California Independent System Operator Corporation

California ISO

Allocating CRR Revenue Inadequacy by Constraint to CRR Holders

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Overview

When transmission constraints are congested in the Day-Ahead market, the revenue collected by the ISO from scheduled load exceeds revenues paid to generation. The ISO's markets are designed to try to return this excess revenue to the investor owned utilities and other load serving entities that own the transmission.

The Congestion Revenue Right (CRR) process converts load serving entities' Day-Ahead market congestion rent rights into forward contracts that can be traded. Load serving entities receive the rights to some Day-Ahead congestion rents through the CRR allocation process. These load serving entities sell rights to the remaining Day-Ahead congestion rents through the CRR auction process.

The revenues received by load serving entities through the CRR auction therefore represent market participants' expected value of the Day-Ahead market congestion rents auctioned by load serving entities. In other words, the revenues that load serving entities receive from the CRR auction should over time be similar to the Day-Ahead congestion rents collected on the transmission capacity that load serving entities made available to the CRR auction.

If there were consistency between the CRR model and the Day-Ahead market model, congestion rents collected in each Day-Ahead market interval would be sufficient to pay all contractual rights to those rents that had been allocated or auctioned through the forward CRR process. However, CRR revenue inadequacy occurs when inconsistencies between the CRR and Day-Ahead market models cause the money owed to CRR holders to exceed the Day-Ahead market congestion rents collected.

Currently the ISO allocates any CRR revenue inadequacy uplift to load serving entities based on measured demand. CRR revenue inadequacy therefore decreases the total revenues received by load serving entities for the congestion revenue rights they made available to the CRR auction. In theory, this is not problematic because the revenue inadequacy represents congestion rents from auctioned capacity that was not actually available in the Day-Ahead market. In practice, however, allocating CRR revenue inadequacy based on measured demand is problematic.

CRR auction participants can increase their CRR revenues by targeting many of the specific modeling issues that caused over $200 million in CRR revenue inadequacy over the last twelve months. Therefore, allocating CRR revenue inadequacy to measured demand allows CRR market participants to increase their CRR revenues at the expense of load serving entities.

This paper describes a general methodology of allocating the CRR revenue inadequacy costs back to CRRs on an interval and constraint specific basis. This alternative allocation would limit the total amount of revenues that can be transferred from load serving entities to CRR holders through uplift. Moreover, this allocation method would reduce CRR market participants' incentives to target the modeling differences that create revenue inadequacy costs. Therefore the allocation method could reduce overall revenue inadequacy.

1 Introduction

In the Congestion Revenue Rights (CRR) process the CAISO awards forward contracts for the transmission rights that will be awarded in the Day-Ahead Market (DAM). In the Day-Ahead market the CAISO awards forward contracts for the physical transmission rights that will be awarded in the Real-Time Market (RTM). Finally, the CAISO awards the physical transmission rights through its RTM schedules.

Currently transmission rights awarded on a forward basis in the CRR market and Day-Ahead market are financially firm and fully funded. However, when the CRR market is run, the actual transmission that will be available in the Day-Ahead market is uncertain. Similarly when the Day-Ahead market is run, the actual transmission that will be available in the RTM is uncertain. Attempting to provide certainty to the payments for the forward contracts for transmission rights does not eliminate this uncertainty. Instead this uncertainty manifests in CRR Revenue Inadequacy and Real-Time Congestion Imbalance Offset (RTCIO) costs.

The full funding of the forward contracts for physical transmission creates incentives to exacerbate these revenue inadequacy costs. Allocating these costs back to the forward contracts would reduce these incentives and allow the uncertainty to be priced in the forward markets. This paper describes a method for allocating CRR Revenue Inadequacy costs back to CRR holders in a way that creates incentives for more efficient CRR auction bids.

In theory CRR Revenue Adequacy would be assured if the transmission models used in the CRR allocation/auction processes were the same as in the Day-Ahead market. However for a variety of practical reasons, when the CRR model is finalized there is inherent uncertainty in the physical transmission capacity that will actually be available at the time the Day-Ahead market is run. These reasons include:

- Unexpected forced transmission outages, potentially by non-ISO participants
- Outages posted too late for inclusion in the CRR model, potentially by non-ISO participants
- Time granularity differences between the monthly CRR products and the daily energy market
- Modeling discrepancies and errors by the ISO
- Unsettled flows in the Day-Ahead market not accounted for in the CRR market

All of these issues arose contributing to over $200 million in CRR revenue inadequacy in CAISO over the last twelve months.[1] Currently CRR revenue inadequacy costs are uplifted to load even though load may have little to no control over the causes of the inadequacy.

CRR payments and Day-Ahead congestion rent collections can both be traced back to individual constraints. The CRR "flows" over a particular constraint are paid the constraint's Day-Ahead market shadow price. CRR positions over a constraint are therefore effectively selling to the Day-Ahead market the transmission capacity that the CRRs acquired in the forward CRR market. Conversely, Day-Ahead market schedule "flows" over a particular constraint pay the constraint's Day-Ahead market shadow

[1] This revenue inadequacy value covers the period September 1st 2013 through August 18th, 2014.

price. Day-Ahead market schedules over a constraint are therefore effectively buying the transmission capacity from the CRR holders.

CRR revenue inadequacy occurs over a particular constraint when more capacity for that constraint has been sold in the CRR market than was actually available in the Day-Ahead market. When this occurs, CRR positions over the constraint are selling more transmission capacity to the Day-Ahead market than is available for Day-Ahead market schedules to purchase. By dynamically de-rating the CRRs on a constraint by constraint and interval by interval basis so that the CRR settled flows are not greater than the Day-Ahead Market settled flows, revenue adequacy could be maintained.

Allocating CRR revenue inadequacy costs by constraint back to the CRR holders in proportion to their CRR holding's effectiveness on that constraint has the equivalent effect on CRR revenue imbalances as dynamically de-rating the CRRs.[2] This allocation method has similarities to methods employed at other ISOs. The PJM[3] and MISO[4] markets allocate CRR revenue inadequacy costs back to CRR holders at an aggregated level. Harvey[5] outlines how the NYISO allocates imbalance costs due to de-rates and outages on a constraint by constraint basis to transmission owners responsible for the outages. The method described here would not allocate Real-Time congestion uplift costs to CRRs. Furthermore, it would not cause net costs to CRRs as the allocations would not be greater than the congestion revenues paid to CRRs.

The current CAISO allocation of revenue inadequacy maintains full funding of CRRs; each CRR will be paid for its full megawatt value. However, this full funding of CRRs is an accounting illusion for CRR holders who have measured demand. The current allocation method transfers the cost of all CRR holders' underfunded CRRs to CRR holders who have measured demand.

The alternative allocation method described below would instead allocate the underfunding costs from a particular constraint to all CRRs in proportion to the CRRs' exposure to the revenues from that constraint. The risks of revenue inadequacy would therefore be incorporated into the CRR bids, allowing these risks to be priced in the auctions. Moreover, this alternative allocation essentially prices CRR revenue imbalances and removes incentives for market participants to take CRR positions that

[2] This method is also described in Oren, Shmuel "Derating CRRs" November 25th, 2003 Public Utility Commission of Texas Workshop and also in Oren, Shmuel S. "Point to Point Flow-based Financial Transmission Rights: Revenue Adequacy and Performance Incentives" Chapter 3 of Financial Transmission Rights: Analysis, Experience and Prospects 2013 Rosellón, Juan and Tarjei Kristiansen Editors

[3] See Section 8 of the PJM Manual 06 "Financial Transmission Rights" Revision 15 October 10, 2013 available at: http://www.pjm.com/~/media/documents/manuals/m06.ashx. Note that there is a difference in that Oren outlines de-rating CRRs to constraint limits where here the de-rate is down to settled DAM flows.

[4] See Section 2.9.3 of the MISO Business Practice Manual "BPM 005 – Market Settlements" June 12, 1014 available at: https://www.misoenergy.org/Library/BusinessPracticesManuals/Pages/BusinessPracticesManuals.aspx.

Harvey, Scott M. "Shortfall Allocation Methodology" 2005 available at http://www.nyiso.com/public/webdocs/committees/bic_spwg/meeting_materials/2005-02-18/shortfall_alloc_whitepaper_revised_21505_clean.pdf.
Alternatively see the LECG "NYISO Congestion Reduction Proposal" 2003 NYISO Market Structures Working Group http://www.nyiso.com/public/webdocs/markets_operations/committees/bic_mswg/meeting_materials/2003-05-01/crtf_presentation_rev.pdf
http://www.nyiso.com/public/webdocs/markets_operations/committees/bic_mswg/meeting_materials/2003-05-01/dam_congestion_reductionProposal_Rev8.pdf

benefit from revenue imbalances. Therefore, this pricing mechanism may reduce revenue inadequacy and the overall underfunding of CRRs.

Allocating CRR revenue inadequacy costs to CRRs on an hourly constraint by constraint basis assigns these costs to the CRRs that receive the excess revenues from the particular constraints underlying the revenue inadequacy. This allocation method could reduce the overall revenue inadequacy costs to the market. It would not, however, reduce the importance of making the CRR and Day-Ahead transmission models as consistent as possible. The allocations would continue to be an indicator of the differences between the models and the quality of the CRR and Day-Ahead markets.

2 Background

Congestion Revenue Rights are financial contracts that are paid the difference in Day-Ahead marginal congestion costs (MCCs) between source and sink nodes for the megawatt quantity of the contract. These contracts are sometimes referred to as Financial Transmission Rights (FTRs) or Transmission Congestion Contracts (TCCs). CRRs are obtained through a combination of allocations and annual and monthly auctions for terms no shorter than one calendar month.

Equation 1 – General CRR Payments

$$Payment_j^{CRR} = MW_j^{CRR} * \left(MCC_{snk,j}^{DA} - MCC_{src,j}^{DA}\right)$$

A CRR acts as a forward contract for Day-Ahead transmission. In the Day-Ahead market (DAM) transmission costs and reservations are implicit in the energy schedules and Locational Marginal Prices (LMPs).[6] As the congestion rents collected in the DAM are used to pay the CRRs, CRRs can be thought of as selling transmission rights to the DAM energy schedules. The DAM congestion rent collections are equal to the scheduled megawatts multiplied by the marginal congestion costs summed over all settled schedules.

Equation 2 – Day-Ahead Market Congestion Rents

$$Rent^{DA} = \sum_{i=1}^{N} MW_i^{DA} * MCC_i^{DA}$$

Hogan[7] shows that, given the same transmission models are used in the CRR and DAM, if the CRRs are feasible in the CRR market (i.e., that the flows in the CRR market do not violate any constraints) there will be sufficient revenue in the DAM to cover all the payments to CRRs. CRR revenue inadequacy generally occurs because of differences in the modeling of transmission and settled flows between the CRR ad DAM models.

Equation 3 – Overall CRR Revenue Adequacy

$$CRR\ Revenue\ Adequacy = \sum_{i=1}^{N} MW_i^{DA} * MCC_i^{DA} - \sum_{j=1}^{M} MW_j^{CRR} * \left(MCC_{snk,j}^{DA} - MCC_{src,j}^{DA}\right)$$

[6] For more information, see Harvey, Scott M., William W. Hogan, and Susan L. Pope "Transmission Capacity Reservations and Transmission Congestion Contracts" 1996 available at http://www.hks.harvard.edu/fs/whogan/tccoptr3.pdf.

[7] Hogan, William W. "Contract Networks for Electric Power Transmission" Journal of Regulatory Economics, Vol.4, 1992. Alternatively, see the version available at http://www.hks.harvard.edu/fs/whogan/acnetref.pdf.

3 Sources of Revenue Imbalances

The payments to a CRR position *j* derive from the sum of the congestion costs of individual constraints. Equation 4 shows the payments to CRRs with the MCCs re-written as the sum of congestion costs from constraints indexed by *k*.

Equation 4 –CRR Payments by Constraint Congestion Components[8]

$$Payment_j^{CRR} = MW_j^{CRR} * \left(\sum_{k=1}^{K} -\lambda^k * SF_{snk,j}^k - \sum_{k=1}^{K} -\lambda^k * SF_{src,j}^k \right)$$

The payment from a particular constraint *k* is shown in Equation 5. It is the difference between source and sink node shift factors to constraint *k*, multiplied by the constraint's shadow value, multiplied by the megawatts of CRRs held. This is the amount of transmission capacity the CRR sells to the Day-Ahead Market schedules from constraint *k*, multiplied by the price of the transmission capacity in the Day-Ahead Market. The shift factor is the amount flow changes on the constraint from a one megawatt injection at a node. Shift factors and shadow values are from the market on which the CRRs settle (Day-Ahead market).

Equation 5 –CRR Payments by Constraint

$$Payment_j^{CRR,k} = MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right) * \lambda^k \; = \; CapacitySold_j^{CRR,k} * \lambda^k$$

The total capacity from a constraint sold to the DAM schedules by CRRs is the sum of the capacities sold from all CRR positions, from *j*=1 to *M*, across the constraint. The total payments to CRRs from a constraint are equal to this capacity multiplied by the shadow value on the constraint, as seen in Equation 6.

Equation 6 – CRR Congestion Payments by Constraint

$$Payments^{CRR,k} = \; \lambda^k * \sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right) = \; \lambda^k * \sum_{j=1}^{M} CapacitySold_j^{CRR,k}$$

Congestion revenues collected from the DAM energy schedules, Equation 7, are the payments the DAM schedules make to CRRs for the transmission capacity. Congestion revenues collected from the DAM are equal to the sum of the DAM settled flows over the constraint multiplied by the shadow value.

Equation 7 – Day-Ahead Market Congestion Collections from Constraint

$$Collection^{Cong,k} = \lambda^k * \sum_{i=1}^{N} -SF_i^k * MW_i^{DAM} = \; \lambda^k * \sum_{i=1}^{N} CapacityBought_i^{DAM,k}$$

[8] Constraint shadow values are multiplied by negative one in this equation due to the CAISO convention of reporting shadow values as positive; a convention which is maintained throughout this paper.

CRR revenue imbalances occur due to differences between the CRR settled flows and DAM settled flows over constraints, as can be seen in Equation 8.[9] The revenue imbalance is positive when the DAM settled flows are greater than the CRR flows, i.e. a revenue surplus. The imbalance is negative when the CRR settled flows are greater than the DAM settled flows. That is, a deficit occurs when the amount of transmission capacity the Day-Ahead schedules buy is less than the capacity for which CRRs are paid.[10] Harvey[11] describes how this imbalance, with some modifications, can be assigned to transmission owners.

Equation 8 – CRR Revenue Imbalance Deficit Occurs when CRR Flows Greater than DAM Flows

$$Imbalance^k = \lambda^k * \left(\sum_{i=1}^{N} -SF_i^k * MW_i^{DAM} - \sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k \right) \right)$$

$$Imbalance^k = \lambda^k * \left(\sum_{i=1}^{N} CapacityBought_i^{DAM} - \sum_{j=1}^{M} CapacitySold_j^{CRR,k} \right)$$

[9] This is a summation notation and DC version of the more general AC formulation developed in the Revenue Adequacy Appendix of Hogan, William W. "Contract Networks for Electric Power Transmission: Technical Reference" 1992 available at: http://www.hks.harvard.edu/fs/whogan/acnetref.pdf

[10] For a derivation of the constraint-level decomposition and analysis of CRR Revenue Inadequacy, as well as explanations of causes of CRR Revenue Inadequacy, see Bautista-Alderete, Guillermo "Revenue Adequacy of Congestion Revenue Rights" 2010 ISO Market Services paper.

[11] Harvey, Scott M. "Shortfall Allocation Methodology" 2005 available at http://www.nyiso.com/public/webdocs/committees/bic_spwg/meeting_materials/2005-02-18/shortfall_alloc_whitepaper_revised_21505_clean.pdf.

4 Potential Causes of Differing CRR and Day-Ahead Settled Flows

4.1 Unexpected or Non-modeled Outages

In order to avoid CRR revenue inadequacy, transmission outages must be known and modeled at the time the CRR Model is run. Any forced outages during the CRR settlement month, or outages that become known before the settlement month but after the deadline for inclusion in the CRR model, can create negative CRR revenue imbalances. Outages reported after the CRR model deadline on transmission lines not controlled by participating transmission owners in the CAISO can also affect the available transmission capacity within CAISO.

Such a situation occurred in April 2014 when an entity outside the CAISO balancing authority area submitted an outage that caused the PACI ITC to be de-rated after the deadline for inclusion in the CRR auction. CRR flows over the PACI ITC were about 300 MWs higher than the DAM settled flows. This resulted in about $6.1 million of negative CRR revenue imbalances.[12]

It is also possible that a transmission outage known in time for inclusion in the monthly CRR model will make previously awarded CRRs infeasible. When this occurs, the CRR model will "…increase the limits on any constraints that are overloaded as a result of transmission outages such that all previously awarded CRRs will be feasible." [13] This creates the potential for negative revenue imbalances on the constraint. This situation occurred in March 2014 when the Tracy 500 ITC was de-rated such that the CRR flows from the annual allocation and auction were greater than the limit. This resulted in approximately $3.1 million of negative revenue imbalance.

4.2 Granularity Differences

CRRs are issued for monthly (or greater) terms, while the Day-Ahead Market runs daily. Transmission outages may only last days or hours. Therefore, constraints can be modeled to precisely reflect the timeframe of outages in the Day-Ahead market, with different limits during different days and hours. However, constraints must be modeled with one single limit for the entire month (or longer) in the CRR model. This difference in modeling granularity can create revenue imbalances. Even if the average CRR flow is equal to, or less than, the average DAM settled flows, there is no guarantee that the CRR revenue surpluses will outweigh deficits. This is due to the likelihood that a constraint will have higher shadow values when the limit is de-rated.[14] Due to the potentially large number of known outages in a month and resource constraints, "…the ISO will select line outages equal to or greater than a certain number of days for analysis…"[15] The inherent differences in modeling granularity means that revenue adequacy cannot be guaranteed.[16]

[12] Constraint level revenue imbalances are estimated from market data, not settlements data.

[13] Section 10.3 of the Business Practice Manual for Congestion Revenue Rights (CRR BPM) http://bpmcm.caiso.com/Pages/BPMDetails.aspx?BPM=Congestion%20Revenue%20Rights

[14] Bautista-Alderete, Guillermo "Revenue Adequacy of Congestion Revenue Rights" 2010 develops a breakeven point analysis that can better estimate the appropriate limits to use in the CRR auction model in this scenario.

[15] CRR BPM Section 10.3.2 Part A http://bpmcm.caiso.com/Pages/BPMDetails.aspx?BPM=Congestion%20Revenue%20Rights

[16] The CAISO attempts to reduce this risk as much as practicable via a global de-rate factor, see CRR BPM Section 10.3.2 Part B.

As an example, the Palo Verde ITC had a two day and a separate three day de-rate in May 2014. These five days had $2.6 million in negative revenue imbalance. This constraint had surpluses across the other twenty-six days in May. However, across the entire month the negative revenue imbalances were $2.5 million. This was because the deficits incurred over the five de-rate days greatly exceeded the surpluses received over the rest of the month.

4.3 General Modeling Discrepancies and Errors

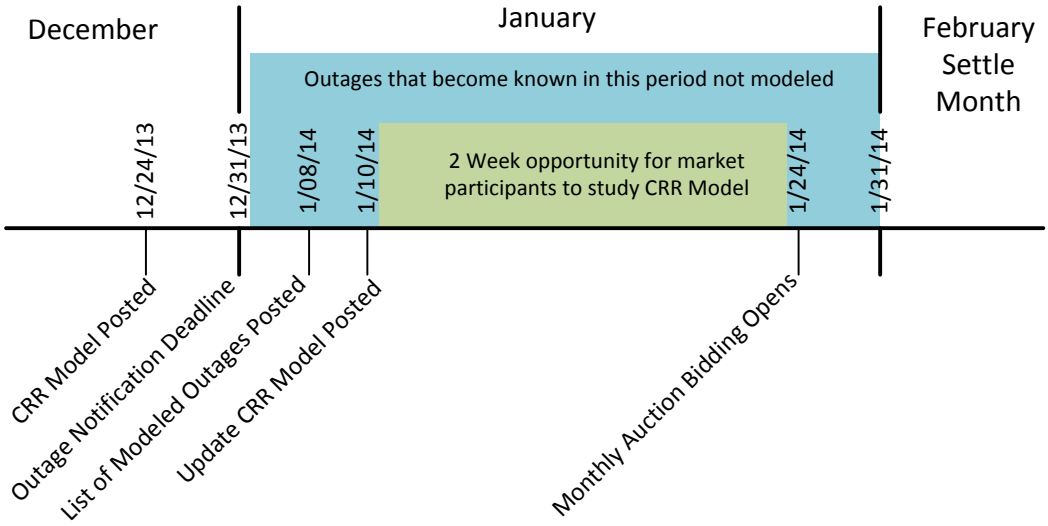
Modeling the transmission network, and ensuring the CRR and Day-Ahead models (which run on different platforms) are consistent across thousands of nodes, transmission constraints and contingency scenarios, is extremely complex. There will always be the possibility of discrepancies and errors between the models. This creates the possibility that CRR awards based on the CRR model will create CRR settled flows larger than Day-Ahead market settled flows.

Examples of this include the Palo Verde ITC in March 2014 and Tracy 500 ITC in April 2014 where there were differences in the constraint limits or node mappings between the CRR and DAM models. These differences led to CRR flows greater than DAM settled flows across both constraints. The Palo Verde modeling issue contributed to approximately $9 million in negative revenue imbalances in March. The Tracy 500 issue contributed to approximately $6.7 million in imbalances over three days in April. While the CRR flows were greater than the DAM flows across Tracy 500 all month, the constraint only bound for those three days in the DAM. Had the constraint been binding in all 30 days of April the revenue imbalances could have been much larger.

Modeling errors and discrepancies can create situations where large or unconstrained amounts of CRRs can be purchased at or near zero cost. Consider two nodes that are electrically located in the same spot except for one constraint between them. If this constraint is not included in the CRR model, CRRs that source and sink at the two nodes will have no effect on other constraints (as net injections would be zero). Their price in the CRR market will be zero because any binding constraint in the CRR market will have the same price impact on both the source and sink. If the two nodes are not the same but very similar, the net flows created by CRRs at the nodes will be very close to zero, and the effects of binding constraints on CRR prices will be small. For example, CRRs purchased at a price of zero received about $7.4 million of revenue from the Palo Verde ITC in March 2014. The constraint generated about $9 million in negative revenue imbalances from all CRRs over the month. Similarly, an outage related to the Devers transmission line from September to early October 2013 created approximately $8.6 million in negative revenue imbalance. Over $3.9 million of these revenues went to CRRs purchased at a zero price.

Finally, the timing of the CRR auction process creates opportunities for entities to target reported outages and modeling discrepancies between the CRR network model and the Day-Ahead market model. Outages reported after a certain deadline cannot be included in the CRR model. However, these outages will be included in the Day-Ahead market model. Therefore, any outages reported during the roughly month-long period after the outage reporting deadline but before the CRR auction closes will create modeling discrepancies that can be actively targeted by CRR auction participants. Allocating the CRR revenue inadequacy to the holders of the CRRs over a constraint that was de-rated during the two-week period shown in Figure 1 would eliminate most incentives CRR holders currently have to target known modeling discrepancies.

Figure 1 – Example of Monthly CRR Modeling and Auction Timeline



4.4 Unsettled Flows in the Day-Ahead Market

Ideally all DAM flows over a constraint would settle at the shadow value of the constraint. However unsettled flows occupy space on transmission constraints reducing the amount of DAM congestion rent used to pay CRRs. Unsettled flows can occur for several reasons including: differences in actual AC flows and calculated flows from the linearized DC shift factors; the use of lossless shift factors[17]; threshold levels on shift factors for inclusion in the DAM optimization; and non-settled injections or withdrawals.

From January 1st to August 18th, 2014 the difference between the congestion rent if all DAM flows paid each constraint's shadow value, and the actual rent paid from DAM schedules that settled in the Day-Ahead Market, was about $85 million. The actual effect this would have on CRR revenue adequacy depends on the cause of the unsettled flow. If the unsettled flows were due to direct injections or withdrawals in the DAM that do not pay congestion, it would cause a direct effect on revenue adequacy. If the cause affects both the DAM and CRR settled flows, the effect on revenue adequacy would depend on the net change in congestion rents collected from DAM schedules and payments to CRRs.

For example, the CAISO has a cutoff threshold that the absolute value of a shift factor must be greater than or equal to 0.02 to be included in the DAM. This can create unsettled flows. This occurs because schedules can create flows over a constraint while being at nodes whose shift factors are below the .02 threshold. Schedules at such nodes are not charged for the flow they contribute to the constraint. Removing the threshold would increase the DAM congestion rent collected from injections at the node,

[17] Lo, Edward O., and Qin Zhou "The Financial Risk of Lossless Shift Factor in ISO Energy Market and its Resolution" Power Engineering and Optimization Conference, 2013 IEEE 7th International

but may also increase payments to CRRs that source or sink at the node. Whether this increases or decreases revenue adequacy would depend on whether the rent collection increased more than the CRR payments. It was not possible to estimate this effect as data on shift factors less than 0.02 in absolute value are not available. Schedules settled at aggregated Trading Hub and Load nodes face the same shift factor threshold. If the aggregated node shift factor is below the threshold, flows created by schedules at the node will not be settled even if the schedules create injections or withdrawal at individual nodes with shift factors greater than the 0.02 threshold. Settling at aggregated nodes can magnify the threshold effect on unsettled flows.[18]

As part of the Full Network Model the CAISO plans on including flow effects of external injections into the DAM. This will create unsettled flows in the Day-Ahead market.[19] If the correct amount of capacity is not withheld from the CRR auctions and allocations this could also result in revenue inadequacy. Modeling the effect of these external injections in the CRR model would have many of the same difficulties as modeling outages. These difficulties include estimating uncertain future values of external injections and granularity differences.

[18] Thanks to the CAISO's Division of Market Validation and Quality Analysis, who spent lot of time and energy to uncover the source of unsettled flows in the IFM, and determined that the main cause in the preceding months was the .02 shift factor threshold.

[19] Modeling these external injections in the DAM will more accurately reflect RTM conditions and reduce RTCIO uplift costs.

5 Allocation of Negative Revenue Imbalances by Constraint

CRR revenue inadequacy could be eliminated by adjusting the CRR settled flows to match the Day-Ahead market flows each hour over constraints with negative revenue imbalances. Positive revenue imbalance on a constraint indicates that the CRR settled flows are less than DAM settled flows. The CRR flows are not increased because the remaining transmission capacity was not purchased by the CRR holders. Allocating the constraint specific negative revenue imbalances to the CRR settled flows over the constraint can achieve the same result as dynamically de-rating individual CRR holdings each hour.

5.1 Adjusting CRR Flows to Match Day-Ahead Market Flows

Recall that the revenue imbalance for a constraint is:

Equation 9 – CRR Revenue Imbalance

$$Imbalance^k = \lambda^k * \left(\sum_{i=1}^{N} -SF_i^k * MW_i^{IFM} - \sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right) \right)$$

A negative imbalance occurs when the CRR settled flow is greater than the DAM settled flow. By reducing the CRR MWs such that the flows are equal on an hourly basis, the imbalance on the constraint would become zero. This can be done by de-rating each CRR by the ratio of DAM flows to the CRR flows, as shown in Equation 10.

Equation 10 – Constraint CRR De-Rate Factor

$$Factor^k = \alpha^k = min\left(1, \frac{Flow^{DAM,k}}{Flow^{CRR,k}}\right) = min\left(1, \frac{\sum_{i=1}^{N} -SF_i^k * MW_i^{DAM}}{\sum_{j=1}^{M}\left(SF_{src,j}^k - SF_{snk,j}^k\right) * MW_j^{CRR}}\right)$$

The revenue neutral payment to CRR position *j* from constraint *k* is shown in Equation 11. The revenue imbalance from constraint *k* would be zero whenever the CRR settled flows equal or exceed the DAM settled flows, Equation 12.

Equation 11 – Adjusted CRR Payments after De-Rate

$$Adj.Payment_j^k = \alpha^k * \lambda^k * MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)$$

Equation 12 – Revenue Imbalances Zero as CRR and DAM Flows are Equal

$$Imbalance^k = \lambda^k * \left(\sum_{i=1}^{N} -SF_i^k * MW_i^{IFM} - \sum_{j=1}^{M} \boldsymbol{\alpha^k} * MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right) \right) = \boldsymbol{\lambda^k * 0}$$
$$when\ \alpha^k \leq 1$$

By adjusting CRR settled flows down to equal the DAM settled flows, the total amount of transmission capacity sold by CRRs to the Day-Ahead market will equal the total amount of transmission capacity purchased by DAM schedules in the Day-Ahead market. The CRR positions will not be "up-rated" if the

DAM procures more transmission capacity than CRRs sell. This is because not all the transmission capacity was purchased by the CRRs. The DAM schedules purchase the capacity in excess of the CRR flows from the transmission system.

5.2 Allocating Negative Revenue Imbalances to CRRs

The same results of de-rating CRR settled flows down to the actual DAM settled flows can be achieved by allocating the negative revenue imbalances to CRR flows on an hourly constraint specific basis. Equation 13 shows this allocation, which is the proposed alternative Revenue Inadequacy allocation formulation.[20]

Equation 13 – Allocation of Revenue Imbalance to CRRs by Constraint

$$Allocation_j^k = Neg.Imbalance^k * \left(\frac{MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)}{\sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)} \right)$$

$$where\ Neg.Imbalance^k = min\left[0\ , \lambda^k * \left(\sum_{i=1}^{N} -SF_i^k * MW_i^{IFM} - \sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right) \right)\right]$$

To show that this method has the same results as the de-rate method, first the revenue imbalance needs to be redefined in terms of α^k. As can be seen in the CRR de-rate section the difference between the unadjusted CRR payments and adjusted CRR payments is the negative revenue imbalance.

Equation 14 – Redefining Imbalance in Terms of α - Step 1

$$Imbalance^k = Payment^k - Adj.Payment^k$$

Equation 15 – Redefining Imbalance in Terms of α - Step 2

$$Imbalance^k = \lambda^k * \sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right) - \alpha^k * \lambda^k * \sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)$$

Equation 16 – Redefining Imbalance in Terms of α - Step 3

$$Imbalance^k = \left(1 - \alpha^k\right) * \lambda^k * \sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)$$

Under the allocation approach CRR *j* would first receive congestion payments from constraint *k* for their entire megawatt quantity flow, as is currently done. This can be defined as the total payments to all

[20] Note that CRRs providing counterflow would receive a payment. The allocation could be altered to take the ratio of positive flow over the sum of all positive flow CRRs. The effects of doing so are not discussed here.

CRRs from the constraint multiplied by the ratio of CRR *j*'s flows to the total flows over *k* as shown in Equation 17.

Equation 17 – Payments to CRRs written as Ratio of Total Congestion Payments

$$Pmt_j^k = \left(\lambda^k * \sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)\right) * \left(\frac{MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)}{\sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)}\right)$$

$$Pmt_j^k = TotPmts^k * \left(\frac{Flow_j^k}{TotFlow^k}\right)$$

CRR *j* is then allocated a portion of the imbalance based on its share of the flows over constraint *k*. Using Equation 16 for the imbalance, the allocation for *j* is shown in Equation 18.

Equation 18 – Allocation of Imbalance in Terms of α

$$Alloc_j^k = \left(\left(1-\alpha^k\right) * \lambda^k * \sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)\right) * \left(\frac{MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)}{\sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)}\right)$$

$$Alloc_j^k = \left(1-\alpha^k\right) * TotPmts^k * \left(\frac{Flow_j^k}{TotFlow^k}\right)$$

The net congestion payments that CRR *j* receives from constraint *k* are equal to the congestion payments from constraint *k* less the imbalance allocations from *k*.

Equation 19 – Net Payment is Total Payment less Imbalance Allocation

$$NetPmt_j^k = TotPmts^k * \left(\frac{Flow_j^k}{TotFlow^k}\right) - \left(1-\alpha^k\right) * TotPmts^k * \left(\frac{Flow_j^k}{TotFlow^k}\right)$$

Expanding Equation 19 yields:

Equation 20 – Net Payment is Total Payment less Imbalance Allocation - Expanded

$$NetPmt_j^k = TotPmts^k * \left(\frac{Flow_j^k}{TotFlow^k}\right) - TotPmts^k * \left(\frac{Flow_j^k}{TotFlow^k}\right) + \alpha^k * TotPmts^k * \left(\frac{Flow_j^k}{TotFlow^k}\right)$$

And the net congestion payment to CRR *j* simplifies to Equation 22, the same as Equation 11 under the de-rate method.

Equation 21 – Net Payments after Imbalance Allocation Equal De-rated CRR Payments - Overall

$$NetPmt_j^k = \alpha^k * TotPmts^k * \left(\frac{Flow_j^k}{TotFlow^k}\right)$$

$$NetPmt_j^k = \alpha^k * \lambda^k * \sum_{j=1}^{M} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right) * \left(\frac{MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)}{\sum_{j=1}^{J} MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)}\right)$$

Equation 22 – Net Payments after Imbalance Allocation Equal De-rated CRR Payments – By CRR

$$NetPmt_j^k = \alpha^k * \lambda^k * MW_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right)$$

From this it can also be seen that allocating revenue imbalances to CRRs is not imposing costs. It nets out the congestion revenues paid to CRRs that were never collected in the DAM. Viewed another way, this allocation method does not allow CRRs to collect payments on transmission capacity not made available to the DAM.

5.3 Real-Time Congestion Uplifts

As described above, the transmission rights held by CRRs are sold to the DAM schedules. These transmission rights are either held by DAM schedules maintained in Real-Time or traded as schedules change in Real-Time. The source of Real-Time congestion imbalances are Real-Time flows that differ from DAM flows over binding constraints, much like with CRR revenue imbalances.[21] However, as the CRRs have released the transmission capacity prior to the Real-Time Market, it would be inappropriate to allocate Real-Time congestion uplift costs to CRRs.[22]

[21] Kurlinski, Ryan E., "Real-Time Revenue Imbalance in CAISO Markets" http://www.caiso.com/Documents/DiscussionPaper-Real-timeRevenueImbalance_CaliforniaISO_Markets.pdf

[22] Hogan, William W., 2012 "Financial Transmission Rights, Up To Congestion Transactions and Multi-Settlement Systems" available at http://www.hks.harvard.edu/fs/whogan/Hogan_UTC_071612.pdf .

6 Further Discussion

The allocation of revenue imbalances back to CRRs can eliminate revenue inadequacy due to differences between the CRR and Day-Ahead market settled flows. The allocation of revenue imbalances does not create net costs for CRRs. Instead, it limits CRR revenues to money received from selling the amount of transmission capacity that was actually made available to the Day-Ahead market. Note that this is not a proposal to allocate Real-Time congestion uplift costs to CRRs.

Currently CRRs are paid for modeling differences and transmission capacity not purchased in the DAM by DAM schedules. This increases the value of the CRR to the CRR holder. In a competitive market this increased revenue potential would be included in the bids for CRRs, and the ultimate CRR auction prices. The expected allocation of the imbalances back to CRRs would be similarly incorporated into lower CRR bids and prices.[23]

However, the CRR auction can differ from this competitive ideal. The CRR awards and prices are set by the auction run by the CAISO, and not by trading between buyers and sellers.[24] Modeling discrepancies can create CRR sales that transmission owners would not make if they had the choice to sell. For example, the CRRs sold at zero prices related to Palo Verde and Devers were worth millions of dollars (see section 4.3). With no constraint between nodes in the CRR model, no shadow price was generated. The expected value of the CRRs was not, and could not be, incorporated into the CRR price. If given the option, a transmission owner would not sell these CRRs in the CRR auction. The total amount of CRRs between such nodes would be unbounded. Allocating revenue inadequacy cost to CRRs on a constraint specific basis would cap the total payments made to CRR holders.

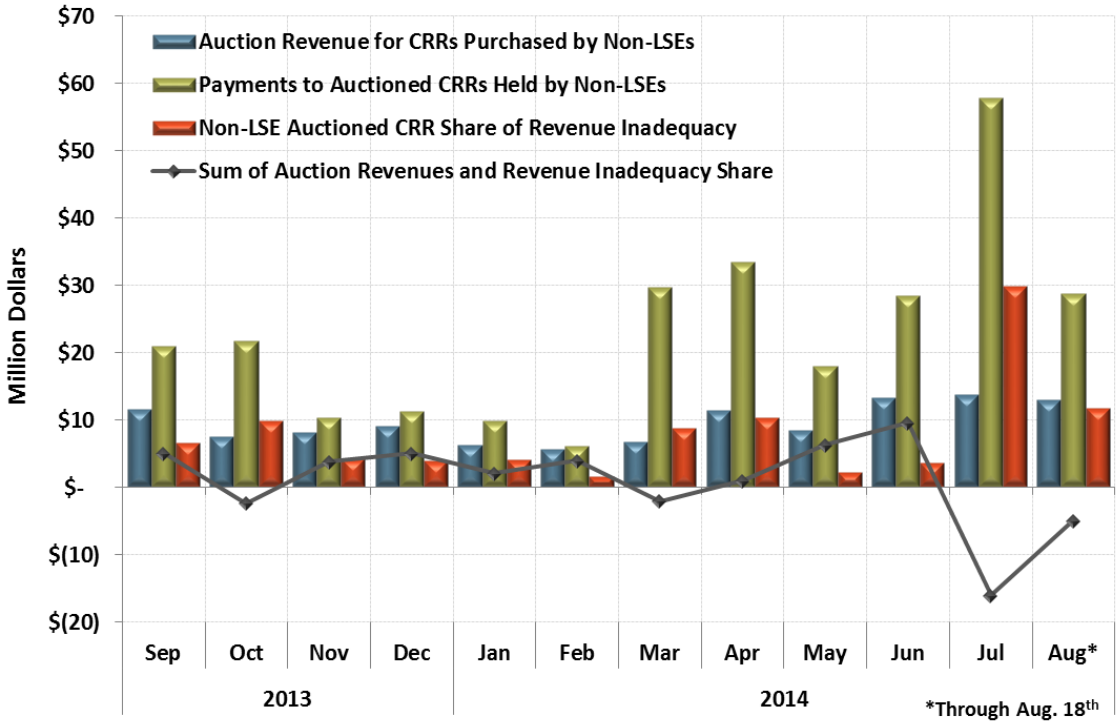
Figure 2 shows estimated auction revenues from, congestion payments to, and revenue inadequacy from, CRRs obtained at auction by Non-Load Serving Entities (Non-LSEs).[25] Load serving entities are used as a proxy for transmission owners, as is currently done in the allocation of revenues or costs from the CRR balancing account. Over the past year, the congestion revenues received by Non-LSE CRR holders (the green bars) have been over twice the purchase cost at auction (the blue bars). This suggests that the value of the CRRs may not have been fully incorporated into the CRR auction prices. Much of these CRR payments appear to be funded by revenue inadequacy (the red bars). The black line shows the estimated auction revenue received by LSEs less the estimated revenue inadequacy costs paid to Non-LSE held CRRs. When this line is negative it indicates that Load Serving Entities, rather than being paid, are in net paying to make their transmission capacity available to the CRR auction.

[23] This is also a point made by others, for example: Hogan, William W., 2013 “Financial Transmission Rights, Revenue Adequacy and Multi-Settlement Electricity Markets” http://www.hks.harvard.edu/fs/whogan/Hogan_FTR_Rev_Adequacy_031813.pdf

[24] This is necessary to get a feasible set of CRRs which could not be obtained efficiently through bilateral trading.

[25] Revenue inadequacy share is a “back of the envelope” calculation applying the share of total CRR revenues to total revenue inadequacy. This likely underestimates the revenue inadequacy paid to Non-LSEs because the proportion of CRRs that benefit from modeling discrepancies held by non-LSEs is likely higher than the overall proportion of CRRs held by non-LSEs.

Figure 2 – Data on Auctioned CRRs Not Held by Entities with Measured Demand



Another departure from the competitive ideal is that entities outside CAISO can affect the constraint limits within CAISO, as was the case in April 2014 on the PACI ITC. Attempts to charge transmission owners the costs of de-rates and outages, as the CAISO allocation does in an aggregated fashion and the NYISO does on a constraint specific level, can break down for these effects external to the CAISO market.

Currently the CAISO estimates the risk of CRR inadequacy from unexpected outages by restricting the number of CRRs issued (through the use of a global de-rate factor). By allocating the CRR revenue inadequacy costs back to CRRs, the risk of this revenue inadequacy will be incorporated into the bids for CRR positions. This will allow the market to evaluate the risk and price it in the CRR auction.

The current CAISO allocation of revenue inadequacy maintains full funding of CRRs; each CRR will be paid for its full megawatt value. However, this full funding of CRRs is an accounting illusion for CRR holders who have measured demand. The current allocation method transfers the cost of all CRR holders' underfunded CRRs to CRR holders who have measured demand.

By instead allocating the revenue inadequacy costs to CRRs by constraint, all CRRs would not be guaranteed full funding. While full funding of CRRs would not be guaranteed, this would simply reflect the reality that there may not be enough transmission capacity in the Day-Ahead market to honor the forward CRR contracts. Curtailments are sometimes necessary. This allocation would be equivalent to a

repurchase of CRRs to restore simultaneous feasibility (revenue adequacy) at the DAM prices.[26] Allocating the revenue inadequacy costs by constraint to CRR holders reduces the current incentive to benefit from revenue inadequacy by targeting differences between the auction and DAM models.

6.1 Potential Alterations to Allocation Methodology

There are several potential alterations and additions that could be made to the allocation methodology described above. A few are outlined below. There are likely other alterations and issues that could be considered.

A complementary change to the allocation methodology could be allocating the CRR auction revenues to transmission owners by constraint. This is done in the NYISO.[27] This would create the incentives for transmission owners to attempt to avoid taking actions that would create CRR revenue inadequacy. Transmission owners would have the incentives to avoid unexpected transmission outages. This is because uncertainty over such outages would decrease CRR holders' willingness to pay in the auction for CRRs over the transmission owner's transmission. As a result, the transmission owner's revenues from future CRR auctions would decrease.

Another potential alteration to the allocation method would be to give CRRs a refund of the purchase cost of the CRRs that are subsequently allocated revenue inadequacy costs. The purchase costs of CRRs in the auction can be rebated as shown in Equation 23 or in a similar fashion.

Equation 23 – Rebate of CRR Purchase Costs

$$Rebate_j^k = max\left[0\ , \frac{\left(1-\alpha^k\right) * P_j^{CRR} * \left(SF_{src,j}^k - SF_{snk,j}^k\right) * MW_j^{CRR}}{CRR\ Term\ Hours_j^k}\right]$$

A third potential change to the allocation would be to use revenues from constraint hours with surpluses over the month to reduce the amount of negative imbalances to be allocated to CRRs. Under such an alteration, allocations would only start when the total system is revenue inadequate in the month, such as in Equation 24. This would allow for greater funding of CRRs while still allocating revenue inadequacy to the CRR flows benefitting from revenue inadequacy when revenue inadequacy occurs. However this may keep intact some incentives to target modeling discrepancies.

Equation 24 – Using Surpluses to Reduce Deficit Allocations

$$Adj.Neg.Imb.^{k,hr} = min\left[0\ , \frac{Neg.Imb.^{k,hr}}{\sum_{hr=1}^{T}\sum_{k=1}^{K} Neg.Imb.^{k,hr}} * \sum_{hr=1}^{T}\sum_{k=1}^{K} Pos.Imb.^{k,hr} + Neg.Imb.^{k,hr}\right]$$

[26] Oren, Shmuel "Derating CRRs" November 25th, 2003 Public Utility Commission of Texas Workshop

[27] LECG "NYISO Congestion Reduction Proposal" 2003 NYISO Market Structures Working Group http://www.nyiso.com/public/webdocs/markets_operations/committees/bic_mswg/meeting_materials/2003-05-01/crtf_presentation_rev.pdf

7 Concluding Remarks

CRR revenue adequacy cannot be guaranteed for a variety of reasons. Currently inadequacy costs are uplifted to load serving entities. The paper describes a potential alternative allocation of CRR revenue inadequacy costs back to CRRs on an hourly and constraint specific basis, as shown in Equation 25.

Equation 25 – Proposed Allocation of Revenue Imbalance to CRRs by Constraint

$$Allocation_j^k = Neg.Imbalance^k * \left(\frac{CRR\ Flow_j^k}{Total\ CRR\ Flow^k}\right)$$

We believe that this allocation method is more efficient and equitable than the current method of allocating CRR revenue inadequacy because:

- It allocates the inadequacy costs to the CRR flows generating the inadequacy.
- It would spread the risk of revenue inadequacy to all CRR holders instead of placing it solely on load serving entities.
- It essentially rescinds payments made to CRRs for capacity not purchased by the Day-Ahead market schedules and would not create net costs that CRRs must pay.
- It allows participants in the CRR auction to price the risk of CRR revenue inadequacy into their bids and price the risk in the market, instead of relying solely on the CAISO to evaluate the risk through the CRR auction and allocation models.
- It reduces incentives for market participants to take CRR positions that benefit from and exacerbate revenue inadequacy. Therefore, the alternative allocation may reduce overall revenue inadequacy.
- It limits the total revenues that can be transferred from load serving entities to CRR holders through revenue inadequacy costs.
- It does not include allocating Real-Time market congestion uplifts to CRRs because CRRs have released their rights to the transmission to the Day-Ahead market.

Such an allocation would not reduce the importance of making the CRR and Day-Ahead markets as consistent as possible. CRR revenue adequacy would still be an important indicator of overall CRR funding and market quality.