FTR Modeling Enhancements for Future Transmission Expansions

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January 25, 2018

Background

- PJM conducts a long-term FTR auction for the three consecutive Planning Periods immediately subsequent to the Planning Period during which the long-term FTR auction is conducted
- The capacity offered for sale in long-term Financial Transmission Rights auctions is the residual system capability after the Annual Auction Revenue Rights allocations and the annual Financial Transmission Rights auction
  - Auction Revenue Rights allocated in the immediately prior annual Auction Revenue Rights allocation process are self-scheduled into Financial Transmission Rights, which are modeled as fixed injections and withdrawals in the long-term Financial Transmission Rights auction

Problem Statement Overview

Current Long-Term FTR modeling practices do not account for future transmission system upgrades

Future upgrades can have significant impacts on congestion revenue

PJM is concerned that its Long-term FTR auction clearing prices may not fully reflect the true future system capability

Proposal Concept

Under today's construct, the Long-term FTR Auction network model does not include future transmission system expansions

However, the Annual ARR/FTR network model does include upgrades that will be in-service by June 30th

PJM proposal concept: expand this current methodology to the Long-term FTR network model for one year into the future

Basis for Proposal – 3 things to consider

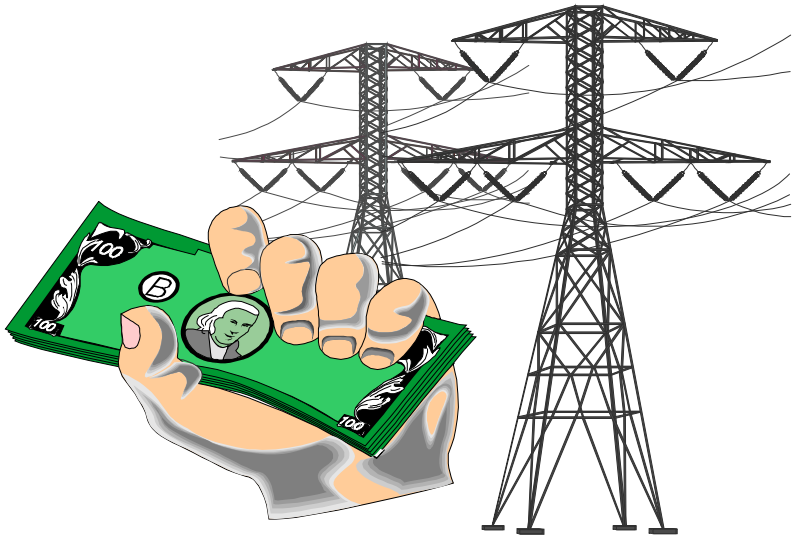
- Timing for transmission upgrades coming into service beyond 12 months is less certain
  - This raises concerns with FTR over-allocations and FTR underfunding
- Methodology for studying only those impactful upgrades
  - Low frequency High Impact methodology
- One year out modeling allows for ARR capability to be carved out of the Long-term FTR model and preserved for the next Annual Allocation
  - Preserves FERC mandated LSE priority rights to congestion revenues

PJM Proposal

Component	Status Quo	PJM Modification	PJM Reasoning
In-service Timing	N/A; For Annual Auctions, FTR group models future upgrades in service by 6/30 of that planning period	Extend Annual process to Long Term. Model upgrades in service by 6/30 of YR1 of Long Term Auction	• In-service timing beyond 12 months is uncertain • Conservative approach for FTR revenue adequacy
What Upgrades Will Be Modeled in LT Auctions	None	Filter upgrades via “low frequency high impact” method	Capture only those upgrades that will impact congestion
ARR Holder Priority Rights to Congestion Revenues	All Planning Period ARRs Self-Scheduled as FTRs in Long Term Auction Model	SQ + Run new Residual ARR Market to carve out additional MWs created by upgrades	Preserve additional transmission capability created by future upgrades

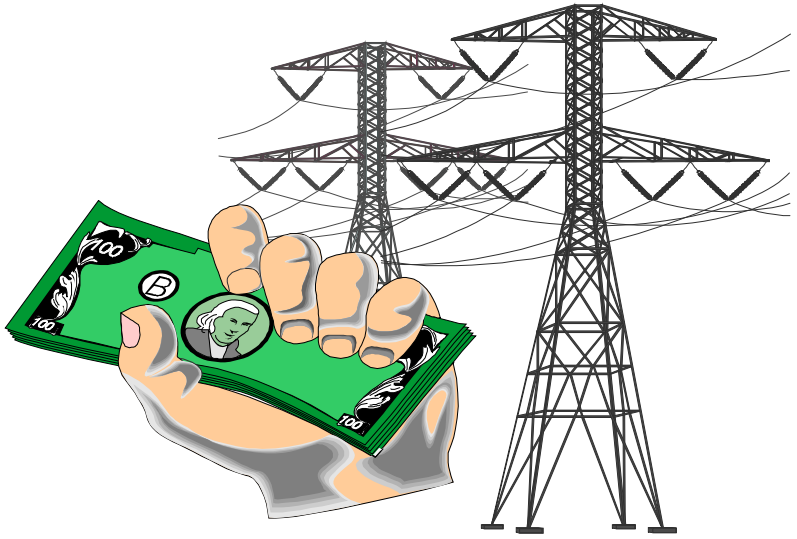
What is Low Frequency High Impact?

- LFHI is a way to frame the scope of the power flow study to only future upgrades with significant impacts on congestion
  - Monitor constraints that have contributed at least $5M to congestion over the past year **or** any future constraint
  - A future transmission upgrade must impact at least one of these constraints by +/-10% or the upgrade must be an identified constraint
    - Line Outage Distribution Factor (LODF) based for new facilities



Determining Upgrades

- PJM will study all approved RTEP projects
  - The FTR group will confer with Planning to discuss each potential upgrade to model based on in-service date
  - Backbone and non-backbone projects approved for market efficiency or reliability



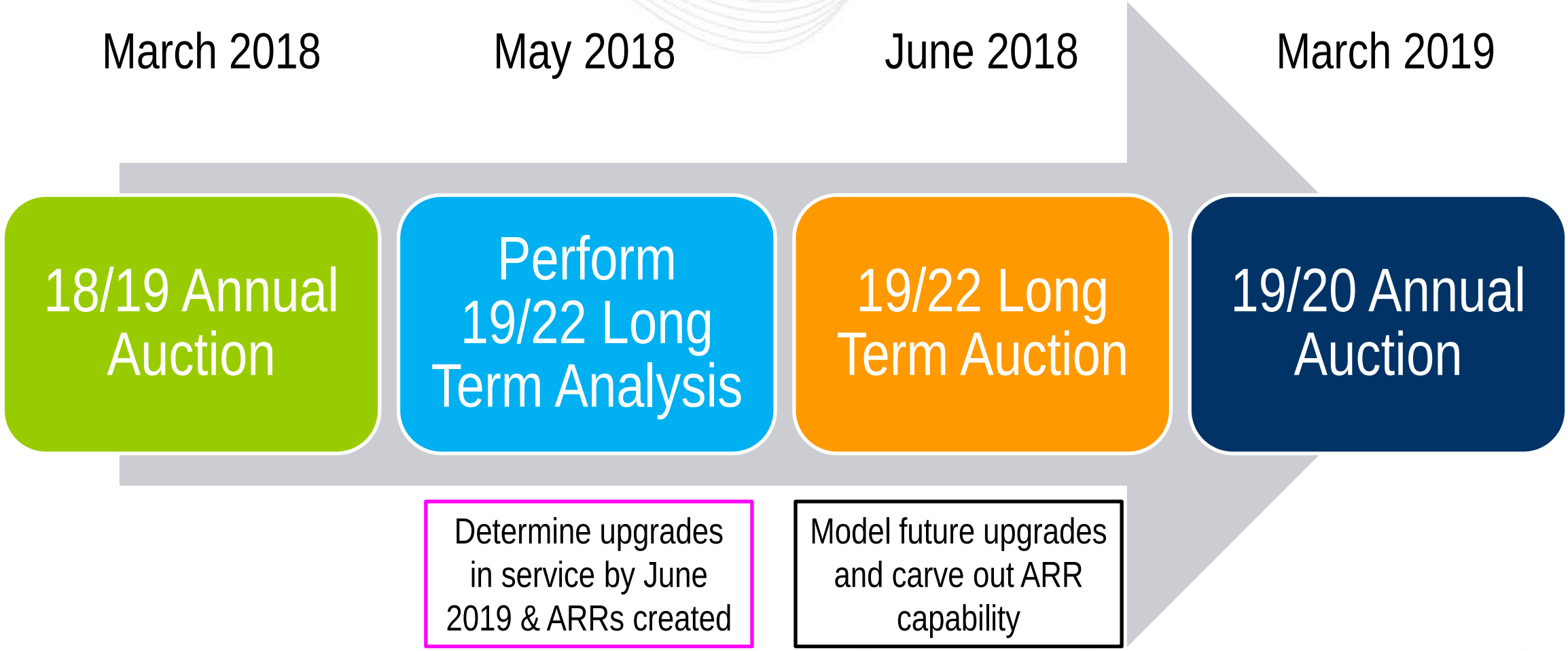
Proposal Details - Timing

- Beyond 12 months out in-service timing becomes uncertain
  - Roughly 1/3 of projects were late, looking out past 12 months
- For this reason, PJM is advocating to limit study to 1 year out upgrades only
  - Specifically, study only those upgrades that will be in-service and confirmed by June 30th of LT FTR Auction YR1
- This assessment will be done before each round of the LT Auction in order to adjust topology for any delays or accelerations
  - Revised In-Service dates are available on pjm.com

Proposal Details – LSE Priority Rights

- PJM Future modeling must ensure ARR holders maintain priority rights to congestion revenues
- Currently, this is achieved by self-scheduling all ARRs for the planning period into the Long-term FTR Auction network model
  - Carve out capability of LT Auction model
- PJM's proposal preserves the status quo and adds an additional step to ensure any incremental capability created by to-be modeled transmission system upgrades is also preserved
  - Done through a new "Long-term Residual ARR Market"

Proposed Process Timeline

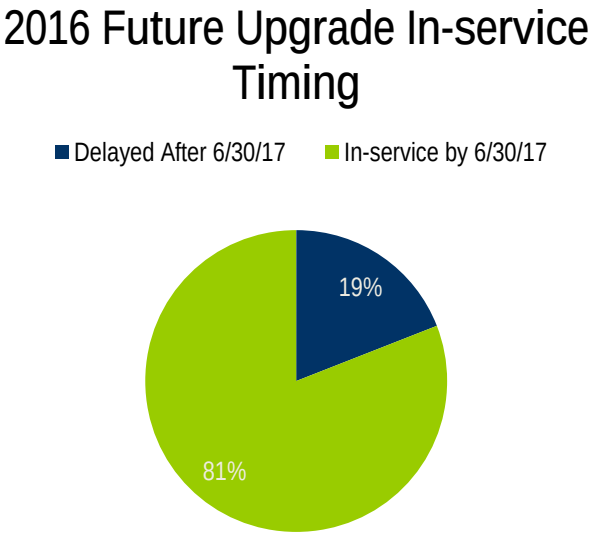


Appendix

LFHI 2016 Example

Test Upgrades with high probability of in-service by June of following year

Description	TO	Projected In-service Date as of 6/3/2016	Actual in-service Data
New Cardiff - Lewis #2 138 kV line and associated substation upgrades, environmental work	AEC	5/31/2017	5/31/2019
Rebuild approximately 2.8 miles of Maliszewski - Polaris 138 kV line in Ohio	AEP	6/1/2017	12/1/2015
Reconductor 6.8 miles of 138kV 336 ACSR with 336 ACSS from Double Toll Gate to Riverton	APS	6/1/2017	5/16/2017
Rebuild Graceton - Bagley 230 kV as double circuit line using 1590 ACSR. Terminate new line at Graceton with a new circuit breaker.	BGE	6/1/2017	2/6/2017
Rebuild the existing Bagley - Raphael Rd. 230 kV line to double circuit 230 kV line	BGE	6/1/2017	2/6/2017
Construct a new Byron to Wayne 345 kV circuit	ComEd	6/1/2017	4/7/2017
Build a new 230 kV circuit from Larrabee to Oceanview	JCPL	6/1/2017	7/14/2017
Install 2nd Hunterstown 230/115 kV transformer	ME	6/1/2017	4/17/2017
Reconductor Hunterstown - Oxford 115 kV line	ME	6/1/2017	5/17/2017
Install a second Eddystone 230/138 kV transformer	PECO	6/1/2017	6/1/2017
Construct Warren 230 kV ring bus and install a second Warren 230/115 kV transformer	PENELEC	12/31/2016	6/30/2017
Loop the 2026 (TMI - Hosensack 500 kV) line in to the Lauschtown substation and upgrade relay at TMI 500 kV	ME	6/1/2017	5/23/2017
Install Lauschtown 500/230 kV substation (below 500 kV portion) - Includes the 500/230 kV transformer	PPL	5/11/2017	6/3/2017
Install Lauschtown 500/230 kV substation (500 kV portion) - Includes 500 kV yard work, 500 kV CBs, and 500 kV line tie-in	PPL	5/11/2017	6/3/2017
Construct a new 230/69 kV Lauschtown substation. The South Akron - Berks 230 kV line and South Akron - South Reading 230 kV line will terminate into the new 230 kV yard at Lauschtown	PPL	5/11/2017	5/1/2017
Reconductor the PSEG portion of the Burlington - Croydon circuit with 1590 ACSS	PSEG	12/15/2016	1/30/2018
Convert the Bayway - Linden "W" 138 kV circuit to 345 kV and any associated substation upgrades	PSEG	6/1/2017	5/6/2017
Convert the Bayway - Linden "M" 138 kV circuit to 345 kV and any associated substation upgrades	PSEG	6/1/2017	5/6/2017
New Bayway 345/138 kV transformer #1 and any associated substation upgrades	PSEG	6/1/2017	1/31/2018
New Bayway 345/138 kV transformer #2 and any associated substation upgrades	PSEG	6/1/2017	5/6/2017
New Linden 345/230 kV transformer and any associated substation upgrades	PSEG	6/1/2017	4/7/2017



LFHI 2016 Example

Monitored Element	Contingency
CONASTON230 KV CNS-NOR2	L500.Brighton-Conastone
GRACETON230 KV 230-1	L230.Graceton-Bagley.2304
BAGLEY 230 KV BAG-GRA	L500.Brighton-Conastone
156 CHER345 KV TR81CT-P	L345.CherryValley-SilverLake.15616
20 BRAID345 KV 2003	L345.DavisCreek-Braidwood.2004 S SPOG 2-24
CONASTON500 KV CNS-PEA	BASE
107 DIXO138 KV 10714	L345.Nelson-Electric Junction.15502
156 CHER345 KV TR82CT-P	L345.CherryValley-SilverLake.15616
Westwood 345/138 BK1 l/o Westwood 345/138 BK2	Westwood 345/138 XF2
COOLSPRI230 KV COL-MIL	L230.IndianRiver-Milford.23034
122 BELV138 KV 15623 2	L345.CherryValley-SilverLake.15616
6 BYRON 345 KV 0621	L345.Nelson-Electric Junction.15502
MAGNTATN138 KV MAG-REY	DEQUINE-WESTWOOD #1 345KV LINE
PLYMOUTH230 KV PLY-WHI3	Limerick-Cromby.220-61
156 CHER138 KV TR82CT-S	L345.CherryValley-SilverLake.15616
BAGLEY 230 KV BAG-RAP	L500.Brighton-Conastone
LINE 230 KV 2045A	L500.Brambleton-Mosby.590A
111 ELEC138 KV 11105	345L11124 Electric Jct-Lombard 345 kV Line
BEDINGTO500 KV BED-BLA	BASE
EMILIE 138 KV EMI-FAL	L230.Croydon-Burlington.D-220-30
CONASTON230 KV CNS-OTT	L500.Conastone-PeachBottom.5012
6 BYRON 345 KV 0622	L345.Byron-Cherry Valley.0621 (SPOG 1-3-F)
JACK ME 230 KV JAC-TMI	230/115.MiddletownJct.T1&2 + 230.MiddltwnJct.Bus4
GRACETON230 KV GRA-SAF	L500.Conastone-PeachBottom.5012
122 BELV138 KV 15623 2	L345.Cherry Valley-Silver Lake.15616
CONASTON230 KV CNS-NOR2	L230.Conastone-Northwest.2310
DUMONT2 765 KV 1-P	Cook.U1
CONASTON500 KV CNS-PEA	L500.Hunterstown-Conastone.5013
APSOUTH contingency 22	L500.Brighton-Conastone
Greentown 765/138 T2 l/o Jefferson-HangingRock 765 kV	L765.HangingRock-Jefferson
LORETTO 138 KV LOR-VIE	L230.IndianRvr-PineyGrve.23002+230/138.PinyGr.AT20
LINE 138 KV CAP-CHE1	L345.Amos-Kanawha River

Monitor ARR impact across these constraints before and after upgrades are applied to power flow simulation model (Transmission Adequacy & Reliability Assessment)

Line Outage Distribution Factor Results for hypothetical 2016 Study

Description	Max LODF Impact	Min LODF Impact	Avg Impact	Constraints above 10% impact
New Cardiff - Lewis #2 138 kV line and associated substation upgrades, environmental work	1.24%	-0.29%	0.05%	0
Rebuild approximately 2.8 miles of Maliszewski - Polaris 138 kV line in Ohio	0.11%	-0.03%	0.01%	0
Reconductor 6.8 miles of 138kV 336 ACSR with 336 ACSS from Double Toll Gate to Riverton	0.49%	-0.22%	0.05%	0
Rebuild Graceton - Bagley 230 kV as double circuit line using 1590 ACSR. Terminate new line at Graceton with a new circuit breaker.	100%	-1.51%	3.81%	6
Rebuild the existing Bagley - Raphael Rd. 230 kV line to double circuit 230 kV line	100%	-2%	3.81%	6
Construct a new Byron to Wayne 345 kV circuit	36.98%	-1.05%	3.47%	4
Build a new 230 kV circuit from Larrabee to Oceanview	0.64%	-0.42%	0.04%	0
Install 2nd Hunterstown 230/115 kV transformer	8.96%	-2.52%	0.65%	0
Reconductor Hunterstown - Oxford 115 kV line	8.96%	-2.52%	0.65%	0
Install a second Eddystone 230/138 kV transformer	1.01%	-0.15%	0.04%	0
Construct Warren 230 kV ring bus and install a second Warren 230/115 kV transformer	0.06%	-0.03%	0.01%	0
Loop the 2026 (TMI - Hosensack 500 kV) line in to the Lauschtown substation and upgrade relay at TMI 500 kV	6.13%	-1.92%	0.26%	0
Install Lauschtown 500/230 kV substation (below 500 kV portion) - Includes the 500/230 kV transformer	6.13%	-1.92%	0.26%	0
Install Lauschtown 500/230 kV substation (500 kV portion) - Includes 500 kV yard work, 500 kV CBs, and 500 kV line tie-in	6.13%	-1.92%	0.26%	0
Construct a new 230/69 kV Lauschtown substation. The South Akron - Berks 230 kV line and South Akron - South Reading 230 kV line will terminate into the new 230 kV yard at Lauschtown	6.13%	-1.92%	0.26%	0
Reconductor the PSEG portion of the Burlington - Croydon circuit with 1590 ACSS		-0.73%	0.22%	0
Convert the Bayway - Linden "W" 138 kV circuit to 345 kV and any associated substation upgrades	0.33%	-0.05%	0.02%	0
Convert the Bayway - Linden "M" 138 kV circuit to 345 kV and any associated substation upgrades	0.33%	-0.05%	0.02%	0
New Bayway 345/138 kV transformer #1 and any associated substation upgrades	0.33%	-0.05%	0.02%	0
New Bayway 345/138 kV transformer #2 and any associated substation upgrades	0.33%	-0.05%	0.02%	0
New Linden 345/230 kV transformer and any associated substation upgrades	0.33%	-0.05%	0.02%	0

LFHI 2016 Example

- As a result, 3 out of 21 upgrades would have been modeled in the 17/20 Long-term FTR Auction
  - Rebuild Graceton - Bagley 230 kV as double circuit line using 1590 ACSR. Terminate new line at Graceton with a new circuit breaker.
  - Rebuild the existing Bagley - Raphael Rd. 230 kV line to double circuit 230 kV line
  - Construct a new Byron to Wayne 345 kV circuit

Proposal Details - LFHI

- Upgrades will be determined via “LFHI” method
  - Perform power flow analysis specifically monitoring historical DA constraints from the previous calendar year with more than $5M in congestion revenue contribution
  - Apply upgrades to studied topology and determine where there is a 10% delta in flow across those monitored constraints
- This method will ensure only significant, impactful upgrades are considered for the long term FTR model
  - If applied for 17/20 LT Auction, 3 upgrades out of 21 would have met this criteria
  - Power flow analysis allows for study of impact from multiple upgrades

Line Outage Distribution Factors

- Purpose of this study is to determine the ARR impact of a transmission upgrade coming in to service on specific monitored facilities
- This can be measured through Line Outage Distribution Factors (LODFs)
- The TARA software reports LODFs as the portion of the base ARR impact on facility X that is redistributed to facility Y as a result of the outage of facility X

SFT Data Inputs

- Transmission Upgrades
- Existing ARRs
- Facility Ratings
- PJM Network Model
- List of Contingencies
- Interface Ratings
- Monitored Constraints

TARA
(DC Powerflow)

Residual ARR Review

- ARRs prorated in Stage 1B of the Annual Allocation may be allocated Residual ARRs for the following:
  - Increased transmission capability made available by certain transmission upgrades made during the planning year that were not modeled in the Annual ARR Allocation
  - Increased transmission capability made available for periods when Annual ARR modeled transmission outages are not out of service

Residual ARR Characteristics

Residual ARR MWs plus previously awarded Stage 1 and Stage 2 MWs cannot exceed the Network Service Peak Load value for a particular participant

Residual ARRs are effective the first month the increased transmission capability is modeled in the Monthly FTR Auction

Economic value of Residual ARRs are based on the MW amount and the nodal clearing price difference between the source and sink nodes for the FTR Obligations resulting from each monthly FTR Auction the Residual ARR is effective

Clearing Residual ARR MWs

- Market is created with prorated stage 1B requests from Annual Allocation
  - All ARR requests from stage 1B that did not fully clear

- Proration is done manually by operator until violated facilities are minimized as much as possible
  - Constraint basis – residual requests that impact violated constraints are prorated

Additional Detail for ARR Carve Out

- In response to member concerns, PJM will include stage 1B & stage 2 prorated paths in the Long Term Residual Market
  - Will provide potential for additional ARR capability to be carved out to preserve ARR holder priority rights to congestion revenues
- Main concept:
  - Any additional capability that could have been awarded in the most recent Annual Allocation, as a result of modeling future upgrades, will be carved out of the Long Term FTR Model

- Create Test Scenario for 17/20 Long Term Market
- 16/17 topology plus modeled upgrades at:
  - Graceton – Bagley – Raphael Road 230 kV (PPL – BGE)
  - Byron – Wayne 345 kV (COMED)
- Compare additional ARRs awarded between 16-17 and 17-18 with capability created in test case for 17/20 Long Term Market for COMED, PPL, BGE
- Results:
  - COMED carve out matched roughly 98%
  - BGE matched roughly 100%

Analysis Results

Zone	Upgrade Modeled	Additional MWs available in 17-18	Long Term Residual Capability Test Run	% Carved Out
BGE	Graceton - Bagley - Raphael Road 230kV	-19.7	265.4	100%
COMED	Byron - Wayne 345kV	1439.7	1413.4	98.2%

Conclusion

- A Long-Term Residual proposal is an accurate method to account for additional capability created if upgrades were modeled in the previous Annual ARR allocation
  - This proposal does not account for all transmission system capability;
  - It accounts for additional ARRs that could have been awarded given extra transmission capability