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New Section 135

Requirements for Electrical Distribution Systems

2013 California Building Energy Efficiency Standards

Architectural Energy Corp. Draft Final Report August 15 2011

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CONTENTS

[redacted]

OVERVIEW

Description	The proposed measure is to require provisions in a building's electrical distribution system that will ensure relatively easy implementation of advanced metering and control, including demand response and the "smart grid"
Type of Change	Mandatory Measure This change would add mandatory measures. (a) Requires the addition of modest total energy readouts to the metering of services. The requirements are progressive, with simple metering provisions up to 250kVA services and some logging capabilities for larger services. Most of these are already provided by utility meters and will easily be part of a smart meter. (b) Requires disaggregating the load types in an electrical system such that major load types can be easily measured at a single point. The actual measuring equipment is not required. (c) Requires feeders to have no greater than 2% voltage drop, and branch circuits to have not more than 3% voltage drop, as recommended by the California Electrical Code 2010. (d) Requires providing automatic shut off of about ½ of all receptacles in offices and related spaces to save energy. (e) Requires all buildings to be enabled to receive and act upon demand response signals. (f) Permits building automation systems to provide required control functions of several sections. This change would slightly increase the scope or direction of the current Standards. This change would not require implementation of systems or equipment that are not already readily available on the market and for use in the proposed applications. These systems are already regulated and included in the current Standards. The Standards and Manuals would be modified in order to include the new requirements. The change would require a new Section 135.

Energy Benefits	Parts (a), (b), (e) and (f) of this measure arenot directly energy saving. Part (c) of the measure saves energy by ensuring that electrical feeders and circuit wiring are designed to minimize voltage drop. Voltage drop is wasted energy. Part (d) of the measure saves energy by shutting off receptacle circuits when a space is unoccupied.
Non-Energy Benefits	Parts (a), (b), (e) and (f) of this measure require basic construction that will enable the addition of control and measurement technologies as the their cost effectiveness improves and as the need for control and measurement becomes important due to demand response, time of use rates and other functions of the future “smart grid”.
Environmental Impact	There are no significant environmental impacts other than energy savings.

Technology Measures	**Measure Availability and Cost:** (a) Should not result in any measurable cost impact. The cost will be borne by the utility companies, and the new meters being installed will meet these requirements at no additional cost to the owner. (b) Should not result in any measurable cost impact. The code requirement would dictate specific wiring choices that are already made on a day-to-day basis. (c) Should not result in any measurable cost impact. Per Articles 210 and 215 of the California Electrical Code, these values are recommended and responsible engineers observe them. With inflation and escalating costs, this code requirement will prevent cost cutting that causes unacceptable amounts of wasted energy. (d) Will result in additional cost. Using conventional, off-the-shelf technology, it will add about 50 cents per square foot to electrical construction costs. (e) Will add a very small amount of cost to projects. It will save considerable cost later when the full brunt of DR and the smart grid becomes reality. (f) Should not result in any measurable cost impact. Its purpose is to overtly state that many of the controls requirements of Section 131 and other sections can be met with an energy management system (EMS) and for which basic requirements are added by this measure. **Useful Life, Persistence and Maintenance:** The proposed provisions of new Section 135 are obvious next steps needed to lay the foundation for energy flow and measurement. All of the parts and work required are conventional electrical construction with long life and predictable performance.
Performance Verification	The proposed update would require some additional commissioning during initial installation of the system by an electrician. Commissioning of this technology is already standard practice and is well understood by contractors.
Cost Effectiveness	Since most of the provisions of this measure have no significant cost impact and no direct energy savings, cost effectiveness is moot. The cost effectiveness of plug load controls cannot be exactly determined due to lack of data, but examples show considerable cost effectiveness in many applications.

Analysis Tools	No further analysis has been performed.
Relationship to Other Measures	The principal relationship of this measure to other measures is that plug load control can easily be tied to automatic lighting shutoff, in essence making one control signal affect two circuits.

METHODOLOGY

This section summarizes how this CASE report was developed.

BASIC CONCEPTS

Since its origin, Title 24 Part 6 has avoided topics related to electrical systems and loads that were not directly tied to the structure and building envelope. However, in its pilot study[1], the Office of the Future project determined plug load exceeded lighting load in in California office buildings. Moreover, the study called attention to the ability to easily disaggregate lighting power from plug load and other building energy uses if properly planned. It was decided that a relatively simple section could require electrical wiring that produces logical points for measurement of energy use.

STRUCTURE

This measure has following separate groups of proposed standards.

1. Standards related to the metering/measurement of electrical systems. These were determined to be mostly logical separations of loads by design. Progressive requirements relaxed the burden on smaller projects.
2. Standards related to controlling plug loads in offices and related spaces. In essence, an additional relay control from local lighting on/off control could be inexpensively adopted for about ½ of the receptacles in commercial buildings.
3. Standards related to designing electrical systems. Voltage drop in electrical systems is energy waste and meeting the California Electrical Code recommendations.
4. Standards related to demand response and building automation. These steps were added with the widest possible range of acceptance, in order to encourage implementation.

OTHER STANDARDS

The metering provisions were interpreted from ASHRAE/IES 189.1.The voltage drop calculations were taken directly from the California Electrical Code sections 210 and 215 and are consistent with existing requirements in IECC 2009 and 90.1-2010.The demand response language was developed from evolving standards of California's IOUs.

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[1] Southern California Edison, oPod (The Office of the Future Phase 1) Report, Doug Avery et al, April 2007

COST-EFFECTIVENESS

As stated above, most of this measure is to make smart provisions in buildings for the future "smart grid" including DR and has little or no cost impact to a building. Cost effectiveness was at least partly demonstrated in other CASE reports[2] and is not repeated here.

We take the position that no cost is involved with requirements to designing electrical systems to meet voltage drop recommendations of the California Electrical Code as it is already considered good practice.Plug load control adds cost. Cost effectiveness was demonstrated in another CASE report[3]. In addition, limited data[4] can be used to further justify cost effectiveness, using a practical model that demonstrates cost effectiveness well. It is presented in part 2.

ANALYSIS AND RESULTS

ANOTHER LOOK AT RECEPTACLE SWITCHING

This proposal requires approximately ½ of all receptacles to be automatically switched off in a manner similar to the current automatic shutoff requirements for lighting. The intent is to reduce energy waste by disabling power to receptacles thatserve loads that only require energizing when the space is occupied. A CASE report by HMG demonstrates cost effectiveness[5]. This report re-examines this proposal on a practical level.

In the Office of the Future phase 1 field study[6], the single largest type of connected load by power density was portable space heaters. The second largest load type was computers and related peripherals, followed by lighting. Over 75% of the load in these three groups was connected to receptacles. (This study avoided unusual and uncommon loads such as server rooms.) Moreover, the balance of the common office plug loads, such as kitchen appliances, office appliances, water coolers, personal electronics, etc. are all served from receptacles as well.

It is understood that a number of devices must have constant power. For instance, a computer screen could be turned off when a worker is not present, but shutting off power to the computer could cause a loss of data. (The IT industry has been improving the energy efficiency of equipment for many years including the ability for computers to sleep without data loss). A refrigerator requires constant power as well to preserve food. But the vast majority other loads

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[2] http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-04-27_workshop/review/AutoDR_for_HVAC_template.pdf and http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-04-04_workshop/review/Nonres_DR_lighting.pdf

[3] http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-04-04_workshop/review/Office_Task_Lighting_Plug_Load_Circuit_Control.pdf

[4] Southern California Edison, Office of the Future Phase II Report, New Buildings Institute, January 12 2008

[5] Op. cit.

[6] oPod Phase I report, op. cit.

could tolerate either a temporary power loss such as might be caused by DR, or an occupancy responsive shut off. A good example is the portable space heater.

COST ANALYSIS

The primary way this measure will be implemented will be in conjunction with a lighting motion sensor. In commercial applications, lighting sensors are either ceiling mounted to "look down" onto the area being controlled, or wall mounted to "look out" into the space being controlled. Line voltage sensors contain the switching circuitry within and are the least expensive type. Low voltage sensors have separate detection heads and remote power packs (transformer relays) that switch the power. In smaller buildings, the lighting is operated at 120 volts, and the sensor could switch both lighting and receptacles with essentially no added cost other than wiring from the sensor. In larger buildings with 277 volt lighting, an auxiliary relay must be added to switch the 120 volts. Power packs cost about $25.00[7] and auxiliary relays about $20 each. In general, installed cost will be about twice this, so we assume the added relay is about $50 for each space.

ENERGY SAVINGS ANALYSIS

Mentioned above, there is no reliable data to predict the amount and type of load on building circuits for testing the cost effectiveness of this measure. Instead, we have constructed a model based on the Office of the Future Phase 1 findings and typical wiring practices, as follows:

- Portable space heaters, 1.25 w/sf, 33% duty cycle[8], energy use 3.7 kWh/sf/yr
- Personal computer peripherals, 1.0 w/sf, 10% duty cycle, 0.9 kWh/sf/yr
- Miscellaneous personal loads, 0.1 w/sf, 100% duty cycle, 0.9 kWh/sf/yr

TOTAL PRE-CONTROL ANNUAL ENERGY USE: 5.5 kWh/sf/yr

The simplicity of this analysis does not warrant a complete economic analysis, and data does not exist to support it. Instead the following foreshortened analysis is offered.

Average Energy Use	5.5 kWh/sf/yr
Average Control Zone	150 SF

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[7] www.shop.montereycorp.com , an Internet retail store, for a Sensor switch single circuit 120/277 volt 20A power pack

[8] The estimated "on" time of the load due to use and/or temperature controls. The "off" power is assumed negligible.

Average Electric Rate	\$.126/kWh[9]
Energy Use and Cost Per Zone	825 kWh, \$103.95

Because the database is very small and there is not really a robust database for predicting energy use, we can easily estimate that the average occupancy will be about 25% of the year (42 hours per week) or less. Thus, if this measure were to save 75% of the energy presently used by these loads, the payback period would be about 9 months. Conversely, even if the estimates are significantly wrong and the measure saved only 82.5 kWh/yr (0.084 w/sf turned off 75% of the time), the payback period would be less than 5 years, well within the statutory requirements.

One of the two exemptions permits motion sensor plug strips under certain conditions. The wholesale cost of a Wattstopper Isole control station is about \$65[10], which requires no installation labor cost, making it fairly consistent with this analysis.

METERING PROVISIONS

These requirements are represented as having no significant cost impact. That is because the break points in the standards were determined on the basis of panelboard sizes feeding branch circuits. For example, the first major break point in the requirements is 25kVA for receptacles (plug loads). This was chosen because 25kVA of load corresponds roughly to the fully loaded capacity of a 100-amp panelboard, a practical standard size that would typically be used to serve an area of 10,000 sf designed for up to 2.5 w/sf. The metering point is the feeder to that panelboard, which with minimal provisions could easily be equipped in the future.

Smaller systems, such as for a tenant retail store, are often served 120/208v three-phase service or 120/240v single-phase service. Even with an air conditioning system on the meter, the service size is likely to be about 10 VA/sf. At this load, a space of up to 5,000 sf could be served and only have the lowest level of requirements. Office occupancies without server farms or other excessive loads are more likely to have a service of about 5 to 6 VA/sf, corresponding to a space of 10,000 sf. In the event that separate 277-volt lighting and 120-volt plug load circuits are used and a central HVAC system is separately fed, the practical area for separately metered tenants could be as large as 12,000 to 15,000 sf with the lowest level of requirements. This is about as large an area as would be served from a single panel due to voltage drop and other practical limits.

The next break point for services is 50kVA, corresponding to about 150 amps at 120/208 volts three phase and 200 amps at 120/240 volts single phase. This will require separate subpanels

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[9] www.eia.gov

[10] Actual cost of components, Office of the Future project at LA Federal Building, spring 2011.

for lighting and receptacles as well as separate feeders for HVAC and bigger loads. For a 20,000 sf grocery store, for example, the service size might be 100 kVA, and it would have connected lighting loads of about 30,000 watts, plug and miscellaneous loads of about 10,000 watts, HVAC loads of about 30,000 watts, and refrigeration and equipment loads of about 30,000 watts. Each group (except plug loads) would be at least 100 amps at 120/208 or 120/240 volts. These are practical sizes for panels and feeders.

Larger buildings naturally break riser systems down into 100 or 200 amp groups. This provision requires a specific organization and in some cases may add some cost, but it will be negligible.

PROPOSED CODE LANGUAGE CHANGE

This section describes the specific recommended language.

SUMMARY OF PROPOSED CHANGES

We propose six specific sections.

(a) Require the addition of modest total energy readouts to the metering of services. The requirements are progressive, with simple metering provisions up to 250kVA services and some logging capabilities for larger services. Most of these are already provided by utility meters and will easily be part of a smart meter.

This will allow building owners and managers to easily make simple readings of how much energy they are using. For larger systems, it will allow electric energy use to be monitored on an hourly, daily, or monthly basis.

(b) Require disaggregating the load types in an electrical system such that major load types can be easily measured at a single point. The actual measuring equipment is not required.

This will allow future metering of systems to be installed at the lowest possible cost and with the most ease.

(c) Require feeders to have no greater than 2% voltage drop, and branch circuits to have not more than 3% voltage drop, as recommended by the California Electrical Code 2010.

While this is considered to be good practice and currently occurs in most buildings, this code requirement will ensure that future projects are not made less efficient due to cost cutting in electrical distribution.

(d) Require providing automatic shut off of some receptacles to save energy.

The low cost of motion sensing devices makes this a relatively inexpensive and easy measure. Whether sharing a sensor with lighting using a separate auxiliary relay, or providing a motion sensor for the area's receptacles alone, this measure should not add more than about 50 cents per *square foot to the cost of an office building or similar uses, and less to schools, retail and other uses with less plug load and plug use.*

(e) Requires all buildings to be enabled to receive and act upon demand response signals.

This prepares buildings for communications to the "smart grid". The cost is very small, but it ensures that the thought was put into the design of the building such that future outfitting of a communication system and its implementation will be low cost and easy to do.

(f) Permits building automation systems to provide required control functions of several sections.

This clarifies that a building-automation system with certain minimum features may be used to achieve the required control of lighting and other building systems. It is added to encourage designers and owners to investigate systems that will permit higher levels of control and interoperability in anticipation of demand response, time of use pricing and the "smart grid".

PROPOSED LANGUAGE

SECTION 135 –ELECTRICAL POWER DISTRIBUTION SYSTEMS

(a) **Service Metering** Each electrical service shall have permanently installed user-accessible metering of total electrical energy use per Table 135-A.

EXCEPTION to Section 135 (a) Buildings for which the utility company provides a meter for occupant or user use that indicates instantaneous kW demand and kWh for a user-resettable period.

(b) **Disaggregation of Electrical Circuits**. Electrical power distribution systems shall be designed to permit the disaggregated measurement of electrical load energy uses downstream from the service meter according to Table 135-B. Additive and subtractive methods may be used to determine aggregate and disaggregated energy use. This may be accomplished by any of the following methods:

1. Separate switchboards, motor control centers, or panelboards to which are connected only the required load or group of loads; or,
2. Subpanels of the above to which are connected only the required load or group of loads and for which the subpanel load can be independently measured in aggregate; or
3. Branch circuits, taps or disconnects requiring overcurrent protection devices rated 60 amperes or greater.

EXCEPTION to Section 135 (b) Buildings for which a complete metering and measurement system is provided.

(c) **Voltage Drop**

1. **Feeders.** Feeder conductors shall be sized for a maximum voltage drop of two percent at design load.
2. **Branch Circuits.** Branch circuit conductors shall be sized for a maximum voltage drop of three percent at design load.

EXCEPTION to Section 135(c): Feeder conductors and branch circuits that are dedicated to emergency services.

(d) **Circuit Controls for 120-Volt Receptacles**. In all buildings, both controlled and uncontrolled 120 volt receptacles shall be provide in each private office, open office area, reception lobby, conference room, kitchen, and copy room, to automatically shut off task lighting and other plug loads when the area is not occupied. Controlled receptacles shall meet the following requirements:

1. Electric circuits serving controlled receptacles shall be equipped with automatic shut-off controls complying with the requirements in section 131(c); and

2. At least one controlled receptacle shall be installed within 6 feet from each uncontrolled receptacle or a split-wired duplex receptacle with one controlled and one uncontrolled receptacle shall be installed; and

3. Controlled receptacles shall have a permanent marking to differentiate them from uncontrolled receptacles, and

4. For open office areas, controlled circuits shall be provided and marked to support installation and configuration of office furniture with receptacles that comply with section 131(a) 1, 2, and 3; and

5. Plug-in strips and other plug-in devices that incorporate an occupancy sensor shall not be used to comply with this requirement.

EXCEPTION 1 to Section 135 (d): In open office areas controlled circuit receptacles are not required, if at time of permit workstations are installed, and each workstation is equipped with a local motion sensor that controls a power strip that is permanently marked to differentiate controlled from uncontrolled receptacles.

EXCEPTION 2 to Section 135 (d): Receptacles which are only for the following specific purposes: refrigerators, water dispensers, kitchen appliances, clocks, network copiers, fax machines, A/V and data equipment other than personal computers, and receptacles on circuits rated more than 20 amperes are exempt from this sections.

(e) **Demand Response Signals.** Demand response signals shall conform to a nationally recognized open communication standard. Acceptable standards include those defined by groups such as the Organization for the Advancement of Structured Information Standards (OASIS), Energy Interoperation Technical Committee (also known as Energy InterOp and OpenADR) or the ZigBee Alliance (also known as Smart Energy profile).

(f) **Energy Management Control System (EMCS)**.

1. An EMCS which at a minimum provides the functionality of a specific lighting control device or system covered in Section 119; meets the acceptance test requirements in Section 134 for that lighting control device or system, meets the specific application requirements for that lighting control device or system in Title 24, Part 6, may be installed as that lighting control device or system for compliance with Title 24, Part 6.

2. An EMCS which at a minimum provides the functionality of a thermostat, including two-stage, electronic, and setback thermostats covered in Sections 144 and 149; meets the acceptance test requirements in Section 134 for that thermostat, meets the specific application requirements for that thermostat in Title 24, Part 6, may be installed as that thermostat for compliance with Title 24, Part 6.

TABLE 135-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

TABLE 135-B MINIMUM REQUIREMENTS FOR SEPARATION OF ELECTRICAL LOAD

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	Not required	All	Each	Each

or greater				
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

MATERIAL FOR COMPLIANCE MANUALS

We will develop material for the compliance manuals in the final CASE report once the proposed code language has been approved by the Commission.

In this section, we will provide information that will be needed to develop the Residential and/or Nonresidential Compliance Manuals, including:

- Possible new compliance forms or changes to existing compliance forms.
- Examples of how the proposed Standards change applies to both common and outlying situations. Use the question and answer format used in the current Residential and Nonresidential Compliance Manuals.
- Any explanatory text that should be included in the Manual.
- Any data tables needed to implement the measure.

BIBLIOGRAPHY AND OTHER RESEARCH

ASHRAE/IES 90.1-2010, Chapter 10

IECC 2009, Chapter 5

ASHRAE/IES 189.1, Chapter 7

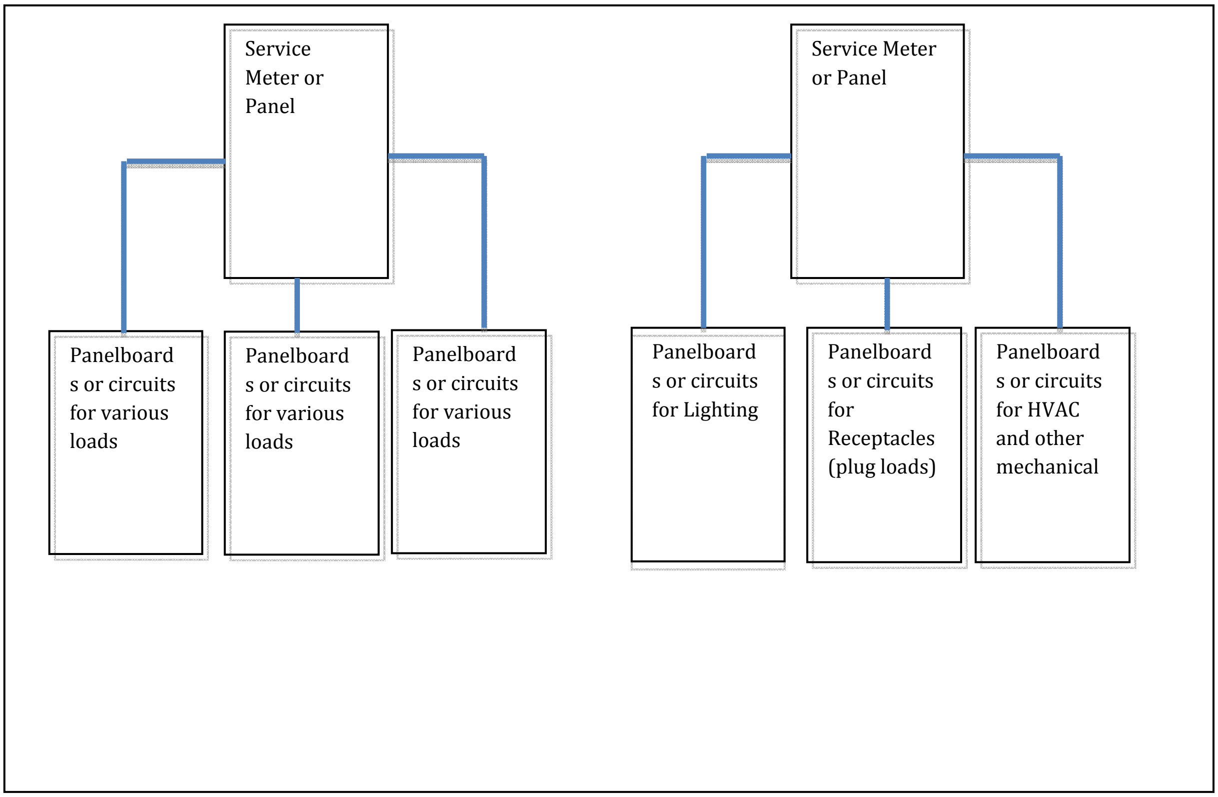
California Electrical Code 2010, Sections 210 and 215

APPENDIX A- COST PROVISIONS OF METERING PROVISIONS

In a building electrical service, the service capacity is based on an electrical code calculation of maximum power demand, plus a moderate safety factor and any provision for future expansion. The service size is commonly larger than normal electric power demand ever requires.

AGGREGATED AND DISAGGREGATED WIRING

Electric services have a main meter that is primarily used to determine the amount to charge customers for energy. The service meter is considered ***aggregated*** because there is no practical way to determine what is consuming the power downstream from the meter. In order to separate load power and/or energy use for assessment and management purposes, the owner of a facility will have to use many meters, or alternately, separate loads into sensible groupings. For the purposes of this document, ***disaggregating*** means to design electric systems such that all loads of one type, such as lighting or HVAC, are served from a common electric circuit or panel such that the load type can be studied independent of other loads. Note that either temporary metering or permanent metering can be used.



In its simplest form, disaggregation begins at the branch circuit level.   For example, connecting only lighting loads to the same circuit(s) and only receptacle loads to other circuit(s) makes it easy to use portable meters to check each circuit.

Disaggregation is at least partially undertaken in commercial buildings with both 120/208 volt and 277/480-volt systems. This standard was dominant when lighting systems operated at 4 to

Aggregated Wiring **Disaggregated Wiring**

Figure 0-1 Simple Disaggregated Wiring

6 w/sf and plug loads were less than 1 w/sf. As these loads are becoming increasingly reversed, fewer 277 volt lighting systems are expected, and disaggregation will need to be achieved some other way. Panels with split buses may be one solution.

DESIRABLE DISAGGREGATION

Disaggregated loads enable practical building management by permitting easy measurements of electric power demand (kW) and energy (kWh) for each. For most commercial buildings, the minimum useful data would include separate measurements of

- Lighting
- Plug Loads
- HVAC

In larger buildings, useful data would be further separated. For instance, in a multi-floor office building, measuring the lighting load for each floor and/or each tenant would permit management to identify excessive users and to take corrective actions when merited. Likewise, measuring large single pieces of equipment, such as package HVAC units, chillers, etc. might provide important data.

Loads are connected to ***branch circuits***, the smallest level of practical disaggregation. A branch circuit consists of the circuit breaker at the panel, and the downstream wiring, connections and loads. For simple disaggregation to work, electrical work must consistently follow the basic rule of connecting like loads to the same circuit. For example, even though it is code-legal to connect both a luminaire and a receptacle to the same branch circuit, it will be necessary to separate them and to maintain separation as the building ages.

Panels that serve branch circuits are located as close to the center of a group of loads as possible. The size of the group is generally based on practical wiring considerations, most notably distance from the panel to the load. Long distances cause increased wire gauge to control voltage drop, which can also cause increased conduit size. Both cause avoidable additional cost. A practical design suggests loading the circuit to about 60% of circuit rating to leave future capacity. For instance, on a 20 amp 277-volt office lighting circuit, about 3,000 watts would be a typical load. The approximate area that this circuit serves will be about 3,000 sf, and a 12-circuit panel would serve roughly 36,000 sf. Located at the center of a square space of 36,000 sf, the average branch circuit would run about 85-100 feet from the panel.

With current design standards, the following approximations can be used for typical load density[11]:

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[11] Professional experience and code restrictions, plus an application factor

Building Type	25 kW of lighting	25 kW of plug and equipment load (includes refrigeration)	25 kW of HVAC (not including electric heating)
Classroom	25,000 sf (1 w/sf)	25,000 sf (1 w/sf)	45,000 sf (.55 w/sf)
Office	25,000 sf (1 w/sf)	15,000 sf (1.7 w/sf)	40,000 sf (.63 w/sf)
Laboratory	15,000 sf (1.7 w/sf)	15,000 sf (1.7 w/sf)	20,000 sf (1.3 w/sf)
Specialty Retail	5,000 sf (5 w/sf)	25,000 sf (1 w/sf)	10,000 sf (2.5 w/sf)
Grocery	15,000 sf (1.7 w/sf)	10,000 sf (2.5 w/sf)	25,000 sf (1 w/sf)
Light Industrial	25,000 sf (1 w/sf)	10,000 sf (2.5 w/sf)	25,000 sf (1 w/sf)
Warehouse	50,000 sf (.5 w/sf)	40,000 sf (.63 w/sf)	50,000 sf (.5 w/sf)

In a small building, there is not enough load to warrant separate panels, and all loads are connected to a single panel. But when a building is large enough, panels are distributed throughout the structure, to which either large single loads or a number of smaller loads are connected. ***Feeders*** are large capacity wiring conductors that serve power to panels. Feeders tend to be at least 60 amps and are usually 100 amps or larger. In short feeders tend to send power in large chunks that are further subdivided downstream, with a practical typical load of at least 25 kW (120/240 volts, 100 amps). For instance, a277-volt lighting panel serving 36,000 sf (above) would have a feeder of 60 amps (277/480 volts three phase).

Based on these observations, the proposed Title 24 code language would employ 25 kW as the threshold of required disaggregation. This will permit simple and inexpensive field metering or inexpensive permanent metering of practical groups of load to collect useful data. To measure any load, it is necessary to simply design and install the building's system such that only the intended loads are connected to a particular feeder or branch circuit.

SERVICE METERING

In most cases, the service entrance is the point at which the building power meter is located. There are two types of meters; one is self-contained including the meter and the current transformers, and one involves a separate current transformer compartment and a smaller meter-only enclosure. The latter applies for larger services when large and heavy current transformers are required.

Utility company metering systems are designed for revenue metering with an accuracy of about 0.2%. Older electro-mechanical meters cannotinexpensively offer other metering options. However, electronic meters, now widely used, can provide additional metering options at little or no added cost, including customer accessible functions such as an instantaneous power (kW) readout and a resettable energy (kWh) readout. This is particularly true with latest generation "smart" meters. In large purchase quantities, the cost difference between the most basic smart meter and one allowing user functions is less than $50[12].

DISAGGREGATION IN SMALL SYSTEMS

Most electric services are provided at the utilization voltage (120/240 or 120/208 volts) and connect directly to a panelboard having circuit breakers feeding load circuits. Panelboards are commonly provided in 100, 200 and 400 amp sizes corresponding to services from 24 kW (120/240 volts single phase, 100 amps) to about 150 kW (120/208 volts three phase, 400 amps).

Load circuits consist of either ***branch circuits***, to which either large single loads or a number of smaller loads are connected, or ***feeders***, which terminate in a downstream panel that in turn, break down into branch circuits. Feeders tend to be at least 60 amps and can be as large as the service or panel itself. Feeders tend to send power in large chunks that are further subdivided downstream, with a practical minimum load of at least 15 kW.

In small systems, sub panels make practical and economic sense when the group load is about 100 amps (24 kW at 120/208 volts or 120/240 volts single phase, or 36 kW at 120/208 volts three phase).

DISAGGREGATION IN LARGE SYSTEMS

Larger electrical systems are defined as those for which a switchboard is required to distribute power. Switchboards typically consist of feeder breakers that serve panelboards. Each feeder breaker is often 60 amps or more.

COST IMPACTS FOR DISAGGREGATED WIRING.

Because the layout of electrical systems is so varied, a practical load group of 25 kW has been selected as the threshold for separation. This corresponds to

- 104 amps at 120/240 volts single phase, nominal 125 amp two pole feeder breaker
- 70 amps at 120/208 volts three phase, nominal 100 amp three pole feeder breaker
- 30 amps at 277/480 volts three phase, nominal 40 amp three pole feeder breaker

In general, because these groups are common sizes there is no significant added cost to requiring disaggregation. Evaluating a number of possible configurations, the worst-case scenario appears to be small retail lighting. Because of high lighting power in certain types of stores, a mall-sized store could have sufficient lighting and plug load to require disaggregated lighting, HVAC and plug/equipment load.

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[12] Citation needed

Assuming a specialty retail store of approximately 5,000 sf, the allowed lighting power will be about 25 kW, preferably at 120 volts as accent and track lighting will be used. Assuming that the store also has about 1 w/sf of receptacle load and about 2.5 w/sf of HVAC, this small system will be about 42.5 kW and would normally consist of a 125 amp service, a 225 amp 42 pole panel, 20 lighting branch breakers, 4 plug load branch breakers, and a 3 pole, 60 amp breaker for the HVAC. To meet this proposed requirement, the main panel would be changed to a 225 amp 20-pole panel with 4 20A plug load branch breakers, a 3 pole 60 amp breaker for HVAC, and a 3 pole 100 amp breaker feeding a 20 pole 100 amp lighting-only panel with 20- 20amp branch breakers.

The differences in costs are:

Cost Item	***Traditional***	***Disaggregated***
Panelboard	(1) 42 pole 225 amp $1323	(1) 20 pole 225 amp $1102[13] (1) 20 pole 100 amp add $ 948[14]
Breakers	(24) 20 amp 1-pole (1) 60 amp 3-pole	(24) 20 amp 1-pole (1) 60 amp 3-pole (1) 100 amp 3-pole add $275[15]

(As an alternative, a split bus panel could be supplied with an upper “equipment and plug load” bus and a lower “lighting” bus. Such panels would be expected to be developed and would mitigate the added costs.)

In this case, the added cost is about $1000 to isolate the lighting from the rest of the load. (The difference in labor is considered negligible). This represents added cost of about 20 cents per square foot or less.

There is no cost effectiveness test for obtaining management data.

A simple calculation of the cost of energy use by the facility:

Lighting: 5 w/sf * 5000 sf *12 hours/day * 360 days/year = 108,000 kWh/year

Receptacles/equipment: 1 w/sf *5000 sf * 18 hours/day *365 days/year = 33,000 kWh/year

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[13] Grainger Electric, retail price

[14] Ibid

[15] Ibid

HVAC: 2 w/sf * 5000 sf * 18 hours/day*365 days/year = 65,000 kWh/year

TOTAL ELECTRICAL CONSUMPTION: ~ 200,000 kWh/year at $0.125 = $25,000 per year

Disaggregation cost = 4% of first year energy cost