(rev 4/28/2021 CH – proposed to but not adopted by TSC 343)

Annex E. Guidance for C22.1 §8 load calculations (informative)

Without EVEMS, the supply circuits for a multi-EVSE site would ordinarily need to be sized for the possibility that all EVSE were simultaneously operating continuously at maximum rated load. The 2018 CEC (C22.1) recognizes that a correctly operating EVEMS can reduce the required circuit capacity while maintaining safe operation of conductors and equipment. Most directly, subrules 8-106 10) and 8-106 11), as well as rule 8-500, regulate the application of EVEMS.

This Annex provides examples of load calculations for several EVEMS systems. For illustrative purposes, numerical examples have been chosen to be at or close to the limits permitted by Section 8. Good design practice would typically add headroom to the example ratings in anticipation of future requirements.

E.1 Introductory example

The benefit of EVEMS is shown in an example for a workplace car park equipped with ten Level 2 charging stations. Fig. E-1 shows a one-line diagram for an unmanaged installation.

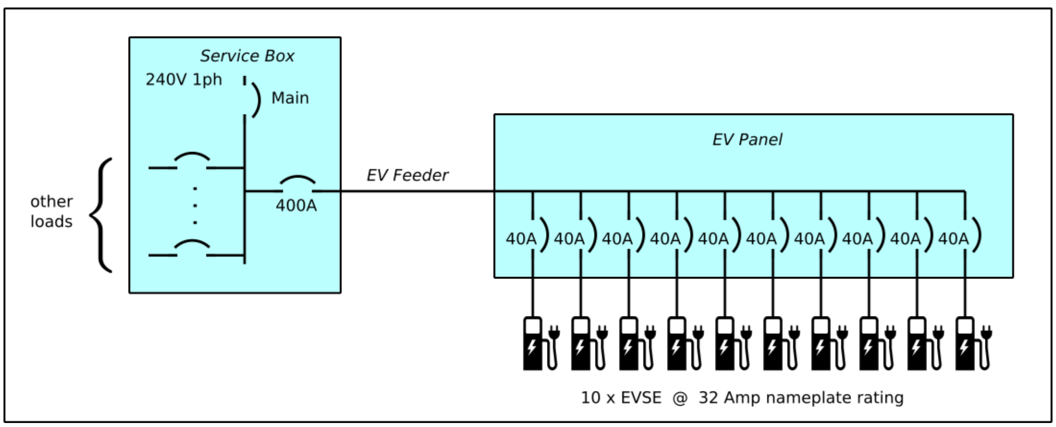

Fig. E-1: Example unmanaged EVSE installation

If all stations are operating at full nameplate rating, the total load is 320 amps. Without an EVEMS, the EV feeder and circuit breaker will typically be sized at 400 amps per subrule 8-104 6) (80%-rated breaker). This is not unreasonable, considering that most employees will arrive at about the same time and immediately start charging at full power. (Note that it is not advisable to apply Table 38 demand factors for workplace charging; that table is based on estimated residential patterns of use.)

An EVEMS will reduce the feeder load by

a) reducing the vehicle charge rates below nameplate rating,
b) sequencing the EVSE operation,

or some combination of these. Fig. E-2 illustrates this.

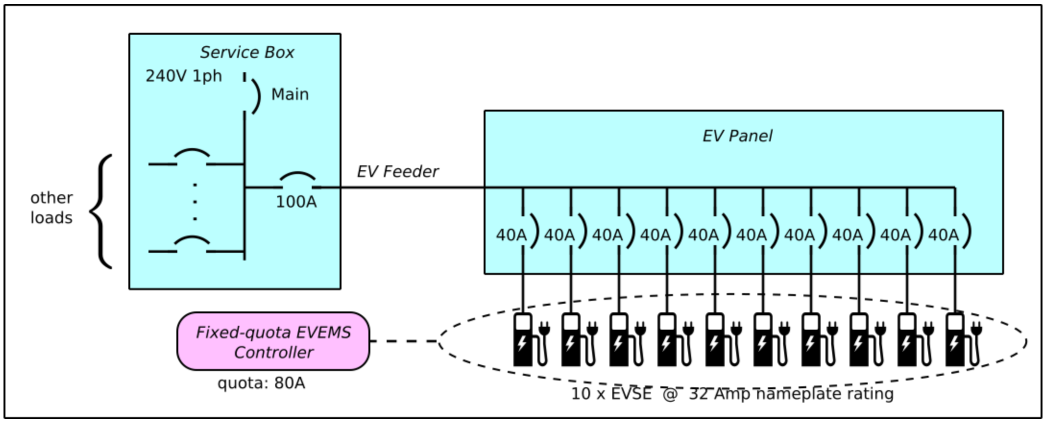

Fig. E-2: Example EVSE installation with EVEMS

Subrule 8-106 10) uses the phrase "maximum load allowed by the electric vehicle energy management system", which usually corresponds to the term *quota* in this standard. For example, the quota for the EV feeder in Fig. E1 might be fixed at 80 amps, which is then the Section 8 demand load for this circuit, and the feeder will be sized at 100 amp. (See section E.3.1 below for the related term *circuit quota*.)

The consumer's service also supplies other loads on the site; as this example is a workplace, subrule 8-210 applies. When determining the required service rating, the total computed load may include the EVSE load at 80 instead of 320 amps (but see E.2 below). As a result, the cost of adequately provisioning both service and feeder equipment is likely to be significantly lower than for an unmanaged system.

E.2 Background on CEC load calculations and hierarchy

A consumer's electrical installation may be described as a hierarchy of circuits, with the service as the topmost level, branch circuits at the bottom, and the intervening levels denoted as feeders. By definition each piece of utilization equipment, including EVSE, is attached to a branch circuit. (Under some circumstances it is possible for a circuit to supply circuit breakers and also to supply utilization equipment directly; in this case it is both a feeder and a branch circuit. See section E.4.1.) At each level of the hierarchy the calculated circuit load is based on the aggregation of the loads at or below it. Rule 8-104 requires that the capacity of each circuit (at any level of hierarchy) be sufficient for the calculated load. Rule 8-106 describes demand factors that apply at any level of hierarchy. Note that *calculated load* is special terminology for Section 8.

Calculated load is defined in Rule 8-002 and the way of calculating it in Rules 8-100 thru 8-400, which are oriented towards the highest level of hierarchy and include demand factors based on consumption diversity. Where a feeder and panel serve a subset of loads, any allowable reduction of calculated load below 100% of connected load should be applied judiciously. In non-residential construction, subrule 8-106 9) allows feeder sizing based on experience at comparable installations elsewhere (demonstrated loads).

Retrofitting of EVSE to existing facilities is expected to be commonplace. Subrule 8-106 8) , which applies to all occupancies (both residential and non-residential) and at any feeder in the hierarchy, allows calculated load for the retrofit to be based on the 12-month history of measured site load. Some utilities with "smart meter" programs may have archival data with adequate time resolution (1-hr) for this purpose. Larger sites may include a rebate meter that may be used.

When the example system in Fig. E-2 is managed at a fixed quota of 80 amps, 8-106 10) dictates that calculated load on the service and feeders serving the EVSE location will be based on this quota. However the actual wording in Rules 8-200 thru 8-210 does not recognize an 8-106 10) exception. (possibly an oversight during code development).

E.3 EVEMS system characteristics

EVEMS installations may be described with respect to several characteristics.

- As "pure" or "mixed" depending on whether the relevant circuits feed only managed EVSE loads or a mixture of managed EVSE and uncontrolled loads.
- As with or without external circuit load monitoring at the service, feeder, or branch level
- As using single- or multi-tier control
- As having a fixed or dynamically-set (e.g. based on external command or programmed schedule) load limit behavior

E.3.1 Pure vs Mixed circuits

EVSE are often supplied by a "pure" branch or feeder circuit which has no other loads. Circuits which are higher in the distribution hierarchy (feeders and services) are almost always mixed. Rule 86-300 2) also specifically allows a branch circuit to mix one or more EVSE and other loads *if* an EVEMS is used (see section E.4.1).

In a mixed circuit we distinguish an EVEMS *quota*, relating to controlled EVSE loads only, and a *circuit quota*, relating to the combination of controlled and uncontrolled loads. Circuit quota is pertinent to load-responsive EVEMS, see section E.3.2 below.

When a mixed circuit is operating under a fixed quota, the circuit loading calculations can be straightforward. For example, in Fig. E-3 the garage feeder calculated load consists of the sum of the demand loads for lighting and fan and the 80 amp quota. Assuming that the lighting and fan branch circuits have been sized at 125% of demand load, the feeder circuit may be rated at

$$1.25*(20/1.25 + 20/1.25 + 35/1.25 + 80) = 175 \text{ amps.}$$

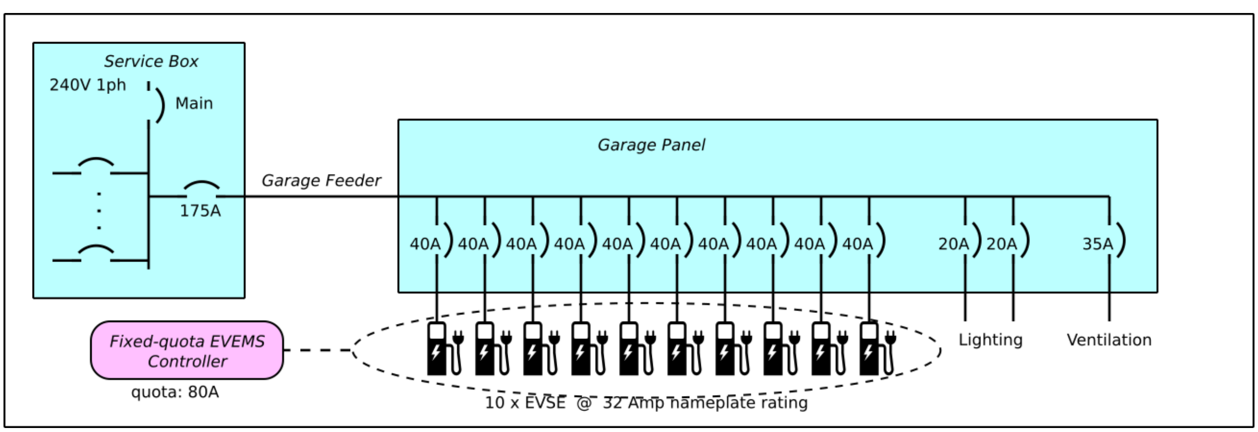

Fig. E-3: Example EVEMS installation with mixed circuit

However, additional optimizations are possible beyond the example of Fig. E-3. In particular, an EVEMS which employs *load monitoring* (E.3.2 below) may allow for further reductions in calculated feeder load.

E.3.2 Load Monitoring in a Monitored Panel Sharing Configuration

Rule 8-106 11) recognizes EVEMS which control the EVSE load based on current that is measured elsewhere in the circuit. For example, Fig. E-4 shows a current transformer (CT) providing information to the EVEMS controller.

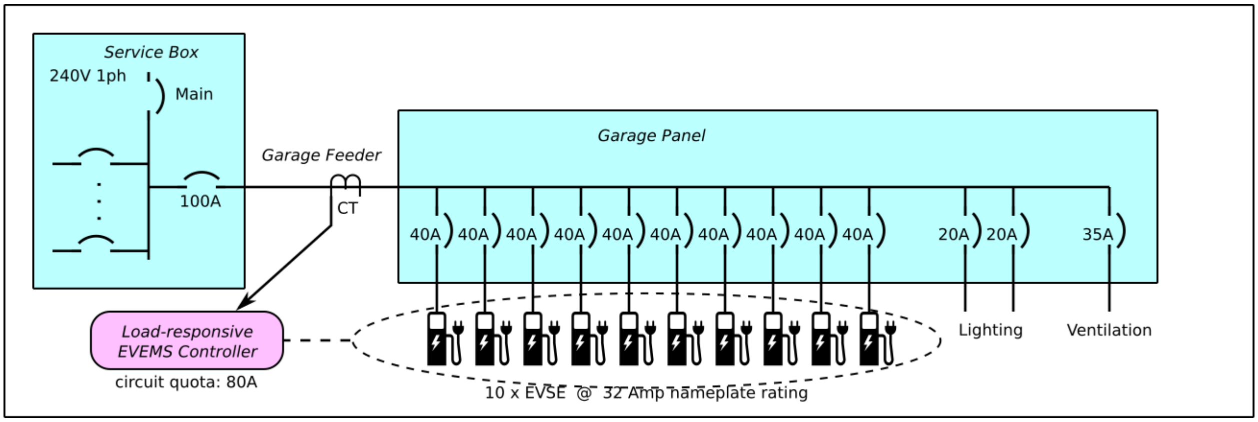

Fig. E-4: Example EVEMS with feeder load measurement and fixed circuit quota

The control algorithm responds to changes in the lighting and ventilation loads (uncontrolled loads), reducing the EVSE power consumption when the uncontrolled load current is high. Since the control is enforcing a constraint on the total circuit load, it is best described by a fixed *circuit quota*. In this example the EVEMS ensures that the combined circuit load on the garage feeder never exceeds 80 amps.

In a mixed circuit with load monitoring, we distinguish between situations in which the uncontrolled demand load exceeds the EVEMS circuit quota, and vice versa. In the former situation, the calculated load for the circuit is the uncontrolled load value. In contrast, in the example of Fig. E-4, the EVEMS circuit quota, 80 amps, exceeds the uncontrolled load and the calculated feeder load is 80 amps and a 100-amp breaker is suitable.

(*Note:* since the EVSE portion of the allowed load, or *quota*, is effectively a variable dependent on the uncontrolled lighting and ventilation load, it has sometimes been described as a *dynamic quota* system. However it is preferred to limit the term *dynamic* to the usage in section E.3.4 below.)

In this example, as in Fig. E-2, the calculated service load under 8-210 can count the EVSE load at 80 amperes. Unfortunately the additional benefit of load-responsiveness in the controller is not recognized; subrule 8-106 11) does not apply, because the total service load is not monitored. If the EVEMS is augmented with current sensing at the service, then 8-106 11) applies (see section E.4.2 below)

E.3.3 Multi-tier Control

An EVEMS using *multi-tier control* regulates EVSE power draw in consideration of individual calculated-load constraints at several different levels of the distribution hierarchy. In Fig. E-5, the EVESE of the earlier examples are divided into two groups fed by an intermediate panel.

The EVEMS controller implements three aggregate load constraints at two tiers. The combined EV feeder at the upper tier supplies the 10 stations under an 80-amp quota, similar to earlier examples, corresponding to a 100-amp rated circuit breaker. Simultaneously, the EVSE draw is regulated by the EVEMS to limit the load on east and west EV feeders to a quota of 48 amps each. This allows these lower-tier circuits to be rated at 60 amps.

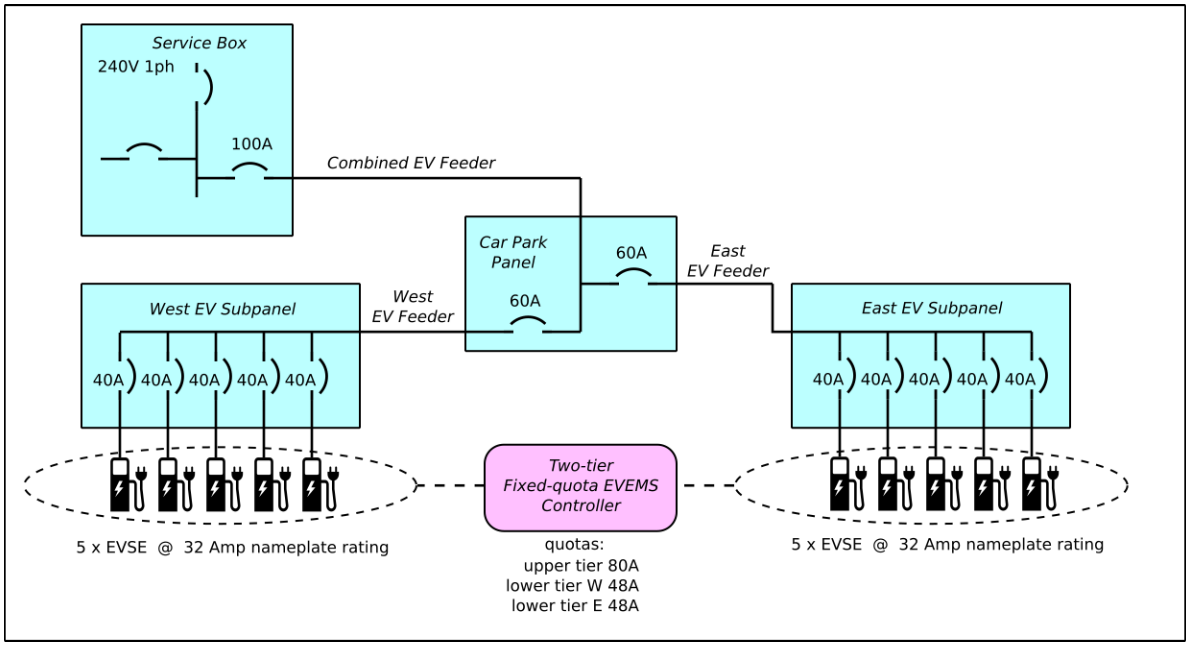

Fig. E-5: Example multi-tier EVEMS control

Multi-tier control may be combined with load monitoring for more sophisticated control.

E.3.4 Dynamic Quota

Earlier examples in this Annex have shown fixed-quota EVEMS (including a fixed-*circuit*-quota example, Fig. E-4). For these systems, the maximum EV or circuit load allowed is typically configured at the time of installation and coordinated with the supply circuit ampere ratings so as to comply with the requirements of CEC Section 8.

An EVEMS supporting dynamic quota values may allow the customer to take advantage of utility rate programs, such as time-of-use, peak demand charges, and demand response. This may be accomplished with external signaling from site equipment or the utility, or by predetermined schedules. Dynamic quotas are only able to reduce the active quota below the configured maximum load value. Dynamically-reduced quotas do not affect compliance with Section 8 circuit loading requirements unless the quota reduction is used to coordinate with other loads and thereby qualify for a demand factor in rule 8-106.

Examples of 8-106 demand factors based on load coordination are

1. Dynamic quota is at times set to zero (i.e. charging power is switched off), to implement a non-coincident load situation under subrule 8-106 2) This would be typical in a shared circuit situation or a signal from a building management system.
2. Dynamic quota is reduced to coordinate with a cyclic load under subrule 8-106 4). This would be typical in a situation with cyclic control of water heaters.
3. Dynamic quota is reduced to coordinate two distinct EVEMS with limited scope of control to implement a composite EVEMS, of larger scope, which falls under subrules 8-106 10) or 11). This would be typical in a situation with different panels being controlled by different manufacturer's products or one feeder / panel being controlled by an un-monitored EVEMS (uncontrolled loads to as second EVEMS) and a second EVEMS that monitors the same feeder / panel.

An example of the third type (*lead-lag EVEMS coordination*) is given in Section E.4.4 below.

The load coordination functions mentioned above may place tight deterministic constraints on EVEMS response time in order to qualify for the rule 8-106 demand factors.

E.4 Additional Examples

E.4.1 Shared Branch Circuits

Rule 86-300 allows a shared branch circuit to serve a group of EVSE when load is managed by an EVEMS. Fig. E-6 illustrates several aspects of branch circuit sharing.

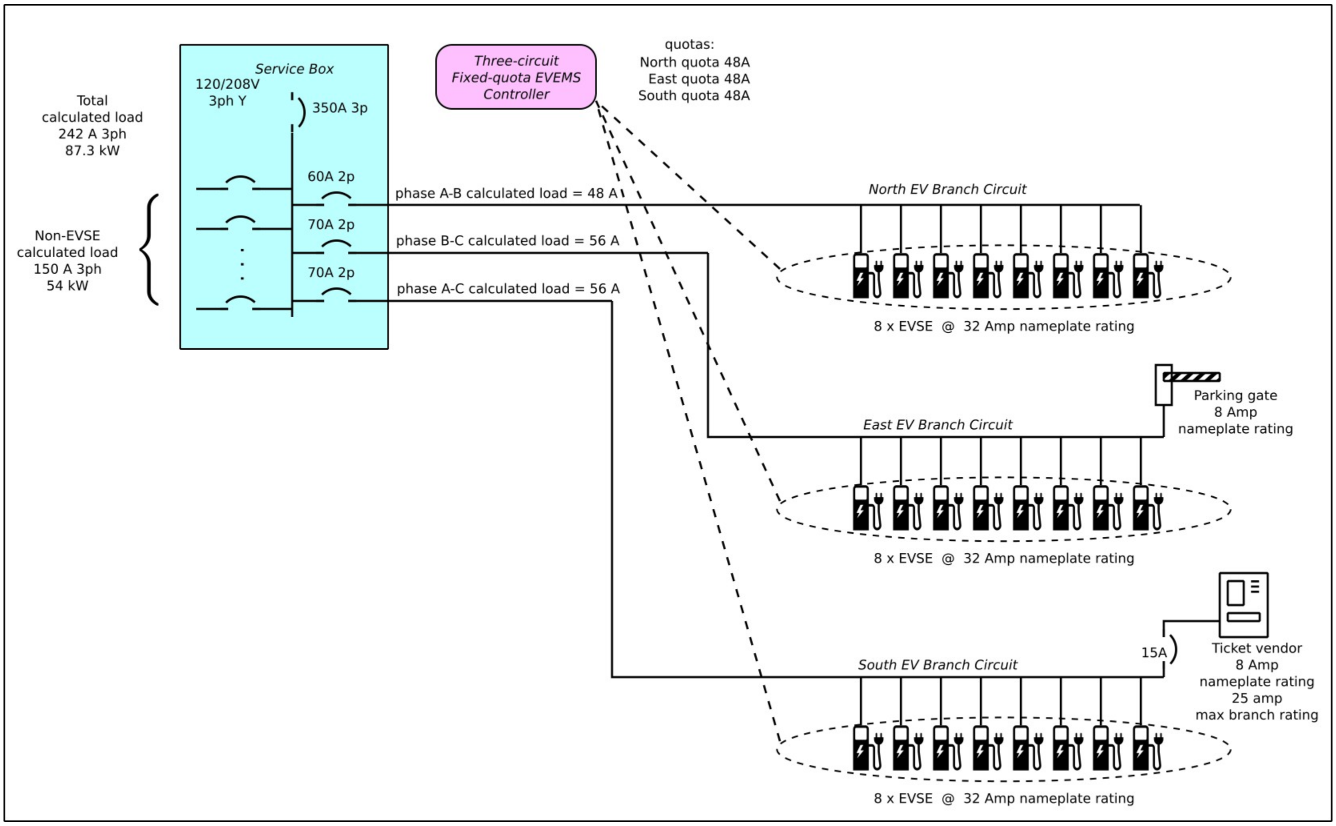

Fig. E-6: Branch circuit sharing example

Figure E-6 shows a non-residential three-phase service serving 24 level 2 EVSE balanced equally across the phases under a simple fixed-quota EVEMS.

The North branch circuit has a connected load of 256 amps, but with the EVEMS managing it to a maximum load of 48 amps, it may be served by a circuit rated 60 amps under subrule 8-106 10).

The East branch serves 8 EVSE, but also a non-EVSE load rated 8 amps. Combination of EVSE and non-EVSE equipment is allowed under subrule 86-300 2). The calculated load for this branch is now 48 + 8, or 56 amps.

Some equipment is marked by the manufacturer with a maximum branch circuit rating, which must be observed. (In the absence of such a marking, a conservative rule of thumb is to assume that the maximum branch circuit rating is 150% of the nameplate rating, but this is not embodied in the CEC.)

In the South branch, we again have 8 EVSE and an added load rated 8 amps. However this equipment also has a maximum branch circuit rating less than 70 amps, so it must be protected with it own overcurrent protection device. (Note that, technically speaking, this creates the unusual situation of the South EV branch circuit being both a branch circuit and a feeder.)

The EVEMS in this example lacks load monitoring, and is unaware of other loads on the service. Therefore the total EVEMS quota must be added to these loads to establish the calculated load at the service.

E.4.2 Subrule 8-106 11) example – multiple-vehicle lot

Fig. E-7 illustrates how a load-responsive EVEMS can be applied in compliance with subrule 8-106 11). It is based on the same configuration as Fig. E-6, with the addition of current sensors and a more sophisticated control algorithm.

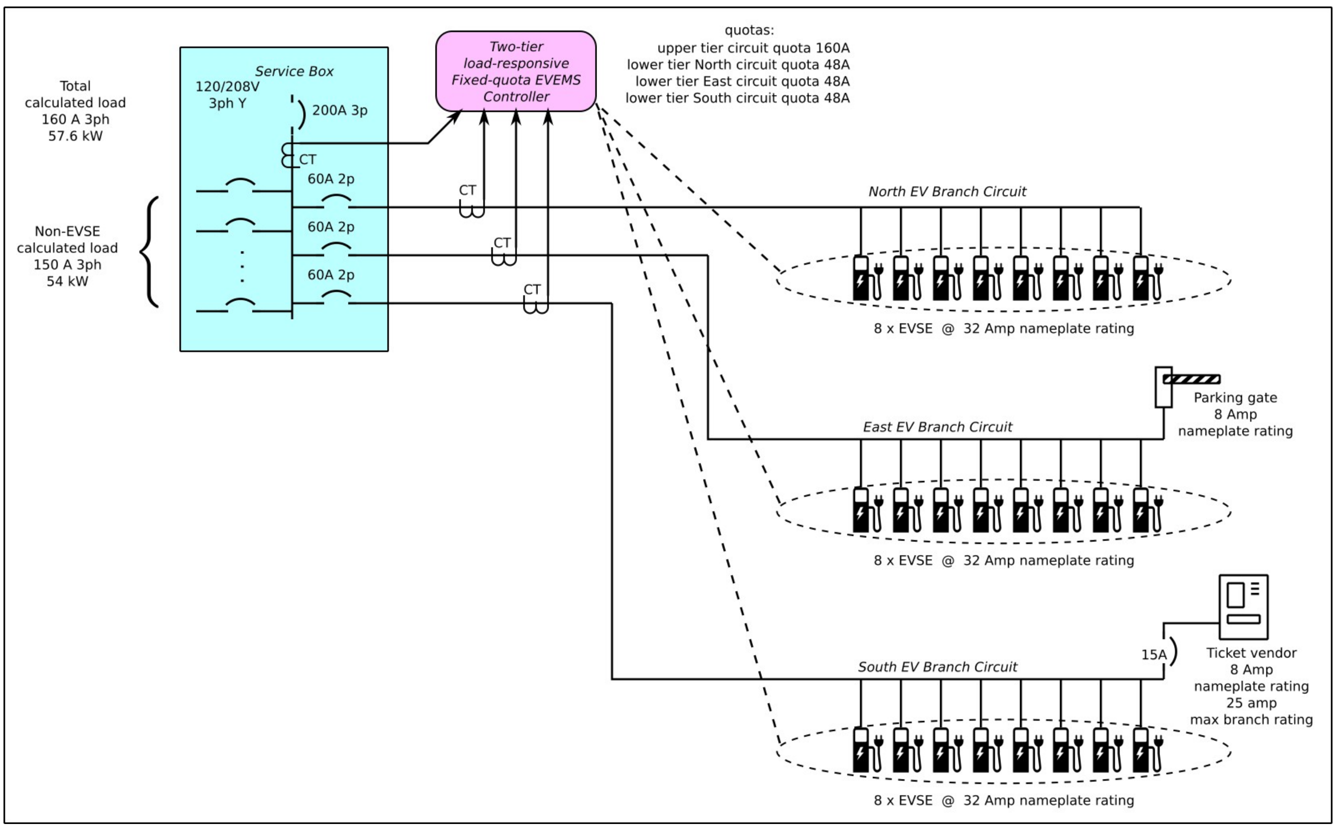

Fig. E-7: Subrule 8-106 11) example

In this example the EVEMS controller implements load measurement at both the lower tier (EV branch circuits) and the upper tier (consumer's service).

At the lower tier, load measurements allows all three circuits to be rated at 60 amps with very little impact on the EVSE charging performance.

At the upper tier, the controller has been configured to control EVSE draw so that the total service load does not exceed 160 amps. This is possible because the calculated load from non-EVSE loads (including the uncontrolled loads on the East and South EV branches) is less than the upper-tier circuit quota setting (160 amps), which is within the allowable load on the 200 amp main breaker. Thus the system complies with 86-500 2), and EVSE loads are ignored for the load calculation under 8-210 c).

E.4.3 Subrule 8-106 11) example – single dwelling

CEC Section 8 supports retrofit of Level 2 EVSE to residences without upgrading service capacity. Fig. E-8 illustrates both line-side-switched and modulated alternatives.

Subrule 8-200 3) allows the calculated load of a single dwelling to equal 100% of the service rating. In Fig E-8 we assume an extreme example: that the service has been fully loaded to this limit. It is nonetheless possible to install an added Level 2 EVSE without a service change. The key is to continuously monitor the service load according to subrule 8-106 11) and rule 8-500, and to enable charging only when other dwelling loads are low. The assumptions justifying non-continuous load treatment in 8-200 3) are invalid when an EVEMS is regulating power level; instead, the service load should be considered continuous and must typically comply with the 80% limitation (subrule 8-104 5)) any time the EVEMS is allowing charging to occur. Thus an EVEMS for this application must monitor the service load and implement a circuit quota no more than 80% of the rated service ampacity.

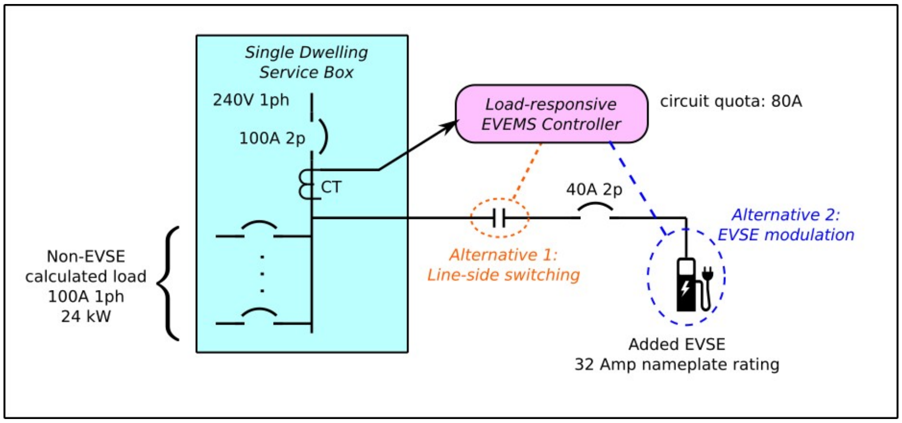

Fig. E-8: Subrule 8-108 11) single dwelling retrofit installation

E.4.4 Lead-lag example

(to be added)

E.4.5 Parallel retrofit example

Fig. E-9, like Fig. E-8, shows a method for adding an EV charging station to an existing single dwelling without increasing service capacity. In this example, capacity is “borrowed” from a hot tub heater branch circuit when the heater is idle. The installer assumes that the service and branch circuit have been correctly sized with the heater as a 25 amp continuous load. The EVEMS shown connects the EVSE load, which must not exceed 25 amps, when it senses no current draw from the hot tub.

In this example, the hot tub heater is counted at 100% demand factor under 8-200 1) a) v); thus the service load is unaffected by swapping it with an EVSE, which also has 100% demand factor under 8-200 1) a) vi). This would *not* be the case if the existing load were a water heating tank which would likely qualify for a 25% demand factor under 8-200 1) a) vii).

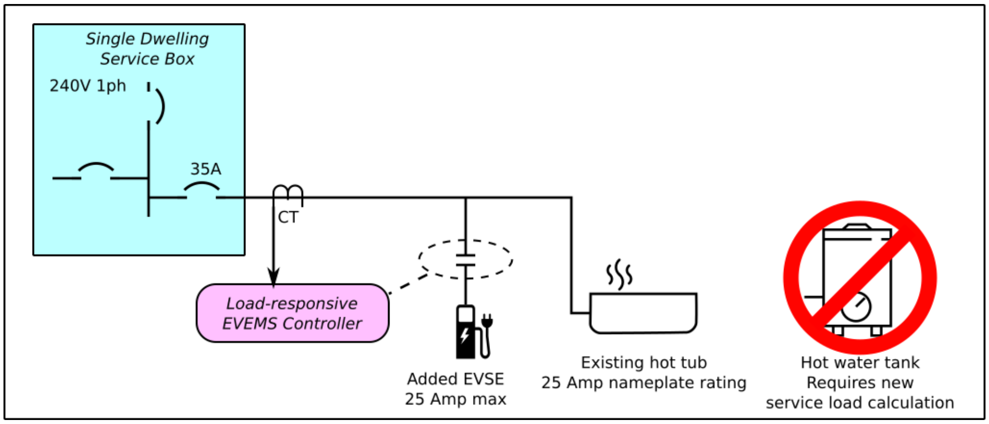

Fig. E-9: Retrofit parallel branch circuit example

A single dwelling service qualifies for non-continuous-load treatment under 8-200 3). This subrule explicitly allows the EVSE load to qualify as well.

Note that this type of arrangement (i.e. “load miser”) long predates modern electric vehicles and can qualify under subrule 8-106 2). Installations under this subrule should draw special attention when loads with different allowable service demand factors are involved.

E.4.6 Embedded EVEMS

Fig. E-10 shows a self-contained dual charging station with an embedded EVEMS. When a single vehicle is connected, the equipment can deliver the full rated 32 amps to it. When two vehicles are connected, the total current draw is limited to the 32 amp nameplate rating; power is allocated between the two vehicles according to the manufacturer’s supported algorithms.

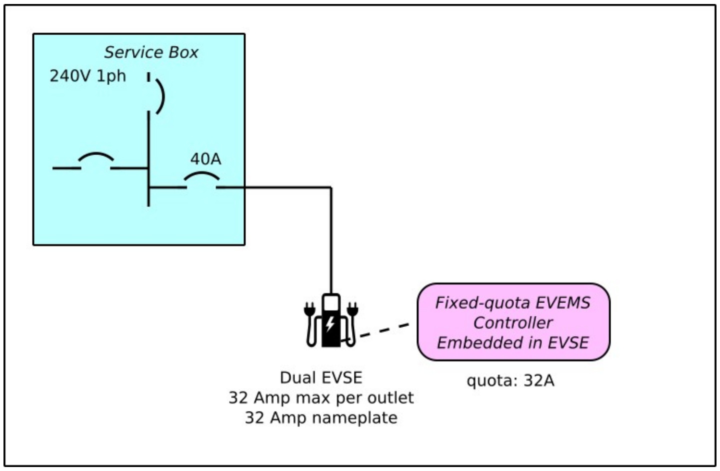

Fig. E-10: Dual EVSE with embedded EVEMS

The dual-port station illustrated in Fig. E-10 involves a single supply power connection and no external communications. It therefore does not present the special characteristics regulated by this standard and may be installed as a single piece of EVSE utilization equipment under CEC Section 86.

A larger installation may "daisy-chain" several similar stations with one "master" station containing the EVEMS and one or more "slave" stations managed from it. Fig. E-11 shows a simple example with two double stations sharing a branch circuit regulated to 48 amps maximum demand load. This standard is applicable to equipment installed in this manner.

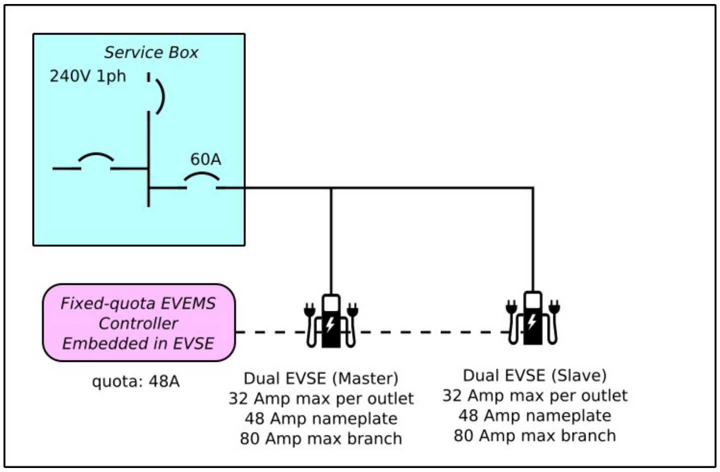

Fig. E-11: Master-slave embedded EVEMS example

E.4.7 Multi-unit Residential Buildings

Multiple dwellings are regulated under subrule 8-200 2) and rule 8-202. In general, these rules allow for load diversity when several dwelling units are served from a common service, while recognizing that some loads (e.g. HVAC, EV charging) have little diversity effect.

Note that subrule 8-106 11) is not applicable unless the entire service is monitored and protected from potential overload caused by EVSE. Without service-level monitoring, a unit owner who installs EVSE should ensure that the overall service is evaluated with updated load calculations.

(to be continued)