long wire runs.

With rising prices of copper and the heavy demand for it in developing countries, there will be continued pressure to use aluminum alloy and copper clad aluminum for typical projects in the US. Past problems with aluminum branch circuits will discourage aluminum branch wiring, but feeders will use increasing amounts to save both cost and weight. Unfortunately, the resistivity of copper is 10.4 ohms per circular mil per foot as compared to 15% copper-clad aluminum (16.1) and AA-8000 series aluminum alloy (17.0). In practice, larger gauge aluminum and copper clad aluminum conductors will be required to reduce the voltage drop.

² The application takes into account how and where the wire or cable is located, such as in free air, in a conduit in a building, directly buried in earth, etc. These affect the cable's dissipation of the heat and the resulting operating temperature of the cable. Cables subject to a lot of heat are derated by the code.

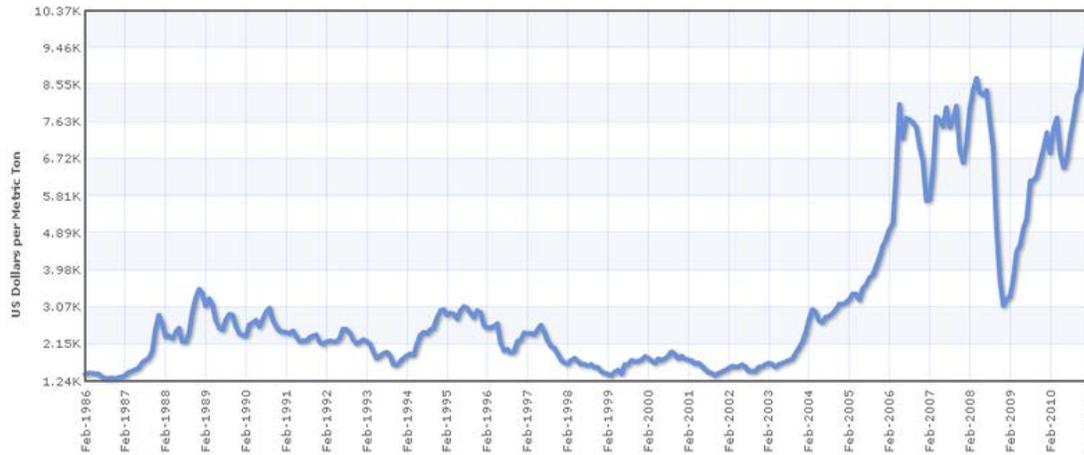


Figure 8-6 Copper Prices 1986-2011

Source: Wikipedia

8.4.2 Applying Voltage Drop Calculations

Voltage drop losses are cumulative, so that 2% loss in feeders and 3% loss in branch circuits add up to 5% loss relative to the load at the end of the branch circuit. Because electrical loads are not constant, the calculation is based on design load. For feeders, this is the calculated maximum demand load on the circuit per the California Electrical Code but does not include any of the additional ampacity required by the California Electric Code. For branch circuits, the design load is either (a) the branch circuit rating for receptacle loads (usually 16 amps), or (b) the 100% load of a specific load such as motor or fixed equipment.

The calculation is for the total length of the feeder, and for the maximum length of branch circuit to the load. For branch circuits, this calculation can be excessively complicated in many cases. For this reason, any of the following methods can be used to calculate branch circuit voltage drop:

- a) A load-by-load, detailed calculation of the voltage drop. This is required for circuits with specific loads such as motors or fixed equipment.
- b) For circuits with many loads such as receptacles, determine the approximate centroid of the load. The centroid is defined as the weighted center of all possible load locations. For a receptacle or lighting circuit, it is the physical center of the room or all rooms served by the circuit. Determine the voltage drop at that point for the actual load or 75% of the maximum allowable circuit amps, whichever is greater.
- c) For circuits as b) but with a common neutral and multiple phase conductors carried as far as a first major junction box, the voltage drop calculated above may be reduced 25% to account for the cancelation of neutral current before the neutral is tapped and single phase circuits begin.

8.4.3 Calculations

While voltage drop calculations can be performed by hand, they are also the output of most modern power design computer programs. In addition there are handy calculators on

the Internet³ and procedures for determining voltage drop are printed in electrician's handbooks.⁴

Calculations are relatively straightforward. Multiply the allowed voltage-drop percentage (2% for feeders, 3% for branch circuits) by the nominal system voltage. This is the allowed drop in the feeder or branch circuit. Note to be careful whether calculating voltage drop in a single-phase or three-phase system, as illustrated in the following example.

Example 8-6

In a 120/208 volt system, the allowed voltage drop for a single phase 120 volt branch circuit load is $(120 \times .03) = 3.6$ volts. For the feeder in the same 120/208 volt three phase system, the allowed voltage drop is $(120 \times .02) = 2.4$ volts, for a cumulative loss of 6 volts (5%).

Next, calculate the actual voltage drop in the circuit. Multiply the resistance times the length of wire in the circuit. Remember, the length of wire is TWICE the distance, as current must flow to the load and back. For three phase circuits, the allowed voltage drop is based on line-to-line volts, not line-to-neutral volts.

Example 8-7

In a 120/208 volt system, a single-phase branch circuit runs 100 feet to the centroid of a number of receptacles. Assuming 12 amps (75% of the maximum allowed load) and cooper wire, the voltage drop in the branch circuit will be

With #12 wire @ .00187 ohms/ft, $E_{\text{drop}} = IR = 12 \times 100 \times 2 \times .00187 = 4.48$ volts

With #10 wire @ .00118 ohms/ft, $E_{\text{drop}} = IR = 12 \times 100 \times 2 \times .00118 = 2.81$ volts

With #8 wire @ .000739 ohms/ft, $E_{\text{drop}} = IR = 12 \times 100 \times 2 \times .000739 = 1.76$ volts

In this case, the branch circuit should be #10 to the first load or junction box. The remainder of the circuit could probably be wired with #12 gauge provided there are no long runs or single large loads.

Example 8-8

A service panel feeds a 120/208 volt three phase panelboard 150 feet away. The design load is 80 amps, three-phase. The panel mains and feeder breaker are rated 100 amps. By code the feeder must be at least #3 AWG copper, but the more common size #2 AWG is used. Does it comply?

For #2 AWG, $E = IR = .000513 \text{ ohms/ft} \times 150 \text{ ft} \times 2 \times 80 \text{ amps} = 12.3$ volts. But the allowed drop is $208 \times .02 = 2.4$ volts. The answer is no, there will be too much loss in the feeder.

The proper feeder will be at least 400 MCM copper to achieve 2.4 volts or less in voltage drop.

8.4.4 Suggested Calculation Approach

Voltage drop calculations are of two principal types:

- Voltage drop in feeders, which are conductors carrying current from one switchboard or panelboard to another; and

³ www.electrical-installation.org

⁴ Ugly's Electrical References, George Hart and Sammie Hart, Jones and Bartlett, Publishers

⁵ The necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the load end of service conductors to a building or other structure, or an otherwise designated area, and intended to constitute the main control and cutoff of the supply. (California Electrical Code, Section 110)

- Voltage drop in branch circuits, which are conductors carrying current from a switchboard or panelboard to one or more connected loads.

As a general rule, “switchboards” include service entrance⁵ or disconnecting gear with or without distribution sections, power distribution gear of switchboard construction⁶ and employing feeder and/or branch circuit distribution breakers or fusible disconnects, motor control centers with motor starters and/or distribution breakers or fusible disconnects, and similar equipment. “Panelboards” include service entrance or disconnecting gear with or without distribution sections, power distribution gear of panelboard construction⁷ and employing feeder and/or branch circuit distribution breakers, and similar equipment.

A. Determining Load Current

For the purposes of voltage drop calculations, loads must be included as volt-amperes (VA), not watts. Because of the increased use of electronic equipment, unity power factor should not be assumed. For the purposes of this calculation, if power factor is known, the following power factors can be used to determine VA and thereby, circuit amps.

For instance, the minimum allowed power factor (pf) for an Energy Star LED lamp is 70% (0.7). Assume a lamp rated at 12 watts at 120 volts. The volt-amps will be

$$VA = \text{Watts}/\text{pf}.$$

In this case, the VA will be $(12/.7) = 17.14$ VA and the current at 120 volts will be about 0.143 amps. This means that a maximum of $(16/0.143) = 111.8$ lamps can be placed on a standard 20 amp circuit. If watts had been used instead of VA, the designer or electrician would have assumed that 160 lamps could be used on a circuit, which would have then drawn nearly 23 amps and tripped the breaker.

In an ideal world, the watts and VA of a load would be equal (pf = 1.0 or 100%). But many LED lighting and electronic branch circuit loads have poor power factor (80% or less). Poor power factor means that the load draws current but does not use all of the power, in essence storing the energy and returning it to the circuit unused. This causes inefficiency as the unused energy still causes power losses in transformers, conductors and other system components. Moreover, many utility tariffs charge customers extra for poor power factor.

⁶ A large single panel, frame, or assembly of panels on which are mounted on the face, back, or both, switches, overcurrent and other protective devices, buses, and usually instruments. Switchboards are generally accessible from the rear as well as from the front and are not intended to be installed in cabinets. (Ibid)

Table 8-3 Typical Power Factors for Voltage Drop Calculations

Load Type	Default Power Factor at 120 volts	Default Power Factor at 277 volts	Note
Fluorescent lighting	0.95	0.95	-----
Compact fluorescent lighting	0.9 (hardwired) 0.5 (GU-24)	0.9 (hardwired) 0.3 (GU-24)	NPF magnetic ballasts use GU-24 values
LED lighting	0.7	0.5	May be higher if specifications call for high power factor drivers
Incandescent lighting	1.0	1.0	-----
HID lighting	0.9	0.9	May be lower if NPF ballasts are specified
HVAC packages	0.85	0.9	-----
Other motors <5 HP	0.8	0.8	-----
Other motors >5 HP	0.85	0.85	-----
Kitchen equipment	0.9	N/A	-----
Receptacles	0.6	N/A	For dedicated receptacles, may be rated according to the load
Electric heating including hot water	1.0	1.0	-----
Other	0.85	0.85	-----

B. Resistance versus Impedance

The resistance of wire (R) is relatively constant and predictable based on material, stranded versus solid cable, and length. There are small variations due to temperature, but for the purposes of voltage drop calculations in building wiring, the resistance at 25°C is generally suitable.

On the other hand, the impedance of wire (Z) depends on many factors, including type of conduit (if any), whether the wires are twisted, and type of insulation. Moreover, in normal operating calculations (not short circuit calculations), the inductive reactance (X_L) plays a small role in circuit impedance, and at 60 Hz, the capacitive reactance (X_C) plays little role in circuit behavior. Moreover, in DC circuits neither X_L nor X_C matter except under transient and short circuit conditions. Because R is the dominant cause of voltage drop, use of wiring resistance only is acceptable for the purposes of these calculations.

C. Feeder Calculations

The approximate length of the feeder can be determined by examining the plans and

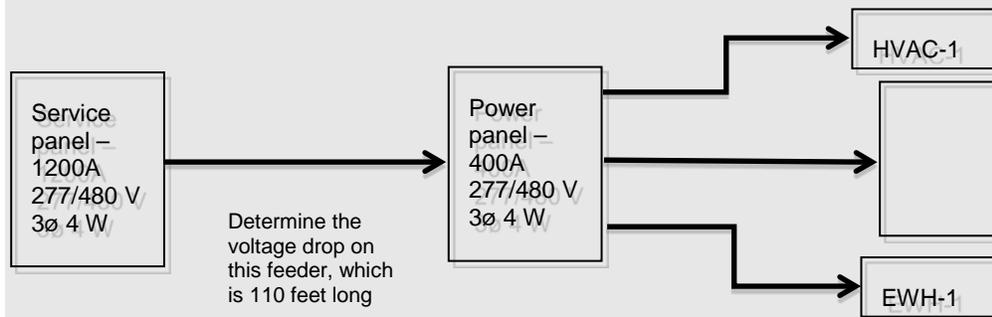
estimating the route that the installing contractor will use. This estimate should include lateral and vertical conduit lengths, with routing at right angles to the building structure.⁷ Diagonal routing may be used for calculations only if indicated on the plans. Note that this estimate should take into account any known conditions shown on the plans, and accuracy of 10% or better is considered acceptable.

The calculation should assume the design load per connected panelboard or switchboard load calculations. This means that the schedule for every panel should be shown on the plans, with circuit VA loads determined according to the California Electrical Code. The voltage drop should be based on the load and is not required to include derating factors. However, if spare feeder or branch circuit overcurrent protection devices or future spaces are provided in the connected panelboard or switchboard, then they are typically assumed to be loaded to 50% of rating. However, in any event the load of the connected panelboard or switchboard must not exceed its full rated load. .

If detailed load schedules are not available, or simply for ease of calculations, the voltage drop for the feeder may assume the connected panelboard or switchboard to be operated at 80% of rated ampacity. For example, for the feeder to a 400 amp panelboard, it is acceptable to assume $(400 \cdot .8) = 320$ amps.

Example 8-9

Feeder calculations



Basic Calculation

A service switchboard feeds a 277/480 volt 400 amp distribution panelboard (power panel) with the following schedule of devices and loads:

- Section 1 - 200-amp three phase breaker – feeds rooftop HVAC unit rated 125 full load amps (FLA) with 500 locked rotor amps (LRA), minimum breaker size 175 amps.
- Section 2 – 100A three-phase breaker – feeds downstream 100A lighting panelboard with 65-amp three-phase connected load and no spare breakers.
- Section 3 – (3) 20-amp single-phase breakers feeding local lighting loads of 12 amps, 8 amps and 10 amps, respectively.
- Section 4 – (1) 60-amp three-phase breaker feeding an electric water heater rated

⁷ These requirements call for assuming right angle (orthogonal) conduit routing as in general, such practice is considered proper workmanship. However, if a diagonal route is specified in the plans, it may be used and will typically result in a shorter circuit. Engineers and electrical designers are encouraged to seek such specifications as this will result in lower energy loss and/or less construction materials, especially conductors.

18 kW and 43 amps per phase.

This example includes a number of common load types and considerations.

- Section 1: for the feeder voltage drop calculation, full load amps (FLA) are to be used. The load on the feeder is 125-amps, three-phase.
- Section 2: for the feeder voltage drop calculation, the lighting load of 65-amps, three-phase is used at 100%.
- Section 3: for the feeder voltage drop calculation, the largest single-phase current is assumed for all three phases, or 12 amps at 100%.
- Section 4: for the feeder voltage drop calculation, the three-phase load of the water heater is $(18,000 \text{ watts}) * 1.0 = 18 \text{ KVA}$, or $(18\text{KVA}/.832) = 21.6 \text{ amps}$.
- The total maximum connected load amps is $(125+65+12+22) = 224 \text{ amps}$.

The engineer specifies (2) 4/0 aluminum 90°C wire (rated 205 amps) aluminum per phase. The resistance of 4/0 stranded aluminum wire is .08360 ohms per 1000 feet at 25° C, so the resistance of two conductors per phase is $(.08360/2) = .04180 \text{ ohms per 1000 feet}$. The maximum permissible voltage drop (line to line) is $480 \text{ volts} * .02 = 9.6 \text{ volts}$.

The total circuit length (line-line) is $110 \text{ feet} * 2 = 220 \text{ ft}$. The circuit voltage drop is

$$E = IR = \text{Amps} \times \text{Resistance per 1000'} \times \text{length(ft)}/1000 = \\ 224 * .04180 * .220 = 2.1 \text{ volts (passes the test).}$$

Spares and Spaces Calculation

Now assume that the power panel above has the following spares and spaces:

- Section 5 – 60-amp three-phase spare
- Section 6 – 100-amp three-phase space

These are typically counted at 50% load (or greater). This means that the new total load for the panel is $(100+60)*.5 = 80 \text{ amps}$. The new total load is 224 amps (as determined above) plus 80 amps for a total of 304 amps.

Repeating the calculation above, the voltage drop in the specified (2) #4/0 aluminum conductors per phase is

$$E = IR = 304 * .04180 * .220 = 2.8 \text{ volts (passes the test).}$$

Ampacity Rating

For simplicity or when loads are not known, it is permissible to use 80% of the panel's rated current. The power panel is rated at 400 amps three-phase, so the load to be used is $400 * .8 = 320 \text{ amps}$. The voltage drop is

$$320 * .04180 * .220 = 2.9 \text{ volts (passes the test).}$$

In order to expedite design, as an alternative to performing detailed calculations, Table

130.5-B allows the selection of acceptable combinations of feeder conductors and distance meeting these voltage-drop requirements.

D. Branch Circuit Calculations

Branch circuits provide power from switchboards, panelboards or other distribution centers to individual loads or groups of loads. An example of an individual load is a rooftop package HVAC unit, which although technically is a group of loads including a compressor, fan, control circuits, etc., it is all in one place and the manufacturer provides the total load amps for the package unit. An example of a group of loads is a lighting branch circuit, to which a large number of individual loads might be connected over a large area.

As a general rule for individual loads, the location of the load is known. First determine the length of the branch circuit, taking into account both the lateral and vertical distance from power source to load. Conduit routing is usually at right angles to the building structure unless specifically shown on the plans. Next, determine the branch circuit voltage drop assuming 100% of rated load, calculated per the California Electrical Code. Derating factors used to determine current amps and conductor size do not need to be included.

As a general rule for branch circuits with multiple loads, in plan identify all loads on the circuit. Determine the centroid of the loads on the circuit, which is defined as the weighted central location of the group of loads. It is usual to determine the approximate location of the centroid of the loads simply by “judging by eye”.. The length of the branch circuit is defined as the distance from this point to the power source. Assume conduit routing at right angles to the building structure unless specifically shown on the plans.⁸ Next, determine the branch circuit voltage drop; this can be based on the following load factors, calculated per the California Electrical Code. Derating factors used to determine current amps and conductor size do not need to be included. Note that since the intent of this calculation is to determine the voltage drop that is primarily contained in the home-run conductors with an approximation for tap conductors, this method can be used for any wiring method.

Table 8-4 Branch Circuit Load Factor

Load type	Percentage of Code connected load to be used	Notes and Special exceptions
Lighting	100%	
Receptacles	75%	100% of all equipment loads using cord and plug connection
Combined lighting and receptacle	100% of lights and 75% of receptacles	-----
Tapped circuits	75% of receptacles 100% of all other loads	For circuits tapped downstream to supply mixed loads

⁸ These requirements call for assuming right angle (orthogonal) conduit routing as in general, such practice is considered proper workmanship. However, if a diagonal route is specified in the plans, it may be used and will typically resort in a shorter circuit. Engineers and electrical designers are encouraged to seek such specifications as this will result in lower energy loss and/or less construction materials, especially conductors.

As a convenience, the calculation may assume the allowed branch circuit capacity. In general, this is 80% of the rating of the overcurrent protection device, e.g. 16 amps for a 20-amp circuit. This is especially recommended for lighting and receptacle branch circuits that might have additional loads connected later.

Example 8-10

Single Load Example

A package HVAC unit running on 208 volts, three-phase has a full load amp (FLA) rating of 10.5 amps and locked rotor amps (LRA) of 45 amps. The engineer specified #12 wires and a 20 amp 3-pole breaker. The physical distance is 200 feet. What is the voltage drop and does it meet section 130.5?

On a 208 volt line-to-line circuit, the allowed branch circuit voltage drop is 3%, or $(208 \cdot .03) = 6.24$ volts.

The resistance of solid copper #12 wire is 1.62 ohms/1000 ft at 25° C. The voltage drop in this circuit is:

$$E = IR = 10.5 \cdot 1.62 \cdot (400/1000) = 6.84 \text{ volts (fails)}$$

This circuit will require #10 wires.

Example 8-11

Centroid Example

90 LED troffers are located in an office space. Each troffer is an LED luminaire rated at 277 volts, 42 watts and .16 amps, for a total of 14.4 amps for all 90 luminaires.⁹ The centroid is at the weighted center of all the luminaires, meaning the “center of mass.” An approximate location is likely to be sufficient for compliance purposes. In this example, the centroid is about 150 feet from the panel. What is the voltage drop and does it meet section 130.5?

On a 277 volt line to neutral circuit, the allowed branch circuit voltage drop is 3%, or $(277 \cdot .03) = 8.31$ volts.

The resistance of solid copper #12 wire is 1.62 ohms/1000 ft at 25° C. The voltage drop in this circuit is:

$$E = IR = 14.4 \cdot 1.62 \cdot (300/1000) = 7.00 \text{ volts (passes)}$$

Note that the voltage drop is $(7/277) = 2.5\%$. The engineer might be advised to use #10 home run conductors and tap down to #12 for the remainder of the branch circuit.

Example 8-12

Branch Circuit Rating Example

It is permissible to use 80% of the branch circuit overcurrent protection device as the circuit current. This method is strongly recommended for branch circuits to which additional loads might be added in the future.

For #12 wires, the overcurrent protection device is 20-amps, so the current to be used for the calculation is 20 amps * 0.8 = 16 amps. If the conduit length is 225 feet, what is the voltage drop and does it meet section 130.5?

On a 277 volt line to neutral circuit, the allowed branch circuit voltage drop is 3%, or $(277 \cdot .03) = 8.31$ volts.

The resistance of solid copper #12 wire is 1.62 ohms/1000 ft at 25° C. The voltage drop in this circuit is:

$$E = IR = 16 \cdot 1.62 \cdot (450/1000) = 11.64 \text{ volts (fails)}$$

For #10 stranded conductors,

$$E = IR = 16 \cdot 1.04 \cdot (450/1000) = 7.84 \text{ volts (passes)}$$

⁹ Note that the power factor of this LED luminaire is 95% - this is common among better quality LED luminaires but not all LED luminaires. If the power factor and amp rating of the LED luminaire was not given, it would be necessary to use the default power factor of 0.5, which would limit the number of luminaires on the branch circuit to about 52.

The engineer should choose #10 home run conductors and may consider tapping down to #12 for the remainder of the branch circuit.

Table 8-5 Summary of Voltage Drop Limits

Circuit Volts (V)	2% Voltage Drop (V)	3% Voltage Drop (V)	Total Loss (V)
120	2.4	3.6	6.0
208	4.2	6.2	10.4
240	4.8	7.2	12.0
277	5.5	8.3	13.9
480	9.6	14.4	24.0

Table 8-6 Voltage Drop for Common Copper Wire Gauges and Current Loads

Wire	Circuit Amps	Maximum Feeder Length					Maximum Branch Circuit Length				
		120	208	240	277	480	120	208	240	277	480
14*	12	39	67	78	90	156	58	101	117	135	233
12*	16	46	80	93	107	185	69	120	139	160	278
10	24	48	83	96	111	192	72	125	144	166	288
8	32	57	99	115	132	229	86	149	172	199	344
6	40	73	127	146	169	293	110	190	220	253	439
4	52	89	154	178	206	356	134	232	267	309	535
2	72	103	178	206	237	412	154	267	309	356	617
0	96	123	212	245	283	490	184	319	368	424	735
00	108	137	238	274	317	549	206	357	412	475	823
0000	144	163	283	327	377	654	245	425	490	566	980
250 (kcmil)	164	170	294	340	392	679	255	441	509	588	1019
300	184	181	314	362	418	725	272	471	543	627	1087
350	200	195	338	390	450	779	292	506	584	675	1169
500	248	224	388	448	517	896	336	582	672	776	1344

Table 8-7 Voltage Drop for Common Aluminum Wire Gauges and Current Loads

Wire	Circuit Amps	Maximum Feeder Length					Maximum Branch Circuit Length				
		120	208	240	277	480	120	208	240	277	480
14*	12	24	41	47	55	95	36	62	71	82	142
12*	16	28	49	56	65	113	42	73	85	98	169
10	24	29	51	59	68	118	44	76	88	102	176
8	32	35	61	70	81	140	53	91	105	121	210
6	40	45	77	89	103	178	67	116	134	154	267
4	52	54	94	109	126	218	82	142	163	188	327
2	72	62	108	125	144	250	94	162	187	216	375
0	96	74	129	149	172	298	112	193	223	258	446
00	108	84	145	167	193	334	125	217	251	289	501
0000	144	99	172	198	229	397	149	258	298	344	595
250 (kcmil)	164	103	179	207	239	413	155	269	310	358	620
300	184	111	192	221	255	442	166	287	332	383	663
350	200	119	206	238	274	475	178	309	356	411	713
500	248	137	237	273	316	547	205	355	410	473	820

8.5 Circuit Controls for 120-Volt Receptacles

This new section addresses receptacles in offices. Office plug loads are now the largest power density loads in most office buildings. The Standard now requires both controlled and uncontrolled 120-volt receptacles in each private office, open office area, reception lobby, conference room, kitchenette in office spaces, and copy room. The controlled outlets must be clearly different from uncontrolled outlets. The two principal ways to comply include:

1. For each uncontrolled outlet, provide a controlled outlet within 6 feet; or,
2. Use split wired duplex receptacles, with one uncontrolled and one controlled.

For open office areas, separate controlled and uncontrolled circuits must be provided to the workstations. If workstations are not installed at the time of occupancy, then when installed they must be equipped with non-residential power strips having motion controls built into the workstation, or alternatively, use the controlled and uncontrolled circuits already built in to the building system.

The controlled outlets must be automatically switched off in the same manner as required for general lighting, as described in Section 130.1(c.). The most common means will be a local motion sensor that can be connected to control both general lighting and outlets and using the occupancy (not vacancy) control method. Another common method will be to employ time of day controls with manual override switches.

Note that plug strips with motion sensors CANNOT be used to meet this requirement. The intent is to have built-in, hardwired power controls. Wireless motion sensors can be used, but the actual power switch must be hardwired.

The requirement for controlled receptacles in all of these spaces allows plug loads to be turned off for energy savings, and perhaps, for demand response. These particular space types were singled out because they commonly employ portable lighting and other loads that can be automatically controlled to save energy.

There are important exceptions not requiring a controlled outlet including:

- Clock outlets (mounted 6' or more above the floor)
- Outlets for copiers, printers and other IT equipment (with the exception of personal computers) in copy rooms.
- Outlets for refrigerators and water dispensary devices in kitchenettes.

8.5.1 Practical Considerations

In general, the most cost effective approach may be:

A. Private Offices, Conference Rooms, and other Spaces with Periodic Occupancy

A common motion sensor can control general lighting and receptacles. If needed because of different voltages, an auxiliary relay can be connected to the sensor. Likewise, with an auxiliary relay, the lighting system could be operated in the vacancy mode, and the controlled receptacles in the occupancy mode, thus permitting lights to be off while receptacles are on.

B. Lobbies, Break Rooms, and other Spaces with Frequent Occupancy During Business Hours

Time of day controls, with either a motion sensor or switch override, can switch the controlled receptacles. Programmable relay panels or controllable breakers can be used, or for less complex projects, a combination of motion sensors and programmable time switches can accomplish the same task. Note that if motion sensing is used, controls need to be room-by-room or space-by-space, but if time of day controls with manual override are used, whole circuits can be controlled together.

C. Open Office Areas

Receptacles in open office areas can be controlled either by the building's automatic shut-off system, or by controls integrated into the furniture systems. If the building provides controls, the most reliable system will most likely employ relays or controllable breakers, with manual override switches for zones within an open office space. A system using motion sensors might also be considered if sensors can be added as needed to address partitioning of the workstations thus ensuring proper operation. Systems contained within workstation systems are an acceptable alternative provided that they are hardwired as part of the workstation wiring system.

D. Networked Control Systems and Building Automation Systems

Most advanced lighting and energy control systems can be easily designed to accommodate outlet controls.

Certain office appliances, e.g. computers and fax machines, need to be powered all the time to provide uninterrupted services. These would be connected to the uncontrolled receptacles. Other appliances, e.g. task lamps, personal fans and heaters, monitors, do not need to be powered without the presence of occupants. They are considered as controllable plug loads and would be plugged into the controlled receptacles for automatic

shutoff controls. A hardwired control system provides the capability and convenience for automatic plug controls. Ultimately, it depends on building occupants to determine the appliances to be controlled.

In open office areas, it is better to implement occupancy sensor control at each workstation (cubicle) to maximize the opportunities of shutoff controls. System furniture (cubicle) is usually

equipped with more than one internal electrical circuit and some of these circuits can be dedicated for controllable plug loads. Electric circuit connectors for system furniture are modularized and, therefore, split between controlled and uncontrolled circuits has to be made at a junction box. If external occupancy sensor switches are used, they all need to be wired to the corresponding junction box and the overall system wiring is complicated. In addition, off-the-shelf occupancy sensors are designed to be mounted on walls, not onto system furniture. For the above reasons, office furniture with embedded occupancy sensor controls are the ideal choice for occupancy sensor controls in open office areas.

- Demand Response

Section 130.5 requires that, in any building or sign having mandatory provisions for demand response (DR), controls and equipment for DR shall be capable of receiving and automatically responding to at least one standards-based DR messaging protocol.

This requirement builds on the requirements of the following sections:

- Section 130.1(e), which requires the lighting in buildings over 10,000 square feet to have automatic demand responsive control.
- Section 130.3(a)3, which requires electronic message centers over 15 kW to have automatic demand responsive control.
- Section 1401.0(b)2l, which requires lighting alteration projects to include automatic demand response in the altered space under certain circumstances, such as when wiring is added or modified, or when the lighting load in the space is increased.

8.5.2 Demand response Application Notes

Note that this requirement only makes the building ready. It does not require buildings to actually respond to a demand signal. The decision to employ demand response is up to the building owner or manager, the utility company, and/or a governing authority.

Demand response signal is defined in Section 100.1 of the Standards as “a signal sent from the local power utility, independent system operator (ISO), or designated curtailment service provider, to a customer, indicating a price or a request to modify electricity consumption for a limited time period”.

The requirements of Sections 130.1(e) and 130.5(e) do NOT mean that a building has to be capable of responding to real time price signals. A building that is capable of responding to a request to reduce load when grid reliability is threatened (for instance with black outs) is sufficient to meet the requirements of the Standards.

Demand response is becoming increasingly important as it permits the temporary reduction of electric load on the grid when extreme weather or supply constraints cause electricity demand to come close to the grid’s maximum supply capabilities. It is also seen as a means to allow building operators to control electricity costs, as future prices are expected to change constantly as a function of overall system demand.

Because mandatory demand response (“DR”) is relatively new, standards and systems are still being developed and evolving. For this reason, Section 130.5 (e) does not specify a particular protocol or system, but rather lets it be specified by the utility company or other authority.

8.6 Energy Management Control System (EMCS)

Section 130.5(f) allows EMCSs to be used as an alternative to standalone controls. An EMCS can be used to provide mandatory lighting controls functionality (required by Section 130.1) and to earn lighting Power Adjustment Factors (PAFs). If an EMCS is used, it must meet the mandatory requirements of Section 130.5, described below.

- The EMCS must provide at least the same functionality as would be required from standalone controls used in the same application. These requirements are set out in Section 110.9.
- EMCS are subject to the acceptance testing and installation certificate requirements set out in Section 130.4.

Section 130.5(b) allows an EMCS to be used as a means of disaggregating electrical loads, as an alternative to using separate panels or subpanels for each load type. If an EMCS is used for this purpose, it must achieve the same level of disaggregation required by Table 130.5-B of the Standards, shown in Table 8-1 of this chapter.

Finally, Section 130.5(f) allows an EMCS to be used to provide the functionality of a standalone thermostat if it complies with all the requirements that would apply to the standalone thermostat.

8.7 Additions and Alterations

Although electrical power distribution systems are not specifically covered by the prescriptive requirements for alterations in Section 141.0(b), they are covered under the blanket requirement:

The altered components of...any newly installed equipment serving the alteration, shall meet the applicable requirements of Sections 110.0 through 110.9, Sections 120.0 through 120.6, and Sections 120.8 through 139130.5

Section 130.5(b)2

Only newly installed electrical power distribution equipment *serving the area being altered* is subject to the Standards. This means that if the equipment serves the altered area but is not located in the altered area, it must still comply. Any equipment that remains in place during the alteration, or is removed and reinstalled, is not subject to any of the requirements of the Standards.

In terms of the specific items of electrical equipment newly installed in an alteration project, the following requirements apply:

A. New electrical services, switchboards, panelboards, motor control centers, and subpanels

Each incoming electrical service must be fitted with a meter as set out in Section 130.5(a), if the service itself is new OR if an existing service supplies a new switchboard, panelboard or motor control center. Loads must be disaggregated into their separate load types as set out in Section 130.5(b) (see Section 8.1.2B above).

B. Feeders and Branch Circuits

New conductors must meet the voltage drop requirements set out in Section 130.5(c) of the Standards (see Section 8.1.2C above). Existing conductors are not subject to these requirements.

New conductors must also be disaggregated as set out in Section 130.5(b). This means that any circuit that has an overcurrent protection device rated at less than 60A must be supplied by a panelboard or subpanel that supplies *only* loads of that same type, as set out in Table 130.5-B of the Standards (shown in Table 8-1 of this chapter).

C. Receptacles

If new *controlled* receptacles are added, they must be equipped with automatic shut-off controls, and they must be permanently marked as being controllable. These requirements are set out in Sections 130.5(d)1 and 3.

If new *uncontrolled* receptacles are added, they are not subject to the requirements of Part 6 of the Standards.

D. Energy Management Control System (EMCSs)

Newly installed EMCS systems must comply with the requirements of Sections 110.9 and 130.4 (see Section 8.6 above) if they are installed to comply with mandatory controls requirements triggered by the alteration project, under Section 141.0(b)2 of the Standards.

If additional functionality is added to an existing EMCS system, this would not be subject to any of the requirements of the Standards, because it is not “newly installed equipment” per Section 141.0(b).

8.8 Electrical Power Distribution Systems Compliance Documents

8.8.1 Overview

This section describes the documentation (compliance form) recommended for compliance with the requirements of the 2013 Standards with regard to electrical power distribution systems.

Documents for compliance with the 2013 requirements are proposed to change as follows:

- A. For the period of January 1 through December 31, 2014, compliance documents are proposed to be similar to the 2008 compliance documents, except they have been updated to reflect changes in the 2013 Standards.
- B. Starting on January 1, 2015, the Energy Commission proposes to have developed electronic compliance documents to replace existing nonresidential paper documents.

8.8.2 Submitting Compliance Documentation

At the time a building permit application is submitted to the enforcement agency, the applicant also submits plans and energy compliance documentation. This section describes the recommended compliance documentation (forms) for complying with the requirements of the Standards. It does not describe the details of the requirements.

This section is addressed to the person preparing construction and compliance documents, and to the enforcement agency plan checkers who are examining those documents for compliance with the Standards.

8.8.3 Varying Number of Rows per Document

The paper prescriptive compliance documents have a limited number of rows per section for entering data. Some designs may need fewer rows, and some designs may need additional rows. If additional rows are required for a particular design, then multiple copies of that page may be used.

8.8.4 Compliance Documentation Numbering

Following is an explanation of the 2013 nonresidential compliance documentation numbering:

NRCC	Nonresidential Certificate of Compliance
NRCA	Nonresidential Certificate of Acceptance
NRCI	Nonresidential Certificate of Installation
ELC	Electrical power distribution systems
01	The first set of compliance documents in this sequence
E	Primarily used by enforcement authority
A	Primarily used by acceptance tester

8.8.5 Certificate of Compliance Documents

For electrical power distribution systems, there is only one compliance form :

- NRCC-ELC-01-E; Certificate of Compliance; Electrical Power Distribution Systems

8.8.6 Instructions for Completing Electrical Power Distribution Systems Certificate of Compliance

This document has seven pages. Each page must appear on the plans (usually near the front of the electrical drawings), and must be accompanied by a voltage drop calculation worksheet. A copy of these documents should also be submitted to the enforcement agency along with the rest of the compliance submittal at the time of building permit application.

The engineer may provide the voltage drop worksheet in whatever format is convenient to them, and is accepted by the inspector. No form has been prescribed for the voltage drop worksheet, because of the wide variety of different, valid, assumptions and unusual variations that the calculations may need to include.

With enforcement agency approval, the applicant may use alternative formats of these documents (rather than the official Energy Commission documents), provided the information is the same and in a similar format.

Project Description

- Project Name is the title of the project, as shown on the plans and known to the enforcement agency.
- Date is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.
- Project Address is the address of the project as shown on the plans and as known to the enforcement agency.
- Climate Zone is the California climate zone in which the project is located. See Reference Joint Appendix JA2 for a listing of climate zones.
- Building CFA is the total conditioned floor area of the building as defined in §100.1(b). For additions, the total conditioned floor area is the total area of the addition alone. For alterations, the total conditioned floor area refers to only to the altered floor area.
- Unconditioned Floor Area is the total floor area of unconditioned space, as defined in §100.1(b). For additions, the total unconditioned floor area refers to the addition alone. For alterations, the total unconditioned floor area refers to the altered floor area.

General Information

“Building Type” is specified because there are special requirements for high-rise residential and hotel/motel guest room occupancies. All other occupancies that fall under the Nonresidential Standards are designated “Nonresidential” including schools. It is possible for a building to include more than one building type. See §100.1(b) for the formal definitions of these occupancies. All appropriate boxes shall be checked:

- **Nonresidential** if the project includes nonresidential indoor lighting.
- **High-Rise Residential** if the project includes common areas of a high-rise residential building. Common areas are any interior areas which are not dwelling units. If this project also includes dwelling units, the residential lighting compliance documentation must also be completed and submitted.
- **Hotel/Motel** if the project includes common areas in a hotel or motel. Common areas of a hotel/motel include any interior areas which are not dwelling units. If the project also includes dwelling units, the low-rise residential lighting compliance documentation must also be completed and submitted.
- **Schools**, which includes relocatable buildings on the school site.
- **Conditioned Spaces** as defined in §100.1(b).
- **Unconditioned Spaces** as defined in §100.1(b).

“Phase of Construction” indicates the status of the building project described in the compliance documents.

- **New construction** should be checked for all newly constructed buildings, newly conditioned space or for new construction to existing buildings (tenant improvements).
- **Addition** should be checked for an addition that is not treated as a stand-alone building.
- **Alteration** should be checked for alterations to an existing building lighting system in accordance with §141.0(b). This includes Lighting System Alterations in accordance with §141.0(b)I(ii); and Luminaire Modifications-in-Place in accordance with §141.0(b)I(iii). Tenant improvements are usually alterations.

“Method of Compliance” indicates the method of compliance used for the project.

- **Complete Building Method**—see section 5.7.1 of this chapter for additional information.
- **Area Category Method**—see section 5.7.2 of this chapter for additional information
- **Tailored Method**—see section 5.7.3 of this chapter for additional information

Documentation Author’s Declaration Statement

The “documentation author” is the person who prepares a Title 24 Part 6 compliance document that must subsequently be reviewed and signed by a responsible person (see below) in order to certify compliance with Part 6. Subject to the requirements of §10-103(a)1 and §10-103(a)2, the person who prepares the Certificate of Compliance documents (documentation authors) shall sign a declaration statement on the documents they prepare to certify the information provided on the documentation is accurate and complete.

A documentation author may have additional certifications such as an Energy Analyst or a Certified Energy Plans Examiner certification number. Enter number in the EA# or CEPE# box, if applicable.

The person’s telephone number is given to facilitate response to any questions that arise.

Responsible Person’s Declaration Statement

The “responsible person” signing the Certificate of Compliance is required to be eligible under Division 3 of the Business and Professions Code to accept responsibility for the building design, to certify conformance with Part 6. If more than one person has responsibility for the building design, each person (such as an eligible lighting designer) shall sign the Certificate of Compliance document(s) applicable to that portion of the design for which the person is responsible. Alternatively, the person with chief responsibility for the building design shall prepare and sign the Certificate of Compliance document(s) for the entire building design.

The person’s telephone number is given to facilitate response to any questions that arise.

8.8.7 Section A: Electrical Service Metering

This table allows the location and rating of each electrical service to be recorded, so the inspector can check that appropriate metering is provided, according to Section 130.5(a).

Each row should contain a separate electrical service. All newly installed services must be included, whether the project is a new construction project or an alteration. Also, existing electrical services must be included if the switchboard or panel they supply has been newly installed.

Each column should be filled out as follows:

- The unique description, location or designation of this electrical service
- The power rating of the service, in Volt-Amps
- Check this column if the meter installed on this electrical service records the instantaneous (at the time) kW demand on the service
- Check this column if the meter records historical peak demand (kW)
- Check this column if the meter allows the total energy consumption value (kWh) to be reset at the meter.
- Check this column if the meter records the energy consumption of the service, broken down according to how much energy was used during each utility rate period (for instance, on-peak vs. off-peak).
- The inspector should check either the “pass” or “fail” box depending on whether the capabilities of the meter on this service meet the requirements of Section 130.5(a), set out in the table below the service schedule..

Below the electrical service schedule, Table 130.5-A from the Standards is reproduced, for ease of reference. This table sets out which metering requirements apply, depending on the size (rating) of the service.

8.8.8 Section B: Disaggregation of Electrical Circuits

There are two ways to comply with the disaggregation requirement of the Standards, set out in Section 130.5(b). The first is to ensure that each feeder supplies only one type of load (subject to the additions and exceptions shown in Table 130.5-B of the Standards). The second is to provide a permanently installed load measurement system that can separately record each type of load, using current transformers. The Certificate of Compliance allows the designer to indicate which method of compliance is being used.

Whichever method of compliance is used, the degree to which each feeder or load must be disaggregated depends on the rating of the electrical service that serves it. For larger

services, more disaggregation is required. These requirements are set out in Table 130.5-B of the Standards, which is reproduced in the Certificate of Compliance for ease of reference.

The table allows each switchboard, panelboard, motor control center or subpanel to be recorded on a separate row. The columns should be filled out as follows:

- A. The unique description, location or designation of this switchboard, panelboards, motor control center or subpanel
- B. The unique description, location or designation of the electrical service that supplies it.
- C. The power rating of the service, in Volt-Amps
- D. The inspector should check either the “pass” or “fail” box depending on whether the feeder to this panel supplies ONLY the type(s) of load described in the relevant cell of the table. Note that:
 - a. In some cases the table states that there is no disaggregation requirement for that combination of load and service rating
 - b. in some cases (such as with plug loads) there are additional limits on how much load or how much area may be served by a single feeder.

If, instead of disaggregated panels and feeders, a permanently installed load measurement system is installed that meets the requirements set out in the table, then the inspector should check the box in the bottom row of the table.

8.8.9 Section C: Voltage Drop

Because there are several valid ways to perform voltage drop calculations, depending on how much is known about the location and type of the loads that will be installed, this section of the Certificate of Compliance simply requires that the engineer attach a worksheet showing voltage drop calculations that comply with the maximum voltage drops allowed by Section 130.5(c) of Standards (2% for feeders, 3% for branch circuits, at design load).

The inspector should check either the “pass” or “fail” box, depending on whether the calculations of the worksheet adequately show that the voltage drops will be within the requirements of the Standards.

For ease of reference, the tables for typical power factor of loads, and for maximum length of typical feeders and branch circuits are shown, reproduced from this chapter of the Compliance Manual.

8.8.10 Section D: Circuit Controls for 120-Volt Receptacles

This section allows the building inspector to check off whether the controlled receptacles meet the requirements of Section 130.5(e) of the Standards.