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**White Paper: Processing Contingencies that disconnect a Settlement Point**

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# Objective

The objective of this white paper is to provide the ERCOT market with an overview of the processing of contingencies that disconnect a Settlement Point. This will be valid upon system implementation.

# Introduction

A contingency is a predefined “what-if” scenario that is analyzed to determine whether the transmission grid is insecure if the contingency were to occur (i.e. are there any transmission branch overloads?). A contingency is typically defined as a group of breaker operations (Open/Close), line outages, and/or transformer outages. Implementation of the contingency may, apart from disconnecting transmission lines and transformers, also result in outage of Load, generation, and/or split or out of service power flow buses.

Contingency Analysis (CA) is used to determine whether any transmission branch overloads would occur when a predefined contingency is applied to a given reference (Base Case Power Flow). This is achieved by implementing the contingency on the Base Case and then re-running a power flow.

For overloaded transmission branches, in the absence of any Remedial Action Schemes (RAS) to manage this transmission branch overload, constraints are passed to the optimization engine to re-dispatch MW to relieve transmission branch overloads in an economical manner.

# Processing of Contingencies that disconnect a Settlement Point

There are some contingencies that disconnect Settlement Points (e.g. Resource Node Settlement Point). If, in the Base Case, there is any injection or withdrawal at the Settlement Point (PTP/CRR source or sink MW, DAM Energy Only Offer/Bid, Generation Resource EOC), then power balance in the post contingency network is not maintained as the net of the injections/withdrawals at this location are “lost”. However, power balance is required before running the power flow. To maintain power balance, this “lost” net injection or withdrawal is redistributed to the other energized generator nodes in the post contingency network. This redistribution is referred to as the “pickup”.

Figure 1 depicts a scenario where a contingency disconnects a Settlement Point that is a source to a PTP. To maintain power balance in the post contingency network, the source MW of the PTP is redistributed, in a predefined manner, to the energized generator nodes at G1, G2, and G3. Also, in this scenario, Line A is overloaded due to this contingency.

In DAM, the redistribution of the “lost” PTP source MW is redistributed to G1, G2, and G3 in proportion to their respective High Reasonability Limits (HRL), i.e.

$$G\_{MW-modified}^{i}=G\_{MW-original}^{i}+ \frac{HRL\_{Gi}}{HRL\_{G1}+HRL\_{G2}+HRL\_{G3}}×PTP\_{MW} , i=1,2,3$$

After this the post contingency power flow is solved. In this scenario, Line A is overloaded due to this contingency. If there is no RAS defined to manage this overload, constraints are passed to the DAM optimization engines to relieve this overload on Line A.

The constraint passed to the DAM optimization engine is,

$$\sum\_{i=1}^{3}SF\_{i}^{Line A}G\_{MW-modified}^{i}-SF\_{PTP-sink@LZ}^{Line A}×PTP\_{MW}\leq Limit\_{Line A}$$

Where,

 $SF\_{i}^{Line A}$ is the shift factor of generator *i*, to Line A and $SF\_{PTP-sink@LZ}^{Line A}$ is the shift factor at Load Zone to Line A.

Expanding the $G\_{MW-modified}^{i}$ term in this equation leads to,

$$\sum\_{i=1}^{3}SF\_{i}^{Line A}G\_{MW-original}^{i}+\left(SF\_{PTP-source pickup}^{Line A}-SF\_{PTP-sink@LZ}^{Line A}\right)×PTP\_{MW}\leq Limit\_{Line A}$$

Where,

$SF\_{PTP-source pickup}^{Line A}= \sum\_{i=1}^{3}SF\_{i}^{Line A}×\frac{HRL\_{Gi}}{HRL\_{G1}+HRL\_{G2}+HRL\_{G3}}$ ; this is referred to as the “pickup” shift factor

PTP source MW

G1 MW

G2 MW

G3 MW

PTP sink MW @LZ

Line A overloaded

Contingency disconnects Settlement Point

Settlement Point

Figure 1.

**Note that this processing is the same for DAM Energy-Only Offers, DAM Energy-Only Bids, CRR source or sink and Generation Resource EOC that are “lost” due to a contingency that disconnects the Settlement Point where they are located.**

# Settlement Point Locational Marginal Price (LMP)

The LMP at a Settlement Point is calculated using the formula:

$$LMP\_{Settlement Point}=λ- \sum\_{c=1}^{k}μ\_{c}×SF\_{Settlement Point}^{c}$$

Where,

$λ$ is the power balance shadow price or “System Lambda”,

$μ\_{c}$ is the shadow price for transmission constraint *c*

$SF\_{Settlement Point}^{c}$ is the shift factor of the settlement point to transmission constraint *c*

**It is important to note that if for a constraint *c*, the Settlement Point is disconnected, then the shift factor** $SF\_{Settlement Point}^{c} $**used in the formula to calculate the Settlement Point LMP is the “pickup” shift factor as described in the previous section.**

# DAM Example

At the end of DAM execution, the following conditions were present:

* A PTP Obligation bid was present with source at S1, sink at S2, and a Not-To-Exceed-Price $(PTP\_{S1-S2}^{\$ Bidm}$ )
* 3 constraints c1, c2, and c3 were binding/violated for an hour with Shadow Prices $SP\_{c1}$, $SP\_{c2}$, $SP\_{c3}$ respectively
* c2 disconnected Settlement Point S1

For the DAM optimization engine, the effective awarded price for the PTP Obligation bid with source at S1 and sink at S2 would be:

$$PTP\_{S1-S2}^{\$ optim}=SF\_{S1}^{c1}×SP\_{c1}+SF\_{S1}^{c2-pickup}×SP\_{c2}+SF\_{S1}^{c3}×SP\_{c3}- SF\_{S2}^{c1}×SP\_{c1}-SF\_{S2}^{c2}×SP\_{c2}-SF\_{S2}^{c3}×SP\_{c3}$$

Note that in the optimization engine, for constraint c2, the PTP source shift factor is the “pickup” shift factor as described earlier.

***Note:*** *The Not-To-Exceed-Price (*$PTP\_{S1-S2}^{\$ Bidm}$*) will ALWAYS be greater than or equal to the awarded price as far as the DAM optimization engine is concerned (i.e.* $PTP\_{S1-S2}^{\$ Bidm}\geq PTP\_{S1-S2}^{\$ optim}$*), and the Settlement for the PTP will be the difference between the sink Settlement Point Price (SPP) (S2) and the source SPP (S1).*

SPP (or LMP) at S1:

 $SPP\_{S1}=λ- SF\_{S1}^{c1}×SP\_{c1}-SF\_{S1}^{c2-pickup}×SP\_{c2}-SF\_{S1}^{c3}×SP\_{c3}$

*Where:*

$λ$ is the power balance Shadow Price (System Lambda)

***Note****: S1 is de-energized for c2, and therefore the Shadow Price for c2 has impacts on the SPP for S1 based on the pickup shift factor.*

SPP (or LMP) at S2:

 $SPP\_{S2}=λ- SF\_{S2}^{c1}×SP\_{c1}-SF\_{S2}^{c2}×SP\_{c2}-SF\_{S2}^{c3}×SP\_{c3}$

*Where*:

$λ$ is the power balance Shadow Price (System Lambda)

***Note:*** *S2 is energized for c2, and therefore the Shadow price for c2 has an impact on the SPP for S2.*

Settlement for the PTP between S1 and S2 is:

$$PTP\_{S1-S2}^{\$ settlement}= SPP\_{S2}- SPP\_{S1}=SF\_{S1}^{c1}×SP\_{c1}+SF\_{S1}^{c2-pickup}×SP\_{c2}+SF\_{S1}^{c3}×SP\_{c3}- SF\_{S2}^{c1}×SP\_{c1}-SF\_{S2}^{c2}×SP\_{c2}-SF\_{S2}^{c3}×SP\_{c3}$$

One can see that $PTP\_{S1-S2}^{\$ optim}=PTP\_{S1-S2}^{\$ settlement}$

***Note:*** *Due to rounding, there can be a $0.01 difference.*

***Note:*** *If the source or sink Settlement Point of a PTP Obligation bid is de-energized in the base case, then the PTP Obligation bid is not considered in the DAM and there will be NO AWARDS.*

# Summary

In the described processing of a contingency that disconnects a Settlement Point, and the Settlement Point LMP calculation, the possibility of a PTP being awarded higher than their Not-To-Exceed Bid price is theoretically eliminated.

It should also be noted that in a generating facility with multiple Resource Node Settlement Points, if there is a contingency that disconnects one of these Resource Nodes AND leads to a binding constraint, then the Settlement Point LMPs at these “close” Resource Nodes can be significantly different (however, the electrically similar Settlement Point processing in DAM and CRR should mitigate any gaming opportunity).

# Implementation notes

1. Changes are required to Real-Time, Day-Ahead Market, CRR Auction process
2. Review process of redistributing “lost” injections/withdrawals due to contingencies that disconnect Settlement Points
	1. Real-Time:
		1. Re-evaluate for correctness, the list of predefined generators (agc flag set to “true”) to which “lost” injection/withdrawals are redistributed to
	2. DAM & CRR:
		1. Align the redistribution methodology as close as possible to Real-Time
		2. Document any deviation in methodology due to necessary approximations (for performance, stability) – for example, the necessity to use HRL weights instead of headroom to avoid divergence and lengthy execution times of the clearing process
3. PTP processing for DAM and CRR:
	1. Instead of removing PTP or CRR in the post contingency network to maintain power balance when a source or sink is disconnected due to a contingency, implement “pickup” as described above.
	2. For CRR auction engine, CRR options that require “pickup” processing needs to ensure that the performance requirements for the CRR auction is met.
4. Settlement Point LMP calculation:
	1. Real-Time:
		1. SCED will require information on which Settlement Points are disconnected in a contingency constraint to trigger the use the “pickup” shift factor in the Settlement Point LMP calculation.
	2. DAM:
		1. Modify the Settlement Point LMP calculation to use “pickup” shift factor when a Settlement Point is disconnected in a contingency that leads to a binding constraint.