Congestion

MMUAC

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Monitoring Analytics

LMP at any bus

ISO's Economic Dispatch Problem

$$\underset{gen}{\text{Min}} \sum_{i=1}^{imax} \sum_{j} Price(i,j) * gen(i,j)$$

Subject to

Load Balance

$$LB: \sum_{i=1}^{nodemax} \sum_{j} gen(i,j) = \sum_{i=1}^{nodemax} dem(i)$$

Normal Constraints (all transmission lines working)

$$N^{U}(l,k): \forall\, l,k \sum_{i=1}^{nodemax} shift((l,k),i) * \left\{ \left[\sum_{j} gen(i,j) \right] - dem(i) \right\} \leq pmax^{n}(l,k)$$

$$N^{L}(l,k): \forall\, l,k \sum_{i=1}^{nodemax} shift((l,k),i) * \left\{ \left[\sum_{j} gen(i,j) \right] - dem(i) \right\} \geq pmin^{n}(l,k)$$

$$LMP_i = \mu + \sum_j dfax_{ij} * \lambda 1_j + \sum_j dfax_{ij} * \lambda 2_j + \ldots$$

LMP = SMP + CLMP1+ CLMP2+…

Congestion

- **CLMP is not congestion. CLMP indicates a difference in LMP relative to a reference price (SMP) due to constraints.**
- **Congestion is the difference between what load pays for energy and what generation is paid for energy due to transmission constraints, net of virtual bids settlement in LMP market.**
- **Congestion collected from load by a binding transmission constraint is based on the shadow price of the constraint and market flow on that constraint.**
- **Total congestion from binding constraint j=**

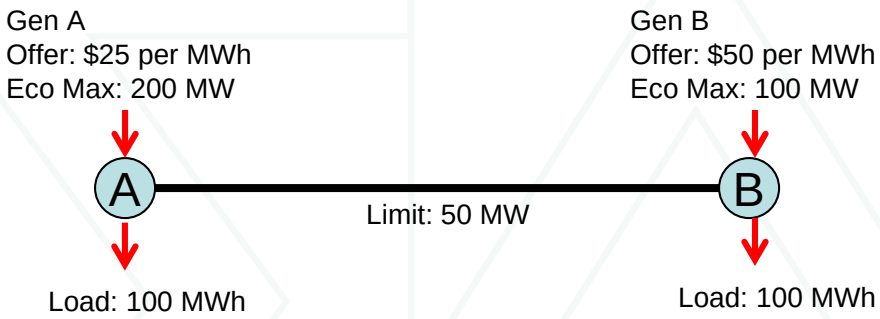
$$\lambda_j(\sum_i \sum_j dfax_{ij} * L_i - \sum_i \sum_j dfax_{ij} * G_i)=$$

λ_j * (market flow on line j) = congestion

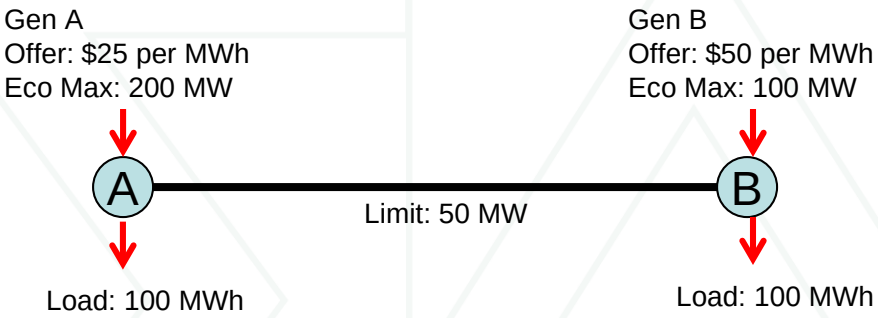
Congestion

- **Load specific contribution to the congestion collected by a constraint is based on the load's proportional contribution to the market flow (relative to all load) on that constraint.**
- **If two loads, each with a DFAX difference of 0.5 to a constraint, each with 10 MW of load, each will have contributed 50 percent of the load related market flow on the constraint.**
- **Each load will have the contributed 50 percent of the congestion caused by that constraint.**

Two Bus Example



Two Bus Example



Least cost, security constrained dispatch:

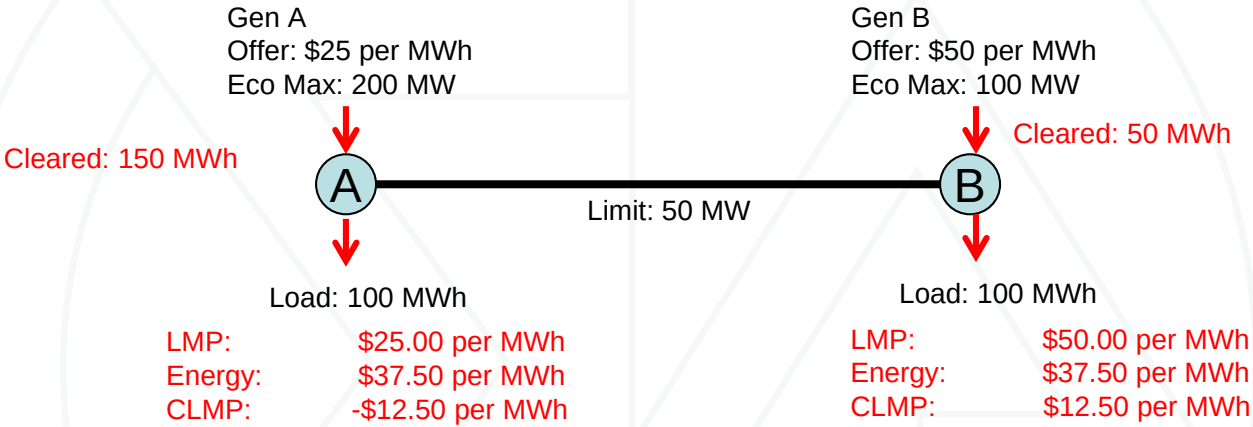
- Minimize GenA*OfferA + GenB*OfferB

Subject to

Total Gen = Load ⟵ Shadow price is SMP or energy price

Flow on Line A B ≤ Limit (50 MW) ⟵ Shadow price x dfax is CLMP
GenA output ≤ GenA EcoMax
GenB output ≤ GenB EcoMax

Two Bus Example (Solution)



Marginal Cost of Reducing the Constraint is:

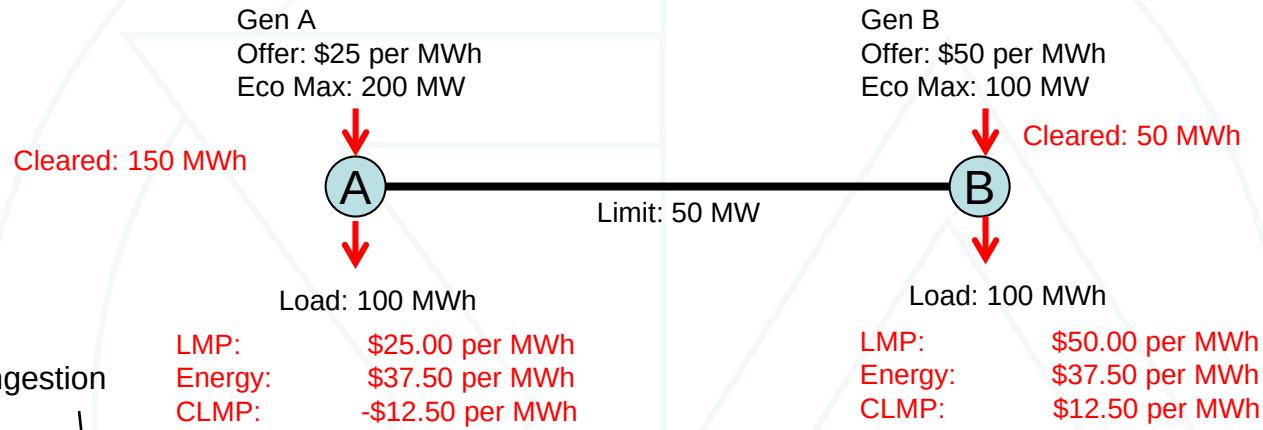
-$50 + $25 = -$25

- Load Reference Bus is between A and B (fictional point)
- SMP = load weighted average LMP = $37.50

One less MW from the expensive resource at B and one more MW from the less expensive resource at A
Shadow price of Power balance Constraint: $-25.0 per MWh, relative (from load reference bus) DFAX of constraint to A = 0.5 and to B = -0.5

LMP at Bus B = SMP + CLMP at B = $37.5 + $12.5 = $50
LMP at Bus A = SMP + CLMP at A = $37.5 - $12.5 = $25

Two Bus Example (Solution)



CLMP is not congestion

Bus	SMP	CLMP	LMP	Load	Gen	Load CLMP Charges	Generation CLMP Credits	Net CLMP Bill?	
A	$37.50	-$12.50	$25.00	100	150	-$1,250.00	-$1,875.00	$625.00	
B	$37.50	$12.50	$50.00	100	50	$1,250.00	$625.00	$625.00	
						$0.00	-$1,250.00	$1,250.00	Congestion
			Load Weighted CLMP Average Price:			$0.00			

CLMP charges are not congestion.
CLMP credits are not congestion.

A customer's net CLMP bill is not congestion

Difference in LMPs creates differences in charges to load and credits to generation. This is congestion.

Two Bus Example (Solution)

Bus	SMP	CLMP	LMP	Load	Gen	Load CLMP Charges	Generation CLMP Credits	Net CLMP Bill?	
A	$37.50	-$12.50	$25.00	100	150	-$1,250.00	-$1,875.00	$625.00	
B	$37.50	$12.50	$50.00	100	50	$1,250.00	$625.00	$625.00	
						$0.00	-$1,250.00	$1,250.00	Congestion
		Load Weighted CLMP Average Price:				$0.00			

- Moving the reference bus changes the components of LMP (changes SMP and CLMP).
- Moving the reference bus does not change LMP and does not change congestion (the difference between what load paid and generation was paid for energy).
- CLMP and CLMP related charges cannot, therefore, be congestion.
- The customer's net energy bill and net CLMP bill does not indicate the congestion paid by that customer.
- Congestion is the difference between network load payments and network generation revenue caused by constraints.

Bus	SMP	CLMP	LMP	Load	Gen	Load CLMP Charges	Generation CLMP Credits	Net CLMP Bill?	
A	$50.00	-$25.00	$25.00	100	150	-$2,500.00	-$3,750.00	$1,250.00	
B	$50.00	$0.00	$50.00	100	50	$0.00	$0.00	$0.00	
						-$2,500.00	-$3,750.00	$1,250.00	Congestion
		Load Weighted CLMP Average Price:				-$12.50			

Two Bus Example (Solution)

- Load customer at B paid the congestion

Bus	SMP	CLMP	LMP	Load	Gen	Load Charges	Generation Credits	Net Bill?	DFAX Difference	Load Contribution to Market Flow (DFAX Difference)	Proportion of Load Flow Contributions/ Congestion	Congestion Paid
A	$37.50	-$12.50	$25.00	100	150	$2,500.00	$3,750.00	-$1,250.00	0	0	0%	$0.00
B	$37.50	$12.50	$50.00	100	50	$5,000.00	$2,500.00	$2,500.00	-1	-100	100%	$1,250.00
						$7,500.00	$6,250.00	$1,250.00		-100		
		Load Weighted Average Price:				$37.50		Congestion				

- Generation does not pay congestion.
- Virtual bids are settled.
- Congestion is paid by load:
  - The residual load overpayment after generation is paid and virtuals are settled.

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