Pacific Gas and Electric Company®

Comments of Pacific Gas and Electric Company
Flexible Ramping Products: Incorporating FMM and EIM Draft Final Proposal

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Pacific Gas and Electric Company (PG&E) offers the following comments in the stakeholder process for the California Independent System Operator's (CAISO) Flexible Ramping Products (FRP) initiative Dec. 4, 2014 Draft Final Proposal (Proposal).

While PG&E continues to support CAISO's efforts to identify a market-based solution to the operational challenge of maintaining system power balance under increasing levels of variable energy resources (VERs), PG&E maintains that critical details regarding precisely how CAISO will procure the Flexible Ramping Up (FRU) and Flexible Ramping Down (FRD) products in each of the Day-Ahead and Real-Time Markets remain unclear in the Proposal. PG&E believes that clarification of critical design details is necessary to prevent an implementation of FRP that could result in systematic over-procurement of FRU and FRD capacity and inefficient or unreasonable prices for Energy and Ancillary Services (FRU and FRD included). This is particularly important because CAISO has not undertaken as part of this stakeholder process any market testing or simulation that might demonstrate to stakeholders whether the proposed changes are likely to yield reasonable market outcomes – despite stakeholders' requests for robust simulation of the FRP design.

Given the state of CAISO's FRP Proposal, the current timeline for Board of Governors approval (February, 2015) appears overly optimistic. CAISO should take the necessary time to address and clarify numerous design details in a Revised Draft Final Proposal before advancing the FRP stakeholder process. Such a step will allow for better stakeholder review and support of the FRP initiative, and will provide greater assurance of a smooth approval and implementation process. PG&E cannot support an approach whereby the design process is rushed with the expectation that a tune-up will be needed, given the size and scale of the CAISO's markets.

PG&E's major comments on the Dec. 4 FRP Draft Final Proposal can be summarized as follows:

1. **CAISO should clarify how it proposes to determine confidence intervals on forecast net load, and the resulting maximum FRU and FRD requirements, in all advisory dispatch intervals.** PG&E is concerned that the current Proposal could cause CAISO's Security-Constrained Economic Dispatch (SCED) algorithm to inefficiently adjust the dispatch in a binding 5-minute Real-Time Dispatch (RTD) interval in order to make available in future advisory RTD intervals FRU and FRD capacity in excess of what is appropriate to meet the unexpected ramping needs likely to materialize in future intervals. Likewise, PG&E is concerned that modifying the Security-Constrained Unit Commitment (SCUC) algorithm used in the Fifteen-Minute Market (FMM) and the Integrated Forward Market (IFM) to incorporate FRU and FRD may result in inefficient adjustments to commitments in IFM or in binding intervals in FMM.

2. **CAISO should clarify how it proposes to calculate demand curves for FRU and FRD.** PG&E would like to understand whether the demand curves for FRU and FRD that will be used in RTD to value FRU and FRD procured in a given 5-minute advisory dispatch period to cover uncertainty in the net load in the next advisory dispatch period measure: (1) the expected value of meeting uncertainty in net load that could arise over the single 5-minute period between the advisory dispatch intervals; or (2) the expected value of meeting uncertainty in net load that could arise over multiple 5-minute periods from the binding dispatch interval up to the next advisory dispatch period. Since in each dispatch interval RTD procures FRU and FRD that can be deployed in 5 minutes, PG&E is concerned that the latter approach may over-value FRU and FRD capacity available in a single 5-minute period and, when combined with the concern in item 1 above, could result in unduly high prices for Energy and Ancillary Services. PG&E has similar concerns regarding the demand curves for FRU and FRD that will be used in FMM and IFM.

3. **The mathematical formulations in Appendix B of the Proposal seem to contain modeling mistakes.** These should be addressed as necessary so that market participants may better evaluate the likely effects of the proposed changes.

4. **PG&E requests that CAISO either clarify its proposal for regional FRP procurement or postpone regional FRP procurement until a follow-up stakeholder initiative.** The Proposal contains no details as to how the CAISO will procure FRP regionally, yet the CAISO indicated that the FRP design will include

regional procurement rules. Analysis of the benefits or necessity of regional FRP procurement should also be shared with stakeholders.

5. **CAISO should clarify the treatment of economically-bid VERs in calculating the probability distributions of net load forecast error used to calculate confidence intervals.** Similarly, CAISO should clarify how economically-bid VERs affect the calculation of the FRU and FRD demand curves.

1. CAISO should clarify how it proposes to determine confidence intervals on forecast net load, and the resulting maximum FRU and FRD requirements, in all advisory dispatch intervals

PG&E is concerned about CAISO's proposed method for calculating the confidence intervals used to set limits on FRU and FRD procurement in each of RTD, FMM and IFM. In what follows, we discuss separately our concerns with the RTD process (in section 1.1) and the FMM and IFM processes (in section 1.2). In the case of RTD, PG&E is concerned that modifying the SCED algorithm to incorporate FRU and FRD might result in inefficient adjustments to the dispatch in a binding interval in order to make FRU and FRD capacity available in future advisory intervals that is in excess of what is appropriate to meet the unexpected ramping needs likely to materialize in these future intervals. In the case of FMM and IFM, PG&E is concerned that modifying the SCUC algorithm to incorporate FRU and FRD might result in inefficient adjustments to commitments in IFM and in binding market intervals in FMM.

PG&E is also concerned about the CAISO's proposed method for calculating demand curves for FRU and FRD that will be used to value FRU and FRD procured in each of RTD, FMM and IFM. While demand curves are discussed in greater detail in section 2 of these comments, we observe here that the Proposal does not seem to treat the probabilities used to construct confidence intervals and demand curves in a consistent manner in the different market runs, which could lead to inefficiencies in the market dispatch. For example, the confidence intervals on FRU and FRD for each advisory interval in RTD appear to be developed using probability distributions on *net load forecast error* in each advisory interval for forecasts made at the time of the binding interval. However, the demand curves for the first advisory interval in RTD are developed using probability distributions on *net load* in the first advisory interval. In general, the probability distributions of *net load* and *net load forecast error* do not convey the same information and may result in inconsistent models. In aggregate, PG&E is concerned that the proposed methods used to develop probability distributions (and hence confidence intervals and demand curves) may result in CAISO over-estimating and over-valuing the amount of FRU and FRD that should be procured for deployment in a single dispatch interval to cover uncertainty that arises over multiple dispatch intervals.

1.1. Concerns with proposed method for developing confidence intervals in RTD

In the following, let T denote the current Trading Day and let t denote the current binding RTD interval. Let $\widehat{NL}_{t+5n|t}^{T}$ denote the net load forecast for Trading Day T RTD interval $t+5n$ made when interval t is the binding interval using information available at interval t. (In this formulation, $n=0$ denotes the binding RTD interval and $n=1,2,\ldots,N$ denotes the advisory RTD intervals.) The net load forecast for the binding interval t, $\widehat{NL}_{t|t}^{T}$, is treated as not having any forecast error because it is used in SCED to produce the dispatch for the binding interval.

CAISO claims on page 15[1] that the probability distribution of the net load in interval $t+5$ is equivalent to the probability distribution of the net load forecast error in interval $t+5$. This indicates that CAISO expects the probability distribution of *net load* in a forecast interval to convey the same information as the probability distribution of *net load forecast error*. This is not correct in general. The forecast of net load in an advisory interval takes into account available forecasts of conditions that affect net load (e.g. weather conditions such as temperature, wind, and cloud cover) which can be modeled as random processes. The more accurate the forecasts of the conditions that affect net load, the more accurate the forecast of net load will be; consequently, the forecast of net load in an advisory interval will be correlated with the actual net load in the interval when the advisory interval becomes binding. If one were able to forecast the net load in an advisory interval with perfect accuracy, the *forecast error* would be zero with probability 1 (i.e. the forecast error would have a variance of zero). However, the *net load* in an interval could still be a random variable with a probability distribution that has a non-zero variance, since the weather conditions that in part drive net load are random processes. It is apparent, therefore, that the probability distribution of net load forecast will not in general convey the same information as the probability distribution of net load forecast error.

Page 12 of the Proposal states: "For each RTD […] market run, the ISO will calculate the forecast error for all advisory intervals and develop a histogram of the distribution of actual RTD net loads". Furthermore, page 13 states: "The ISO proposes to use a rolling 30 days, with adjustments for weekends and holidays, to evaluate the historical advisory RTD imbalance energy requirement error pattern for each market run".

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[1] The Proposal states: "This method relies on the […] distribution of net load $\widetilde{NL}_{t+5}$, or equivalently the destruction [*sic*] of $\widetilde{NL}_{t+5} - NL_{t+5}^{forecast}$".

At times, the Proposal talks about developing a histogram of actual RTD net loads. At other times, the Proposal talks about calculating a histogram of historical forecast errors. As discussed above, these convey different information. We believe that CAISO should work with the distribution of net load forecast errors. <u>We would therefore request that CAISO verify our understanding that it proposes to follow the approach outlined below for calculating 95% confidence intervals on forecast net load.</u>

Let $D(T)$ denote the set of 30 Trading Days prior to Trading Day T, with appropriate adjustments for weekends and holidays. Then, for each $d \in D(T)$ and $n = 1,2, \dots, N$, the "historical forecast error" in the forecast of net load for advisory interval $t + 5n$ when the forecast was made in binding interval t would be calculated as follows:

$$\epsilon_{t+5n|t}^{T-d} = \widehat{NL}_{t+5n|t+5n}^{T-d} - \widehat{NL}_{t+5n|t}^{T-d}$$

We understand that CAISO will identify, for each $n = 1,2, \dots, N$, the 2.5 percentile and the 97.5 percentile of the following set of historical forecast errors:

$$\left\{\epsilon_{t+5n|t}^{T-d} \mid d \in D(T)\right\}$$[2]

For the advisory interval indexed by $n \geq 1$, denote these percentiles by $\epsilon_{t+5n|t}^{0.025,T}$ and $\epsilon_{t+5n|t}^{0.975,T}$, respectively.

CAISO would use the 95% confidence intervals as calculated above to limit procurement of FRU and FRD in dispatch interval $t + 5(n-1)$ to cover uncertainty in interval $t + 5n$ for each n in the RTD run for binding interval t. On page 19, the Proposal gives a verbal description of the maximum and minimum amounts of FRU and FRD that CAISO would procure in a given dispatch interval to cover uncertainty in net load in the next dispatch interval. We would request that CAISO verify our understanding that it proposes to set the maximum limits on FRU and FRD capacity that it would procure in interval $t + 5(n-1)$ to cover uncertainty in net load in advisory interval $t + 5n$ $(n = 1,2, \dots, N)$ in the SCED run at binding interval t as follows:

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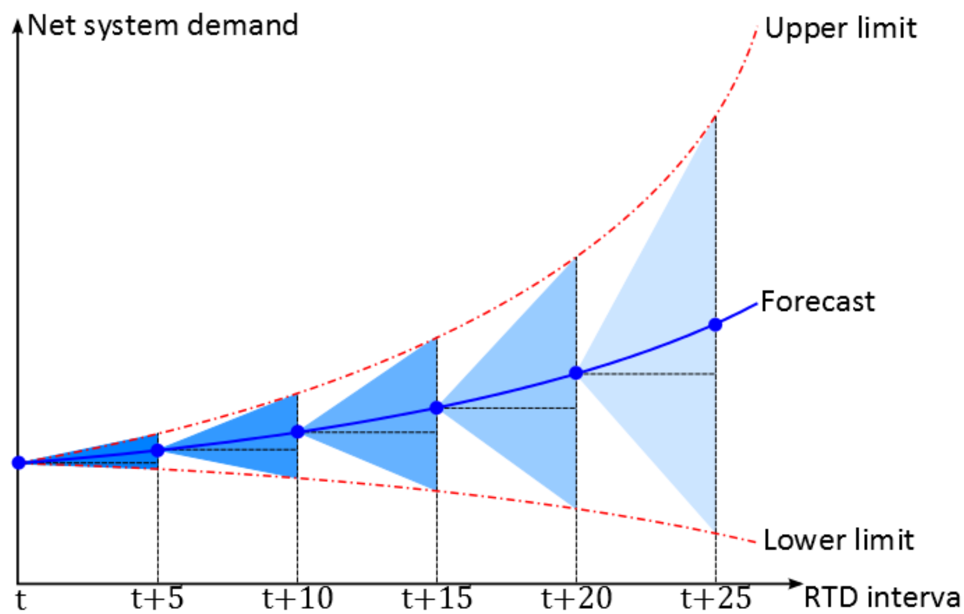
[2] This notation would indicate that CAISO plans to look at each RTD dispatch interval over the historic period separately – for example, it would look at the third dispatch interval in hour 10 over all 30 days to develop the probability distribution of net load forecast error in the third interval of hour 10. This may not provide a sufficiently rich historical record by which to estimate probability distributions on forecast errors. CAISO could instead consider all dispatch intervals in a given hour or over several hours to estimate the probability distribution of forecast errors for net load in a given interval. For instance, page 13 states: "the ISO will evaluate if hours with similar ramping patterns […] could be combined to increase the sample size used in the historical analysis". Letting $S(t)$ denote the set of RTD intervals in hours with "similar ramping patterns" to the hour containing the current binding interval t, we could then generalize the above set of historical net load forecast errors as follows:

$$\left\{\widehat{NL}_{s+5n|s+5n}^{T-d} - \widehat{NL}_{s+5n|s}^{T-d} \mid s \in S(t) \text{ and } d \in D(T)\right\}$$

- Max requirement for FRU: $\max\{\widehat{NL}^T_{t+5n|t} - \widehat{NL}^T_{t+5(n-1)|t} + \epsilon^{0.975,T}_{t+5n|t}, 0\}$
- Max requirement for FRD: $\min\{\widehat{NL}^T_{t+5n|t} - \widehat{NL}^T_{t+5(n-1)|t} - \epsilon^{0.025,T}_{t+5n|t}, 0\}$

This seems to follow the statement on page 5 of the Proposal that "the requirement in RTD […] will be based on the forecast net load change plus the historical forecast error between advisory and binding market intervals for each time period in each market optimization run". This approach to setting the minimum and maximum FRU and FRD requirements is illustrated in Figure 1 below (which builds upon Figure 6 on page 20 of the Proposal).

Figure 1: Proposed minimum and maximum FRU and FRD requirements in RTD



This approach estimates the probability of a given level of forecast error in period $t + 5n$ by including scenarios in which net loads in intervals from t to $t + 5n$ follow different paths than the forecast path illustrated in Figure 1. For net system demand to reach either of the dotted red lines in period $t + 5n$ in Figure 1 may require that the net load deviate from the forecast path in periods before $t + 5n$. The forecast error in interval $t + 5n$ will likely be correlated with the net load forecast errors in intervals $t + 5$ through $t + 5(n - 1)$.

Because the forecast errors are correlated, this approach tends to over-estimate the 95 percentile range of net demand uncertainty that could arise over a single 5-minute period (i.e. a blue cone in Figure 1). For example, the upper limit at the advisory interval $t + 25$ covers the 97.5 percentile of uncertainty in the forecast of net load for dispatch interval $t + 25$ made when dispatch interval t is the binding interval, *not* the 97.5 percentile of uncertainty in the forecast of net load for dispatch interval $t + 25$ made when interval

$t + 20$ is the binding interval. The 95% confidence interval on change in net load from advisory interval $t + 20$ to advisory interval $t + 25$ is likely smaller than the upper and lower limits which represent the 95% confidence interval on change in net load from dispatch interval t to advisory interval $t + 25$.

The proposed modification of SCED will dispatch resources to meet net load in the binding interval and the forecast of net load in each advisory interval over the dispatch horizon used in RTD. It will also procure FRU and FRD in each dispatch interval $t + 5(n - 1)$ that would be cost effective given the uncertainty in net load in the next advisory dispatch interval $t + 5n$, for $n = 1,2, \dots, N$. As currently proposed, the net load forecast error in a given advisory dispatch interval, say $t + 5n$, is correlated with the net load forecast errors in the previous advisory dispatch intervals $t + 5$ to $t + 5(n - 1)$. However, the Proposal does not model this correlation across dispatch intervals in the confidence intervals nor in the demand curves. SCED will treat the net load forecast errors in different intervals as independent random variables. Consequently, SCED could procure FRU and FRD in each dispatch interval from t to $t + 5(n - 2)$ that would cover some of the same uncertainty in net load forecast error in $t + 5n$ for which SCED would procure FRU and FRD in advisory interval $t + 5(n - 1)$. By not modeling correlation of forecast errors across advisory intervals, SCED could over-procure FRU and FRD in later advisory intervals. This can result in SCED adjusting dispatch in earlier dispatch intervals so that it has available additional FRU and FRD in an advisory dispatch interval, say $t + 5(n - 1)$, to cover net load forecast errors that would have occurred in earlier dispatch intervals and that should have been addressed by FRU and FRD procurement in those intervals. To take such path dependencies and correlations into account would require a stochastic optimization model, which is beyond the current scope of the FRP initiative.

During the Dec. 11, 2014 FRP stakeholder conference call, CAISO indicated that its demand curves for FRU and FRD will prevent SCED from undertaking costly adjustments to dispatch to enable procurement of FRU and FRD for deployment in one 5-minute period to cover uncertainty that arose in previous intervals. Why this would be the case is not clear and should be demonstrated. In particular, CAISO should show that the modeling approach used could not or is unlikely to result in material deviations from an optimal dispatch and associated prices in the binding interval to allow for procurement of unrealistically high levels of FRU or FRD capacity in a later advisory interval whose deployment in a single 5-minute interval would cover uncertainty that arose over multiple dispatch intervals. We will address this concern in more detail in section 2.

1.2. Concerns with method for developing confidence intervals in FMM and IFM

PG&E requests that CAISO clarify the calculation of FRP requirements in the FMM and IFM. For the FMM, the Draft Final Proposal states on page 14:

> "In the FMM, the ISO will develop a ramping envelope by comparing the advisory FMM intervals with the maximum and minimum financially binding RTD intervals within the timeframe of the advisory fifteen-minute interval. For example, assume that the FMM net load is forecasted to be 1000 MW for the advisory interval between 9:00 and 9:15. The financially binding RTD intervals are: 975 MW (9:00-9:05), 1000 MW (9:05-9:10) and 1100 MW (9:10-9:15). The highest RTD interval is 1100 MW, which illustrates that RTD must have available resource that can be dispatched up 100 MW higher than assumed in FMM schedule. The lowest RTD interval is 975 MW, which illustrates that RTD must be able to be dispatched down 25 MW lower than assumed in the FMM advisory schedule."

This could be interpreted as CAISO proposing to evaluate the historical differences between FMM net load forecast in a given 15-minute interval and the maximum and minimum 5-minute net loads that actually occur in real-time in the 15-minute interval over a number of days prior to the Trading Day and using that to estimate a probability distribution for maximum positive (or largest negative) net load forecast error. However, nowhere does the Proposal state that CAISO plans to form such a probability distribution function for net load forecast errors over the FMM dispatch intervals. PG&E requests that CAISO verify whether this is indeed the case.

We have similar uncertainty about CAISO's proposal to treat forecast errors in IFM.

CAISO will modify the Security-Constrained Unit Commitment (SCUC) algorithms it uses in the FMM and IFM to incorporate FRU and FRD. For FMM in particular, we have similar concerns to those in RTD – namely, the modeling approach employed could result in material deviations from an optimal dispatch and associated prices in one 15-minute interval to allow for procurement of unrealistically high levels of FRU or FRD capacity in a later advisory 15-minute interval whose deployment in a single 15-minute interval would cover uncertainty that evolved over multiple 15-minute intervals. In addition, we have concerns that the modeling approach could result in material deviations from an optimal commitment in FMM. CAISO should show that the modeling approach could not or is unlikely to result in a material deviation from an optimal dispatch and commitment in the binding interval to allow for procurement of unrealistically high levels of FRU and FRD capacity that could be deployed in a single 15-minute interval to cover uncertainty that evolved over several 15-minute intervals.

2. CAISO should clarify how it proposes to calculate demand curves for FRU and FRD

The Proposal does not specify whether the demand curves for FRU and FRD calculate the expected value of FRU and FRD procured in a given market interval considering the probability distribution of net load forecast error that can arise over a single interval or over multiple intervals. PG&E is concerned that the latter approach may over-value FRU and FRD capacity and, when combined with our concerns from section 1 about setting confidence intervals on FRU and FRD, could result in unduly high prices for Energy and Ancillary Services. We would therefore request that CAISO clarify the modeling approach it will use to calculate demand curves for FRU and FRD and demonstrate that this approach could not or is unlikely to result in a material deviation from an optimal dispatch (in the case of RTD) and commitment (in the case of FMM and IFM) and associated prices in the binding interval to allow for procurement of unrealistically high levels of FRU and FRD capacity in later advisory intervals that could be deployed in a single dispatch interval to cover uncertainty that evolved over several dispatch intervals. Again, we discuss separately our concerns with the RTD process (in section 2.1) and the FMM and IFM processes (in section 2.2).

2.1. Concerns with proposed method for calculating demand curves in RTD

On page 15, the Proposal gives the following formula for calculating the expected value of x MW of FRU capacity above net load forecast in interval $t + 5$:

$$E(PPBC\_penalty\_cost|FRU = x) =$$
$$\sum_y\left[\text{Prob}\left(\widetilde{NL}_{t+5} = y\right) \cdot \max\left(y - NL_{t+5}^{forecast} - x, 0\right) \cdot \text{PPBC\_penalty}\left(y - NL_{t+5}^{forecast} - x\right)\right]$$

This formulation assumes that the forecast of net load at time $t + 5$ is independent of the net load that will occur when $t + 5$ becomes the binding interval. As discussed in section 1.1 above, we believe this is incorrect and deviates from the probability distributions used in calculating the confidence intervals (i.e. probability distributions for net load forecast error). Correcting this problem we would have:

$$E(PPBC\_penalty\_cost|FRU = x) =$$
$$\sum_y\left[\text{Prob}\left(\widetilde{NL}_{t+5} - NL_{t+5}^{forecast} = y\right) \cdot \max(y - x, 0) \cdot \text{PPBC\_penalty}(y - x)\right]$$

However, this still leaves the open question of how the probability distribution of net load forecast error used in the demand curve calculation will be estimated. To address this question, we will use the notation developed in section 1.1 above.

1) Is the estimate of the probability distribution of net load forecast error in advisory interval $t + 5n$ based on the difference between net load when interval $t + 5n$ becomes the binding interval and the net load forecast for interval $t + 5n$ when $t + 5(n - 1)$ is the binding interval? That is, is it based on the historical distribution of:

$$\left\{\widehat{NL}^{T-d}_{t+5n|t+5n} - \widehat{NL}^{T-d}_{t+5n|t+5(n-1)} \middle| d \in D(T)\right\}$$[3]

It is our understanding that this is the method that was included in the previous FRP Straw Proposals.

2) Is the estimate of the probability distribution of net load forecast error in advisory interval $t + 5n$ based on the difference between net load when interval $t + 5n$ becomes the binding interval and the net load forecast for interval $t + 5n$ when t is the binding interval? That is, is it based on the historical distribution of:

$$\left\{\widehat{NL}^{T-d}_{t+5n|t+5n} - \widehat{NL}^{T-d}_{t+5n|t} \middle| d \in D(T)\right\}$$[4]

In the remainder of this section we focus on FRU; similar comments can be made for FRD.

Using the probability distribution from the first method, the demand curve for FRU in interval $t + 5(n-1)$ would calculate the expected value for FRU to meet deviation of net load in interval $t + 5n$ from the forecast of net load in $t + 5n$ made in interval $t + 5(n-1)$. It only looks at uncertainty in net load that can arise in a single 5-minute period. It does not consider that the forecast error in $t + 5n$ could build up over several intervals when calculating the expected value of FRU. Since SCED procures FRU in each dispatch interval that can be deployed in a single 5-minute interval, the demand curve is aligned with the SCED procurement. However, it is not aligned with the proposed method used to calculate confidence intervals for FRU (and FRD). Also, it cannot value FRU that could be procured to meet uncertainty that builds over several intervals as modeled in the confidence intervals used to set FRU and FRD limits.

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[3] This assumes that the historical distribution of net load forecast errors in the given interval over the days in the historical period is used. This could be expanded to use the distribution of net load forecast errors over all dispatch intervals that are in hours with similar ramping characteristics – that is:

$$\left\{\widehat{NL}^{T-d}_{s+5n|s+5n} - \widehat{NL}^{T-d}_{s+5n|s+5(n-1)} \middle| s \in S(t) \text{ and } d \in D(T)\right\}$$

where $S(t)$ denotes the set of RTD intervals in hours with "similar ramping patterns" to the hour containing the current binding interval t.

[4] As in the previous footnote, this assumes that the historical distribution of net load forecast errors in the given interval over the days in the historical period is used. This could be expanded to use the distribution of net load forecast errors over all dispatch intervals that are in hours with similar ramping characteristics – that is:

$$\left\{\widehat{NL}^{T-d}_{s+5n|s+5n} - \widehat{NL}^{T-d}_{s+5n|s} \middle| s \in S(t) \text{ and } d \in D(T)\right\}$$

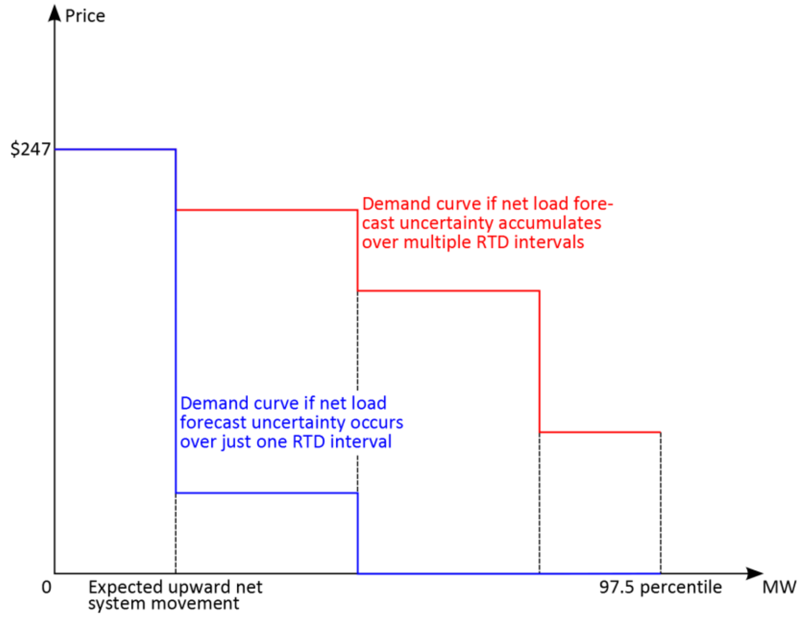
where $S(t)$ denotes the set of RTD intervals in hours with "similar ramping patterns" to the hour containing the current binding interval t.

Using the probability distribution from the second method, the demand curve for FRU in interval $t + 5(n - 1)$ would calculate the expected value for FRU to meet deviation of net load in interval $t + 5n$ from the forecast of net load in $t + 5n$ made in interval t. It looks at uncertainty in net load that can arise over multiple 5-minute dispatch intervals and so considers that the net load forecast error in $t + 5n$ could build up over several intervals when calculating the expected value of FRU. Since SCED procures FRU in each dispatch interval that can be deployed in a single 5-minute interval, the demand curve is not aligned with the SCED procurement. This demand curve may cause SCED to incur increased costs to procure ramp in a single interval to meet uncertainty that arose over several intervals and could be met more cost effectively by procuring ramp in multiple dispatch intervals to cover uncertainty as it arises. However, it is aligned with the method used to calculate confidence intervals for FRU and FRD.

For advisory intervals later than the first advisory interval (i.e. for $n > 1$), the probability distribution used in the second method would have thicker tails than the distribution used in the first method. This is because the forecast for the net load in the interval is made farther from the advisory interval in the second method than in the first method and so it is subject to greater error. Also, as discussed in section 1.1 above, the probabilities for forecast errors in an advisory dispatch interval calculated using the second method are correlated with those in prior intervals. This would result in the demand curve for interval $t + 5n$ considering the effects of forecast errors in earlier intervals on the probabilities of forecast errors in $t + 5n$. As such, its use in calculating demand curves would likely place higher expected values on FRU than demand curves that were calculated using probabilities estimated using the first approach, as can be seen by comparing the blue and red demand curves in Figure 2.

If the probability distribution of net load forecast error calculated using the second approach is used to calculate the demand curves for FRU and FRD that will be used in SCED, it would estimate growing uncertainty in the net forecast load for intervals later in the dispatch horizon of SCED. It would also calculate the expected value of FRU in interval $t + 5n$ ignoring the fact that forecast errors in $t + 5n$ are correlated with forecast errors in earlier dispatch intervals and that the demand curves for intervals $t + 5$ through $t + 5(n - 1)$ will already have valued procuring FRU to cover some of this uncertainty. Such demand curves may lead to procuring FRU over multiple intervals to cover some of the same drivers of uncertainty. That is, it may over-procure FRU in a given interval given the actual uncertainty faced in that interval as opposed to previous intervals.

Figure 2: FRU demand curves for low vs. high net load forecast uncertainty

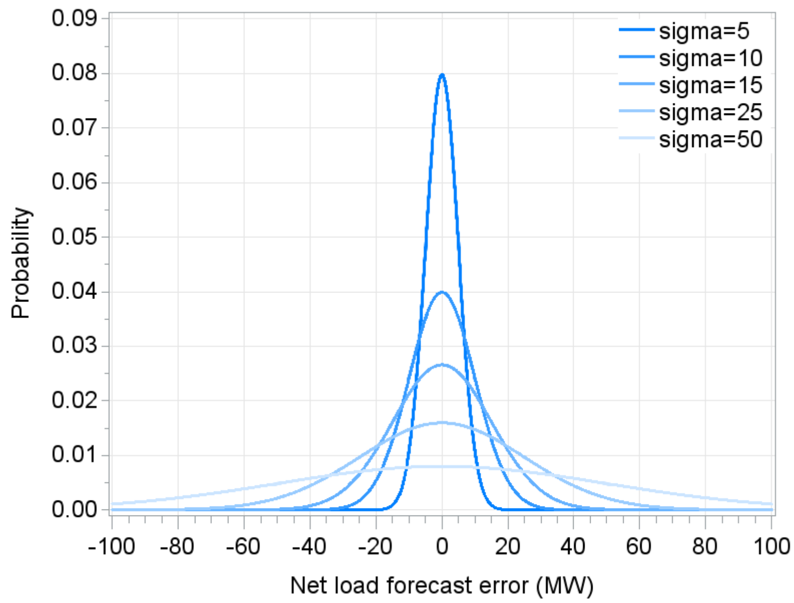


The first approach does not have the problem of procuring FRU over multiple periods to cover the net load forecast errors in earlier intervals. However, it does not consider that errors may evolve along different paths. To treat forecast errors evolving along different paths properly would require a stochastic optimization framework, which is beyond the scope of the current Proposal. As such, neither the first nor the second method of calculating demand curves will produce a completely accurate value of FRU and FRD to procure for deployment in a single interval to cover uncertainty that may build over time. They are approximations only.

If CAISO is proposing to use the second approach, PG&E strongly recommends performing full-scale simulations of the approach to show that it does not over-procure FRU and FRD in one 5-minute dispatch interval to cover the drivers of uncertainty that arose over multiple intervals and so result in over-procurement. Repeating the comment from section 1.1, CAISO should show that the modeling approach used could not or is unlikely to result in material deviations from an optimal dispatch and associated prices in the binding interval to allow for procurement of unrealistically high levels of FRU or FRD capacity in a later advisory interval whose deployment in a single 5-minute interval would cover uncertainty that arose over multiple dispatch intervals. Absent such testing, rather than over-procuring FRU and FRD (which the second approach might do), PG&E would recommend using the first approach. While the first approach may not procure FRU and FRD to cover all uncertainty that may arise over time, it is a step forward from current market formulations that commit and dispatch to meet a single forecast only.

In order to make this point concrete, consider a simple hypothetical example. Draw 360 independent observations on the "net load forecast error" from a normal distribution with mean zero and variance σ^2 – i.e. $\epsilon_i \sim N(0, \sigma^2)$, for $i = 1,2, \ldots, 360$.[5] We will consider five different values of σ: 5, 10, 15, 25, and 50. As discussed above, larger values of σ represent greater uncertainty associated with increased time between binding interval t and advisory interval $t + 5n$. Figure 3 plots the probability density function (pdf) for each of our five hypothetical distributions of the net load forecast error.

Figure 3: Hypothetical probability density functions for net load forecast error



Recognizing the correction to page 15 of the Proposal identified above, the expected value of x MW of FRU capacity in any given advisory interval is:

$$E(PPBC\_penalty\_cost|FRU = x) = \frac{1}{360} \cdot \sum_{i=1}^{360} 1000 \cdot (\epsilon_i - x) \cdot \mathbf{1}\{\epsilon_i > x\}$$

where $\mathbf{1}\{\cdot\}$ is the indicator function (such that $\mathbf{1}\{\epsilon_i > x\} = 1$ if $\epsilon_i > x$ and $\mathbf{1}\{\epsilon_i > x\} = 0$ otherwise).

Now, set the step size for the FRU demand curve to 10 MW and compute the FRU demand curve prices in the manner identified on page 16 of the Proposal:

- $Price(\text{0-10 MW}) = [E(PPBC\_pen\_cost|FRU = 0) - E(PPBC\_pen\_cost|FRU = 10)]/10$

[5] We choose 360 observations, as this implies 30 historical days times 12 5-minute intervals per hour.

- $Price(\text{10-20 MW}) =$
  $[E(PPBC\_pen\_cost|FRU = 10) - E(PPBC\_pen\_cost|FRU = 20)]/10$
- $Price(\text{20-30 MW}) =$
  $[E(PPBC\_pen\_cost|FRU = 20) - E(PPBC\_pen\_cost|FRU = 30)]/10$
- $Price(\text{30-40 MW}) =$
  $[E(PPBC\_pen\_cost|FRU = 30) - E(PPBC\_pen\_cost|FRU = 40)]/10$
- $Price(\text{40-50 MW}) =$
  $[E(PPBC\_pen\_cost|FRU = 40) - E(PPBC\_pen\_cost|FRU = 50)]/10$

Results are presented in Table 1 below.[6] Notice that as net load forecast error uncertainty increases (i.e. as σ increases), the FRU demand curve price associated with any given FRU demand curve quantity increases – that is, the FRU demand curve shifts upward, as in Figure 2.

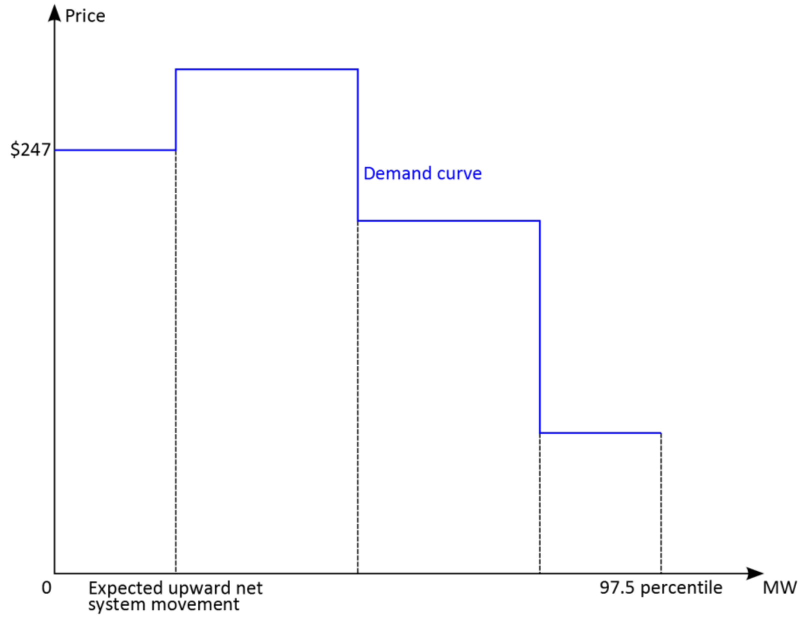
Table 1: Hypothetical FRU demand curve prices under different assumptions about net load forecast error variance

FRU quantity	$\sigma = 5$	$\sigma = 10$	$\sigma = 15$	$\sigma = 25$	$\sigma = 50$
0-10 MW	202.6	356.9	369.7	412.9	467.2
10-20 MW	2.2	92.7	169.2	280.2	382.6
20-30 MW	0	8.2	46.4	158.4	311.8
30-40 MW	0	0.8	5.2	71.2	243.5
40-50 MW	0	0	0	34.2	205.2

While the results in Table 1 are purely hypothetical, they are indicative of a phenomenon that could actually occur. Notice that for sufficiently large values of σ the demand curve prices are higher than the $247/MW penalty price that CAISO says it will enforce in SCED. How does CAISO plan to calculate the FRU demand curve in the event that the price for FRU in excess of the minimum procurement amount is greater than $247/MW? Presumably the CAISO does not plan to use a demand curve that is at first increasing, but then decreasing in quantity, as depicted in Figure 4?

[6] Note that Table 1 only shows the effect of increasing variance of net load forecast error in a single interval; it does not show the effect of correlated net load forecast errors across time intervals on procuring FRU in different intervals that would cover the same drivers of uncertainty over several periods.

Figure 4: Hypothetical FRU demand curve with prices in excess of $247/MW



2.2. Concerns with proposed method for calculating demand curves in FMM and IFM

The Proposal does not state how CAISO will calculate demand curves for FRU and FRD in FMM and IFM. A discussion of how CAISO proposes to calculate these demand curves should be provided so that stakeholders can properly evaluate the likely performance of FRP in those markets. Does CAISO plan to use the same demand curves that are calculated for RTD or will CAISO calculate new demand curves using estimated probability distributions for net load forecast errors in the FMM 15-minute intervals and the IFM hourly dispatch that are based on the historical net load forecast errors?

We have similar questions as those in section 2.1 about the demand curves for FRU and FRD that will be used in the SCUC models in FMM to determine the expected value of FRU and FRD procured in each 15-minute interval of FMM. Will the demand curves calculate the expected value of FRU and FRD procured in a given interval considering the probability distribution of net load forecast error that can arise over a single interval or over multiple intervals? CAISO should show that the modeling approach used to calculate demand curves for FMM could not or is unlikely to result in a material deviation from an optimal dispatch and commitment in the binding 15-minute interval to allow for procurement of unrealistically high levels of FRU and FRD capacity in later advisory intervals that could be deployed in a single 15-minute interval to cover uncertainty that evolved over several 15-minute intervals.

Also, CAISO indicated that it would develop confidence intervals on net load forecast errors in a FMM 15-minute interval based on the largest differences between the net load forecast for the 15-minute period and the actual net loads in each of the 5-minute RTD intervals in the 15-minute FMM dispatch interval. Using such an approach to develop demand curves for 15-minute periods would seem to assume that the largest potential shortage over the entire 15-minute period would persist for the full duration of the 15-minute period rather than just a single 5-minute period. This could over-value ramp. On the other hand, assuming that the largest potential shortage over the entire 15-minute period would occur in only a single 5-minute period (with the other two 5-minute periods experiencing no shortage) could under-value ramp. CAISO should clarify its proposed calculation of demand curves in FMM.

Similar problems exist in the proposed treatment of demand curves in IFM, and PG&E requests further clarifications regarding IFM demand curves as well.

3. The mathematical formulations in Appendix B of the Proposal seem to contain modeling mistakes

The mathematical formulations in Appendix B of the Proposal seem to contain at least two modeling mistakes, as discussed below. These issues should be corrected or clarified so that market participants may better evaluate the likely effects of the proposed changes.

3.1. Upward ramping capability limit

The constraint, as formulated by CAISO, will ensure that a resource's FRU award plus the total amount of upward reserves (regulation-up, spinning, and non-spinning) awards does not exceed its upward ramping capability over the market clearing interval:

$$\frac{FRU_{i,t} + RU_{i,t} + SP_{it} + NS_{i,t}}{RR_i^{OP}} \leq MCG$$

That is, the same ramp capability cannot be used to provide both FRU and spinning reserves, for example.

FRU not only covers ramp needed to cover uncertainty in net load forecast, it also covers ramp needed to move from one energy dispatch point to another in SCED. Previous CAISO documents on Market Optimization indicate that the same ramp capability can be used to provide spinning reserves and to move energy dispatch levels between dispatch intervals in IFM, FMM and RTD; moreover, ramping capability used for regulation reserves may also be used to move from one energy dispatch to another between dispatch intervals in RTD.[7] The above constraint appears to contradict these previously published details concerning

[7] CAISO Technical Bulletin 2009-06-05 Market Optimization Details, pp. 2-36 to 2-39.

market optimization. Further restricting the use of ramp as described in this constraint may adversely affect market operation and outcomes.

In addition, regulation, spinning reserve and non-spinning reserve must be able to be deployed in 10 minutes. The above constraint considers deployment over different intervals based on market granularity. For example, in RTD MCG equals 5 minutes. This would mean that reserve products that were procured assuming a 10-minute deployment would cause a revised SCED to hold aside ramp to deploy them in 5 minutes. This could result in an infeasible SCED in real-time or greatly increase the cost of the RTD dispatch.

We note that a similar problem exists for the downward ramping capability limit and request that CAISO provide similar clarification.

3.2. Upward and downward flexible ramping requirements

CAISO should show how it proposes to include the demand curves that price FRU and FRD in the objective function. The formulation should show how the demand curves will be weighted in the objective function for IFM, FMM and RTD. For example, the demand curve in RTD shows the price for a MW shortage over the hour. Since SCED models the shortage in 5 minutes in RTD, a weight of 1/12 should be applied.

4. CAISO should either clarify its proposal for regional FRP procurement or postpone regional FRP procurement until a follow-up stakeholder initiative

Page 8 of the Proposal states: "The ISO proposes to procure the flexible ramping products regionally if necessary to distribute ramping capability within a balancing authority area". PG&E believes that deliverability of FRP (such that procured ramping capacity is not stranded behind transmission constraints) is an important consideration, as it is expected that flexible ramping capacity will be dispatched for Energy regularly in RTD. We note, however, that the Proposal provides no details regarding how CAISO would actually procure FRP on a regional basis. In spite of this, CAISO seemed to indicate during the Dec. 11 FRP stakeholder conference call – and then again at the Dec. 16 Market Surveillance Committee meeting – that it plans to procure FRU and FRD regionally upon initial implementation of the FRP market design changes. PG&E requests that CAISO either make clear to stakeholders its proposal for regional FRP procurement, or postpone regional FRP procurement until a follow-up stakeholder initiative (e.g. "Flexible Ramping Products One-Year Enhancements").

5. **CAISO should clarify the treatment of economically-bid VERs in calculating the probability distributions of net load forecast error used to calculate confidence intervals**

The definition of net load in relation to economically-bid VERs is not clear. On page 13, the Proposal states:

> "The net load is the amount of energy that must be dispatched from resources with economic bids in RTD to meet the required imbalance from resources and load without the ability to be dispatched."

This would seem to indicate that a VER that is economically bid cannot contribute to net load and therefore net load forecast errors. However, the Proposal goes on to state:

> "Resources must be dispatched to meet ramping requirements for a variety of reasons:
> […]
> - The forecast of a variable energy resource that is economically bidding decreases between market intervals. Note an increase in the forecast does not necessarily require other resources to be dispatched down. Other resources are only dispatched down if the variable energy resource is more economic than the other resources."

This last statement would seem to indicate that a VER could contribute to upward uncertainty in net load that could lead to procurement of FRU, but cannot contribute to downward uncertainty in net load and so would not lead to procurement of FRD. It is unclear how CAISO proposes to treat economically-bid VERs in calculating probability distributions on net load forecasting error used to calculate the confidence intervals used in setting limits on FRU and FRD procurement. Similarly, it is not clear how CAISO proposes to treat economically-bid VERs in calculating demand curves. PG&E therefore requests that additional details be provided regarding how CAISO will treat economically-bid VERs when calculating the probability distributions of net load forecast errors used to derive confidence intervals on FRU and FRD and demand curves for FRU and FRD.