Qualifying Capacity and Effective Flexible Capacity Calculation Methodologies for Energy Storage and Supply-Side Demand Response Resources

Revised Staff Proposal
Resource Adequacy Proceeding R.11-10-023
California Public Utilities Commission – Energy Division

April 9, 2014

Introduction

This Revised Energy Division (ED) Staff Proposal (Revised Proposal) recommends methodologies for the California Public Utilities Commission (CPUC) determination of Qualifying Capacity (QC) and Effective Flexible Capacity (EFC) for energy storage and supply-side demand response (DR) resources. A resource's QC is the number of megawatts eligible to be counted towards meeting a load serving entity's (LSE's) System and Local Resource Adequacy (RA) requirements, subject to deliverability constraints.[1] A resource's EFC is the number of megawatts eligible to be counted towards meeting an LSE's Flexible RA requirements.

As part of the RA proceeding (R.11-10-023), ED staff has considered a variety of approaches to capacity calculations, and has considered stakeholder comments in response to the Draft Staff Proposal and Staff Proposal Outline, published in September 2013 and January 2014, respectively. This Revised Proposal represents the final version of the staff proposal. Parties will be able to submit formal comments following an associated workshop on April 9, 2014. Party comments will inform the development of a Proposed Decision, and will become part of the rulemaking's record. In addition, the comments submitted in response to this Revised Proposal may inform staff efforts in the storage and DR as well as other related proceedings, for example in the development of performance testing protocols.

The only storage and DR resources that are included in the scope of this Proposal are those that bid or self-schedule into California Independent System Operator (CAISO) markets and are subject to a Must-Offer Obligation (MOO). These resources are: transmission-level energy storage, some distribution-level and behind-the-meter storage (depending on whether it is operated in accordance with the above requirements), and supply-side demand response.[2]

[1] The revised QC that incorporates deliverability constraints is called the Net Qualifying Capacity (NQC).

[2] Information on the energy storage and demand response proceedings, including additional details on what types of resources are considered to be energy storage and supply-side demand response, can be found at http://www.cpuc.ca.gov/PUC/energy/electric/storage.htm and http://www.cpuc.ca.gov/PUC/energy/Demand+Response/DemandResponseWorkshops.htm, respectively.

Supply-side demand response is distinguished here from customer-focused programs and rates and existing "Retail DR" utility programs. On March 27, 2014, the Commission adopted D.14-03-026, which adopted the bifurcation framework for DR programs. In the next phase of the DR Rulemaking, R.13-09-011, the Commission will begin the process of defining programs as Supply Resources and Load-Modifying Resources. ED staff will coordinate across both that rulemaking and the RA rulemaking to ensure consistency. Customer-focused programs and rates (and existing Retail DR programs) will continue to receive RA credit in the 2015 RA compliance year as they have in past years, according to existing rules; they are not addressed in this document.

RA Eligibility Requirements for Energy Storage and Supply-Side DR

Operational Requirements

To the extent possible, System, Local, and Flexible RA eligibility requirements should remain consistent across all resource types, including storage and supply-side DR. These requirements include the ability to operate for at least four consecutive hours at maximum power output ($Pmax_{RA}$), and to do so over three consecutive days.

Resources wishing to qualify for System or Local RA must also have the capability to offer into the CAISO markets, either via economic bids or via self-scheduling, under the Must Offer Obligation (MOO) applicable for that resource type.

Resources that wish to be qualified as Flexible RA must comply with the bidding and availability requirements expressed in the CAISO's Flexible RA Criteria and Must Offer Obligations (FRAC-MOO).[3] However, storage and DR resource operators that wish to receive Flexible RA credit for charging capacity need not meet the storage-specific requirements of FRAC-MOO. Specifically, no resource is required by the CPUC to register as a non-generating resource (NGR) in order for charging capability to contribute towards that resource's Commission-adopted EFC.

Co-located storage operating in conjunction with (i.e., not independently dispatchable from) another, larger RA-eligible resource need not meet the RA eligibility requirement of being able to operate for four

[3] A must-offer obligation, or MOO, is a commitment to be available for economic dispatch by the CAISO during standard hours that are set by the CAISO. The MOO, which sets a window of availability for dispatch, is distinct from the four hour capability requirement for continuous operation upon dispatch. System and Local RA resources, whether DR or storage, may either bid into the CAISO markets or self-schedule. The recently-approved MOO for Flexible RA resources (FRAC-MOO) aims to ensure that flexible resources will be available to contribute to the times of greatest system ramping. The FRAC-MOO requirements can be found at https://www.caiso.com/informed/Pages/StakeholderProcesses/FlexibleResourceAdequacyCriteria-MustOfferObligations.aspx and http://www.caiso.com/Documents/Board%20of%20Governors%20meetings/Board%20of%20Governors%20meetings%20-%202014/Board%20of%20Governors%20meeting%20Mar%2019-20,%202014/Board%205)%20Decision%20on%20flexible%20resource%20adequacy%20criteria%20and%20must%20offer%20obligation.

consecutive hours on three consecutive days; the RA qualification of the primary generating facility is sufficient.

Future modeling of reliability may indicate ways in which some of the above requirements could be altered; future RA proceedings will be informed by that analysis. For example, ED's ongoing reliability modeling study may suggest that resources that are currently RA-ineligible can nevertheless contribute to reliability. Once this study is complete, the Commission may revisit the RA eligibility rules for all resources. Several parties also suggested that Flexible and System RA be unbundled for storage and DR resources; in other words, they request that Flexible RA resources not be required to meet System RA requirements. Because the bundling rule currently applies to all resource types, it will not be considered in this Proposal. However, staff may further examine unbundling and its implications in future years.

Resource Aggregation

Energy storage resources located within a single Sub-LAP may be aggregated to form a single, RA-eligible storage resource. DR resources located within a single Sub-LAP may be aggregated to form a single, RA-eligible DR resource. Storage and DR may not be jointly aggregated to create a combined Storage-DR resource at this time, but staff looks forward to exploring this possibility in future RA compliance years. Staff acknowledges some parties' support for larger aggregation granularity (e.g., by Local Capacity Area for Local RA, or DLAP for System/Flexible RA), and looks forward to coordinating with the CAISO on this matter for future RA compliance years. To be eligible for Local RA, storage and DR assets must be located within a single Sub-LAP or Custom LAP *and* within a single Local Capacity Area.

Elements of aggregated resources need not individually meet RA eligibility requirements; rather, the resource as a whole must demonstrate eligibility. For example, a demand response provider may aggregate one resource that provides up to 1 MW for up to two hours and is available between the hours of 1 and 4 pm with another resource that is able to provide up to 1 MW for up to two hours and is available between the hours of 3 and 6 pm, in order to create an aggregated resource that is able to provide up to 1 MW for up to four hours and is available between the hours of 1 and 6 pm. An additional example of resource aggregation is shown in Figure 1, below.

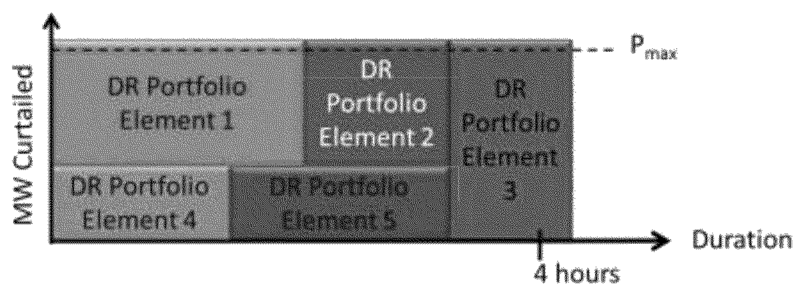

Figure 1. Supply-side demand response resource aggregation example

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CPUC Testing and Verification Requirements

QC and EFC determinations shall incorporate historical performance data where possible. To the extent that historical performance data is not available or appropriate, program design and/or test data may be used. Resource operators may elect to request a QC or EFC that is lower than that calculated by Energy Division, if they wish to reduce the amount of capacity that is subject to a MOO. For example, operators may request to qualify an aggregate resource for an RA capacity that is less than its theoretical maximum output, as illustrated in Figure 1 above, in order to account for anticipated non-performance in some portion of the portfolio. This would allow operators to account for some storage not being in the desired state when dispatched, or to account for a portion of DR participants overriding dispatches.

In proposing the rules that follow for the 2015 RA compliance year, staff looks forward to further refinement of testing and performance reporting protocols in future years, as it seeks to balance the needs for verifiable performance, practical feasibility, and reasonable cost. Additionally, the Commission may consider testing and assessment protocols that can measure the performance of storage and supply-side demand response resources as part of the storage and demand response proceedings.

Demand Response Testing and Verification Requirements

Testing Requirements

DR must be tested and/or dispatched at least once annually, to demonstrate initial and continued performance. Testing should simulate expected dispatch conditions, including adherence to the notification period specified in the applicable CAISO tariff, and two-hour testing is required to ensure performance does not degrade over the course of operation. Resources offering both curtailment (reducing customer consumption) and dispatchable load (increasing customer consumption) must demonstrate both operational modes in testing. These two modes may be demonstrated in either one single test event or in two separate test events, as required to comply with CAISO testing requirements and any DR evaluation rules that are promulgated by ED in the future.

Operators should be paid for the test event exactly as if it were a regular dispatch event. This testing will be designed in coordination with the CAISO, to avoid duplicative testing. The testing must only be repeated if the DR program is not dispatched for two or more consecutive hours at any time over a given twelve-month period. If the DR is dispatched for at least two consecutive hours on at least one day during a rolling twelve-month period, additional testing is not required.

DR wishing to qualify as Flexible RA must submit to testing that occurs within the applicable must-offer obligation window; this time window will depend on the Flexible RA category for which the resource wishes to qualify, as described in the recently-approved CAISO FRAC-MOO proposal. This testing should occur within a three-month period chosen by the demand response provider, with the day and time randomly selected by the CAISO. The CAISO should still provide the advance notification specified in the applicable tariff. In other words, while the date and time may be randomly selected by the CAISO, a resource with a tariff that requires four hours of advance notice will still receive at least four hours' notice of the test dispatch.

Successful testing to qualify as Flexible RA will be deemed sufficient for qualification as System and Local RA, provided that the program design complies with those product types. Namely, the program must be available during at least four of the standard availability assessment hours each day to qualify as System RA, and the program must also be locally dispatchable to qualify as Local RA.

If a resource does not wish to qualify for Flexible RA, it must submit to similar testing in order to be qualified as a System or Local RA resource; however, this testing may be conducted at a time of the operator's own choosing, rather than at a time selected by the CAISO. The timing shall nevertheless be constrained to the standard availability assessment hours that apply to System and Local RA resources.

Performance Assessment

DR performance will be measured based on ex-post (after-the-fact) analysis of testing and dispatches using the load impact protocols, as is already the case for the utilities' current DR programs (Retail DR).[4] In determining the resource's QC and EFC, test results may be adjusted by the CPUC to reflect anticipated changes in weather, enrollment, or program design. Resource operators may request such adjustments if they submit documentation of anticipated changes to ED (such as new enrollment data or program design changes). If ED chooses to adjust test results (whether upwards or downwards), an explanation of the adjustments made will be made publicly available.

Energy Storage Testing and Verification Requirements

Energy storage must be tested in the same manner as fossil generators, and the results must also be submitted to the CAISO in the same manner as for fossil generators. However, storage resources must demonstrate not only maximum and minimum rated discharge levels (in MW), but also maximum and minimum rated charging levels (in MW).[5] Resource operators must also submit additional relevant resource characteristics to the CAISO for inclusion in its MasterFile, as listed and described in the *Nomenclature* section below.

Reporting for Aggregated Resources

In accordance with applicable CAISO tariffs, aggregated resources may provide performance data from a single aggregation point and need not report individual element performance in real time or on a regular basis. Regardless of aggregation, individual element performance data must be made available to the CPUC and the CAISO for auditing and verification purposes upon request and as part of initial testing for RA qualification.

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[4] The load impact protocols were specified by Decision 08-04-050, and modified by Decision 10-04-006.

[5] For further clarification on the various charge/discharge levels, see the *Nomenclature* section below.

Approach Recommended for QC and EFC Calculations for the 2015 RA Compliance Year

Qualifying Capacity (QC)

Staff recommends that dispatchable storage receive a QC in the same manner as other dispatchable resources, including testing and verification in CAISO operations. Because all RA resources must be able to operate for four or more consecutive hours, the storage operator must submit to the CAISO an output level (in MW) at which the resource is capable of discharging for four or more uninterrupted hours; this is defined to be its $Pmax_{RA}$, the maximum output that can be considered for RA calculations. Like fossil generators, the storage facility must then submit to physical testing by the CAISO to verify that it can be dispatched at this capacity. The QC will be equal to this $Pmax_{RA}$ value. The facility will also be subject to the standard CAISO NQC process, whereby the Net Qualifying Capacity of a resource is limited to an output level that is deliverable to the aggregate of CAISO load; this process is also undertaken for conventional resources.

Storage facilities may also submit a short-term maximum rated output to the CAISO, for dispatch purposes. This is defined as the resource's Pmax, and is a value which could be greater than $Pmax_{RA}$. If the Pmax output duration is below the four hour requirement for RA eligibility, it cannot be used as the $Pmax_{RA}$ value in RA credit determinations.

DR resources should receive QC values based on the load impact protocols, in the same manner as existing Retail DR. Adjustments may be made by CPUC staff as described in the Demand Response Testing and Verification Requirements section.

Effective Flexible Capacity (EFC)

EFC Framework

Storage and DR resources should receive an EFC in accordance with the currently-adopted bundling principle, which holds that all Flexible RA resources must also qualify as System RA resources. In other words, storage and DR facilities wishing to qualify for Flexible RA must also be qualified for System RA, and must receive QC values as described previously. Additionally, $Pmax_{RA}$ values for Flexible RA shall be identical to those utilized in determining the resource's System RA credit, and set according to the rules previously described.

EFC should incorporate dispatchable load and charging (for DR and storage, respectively) because these operational modes can address ramping needs. Qualifying capacity, because it solely aims to address capacity shortfalls, should not incorporate these operational modes. This difference will frequently result in EFC being greater than QC. While EFC is currently limited to be less than or equal to NQC, Staff recommends that the Commission modify that rule to allow EFC to be limited by the greater of NQC and (NQC – $Pmin_{RA}$), where $Pmin_{RA}$ is the minimum sustainable operating level of a facility, as defined in more detail below. If a facility is capable of dispatchable charging (in the case of storage) or load increase (in the case of DR), its $Pmin_{RA}$ will be negative.

All facilities are subject to CAISO testing to verify the submitted $Pmin_{RA}$, as previously described in the *CPUC Testing and Verification Requirements* section. Negative $Pmin_{RA}$ will also be subject to limits on how much charging is possible given transmission or other physical constraints, if the CAISO develops deliverability or other physically-based assessments for that condition. Staff does not recommend adoption of the EFC counting convention described in the CAISO FRAC-MOO initiative as a methodology for limiting $Pmin_{RA}$, unless that approach is revised in the future to be based on deliverability or operational studies.

Staff recommends that all EFC values be based on the currently-adopted definition of flexibility: the ability to ramp and sustain output over three hours.[6] Because storage and demand response resources can have positive generation (discharge or load curtailment), negative generation (dispatchable charging or load increase), or both positive and negative operating ranges, and because certain resources are better suited to either ramping or sustaining output, multiple methodologies are recommended to address the multiple operational modes permissible for flexible resources under the current definition.

Based on its understanding of the FRAC-MOO Fifth Revised Straw Proposal, staff believes that the EFC calculation methodology described in this Staff Proposal is consistent with the FRAC-MOO proposal, with the following exceptions:

1. Resources with negative operating capability (dispatchable charging or load increase) need not be registered as non-generating resources.
2. Resources need not ramp over three hours; sustained output is also acceptable.
3. Up to 45 minutes of transition time between negative (charging or load increase) and positive (discharging or load curtailment) operational modes is permitted, and does not count towards the three hour period, as described in Case 3 below. Discontinuity in dispatchable output is also permitted during this transition time (e.g., due to minimum pump loads).
4. For resources that have both negative and positive operating capability (dispatchable charging or load increase and dispatchable discharging or load curtailment), charging or load increase energy is limited to double the discharging or load curtailment energy.
5. Positive generation is limited to the $Pmax_{RA}$ calculated for System RA eligibility (in accordance with the currently adopted policy of bundling System and Flexible RA) and remains subject to NQC derating.

Nomenclature

Conventional generators in the RA program are described by two key operational points: Pmax, the maximum sustainable output, and Pmin, the minimum sustainable output. Storage and demand response resources, on the other hand, are characterized by up to four operational points (all in MW):

[6] D.13-06-024, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M070/K423/70423172.PDF.

1. $Pmax_{RA}$ – the maximum output sustainable for four hours (as described in the QC section above); may be less than the maximum rated discharge/curtailment level.

2. $Psupply_{min}$ – a positive number representing the minimum amount of discharging or load curtailment that is sustainable for three or more consecutive hours (for example, the minimum amount of DR that may be dispatched); does not apply to resources with only negative operating ranges, and may be zero for resources that do not have physically or programmatically-constrained minimum output levels.

3. $Pdemand_{min}$ – a negative number representing the smallest magnitude of charging or load increase that is sustainable for the duration required in calculating EFC (for example, minimum pump loads); does not apply to resources with only positive (discharging or load curtailment) operating ranges, and may be zero for resources that do not have physically or programmatically-constrained minimum charging/load increase levels.

4. $Pmin_{RA}$ – either equal to $Psupply_{min}$ for resources with only positive operating ranges (those that can only discharge), or a negative number representing the largest magnitude of charging or load increase eligible for consideration in calculating EFC, as described further below; if negative, may be smaller in magnitude (closer to zero) than the maximum rated charge or load increase level.

Storage and demand response resources are also described by several other operating characteristics:

- Ramp Rate – the maximum MW/minute by which a facility can increase its power output over a particular output interval (for example, from 20 to 50 MW). An increase in output is defined as a change in output that is in the direction from $Pmin_{RA}$ to $Pmax_{RA}$ (i.e., more positive generation or more load reduction); for DR, for example, increased output means an increase in the magnitude of load that is reduced. The ramp rate may change over different segments of operation; for example, a facility's ramp rate may be lower between 10 and 20 MW than it is between 20 and 50 MW.

- ARR (MW weighted average ramp rate) – the MW encompassed by a given operating range, divided by the amount of time it takes the facility to increase its output from the bottom to the top of the range. For resources with a negative operating range, ARR_{neg} covers the range from $Pmin_{RA}$ to $Pdemand_{min}$. For resources with a positive operating range, ARR_{pos} covers the range from $Psupply_{min}$ to $Pmax_{RA}$.

- Round Trip Efficiency (only applies to storage with both charging and discharging capabilities) – the efficiency with which a storage resource takes charge and converts it to discharge. This value is a percentage that represents the portion of the charge that can be discharged, considering losses. This value is equivalent to the ENERGY_EFFIC variable in the CAISO MasterFile.

- Available Energy – the total MWh of energy available to be discharged from a storage device (or to be dispatched from a single call of a DR resource). This is equivalent to the MAX_CONT_ENERGY_LIMIT variable in the CAISO MasterFile.

- Transition Time – the time it takes for a storage or demand response facility to switch from positive generation (discharge or load curtailment) to negative generation (charging or load increase), or vice versa. In the case of pumped storage, this variable is equivalent to the MIN_DWN_TM_PG and MIN_DWN_TM_GP variables in the CAISO MasterFile.

- Shut-down Time – the time it takes for a resource to fully shut down, or to cease charging/discharging (or to cease increasing/decreasing load relative to baseline). For pumped storage facilities, this variable is equivalent to the PUMP_SHTDWN_TM variable in the CAISO MasterFile.

$Pmin_{RA}$ Methodology Examples

Case 1: Storage or DR with only positive output ranges (discharge/curtailment only)

Storage and DR resources with *only positive output ranges* have a $Pmin_{RA}$ equal to the minimum operating level (in MW) sustainable for three or more consecutive hours (equivalent to $Psupply_{min}$). $Pmin_{RA}$ may be zero, if the resource does not have a non-zero minimum output constraint. For example, consider a DR resource that can curtail only, and can curtail anywhere between 1 and 2 MW when dispatched. If the resource can curtail at its minimum level (1 MW) over three or more hours, then that 1 MW is its $Pmin_{RA}$. This example is illustrated in Figure 2, below.

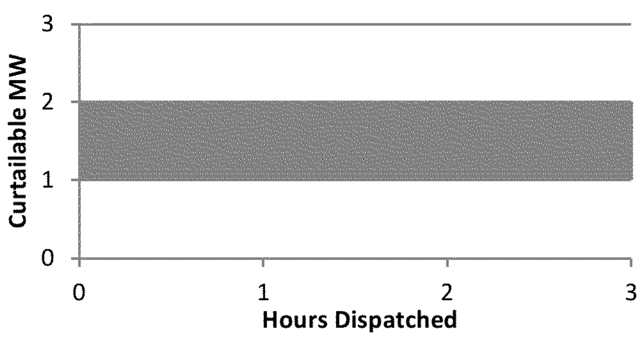

Figure 2. An example DR resource with $Pmin_{RA}$ = $Psupply_{min}$ = 1 MW

Case 2: Storage or DR with only negative output ranges (dispatchable charge/load increase only)

Facilities with a *negative operating range only* (i.e., a $Pmax_{RA}$ of zero) must submit a $Pmin_{RA}$ value that is either sustainable for the full three hours required for Flexible RA eligibility, or that can serve as a starting point for upward ramping (generation becoming less negative) at a constant rate over the course of the three hours required for Flexible RA eligibility. They must also submit $Pdemand_{min}$, which represents the smallest magnitude of charging or load increase that is dispatchable (such as minimum pumping loads or the minimum increment of load increase that can be dispatched).

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For example, if a 12 MWh storage resource is capable of dispatchable charging but not of dispatchable discharging, then its $Pmin_{RA}$ would be −12 MWh ÷ 3 hrs = −4 MW (unless the resource is further limited by its maximum rated charging capability), if the operator chooses the sustainable operation option.[7] The minus sign in this example indicates charging mode. This example is illustrated in Figure 3, below.

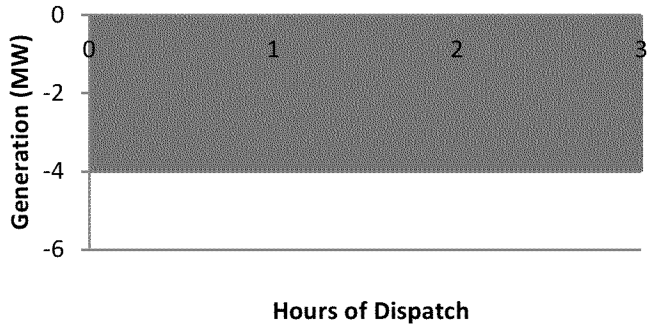

Figure 3. An example 12 MWh resource with dispatchable charging, no dispatchable discharging, and Pmin $_{RA}$ = -4 MW

Alternatively, if the operator chooses the upward ramping option, $Pmin_{RA}$ will be based on the ability to ramp upwards from $Pmin_{RA}$ to $Pdemand_{min}$ over three hours. If the resource has a $Pdemand_{min}$ of zero (meaning that it can ramp continuously to 0 MW), the resource will have a $Pmin_{RA}$ of −8 MW. This is because the −12 MWh of available charging energy is equal to the area of the triangle with height of −8 MW and base of 3 hours: 0.5 * −8 MW * 3 hrs = −12 MWh). This example is illustrated in Figure 4, below.

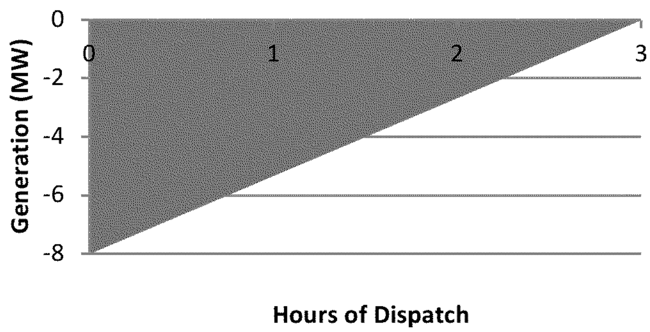

Figure 4. An example 12 MWh resource with dispatchable charging, no dispatchable discharging, and Pmin $_{RA}$ = -8 MW

If the resource is unable to ramp all the way to 0 MW (for example, due to pumps that have minimum energy requirements for operation), then $Pdemand_{min}$ is equal to the smallest possible magnitude of charging or load increase. For example, if the resource with −12 MWh of available charging energy has a $Pdemand_{min}$ of −1 MW, then the resource will have a $Pmin_{RA}$ of −7 MW (−1 MW from $Pdemand_{min}$ and −6

[7] Storage resources are typically rated based on the total discharge volume, not their charge capabilities; assuming that convention, this example neglects round-trip efficiency and depth of charge considerations. More precisely, the resource needs to be capable of accepting 12 MWh in charging energy (and have a maximum rated charging capability of at least 4 MW) in order for it to have a $Pmin_{RA}$ of −4 MW.

MW from ramping): −1 MW * 3 hrs + 0.5 * −6 MW * 3 hrs = −12 MWh. This example is illustrated in Figure 5, below.

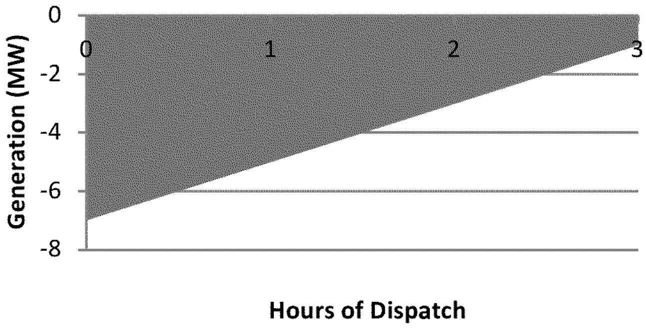

Figure 5. An example 12 MWh resource with dispatchable charging, no dispatchable discharging, and $Pmin_{RA}$ = -7 MW

More generally, the $Pmin_{RA}$ for a resource with only negative operating range that chooses the upward ramping option can be expressed as the lowest magnitude of either (1) the maximum rated charging or load-increase capability in MW, or (2) the largest magnitude of charge or load increase in MW from which the resource can ramp continuously for three hours, as shown in the equation below:

The equation above (which reflects the geometric calculations shown in the previous examples) can be algebraically simplified to:

where $Pdemand_{min} \leq 0$ and is sustainable for at least 3 hours, and Maximum Available Energy < 0.

<u>Case 3: Storage or DR with both positive and negative output ranges</u>

Facilities with *both positive and negative operating ranges* must submit to the CAISO a $Pmin_{RA}$ (in MW) at which the facility is capable of charging (or increasing demand) for 1.5 or more uninterrupted hours, where $Pmin_{RA}$ is either sustained at a constant level or serves as a starting point for continuous upward ramping at a constant rate. Such facilities can thus meet the three-hour ramping requirement for flexibility by charging (or increasing demand) for the first half of the three-hour ramp and then discharging at or above $Pmax_{RA}$ for the remainder of the ramp.

For example, if a 12 MWh storage resource with 100% roundtrip efficiency is capable of dispatchable charging and of dispatchable discharging and chooses the sustainable output option, then its $Pmin_{RA}$ would be −12 MWh ÷ 1.5 hrs = −8 MW (unless the resource is further limited by its maximum rated charging capability), if the operator chooses the sustainable operation option. The minus sign in this example indicates charging mode. Its $Pmax_{RA}$ would remain equal to its 4-hour dispatch capacity, as calculated for its System RA QC value. In this case, $Pmax_{RA}$ = 12 MWh ÷ 4 hrs = 3 MW. Because of the bundling concept, whereby all Flexible RA must also be qualified as System RA, this value remains in effect despite the fact that for flexibility, only 1.5 hours of discharge are expected. This example is illustrated in Figure 6, below.

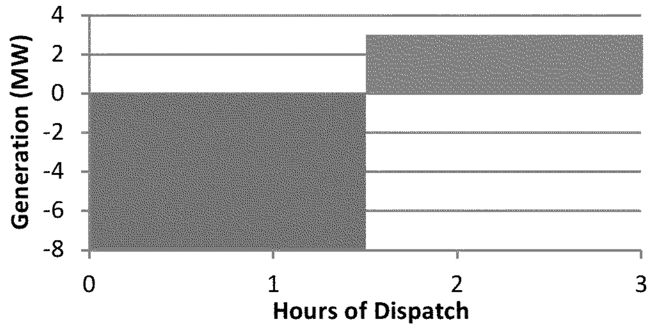

Figure 6. An example 12 MWh resource with dispatchable charging and discharging, $Pmin_{RA}$ = -8 MW, and $Pmax_{RA}$ =3 MW

Alternatively, if the operator chooses the upward ramping option, $Pmin_{RA}$ will be based on the ability to ramp upwards from $Pmin_{RA}$ to $Pdemand_{min}$ over 1.5 hours. If the resource has a $Pdemand_{min}$ of zero (meaning that it can ramp continuously to 0 MW), then a 12 MWh resource with 100% roundtrip efficiency will have a $Pmin_{RA}$ of −16 MW. This is because the −12 MWh of available charging (or load increase) energy is equal to the area of the triangle with height of −16 MW and base of 1.5 hours: 0.5 * −16 MW * 1.5 hrs = −12 MWh). This example is illustrated in Figure 7, below.

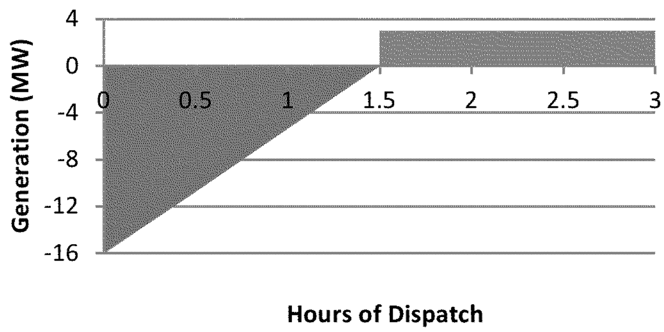

Figure 7. An example 12 MWh resource with dispatchable charging and discharging, $Pmin_{RA}$ = -16 MW, and $Pmax_{RA}$ =3 MW

If the resource is unable to ramp all the way to 0 MW (for example, due to pumps that have minimum energy requirements for operation), then $Pdemand_{min}$ is equal to the smallest possible magnitude of charging or load increase (and $Psupply_{min}$ is similarly equal to the smallest magnitude of dispatchable discharging or load curtailment). For example, if the resource with −12 MWh of available charging energy has a $Pdemand_{min}$ of −2 MW, then the resource will have a $Pmin_{RA}$ of −14 MW (−2 MW from $Pdemand_{min}$ and −12 MW from ramping): −2 MW * 1.5 hrs + 0.5 * −12 MW * 1.5 hrs = −12 MWh. This example is illustrated in Figure 8, below.

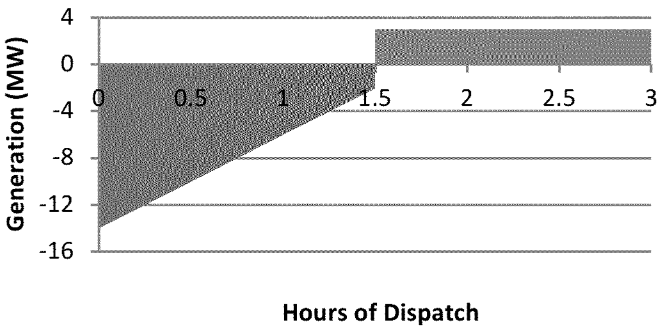

Figure 8. An example 12 MWh resource with dispatchable charging and discharging, $Pmin_{RA}$ = -14 MW, and $Pmax_{RA}$ =3 MW

More generally, the $Pmin_{RA}$ for a resource with both positive and negative operating ranges that chooses the upward ramping option can be expressed as the lowest magnitude of either (1) the maximum rated charging or load-increase capability in MW, or (2) the largest magnitude of charge or load increase in MW from which the resource can ramp continuously for 1.5 hours, as shown in the equation below:

The equation above (which reflects the geometric calculations shown in the previous examples) can be algebraically simplified to:

where $Pdemand_{min} \leq 0$ and is sustainable for at least 1.5 hours, and Maximum Available Charge or Load Increase Energy < 0.

Transition time required to go from $Pdemand_{min}$ (minimum dispatchable magnitude of charge or demand increase) to $Psupply_{min}$ (minimum dispatchable discharge or load curtailment) does not count towards these three hours of operation, and may not exceed 45 minutes. This transition time also does not impact the $Pmax_{RA}$ previously calculated. Staff requests parties' feedback as to whether 45 minutes is a reasonable transition time to permit.

Additionally, resources that have both positive and negative operational modes are expected to be relatively symmetric. To avoid major deviation from charging symmetry, maximum available energy for charging or demand increase should not exceed the maximum available energy for discharge or load curtailment by more than a factor of two. For example, a resource with a $Pmax_{RA}$ of 3 MW that can operate for four consecutive hours has a maximum available energy for discharge/curtailment of 3 MW * 4 hrs = 12 MWh. That resource is then permitted to have a maximum available energy for charging or load increase of up to –12MWh*2 = –24 MWh. Staff requests parties' feedback as to whether a factor of two is reasonable.

Ramp Rates

A ramp rate is defined as the maximum MW/minute by which a facility can increase its power output over a given operating range. The ramp rate may change over different segments of operation; for example, a 50 MW facility's ramp rate may be lower between 10 and 20 MW than it is between 20 and 50 MW. A facility's MW weighted average ramp rate is calculated based on these submitted ramp rates and is used to calculate its EFC.

Facilities with both positive and negative operating ranges will have two average ramp rates, one for each operating mode. For negative operation, ramping from $Pmin_{RA}$ to $Pdemand_{min}$ is included. For positive operation, ramping from $Psupply_{min}$ to $Pmax_{RA}$ is included. In both cases, the average ramp rate is defined as the MW encompassed by the applicable range, divided by the amount of time it takes the facility to increase its output from the bottom to the top of the range. For example, if a facility can go from $Pmin_{RA}$ = – 6 MW to $Pdemand_{min}$ = – 1 MW over the course of five minutes, then its average ramp rate in the negative operating range, ARR_{neg}, is (–1 MW + 6 MW) ÷ 5 minutes = 1 MW/minute. If the same resource can ramp from $Psupply_{min}$ = 0 MW to $Pmax_{RA}$ = 5.5 MW over the course of one minute, then its average ramp rate in the positive operating range, ARR_{pos}, is (5.5 MW – 0 MW) ÷ 1 minute = 5.5 MW/minute.

EFC Formula

Both storage and DR EFC calculations should be based on the conventional EFC formulas, with modifications to allow for negative $Pmin_{RA}$ (indicating dispatchable load or charging) and for differences in ramping rates in the two operational modes. Generally speaking, the EFC will represent the output that can be sustained or ramped over three hours. In the formulas that follow, average ramp rate is written as ARR_{pos} for the positive generation range and ARR_{neg} for the negative generation range. The start-up time is the number of minutes it takes the resource to go from being turned off (cold start) to generating at $Pmin_{RA}$. The shut-down time is the number of minutes it takes the resource to go from being at its minimum sustainable operating level to being fully turned off.

- For storage and DR resources with positive generation only (no charging or dispatchable load increase component; $Pmin_{RA} \geq 0$) and start-up time (SUT) < 90 minutes:
    - EFC = Minimum of (NQC) and ($Pmin_{RA}$ + (180 minutes – Start-up Time) * ARR_{pos})
- For storage and DR facilities with positive generation only (no charging or dispatchable load increase component; $Pmin_{RA} \geq 0$) and start-up time (SUT) > 90 minutes:
    - EFC = Minimum of (NQC – $Pmin_{RA}$) and (180 minutes * ARR_{pos})

- For storage or DR resources with negative generation only (only charging or dispatchable load increase, no discharging or load curtailment; $Pmin_{RA} < 0$ and $Pmax_{RA} = 0$[8]):
    - EFC = Minimum of ($Pdemand_{min} - Pmin_{RA}$) and (180 minutes * ARR_{neg}), plus the absolute value of $Pdemand_{min}$ iff $180 - (Pdemand_{min} - Pmin_{RA})/ARR_{neg} \geq$ shut-down time (SDT)
    - The formula above prevents an EFC that assumes the resource would go from $Pmin_{RA}$ at the beginning of the three-hour ramp to an operating point that is between $Pdemand_{min}$ and zero, because that operating point would not be physically sustainable. The resource can only ramp to an operating point between $Pdemand_{min}$ and $Pmin_{RA}$ (inclusive), or to zero (shut down). Therefore, the final $Pdemand_{min}$ term is subject to the shut-down time constraint shown, and included only if it is physically achievable for the resource to go from $Pmin_{RA}$ to zero over three hours.
- For storage or DR resources that have both curtail/discharge as well as load increase/charge components ($Pmin_{RA} < 0$ and $Pmax_{RA} > 0$):
    - EFC = Minimum of (NQC) and ($Psupply_{min}$ + 90 min * ARR_{pos}) + Minimum of ($-Pmin_{RA}$) and ($-Pdemand_{min}$ + 90 minutes * ARR_{neg})

Co-Located Storage

Energy storage that is co-located and operated in conjunction with (i.e., is not independently dispatchable from) an RA-eligible conventional facility or variable energy resource (such as wind or solar) should not receive a separate QC or EFC, and may instead modify the QC and EFC of the primary facility (to the extent permitted under the QC and EFC counting rules for that resource type).[9] In the event that a storage facility is independently dispatchable or larger than the co-located energy generator, the energy storage device will be viewed as an independently operating resource and be separately evaluated for QC and EFC. It will also require a separate deliverability study and Scheduling Resource ID (Scheduling ID) to receive an NQC value.

Aggregated Resources

Aggregated storage resources and aggregated DR resources should be granted a composite QC and EFC, based on both the duration over which the individual facilities can operate and the magnitude of their output. An example of this is shown in Figure 1, above. Resource operators may request a QC or EFC that is less than the theoretical maximum of all individual elements summed together, to account for

[8] Facilities with $Pmax_{RA} = 0$ will automatically have NQC = 0, so that term is not included. Additionally, it is impossible for $Pmax_{RA}$ to be less than zero, so that option is not defined.

[9] The calculation methodologies for wind and solar facilities have been addressed in a separate staff proposal, sent to the R.11-10-023 service list on January 16, 2014.

non-performance in a portion of the portfolio (e.g., due to state of charge or due to participant override of a DR dispatch). Storage and DR resources may not be aggregated with one another into a single storage-DR resource at this time.

QC and EFC Methodology Development Recommended for Consideration Beyond the 2015 RA Compliance Year

The proposed rules for the 2015 RA compliance year may be re-evaluated in future years as CAISO and CPUC analyses of system needs and resource benefits evolve. For example, the recent CAISO FRAC-MOO initiative will allow storage resources to bid into a regulation energy management market without bidding into the energy market. Because this proposal has not had the time to be fully vetted by parties in the RA proceeding, Energy Division staff proposes to explore the implications of this proposal for the 2016 RA compliance year.

Additionally, staff recommends that the QC and EFC for storage and DR ultimately be based on probabilistic modeling, which assesses likely system needs, rather than on deterministic modeling, which is based on a single assumed case (e.g., a 1-in-2 weather condition for DR ex-ante forecasting). The probabilistic modeling should yield:

- an Effective Load Carrying Capability (ELCC)[10], which expresses how well the resource is able to meet reliability conditions and reduce expected reliability problems or outage events (considering availability and use limitations) as compared to a "perfect" generator,[11] and
- an Effective Ramping Capability (ERC), which expresses how well the resource is able to meet three-hour upward ramping and intra-hour operational needs (considering availability and use limitations) as compared to a perfect generator.

If this approach is adopted in the future, QC and EFC would reflect the greatest magnitude of capacity available from a resource, derated by its ELCC and ERC respectively, in order to capture resource availability, use limitations, and the usefulness of the resource's operating characteristics towards meeting system needs. For example, if modeling indicates that reliability needs are greatest in the afternoon, then a resource that only operates in the morning would be derated more than an otherwise-identical resource that only operates during the afternoon. QC and EFC would then be calculated according to the following equations:

- QC = ELCC*Pmax

[10] For additional reading on ELCC methodologies, see http://www.nerc.com/docs/pc/ivgtf/ieee-capacity-value-task-force-confidential%20(2).pdf.

[11] A perfect generator has ideal operating characteristics: immediate start-up, infinite ramping capability, no use limitations, and no outages. This generator has positive output only (no charging or dispatchable load).

- EFC = ERC*(Pmax-Pmin), for Pmin < 0
- EFC = ERC*Pmax for all other resources

Staff recommends further exploring this possibility via additional staff white papers and workshops in 2014 and 2015, including publication and discussion of inputs, assumptions, and indicative QC and EFC values calculated through probabilistic methods.