PG&E's Comments

Contingency Modeling Enhancements CRR Alternatives Discussion Paper

Submitted by	Company	Date Submitted
Paul Gribik (415) 973-6274 *Nivad Navid (415) 973-1321*	*Pacific Gas & Electric*	*February 23, 2016*

PG&E appreciates the opportunity to comment on CAISO's CRR Alternatives Discussion Paper on "Contingency Modeling Enhancements," dated February 3, 2016 and the MSC presentation, dated February 11, 2016. PG&E appreciates CAISO's efforts to incorporate the new transmission constraints for corrective contingencies in the CRR allocation/auction processes. By incorporating these constraints in the Simultaneous Feasibility Test for CRRs, CAISO can provide CRRs that will be revenue adequate, assuming that the models do not change between the CRR processes and the Day-Ahead market, without overly limiting the CRRs it provides to those seeking hedges.

In the discussion paper, CAISO provided a number of options to conform its CRR processes that today do not model the new corrective-contingency constraints introduced in the CME initiative with the Day-Ahead market which will incorporate such constraints when CME is implemented. The CAISO sought stakeholder input on the extent to which CAISO should adjust the CRR definition and auction/allocation processes to reflect CME and its effect on congestion rents in the Day-Ahead market so that the CRR modeling and settlement is consistent with the proposed changes to the Day-Ahead market. The CAISO introduced the following alternatives:

1) minimal implementation
2) use a new product to rescind congestion revenue in excess of available transmission capability
3) create all new products that distribute congestion revenue associated with available transmission capability

For each alternative multiple options are introduced. Among them:

Option 3(a): Separate bids for allocation/auction of CRR^{k} and CRR^{kc}. In this option, market participants would provide nominations or bids for $CRR^{0:K}$, and they would also be able to

separately provide nominations or bids for CRR^{kc} for each corrective contingency kc. While not discussed in the paper, it would be possible to extend Option 3(a) to allow participants to submit bids or nominations for CRRs that are settled like today's CRRs in the auction or allocation as well as the $CRR^{0:K}$s and CRR^{kc}s..

Option 3(d): Single bid for allocation/auction of CRR^{k} only. In this option, the ISO would not change the CRR allocation or auction mechanisms. Market participants would provide nominations or bids for $CRR^{0:K}$s only. CAISO would ignore the transmission constraints in corrective contingencies in the CRR allocations and auctions and allocate CRRs that are simultaneously feasible only considering the transmission constraints in the base case and in the preventive contingencies. The congestion rents due to these $CRR^{0:K}$s would be calculated only using the components of the MCC that arise from congestion on transmission constraints in the base case and in preventative contingencies. These CRRs would be revenue adequate assuming that the network model used in the CRR processes matches that used in the Day-Ahead market. However, they would not provide a hedge against congestion costs in the Day-Ahead market due to transmission congestion in the the corrective contingencies.

In response, PG&E offers the following comments:

- PG&E supports efforts to resolve revenue inadequacy that may arise in the CRR allocation and auction processes once CME is implemented.
- PG&E's preference is to start the CRR allocation and auctions once CME is implemented using Option 3(d). However, PG&E requests that CAISO provide more information regarding how it would treat the congestion rents collected on the transmission constraints in the corrective contingencies. Since CRR^{kc}s would not be provided to participants under Option 3(d), this congestion rent would not be used to fund CRRs and participants would not be able to acquire CRRs that could be used to hedge these congestion costs. This option could potentially produce a large amount of congestion rents that are not refunded to participants via CRRs. As a consequence, for this option to be acceptable, CAISO should agree to closely monitor and track the amount of congestion rent collected on transmission constraints in the corrective contingencies and to trigger an expeditious re-design to incorporate the corrective contingencies in the allocation and auction processes (*e.g.* via Option 3(a)) if these un-hedged congestion costs were material.
- Among the options presented in the paper, PG&E believes that Option 3(a) would provide the best solution over the long term. However, it is complex and CAISO may need more time to implement Option 3(a). Also, stakeholders may need more time to develop protocols and systems to deal with the complexity of acquiring a suite of CRRs under Option 3(a). As a consequence, it may not be the best option to use at the start of CME implementation. CAISO should continue work on the design of Option 3(a) so that

it would be at a stage to expedite its implementation if tracking of the performance of a simpler option such as Option 3(d) indicates the need for a more comprehensive design. PG&E also suggests extending this option to include CRRs that are settled like today's CRRs in addition to $CRR^{0:K}$s and CRR^{kc}s in the allocation and auction processes.

- PG&E reiterates its previous comment related to the test case results from CAISO to evaluate the possible benefits of implementing CME and assurance that the system performance will not degrade as a result.

A. PG&E supports CAISO's efforts to enhance the CRR processes.

To keep the consistency between the proposed changes in the day ahead market (driven by the CME enhancements), and CRR modelling and settlement, the CAISO would have to adjust the CRR model and/or CRR compensation to reflect corrective capacity and its effect on congestion costs. PG&E supports efforts to make adjustments to seek a revenue adequate set of CRRs.

B. PG&E supports Option 3(d) but requests that CAISO provide more detail regarding its operation.

In Option 3(d), participants could nominate or bid for $CRR^{0:K}$s. These CRRs would settle using the components of the MCCs at source and sink that arise from congestion only on transmission constraints in the base case and preventative contingencies. CAISO would not allocate or auction any CRR^{kc}s that would settle using the components of the MCCs at source and sink that arise from congestion on transmission constraints in a corrective contingency kc.

Since CAISO would enforce the transmission constraints only in the base case and preventative contingencies when allocating or auctioning the $CRR^{0:K}$s and not allocate or auction any CRR^{kc}s, the CRRs would be revenue adequate assuming conditions such as the transmission system modeled in the CRR allocation/auction and in the Day-Ahead market being the same.

While CAISO would collect congestion rent arising from binding transmission constraints in the corrective contingencies in the Day-Ahead market, no CRRs would be provided that would let participants hedge these congestion costs. PG&E requires more information is needed to evaluate the effect of this. In particular, CAISO should specify how they would use any excess congestion rent collected as a result of not providing any CRR^{kc}s while collecting congestion rent on binding transmission constraints in the corrective contingencies. The method of dealing with congestion rents collected on the transmission constraints in the corrective contingencies should be discussed in the stakeholder process.

CAISO should closely monitor and track the amount of congestion rent collected on transmission constraints in the corrective contingencies for which hedges are not supplied. Thresholds should be defined that would trigger an expeditious re-design to incorporate the

corrective contingencies in the allocation and auction processes if these un-hedged congestion costs were material.

Finally, not allocating CRR^{kc}s at the start of CME implementation would give CAISO time to gain experience in modeling the transmission constraints in the corrective contingencies. In particular, it would give CAISO time to evaluate the best way to model transmission constraints in the corrective contingencies consistently in the Day-Ahead market and in the CRR allocations/auctions. Also, the information produced in operating the Day-Ahead market with CME will provide participants more information on valuing CRR^{kc}s.

C. PG&E supports continued work on designing an extended version of Option 3(a).

Under Option 3(a), participants can submit nominations or bids for $CRR^{0:K}$s and CRR^{kc}s. This provides considerable flexibility for a participant to specify the amount and kinds of CRRs that it would like as well as the value that it places on such CRRs in an auction. However, these are new instruments with which participants have no experience at present. Because of the complexity of implementation, PG&E believes that Option 3(d) may be the best option at the start of CME. However, design work on Option 3(a) should continue so that there is a viable option to implement in case monitoring and tracking indicate large unhedged congestion costs in Option 3(d). Also, as the transmission system operated by CAISO expands to other states in the west, the more comprehensive solution provided by Option 3(a) may be required to ensure that congestion rents collected from participants are not shifted inequitably across regions.

The complexity of participants dealing with Option 3(a) could be mitigated by extending the option to allow participants to submit nominations or bids for CRRs that are defined and settled like today's CRRs as well as the $CRR^{0:K}$s and CRR^{kc}s discussed in Option 3(a). We will call these CRR^{all}s since they allocate congestion rent collected on all transmission constraints (transmission constraints in the base case, preventative contingencies, and all corrective contingencies) to the CRR^{all}. Participants have experience estimating the value of such instruments since they cover all congestion related costs for moving power from one point to another as today's CRRs do. PG&E believes that extending Option 3(a) in this fashion will provide valuable flexibility and make it easier for participants to make the transition to nominating or bidding for $CRR^{0:K}$s and CRR^{kc}s if they so desire.

A participant could nominate or bid to receive CRR^{all}s that behave like today's CRRs using its existing procedures to determine the amount of CRR^{all}s it would like and the value it would place on them. Also, a participant would not have to nominate or bid for $CRR^{0:K}$s and CRR^{kc}s. Over time, the participant could expand its nominations and bids to include $CRR^{0:K}$s and CRR^{kc}s as it gains experience with the new products and collects data needed to estimate their values.

A MW of CRR_q^{all} from source src(q) to sink snk(q) could be decomposed into a portfolio of CRRs:

- A MW of $CRR_q^{0:K}$ from source src(q) to sink snk(q)
- A MW of CRR_q^{kc} from source src(q) to sink snk(q) for each corrective contingency kc.

Participants could submit separate nominations or bids for CRR_q^{all}, $CRR_q^{0:K}$, and CRR_q^{kc} for each corrective contingency. However, a participant may receive more CRRs than it desired from source src(q) to sink snk(q) if it were awarded its nominated or bid value of CRR_q^{all}, $CRR_q^{0:K}$, and CRR_q^{kc} for each corrective contingency. To aid participants in indicating their maximum quantity of CRRs from src(q) to snk(q), the nomination and bidding process could be extended to allow nominations or bids for portfolios of CRRs

A given nomination, CRR_q^{Nom}, could be a nomination for a portfolio of CRRs:

- a CRR that will settle using the terms in the MCC of the LMP that arise from congestion in the base case, preventative contingencies and all corrective contingencies (CRR_q^{all})
- a CRR that will settle using the terms in the MCC of the LMP that arise from congestion in the base case and preventative contingencies ($CRR_q^{0:K}$)
- for each corrective contingency kc, a CRR that will settle using the terms in the MCC of the LMP that arise from congestion in the corrective contingency (CRR_q^{kc}).

The portfolio nomination would specify a maximum MW, $MWCRR_q^{Nom}$, requested for:

- CRRs that are assigned rights to congestion rents arising from congestion in the base case and preventative contingencies, namely CRR_q^{all} and $CRR_q^{0:K}$
- CRRs that are assigned rights to congestion rents arising from congestion in a given corrective contingency kc, namely CRR_q^{all} and CRR_q^{kc}

Similarly, a given bid, CRR_q^{Bid}, could be a bid for a portfolio of CRRs with the same source and sink:

- a CRR that will settle using the terms in the MCC of the LMP that arise from congestion in the base case, preventative contingencies and all corrective contingencies (CRR_q^{all})
- a CRR that will settle using the terms in the MCC of the LMP that arise from congestion in the base case and preventative contingencies ($CRR_q^{0:K}$)
- for each corrective contingency kc, a CRR that will settle using the terms in the MCC of the LMP that arise from congestion in the corrective contingency (CRR_q^{kc}).

For each portfolio bid CRR_q^{Bid}, participants would submit three prices:

- A price to buy a CRR that would settle using components of the source and sink MCCs arising from congestion in the base case and all contingencies:

$$c_q^{all} \ \$/\mathrm{MW} \quad \text{for } q = 1,\ldots NQ$$

- A price to buy a CRR that would settle using components of the source and sink MCCs arising from congestion in the base case and preventative contingencies only:

$$c_q^{0:K} \ \$/\mathrm{MW} \quad \text{for } q = 1,\ldots NQ$$

- For each corrective contingency kc, a price to buy a CRR that would settle using components of the source and sink MCCs arising from congestion in the corrective contingency kc

$$c_q^{kc} \ \$/\mathrm{MW} \quad \text{for } q = 1,\ldots NQ \text{ and } kc = K+1,\ldots,K+KC$$

In a portfolio bid CRR_q^{Bid}, a participant would specify the maximum MW, $MWCRR_q^{\max}$, desired for

- CRRs that are assigned rights to congestion rents arising from congestion in the base case and preventative contingencies, namely CRR_q^{all} and $CRR_q^{0:K}$
- CRRs that are assigned rights to congestion rents arising from congestion in a given corrective contingency kc, namely CRR_q^{all} and CRR_q^{kc}

By allowing nominations and bids as portfolio nominations and bids, a participant would not run the risk of receiving more CRRs than desired, or adjusting its nomination/bid to attempt to prevent over procurement but causing it not to receive the level desired as a result.

Further details of such an approach are provided in the appendix below.

D. PG&E would not support combining CRR^{kc} defined individually for corrective contingencies kc = K+1,…,K+KC into a single CRR that would be settled using MCC components arising from congestion in all corrective contingencies in Option 3(a).

In the MSC meeting, it was suggest that CAISO could simplify Option 3(a) by defining CRRs (that we will call CRR$^{K+1:K+KC}$s) that would be settled using MCC components arising from congestion in all corrective contingencies rather than defining CRR^{kc}s by individual corrective contingency that settle using MCC components arising from congestion in that single corrective contingency, kc. PG&E believes that this would unduly limit the amount of CRRs that CAISO could allocate to hedge congestion costs arising in the corrective contingencies.

In the design in Option 3(a), CAISO allocates CRRs in a corrective contingency kc that would "place" flows on the system up to the transmission constraint limits in the single corrective contingency. The proposed change would limit the allocated CRR$^{K+1:K+KC}$s based on the flows that the CRR$^{K+1:K+KC}$s would place on transmission constraints in all corrective contingencies. This would reduce the CRRs that could be allocated.

Furthermore, the Day-Ahead market that incorporates CME constrains the flows placed by the energy schedules plus the corrective capacity procured for a given corrective contingency to the transmission limits in the given corrective contingency. By defining the CRR^{kc}s by individual corrective contingency kc, CAISO will be able to define CRRs that would provide more of the congestion rents it collects in the Day-Ahead market for a given corrective contingency to the CRRs it allocates.

The proposed change would instead correspond to a Day-Ahead market with a CME formulation that procures corrective capacity that would be completely deployed in all corrective contingencies, not just deployed in a single corrective contingency. It would constrain the flows placed by the energy schedules plus corrective capacity procured to the transmission limits in all corrective contingencies. This would reduce the efficiency of the dispatch.

E. PG&E seeks test case results and assurance of acceptable system performance.

The CAISO should provide test cases that show results of implementing CME using system data. This is needed to demonstrate that CAISO can reliably solve the more complex commitment and dispatch problems when contingency transmission constraints are added to the Day-Ahead and Real-Time markets. Also, this data will indicate the value that CME can be expected to provide in actual operations.

In addition, this will provide information as to which binding transmission constraints are likely to produce most of the congestion rent in the market. This will help evaluate whether a simpler CRR allocation and auction could be acceptable.

While PG&E supports the CME design principle, this information will be necessary for PG&E evaluate the benefits of CME to support proceeding with the implementation.

Furthermore, the test cases should demonstrate that there will not be major performance issues raised by this enhancement and that the market functions can be executed within the available time for running the various market processes.

Appendix: Adding CRR^{all}s to Option 3(a).

In the following, we outline a way in which Option 3(a) could be extended. In this formulation, we treat each nomination as a nomination for a portfolio of CRR^{all}s, $CRR^{0:K}$s and CRR^{kc}s for each corrective contingency kc. Separate nominations for CRR^{all}s, $CRR^{0:K}$s and CRR^{kc}s could easily be accommodated. We will use the notation used in the CAISO white paper in the following.

Allocating CRRs

The weighted least squares method used to allocate CRRs today could be extended to allocate:

- CRRs that are like today's CRRs in that they are settled using the full MCCs of the LMPs

  $$\sum_{k=0}^{K}\sum_{l=1}^{m} SF_{l,i}^{k} \cdot \mu_l^{k} + \sum_{kc=K+1}^{K+KC}\sum_{l=1}^{m} SF_{l,i}^{kc} \cdot \mu_l^{kc}$$

  which we will term CRR^{all}s

- CRRs that are settled using the components of the MCCs arising from congestion on only the transmission constraints in the base case and preventative contingencies

  $$\sum_{k=0}^{K}\sum_{l=1}^{m} SF_{l,i}^{k} \cdot \mu_l^{k}$$

  which are called $CRR^{0:K}$s in CAISO's white paper

- For each corrective contingency kc, CRRs that are settled using the components of the MCCs arising from congestion on only the transmission constraints in corrective contingency kc

  $$\sum_{l=1}^{m} SF_{l,i}^{kc} \cdot \mu_l^{kc}$$

  which are called CRR^{kc}s in CAISO's white paper.

Let the set of portfolio nominations for CRRs be denoted by $\left\{CRR_q^{Nom} \middle| q = 1,\ldots, NQ\right\}$

Each nominated CRR_q^{Nom} is a nomination for a portfolio of CRRs:

- a CRR that will settle using the terms in the MCC of the LMP that arise from congestion in the base case, preventative contingencies and all corrective contingencies (CRR_q^{all})
- a CRR that will settle using the terms in the MCC of the LMP that arise from congestion in the base case and preventative contingencies ($CRR_q^{0:K}$)
- for each corrective contingency kc, a CRR that will settle using the terms in the MCC of the LMP that arise from congestion in the corrective contingency (CRR_q^{kc}).

The CRRs allocated for the nominated CRR_q^{Nom} (CRR_q^{all}, $CRR_q^{0:K}$ and CRR_q^{kc} for kc = K+1,…,K+KC) will have the same source and sink as the nominated CRR_q^{Nom}.

For CRR_q^{Nom}, let

- $src(q)$ denote the source of CRR_q^{Nom}

- $snk(q)$ denote the sink of CRR_q^{Nom}
- $MWCRR_q^{Nom}$ be the maximum MW requested for
    - CRRs that are assigned rights to congestion rents arising from congestion in the base case and preventative contingencies, namely CRR_q^{all} and $CRR_q^{0:K}$
    - CRRs that are assigned rights to congestion rents arising from congestion in a given corrective contingency kc, namely CRR_q^{all} and CRR_q^{kc}

The allocation would limit the total award of CRR_q^{all} and $CRR_q^{0:K}$ to $MWCRR_q^{Nom}$:

$$MWCRR_q^{all} + MWCRR_q^{0:K} \le MWCRR_q^{Nom} \quad \text{for } q = 1,\ldots,NQ$$

It would also limit the total award of CRR_q^{all} and CRR_q^{kc} to $MWCRR_q^{Nom}$:

$$MWCRR_q^{all} + MWCRR_q^{kc} \le MWCRR_q^{Nom} \quad \text{for } q = 1,\ldots,NQ \text{ and } kc = K+1,...,K+KC$$

One possible way to expand the WLS process would be as follows:

$$\min\left[\sum_{q=1}^{NQ}\left(\frac{1}{MWCRR_q^{Nom}}\left(MWCRR_q^{Nom} - MWCRR_q^{all} - MWCRR_q^{0:K}\right)^2\right) + \sum_{kc=K+1}^{K+KC}\sum_{q=1}^{NQ}\left(\frac{1}{MWCRR_q^{Nom}}\left(MWCRR_q^{Nom} - MWCRR_q^{all} - MWCRR_q^{kc}\right)^2\right)\right]$$

over all $MWCRR_q^{all}$, $MWCRR_q^{0:K}$, $MWCRR_q^{kc}$ subject to

$$\sum_{q=1}^{NQ}\left(SF_{l,scr(q)}^{k} - SF_{l,snk(q)}^{k}\right)\cdot\left(MWCRR_q^{all} + MWCRR_q^{0:K}\right) \le F_l^{k,\max} \quad \text{for } l = 1,\ldots,m \text{ and } k = 0,\ldots,K$$

$$\sum_{q=1}^{NQ}\left(SF_{l,src(q)}^{kc} - SF_{l,snk(q)}^{kc}\right)\cdot\left(MWCRR_q^{all} + MWCRR_q^{kc}\right) \le F_l^{kc,\max} \quad \begin{cases} \text{for } l = 1,\ldots,m \text{ and} \\ kc = K+1,\ldots,K+KC \end{cases}$$

$$0 \le MWCRR_q^{all} \quad \text{for } q = 1,\ldots,NQ$$

$$0 \le MWCRR_q^{0:K} \quad \text{for } q = 1,\ldots,NQ$$

$$0 \le MWCRR_q^{kc} \quad \text{for } q = 1,\ldots,NQ \text{ and } kc = K+1,\ldots,K+KC$$

$$MWCRR_q^{all} + MWCRR_q^{0:K} \le MWCRR_q^{Nom} \quad \text{for } q = 1,\ldots,NQ$$

$$MWCRR_q^{all} + MWCRR_q^{kc} \le MWCRR_q^{Nom} \quad \text{for } q = 1,\ldots,NQ \text{ and } kc = K+1,\ldots,K+KC$$

The transmission constraints embedded in this allocation ensure that the CRRs allocated are simultaneously feasible. In addition, this formulation could be modified to allow a participant to

block it being given allocations of $CRR^{0:K}$s and CRR^{kc}s and only to be allocated CRR^{all}s in response to its nomination.

Other formulations are possible that could be used to allocate all three types of CRRs while satisfying simultaneous feasibility. For example, the allocation process could be designed to give priority to available transmission capacity to CRR^{all}s by allocating them first. The allocation of $CRR^{0:K}$s and CRR^{kc}s would then be done; this subsequent allocation would decompose into separate allocation problems.

CRR Auction

An auction could be formulated in which participants submit a bid for a portfolio of CRRs similar to the portfolio nomination given above. Each portfolio bid specifies a source, sink, a MW quantity, and a price for each kind of CRR.

Let the set of portfolio bids for CRRs be denoted by $\left\{CRR_q^{Bid} \middle| q = 1,..., NQ\right\}$

For CRR_q^{Bid}, let

- $src(q)$ denote the source of CRR_q^{Bid}
- $snk(q)$ denote the sink of CRR_q^{Bid}
- $MWCRR_q^{\max}$ be the maximum MW requested for
    - CRRs that are assigned rights to congestion rents arising from congestion in the base case and preventative contingencies, namely CRR_q^{all} and $CRR_q^{0:K}$
    - CRRs that are assigned rights to congestion rents arising from congestion in a given corrective contingency kc, namely CRR_q^{all} and CRR_q^{kc}

For each CRR_q^{Bid}, participants would submit three prices.

- A price to buy a CRR that would settle using components of the source and sink MCCs arising from congestion in the base case and all contingencies:

  c_q^{all} \$/MW for $q = 1,\ldots NQ$

- A price to buy a CRR that would settle using components of the source and sink MCCs arising from congestion in the base case and preventative contingencies only:

  $c_q^{0:K}$ \$/MW for $q = 1,\ldots NQ$

- For each corrective contingency kc, a price to buy a CRR that would settle using components of the source and sink MCCs arising from congestion in the corrective contingency kc

$$c_q^{kc} \text{ \$/MW} \quad \text{for } q = 1,\ldots NQ \text{ and } kc = K+1,\ldots,K+KC$$

For each CRR_q^{Bid}, the auction could award CRRs that will settle using:

- all components of the MCC of the LMP (CRR_q^{all}),
- only the components of the MCC that arise from congestion on the transmission constraints in the base case and preventative contingencies ($CRR_q^{0:K}$), and
- for each corrective contingency kc, only the components of the MCC that arise from congestion on the transmission constraints in the corrective contingency (CRR_q^{kc}).

The auction would limit the size of CRR_q^{all} and $CRR_q^{0:K}$ to $MWCRR_q^{\max}$:

$$MWCRR_q^{all} + MWCRR_q^{0:K} \le MWCRR_q^{\max} \qquad \text{for } q = 1,\ldots,NQ$$

It would also limit the size of CRR_q^{all} and CRR_q^{kc} to $MWCRR_q^{\max}$:

$$MWCRR_q^{all} + MWCRR_q^{kc} \le MWCRR_q^{\max} \qquad \text{for } q = 1,\ldots,NQ$$

The auction can be formulated as:

$$\max \sum_{q=1}^{NQ} c_q^{all} \cdot MWCRR_q^{all} + \sum_{q=1}^{NQ} c_q^{0:K} \cdot MWCRR_q^{0:K} + \sum_{kc=K+1}^{K+KC} \sum_{q=1}^{NQ} c_q^{kc} \cdot MWCRR_q^{kc}$$

over all $MWCRR_q^{all}, MWCRR_q^{0:K}, MWCRR_q^{kc}$ subject to

$$0 \le MWCRR_q^{all} \qquad \text{for } q = 1,\ldots,NQ$$

$$0 \le MWCRR_q^{0:K} \qquad \text{for } q = 1,\ldots,NQ$$

$$0 \le MWCRR_q^{kc} \qquad \text{for } q = 1,\ldots NQ \text{ and } kc = K+1,\ldots,K+KC$$

$$MWCRR_q^{all} + MWCRR_q^{0:K} \le MWCRR_q^{\max} \qquad \text{for } q = 1,\ldots,NQ$$

$$MWCRR_q^{all} + MWCRR_q^{kc} \le MWCRR_q^{\max} \qquad \text{for } q = 1,\ldots NQ \text{ and } kc = K+1,\ldots,K+KC$$

$$\sum_{q=1}^{NQ} \left(SF_{l,src(q)}^{k} - SF_{l,snk(q)}^{k}\right) \cdot \left(MWCRR_q^{all} + MWCRR_q^{0:K}\right) \le F_l^{k,\max} \quad \text{for } l = 1,\ldots,m \text{ and } k = 0,\ldots,K$$

$$\sum_{q=1}^{NQ} \left(SF_{l,src(q)}^{kc} - SF_{l,snk(q)}^{kc}\right) \cdot \left(MWCRR_q^{all} + MWCRR_q^{kc}\right) \le F_l^{\max} \quad \begin{cases} \text{for } l = 1,\ldots,m \text{ and} \\ kc = K+1,\ldots,K+KC \end{cases}$$

The transmission constraints embedded in this auction ensure that the CRRs awarded in the auction are simultaneously feasible.

This auction could be extended to accommodate bids to buy or sell separate CRR^{all}s, $CRR^{0:K}$s and CRR^{kc}s. Other formulations are possible that could be used to auction all three types of CRRs while satisfying simultaneous feasibility.