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Incorporating Dispatchable VERs into California's Flexible Capacity Procurement Framework

Comments Prepared by E3 on Behalf of First Solar

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1. Introduction

On November 20, 2017, the California Independent System Operator (ISO) released a Draft Flexible Capacity Framework, which represents a proposed revision to the current Flexible Resource Adequacy Capacity – Must-Offer Obligation (FRAC-MOO) procurement requirements. The ISO proposes to create new flexible capacity products to better align forward procurement with the operational needs of the ISO system. The ISO currently seeks comment on these proposals.

First Solar retained Energy and Environmental Economics, Inc. (E3) to prepare these draft comments on incorporating dispatchable variable energy resources (DVERs) into the ISO's flexible capacity framework. First Solar has a longstanding interest in promoting the use of DVERs to provide grid services, as indicated by the demonstration project carried out in 2016 by First Solar, the ISO and the National Renewable Energy Laboratory (NREL) (https://www.nrel.gov/docs/fy17osti/67799.pdf). First Solar and E3 continue to explore the potential economic benefits of widespread DVER dispatch. While First Solar sponsored these E3 comments, the ideas expressed here are E3's alone at the present time and are not necessarily endorsed by First Solar.

DVERs have the potential to provide significant value to the ISO system by reducing the quantity of flexible capacity services needed from thermal generators or other resources. Consideration of these comments will significantly enhance the effectiveness of ISO's flexible capacity initiatives and reduce the overall cost of serving California ratepayers at high levels of VER penetration.

While these comments are geared toward incorporation of DVERs into the ISO's Flexibility framework, we note that many of the issues and solutions described here would be equally valid if applied to load-based flexibility solutions such as flexible loads or energy storage.

2. Defining Flexibility Need Under High VER Penetration

2.1. What is Flexibility?

We begin with a brief theoretical examination of operations under high VER penetration and the consequent needs for Capacity and Flexibility. Flexibility does not have a standard definition, but is generally thought of as the ability to meet "net load", or load minus must-run generation, at any two points A and B, separated by a time interval *T*. For simplicity, all VER generation is assumed to be must-run in this formulation.

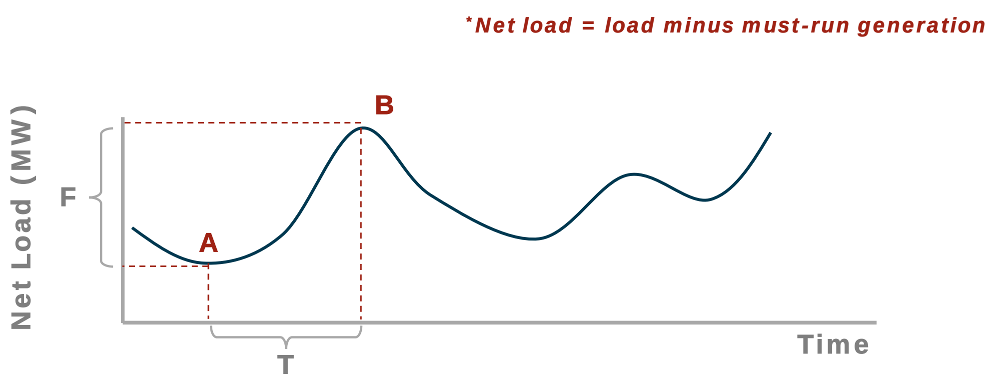

Figure 1. Under perfect foresight, the Flexibility Need *F* is defined as net load at Point B minus net load at Point A

Assuming perfect foresight, the size of the Flexibility need *F* is determined by $NL_B - NL_A$. For upward Flexibility need, point A represents a "trough" and point B represents a "peak"; for downward Flexibility need, the roles are reversed. The time period *T* can range from milliseconds to multiple hours, e.g., the three-hour ramping period considered in the ISO's original FRAC-MOO initiative. This is illustrated in Figure 1.

As more VERs are added to the system, the Flexibility need *F* grows because the trough at point A becomes lower and $NL_B – NL_A$ therefore becomes larger. This is illustrated in Figure 2 below. The second net load line represents net load after the introduction of additional VERs.

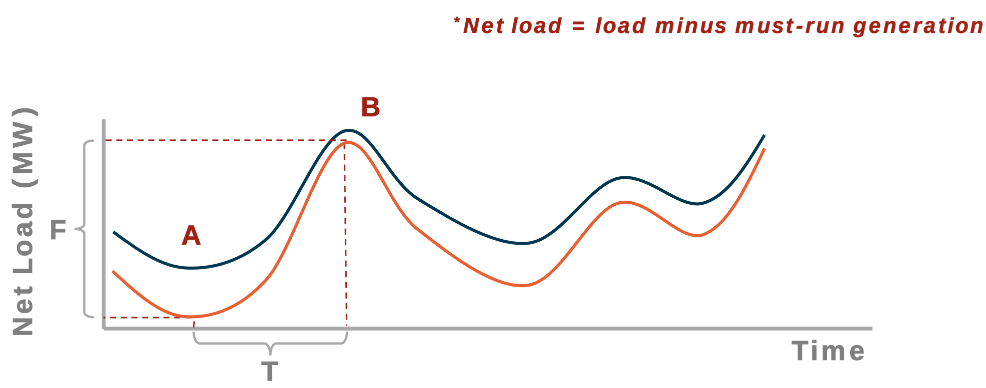

Figure 2. Flexibility need *F* increases as more VERs are added to the system

While rudimentary, this examination produces several useful propositions for understanding system reliability needs:

I. First, since the Flexibility need is defined as $NL_B – NL_A$, it follows that a flexibility "solution" is one that can either:

   a. Enhance the ISO's ability to meet load at Point B, e.g., by increasing production or reducing load; or

   b. Increase the net load at Point A, e.g., by increasing load or reducing must-run generation, e.g., VER production.

   In other words, to ensure that it has enough Flexibility to meet changing net load conditions, the ISO must procure a combination of "Inc" bids at Point B and "Dec" bids at Point A to meet the maximum expected value for $NL_B – NL_A$. This means that:

   c. Under perfect foresight, Dec A and Inc B bids contribute equally to meeting the upward Flexibility need and should not be differentiated from each other.

II. Second, it can be seen from Figure 2 that the need for Capacity—resources needed to generate energy under adverse conditions such as extreme weather events combined with loss of multiple generation or transmission system elements—is unrelated to the need for Flexibility. As more VERs are added to the system, Flexibility need increases due to higher net load variability, while Capacity need decreases because VERs are expected to produce some amount of energy during peak hours (defined by the VER Net Qualifying Capacity (NQC) value). This implies that:

a. Quantification of the need for Flexibility should be considered independently of the need for Capacity; and

b. The ability of VERs and demand-side resources to provide Flexibility should be calculated independently from their ability to provide Capacity.

Of course, in reality perfect foresight doesn't exist. Higher Flexibility needs could result from an under-forecast of net load at Point B, as illustrated in Figure 3 below, or an over-forecast of net load at Point A. The ISO recognizes this point and proposes to procure additional Flexibility to account for the possibility of forecast error.

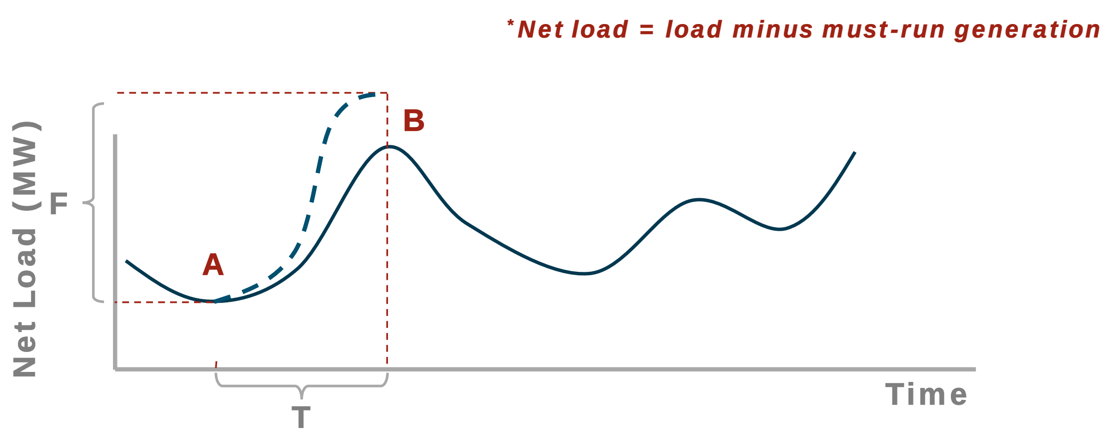

Figure 3. Flexibility need *F* is higher if net load at Point B is subject to forecast error

2.2. Participation of VERs

We have seen above that Flexibility need is defined as $NL_B - NL_A$ over a given time period T = B-A. Flexibility need can be satisfied with either Inc bids at B ("Inc B") or Dec bids at A ("Dec A"). DVERs can help meet the Flexibility need by providing either Inc B or Dec A bids.

1. Dec A bids. A DVER can provide Flexibility by offering to reduce production at Point A, i.e., by providing a Dec A bid. Deploying a Dec A bid requires the ISO to curtail DVER production at Point A to a given quantity below the maximum potential production over the time period *T*. The size of the potential Dec A bid is bounded by the scheduled production at Point A, including a margin of error.
2. Inc B bids. A DVER can also provide Flexibility by offering to increase production at Point B. In practice this will likely occur when the resource has been economically dispatched to lower than maximum potential production levels. The size of the Inc B bid is bounded by the potential production, based on resource availability, minus scheduled production at Point B.

In both cases, the quantity of DVER available to provide Flexibility is a function of the potential and scheduled production during a given time period *T*. Therefore, the Flexibility counting rules must consider DVERs' time-varying production capability. This is intuitive and lines up well with system needs, as the Flexibility need is greatest during time periods when VER production is highest. This also suggests that both the need for Flexibility, and the quantity of Flexibility available from the DVER fleet, cannot be known with certainty until the day-ahead scheduling period and in fact are jointly determined through the day-ahead scheduling process.

In reality, when DVERs submit bids into energy markets, net load is an *output* rather than an *input* to the need for Flexibility. However, for simplicity we have assumed here that all VERs are must-run to determine the starting point from which to calculate flexibility need. DVERs are then considered a source of Flexibility to meet system needs.

2.3. Example of Economic Provision of Flexibility by DVERs

Provision of Flexibility by DVERs can be an economic way to meet to the ISO's reliability needs. The following table shows an example of DVERs providing 1000 MW of 3-hour upward Flexibility. The cost of DVER-provided curtailment is entirely an opportunity cost based on lost production. Lost production has value even during hours when prices are negative because DVER production generates a Renewable Energy Certificate (REC) which a Load-Serving Entity (LSE) can use for compliance with the state's Renewables Portfolio Standard (RPS). Based on bidding behavior observed in the ISO market, LSEs currently value "Bucket 1" RECs at $10-25/MWh. The cost is therefore a function of the quantity of actual DVER curtailment.

In the example below, the expected DVER curtailment is 1000 MW during hour 1, 667 MW during hour 2, 333 MW during hour 3, and 0 MW during hour 4. The total cost of providing Flexibility from DVERs is estimated at $0.70-9.00/kW-yr.

It should be noted that this example assumes the maximum deployment of Flexibility from the DVER resource. If actual deployment is less, then the cost of DVER-provided Flexibility would be lower than shown in the example. This implies that the most economic bid structure for DVER-provided Flexibility would be a two-part bid, with a fixed charge for making the DVER available for Flexibility provision and a "mileage charge" for its actual deployment.

Table 1. Example estimate of the cost of DVER providing 3-hour Flexibility product

Item	Low Value	High Value	Unit
Quantity of Flexibility Offered	1,000		MW
DVER curtailment, hour 1	1,000		MWh
DVER curtailment, hour 2	667		MWh
DVER curtailment, hour 3	333		MWh
Total daily DVER curtailment	2,000		MWh
% of days with DVER curtailment	10%	50%	$/MWh
Value of DVER curtailment	$10	$25	$/MWh
Total daily cost of DVER curtailment	$2,000	$25,000	$/day
Total annual cost of DVER curtailment	$730,000	$9,125,000	$/yr.
Unit cost of DVER Flexibility provision	$0.73	$9.13	$/kW-yr.

Shorter-duration Flexibility products would require significantly less curtailment and could therefore be offered at a significantly lower cost. Table 2 provides an example of the cost of DVER providing a 5- or 15-minute downward Flexibility product. E3 research has indicated that DVERs providing reserves are likely to lose 20-30% of energy production to sub-hourly curtailment when providing down Regulation or Load Following. Even so, DVERs can provide downward sub-hourly flexibility at an estimated cost of $2-7/MWh, comparable to the price of Down Regulation in the current ISO markets.

Table 2. Example estimate of the cost of DVER providing 5- or 15-minute downward Flexibility product

Item	Low Value	High Value	Unit
Quantity of Flexibility Offered	1,000		MW
Sub-hourly DVER curtailment, per hour	200	300	MWh
Value of DVER curtailment (low)	$10	$25	$/MWh
Unit cost of DVER Flexibility provision	$2.00	$7.50	$/MWh

Table 3 shows an example cost range for DVERs providing upward flexibility reserve. For the High Value, pre-curtailment of DVER output is assumed to be required. However, between 20% and 30% of lost production is recovered through the provision of upward reserves inside the operating hour. The total curtailment of 800 MWh leads to a relatively high cost of $20/MWh of upward reserves provided.

However, the "low" value for upward reserve provision actually results in a negative cost, or an overall savings. This occurs in a situation where the DVER is already curtailed due to system-wide oversupply conditions. In this case, the DVERs already have "headroom" to accommodate upward dispatch. Sub-hourly dispatch results in more renewable energy deliveries, providing net value to the DVER owner, who is therefore willing to pay as much as $3/MWh of upward reserves provided.

Table 3. Example estimate of the cost of DVER providing 5- or 15-minute upward Flexibility product

Item	Low Value	High Value	Unit
Quantity of Flexibility Offered	1,000		MW
DVER pre-curtailment, per hour	0	1000	MWh
Sub-hourly DVER upward dispatch, per hour	-300	-200	MWh
Total DVER curtailment, per hour	-300	800	MWh
Value of DVER curtailment (low)	$10	$25	$/MWh
Unit cost of DVER Flexibility provision	-$3.00	$20.00	$/MWh

3. Comments on ISO Proposal

We provide the following comments on the ISO's proposed framework in light of the discussion above.

3.1. ISO Flexibility Need Definition

The ISO proposes to determine a Flexibility need equal to:

- Maximum 3-Hour ramp + 3% of the monthly expected peak load + 50% of incremental real-time flexible capacity need;
- Flexibility need is broken into three separate Flexible RA products:
    - Day-ahead Shaping Capacity
    - Fifteen-minute Flexible RA product
    - Five-minute Flexible RA product
- The ISO's three Flexibility products are generally reasonable. Day-Ahead Shaping essentially allows load and DVER products to contribute to reducing the need to commit thermal generators through economic bids at the Day-Ahead timestep. As noted above, DVERs can provide a low-cost source of Day-Ahead Shaping capability. Additional products allow the ISO to commit supplement resources to meet intra-day flexibility needs.
- Day-Ahead Shaping need should be determined based on scheduled load and must-run generation.
    - To line up with the current Flexible RA paradigm, DVERs can be treated as must-run generation for the determination of flexibility need. DVER economic bids can then be treated as a means for providing the needed Flexibility products.
    - Alternatively, Flexibility need could be determined based on $NL_B – NL_A$, where net load is defined as load minus must-run generation, i.e., generation that does not submit economic dispatch bids. In this formulation, DVERs neither

contribute to the need for Flexibility nor provide Flexibility products in response to a defined need.

- The ISO has not demonstrated that the need for the three Flexibility products is incremental. In fact, the needs are nested within each other; unexpected downward needs can occur on a fifteen-minute timescale within the envelope of a steep upward 3-hour net load ramp. Moreover, the resources that provide the Day-Ahead Shaping product are also available to provide 15-minute and 5-minute Flexibility Products without compromising their ability to provide 3-hour ramping.
    - For example, assume the Day-Ahead Shaping need is 15,000 MW. This represents the anticipated net load ramp between 4 PM and 7 PM. Absent forecast error, the fifteen-minute net load ramp is the manifestation of the 3-hour net load ramp on the fifteen-minute timestep. With forecast error, the fifteen-minute need may be slightly larger than an allocated share of the diurnal ramping need. However, if 15,000 MW of thermal generators are identified to provide Day-Ahead shaping, these resources would also be available to independently provide fifteen-minute and five-minute flexibility. If the need is higher during a given 15-minute interval due to an unexpectedly high net load, this means that the upward ramp during a subsequent 15-minute interval will be correspondingly lower, if the 15,000 MW Day-Ahead need is unchanged.
    - Instead, the ISO should independently identify the need for Flexibility as NL_B – NL_A over each relevant time frame. At the day-ahead time period, Point A and Point B represent the three-hour net load ramp over a rolling window throughout the operating day, resulting from the day-ahead scheduling process. In the intraday timeframe, Point B represents the timestep 15-minutes and 5-minutes from Point A. The ISO should identify the maximum potential upward ramping need over each interval and commit additional resources if needed to meet any identified need.
- The need for additional RA quantities based on contingency reserves is unrelated to flexibility and is subsumed within the existing 15% Planning Reserve Margin. Contingency Reserves are procured to ensure that the system can meet NERC operating

standards after the sudden loss of a major generation or transmission element. This is entirely separate from and unrelated to Flexibility needs caused by high VER penetration. Moreover, it is standard practice to include the need for contingency reserves as part of the Planning Reserve Margin. The ISO's rules should therefore ensure that LSE RA procurement includes a sufficiently large portion of resources that qualify to provide spinning and supplemental reserves, but this issue should not be comingled with determination of Flexibility needs.

3.2. Participation of DVERs

The ISO should ensure that the procurement guidelines and market rules take maximum advantage of the ability of DVERs to provide an economic source of Flexibility.

- Day-ahead Shaping Capacity. DVERs can provide Flexibility through Dec A and Inc B bids as discussed above. The quantity of Flexibility available for Day-Ahead Shaping is defined by the Day-Ahead forecast of DVER production during each hour. For example, Table 2 below shows the DA forecast of DVER production for solar and wind by hour. Assuming an error margin of 20%, the table shows that over 8000 MW of DVER might be available to provide upward Flexibility through Dec A bids during Hour Ending 9:00 through Hour Ending 16:00. The resources would simply need the capability to follow an hourly dispatch signal.

Table 4. Example estimate of available upward Day-Ahead Shaping Flexibility from DVERs through Dec A bids

	Hour Ending:																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
DVER - Solar (MW)	0	0	0	0	0	1000	2000	4000	8000	9000	9500	9900	9900	9500	9000	8000	4000	2000	1000	0	0	0	0	0
DVER - Wind (MW)	3000	2900	2800	2700	2600	2500	2400	2300	2200	2100	2000	2000	2000	2000	2000	2000	2000	2100	2200	2300	2400	2500	2600	2700
Error Margin	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Total Dec A Bids (MW)	2400	2320	2240	2160	2080	2800	3520	5040	8160	8880	9200	9520	9520	9200	8800	8000	4800	3280	2560	1840	1920	2000	2080	2160

- Fifteen- and five-minute Flexible RA product. If the DVER has the capability of following a dispatch signal over a 15-minute or 5-minute time frame, these resources would also be available to provide downward or upward Real-Time Flexibility. Table 3 shows an example calculation of five-minute Flexibility available from DVERs based on 5-minute production forecasts. Here we have introduced a random element to the production forecast to represent anticipated cloud cover, wind variations, etc. We have also assumed a 50% error margin to ensure that the resources the is relying on for real-time Flexibility are actually available for dispatch at the required quantities, subject to forecast error.

Table 5. Example estimate of available upward Day-Ahead Shaping Flexibility from DVERs through Dec A bids

	Minute											
	5	10	15	20	25	30	35	40	45	50	55	60
DVER - Solar (MW)	8879	8828	8750	8743	8633	8553	8422	8273	8152	8172	7990	8058
DVER - Wind (MW)	1997	2002	2004	1995	1972	2027	1900	1924	1961	2049	1951	2026
Error Margin	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Total Dec A Bids (MW)	5438	5415	5377	5369	5303	5290	5161	5099	5056	5111	4970	5042

It should be noted that deployment of DVER to meet Flexibility needs requires "pre-curtailment", i.e. prospective curtailment of VER generation in order to avoid a situation in which the system runs out of Flexibility and cannot meet an upward or downward ramping need. This requires the ISO to have a "look-ahead" process in which the potential upward and downward net load ramps are assessed, bids for providing Flexibility products are considered, the least-cost set of Flexibility resources are selected.

3.3. Answers to ISO DVER Questions

The ISO posed the following question related to provision of Flexibility by DVERS:

1. How should the ISO determine the EFC for VERs willing to economically bid into the ISO markets?
2. What additional studies are needed to ensure that any EFC capacity is deliverable?

We provide the following answers based on the discussion above.

1. EFC for DVERs should be determined based on the forecast production as demonstrated above. For Day-Ahead Shaping Flexibility, the determination should be made based on hourly production forecasts. These represent the ability of DVERs to provide Flexibility through submission of Dec A bids, on a timestep that is consistent with unit commitment decisions made by the ISO to address daily Flexibility needs. It would be reasonable for the ISO to incorporate an error margin, e.g., 20%, to reflect the potential uncertainty and forecast error associated with DVER production. This error margin should be determined empirically based on statistical analysis of load and DVER variation, taking into consideration the fact that Flexibility need is highly correlated with VER production.

2. No deliverability requirement is necessary for Flexibility. The ISO's delivery requirement is based on delivery of Capacity to load pockets during peak load conditions. The need for Flexibility is defined by variations in system net load, which is a function of load and VER production everywhere on the ISO system, e.g., solar production in the Mojave Desert and load in the Bay Area. It would be inappropriate and counterproductive to assign a specific delivery point for Flexibility, since the geographic source of the net load variation cannot be known in advance.

   If the ISO is concerned about the need for Flexibility in a given area, it should perform a study of the flexibility needs *for that area*, taking into consideration the variation in load and VER production in that area in addition to the ability of imports and exports to vary over multiple time scales.

4. Summary of Recommendations

We provide the following summary of our recommendations to the ISO with respect to determine the needs for Capacity and Flexibility.

1. The ISO should define the need for and capability of providing Capacity and Flexibility products independently of each other.

2. The ISO should define four products to ensure sufficient Capacity and Flexibility for reliable operations:

a. Monthly Resource Adequacy Capacity, with a Planning Reserve Margin sufficient to ensure adequate spinning and non-spinning reserves;

b. Day-Ahead Flexibility, based on rolling 3-hour upward and downward ramping needs throughout the operating day;

c. Fifteen-minute Flexibility, based on the potential deviation from the DA to the 15-minute timeframes; and

d. Five-minute Flexibility, based on potential deviations from the 15-minute to the 5-minute timeframe.

3. The ISO should ensure that its calculation of Flexibility needs is statistically rigorous, incorporates important correlations, and does not double-count the need for Flexibility during alternative timeframes.

4. The ISO should enable participation by DVERs in providing Flexibility products based on the Dec A/Inc B framework described above.

5. The ISO should implement a "look-ahead" process where it calculates potential upward and downward ramping needs over multiple time periods and selects bids for provision of Flexibility products, including from DVERs, to minimize total system costs.

6. The procurement framework should facilitate the submission and evaluation of separate capacity reservation and usage components to ensure a fair comparison between thermal, DVER and demand-side Flexible resources.