



# Auction Revenue Rights Allocation Example

April 26, 2002

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## Objectives

**At the completion of this presentation, you should be able to understand the concepts and principles of ...**

- **Interim Incremental ARR**s
- **The four-stage ARR Allocation process**
- **Achieving revenue neutrality in the allocation of FTR Auction revenues**

This presentation distributes revenues from the FTR Auction example I wrote for section 6 of [M-06 Financial Transmission Right Draft 04-22-02.doc](#) located on [http://www.iso-ne.com/cmsmss/Standard\\_Market\\_Design/Draft\\_Manuals/](http://www.iso-ne.com/cmsmss/Standard_Market_Design/Draft_Manuals/)



## Agenda

- Introduction to ARR Allocations and Interim Incremental ARRs
- Introduction to the PJM Five-Bus Power System Model used in the Examples
- Overview of the FTR Auction Examples from Manual 6
- Review the Interim Incremental ARR Examples on the assignment of FTR Auction Revenues to an Eligible Transmission Upgrade
- Review the ARR Allocation Examples that distribute FTR Auction Revenues to ARR Holders
- Review how Revenue Neutrality is achieved in the ARR Allocation Examples



# Understanding ARRs



## What is an ARR?

### An Auction Revenue Right (ARR) is ...

- Schedule 15 of the NOATT Tariff specifies that revenue collected in the FTR Auctions be allocated to *ARR holders* and *Incremental ARR holders*<sup>1</sup>.
- A right to receive FTR Auction Revenues from the sale of FTRs other than FTRs sold by FTR Holders.
- Determined and allocated to Congestion Paying Entities, Transmission Customers and NEMA LSEs (including any of the foregoing that are parties to Excepted Transactions that are included in the list of transactions in Attachments G and G-2 of the Tariff), using a four-stage process as described in this example.

<sup>1</sup> Incremental ARR holders are entities who pay for new transmission upgrades which increase transfer capability on the NEPOOL Transmission System, making it possible for the System Operator to award additional FTRs in the FTR Auction, shall be awarded ARRs.



## How are ARRs obtained?

### ARRs are obtained by an allocation ...

- Every entity with load that is responsible for making congestion payments receives an ARR that represents a load weighted ratio share of all capacity sources delivered to their load sink.
- Participant rights to the auction revenues are assured in the four-stage ARR Allocation by ensuring that injections and withdrawals that result from ARRs awarded in the allocation will not overload the NEPOOL Transmission System under normal conditions.



## What an ARR is not

### **The ARR process does not ...**

Guarantee that the four-stage process will allocate all FTR Auction Revenues without scaling the solution to achieve revenue neutrality.



## Understanding Interim Incremental ARR



## What are Interim Incremental ARR's?

### Interim Incremental ARR's are ...

- An Interim Incremental ARR provides a right to entities who provide an upgrade to the transmission system which is not included in the Pool RNS Rate to receive ARR's that are consistent with the increase in FTRs that clear the FTR Auction as a result of the transmission upgrade.
- Interim Incremental ARR's awarded to an entity who pays for transmission upgrades will not be subject to reduction in Stages 2, 3, and 4 of the ARR Allocation process.
- The Interim Incremental ARR (IIARR) methodology is to be effective until the advent of the first Annual FTR Auction (tentatively scheduled for April 2004).



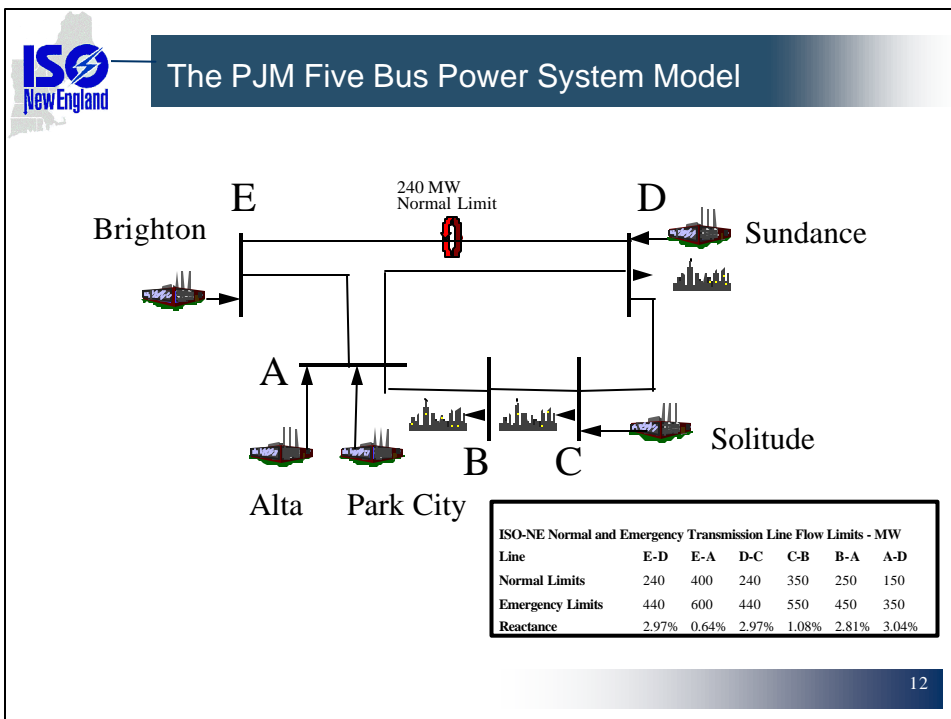
## How are Interim Incremental ARR's obtained?

### Interim Incremental ARR's are obtained through the auction ...

- The award is in direct proportion to the percentage of the costs of the upgrade paid for by an entity to the extent that the costs are not reimbursable under the Pool RNS Rate.
- The FTR Auction is conducted with and without the eligible transmission upgrade and the difference in FTRs are priced at the FTR Auction's Clearing Price yielding the IIARR payment for the upgrade.

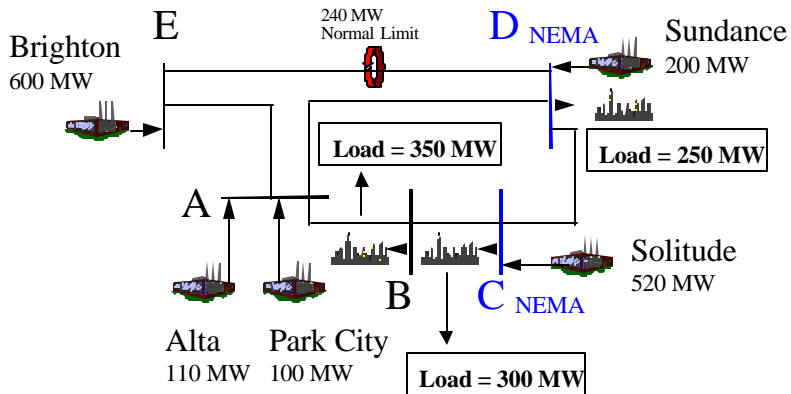


# The Five Bus Power System Model





## Five Bus ARR Model with Load & Generation

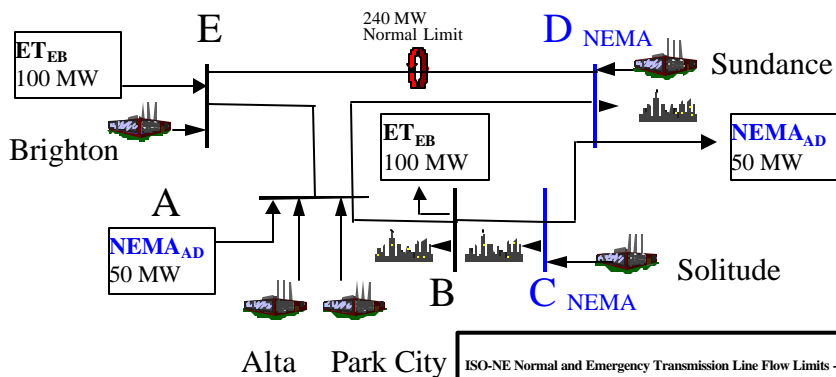


ISO-NE Normal and Emergency Transmission Line Flow Limits - MW						
Line	E-D	E-A	D-C	C-B	B-A	A-D
Normal Limits	240	400	240	350	250	150
Emergency Limits	440	600	440	550	450	350
Reactance	2.97%	0.64%	2.97%	1.08%	2.81%	3.04%

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## Five Bus ARR Model with ET & NEMA Contracts



ISO-NE Normal and Emergency Transmission Line Flow Limits - MW						
Line	E-D	E-A	D-C	C-B	B-A	A-D
Normal Limits	240	400	240	350	250	150
Emergency Limits	440	600	440	550	450	350
Reactance	2.97%	0.64%	2.97%	1.08%	2.81%	3.04%

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## What is an SFT?

**A Simultaneous Feasibility Test (SFT) is an integral part of the process...**

- It provides the Linear Programming (LP) based auction and dispatch algorithms with a determination as to whether transmission line flows are physically achievable without exceeding the MW flow limits
- In addition, the SFT used with the auction and allocation algorithms is used not only to determine secure transmission line flows with all lines in-service, but also to determine secure transmission line flows for each contingency
- The SFT for this example, takes each of the six transmission lines of the five-bus power system model out-of-service one at a time as a separate contingency

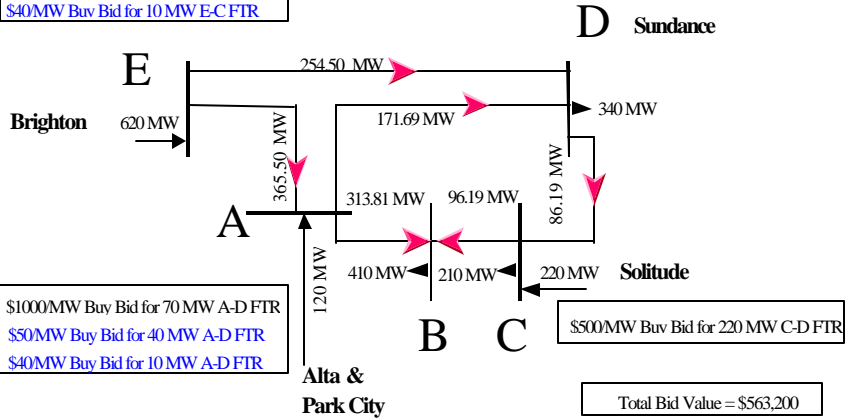


## Annual FTR Auction Example

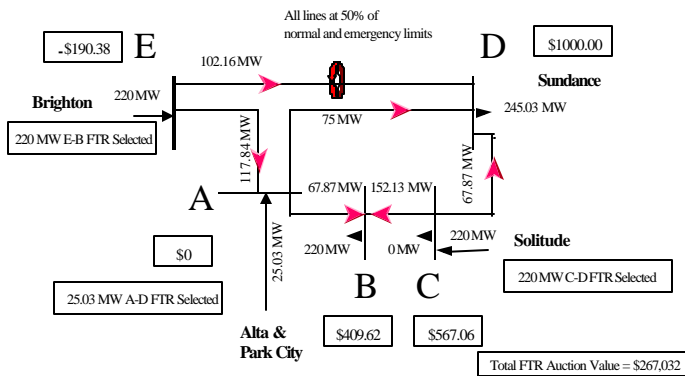


## Annual FTR Auction Ignoring Transmission Limits

\$600/MW Buy Bid for 400 MW E-B FTR  
 \$700/MW Buy Bid for 200 MW E-C FTR  
 \$40/MW Buy Bid for 10 MW E-B FTR  
 \$40/MW Buy Bid for 10 MW E-C FTR



## Annual FTR Auction Respecting Transmission Limits



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	50% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						50% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	102.16	120	0.00	220.00	133.19	32.62	133.19	151.30	220
E-A	117.84	200	220.00	0.00	86.81	187.38	86.81	68.70	300
D-C	-67.87	120	-99.24	-31.69	0.00	-220.00	0.00	-93.73	220
C-B	152.13	175	120.76	188.31	220.00	0.00	220.00	126.27	275
B-A	-67.87	125	-99.24	-31.69	0.00	-220.00	0.00	-93.73	225
A-D	75.00	75	145.79	-6.65	111.84	-7.58	111.84	0.00	175



## Annual FTR Auction Selection of Winning Bids with Transmission Upgrade

1 Bid Path	2 Bid Quantity (MW)	3 Bid Price (\$/MW)	4 Sensitivity Factors <sup>1</sup>		5 = 3 / 4 Cost Effectiveness Ratio (\$/MW)		6 FTRs Selected (MW)	7 = 3 * 6 Auction Value \$	8 = 4 * 6 Flow on Constrained Lines (MW)	
			Line A-D	Line E-D	Line A-D	Line E-D			Line A-D	Line E-D
E-B	400	600	0.1017	1.0000	5902	600	220	\$132,000	22.37	220.00
E-C	200	700	0.1706	1.0000	4104	700	0	\$0	0.00	0.00
C-D	220	500	0.1895	0.0000	2639	0	220	\$110,000	41.68	0.00
A-D	70	1000	0.4376	0.0000	2285	0	25.03239	\$25,032	10.95	0.00
A-D	40	50	0.4376	0.0000	114	0	0	\$0	0.00	0.00
E-B	10	40	0.1017	1.0000	393	40	0	\$0	0.00	0.00
A-D	10	40	0.4376	0.0000	91	0	0	\$0	0.00	0.00
E-C	10	40	0.1706	1.0000	235	40	0	\$0	0.00	0.00
								\$267,032	75.00	220.00

<sup>1</sup> Sensitivity factors change under contingencies. Sensitivity factors for line A-D are for all lines in-service. Sensitivity factors for line E-D result from the contingent loss of line E-A.



## Annual FTR Auction Clearing Prices

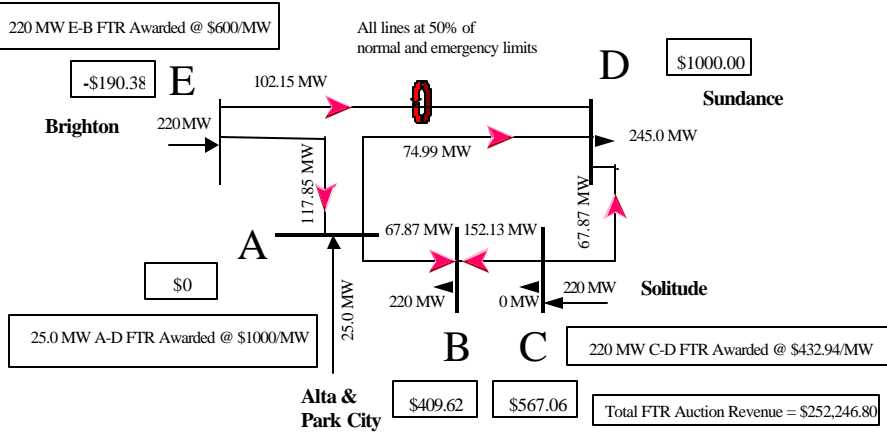
From Bus A	Calculation for Components of FTR Clearing Price		FTR Clearing Price = <sup>S</sup> Cost Components
	Binding Constraint A-D	Binding Constraint E-D	
A	Reference	Reference	\$0.00
B	\$409.62	\$0.00	\$409.62
C	\$567.06	\$0.00	\$567.06
D	\$1000.00	\$0.00	\$1000.00
E	\$177.285	-\$367.664	-\$190.38

### Annual FTR Auction Clearing Prices by Path - \$/MW

Source \ Sink	A	B	C	D	E
A	0	409.62	567.06	1000	-190.38
B	-409.62	0	157.44	590.38	-600
C	-567.06	-157.44	0	432.94	-757.44
D	-1000	-590.38	-432.94	0	-1190.38
E	190.38	600	757.44	1190.38	0



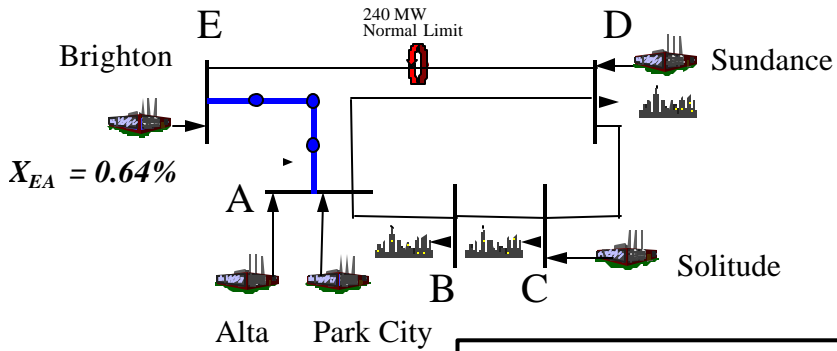
## Annual FTR Auction Results



## Interim Incremental ARR Allocation of Annual FTR Auction Revenues



## The Five Bus Model - Post Line E-A Upgrade

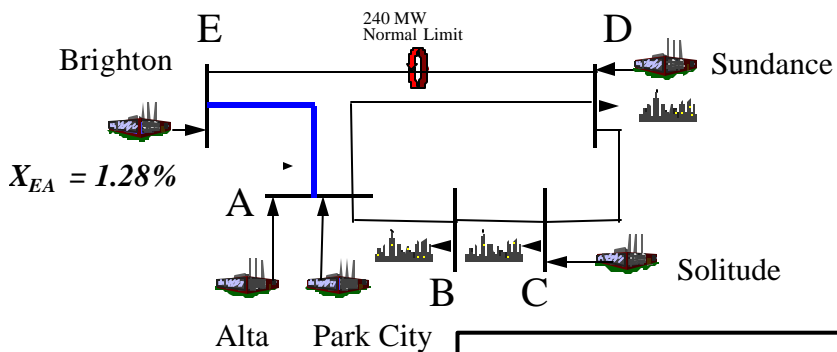


ISO-NE Normal and Emergency Transmission Line Flow Limits - MW						
Line	E-D	E-A	D-C	C-B	B-A	A-D
Normal Limits	240	400	240	350	250	150
Emergency Limits	440	600	440	550	450	350
Reactance	2.97%	0.64%	2.97%	1.08%	2.81%	3.04%

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## The Five Bus Model - Pre Line E-A Upgrade

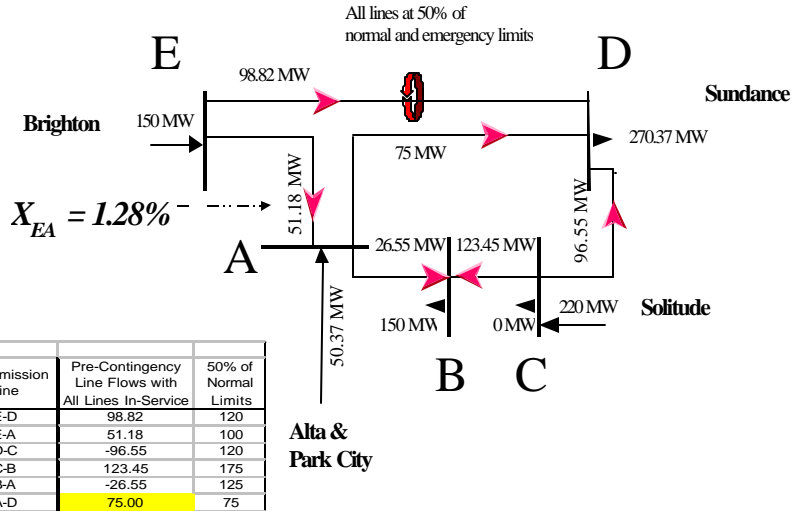


ISO-NE Normal and Emergency Transmission Line Flow Limits - MW						
Line	E-D	E-A	D-C	C-B	B-A	A-D
Normal Limits	240	200	240	350	250	150
Emergency Limits	440	300	440	550	450	350
Reactance	2.97%	1.28%	2.97%	1.08%	2.81%	3.04%

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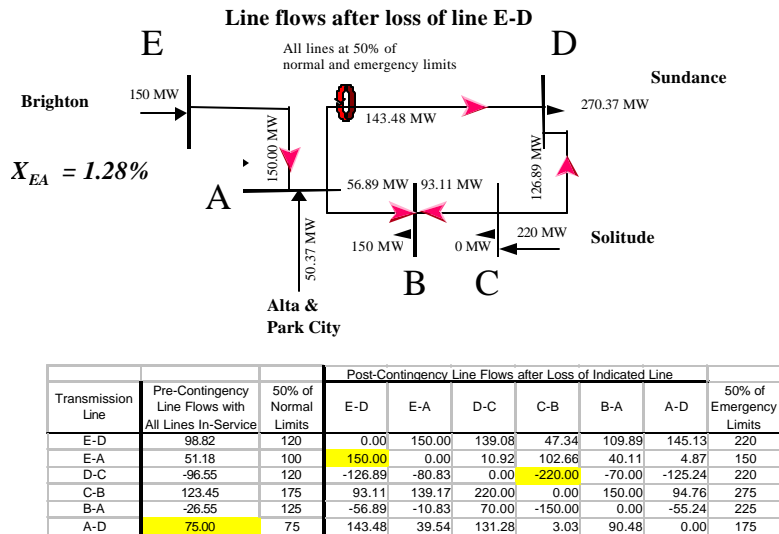
## Comparison of Line Flows with Limits - MW



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## Contingency Line Flows Compared with Limits - MW



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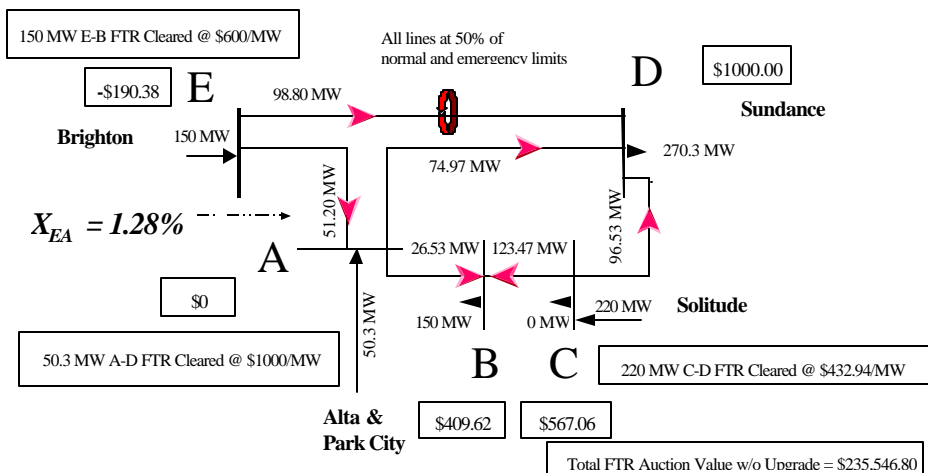
## Annual FTR Auction Results without the Transmission Upgrade to Line E-A

1 Bid Path	2 Bid Quantity (MW)	3 Bid Price (\$/MW)	4 Sensitivity Factors <sup>1</sup>		5 = 3 / 4 Cost Effectiveness Ratio (\$/MW)		6 FTRs Selected (MW)	7 = 3 * 6 Auction Value w/o Upgrade \$	8 = 4 * 6 Flow on Constrained Lines (MW)	
			Line A-D	Line E-A	Line A-D	Line E-A			Line A-D	Line E-A
			E-B	400	600	0.0502			1.0000	11942
E-C	200	700	0.1232	1.0000	5683	700	0	\$0	0.00	0.00
C-D	220	500	0.2006	0.0000	2493	0	220	\$110,000	44.13	0.00
A-D	70	1000	0.4633	0.0000	2158	0	50.3687	\$50,369	23.34	0.00
A-D	40	50	0.4633	0.0000	108	0	0	\$0	0.00	0.00
E-B	10	40	0.0502	1.0000	796	40	0	\$0	0.00	0.00
A-D	10	40	0.4633	0.0000	86	0	0	\$0	0.00	0.00
E-C	10	40	0.1232	1.0000	325	40	0	\$0	0.00	0.00
								\$250,369	75.00	150.00

<sup>1</sup> Sensitivity factors change under contingencies and also with certain transmission upgrades. Sensitivity factors for line A-D reflect the transmission system without the upgrade to line E-A as is for all lines in-service. Sensitivity factors for line E-A result from the contingent loss of line E-D.



## Annual FTR Auction Results without Line E-A Upgrade





## Interim Incremental ARR Payment

The Interim Incremental ARR payment is the difference in value between the Annual FTR Auction results with and without the eligible transmission upgrade:

	Annual FTR Auction \$
With Upgrade	252,246.80
Without Upgrade	235,546.80
Total IIARR Payment	16,700.00

The IIARR would be settled at a monthly rate for the duration of the effective period of the FTR Auction (i.e.  $16,700 / 12 = 1,391.67$  month).



## Annual ARR Allocation Example



## Collection and Disbursal of FTR Auction Revenues

In the Annual FTR Auction Example, the total revenue resulting from the FTR Auction was \$252,246.80. Interim Incremental ARR were allocated \$16,700.00 of this sum, leaving \$235,546.80 to distribute through the ARR process.

The following Annual ARR Allocation Example will demonstrate how one-twelfth of the revenue from the annual example will be collected and disbursed on a monthly basis.



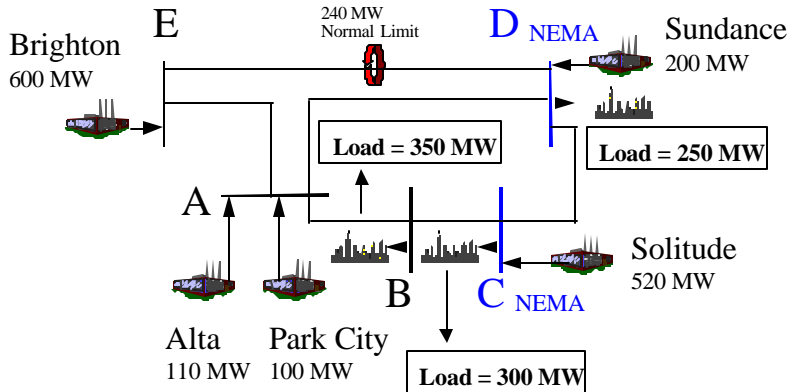
## Stage 1 ARRs

**ARRs are allocated in two steps in the first stage of the ARR Allocation ...**

- Excepted Transactions are assigned ARRs from a capacity source to a load sink
- The remaining capacity sources and load sinks are assigned as ARRs in proportion to capacity and load



## Five Bus ARR Model with Load & Generation



ISO-NE Normal and Emergency Transmission Line Flow Limits - MW						
Line	E-D	E-A	D-C	C-B	B-A	A-D
Normal Limits	240	400	240	350	250	150
Emergency Limits	440	600	440	550	450	350
Reactance	2.97%	0.64%	2.97%	1.08%	2.81%	3.04%

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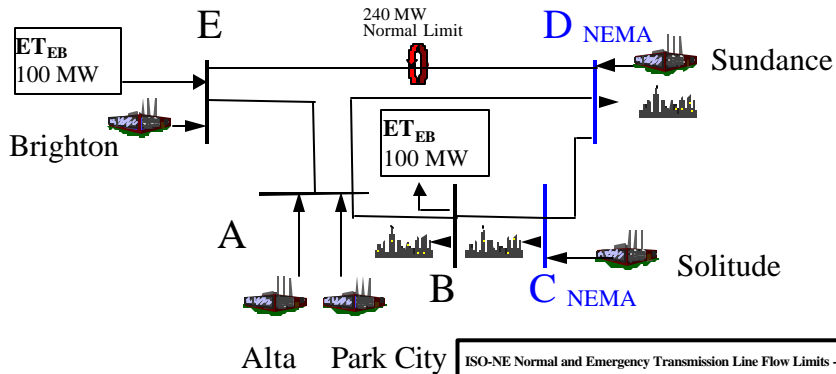
## Stage 1 ARRs - Excepted Transactions

**This example assumes that there is a 100 MW Excepted Transaction between Brighton at Node E and the load sink at Node B.**

- The entity responsible for paying the congestion costs associated with energy purchased under this Excepted Transaction would be allocated Stage 1 ARRs that correspond to this transaction.
  - 100 MW of Stage 1 ARRs would be initially allocated from Node E to Node B.

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## Five Bus ARR Model with Excepted Transaction



Line	E-D	E-A	D-C	C-B	B-A	A-D
Normal Limits	240	400	240	350	250	150
Emergency Limits	440	600	440	550	450	350
Reactance	2.97%	0.64%	2.97%	1.08%	2.81%	3.04%

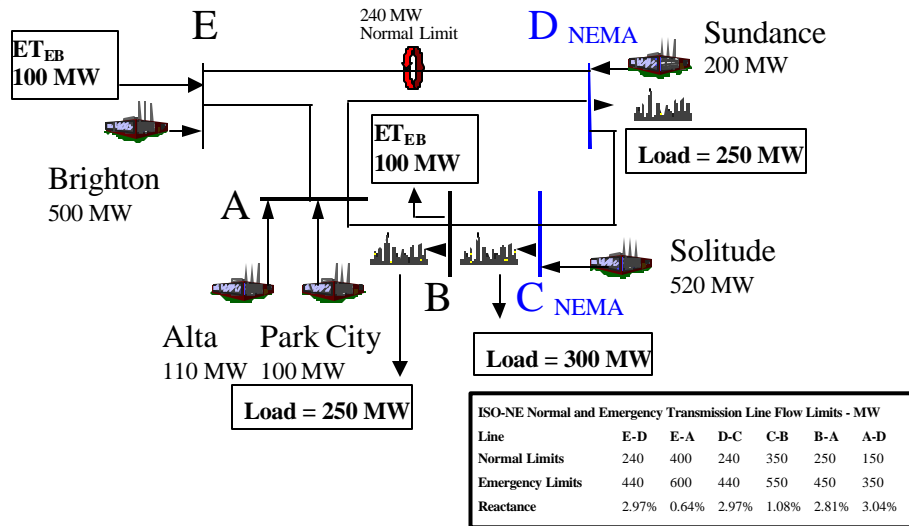
## Stage 1 ARRs - Load Ratio ARRs

**Stage 1 ARRs would also be allocated from each generator (net of capacity allocated to Excepted Transactions) to each load in proportion to Monthly Peak Load (net of load met by Excepted Transactions). The amount of ARRs allocated from each source will be equal to total generating capacity at that node.**

- For example, since Alta has a capacity of 110 MW, a total of 110 MW of ARRs will be allocated from Node A.
- Since there is a total of 1530 MW of capacity on this five-bus network, less 100 MW delivered under Excepted Transactions, a total of 1430 MW of Load Ratio ARRs will be allocated in this step.
- Other capacity sources, such as tie lines to other control areas, would also count as “generators” for the purposes of defining Stage 1 ARRs.



## Five Bus ARR Model with ET, Load & Generation



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## Stage 1 ARRs - Load Ratio Determination

Stage 1 ARRs are allocated among the entities that are responsible for paying the congestion costs associated with serving load, in proportion to the load's share of the NEPOOL Monthly Peak Load.

- Each load's share of the NEPOOL Monthly Peak Load, which is 800 MW (after deducting 100 MW of Monthly Peak Load served by Excepted Transactions) is calculated in the table below.
- Since load at Node B constitutes 31.25% of the NEPOOL Monthly Peak Load, the entities responsible for paying congestion costs associated with serving load in Node B will receive 31.25% of the ARRs from each generator location to Node B.

Load Location	Peak Load MW	Peak Load Distribution
Node B	250	31.25%
Node C	300	37.50%
Node D	250	31.25%

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## Stage 1 ARR - Initial Allocation

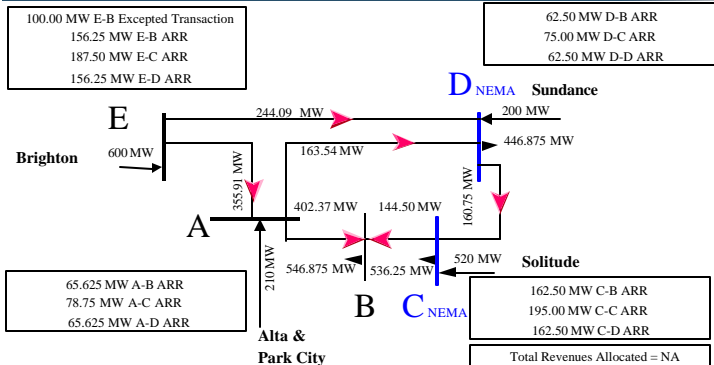
The table below indicates the Stage 1 allocation of ARRs from each generator to load. The “ET” notation indicates that those ARRs were allocated in association with an Excepted Transaction.

Source Location	Sink Location	Load Name	Peak Load Distribution	Capacity (MW)	Initial ARRs (MW)
A	B	Node B	31.25%	210	65.625
A	C	Node C	37.50%	210	78.75
A	D	Node D	31.25%	210	65.625
C	B	Node B	31.25%	520	162.5
C	C	Node C	37.50%	520	195
C	D	Node D	31.25%	520	162.5
D	B	Node B	31.25%	200	62.5
D	C	Node C	37.50%	200	75
D	D	Node D	31.25%	200	62.5
E	B	Node B (“ET”)	NA	100	100
E	B	Node B	31.25%	500	156.25
E	C	Node C	37.50%	500	187.5
E	D	Node D	31.25%	500	156.25

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## Stage 1 Line Flows Compared with Limits - MW

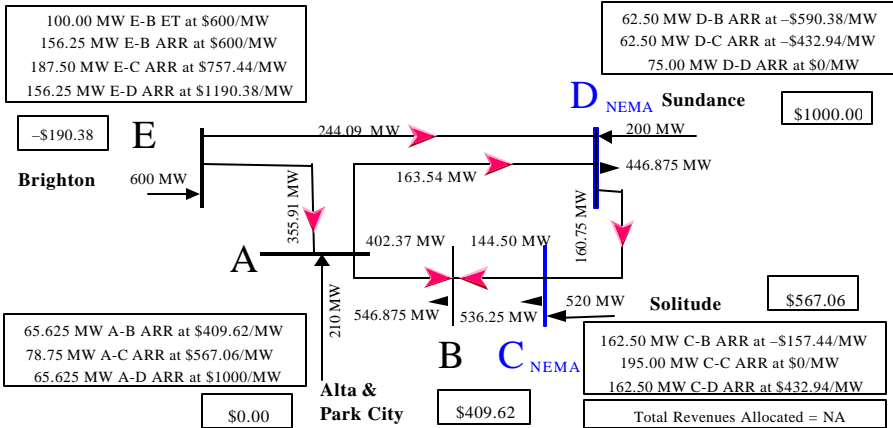


Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	244.09	240	0.00	600.00	170.60	178.03	428.03	351.24	440
E-A	355.91	400	600.00	0.00	429.40	421.97	171.97	248.76	600
D-C	160.75	240	85.80	270.04	0.00	16.25	563.12	104.37	440
C-B	144.50	350	69.55	253.79	-16.25	0.00	546.87	88.12	550
B-A	-402.37	250	-477.32	-293.08	-563.12	-546.87	0.00	-458.76	450
A-D	163.54	150	332.68	-83.08	76.27	85.09	381.97	0.00	350

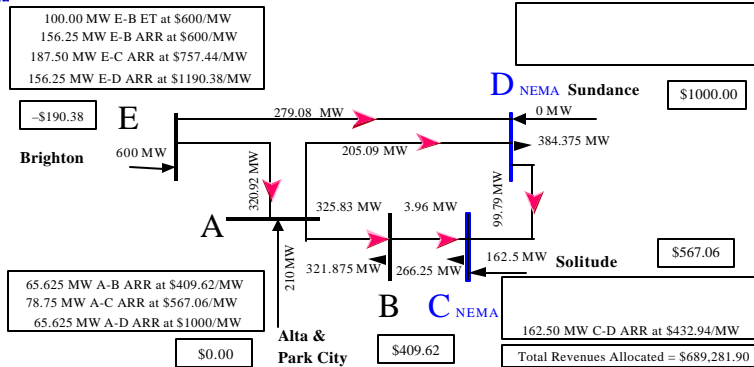
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## Stage 2 Line Flows with all Initial ARR



## Stage 2 Positive ARR Line Flows Compared with Limits - MW



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line					100% of Emergency Limits	
			E-D	E-A	D-C	C-B	B-A		A-D
E-D	279.08	240	0.00	600.00	233.46	280.89	428.03	413.45	440
E-A	320.92	400	600.00	0.00	366.54	319.11	171.97	186.55	600
D-C	99.79	240	14.10	198.34	0.00	103.75	425.62	29.08	440
C-B	-3.96	350	-89.65	94.59	-103.75	0.00	321.87	-74.67	550
B-A	-325.83	250	-411.53	-227.29	-425.62	-321.88	0.00	-396.55	450
A-D	205.09	150	398.47	-17.29	150.92	207.24	381.97	0.00	350



## Stage 2 Line Flows Compared with Limits - MW & %

Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	279.08	240	0.00	600.00	233.46	280.89	428.03	413.45	440
E-A	320.92	400	600.00	0.00	366.54	319.11	171.97	186.55	600
D-C	99.79	240	14.10	198.34	0.00	103.75	425.62	29.08	440
C-B	-3.96	350	-89.65	94.59	-103.75	0.00	321.87	-74.67	550
B-A	-325.83	250	-411.53	-227.29	-425.62	-321.88	0.00	-396.55	450
A-D	205.09	150	398.47	-17.29	150.92	207.24	381.97	0.00	350

Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	116.3%	240	0.0%	136.4%	53.1%	63.8%	97.3%	94.0%	440
E-A	80.2%	400	100.0%	0.0%	61.1%	53.2%	28.7%	31.1%	600
D-C	41.6%	240	3.2%	45.1%	0.0%	23.6%	96.7%	6.6%	440
C-B	1.1%	350	16.3%	17.2%	18.9%	0.0%	58.5%	13.6%	550
B-A	130.3%	250	91.5%	50.5%	94.6%	71.5%	0.0%	88.1%	450
A-D	136.7%	150	113.8%	4.9%	43.1%	59.2%	109.1%	0.0%	350

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## Stage 2 ARR Scaling to Achieve Simultaneously Feasibility

1	2	3	4	5 = 3 * 4	6	7 = 5 * 6	8 = 4 * 7
Type	ARR Path	Initial ARRs (MW)	Line A-D Sensitivity Factors <sup>1</sup>	Flow on Constrained Line A-D (MW)	Scale Reduction Factor	Stage 2 ARRs (MW)	Flow on Constrained Line A-D (MW)
ARR	A-B	65.625	0.1792	11.76	0.73139	47.997	8.60
ARR	A-C	78.75	0.2481	19.54	0.73139	57.597	14.29
ARR	A-D	65.625	0.4376	28.72	0.73139	47.997	21.00
ARR	C-D	162.5	0.1895	30.79	0.73139	118.850	22.52
ET	E-B	100	0.1017	10.17	0.73139	73.139	7.44
ARR	E-B	156.25	0.1017	15.89	0.73139	114.279	11.62
ARR	E-C	187.5	0.1706	31.98	0.73139	137.135	23.39
ARR	E-D	156.25	0.3600	56.25	0.73139	114.279	41.14
				205.09			150.00

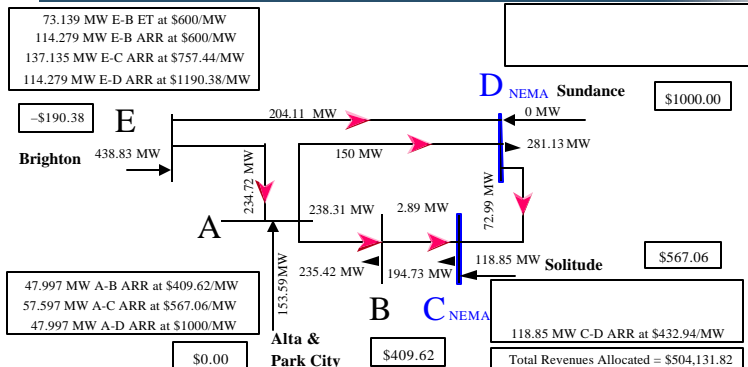
<sup>1</sup> Sensitivity factors for line A-D are for all lines in-service.

$$\text{Scale Reduction Factor} = (\text{Flow Limit on Line A-D}) / (\text{Flow on Line A-D}) = 150 / 205.09 = 0.73139$$

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## Stage 2 Line Flows Compared with Limits - MW



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	204.11	240	0.00	438.83	170.75	205.44	313.06	302.40	440
E-A	234.72	400	438.83	0.00	268.08	233.39	125.78	136.44	600
D-C	72.99	240	10.31	145.06	0.00	75.88	311.30	21.27	440
C-B	-2.89	350	-65.57	69.18	-75.88	0.00	235.42	-54.61	550
B-A	-238.31	250	-300.99	-166.23	-311.30	-235.42	0.00	-290.03	450
A-D	150.00	150	291.44	-12.64	110.38	151.57	279.37	0.00	350



## Stage 3 NEMA ARRs - NEMA Contract Treatment

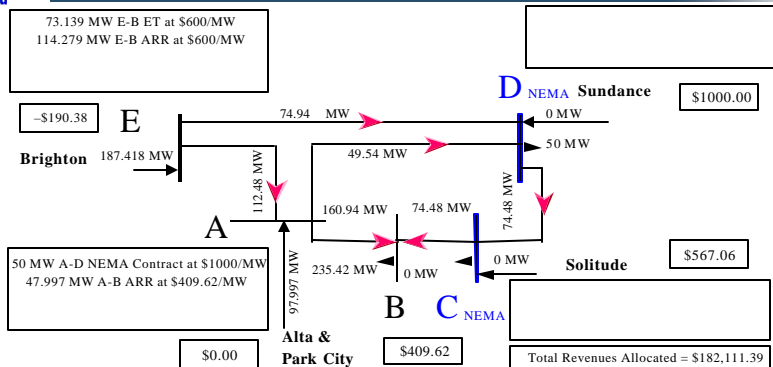
In Stage 3, ARRs are allocated to NEMA load serving entities (LSEs) with qualifying long-term purchase contracts.

- This reallocation of ARRs among NEMA LSEs is not to affect the allocation of ARRs in Stage 2 to entities that are not NEMA LSEs.
- The ARRs that correspond to these purchase contracts will be reduced if necessary to ensure simultaneous feasibility.
- No other NEMA ARRs are included in this power flow, so the ARRs that correspond to these purchase contracts will only be reduced if necessary to ensure simultaneous feasibility, even if no other NEMA LSE's were awarded any ARRs.

Then in Stage 4, ARRs for the remaining NEMA LSEs' loads are taken into account, and reduced as necessary to maintain simultaneous feasibility.



## Stage 3 Line Flows Compared with Limits - MW



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	74.94	240	0.00	187.42	40.89	40.89	148.51	107.40	440
E-A	112.48	400	187.42	0.00	146.52	146.52	38.91	80.02	600
D-C	74.48	240	51.47	109.02	0.00	0.00	235.42	57.40	440
C-B	74.48	350	51.47	109.02	0.00	0.00	235.42	57.40	550
B-A	-160.94	250	-183.95	-126.40	-235.42	-235.42	0.00	-178.02	450
A-D	49.54	150	101.47	-28.40	9.11	9.11	136.90	0.00	350

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## Stage 4 Initial ARR Scaling to test for Feasibility

1	2	3	4	5	6 = 3 * 5	8 = 4 * 6
Type	ARR Path	Initial ARRs (MW)	Line A-D Sensitivity Factors <sup>1</sup>	Scale Reduction Factor	Stage 4 ARRs (MW)	Flow on Constrained Line A-D (MW)
ARR	A-B	47.997	0.1792	1	47.997	8.60
ARR	A-C	57.597	0.2481	1	57.597	14.29
ARR	A-D	47.997	0.4376	0.8	38.398	16.80
NEMA	A-D	50	0.4376	1	50.000	21.88
ARR	C-D	118.850	0.1895	0.8	95.080	18.01
ET	E-B	73.139	0.1017	1	73.139	7.44
ARR	E-B	114.279	0.1017	1	114.279	11.62
ARR	E-C	137.135	0.1706	1	137.135	23.39
ARR	E-D	114.279	0.3600	0.8	91.423	32.91
						154.95

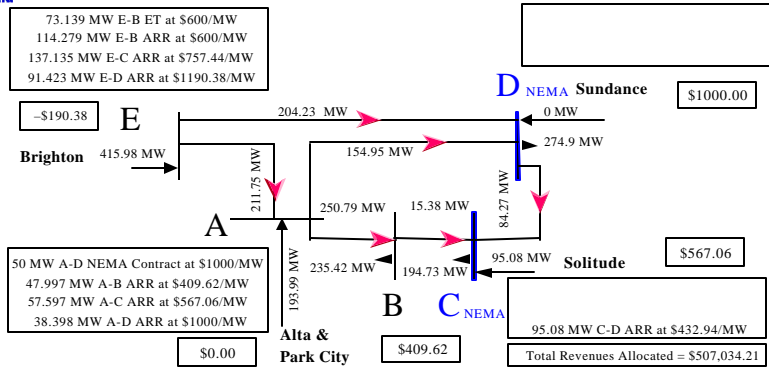
<sup>1</sup> Sensitivity factors for line A-D are for all lines in-service.

Scale Reduction Factor for NEMA ARRs at a load location affected by a NEMA Contract:  
 $[ 1 - (\text{NEMA Contract} / \text{Nodal Load}) ] = [ 1 - ( 50 / 250 ) ] = 0.8$

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## Stage 4 Line Flows Compared with Limits - MW



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	204.23	240	0.00	415.98	165.70	211.26	318.88	305.75	440
E-A	211.75	400	415.98	0.00	250.27	204.72	97.10	110.23	600
D-C	84.27	240	21.56	149.30	0.00	99.65	335.07	30.85	440
C-B	-15.38	350	-78.09	49.64	-99.65	0.00	235.42	-68.80	550
B-A	-250.79	250	-313.50	-185.77	-335.07	-235.42	0.00	-304.22	450
A-D	154.95	150	296.46	8.22	109.20	163.29	291.09	0.00	350



## Stage 4 Line Flows Compared with Limits - MW & %

Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	204.23	240	0.00	415.98	165.70	211.26	318.88	305.75	440
E-A	211.75	400	415.98	0.00	250.27	204.72	97.10	110.23	600
D-C	84.27	240	21.56	149.30	0.00	99.65	335.07	30.85	440
C-B	-15.38	350	-78.09	49.64	-99.65	0.00	235.42	-68.80	550
B-A	-250.79	250	-313.50	-185.77	-335.07	-235.42	0.00	-304.22	450
A-D	154.95	150	296.46	8.22	109.20	163.29	291.09	0.00	350

Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	85.1%	240	0.0%	94.5%	37.7%	48.0%	72.5%	69.5%	440
E-A	52.9%	400	69.3%	0.0%	41.7%	34.1%	16.2%	18.4%	600
D-C	35.1%	240	4.9%	33.9%	0.0%	22.6%	76.2%	7.0%	440
C-B	4.4%	350	14.2%	9.0%	18.1%	0.0%	42.8%	12.5%	550
B-A	100.3%	250	69.7%	41.3%	74.5%	52.3%	0.0%	67.6%	450
A-D	103.3%	150	84.7%	2.3%	31.2%	46.7%	83.2%	0.0%	350



## Stage 4 ARR Scaling to test for Simultaneous Feasibility

1	2	3	4	5 = 3 * 4	6	7	8 = 3 * 7	9 = 4 * 8
Type	ARR Path	Initial Stage 4 ARRs (MW)	Line A-D Sensitivity Factors <sup>1</sup>	Flow on Constrained Line A-D (MW)	NEMA ARRs Subject to Reduction (MW)	Scale Reduction Factor	Stage 2 ARRs (MW)	Flow on Constrained Line A-D (MW)
ARR	A-B	47.997	0.1792	8.60		1	47.997	8.60
ARR	A-C	57.597	0.2481	14.29	14.29	0.95307	54.894	13.62
ARR	A-D	38.398	0.4376	16.80	16.80	0.95307	36.596	16.01
NEMA	A-D	50	0.4376	21.88		1	50.000	21.88
ARR	C-D	95.080	0.1895	18.01	18.01	0.95307	90.618	17.17
ET	E-B	73.139	0.1017	7.44		1	73.139	7.44
ARR	E-B	114.279	0.1017	11.62		1	114.279	11.62
ARR	E-C	137.135	0.1706	23.39	23.39	0.95307	130.699	22.29
ARR	E-D	91.423	0.3600	32.91	32.91	0.95307	87.133	31.37
				154.95	105.41			150.00

<sup>1</sup> Sensitivity factors for line A-D are for all lines in-service.

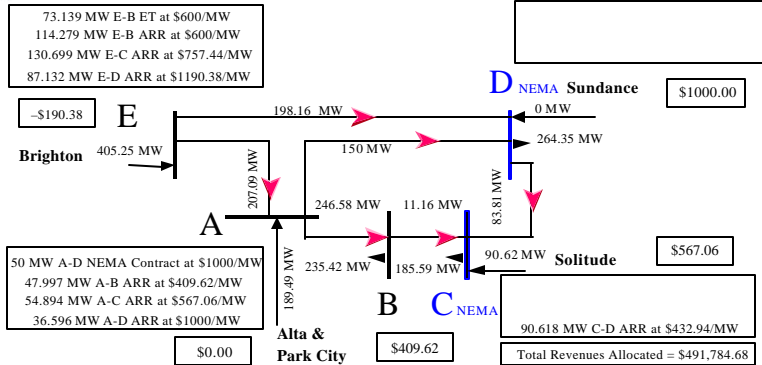
Scale Reduction Factor for NEMA ARRs subject to reduction:

$$[ 1 - (\text{Total Flow on Constrained Line} - \text{Line Limit}) / \text{NEMA ARRs subject to reduction} ] = [ 1 - (154.95 - 150) / 105.41 ] = 0.95307$$

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## Stage 4 Line Flows Compared with Limits - MW



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line					100% of Emergency Limits	
			E-D	E-A	D-C	C-B	B-A		A-D
E-D	198.16	240	0.00	405.25	159.85	203.26	310.88	296.44	440
E-A	207.09	400	405.25	0.00	245.40	201.99	94.37	108.81	600
D-C	83.81	240	22.97	147.41	0.00	94.97	330.39	32.10	440
C-B	-11.16	350	-72.01	52.43	-94.97	0.00	235.42	-62.88	550
B-A	-246.58	250	-307.42	-182.98	-330.39	-235.42	0.00	-298.29	450
A-D	150.00	150	287.31	6.50	104.50	156.06	283.86	0.00	350

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# Revenue Neutrality Adjustment to the Annual ARR Allocation Example



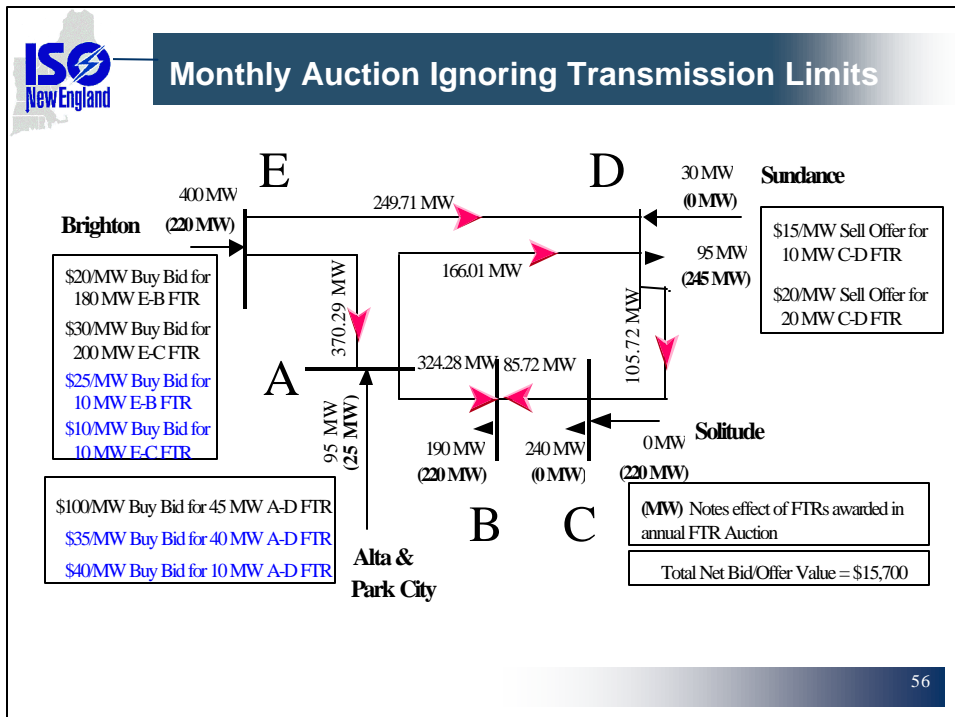
## First Month's Allocation of Annual FTR Revenues to ARR Holders

Type	ARR Path	Stage 4 ARR's MW	FTR Path Clearing Price \$/MW	Stage 4 ARR Allocation Calculation	Monthly Scale Factor <sup>1</sup>	Monthly Stage 4 ARR Settlement Allocation	1st Month's Node B Settlement Allocation	1st Month's Node C Settlement Allocation	1st Month's Node D Settlement Allocation
ARR	A-B	47.997	409.62	\$19,660.63	0.03991	\$784.73	\$784.73		
ARR	A-C	54.894	567.06	\$31,127.91	0.03991	\$1,242.43		\$1,242.43	
ARR	A-D	36.596	1000.00	\$36,595.67	0.03991	\$1,460.67			\$1,460.67
NEMA	A-D	50.000	1000.00	\$50,000.00	0.03991	\$1,995.68			\$1,995.68
ARR	C-D	90.618	432.94	\$39,232.10	0.03991	\$1,565.90			\$1,565.90
ET	E-B	73.139	600.00	\$43,883.19	0.03991	\$1,751.54	\$1,751.54		
ARR	E-B	114.279	600.00	\$68,567.48	0.03991	\$2,736.78	\$2,736.78		
ARR	E-C	130.699	757.44	\$98,996.53	0.03991	\$3,951.31		\$3,951.31	
ARR	E-D	87.133	1190.38	\$103,720.85	0.03991	\$4,139.88			\$4,139.88
				\$491,784.37		\$19,628.90	\$5,273.04	\$5,193.74	\$9,162.12

<sup>1</sup> The monthly scale factor is one-twelfth of the Annual FTR Auction revenues divided by the Stage 4 ARR Allocation less any Interim Incremental ARR's (i.e. (\$252,246.80 - \$16,700.00) / 12 = 19,628.90 and 19,628.90 / 491,784.37 = 0.039914).

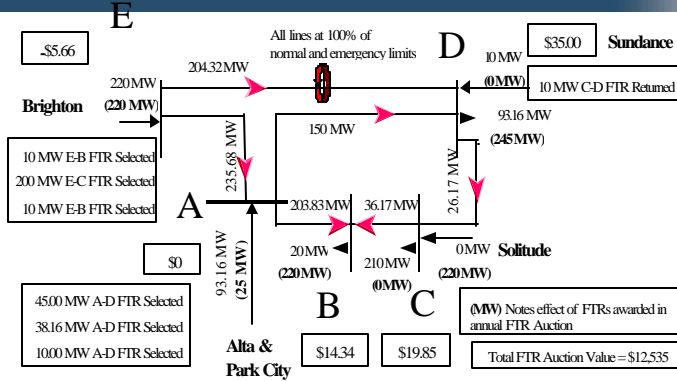


# Monthly FTR Auction Example





## Monthly FTR Auction Respecting Transmission Limits



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	204.32	240	0.00	440.00	192.36	187.79	297.50	302.60	440
E-A	235.68	400	440.00	0.00	247.64	252.21	142.50	137.40	600
D-C	26.17	240	-36.57	98.54	0.00	-10.00	230.00	-25.55	440
C-B	36.17	350	-26.57	108.54	10.00	0.00	240.00	-15.55	550
B-A	-203.83	250	-266.57	-131.46	-230.00	-240.00	0.00	-255.55	450
A-D	150.00	150	291.58	-13.31	135.80	130.37	260.65	0.00	350



## Monthly FTR Auction Selection of Winning Bids & Offers

1 Bid Path	2 Bid Quantity (MW)	3 Bid Price (\$/MW)	4 Sensitivity Factors <sup>1</sup>		5 = 3 / 4 Cost Effectiveness Ratio (\$/MW)		6 FTRs Selected (MW)	7 = 3 * 6 Auction Value \$	8 = 4 * 6 Flow on Constrained Lines (MW)	
			Line A-D	Line E-D	Line A-D	Line E-D			Line A-D	Line E-D
E-B	180	20	0.1017	1.0000	197	20	10	\$200	1.02	10.00
E-C	200	30	0.1706	1.0000	176	30	200	\$6,000	34.11	200.00
E-B	10	25	0.1017	1.0000	246	25	10	\$250	1.02	10.00
E-C	10	10	0.1706	1.0000	59	10	0	\$0	0.00	0.00
A-D	45	100	0.4376	0.0000	229	0	45	\$4,500	19.69	0.00
A-D	10	40	0.4376	0.0000	91	0	10	\$400	4.38	0.00
A-D	40	35	0.4376	0.0000	80	0	38.15515	\$1,335	16.70	0.00
Sell Offers	Sell Quantity	Sell Price								
C-D	10	15	-0.1895	0.0000	-79	0	10	-\$150	-1.89	0.00
C-D	20	20	-0.1895	0.0000	-106	0	0	\$0	0.00	0.00
Total Auction Value								\$12,535		
Line Flows Resulting from FTRs Awarded in the Annual FTR Auction									74.99	220.00
Total Flow on Constrained Transmission Lines									150.00	440.00

<sup>1</sup> Sensitivity factors change under contingencies. Sensitivity factors for line A-D are for all lines in-service. Sensitivity factors for line E-D result from the contingent loss of line E-A.



## Monthly FTR Auction Clearing Prices

From Bus A	Calculation for Components of FTR Clearing Price		FTR Clearing Price = S Cost Components
	Binding Constraint A-D	Binding Constraint E-D	
A	Reference	Reference	\$0.00
B	\$14.34	\$0.00	\$14.34
C	\$19.85	\$0.00	\$19.85
D	\$35.00	\$0.00	\$35.00
E	\$6.205	-\$11.868	-\$5.66

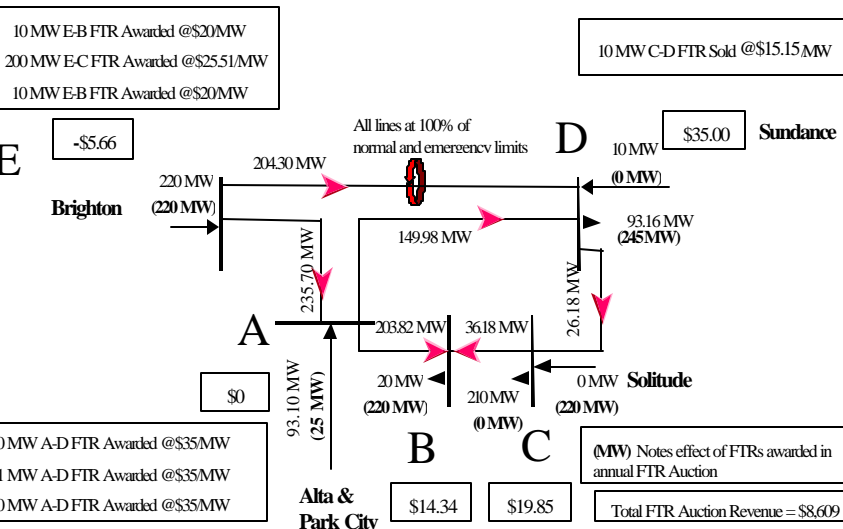
Monthly FTR Auction Clearing Prices by Path - \$/MW

Sink Source	A	B	C	D	E
A	0	14.34	19.85	35	-5.66
B	-14.34	0	5.51	20.66	-20
C	-19.85	-5.51	0	15.15	-25.51
D	-35	-20.66	-15.15	0	-40.66
E	5.66	20	25.51	40.66	0

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## Monthly FTR Auction Results



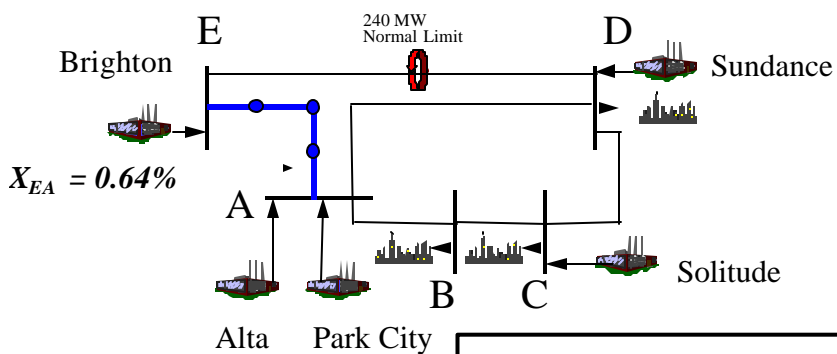
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# Interim Incremental ARR Allocation of Monthly FTR Auction Revenues

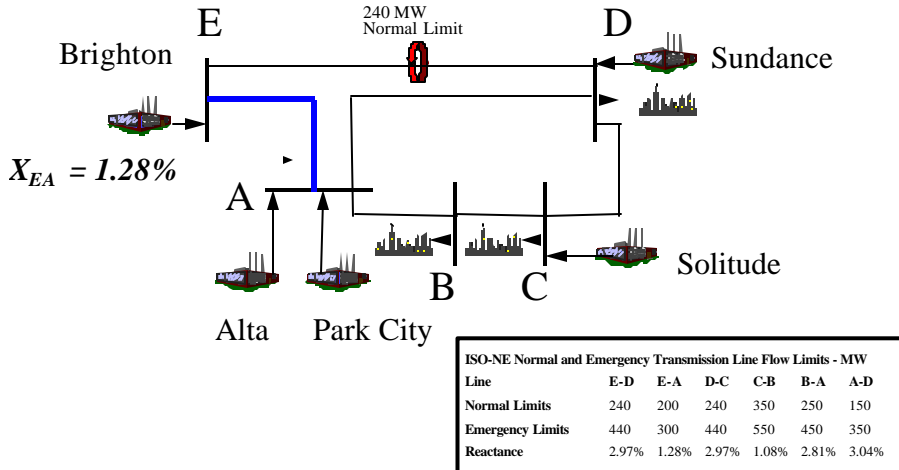


## The Five Bus Model - Post Line E-A Upgrade

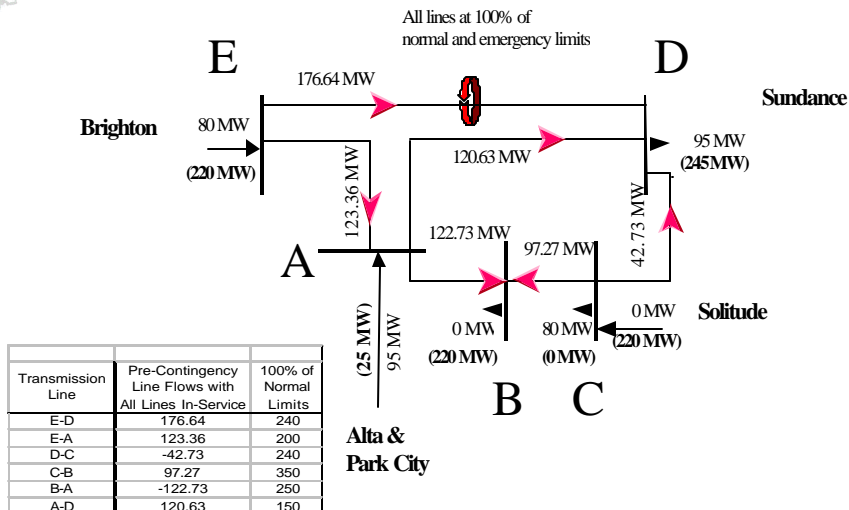


ISO-NE Normal and Emergency Transmission Line Flow Limits - MW						
Line	E-D	E-A	D-C	C-B	B-A	A-D
Normal Limits	240	400	240	350	250	150
Emergency Limits	440	600	440	550	450	350
Reactance	2.97%	0.64%	2.97%	1.08%	2.81%	3.04%

## The Five Bus Model - Pre Line E-A Upgrade

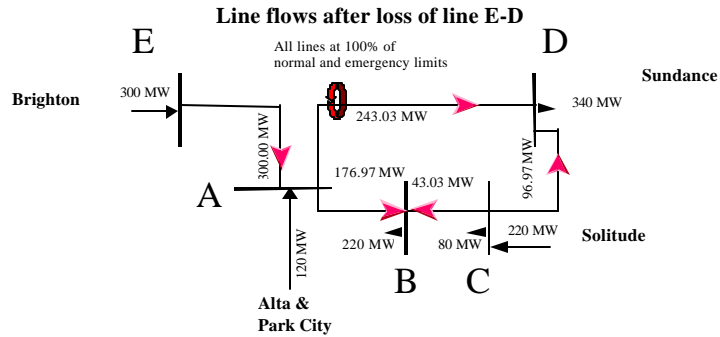


## Comparison of Line Flows with Limits - MW





## Contingency Line Flows Compared with Limits - MW



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	176.64	240	0.00	300.00	194.46	136.08	227.82	251.13	440
E-A	123.36	200	300.00	0.00	105.54	163.92	72.18	-48.87	300
D-C	-42.73	240	-96.97	-4.85	0.00	-140.00	80.00	-88.87	440
C-B	97.27	350	43.03	135.15	140.00	0.00	220.00	51.13	550
B-A	-122.73	250	-176.97	-84.85	-80.00	-220.00	0.00	-168.87	450
A-D	120.63	150	243.03	35.15	145.54	63.92	192.18	0.00	350

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## Monthly FTR Auction Results without the Transmission Upgrade to Line E-A

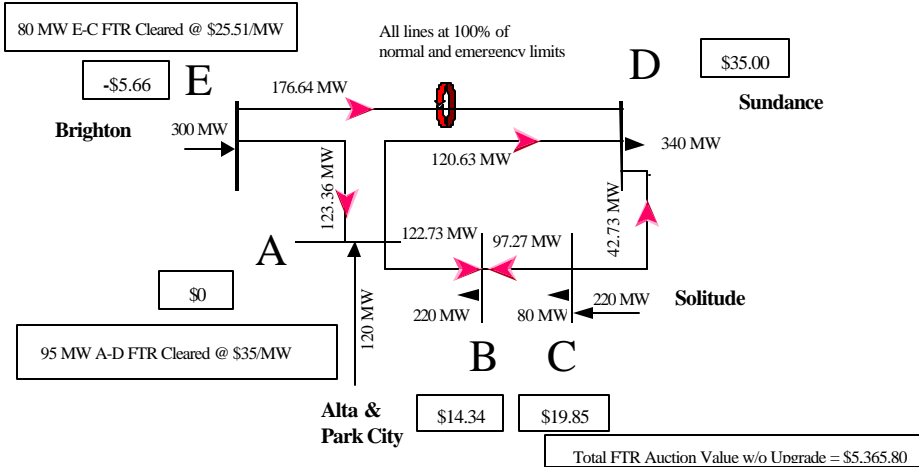
1	2	3	4	5 = 3 / 4	6	7 = 3 * 6	8 = 4 * 6
Bid Path	Bid Quantity (MW)	Bid Price (\$/MW)	Sensitivity Factors <sup>1</sup>	Cost Effectiveness Ratio (\$/MW)	FTRs Selected (MW)	Auction Value \$	Flow on Constrained Lines (MW)
			Line E-A	Line E-A			Line E-A
E-B	180	20	1.0000	20	0	\$0	0.00
E-C	200	30	1.0000	30	80	\$2,400	80.00
E-B	10	25	1.0000	25	0	\$0	0.00
E-C	10	10	1.0000	10	0	\$0	0.00
A-D	45	100	0.0000	0	45	\$4,500	0.00
A-D	10	40	0.0000	0	10	\$400	0.00
A-D	40	35	0.0000	0	40	\$1,400	0.00
Sell Offers	Sell Quantity	Sell Price					
C-D	10	15	0.0000	0	0	\$0	0.00
C-D	20	20	0.0000	0	0	\$0	0.00
Total Auction Value						\$8,700	
Line Flows Resulting from FTRs Awarded in the Annual FTR Auction							220.00
Total Flow on Constrained Transmission Lines							300.00

<sup>1</sup> Sensitivity factors change under contingencies. Sensitivity factors for line A-D are for all lines in-service. Sensitivity factors for line E-D result from the contingent loss of line E-A.

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## Monthly FTR Auction Results without Line E-A Upgrade



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## Interim Incremental ARR Payment

The Interim Incremental ARR payment is the difference in value between the Monthly FTR Auction results with and without the eligible transmission upgrade:

	Monthly FTR Auction \$
With Upgrade	8,609.00
Without Upgrade	5,365.80
Total IIARR Value	3,243.20

Since half of the value of the upgrade was settled in the Annual FTR Auction Example, half of the value of the upgrade is settled in the Monthly FTR Auction. Therefore the IIARR would be settled at  $\$3,243.20 / 2 = \$1,621.60$  for the month.

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## Monthly ARR Allocation Example



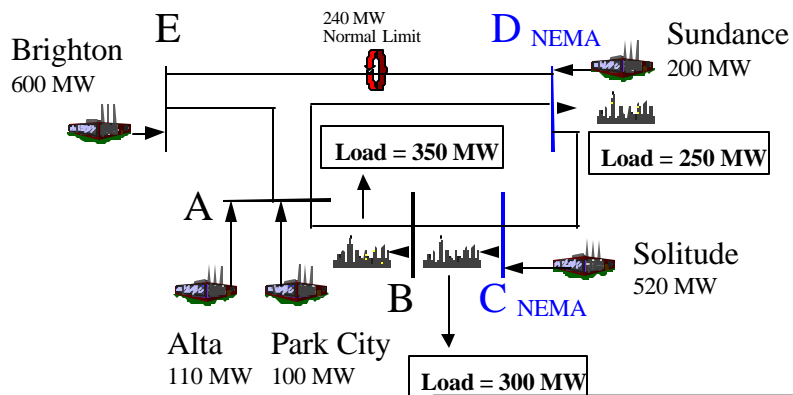
### Collection and Disbursal of FTR Auction Revenues

In the Monthly FTR Auction Example, the total revenue resulting from the FTR Auction was \$8,609.00. Interim Incremental ARR's were allocated \$1,621.60 of this sum, leaving \$6,987.40 to distribute through the ARR process.

The following Monthly ARR Allocation Example will demonstrate how the revenue from the monthly example will be collected and disbursed for this month.

ARRs are allocated in two steps in the first stage of the ARR Allocation ...

- Excepted Transactions are assigned ARRs from a capacity source to a load sink
- The remaining capacity sources and load sinks are assigned as ARRs in proportion to capacity and load



ISO-NE Normal and Emergency Transmission Line Flow Limits - MW						
Line	E-D	E-A	D-C	C-B	B-A	A-D
Normal Limits	240	400	240	350	250	150
Emergency Limits	440	600	440	550	450	350
Reactance	2.97%	0.64%	2.97%	1.08%	2.81%	3.04%



## Stage 1 ARRs - Excepted Transactions

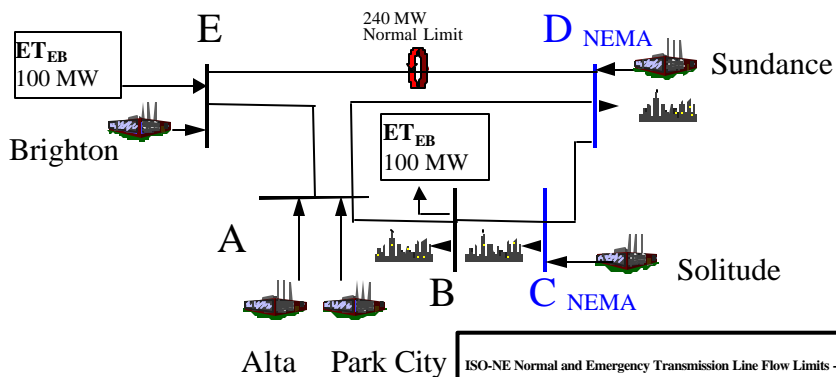
This example assumes that there is a 100 MW Excepted Transaction between Brighton at Node E and the load sink at Node B.

- The entity responsible for paying the congestion costs associated with energy purchased under this Excepted Transaction would be allocated Stage 1 ARRs that correspond to this transaction.
  - 100 MW of Stage 1 ARRs would be initially allocated from Node E to Node B.

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## Five Bus ARR Model with Excepted Transaction



Line	E-D	E-A	D-C	C-B	B-A	A-D
Normal Limits	240	400	240	350	250	150
Emergency Limits	440	600	440	550	450	350
Reactance	2.97%	0.64%	2.97%	1.08%	2.81%	3.04%

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## Stage 1 ARR - Load Ratio ARRs

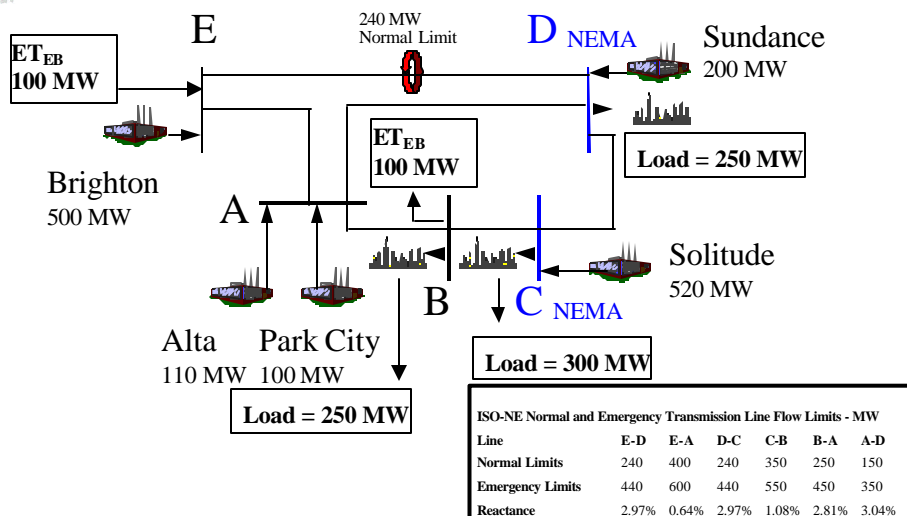
Stage 1 ARRs would also be allocated from each generator (net of capacity allocated to Excepted Transactions) to each load in proportion to Monthly Peak Load (net of load met by Excepted Transactions). The amount of ARRs allocated from each source will be equal to total generating capacity at that node.

- For example, since Alta has a capacity of 110 MW, a total of 110 MW of ARRs will be allocated from Node A.
- Since there is a total of 1530 MW of capacity on this five-bus network, less 100 MW delivered under Excepted Transactions, a total of 1430 MW of Load Ratio ARRs will be allocated in this step.
- Other capacity sources, such as tie lines to other control areas, would also count as “generators” for the purposes of defining Stage 1 ARRs.

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## Five Bus ARR Model with ET, Load & Generation



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## Stage 1 ARR - Load Ratio Determination

Stage 1 ARRs are allocated among the entities that are responsible for paying the congestion costs associated with serving load, in proportion to the load's share of the NEPOOL Monthly Peak Load.

- Each load's share of the NEPOOL Monthly Peak Load, which is 800 MW (after deducting 100 MW of Monthly Peak Load served by Excepted Transactions) is calculated in the table below.
- Since load at Node B constitutes 31.25% of the NEPOOL Monthly Peak Load, the entities responsible for paying congestion costs associated with serving load in Node B will receive 31.25% of the ARRs from each generator location to Node B.

Load Location	Peak Load MW	Peak Load Distribution
Node B	250	31.25%
Node C	300	37.50%
Node D	250	31.25%

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## Stage 1 ARR - Initial Allocation

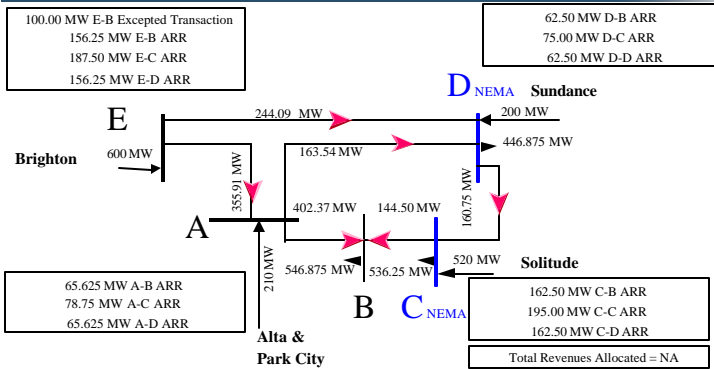
The table below indicates the Stage 1 allocation of ARRs from each generator to load. The "ET" notation indicates that those ARRs were allocated in association with an Excepted Transaction.

Source Location	Sink Location	Load Name	Peak Load Distribution	Capacity (MW)	Initial ARRs (MW)
A	B	Node B	31.25%	210	65.625
A	C	Node C	37.50%	210	78.75
A	D	Node D	31.25%	210	65.625
C	B	Node B	31.25%	520	162.5
C	C	Node C	37.50%	520	195
C	D	Node D	31.25%	520	162.5
D	B	Node B	31.25%	200	62.5
D	C	Node C	37.50%	200	75
D	D	Node D	31.25%	200	62.5
E	B	Node B ("ET")	NA	100	100
E	B	Node B	31.25%	500	156.25
E	C	Node C	37.50%	500	187.5
E	D	Node D	31.25%	500	156.25

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## Stage 1 Line Flows Compared with Limits - MW

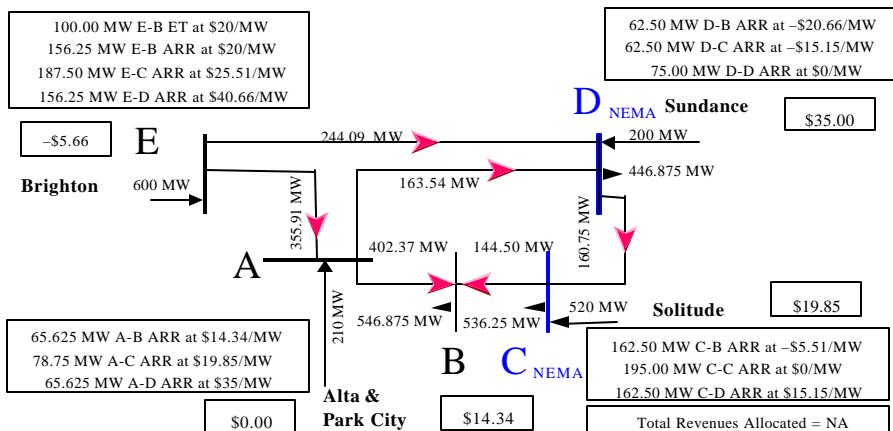


Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	244.09	240	0.00	600.00	170.60	178.03	428.03	351.24	440
E-A	355.91	400	600.00	0.00	429.40	421.97	171.97	248.76	600
D-C	160.75	240	85.80	270.04	0.00	16.25	563.12	104.37	440
C-B	144.50	350	69.55	253.79	-16.25	0.00	546.87	88.12	550
B-A	-402.37	250	-477.32	-293.08	-563.12	-546.87	0.00	-458.76	450
A-D	163.54	150	332.68	-83.08	76.27	85.09	381.97	0.00	350

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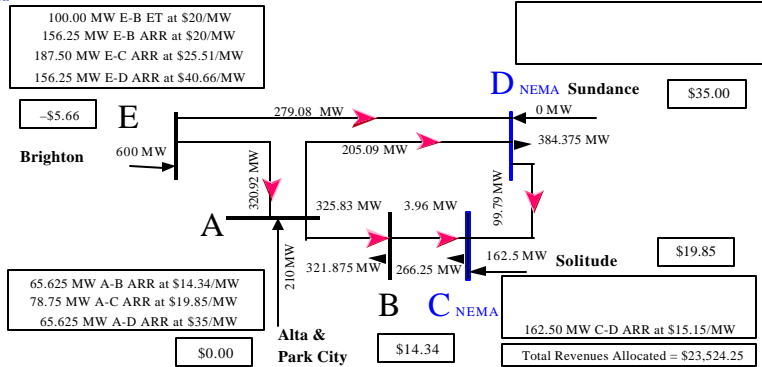
## Stage 2 Line Flows with all Initial ARRs



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## Stage 2 Positive ARR Line Flows Compared with Limits - MW



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line					100% of Emergency Limits	
			E-D	E-A	D-C	C-B	B-A		A-D
E-D	279.08	240	0.00	600.00	233.46	280.89	428.03	413.45	440
E-A	320.92	400	600.00	0.00	366.54	319.11	171.97	186.55	600
D-C	99.79	240	14.10	198.34	0.00	103.75	425.62	29.08	440
C-B	-3.96	350	-89.65	94.59	-103.75	0.00	321.87	-74.67	550
B-A	-325.83	250	-411.53	-227.29	-425.62	-321.88	0.00	-396.55	450
A-D	205.09	150	398.47	-17.29	150.92	207.24	381.97	0.00	350

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## Stage 2 Line Flows Compared with Limits - MW & %

Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line					100% of Emergency Limits	
			E-D	E-A	D-C	C-B	B-A		A-D
E-D	279.08	240	0.00	600.00	233.46	280.89	428.03	413.45	440
E-A	320.92	400	600.00	0.00	366.54	319.11	171.97	186.55	600
D-C	99.79	240	14.10	198.34	0.00	103.75	425.62	29.08	440
C-B	-3.96	350	-89.65	94.59	-103.75	0.00	321.87	-74.67	550
B-A	-325.83	250	-411.53	-227.29	-425.62	-321.88	0.00	-396.55	450
A-D	205.09	150	398.47	-17.29	150.92	207.24	381.97	0.00	350

Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line					100% of Emergency Limits	
			E-D	E-A	D-C	C-B	B-A		A-D
E-D	116.3%	240	0.0%	136.4%	53.1%	63.8%	97.3%	94.0%	440
E-A	80.2%	400	100.0%	0.0%	61.1%	53.2%	28.7%	31.1%	600
D-C	41.6%	240	3.2%	45.1%	0.0%	23.6%	96.7%	6.6%	440
C-B	1.1%	350	16.3%	17.2%	18.9%	0.0%	58.5%	13.6%	550
B-A	130.3%	250	91.5%	50.5%	94.6%	71.5%	0.0%	88.1%	450
A-D	136.7%	150	113.8%	4.9%	43.1%	59.2%	109.1%	0.0%	350

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## Stage 2 ARR Scaling to Achieve Simultaneously Feasibility

1	2	3	4	5 = 3 * 4	6	7 = 5 * 6	8 = 4 * 7
Type	ARR Path	Initial ARRs (MW)	Line A-D Sensitivity Factors <sup>1</sup>	Flow on Constrained Line A-D (MW)	Scale Reduction Factor	Stage 2 ARRs (MW)	Flow on Constrained Line A-D (MW)
ARR	A-B	65.625	0.1792	11.76	0.73139	47.997	8.60
ARR	A-C	78.75	0.2481	19.54	0.73139	57.597	14.29
ARR	A-D	65.625	0.4376	28.72	0.73139	47.997	21.00
ARR	C-D	162.5	0.1895	30.79	0.73139	118.850	22.52
ET	E-B	100	0.1017	10.17	0.73139	73.139	7.44
ARR	E-B	156.25	0.1017	15.89	0.73139	114.279	11.62
ARR	E-C	187.5	0.1706	31.98	0.73139	137.135	23.39
ARR	E-D	156.25	0.3600	56.25	0.73139	114.279	41.14
				205.09			150.00

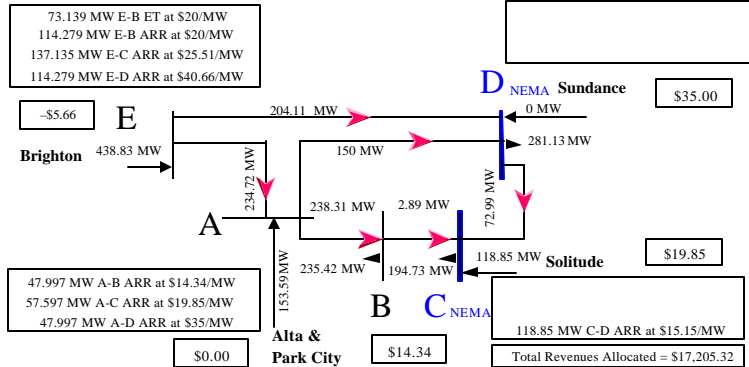
<sup>1</sup> Sensitivity factors for line A-D are for all lines in-service.

$$\text{Scale Reduction Factor} = (\text{Flow Limit on Line A-D}) / (\text{Flow on Line A-D}) = 150 / 205.09 = 0.73139$$

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## Stage 2 Line Flows Compared with Limits - MW



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line					100% of Emergency Limits	
			E-D	E-A	D-C	C-B	B-A		A-D
E-D	204.11	240	0.00	438.83	170.75	205.44	313.06	302.40	440
E-A	234.72	400	438.83	0.00	268.08	233.39	125.78	136.44	600
D-C	72.99	240	10.31	145.06	0.00	75.88	311.30	21.27	440
C-B	-2.89	350	-65.57	69.18	-75.88	0.00	235.42	-54.61	550
B-A	-238.31	250	-300.99	-166.23	-311.30	-235.42	0.00	-290.03	450
A-D	150.00	150	291.44	-12.64	110.38	151.57	279.37	0.00	350

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## Stage 3 NEMA ARRs - NEMA Contract Treatment

**In Stage 3, ARR are allocated to NEMA load serving entities (LSEs) with qualifying long-term purchase contracts.**

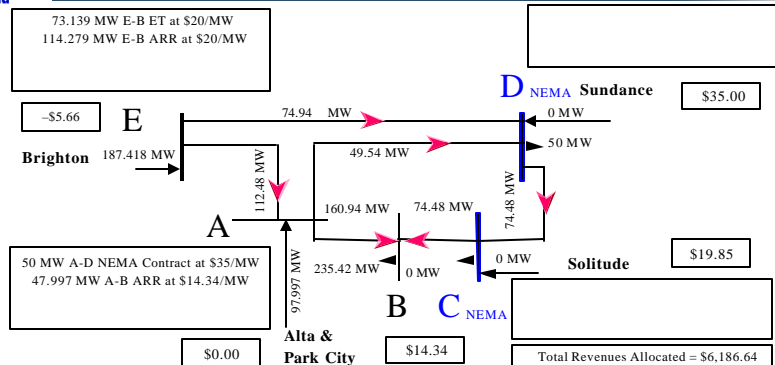
- This reallocation of ARR among NEMA LSEs is not to affect the allocation of ARR in Stage 2 to entities that are not NEMA LSEs.
- The ARR that correspond to these purchase contracts will be reduced if necessary to ensure simultaneous feasibility.
- No other NEMA ARR are included in this power flow, so the ARR that correspond to these purchase contracts will only be reduced if necessary to ensure simultaneous feasibility, even if no other NEMA LSE's were awarded any ARR.

**Then in Stage 4, ARR for the remaining NEMA LSEs' loads are taken into account, and reduced as necessary to maintain simultaneous feasibility.**

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## Stage 3 Line Flows Compared with Limits - MW



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	74.94	240	0.00	187.42	40.89	40.89	148.51	107.40	440
E-A	112.48	400	187.42	0.00	146.52	146.52	38.91	80.02	600
D-C	74.48	240	51.47	109.02	0.00	0.00	235.42	57.40	440
C-B	74.48	350	51.47	109.02	0.00	0.00	235.42	57.40	550
B-A	-160.94	250	-183.95	-126.40	-235.42	-235.42	0.00	-178.02	450
A-D	49.54	150	101.47	-28.40	9.11	9.11	136.90	0.00	350

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## Stage 4 Initial ARR Scaling to test for Feasibility

1	2	3	4	5	6 = 3 * 5	8 = 4 * 6
Type	ARR Path	Initial ARRs (MW)	Line A-D Sensitivity Factors <sup>1</sup>	Scale Reduction Factor	Stage 4 ARRs (MW)	Flow on Constrained Line A-D (MW)
ARR	A-B	47.997	0.1792	1	47.997	8.60
ARR	A-C	57.597	0.2481	1	57.597	14.29
ARR	A-D	47.997	0.4376	0.8	38.398	16.80
NEMA	A-D	50	0.4376	1	50.000	21.88
ARR	C-D	118.850	0.1895	0.8	95.080	18.01
ET	E-B	73.139	0.1017	1	73.139	7.44
ARR	E-B	114.279	0.1017	1	114.279	11.62
ARR	E-C	137.135	0.1706	1	137.135	23.39
ARR	E-D	114.279	0.3600	0.8	91.423	32.91
						154.95

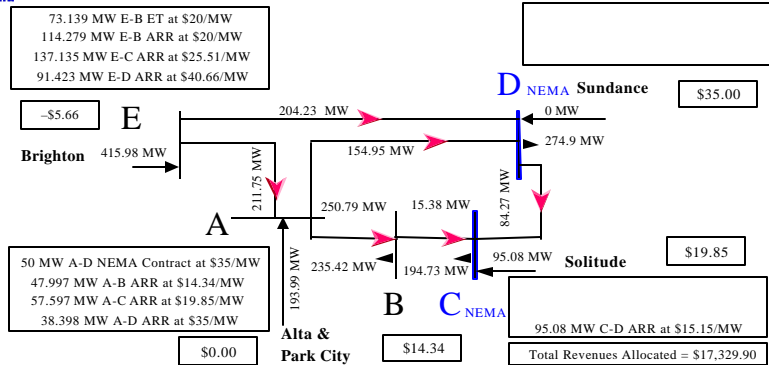
<sup>1</sup> Sensitivity factors for line A-D are for all lines in-service.

Scale Reduction Factor for NEMA ARRs at a load location affected by a NEMA Contract:  
 $[1 - (\text{NEMA Contract} / \text{Nodal Load})] = [1 - (50 / 250)] = 0.8$

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## Stage 4 Line Flows Compared with Limits - MW



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line					100% of Emergency Limits	
			E-D	E-A	D-C	C-B	B-A		A-D
E-D	204.23	240	0.00	415.98	165.70	211.26	318.88	305.75	440
E-A	211.75	400	415.98	0.00	250.27	204.72	97.10	110.23	600
D-C	84.27	240	21.56	149.30	0.00	99.65	335.07	30.85	440
C-B	-15.38	350	-78.09	49.64	-99.65	0.00	235.42	-68.80	550
B-A	-250.79	250	-313.50	-185.77	-335.07	-235.42	0.00	-304.22	450
A-D	154.95	150	296.46	8.22	109.20	163.29	291.09	0.00	350

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## Stage 4 Line Flows Compared with Limits - MW & %

Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	204.23	240	0.00	415.98	165.70	211.26	318.88	305.75	440
E-A	211.75	400	415.98	0.00	250.27	204.72	97.10	110.23	600
D-C	84.27	240	21.56	149.30	0.00	99.65	335.07	30.85	440
C-B	-15.38	350	-78.09	49.64	-99.65	0.00	235.42	-68.80	550
B-A	-250.79	250	-313.50	-185.77	-335.07	-235.42	0.00	-304.22	450
A-D	154.95	150	296.46	8.22	109.20	163.29	291.09	0.00	350

Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	85.1%	240	0.0%	94.5%	37.7%	48.0%	72.5%	69.5%	440
E-A	52.9%	400	69.3%	0.0%	41.7%	34.1%	16.2%	18.4%	600
D-C	35.1%	240	4.9%	33.9%	0.0%	22.6%	76.2%	7.0%	440
C-B	4.4%	350	14.2%	9.0%	18.1%	0.0%	42.8%	12.5%	550
B-A	100.3%	250	69.7%	41.3%	74.5%	52.3%	0.0%	67.6%	450
A-D	103.3%	150	84.7%	2.3%	31.2%	46.7%	83.2%	0.0%	350

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## Stage 4 ARR Scaling to test for Simultaneous Feasibility

1	2	3	4	5 = 3 * 4	6	7	8 = 3 * 7	9 = 4 * 8
Type	ARR Path	Initial Stage 4 ARRs (MW)	Line A-D Sensitivity Factors <sup>1</sup>	Flow on Constrained Line A-D (MW)	NEMA ARRs Subject to Reduction (MW)	Scale Reduction Factor	Stage 2 ARRs (MW)	Flow on Constrained Line A-D (MW)
ARR	A-B	47.997	0.1792	8.60		1	47.997	8.60
ARR	A-C	57.597	0.2481	14.29	14.29	0.95307	54.894	13.62
ARR	A-D	38.398	0.4376	16.80	16.80	0.95307	36.596	16.01
NEMA	A-D	50	0.4376	21.88		1	50.000	21.88
ARR	C-D	95.080	0.1895	18.01	18.01	0.95307	90.618	17.17
ET	E-B	73.139	0.1017	7.44		1	73.139	7.44
ARR	E-B	114.279	0.1017	11.62		1	114.279	11.62
ARR	E-C	137.135	0.1706	23.39	23.39	0.95307	130.699	22.29
ARR	E-D	91.423	0.3600	32.91	32.91	0.95307	87.133	31.37
				154.95	105.41			150.00

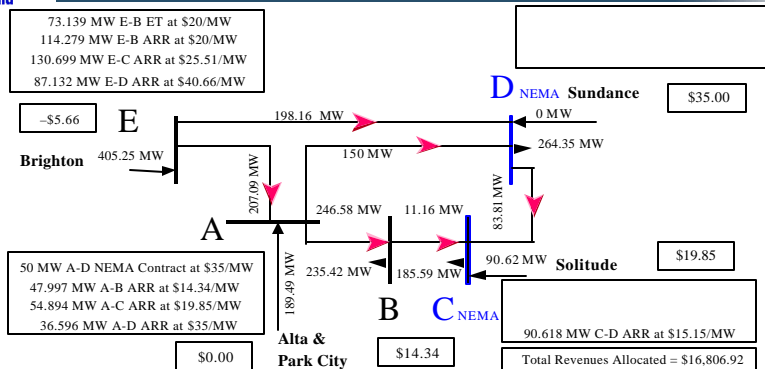
<sup>1</sup> Sensitivity factors for line A-D are for all lines in-service.

Scale Reduction Factor for NEMA ARRs subject to reduction:  
 $[ 1 - ( \text{Total Flow on Constrained Line} - \text{Line Limit} ) / \text{NEMA ARRs subject to reduction} ] =$   
 $[ 1 - ( 154.95 - 150 ) / 105.41 ] = 0.95307$

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## Stage 4 Line Flows Compared with Limits - MW



Transmission Line	Pre-Contingency Line Flows with All Lines In-Service	100% of Normal Limits	Post-Contingency Line Flows after Loss of Indicated Line						100% of Emergency Limits
			E-D	E-A	D-C	C-B	B-A	A-D	
E-D	198.16	240	0.00	405.25	159.85	203.26	310.88	296.44	440
E-A	207.09	400	405.25	0.00	245.40	201.99	94.37	108.81	600
D-C	83.81	240	22.97	147.41	0.00	94.97	330.39	32.10	440
C-B	-11.16	350	-72.01	52.43	-94.97	0.00	235.42	-62.88	550
B-A	-246.58	250	-307.42	-182.98	-330.39	-235.42	0.00	-298.29	450
A-D	150.00	150	287.31	6.50	104.50	156.06	283.86	0.00	350



## Revenue Neutrality Adjustment to the Monthly ARR Allocation Example



## Allocation of Monthly FTR Revenues to ARR Holders

Type	ARR Path	Stage 4 ARRs MW	FTR Path Clearing Price \$/MW	Stage 4 ARR Allocation Calculation	Month's Scale Factor <sup>1</sup>	Monthly Stage 4 ARR Settlement Allocation	Month's Node B Settlement Allocation	Month's Node C Settlement Allocation	Month's Node D Settlement Allocation
ARR	A-B	47.997	14.34	\$688.28	0.41575	\$286.15	\$286.15		
ARR	A-C	54.894	19.85	\$1,089.64	0.41575	\$453.01		\$453.01	
ARR	A-D	36.596	35.00	\$1,280.85	0.41575	\$532.51			\$532.51
NEMA	A-D	50.000	35.00	\$1,750.00	0.41575	\$727.55			\$727.55
ARR	C-D	90.618	15.15	\$1,372.86	0.41575	\$570.76			\$570.76
ET	E-B	73.139	20.00	\$1,462.77	0.41575	\$608.14	\$608.14		
ARR	E-B	114.279	20.00	\$2,285.58	0.41575	\$950.22	\$950.22		
ARR	E-C	130.699	25.51	\$3,334.13	0.41575	\$1,386.15		\$1,386.15	
ARR	E-D	87.133	40.66	\$3,542.81	0.41575	\$1,472.91			\$1,472.91
				\$16,806.92		\$6,987.40	\$1,844.51	\$1,839.16	\$3,303.73

<sup>1</sup> The month's scale factor is the Month's FTR Auction revenues divided by the Stage 4 ARR Allocation less any Interim Incremental ARRs (i.e. (\$8,609.00 - \$1,621.60) / \$16,806.92 = 0.41575 ).



## Acknowledgements

To Dr. N. S. Rau for his tutelage in optimization theory.

To the PJM Interconnection for the five-bus power system model upon which this example is based.

To LECG for their initial contributions to the ARR market design.



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**Questions?**