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Revenue Adequacy, Shortfall Allocation and Transmission Performance Incentives in FTR/FGR Markets

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Question Addressed

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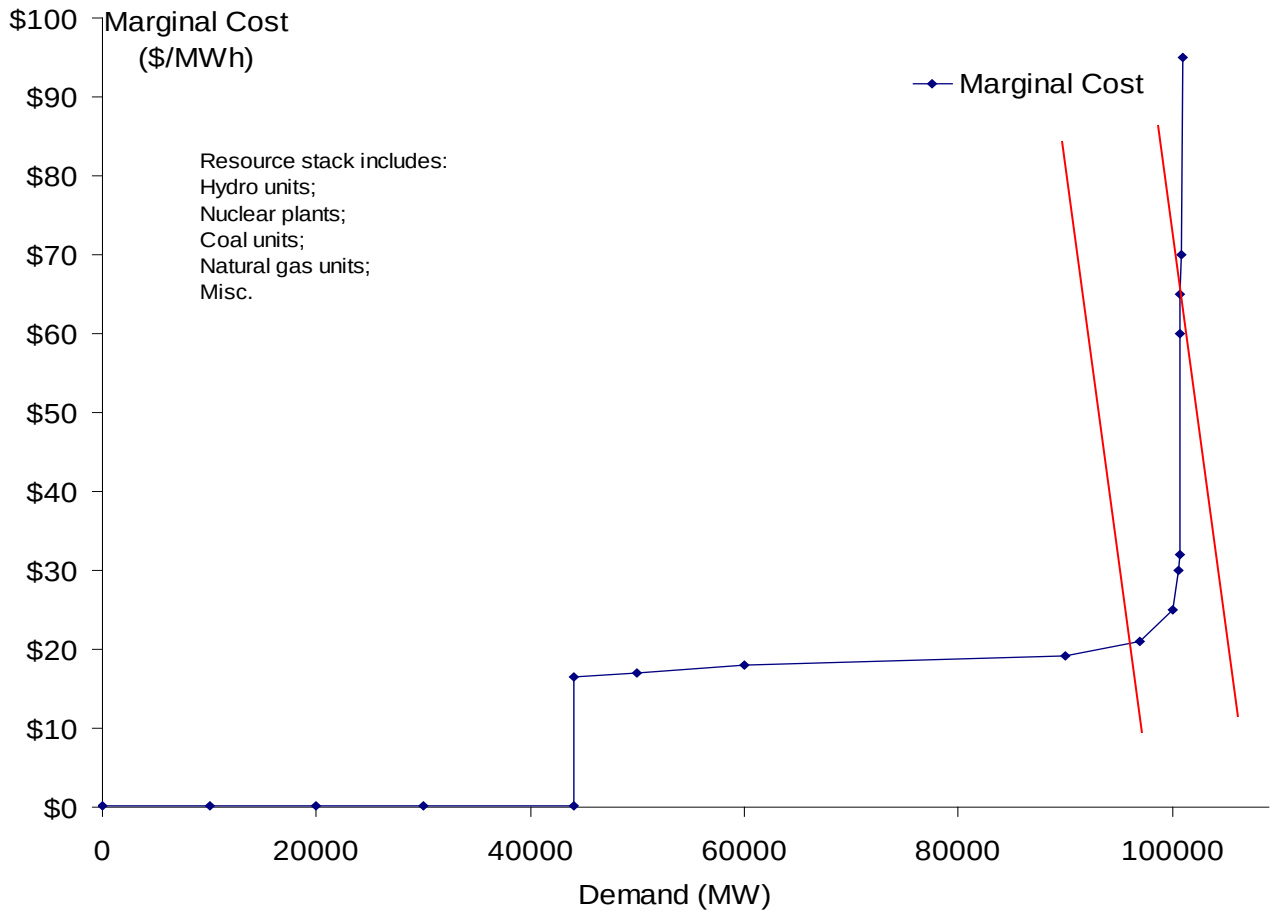
- What are financial transmission rights (FTR)
- How Should FTR settlement (congestion revenues) shortfalls be directly assigned to market participants?
- How can active participation by transmission owners in the FTR market incentivize transmission performance through incremental and long term investment?

Typical Electricity Supply and Demand Functions



On-peak Balancing Market Prices at ERCOT

January 2002 thru July 2007

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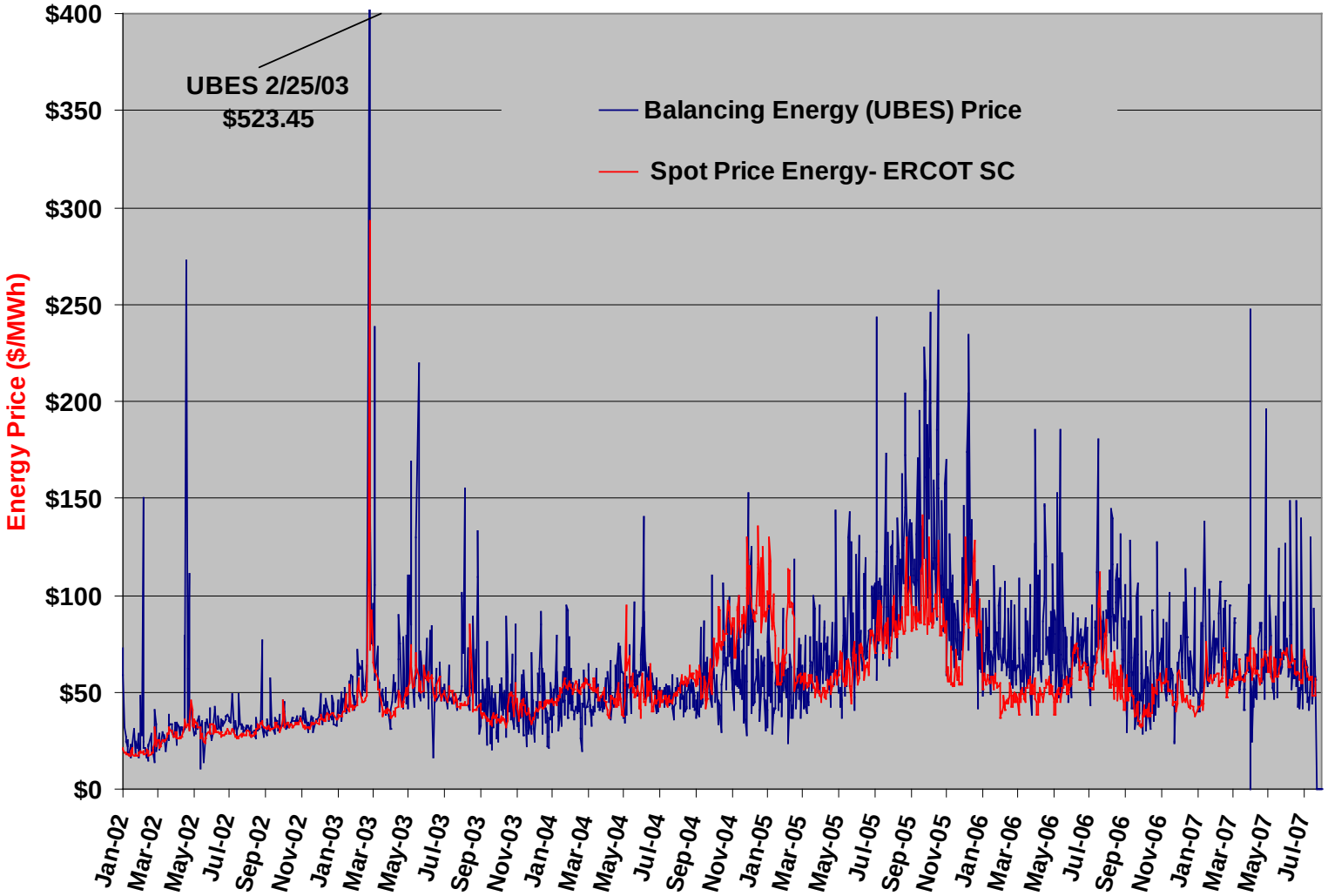

Nodal Pricing

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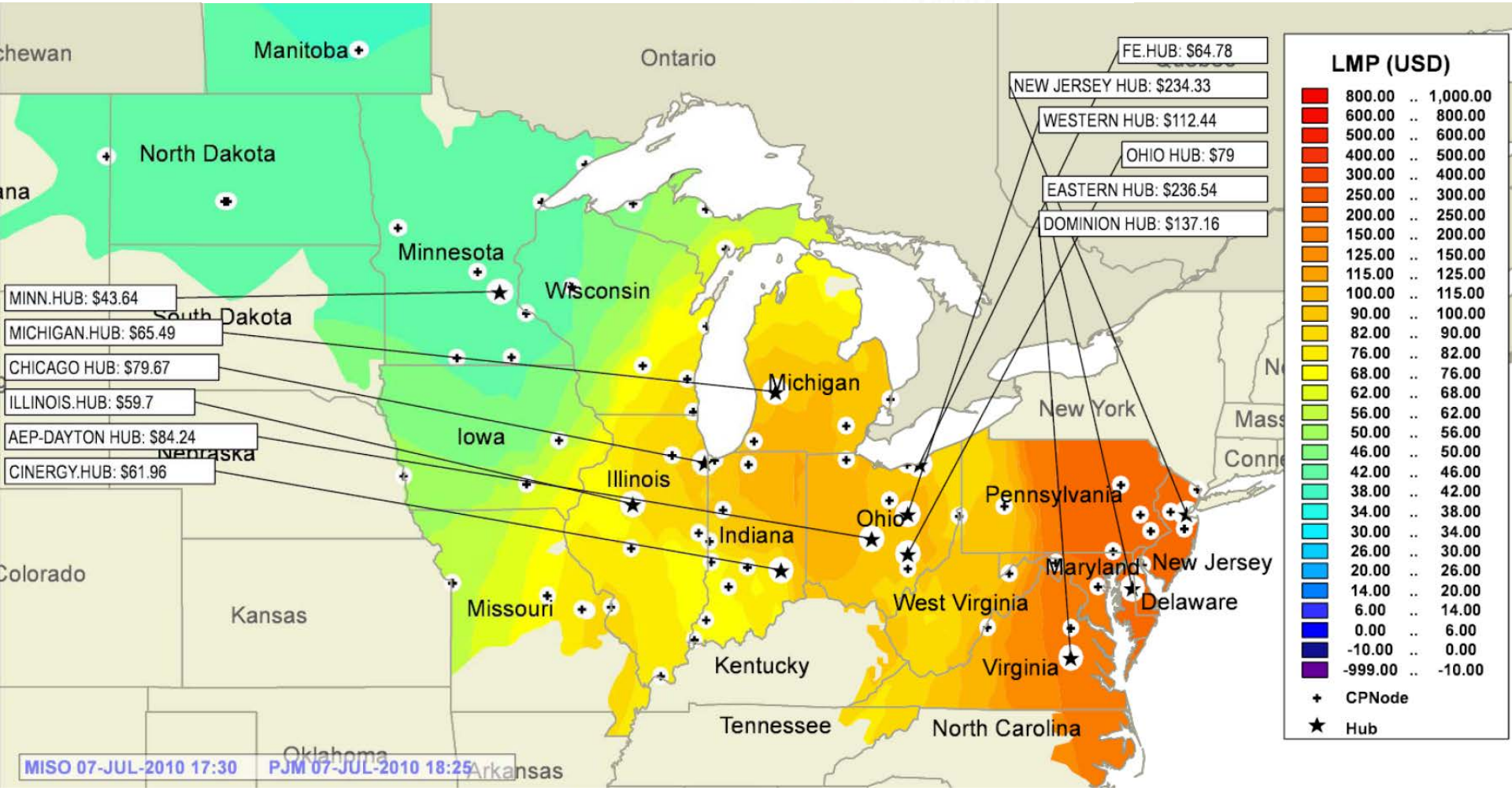
MidwestISO
Energizing the Heartland

pjm



Congestion Charges and Financial Transmission Rights

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- Bilateral transactions are subject to congestion charges = difference in nodal prices between withdrawal and injection points (no arbitrage pricing)
- Financial transmission rights define property rights to the transmission grid and provide a hedging mechanism to market participants against congestion risk

Basic Definitions of the Financial Transmission Rights Underlyings

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- **Nodal Price** at node i = The least cost of providing an incremental MWh at node i under security constrained economic dispatch while observing all flow limits
- **Flowgate Shadow Price** on line ij = The decrease in total dispatch cost due to a 1MW increase in the flow limit of line ij

Forms of Financial Transmission Rights

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- FTR (Obligation):
  - Holder is entitled to or obligated to pay nodal price difference between designated locations per MW denomination
- FTR Options
  - Holder is entitled to nodal price difference between designated locations per MW denomination if value is positive but can walk away if it is negative
- FGR (Option)
  - Holder is entitled to shadow price on congested elements in designated direction per MW denomination

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Fundamental Relationship Between Nodal Prices and Flowgate Shadow Prices

N_i = Energy nodal spot price at bus i

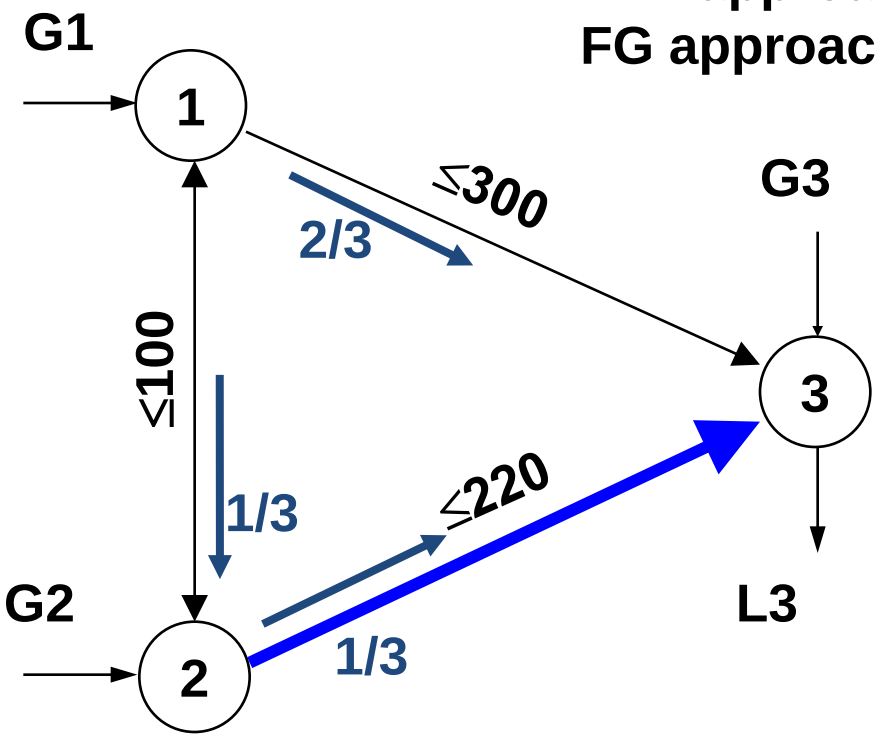
SP_j = Shadow price on flowgate j (zero if line uncongested)

$PTDF_{ik,j}$ = Power Transfer Distribution Factor ik,j = Fraction of flow from node i to node k going through flowgate j

$$N_k - N_i = \sum_{\text{all flowgates j}} SP_j * PTDF_{ik,j}$$

Hedging Forward Transactions with FTRs and FGRs

- G1 has a bilateral contract with L3 to deliver 150 MW and wants to hedge congestion charges:



PTP approach: Buy 150MW of FTR 1 → 3

FG approach: Buy 100MW of FGR 1 → 3

50MW of FGR 1 → 2

50MW of FGR 2 → 3

(FGR portfolio emulates the distribution of flow according to the PTDFs)

Real time settlements

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- Suppose real time dispatch is based on security constrained OPF and the flow constraint on link 2→3 with corresponding shadow price SP_{23} (shadow prices on uncongested links are zero) and nodal prices N_1 , N_2, N_3
- Nodal pricing based congestion charges paid by the generator for the 150MW transaction from node 1 to 3 are $150*(N_3- N_1)$
- Settlement for 150MW FTR 1→3 paid to the generator is $150*(N_3- N_1)$
- Settlement for 50MW FGR 2→3 is $50* SP_{23.}$. But

  $N_3- N_1=1/3* SP_{23}$ (relation of nodal and shadow prices)
- Both the FTR and FGR settlements offset the real time congestion charges (full hedging)

Simultaneous Feasibility of FTRs

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- To insure that congestion revenues can cover FTR settlements (revenue adequacy), they must meet the "simultaneous feasibility test" (SFT)
- In an FTR auction bidders submit bids for specific FTRs, ISO selects winning bids by treating FTR bids as proposed schedules using a security constraint OPF that maximizes the FTR auction revenues
- The virtual "FTR operating point" corresponding to simultaneous bilateral schedules replicating all outstanding FTRs must meet all security and flow constraints i.e. the grid must be able to support all the bilateral transactions covered by the FTRs.
- The FTR operating point may differ from real time dispatch but if it represents a feasible dispatch (and if the nomogram is convex) then the congestion revenues will be sufficient to cover the FTR settlements.

The SFT Nomogram

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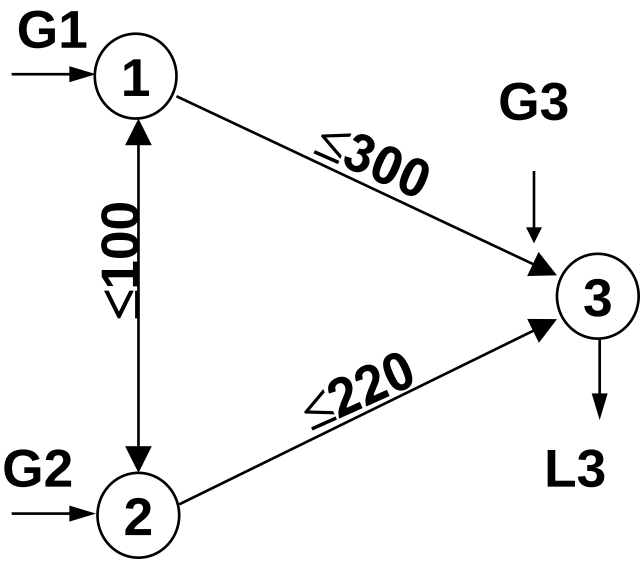
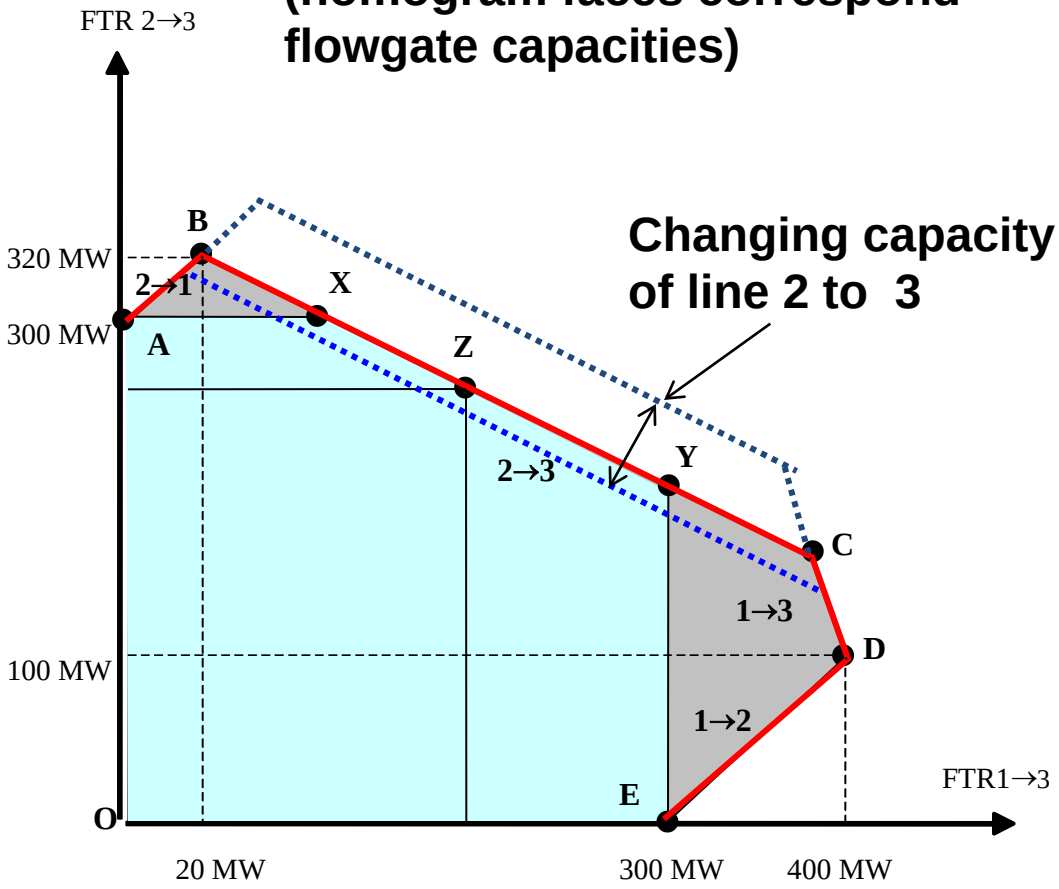


$$\tfrac{2}{3}G1+\tfrac{1}{3}G2\le 300$$

$$\tfrac{1}{3}G1+\tfrac{2}{3}G2\le 220$$

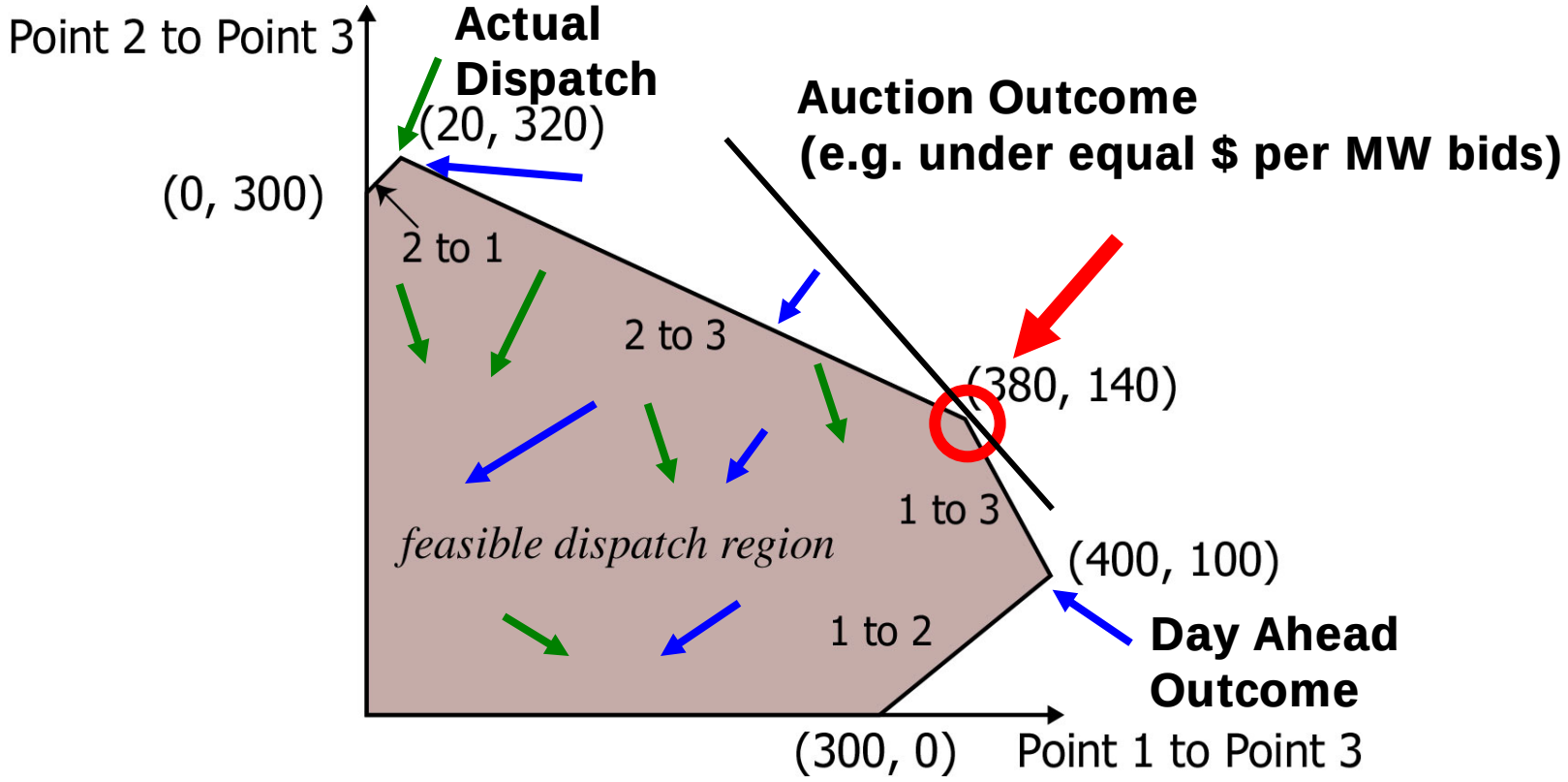
$$-100\le \tfrac{1}{3}(G1-G2)\le 100$$

(nomogram faces correspond flowgate capacities)



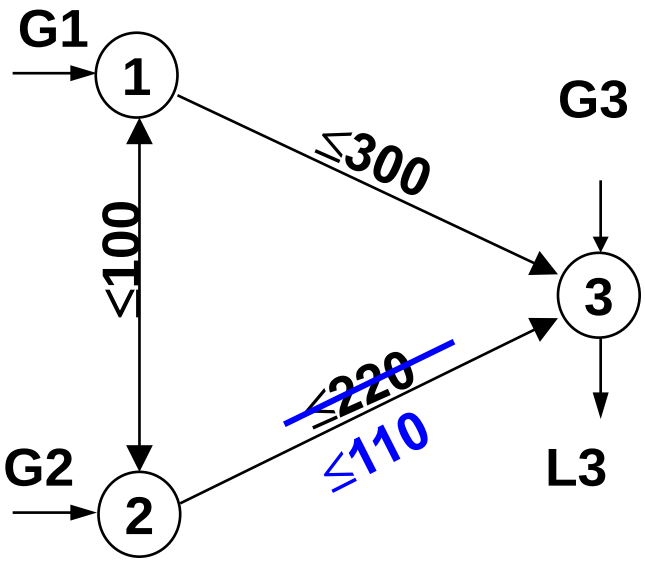
- **Two sided FTRs must stay within the outer nomogram**
- **One sided FTRs (options) must stay within the inner nomogram because we cannot rely on counterflows to alleviate congestion.**

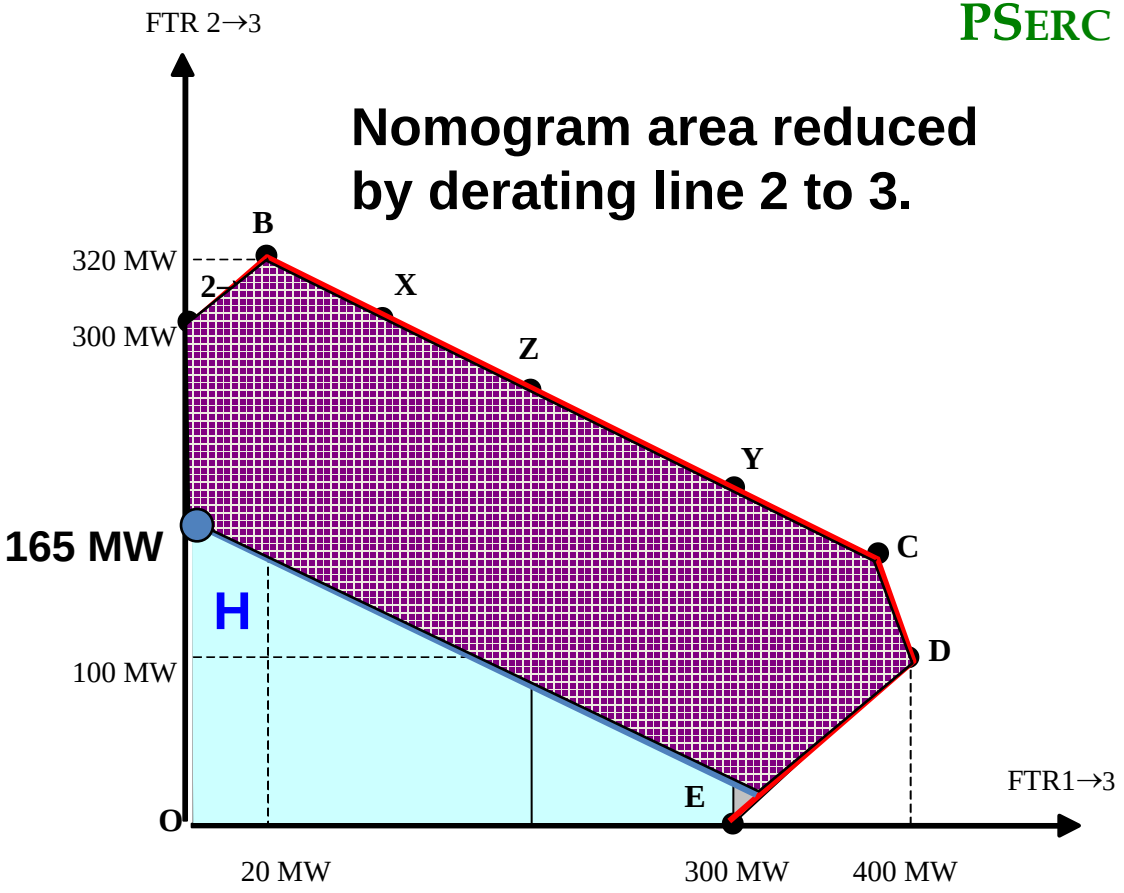
Actual Dispatch May Differ From Auction Results (FTR Operating Point)



The auction outcome (FTR operating point) is such that line 1-2 is not binding so the capacity of line 1-2 is undersold. If that line is congested in actual dispatch then the congestion revenues will exceed FTR settlements, resulting in a surplus.

Derating





Nomogram area reduced by derating line 2 to 3.

If FTRs are awarded based on Pt. B or D. and RT dispatch is at Pt. H, then congestion revenues will not cover FTR settlements.

3-Bus FTR Revenue Adequacy Example

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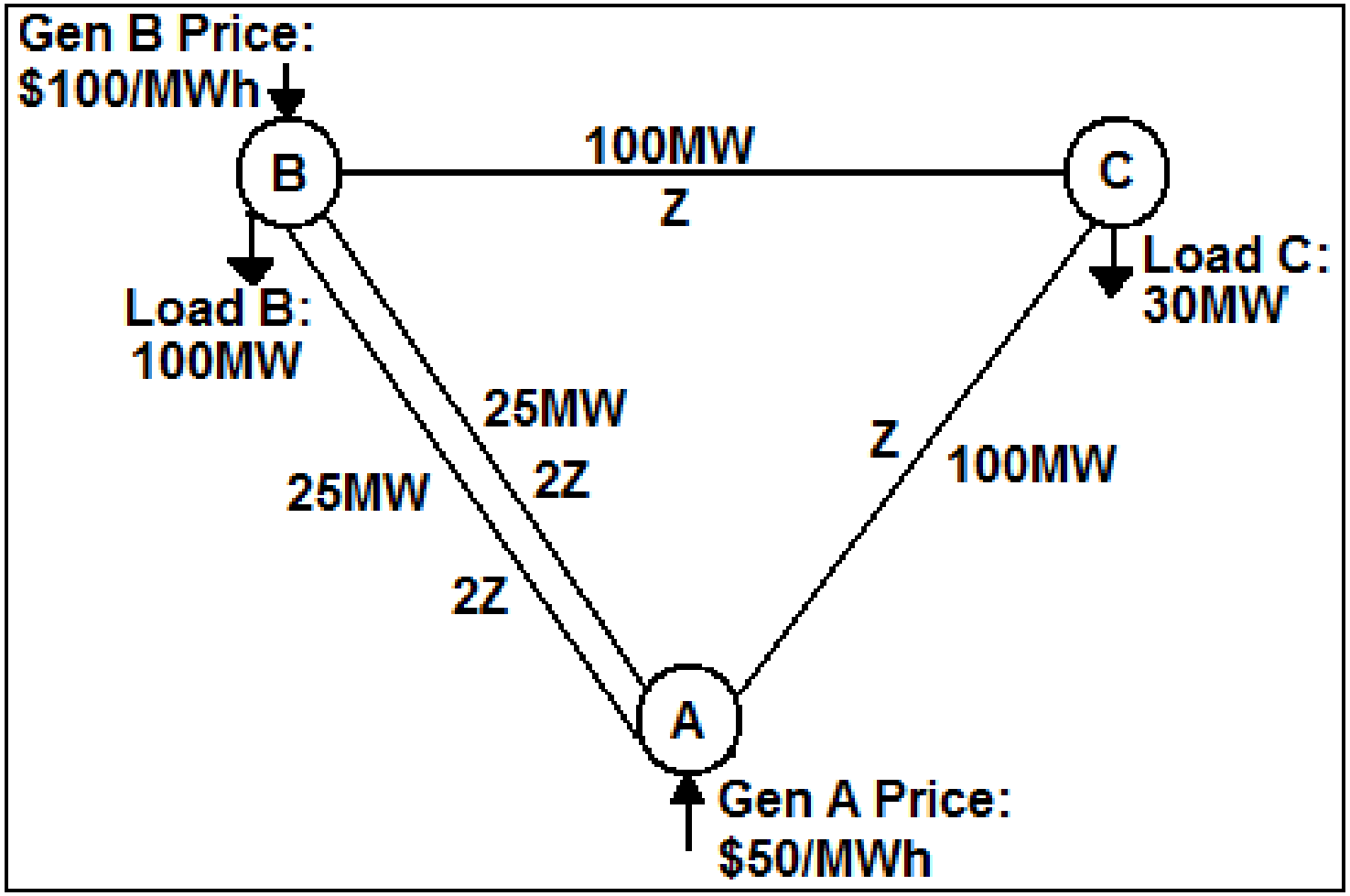

Revenue Inadequacy due to Transmission Switching

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3-bus example C optimal dispatch results (no switching)

Bus:	Gen Pg:	LMP:	Gen Cost:		Transaction:	MW:	Cong. Rent:
A	90MW	$50/MWh	$4,500		A – B	60MW	$3,000
B	40MW	$100/MWh	$4,000		A – C	30MW	$750
C	0MW	$75/MWh	$0		**Total Congestion Rent:**		**$3,750**
Total Generation Cost:			**$8,500**				

3-bus example C optimal dispatch results (lines A-B1 and A-B2 open)

Bus:	Gen Pg:	LMP:	Gen Cost:		Transaction:	MW:	Cong. Rent:
A	100MW	$50/MWh	$5,000		A – B	70MW	$3,500
B	30MW	$100/MWh	$3,000		A – C	30MW	$1,500
C	0MW	$100/MWh	$0		**Total Congestion Rent:**		**$5,000**
Total Generation Cost:			**$8,000**				

3-bus example C results – FTR settlements

Source to Sink:	FTR Quantity:	FTR Settlements (No Switching):	FTR Settlements (Lines A-B1 and A-B2 Open):
A to B	45MW	$2,250 (LMP gap: $50/MWh)	$2,250 (LMP gap: $50/MWh)
A to C	60MW	$1,500 (LMP gap: $25/MWh)	$3,000 (LMP gap: $50/MWh)
Total FTR Settlements:		**$3,750**	**$5,250**

Revenue Inadequacy due to Transmission Switching

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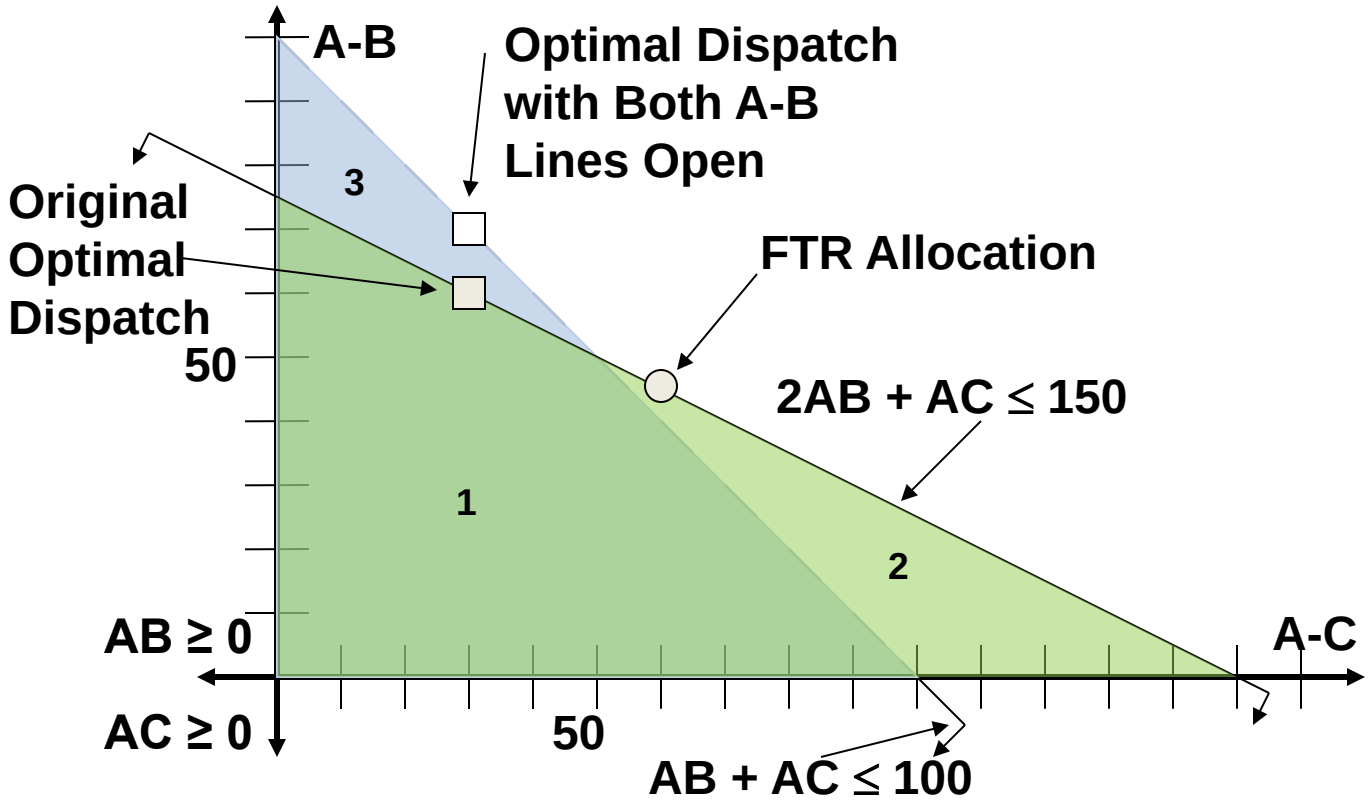
- FTR allocation is revenue adequate for initial topology but revenue inadequate for optimal network topology with both A-B lines open



Transmission Switching Can Help Regain Revenue Adequacy

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3-bus example C results (line A-B1 failed)

Bus:	Gen Pg:	LMP:	Gen Cost:		Transaction:	MW:	Cong. Rent:
A	65MW	$50/MWh	$3,250		A – B	35MW	$1,750
B	65MW	$100/MWh	$6,500		A – C	30MW	$750
C	0MW	$75/MWh	$0		**Total Congestion Rent:**		**$2,500**
Total Generation Cost:			**$9,750**				

3-bus example C optimal dispatch results (lines A-B1 failed A-B2 open)

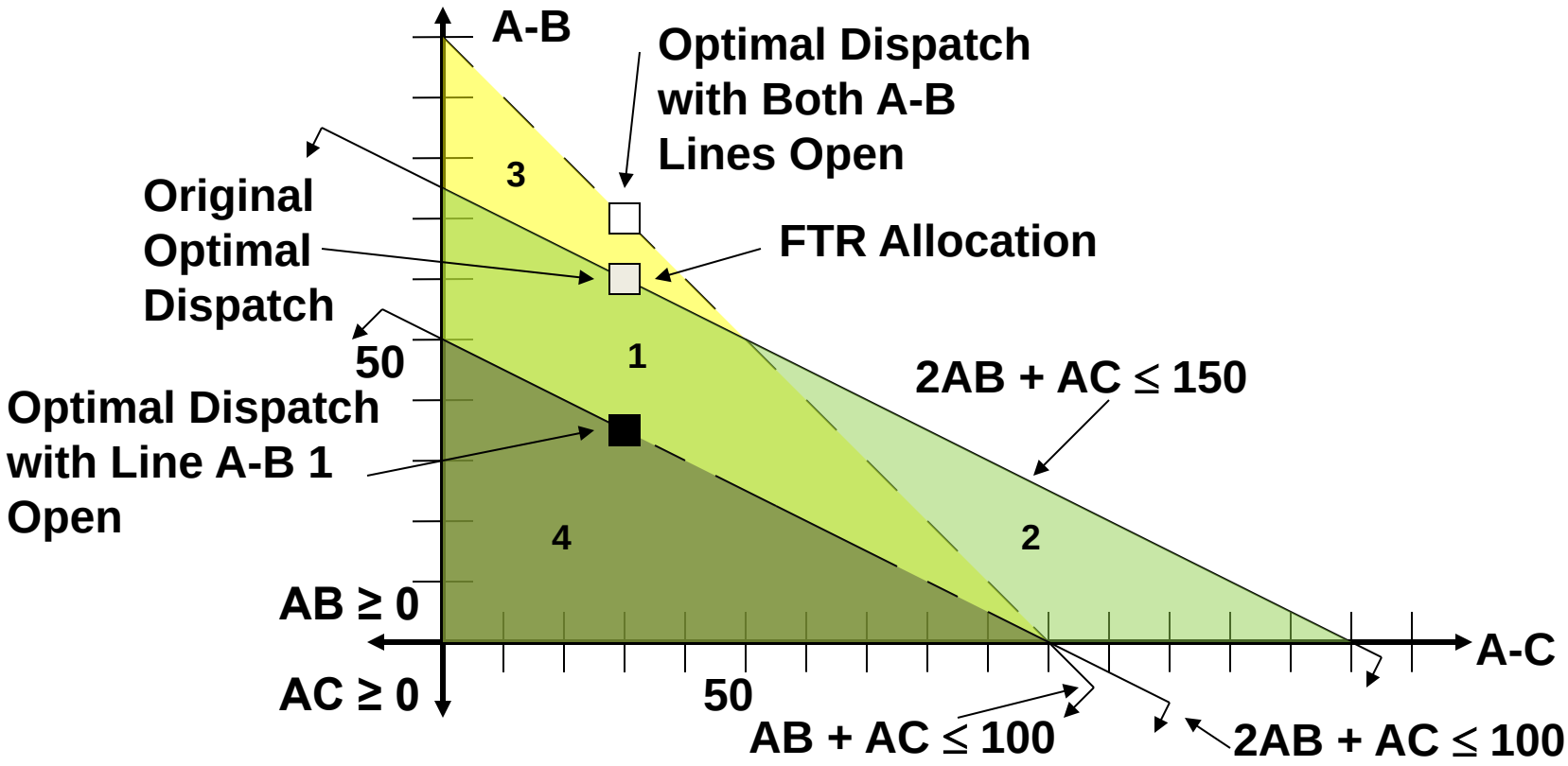
Bus:	Gen Pg:	LMP:	Gen Cost:		Transaction:	MW:	Cong. Rent:
A	100MW	$50/MWh	$5,000		A – B	70MW	$3,500
B	30MW	$100/MWh	$3,000		A – C	30MW	$1,500
C	0MW	$100/MWh	$0		**Total Congestion Rent:**		**$5,000**
Total Generation Cost:			**$8,000**				

3-bus example C results – FTR settlements (line A-B1 failed)

Source to Sink:	FTR Quantity:	FTR Settlement (No Switching):	FTR Settlement (Line A-B2 Opened):
A to B	60MW	$3,000 (LMP gap: $50/MWh)	$3,000 (LMP gap: $50/MWh)
A to C	30MW	$750 (LMP gap: $25/MWh)	$750 (LMP gap: $25/MWh)
Total FTR Settlements:		**$3,750**	**$3,750**

Transmission Switching Can Help Regain Revenue Adequacy

- Line outage causes revenue inadequacy (loss of A-B 1)
- Further grid modifications may regain revenue adequacy and improve market surplus (open line A-B 2)



Options for Covering Shortfalls

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1. Full payment to FTRs based on nodal prices and uplift of the shortfall to sellers or buyers of energy (full funding approach)
2. Prorate settlement to all FTRs to cover shortfall ("haircut" approach)
3. Intertemporal smoothing of congestion revenue accounting by carrying over revenue surpluses and shortfall over an extended time period.
4. Prorate settlement to FTRs based on impact of derated flowgates
5. Full funding of FTRs and assignment of shortfall to owners of derated flowgates.

- Options 1 and 2 and 3 socialize cost of derated lines (1 to load, 2 to FTR holders, across time periods) Extreme case when derated line is radial (vulnerability to DEC game).
- Options 4 and 5 directly assigns shortfall to users or owner of derated flowgates.

Derating Mechanics Under Direct Assignment

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- 1 MW FTR 1 to 3 contains 1/3 MW on flowgate 2-3
- 1 MW FTR 2 to 3 contains 2/3 MW on flowgate 2-3
- IF flowgate 2-3 is derated by 50% congestion revenue shortfall will be 110 x flowgate 2-3 shadow price (SP_{2-3}) which can be either assigned to the line owner and preserve full funding or allocated to the PTP settlements as follows:
  - Settlement of 1 MW FTR 1 to 3 reduced by $0.5x1/3x(SP_{2-3})$
  - Settlement of 1 MW FTR 2 to 3 reduced by $0.5x2/3x(SP_{2-3})$

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When Multiple Flowgates are Derated

- Suppose that flowgate 2-3 is derated by 50% and flowgate 1-3 is derated by 20%
- Settlement to 1 MW FTR 1 to 3 reduced by $0.5x1/3x(SP_{2-3})+0.2x2/3x(SP_{1-3})$
- Settlement to 1 MW FTR 2 to 3 reduced by $0.5x2/3x(SP_{2-3})+0.2x1/3x(SP_{1-3})$
- Mutual fund analogy

Expanding FTR Feasibility with Short FGR Positions

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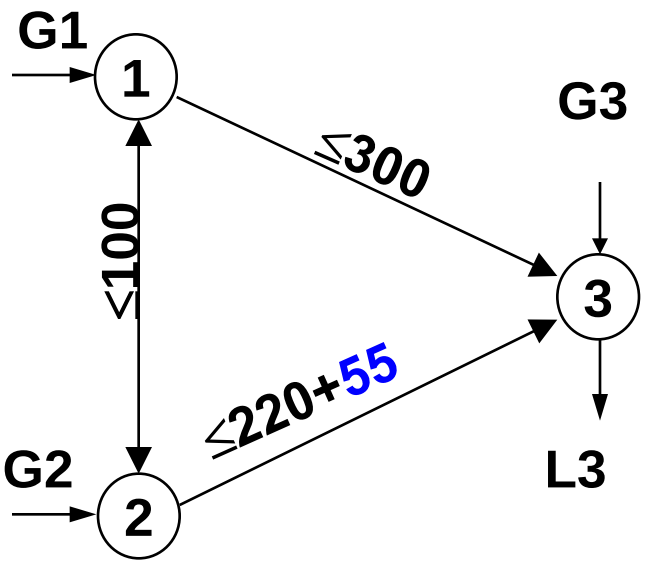
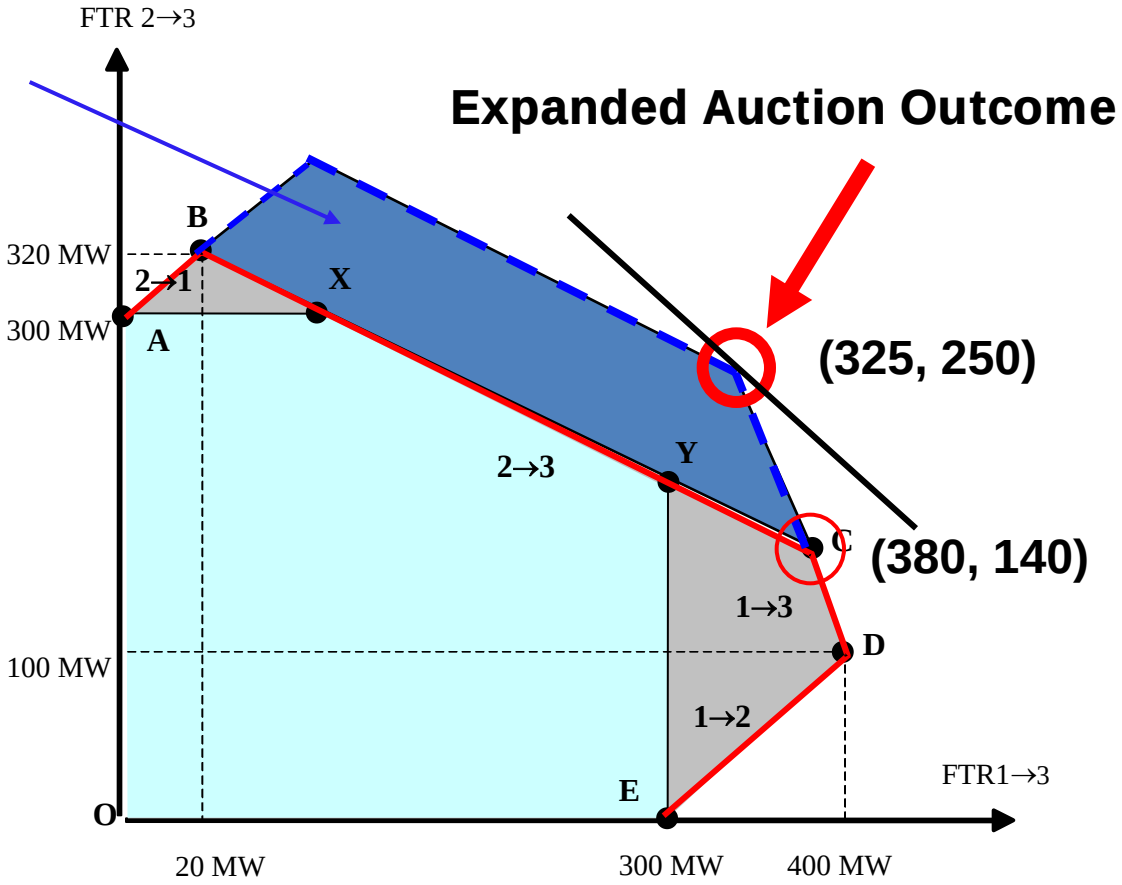
(nomogram area increased by adding 55 MW of virtual capacity to line 2 to 3)





Assume clearing price for both FTRs $10/MW/h, then shadow price on Line 2-3 is also $10/MW/h. Short position of 55MW gets 55xSP_{23}=550=Increase in FTR Revenue

RT (or DA) Settlement

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- If no change in physical network then the network model used for nodal prices and congestion settlements is represented by the original nomogram (without short positions).
- If line 2-3 is at its limit, then the congestion revenues cannot cover the settlement of all outstanding FTRs.
- Payment of RT shadow price on short flowgate positions will produce sufficient income to cover the shortfall.
- In expectation the auction income for short flowgate positions should cover the real time payout for these positions

Who Should Underwrite Short FGR Positions

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- **Option 1:** Create a fund maintained by the ISO that accumulates the auction revenues corresponding to "oversold" flowgate capacity which can be used to cover the revenue shortfall due to such overselling.
- **Option 2:** Transmission owners take short flowgate positions, get the auction revenues for the incremental FTRs and are liable for the resulting shortfall at settlement time.

Why Should TOs Take the Risk

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- Short flowgate position provides incentives for incremental improvements and maintenance (e.g. vegetation control) that can enhance RT transmission capacity
- If a line is not binding in RT the TO retains the auction income for the short position taken.
- Short positions on long term flowgate rights can finance planned upgrades and investments that will alleviate congestion on the shorted flowgates while enabling the ISO to issue long term FTRs against such upgrades.

Implementation Issues

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- Like in every performance based incentive scheme, performance must be measured against a credible and stable yardstick

  (e.g. PBR scheme for NGC in the UK)
- TOs should get assurances that they will not face a moving target and improvements they make will not change the nominal line rating used in subsequent CRR auctions
- Active participation by TOs in FTR trading must be regulated to insure correct incentives (e.g. long positions by TOs should not be allowed since they create incentives to restrict flow)