

Basic Congestion Concepts and Calculating Project Benefits

MEPETF

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Monitoring Analytics

Congestion

- **Congestion = The difference between total charges to load and total payments to generation caused by binding transmission constraints.**
 - **Binding transmission constraints cause price differences on the system**
 - **With binding constraints, load pays more for energy than generation gets paid for energy**
 - **Generation upstream of a binding constraint is paid lower prices than generation downstream of a binding constraint**
 - **Load downstream of a binding constraint pays the higher (upstream price) for all of its energy**
 - **The difference in payments from load to generators is congestion**

Simple System Example: No Congestion

A

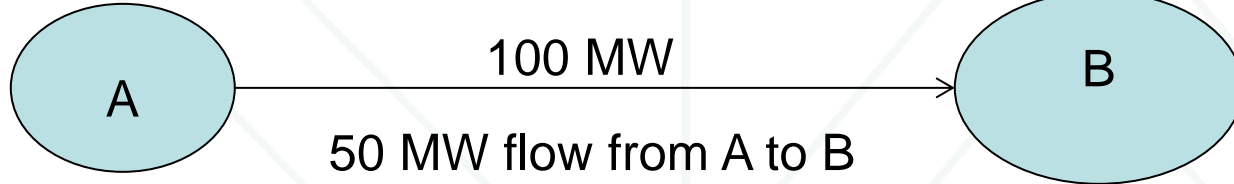
Load: 0
Gen: 50

Gen MC = \$5

B

Load: 50
Gen: 0

Gen MC = \$15



LMP = \$5

Line AB does not constrain flow from A to B

LMP = \$5

What are the LMPs at A and B?

	A	Constraint	B		
LMP	\$5	---->	\$5		
	Zone A		Zone B		
Load MW	0		50		
Marginal Price of Power	\$5.00		\$5.00		
(LMP x MW)	Zone A		Zone B		Total
Load Charges	\$0.00		\$250.00	\$250.00	\$250.00
Generation Credits	\$250.00		\$0.00	\$250.00	\$250.00
Total Credits/Charges	(\$250.00)		\$250.00	\$0	\$0

Congestion = Load Charges – Gen Credits

Congestion = The difference between total charges to load and total payments to generation caused by binding transmission constraints.

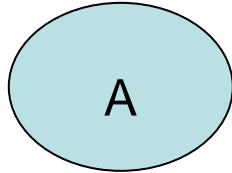
Simple System Example: Congestion

A

Load: 0
Gen: 100

Gen MC = \$5

LMP = \$5



100 MW

100 MW flow from A to B

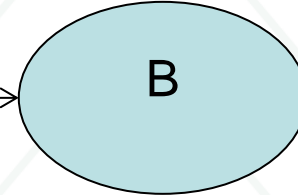
Line AB constrains the flow from A to B
Gen at B is needed to meet some of load.

B

Load: 150
Gen: 50

Gen MC = \$15

LMP = \$15



	A	Constraint	B		
LMP	\$5	---->	\$15		
	Zone A		Zone B		
Load MW	0		150		
Marginal Price of Power	\$5.00		\$15.00		
(LMP x MW)	Zone A		Zone B		Total
Load Charges	\$0.00		\$2,250.00	\$2,250.00	
Generation Credits	\$500.00		\$750.00	\$1,250.00	
Total Credits/Charges	(\$500.00)		\$1,500.00	\$1,000	

Congestion = Load Charges – Gen Credits

Congestion = The difference between total charges to load and total payments to generation caused by binding transmission constraints.

Allocation of congestion: Affect on Average Cost of Load

	A	Constraint	B
LMP	\$5	---->	\$15
SMP	\$5		\$5
CLMP	\$0		\$10
	Reference Bus	100	
Load MW	0		150
Gen MW	100		50
CLMP x MW	Zone Based A	Zone Based B	Total Congestion
Load Charges	\$0	\$1,500	\$1,500
Gen Credits	\$0	\$500	\$500
Total Charges	\$0	\$1,000	\$1,000
	Zone A	Zone B	
Load MW	0	150	
Marginal Price of Power	\$5.00	\$15.00	
Total Load Charges	\$0.00	\$2,250.00	
Average Cost of Power	\$5.00	\$15.00	
Congestion Allocation	\$0.00	\$1,000.00	
Net Load Charges	\$0.00	\$1,250.00	
Marginal Price of Power	\$5.00	\$15.00	
Average Cost of Power	NA	\$8.33	

Marginal Price does not change

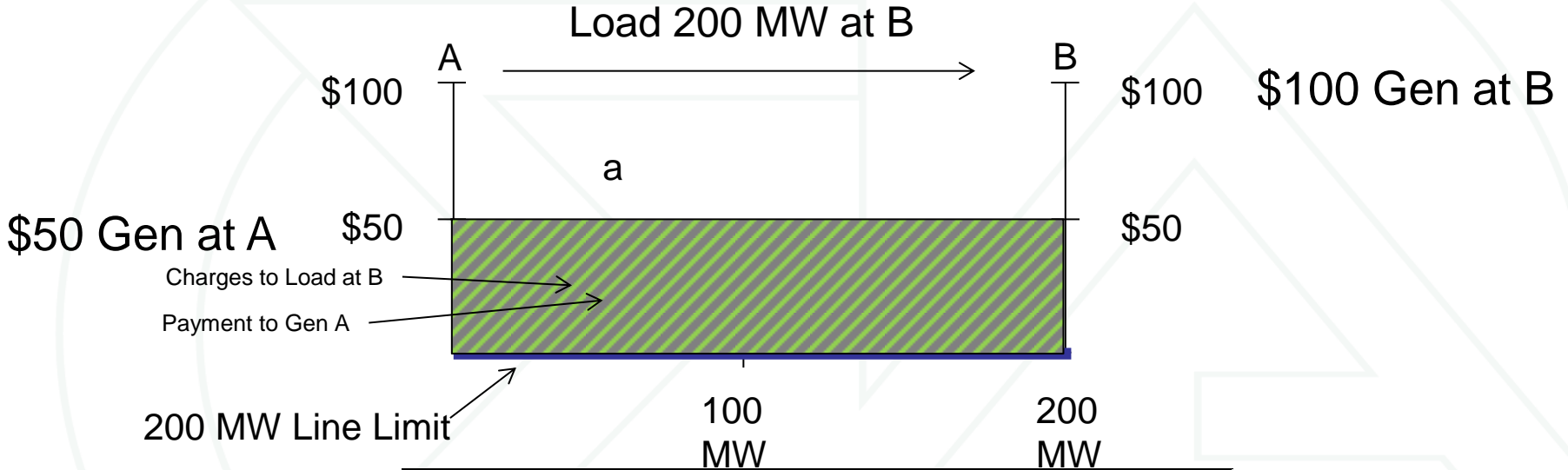
With correct congestion allocation, average cost of power reflects actual average cost for serving zone



No constraints



Congestion



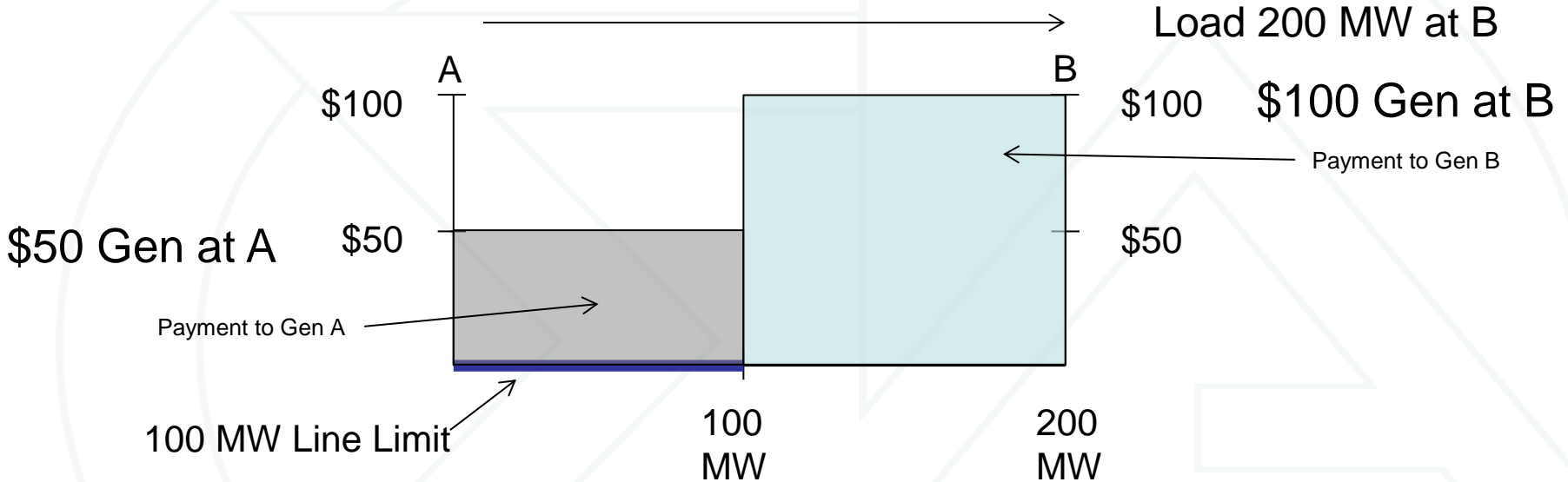
Day Ahead	Bus A	Transfer A to B	Bus B
Price	\$50		\$50
Load	-	→	200
Generation	200	200	-

Day Ahead	Bus A	Bus B	Congestion
Load	\$ -	\$ 10,000	
Generation	\$ 10,000	\$ -	
Total	(\$10,000)	\$10,000	\$0

Congestion: Binding Constraints



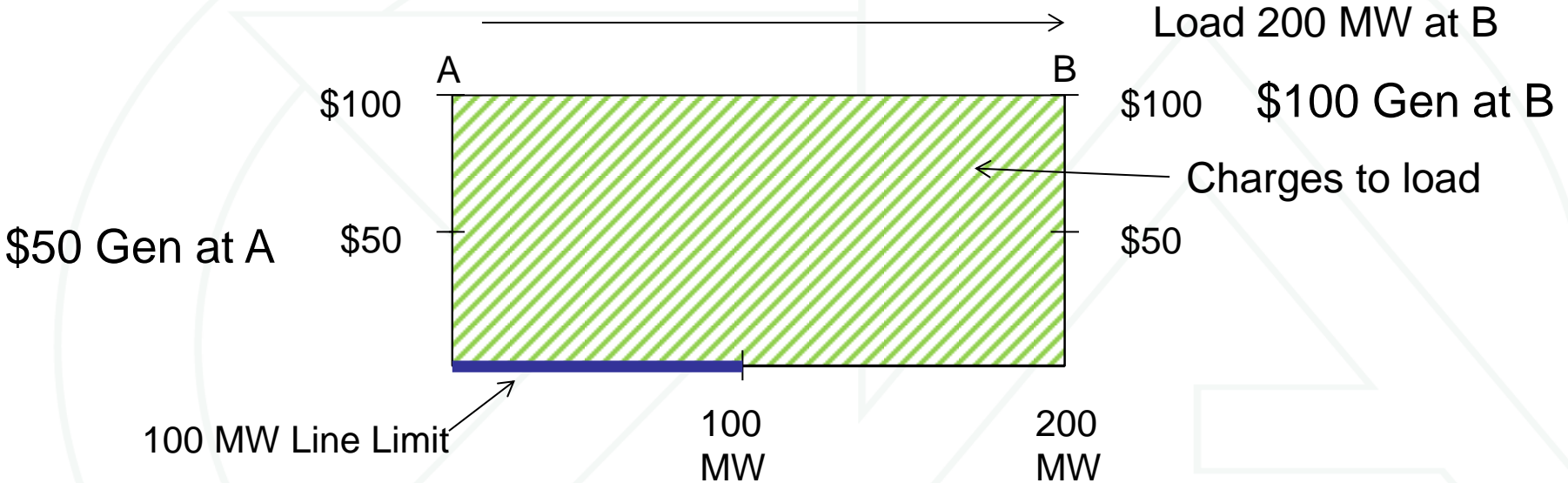
Congestion



Day Ahead	Bus A	Transfer A to B	Bus B
Price	\$50		\$100
Load	-	→	200
Generation	100	100 MW	100

Day Ahead	Bus A	Bus B	Congestion
Load	\$ -	\$20,000	
Generation	\$ 5,000	\$10,000	
Total	(\$5,000)	\$10,000	\$5,000

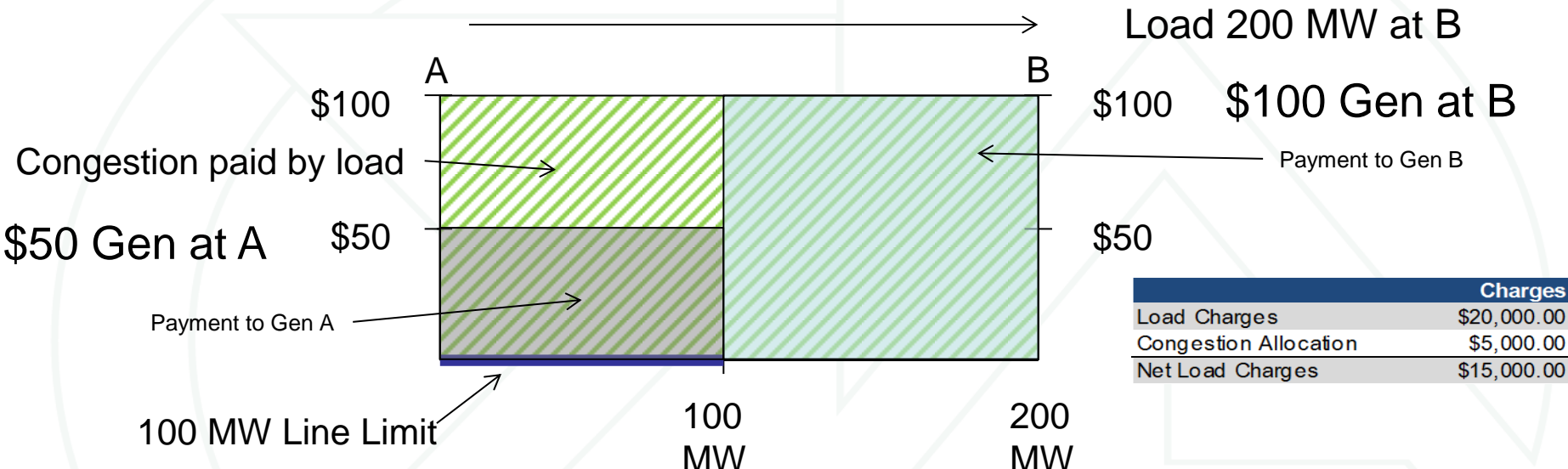
Congestion



Day Ahead	Bus A	Transfer A to B	Bus B
Price	\$50		\$100
Load	-	→	200
Generation	100	100 MW	100

Day Ahead	Bus A	Bus B	Congestion
Load	\$ -	\$20,000	
Generation	\$ 5,000	\$10,000	
Total	(\$5,000)	\$10,000	\$5,000

Congestion



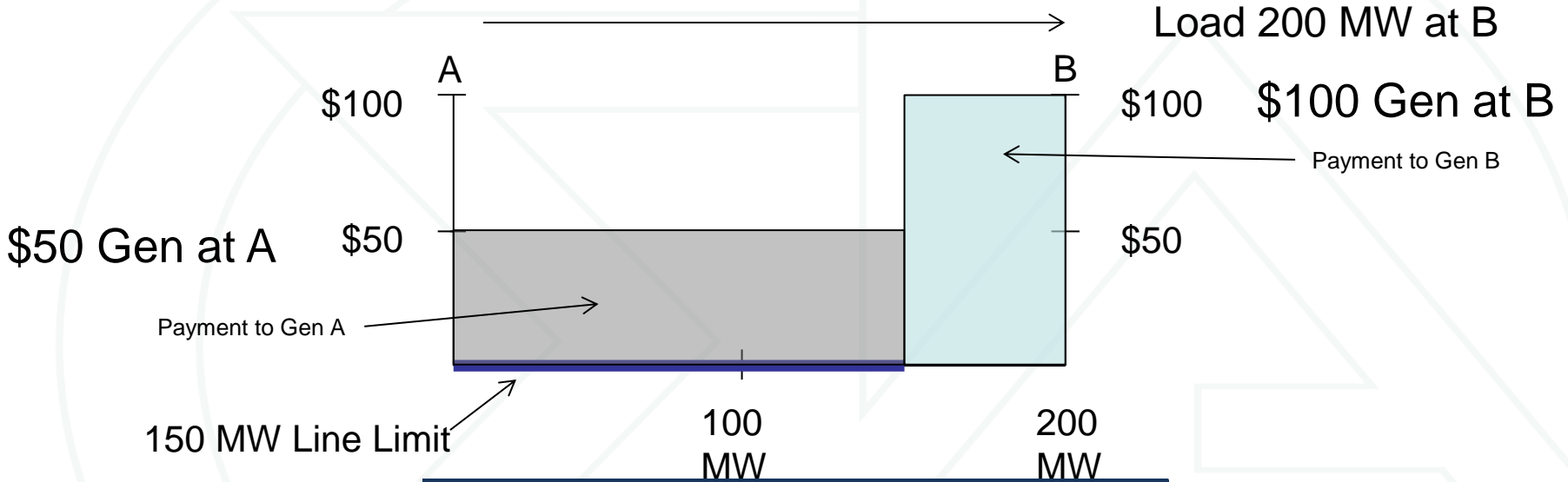
	Charges
Load Charges	\$20,000.00
Congestion Allocation	\$5,000.00
Net Load Charges	\$15,000.00

Day Ahead		Bus A	Transfer A to B	Bus B		
Price		\$50		\$100		
LMP	MW	Total Load Charges	Average Cost	Congestion Allocation	Net Load Bill	Average Cost
\$ 100	200	\$20,000.00	\$100.00	\$5,000.00	\$15,000.00	\$75.00
	Load	\$ -		\$20,000		
	Generation	\$ 5,000		\$10,000		
	Total	(\$5,000)		\$10,000	\$5,000	

Congestion: Constraint with Increased Line Limit



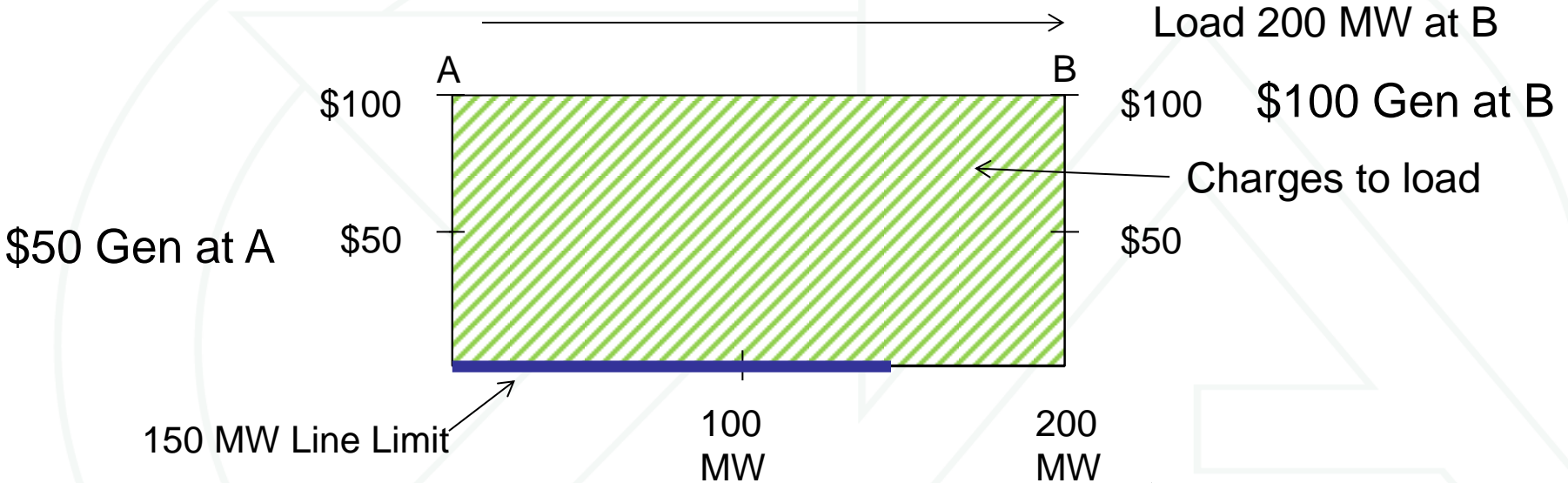
Congestion



Day Ahead	Bus A	Transfer A to B	Bus B
Price	\$50		\$100
Load	-	→	200
Generation	150	150 MW	50

Day Ahead	Bus A	Bus B	Congestion
Load	\$ -	\$ 20,000	
Generation	\$ 7,500	\$ 5,000	
Total	(\$7,500)	\$15,000	\$7,500

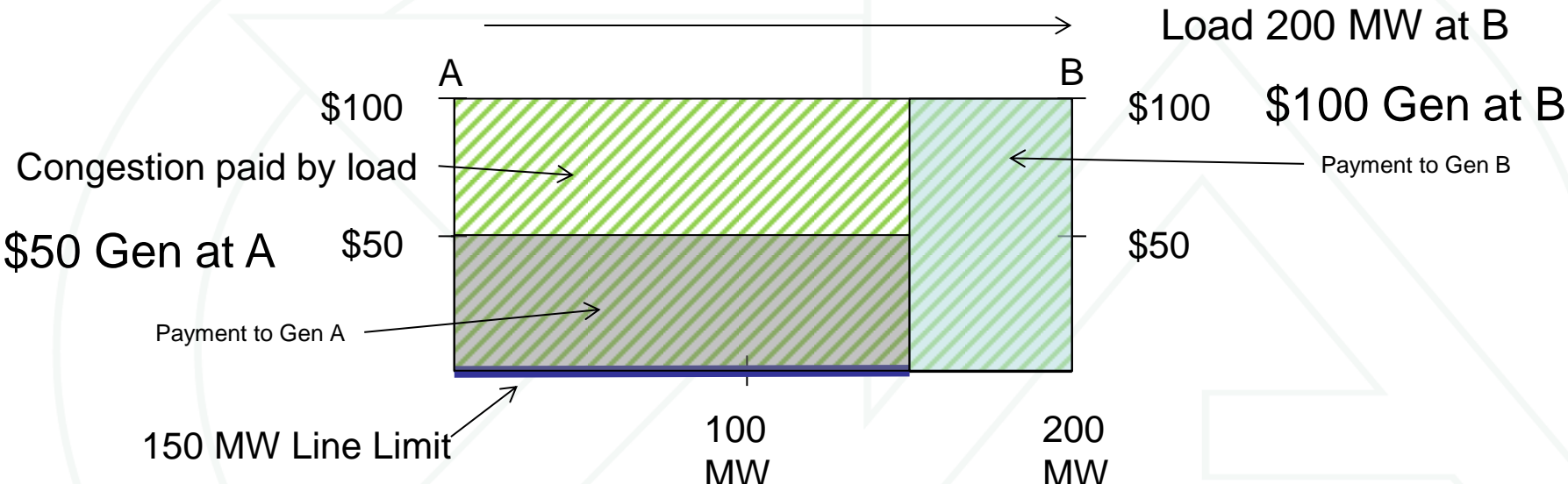
Congestion



Day Ahead	Bus A	Transfer A to B	Bus B
Price	\$50		\$100
Load	-	→	200
Generation	150	150 MW	50

Day Ahead	Bus A	Bus B	Congestion
Load	\$ -	\$ 20,000	
Generation	\$ 7,500	\$ 5,000	
Total	(\$7,500)	\$15,000	\$7,500

Congestion



Day Ahead	Bus A	Transfer A to B	Bus B
Price	\$50		\$100
Load	-	→	200
Generation	100	100 MW	100

Day Ahead	Bus A	Bus B	Congestion
Load	\$ -	\$ 20,000	
Generation	\$ 5,000	\$ 10,000	
Total	(\$5,000)	\$10,000	\$5,000

Day Ahead	Bus A	Transfer A to B	Bus B
Price	\$50		\$100
Load	-	→	200
Generation	150	150 MW	50

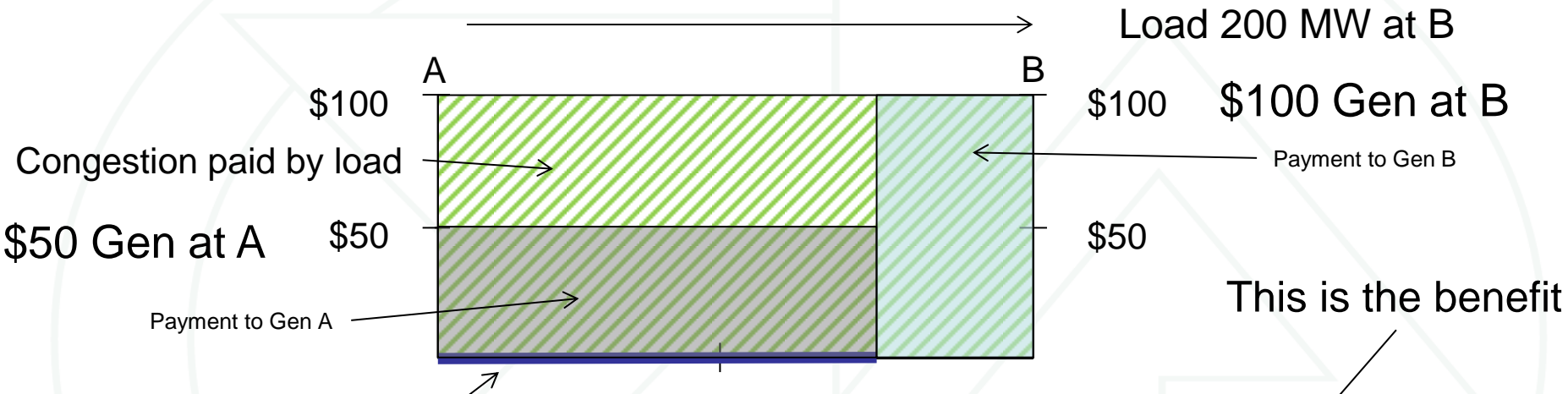
Day Ahead	Bus A	Bus B	Congestion
Load	\$ -	\$ 20,000	
Generation	\$ 7,500	\$ 5,000	
Total	(\$7,500)	\$15,000	\$7,500



Calculating Benefits



Congestion



150 MW Line

With 100 MW Transmission							
LMP	MW	Total Load Charges	Average Cost	Congestion Allocation	Net Load Bill	Average Cost	
\$ 100	200	\$20,000.00	\$100.00	\$5,000.00	\$15,000.00	\$75.00	
With 150 MW Transmission							
LMP	MW	Total Load Charges	Average Cost	Congestion Allocation	Net Load Bill	Average Cost	
\$ 100	200	\$20,000.00	\$100.00	\$7,500.00	\$12,500.00	\$62.50	
				Change in congestion allocation available	Change in Net Bill	Change in Average Cost	
				\$2,500.00	-\$2,500.00	-\$12.50	

This is the benefit

Compare this to cost (Change * -1)



Current Approach to Benefit Calculation

Day Ahead	Bus A	Transfer A to B	Bus B
Price	\$50		\$100
Load	-	→	200
Generation	100	100 MW	100

Day Ahead	Bus A	Bus B	Congestion
Load	\$ -	\$ 20,000	
Generation	\$ 5,000	\$ 10,000	
Total	(\$5,000)	\$10,000	\$5,000

Day Ahead	Bus A	Transfer A to B	Bus B
Price	\$50		\$100
Load	-	→	200
Generation	150	150 MW	50

Day Ahead	Bus A	Bus B	Congestion
Load	\$ -	\$ 20,000	
Generation	\$ 7,500	\$ 5,000	
Total	(\$7,500)	\$15,000	\$7,500

	Total Generation Credits	Total Load Charges
Before	\$15,000.00	\$20,000.00
After	\$12,500.00	\$20,000.00
Change	-\$2,500.00	\$0.00

Regional Benefit Calculation	Subregional Benefit Calculation	Net Benefits
(Net gen + Load Savings Only)	(Load Savings Only)	Net gen + net load savings
\$ 1,250.00	\$0.00	\$ 1,250.00

Things to Consider

- **Overall concept: Total Net Benefit > Total Cost**
 - **In closed system benefits can be shared**
- **Load Charges, both positive and negative**
 - **Who benefits?**
 - **Downstream load benefits**
 - **Upstream load loses**
 - Will only benefit in closed system with average cost allocation
 - Within utility zone upgrade

Things to Consider

- **Generation Credits (Production Costs), both positive and negative**
 - **Who saves generation production charges?**
 - **Downstream load “benefits”**
 - **Upstream load does not benefit**
 - Only benefits in a closed system with average cost allocation
 - Within utility zone upgrade
 - **Upstream generation wins**
 - **Downstream generation loses**



Things to Consider

- **Benefit calculations are very sensitive to LMP estimates/assumptions**
- **Current approach does not examine benefit on the basis of whole system**
- **Would be more correct if run by a single utility that had a cost minimization goal**
 - **Should include the consideration of generation alternatives to project**
 - **Current approach ignores generation competitive alternatives**

Things to Consider

- **Current regional approach does not allocate cost solely to beneficiaries**
 - **Socializes cost to those helped and hurt by project**
 - **50% to socialized to system and 50% assigned to winners**
 - **Regardless of proportion that is generation production savings or load energy savings**



50 MW Increased Transfer: Case 1

		Transfer			
Bus A	Bus A	Limit	Bus B	Bus B	Total Charges
LMP	\$50	100	LMP	\$100	
Load	100		Load	200	
Gen (\$50): 1-300	200		Gen (\$100): 1-200	100	
Gen (\$75): 1-100			Gen (\$200): 1-100		
Load Charges	\$5,000		Load Charges	\$20,000	\$25,000
Gen Credits	\$10,000		Gen Credits	\$10,000	\$20,000
Net Charges	-\$5,000		Net Charges	\$10,000	\$5,000
Total Congestion				\$5,000	
Load Charges			Load Charges		
After Allocation of			After Allocation of		
Congestion	\$5,000		Congestion	\$15,000	\$20,000
Average Price for					
Load	\$50.00			\$75.00	
Average Price for					
Generation	\$50.00			\$100.00	

		Transfer			
Bus A	Bus A	Limit	Bus B	Bus B	Total Charges
LMP	\$50	150	LMP	\$100	
Load	100		Load	200	
Gen (\$50): 1-300	250		Gen (\$100): 1-200	50	
Gen (\$75): 1-100	0		Gen (\$200): 1-100		
Load Charges	\$5,000		Load Charges	\$20,000	\$25,000
Gen Credits	\$12,500		Gen Credits	\$5,000	\$17,500
Net Charges	-\$7,500		Net Charges	\$15,000	\$7,500
Total Congestion				\$7,500	
Load Charges			Load Charges		
After Allocation of			After Allocation of		
Congestion	\$5,000		Congestion	\$12,500	\$17,500
Average Price for					
Load	\$50.00			\$62.50	
Average Price for					
Generation	\$50.00			\$100.00	

Average Cost To Load (System)	Average Cost To Load (System)	Benefit Calc Regional	Benefit Calc Local	Net Benefit
\$67	\$58	\$1,250	\$0	\$1,250

Changes	Bus A	Bus B	Change
LMP	\$0	\$0	
Load	0	0	
Generation	0	-50	
Generation	50	0	
Change in Load Charges	\$0	\$0	\$0
Change in Gen Credits	\$2,500	-\$5,000	-\$2,500
Change in Net Charges	-\$2,500	\$5,000	\$2,500
Change in Congestion	\$0	\$2,500	\$2,500
Change in net Load			
Charges After Congestion			
Allocation	\$0	-\$2,500	-\$2,500
Change in Average Price for			
Load	\$0.00	-\$12.50	
Charge in Average Price for			
Generation	\$12.50	\$0.00	

(50% of each)
Benefit!

Net Load Charges (Congestion)
\$2,500

50 MW Increased Transfer: Case 2

Transfer				
Bus A	Bus A	Limit Bus B	Bus B	Total Charges
LMP	\$50	100 LMP	\$100	
Load	100	Load	200	
Gen (\$50): 1-200	200	Gen (\$100): 1-200	100	
Gen (\$75): 1-100	0	Gen (\$200): 1-100	0	
Load Charges	\$5,000	Load Charges	\$20,000	\$25,000
Gen Credits	\$10,000	Gen Credits	\$10,000	\$20,000
Net Charges	-\$5,000	Net Charges	\$10,000	\$5,000
Total Congestion			\$5,000	

Load Charges After Allocation of Congestion	\$5,000	Load Charges After Allocation of Congestion	\$15,000	\$20,000
Average Price for Load	\$50.00		\$75.00	
Average Price for Generation	\$50.00		\$100.00	

Transfer				
Bus A	Bus A	Limit Bus B	Bus B	Total Charges
LMP	\$75	150 LMP	\$100	
Load	100	Load	200	
Gen (\$50): 1-200	200	Gen (\$100): 1-200	50	
Gen (\$75): 1-100	50	Gen (\$200): 1-100		
Load Charges	\$7,500	Load Charges	\$20,000	\$27,500
Gen Credits	\$18,750	Gen Credits	\$5,000	\$23,750
Net Charges	-\$11,250	Net Charges	\$15,000	\$3,750
Total Congestion			\$3,750	

Load Charges After Allocation of Congestion	\$7,500	Load Charges After Allocation of Congestion	\$16,250	\$23,750
Average Price for Load	\$75.00		\$81.25	
Average Price for Generation	\$93.75		\$100.00	

Average Cost To Load (System)	\$67	Average Cost To Load (System)	\$79	Benefit Calc Regional	Benefit Calc Local	Net Benefit
				-\$1,875	\$0	-\$3,125

Changes	Bus A	Bus B	Change in Totals
LMP	\$25	\$0	
Load	0	0	
Generation	0	-50	
Generation	50	0	
Change in Load Charges	\$2,500	\$0	\$2,500
Change in Gen Credits	\$8,750	-\$5,000	\$3,750
Change in Net Charges	-\$6,250	\$5,000	-\$1,250
Change in Congestion	\$0	-\$1,250	-\$1,250
Change in net Load Charges After Congestion Allocation	\$2,500	\$1,250	\$3,750
Average Price for Load	\$25.00	\$6.25	
Average Price for Generation	\$43.75	\$0.00	

Benefit?

Net Load Charges (Congestion)	-\$3,750
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50 MW Increased Transfer: Case 3

Bus A		Transfer		Bus B		Total Charges
Bus A	Bus A	Limit	Bus B	Bus B	Total Charges	
LMP	\$50	100	LMP	\$200		
Load	100		Load	200		
Gen (\$50): 1-300	200		Gen (\$100): 1-60	60		
Gen (\$75): 1-100			Gen (\$200): 1-100	40		
Load Charges	\$5,000		Load Charges	\$40,000		\$45,000
Gen Credits	\$10,000		Gen Credits	\$20,000		\$30,000
Net Charges	-\$5,000		Net Charges	\$20,000		\$15,000
Total Congestion					\$15,000	
Load Charges		Load Charges				
After Allocation of		After Allocation of				
Congestion		Congestion		\$5,000	\$25,000	\$30,000
Average Price for						
Load				\$50.00	\$125.00	
Average Price for						
Generation				\$50.00	\$200.00	

Bus A		Transfer		Bus B		Total Charges
Bus A	Bus A	Limit	Bus B	Bus B	Total Charges	
LMP	\$50	150	LMP	\$100		
Load	100		Load	200		
Gen (\$50): 1-300	250		Gen (\$100): 1-60	50		
Gen (\$75): 1-100	0		Gen (\$200): 1-200			
Load Charges	\$5,000		Load Charges	\$20,000		\$25,000
Gen Credits	\$12,500		Gen Credits	\$5,000		\$17,500
Net Charges	-\$7,500		Net Charges	\$15,000		\$7,500
Total Congestion					\$7,500	
Load Charges		Load Charges				
After Allocation of		After Allocation of				
Congestion		Congestion		\$5,000	\$12,500	\$17,500
Average Price for						
Load				\$50.00	\$62.50	
Average Price for						
Generation				\$50.00	\$100.00	

Average
Cost To
Load
(System)
\$100



Average
Cost To
Load
(System)
\$58

Benefit
Calc
Regional

\$16,250

Benefit
Calc
Local

\$20,000

Net
Benefit
\$16,250

Changes

	Bus A	Bus B	Change
LMP	\$0	-\$100	
Load	0	0	
Generation	50	-10	
Generation	0	-40	
Change in Load Charges	\$0	-\$20,000	-\$20,000
Change in Gen Credits	\$2,500	-\$15,000	-\$12,500
Change in Net Charges	-\$2,500	-\$5,000	-\$7,500
Change in Congestion	\$0	-\$7,500	-\$7,500
Change in net Load			
Charges After Congestion			
Allocation			
	\$0	-\$12,500	-\$12,500
Change in Average Price for			
Load			
	\$0.00	-\$62.50	
Charge in Average Price for			
Generation			
	\$0.00	-\$100.00	

Benefit!

Net Load
Charges
(Congestion)
\$12,500



Case 4

Transfer				
Bus A	Bus A	Limit Bus B	Bus B	Total Charges
LMP	\$50	50 LMP	\$200	
Load	500	Load	150	
Gen (\$50): 1-600	550	Gen (\$80): 1-60	60	
Gen (\$75): 1-100		Gen (\$200): 1-100	40	
Load Charges	\$25,000	Load Charges	\$30,000	\$55,000
Gen Credits	\$27,500	Gen Credits	\$20,000	\$47,500
Net Charges	-\$2,500	Net Charges	\$10,000	\$7,500
Total Congestion			\$7,500	
Load Charges After Allocation of Congestion		Load Charges After Allocation of Congestion		
	\$25,000		\$22,500	\$47,500
Average Price for				
Load	\$50.00		\$150.00	
Average Price for				
Generation	\$50.00		\$200.00	

Transfer				
Bus A	Bus A	Limit Bus B	Bus B	Total Charges
LMP	\$75	110 LMP	\$80	
Load	500	Load	150	
Gen (\$50): 1-600	600	Gen (\$100): 1-60	40	
Gen (\$75): 1-100	10	Gen (\$200): 1-200		
Load Charges	\$37,500	Load Charges	\$12,000	\$49,500
Gen Credits	\$45,750	Gen Credits	\$3,200	\$48,950
Net Charges	-\$8,250	Net Charges	\$8,800	\$550
Total Congestion			\$550	
Load Charges After Allocation of Congestion		Load Charges After Allocation of Congestion		
	\$37,500		\$11,450	\$48,950
Average Price for				
Load	\$75.00		\$76.33	
Average Price for				
Generation	\$76.25		\$80.00	

Average Cost To Load (System)
\$73

Average Cost To Load (System)
\$75

Benefit Calc Regional	Benefit Calc Local	Net Benefit
\$8,275	\$18,000	\$2,025

Changes	Bus A	Bus B	Change
LMP	\$25	-\$120	
Load	0	0	
Generation	50	-20	
Generation	10	-40	
Change in Load Charges	\$12,500	-\$18,000	-\$5,500
Change in Gen Credits	\$18,250	-\$16,800	\$1,450
Change in Net Charges	-\$5,750	-\$1,200	-\$6,950
Change in Congestion	\$0	-\$6,950	-\$6,950
Change in net Load Charges After Congestion Allocation			
	\$12,500	-\$11,050	\$1,450
Change in Average Price for			
Load	\$25.00	-\$73.67	
Change in Average Price for			
Generation	\$26.25	-\$120.00	

Net Load Charges (Congestion)
-\$1,450

Benefit?



Case 5

Transfer		Transfer		Total Charges
Bus A	Bus A	Limit Bus B	Bus B	
LMP	\$50	50 LMP	\$200	
Load	1000	Load	150	
Gen (\$50): 1-1100	1050	Gen (\$80): 1-60	60	
Gen (\$75): 1-100		Gen (\$200): 1-100	40	
Load Charges	\$50,000	Load Charges	\$30,000	\$80,000
Gen Credits	\$52,500	Gen Credits	\$20,000	\$72,500
Net Charges	-\$2,500	Net Charges	\$10,000	\$7,500
Total Congestion			\$7,500	
Load Charges After Allocation of Congestion		Load Charges After Allocation of Congestion		
	\$50,000		\$22,500	\$72,500
Average Price for Load				
	\$50.00		\$150.00	
Average Price for Generation				
	\$50.00		\$200.00	

Transfer		Transfer		Total Charges
Bus A	Bus A	Limit Bus B	Bus B	
LMP	\$75	110 LMP	\$80	
Load	1000	Load	150	
Gen (\$50): 1-1100	1100	Gen (\$80): 1-60	40	
Gen (\$75): 1-100	10	Gen (\$200): 1-200		
Load Charges	\$75,000	Load Charges	\$12,000	\$87,000
Gen Credits	\$83,250	Gen Credits	\$3,200	\$86,450
Net Charges	-\$8,250	Net Charges	\$8,800	\$550
Total Congestion			\$550	
Load Charges After Allocation of Congestion		Load Charges After Allocation of Congestion		
	\$75,000		\$11,450	\$86,450
Average Price for Load				
	\$75.00		\$76.33	
Average Price for Generation				
	\$75.68		\$80.00	

Average Cost To Load (System)	Average Cost To Load (System)	Benefit Calc Regional	Benefit Calc Local	Net Benefit
\$63	\$76	\$2,025	\$18,000	-\$10,475

Changes	Bus A	Bus B	Change
LMP	\$25	-\$120	
Load	0	0	
Generation	50	-20	
Generation	10	-40	
Change in Load Charges	\$25,000	-\$18,000	\$7,000
Change in Gen Credits	\$30,750	-\$16,800	\$13,950
Change in Net Charges	-\$5,750	-\$1,200	-\$6,950
Change in Congestion	\$0	-\$6,950	-\$6,950
Change in net Load Charges After Congestion Allocation	\$25,000	-\$11,050	\$13,950
Change in Average Price for Load	\$25.00	-\$73.67	
Charge in Average Price for Generation	\$25.68	-\$120.00	

Benefit?

Net Load Charges (Congestion)
-\$13,950



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