Transfer Limit Hardening Methodology Descriptions

Introduction:

The 3 proposed transfer limit hardening methodologies are based on the 2020,2025, 2030 and 2035 data sets from the Future 1 – BAU Soft Constraint data output. The data set contains the following information for each interface (in both directions; ~100 interfaces) for each load block:

- Base-case flows over the baseline pipe
- OL75 flows over the baseline pipe and flows over the overload pipe
- OL25 flows over the baseline pipe and flows over the overload pipe
- Base-case shadow prices (marginal benefit of increasing the flow by 1 MW all else being equal)
- Overload charges for OL75 and OL25 cases ($/MW charge applied to each flows over the overload pipe; overload charges set to 75% or 25% of the average annual shadow price adjusted for load block size during only the congested hours)
- OL75 and OL25 shadow prices (always less than or equal to the overload charge)

This data is processed using the master transfer limit hardening methodology spreadsheet developed largely by Stan Hadley. That data set outputs the following information:

- Fixed transfer limit increases for all pipes for each transfer limit hardening methodology
- Flow duration curves for both OL75 and OL25 sensitivities for each year and for the combined years
- Pipe target capacity factor-capacity curves for both OL75 and OL25 sensitivities for each year and for combined years (curves show different pipe magnitudes for different target pipe capacity factors assuming the OL75 or OL25 flows do not change; combined years target capacity factor-capacity curve graphed)
- Average transfer limit capacity for each year and for each year and for the combined years for both the total flows and the overload flows (MWh flows divided by time period hours)
- Average shadow prices for the combined years (calculated by summing the products of load block hours by load block shadow price and dividing by either total hours or congested hours)

Each of the three methodologies has a series of parameters that can be easily adjusted in the master spreadsheet with the results for all methodologies for both the OL75 and the OL25 sensitivities being displayed on the All Lines tab.

The following will describe each of the methodologies in detail with possible benefits and negatives of each methodology described.

Ruthven/Hadley/Chattopadhyay Methodology – Building to a Target Capacity Factor by Shadow Price

The RHC methodology calculates an increased transfer limit based on the average pipe increase developed from target capacity factors determined according to shadow prices applied to both total flows and overload flows.

1. For the total flow increase portion, RHC takes the total flows over a pipe (flows over the baseline pipe + flows over the overload pipe) and develops a new pipe size according to a target pipe capacity factor.
    a. The target pipe capacity factor of a pipe is determined proportionally to its average total shadow price.
        i. The average total shadow price is calculated by taking the total marginal congestion (shadow price for each load block times load block hour summed) and dividing it by the total hours.
        ii. The average total shadow price is used as it is indicative of, all things being equal, the amount of value that could be accessed over the course of the time period if the pipe were increased by one MW.
    b. To determine the target pipe CF, the total flow CF-shadow price curve parameter (default value of 1) is divided by the average total shadow price (average total shadow price's less than the parameter have a target pipe CF of 100%).
    c. The pipe is then resized such that it can achieve that target pipe CF assuming the flow patterns do not change. The pipe increase is assumed to be 0 if the resized pipe is less than the baseline pipe size
2. For the overload flow increase portion, RHC takes the overload flows over a pipe and develops a new overload pipe according to a target overload pipe capacity factor
    a. The target pipe capacity factor of a pipe is determined proportionally to its average total shadow price.
        i. The average congested shadow price is calculated by taking the total marginal congestion (shadow price for each load block times load block hour summed) and dividing it by the congested hours.
        ii. The average congested shadow price is higher than the average total shadow price as it is calculated using a smaller number of hours. Some participants believe it is more appropriate to only consider the congested hours when resizing the overload pipe. CRA uses the average congested hour shadow price when calculating Overload Charges
    b. To determine the target overload pipe CF, the overload flow CF-shadow price curve parameter (default value of 1) is divided by the average congested shadow price
    c. If the above methodology results in a target overload pipe CF greater than the max overload pipe CF parameter (default value of 33%), then the max overload pipe CF is used

        i. Allowing the overload pipe CF to go above a certain value because of low or 0 shadow prices when cause unnecessary downstream congestion. CRA assigned pipes with no congestion a $0 overload charge in order to prevent the soft constraint method from moving congestion "one gate down" (i.e. when one congested pipe was expanded all the congested energy that wasn't quickly absorbed would move to the next pipe down that had previously been uncongested). Assigning a max CF value alleviates this concern to a certain extent
    d. The overload pipe is then resized such that it can achieve that target overload pipe CF assuming the overload flow patterns do not change.

3. The total flow increase and the overload flow increase are then averaged to give a total pipe increase
    a. Total flows are used to determine a new pipe size as total flows give information on where the pipe would like to expand. Particularly for pipe with a lot of congestion, overload pipes are likely to be used more than is shown in the overload flows as new, resized pipes would not have an overload charge associated with their use. Only looking at the overload flows would likely lead to pipes being too small.
    b. Overload flows are used to determine a new pipe size as they give specific information on where the model would like to build generation and increase generation utilization. If only total flows were used, a pipe could be expanded significantly even if the model preferred to expand other interfaces more to access cheaper generation potential.

NGO Methodology – Building to a Target Flow Duration Threshold

The NGOs recommend a solely-flow based methodology that calculates a new path size based on the flow duration curve that results from the sensitivity run(s). It selects a new pipe size based on the flow needed for all *except* the last X% of hours of the period. X (cutoff, or threshold value) can be, e.g., 5%, 10%, 20%, or even higher (meaning that you build-out to meet the flow needs for 95%, 90% or 80% of the time, respectively). The NGO's suggest a default value for X of 20% for OL25 flows, and 10% for OL75 flows. If the flows at the cutoff point are less than the current path limit, there is no path size expansion. The NGO methodology is intuitively simple, avoiding unnecessary complications that might provide little value to an undertaking of this size. By determining increases off of flow patterns, the methodology implicitly takes into account economic information as the flows are a result of the economic choices made by the model. Furthermore, the NGO methodology avoids the complication of determining an appropriate pipe capacity factor as pipe capacity factors are an output, not an input of the model.

1. The mechanics of the method are as follows:
    a. For each of the 101 paths, combine the base flow (MW) and overload flow (MW) values (by year, and by load block), for each of the applicable sensitivity runs - OL25 and OL75 – to develop a "total flow" parameter for each run.
    b. Create the total flow duration curve for each path representing all four years of data - 2020, 2025, 2030, 2035 – by combining total flow data from the sensitivity runs and sorting on the flow metric, largest to smallest value (y-axis value). Prior to sorting, retain the "duration" or hourly weight metric for each of these flows to subsequently construct the x-axis duration value.
    c. Pick a threshold or x-axis cutoff value (hourly duration percentile – "parameter 1") for each of the OL25 and OL75 sensitivity cases and determine the associated y-axis total flow by moving vertically upward from the x-axis cutoff point to the flow duration curve above.
    d. If the associated total flow is lower than the current path limit, then no increase to the pipe size for the path is required.
    e. If the associated total flow is higher than the current path limit, then this flow value represents the total MW capacity of the increased path (pipe) size.
    f. Screen the results for anomalous conditions. Changes to the new pipe size can be made by either choosing a different cutoff point, or directly specifying a pipe size based on other factors following discussion with the Transmission sub-team.

Johnson Methodology – Building to a Target Capacity Factor based on Average Energy Transfers

The methodology is an energy transfer based methodology that filters pipes according to average annual energy utilization of the existing pipe and then resizes pipes according to a desired capacity factor. If an existing pipe is being used greater than 90% of the time (taking into account both baseline and overload flows, a pipe can be used more than 100% of the time), then it builds a new path size to a 75% capacity factor. I.e., it recognizes that the existing pipe is nearing its annual limit, and bumps it up accordingly – and proportionately – to the new flow from the sensitivity run.

The methodology relies on the idea that the "energy transfers" from the OL25 and/or OL75 transmission sensitivities implicitly encapsulate the marginal cost of production and capital cost differentials between NEEM regions.

The mechanics of the method are as follows:

1. The average annual energy transfer (MW) for a pipe is calculated (total flows over a pipe divided by total hours
2. The average annual capacity utilization is calculated (average annual energy transfer MW divided by baseline pipe capacity MW)
3. If the average annual capacity utilization is greater than the capacity utilization threshold (parameter 1 – default value of 90%) then the pipe is considered for an increase
4. Pipes considered for increase are upgraded to a target capacity factor (parameter 2 – default value of 75%)
    a. Average annual energy transfer is divided by the target capacity factor to yield the new pipe size
    b. If the new pipe size is smaller than the baseline pipe, then the pipe is not expanded

See the methodology examples section below for a numeric example.

OPTION:

The methodology has an option to combine the OL25 and OL75 pipe resizing upgrades as a compromise if the SSC cannot achieve consensus.

The OL75 and OL25 interface upgrades are combined through OL25/OL75 ratios applied to OL75 upgrade levels where available. The concept is that if OL25 flows are higher than the OL25 results then "more" spare capacity is designed into the upgraded interface e.g. energy transfers "increased" when the constraint was relaxed further in OL25. If OL25 results are less than OL75 results then less spare capacity is designed into the interface e.g. energy transfers "decreased" as the constraint was relaxed further in OL25. If only OL75 upgrade occurs and not an O25 then minimal spare capacity is designed into the interface and if only a OL25 result occurs and not a OL25 then the OL25 result is used with minimal spare capacity designed into the interface.

Methodology Demonstration Examples

RHC Methodology Steps Taken for OL75 NE to SPP-N Transfer Limit:

1. Target Capacity factor for total flow calculated = 81%
    a. Average shadow price calculated for all hours = $1.24
        i. $43,400 marginal congestion/35040 hours =$1.24
    b. Calculate capacity factor using Total Flow CF-Shadow Price Curve Parameter = 1.0
        i. 1/1.24= 81%
2. Target Capacity factor for overload flow calculated = 20%
    a. Average shadow price calculated for all congested hours = $4.95
        i. $43,400 marginal congestion/8772 congested hours = $4.95
    b. Calculate capacity factor using Overload Flow CF-Shadow Price Curve Parameter =1.0
        i. 1/4.95 = 20%
3. Calculate any increase in pipe capacity based on total flow target capacity factor-capacity curve = 0 MW
    a. Total flows over line size X (assuming flow pattern remains identical)/potential total flows over line size X = line CF
    b. Total flow target cf-capacity curve shows at 81% CF, transfer limit should be ~1500 MW
    c. Actual baseline capacity is 1800 MW so no increase
4. Calculate any increase in pipe capacity based on overload flow target capacity factor-capacity curve = 1244 MW
    a. Overload flows over overload line size X (assuming flow pattern remains identical)/potential total flows over overload line size X = line CF
    b. Overload flow target cf-capacity curve shows at 20% CF, overload transfer limit should be 1244 MW
    c. Calculate average of pipe increase due to total flows and average of pipe increase due to overload flows = 622 MW

NGO Methodology Steps Taken for OL 75 NE to SPP-N Transfer Limit:

1. Flow duration curve created using total flows for all hours of the combined years
2. Pipe size equal to a designated cutoff to upper end of flow duration curve
    d. Flow duration curve target parameter = 10%
    e. Flows at 10% target cutoff = 3014 MW
    f. Since pipe increase is greater than 1800 MW baseline capacity, pipe increased by 1214 MW

Johnson Methodology Steps Taken for OL75 NE to SPP-N Transfer Limit:

1. Average total MW energy transfers calculated for combined years= 1665 MW
    a. Total energy transfers = 58331 GWh divided by Total Hours = 35040 times 1000 = 1665 MW
2. Capacity utilization threshold applied
    a. Average MW energy transfers divided by baseline capacity (1800 MW) = 92%

    b. 92%> threshold interface utilization parameter (default value of 90%)
    c. Since pipe passes threshold, pipe is considered for expansion
3. Pipe size increase calculated = 420 MW
    a. Average MW energy transfers 1665 MW divided by average capacity factor for total line parameter (default value of 75%) = 2220 MW
    b. Since new pipe size is greater than baseline pipe (1800 MW), pipe increased by 420 MW

Transfer Limit Hardening Methodology Increases

OL75 Methodology Transfer Limit Increases			
	RHC	Johnson	NGO
MISO_WUMS_2_MISO_W	2310	684	1367
MISO_WUMS_2_MISO_MI	770	820	1497
NYISO_A-F_2_NYISO_G-I	530	0	1749
NE_2_SPP_N	622	420	1214
IESO_2_MISO_W	84	439	1079
MISO_W_2_MAPP_CA	0	0	1185
MISO_MO-IL_2_MISO_W	576	0	194
NEISO_2_NYISO_A-F	0	0	603
NEISO_2_NYISO_G-I	0	0	559
PJM_ROR_2_VACAR	0	0	440
NEISO_2_NYISO_J-K	62	95	252
IESO_2_MAPP_CA	135	57	202
IESO_2_NYISO_A-F	0	0	349
NYISO_G-I_2_NYISO_J-K	0	0	232
NYISO_J-K_2_PJM_E	0	105	0

OL25 Methodology Transfer Limit Increases			
	RHC	Johnson	NGO
MISO_WUMS_2_MISO_MI	8124	8625	8531
MISO_WUMS_2_MISO_W	5054	2141	2917
NE_2_SPP_N	2805	2134	2817
MISO_W_2_MAPP_CA	1737	1298	2737
MISO_MI_2_MISO_IN	988	1296	2296
NYISO_A-F_2_NYISO_G-I	621	1047	0
SPP_S_2_SPP_N	520	258	178
IESO_2_NYISO_A-F	0	0	573
IESO_2_MISO_W	19	320	0
NEISO_2_NYISO_G-I	0	0	299
NYISO_J-K_2_PJM_E	0	162	0
IESO_2_MAPP_CA	0	145	0
NEISO_2_NYISO_J-K	5	87	0
NEISO_2_NYISO_A-F	0	0	56

Methodology Critiques

The NEEM-TX Subteam agrees that based on our examination of the current data all three proposed methodologies could be useful for EIPC purposes. All three methodologies have certain possible benefits and certain possible negatives. Below is a list of critiques that have been offered regarding the three methodologies. These critiques are meant to inform the SSC on what certain members of the Subteam think might be possible concerns with the methodologies but are not meant to be taken as a consensus Subteam view of the methodologies.

1. Possible RHC Methodology critiques
    a. The model might be overly complex given the task at hand
    b. The target cf-shadow price curves are somewhat arbitrary
        i. The curves were developed only to give a decreasing target capacity factor given an increasing shadow price and we judged them to produce "appropriate" levels of build but they are not based on actual transmission planning. Appropriate target capacity factors could vary greatly depending on the level of economic or reliability value they provide and the cost the transmission build.
    c. Base run shadow prices should not be heavily relied upon
        i. Shadow prices only reflect the marginal benefit of increasing a transfer limit by 1 MW assuming everything else stays the same in the base run. Shadow prices do not reflect differences in generation capital costs or differences in wind capacity factors. Therefore, relying too much on shadow prices could detrimentally affect the expansion of some transfer limits. Differential capacity cost or wind capacity factor information is implicitly included in the total and overload flows as the model economically selects where to build generation in order to reduce costs.
        ii. Certain stakeholders have also questioned the accuracy of the shadow prices produced by the model and have argued that they do not always compare well with real shadow prices seen in the actual system
        iii. Certain stakeholders believe that the methodology properly balances the consideration of economic information provided by shadow prices with implicit economic information provided by the flows
2. Possible NGO Methodology Critiques
    a. Methodology does not take into account shadow prices so might be missing some important economic information about potentially more beneficial expansions
        i. Methodology implicitly takes into account economic information that drives flows
    b. Flow duration curve threshold parameter is somewhat arbitrary

        i. The default values were selected as they were judged to produce "appropriate" levels of expansion but they are not based on actual transmission planning parameters
    c. Methodology could give similar results for pipes with potentially large differences in flow patterns
        i. The relevant criteria for the methodology is the flow level at the flow duration threshold. Different interfaces could have identical levels at the flow duration threshold but might have different flow patterns preceding or exceeding the threshold that could be indicative of greater or less degrees of potential "value" associated with expanding those interfaces
        ii. Certain stakeholders believe this concern is unlikely to meaningfully affect the methodology results
3. Possible Johnson Methodology Critiques
    a. Methodology does not take into account shadow prices so might be missing some important economic information about potentially more beneficial expansions
        i. Methodology implicitly takes into account economic information that drives flows
    b. The utilization threshold and the target cf are somewhat arbitrary
        i. The utilization threshold and target capacity factor used were chosen based on stakeholder views as to what would be necessary to incent building transmission and on what parameters would produce "appropriate" levels of build but they are not based on actual transmission planning. Appropriate target capacity factors or utilization thresholds could vary greatly depending on the level of economic or reliability value they provide and the cost the transmission build.