FTR Trading Fundamentals & Tools

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About CES

- Cambridge Energy Solutions is a software company with a mission to develop software tools for participants in deregulated electric power markets.
- CES-US provides information and tools to assist market participants in analyzing the electricity markets on a locational basis, forecast and value transmission congestion, and to understand the fundamental drivers of short- and long-term prices.
- CES-US staff are experts on market structures in the US, system operation and related information technology

Presentation Outline

- Fundamentals of Nodal Pricing in Electric Power Markets
  - Markets Overview and Price Formation mechanism
  - Purpose of FTR/CRR/TCR Markets
  - Transmission Congestion and FTRs
- FTR Valuation Tools and Techniques
  - Sources of information and software to forecast LMP and congestion
  - Modelling approaches and the tools available for FTR valuation
  - DAYZER Software
- Building FTR Portfolios, Finding, Evaluation and Bidding

Fundamentals of Nodal Pricing (LMPs) in Electric Power Markets

- Overview and Locational Marginal Price Formation mechanism
- Purpose of FTR/CRR/TCR markets
- Transmission Congestion and FTRs

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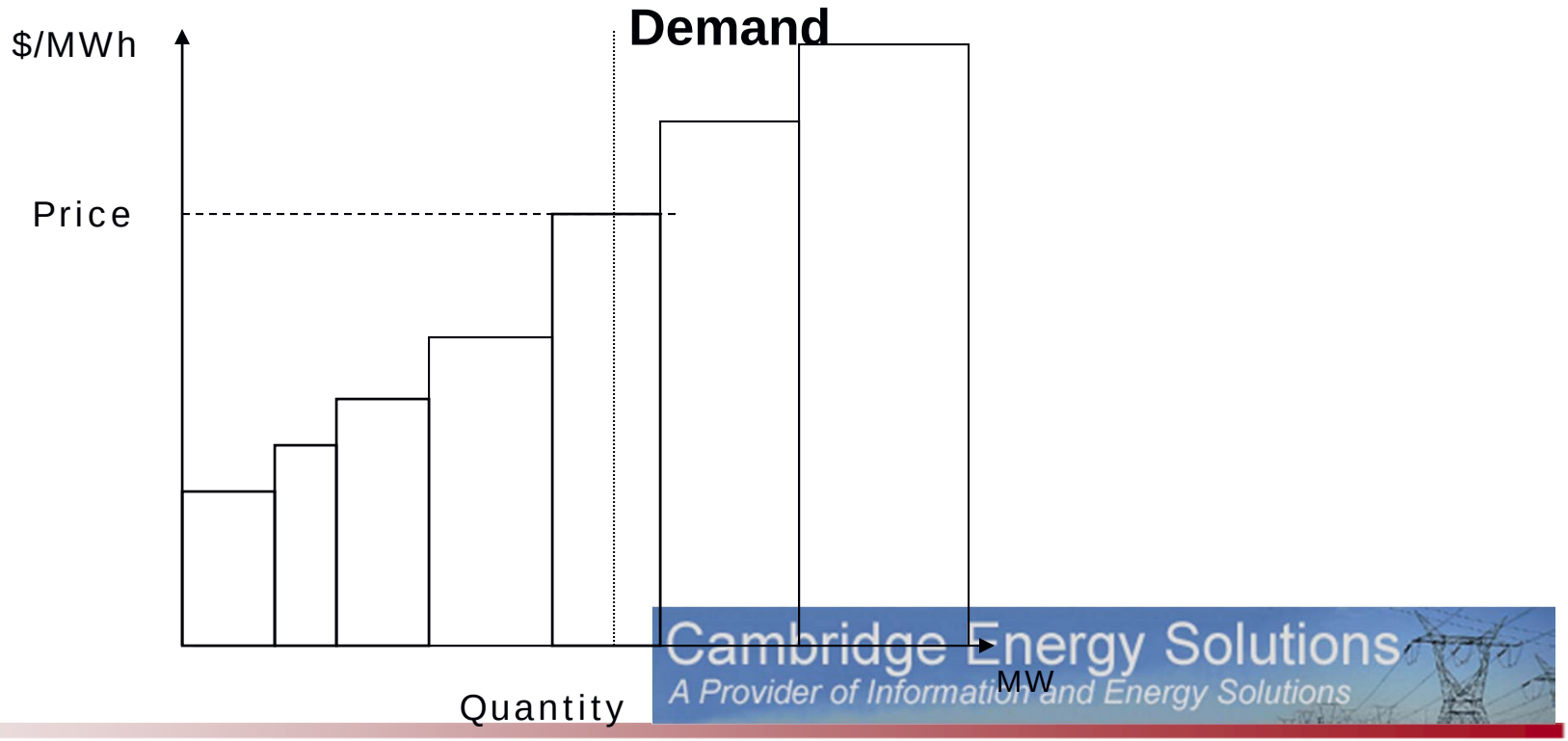
Overview of Day-Ahead Electric Power Markets

- Financial markets with physical clearing. The constraints on the physical transmission system, and engineering constraints on the generation units drive the market clearing prices in DAM and RT, and effectively in the futures as well.
- Market participants behavior: Profit maximization (generators), Cost minimization (LSEs), Risk Management & Hedging, and Arbitrage (traders,….)
- Independent System Operator (other markets) !!!

Overview and Locational Marginal Price Formation mechanism-Theory

- The market clearing price is the marginal cost of the marginal unit in the absence of transmission constraints and losses. In economics terms, the market clearing price is the point of intersection of supply and demand curves



Overview and Locational Marginal Price Formation mechanism-Theory

- In the presence of limiting transmission constraints and/or marginal losses, prices vary by location.
- Nodal pricing applies spatial and temporal pricing theory to derive a bus by bus Locational Marginal Price (LMP)
- Calculations are based on Security Constrained Unit Commitment and Dispatch models
- All transactions on the grid *ARE CHARGED or CREDITED* at the LMP (zonal avg. LMP)
- Generators are paid their locational price and consumers are charged their locational price

LMP Price Calculation Procedures

- Generators offer their willingness to supply at their location
- Consumers bid to purchase their location
  - ISOs forecast demand for reliability
- The system operator commits and dispatches generation units so as to minimize cost or maximize social welfare
- LMP calculated for each bus/node
- Pay the generators; Charge the loads
- Multiple Clearing times / markets
  - Day ahead market to correspond to the scheduling / commitment time frame
  - Hour ahead schedule or market
  - and real time markets

Unit Commitment and Day-Ahead Markets

- Transmission rights are settled in the DAM
- Day Ahead market involves a Security Constrained Unit Commitment (SCUC) and Security Constrained Dispatch
- Unit Commitment minimize the total production cost (bids) over 24 hour period, given constraints on:
  - Generation units, (e.g. MUT, MDT, Ramping)
  - Transmission system
  - Forecasted load
  - Operating reserves and reliability

Nodal Marginal Pricing - Theory

- Nodal prices are not necessarily capped by the marginal costs (or bids) of marginal units - they can be higher than the most expensive unit, or negative

LMP Decomposition

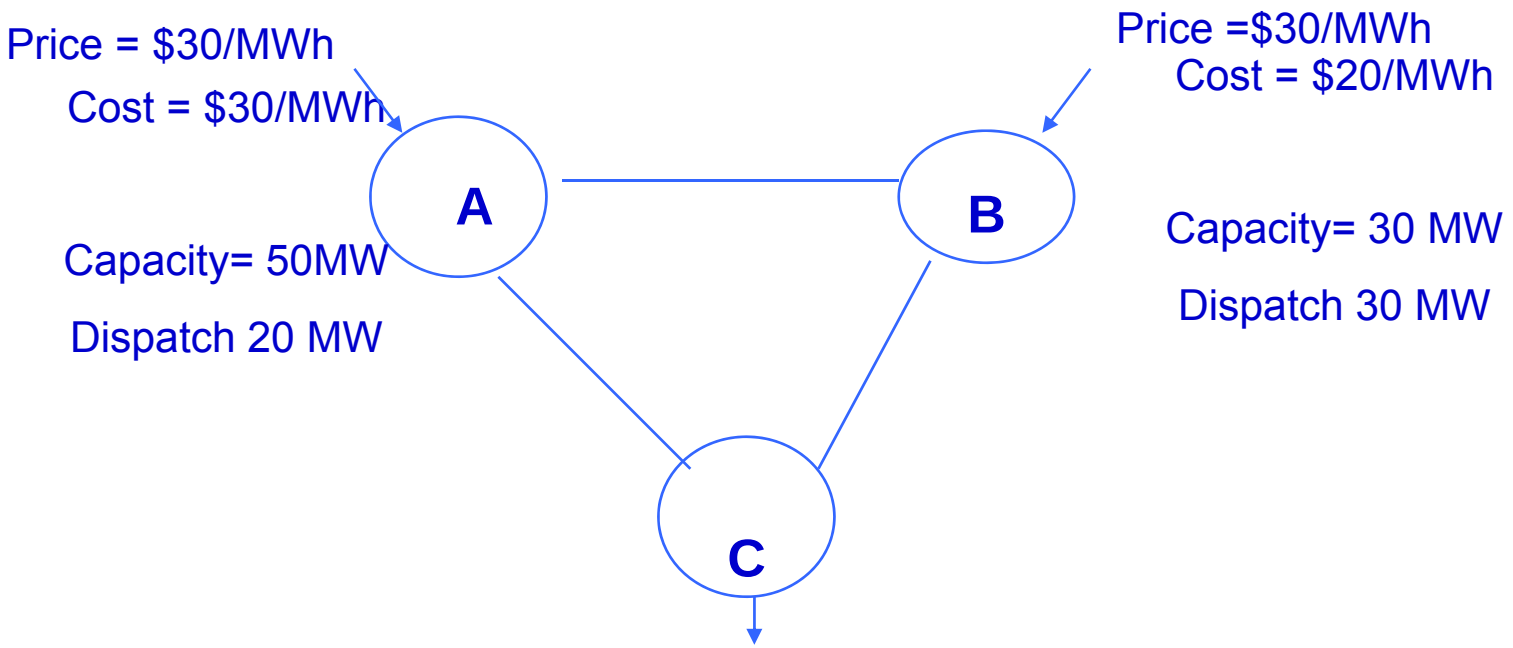
- LMP @ i = Energy + M Losses @i + M Cong @i
- Energy component is the shadow price of the energy balance equation (Total Gen= Total load + Trans. losses)
- Marginal Losses @i: Energy * Marginal loss factor @i
- Marginal Congestion @i: Sum over all constraints c of (shift factors i on constraint c * Shadow Price c)
  - The congestion component can be decomposed by constraint

LMP Decomposition – Shift Factors

- A shift factor for node on a constraint is the sensitivity of the power flows on that constraint for injection (or withdrawal) of power (1 MW) at that node.
- Shift Factors determine the impact of a binding constraint on the LMP at a given node (congestion component is proportional to shift factors).
  - High shift factors at nodes contributing to congestion on a constraint, causes low LMPs at those nodes
  - High shift factors at nodes reducing congestion on a constraint, causes high LMPs at those nodes

Nodal Marginal Pricing - Theory

- Example of nodal prices without constraints.



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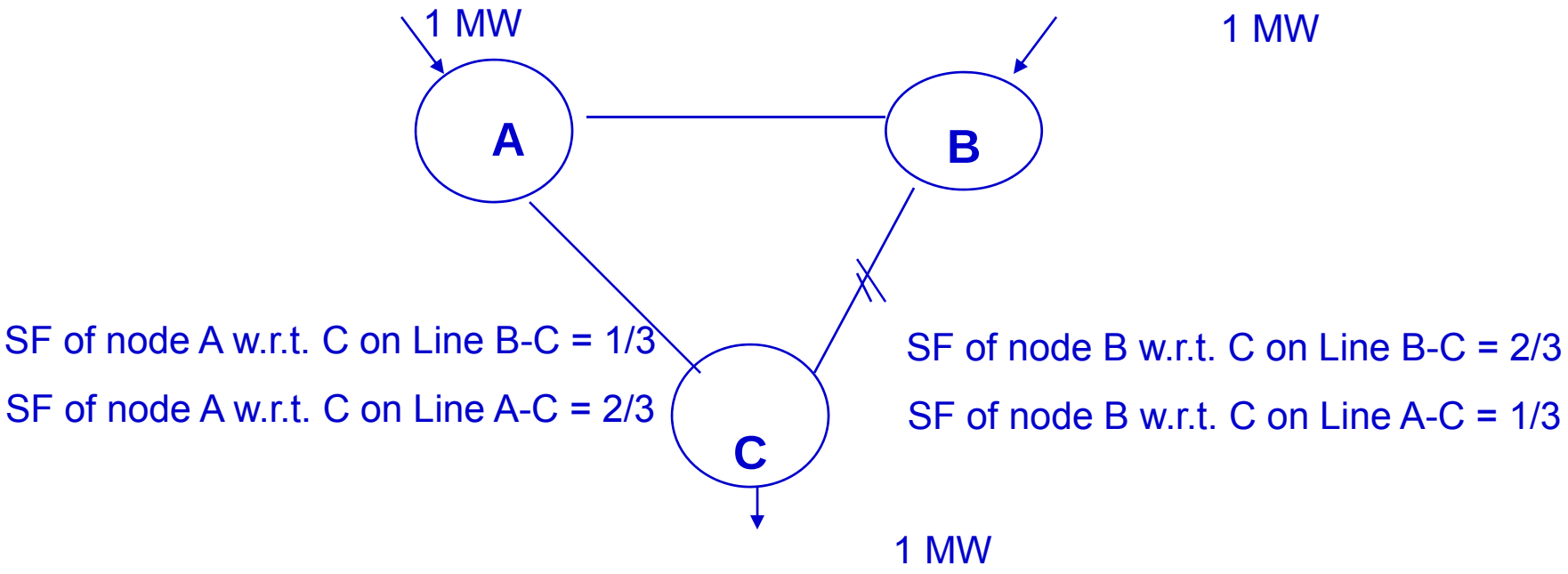
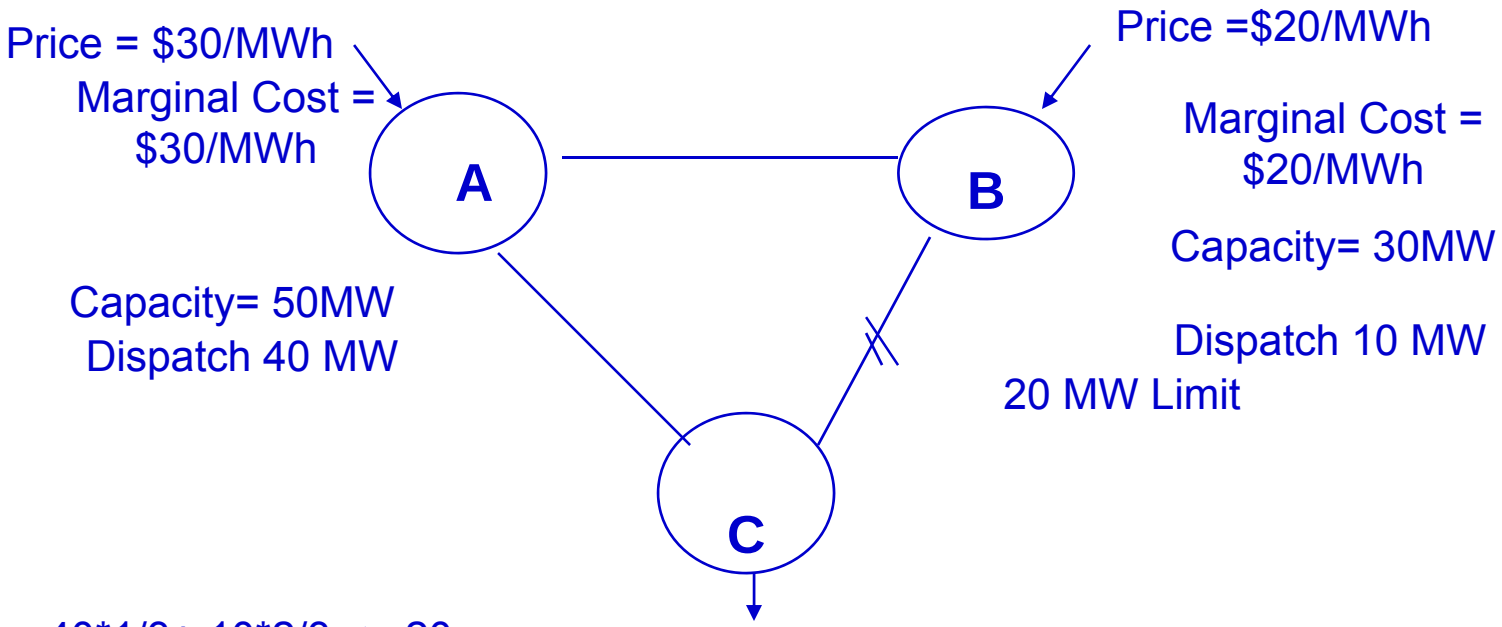
Nodal Marginal Pricing - Shift Factors



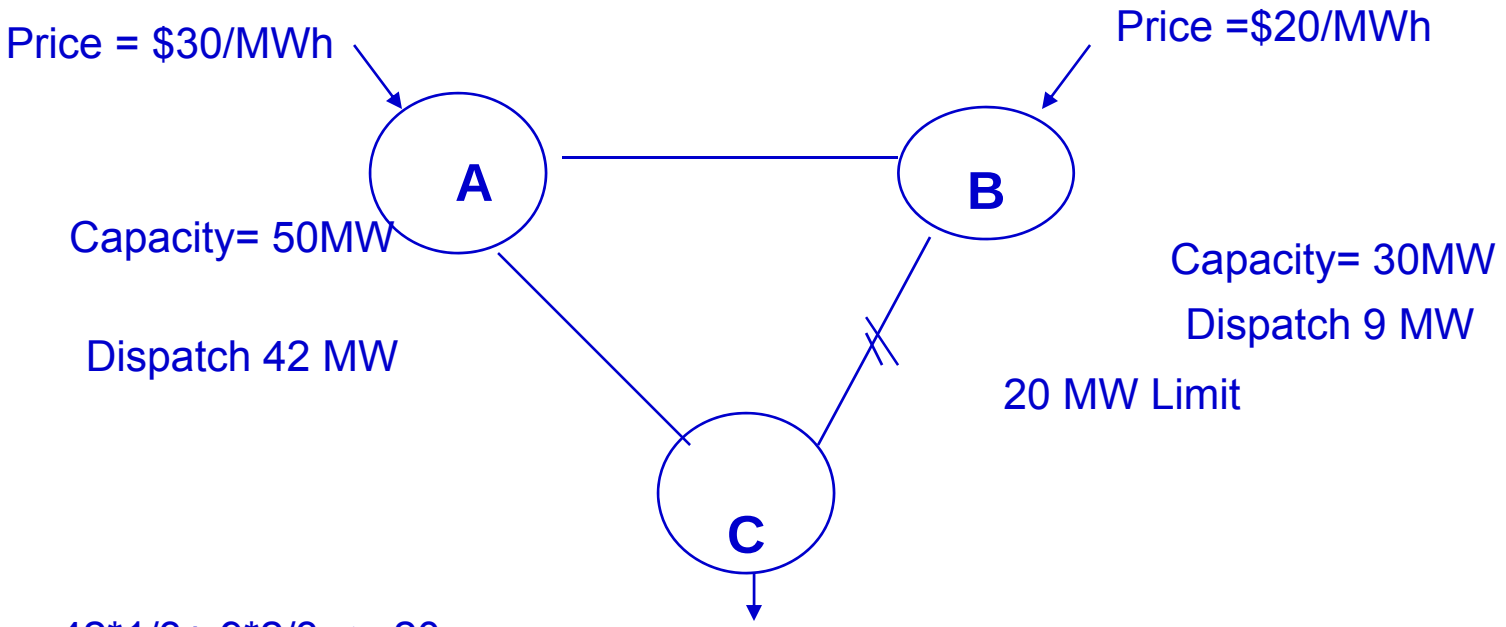
Nodal Marginal Pricing - Theory

- Example of nodal prices with constraints



Nodal Marginal Pricing - Theory

- Example of nodal prices with constraints
  - Cost of serving 1 MW of additional load



42*1/3+ 9*2/3 <= 20

42+9 =51

Load =51 MW Price =$40/MWh

=2*30- 1*20

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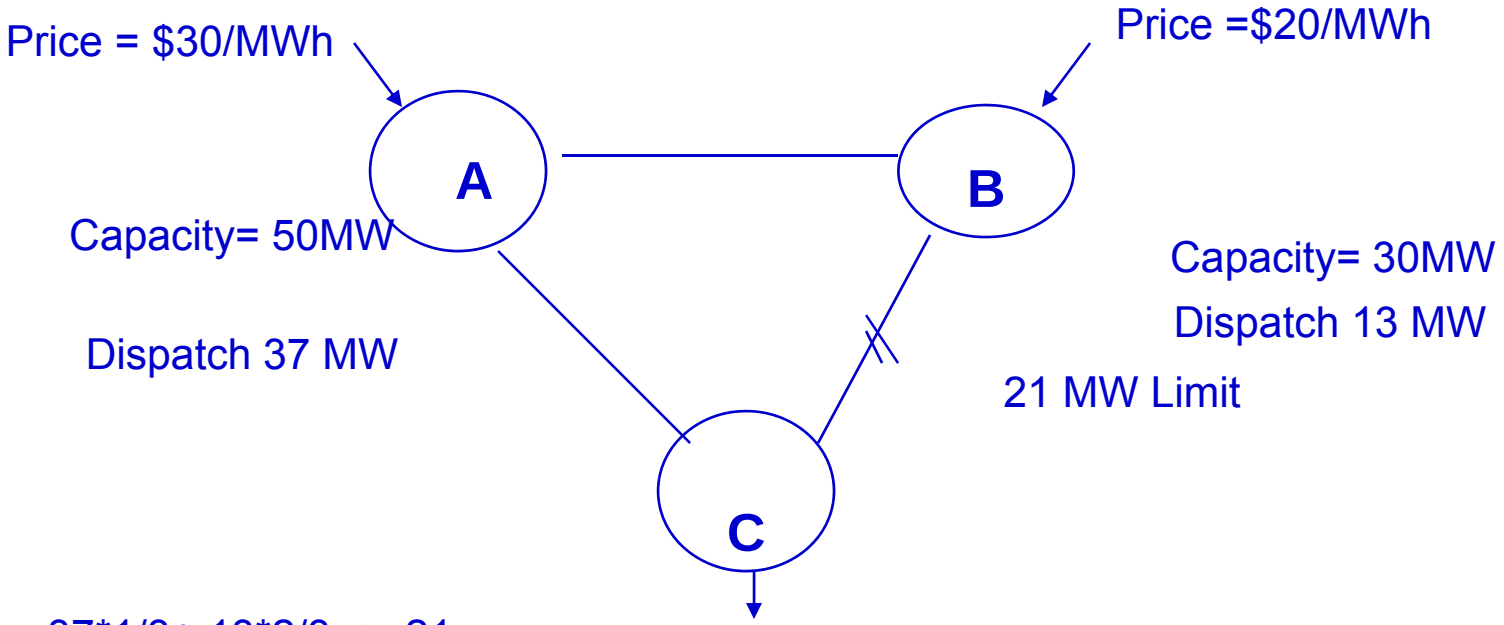
Nodal Marginal Pricing - Theory

- Shadow Prices: Total system Savings for relaxing constraint by one per unit



37*1/3+ 13*2/3 <= 21

37+13 =50

Savings = Shadow price

3*30-3*20 =$30/MWh

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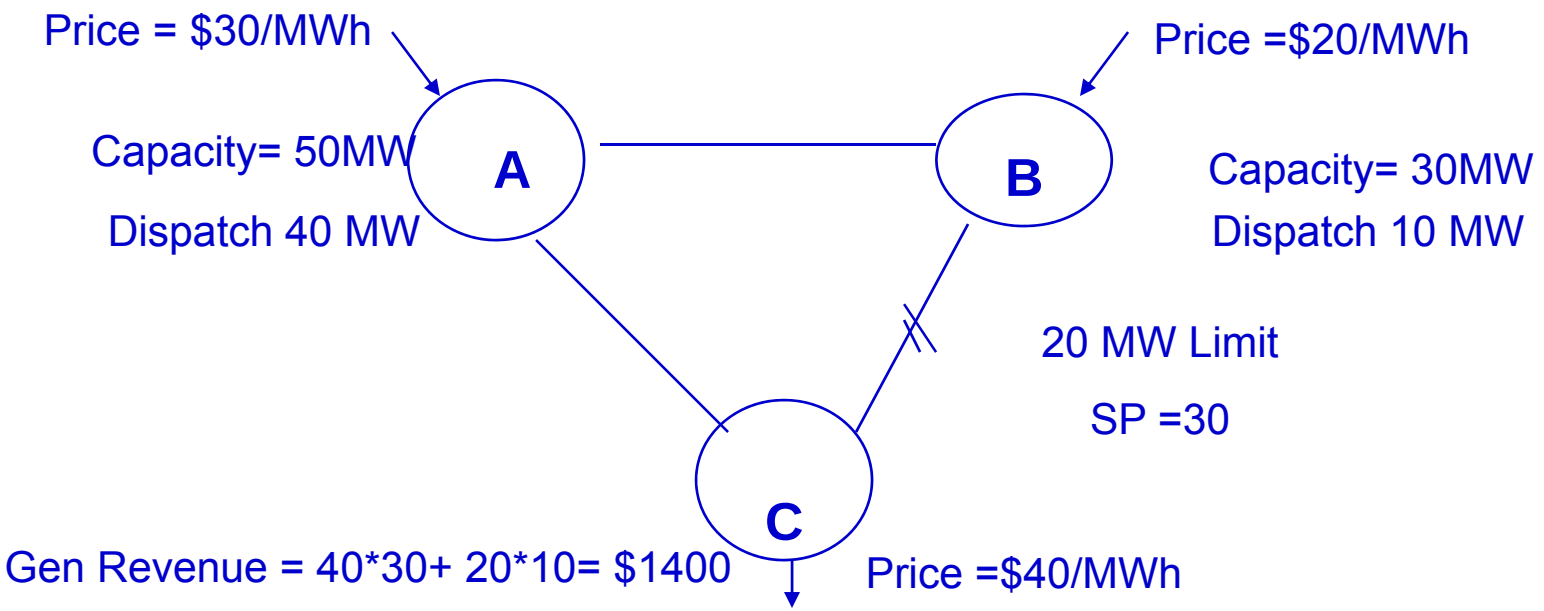
Nodal Marginal Pricing - Theory

- Congestion cost = Shadow Prices times Limit



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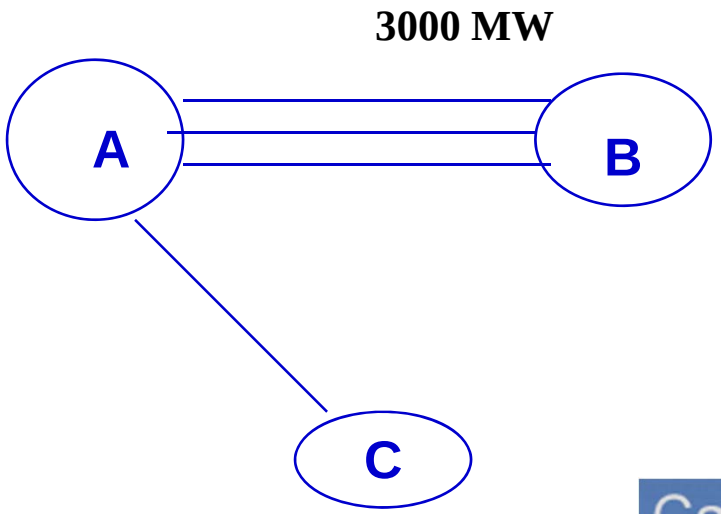
Nodal Marginal Pricing – Line Outage Distribution Factors (LODF)

- Assume there are three lines from A to B, with equal Impedance, each carrying 1000 MW
- The loss of one line (line 1) will cause the power to be distributed on the two remaining lines



LODF of line 1 on line 2= 0.5
LODF of line 1 on line 3= 0.5

Questions ?

Fundamentals of Nodal Pricing (LMPs) in Electric Power Markets

- Overview and Locational Marginal Price Formation mechanism
- Objectives of FTR/CRR/TCR markets
- Transmission Congestion and FTRs

Objectives of FTR Markets

- A mechanism for market participants to hedge against the volatility of transmission congestion
  - Generators can sell to a load delivery point
  - Demand/Load can buy from specific generator
  - Traders can provide full service deals
- Allocate the scarce transmission capacity to market participants in an efficient manner based on value
- Allocation of the ISO overcollection from the Energy Market
- Provide price signals for investment in transmission expansion or locational generation

FTR Markets

- Administrated and FTRs sold by the ISOs
- Large number of products (square of tradable nodes)
  - Low liquidity/few participants
  - Correlated FTRs
  - Infrequent auctions
  - Complex models combined with low transparency
  - Sensitive to administrator mistakes/assumptions and rules
- Weak Secondary markets
- Need to be redesigned !!

Fundamentals of Nodal Pricing (LMPs) in Electric Power Markets

- Overview and Locational Marginal Price Formation mechanism
- Purpose/Objective of FTR/CRR/TCR markets
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Transmission Property Rights

- Financial rights
  - Guarantees the holder the financial equivalent of using the transmission right, but not the physical certainty.
  - The value is independent of actual power flow, and depends on congestion on the system.
  - Point-to-Point (most ISOs) or Flowgate based
- Physical rights (Pt-to-Pt or network)
  - The right to inject a certain amount of power at point A and take it out at point B, or at a set of load nodes.
  - The holders are guaranteed the scheduling certainty for their rights, depending on the firmness of the right
  - Use it or lose it type of rights to prevent hoarding.
  - Can be converted to FTRs through some mechanism (ARRs)

Types of Financial Trans. Property Rights

- Obligation type rights
  - The value of the right is equal to the LMP at receiving point minus the LMP at the sending point, times the quantity of the right.
  - The holders are responsible for negative payments
- Option type rights
  - Same as obligation type rights except that the holders are NOT responsible for negative payments

Auctions of FTRs (Example PJM)

- Monthly FTR Auction
  - Single-round
  - Purchase "left over" capability
- Annual FTR Auction
  - Multi-round (4 rounds)
  - Entire system capability minus approved Long-Term FTRs
- Long-Term FTR Auction
  - Multi-round (3 rounds)
  - Purchase residual system capability assuming the self-scheduling of ARRs

Duration Financial Trans. Property Rights

- On Peak, Off Peak, ATC
- Monthly, Annual, Long term (3 years)

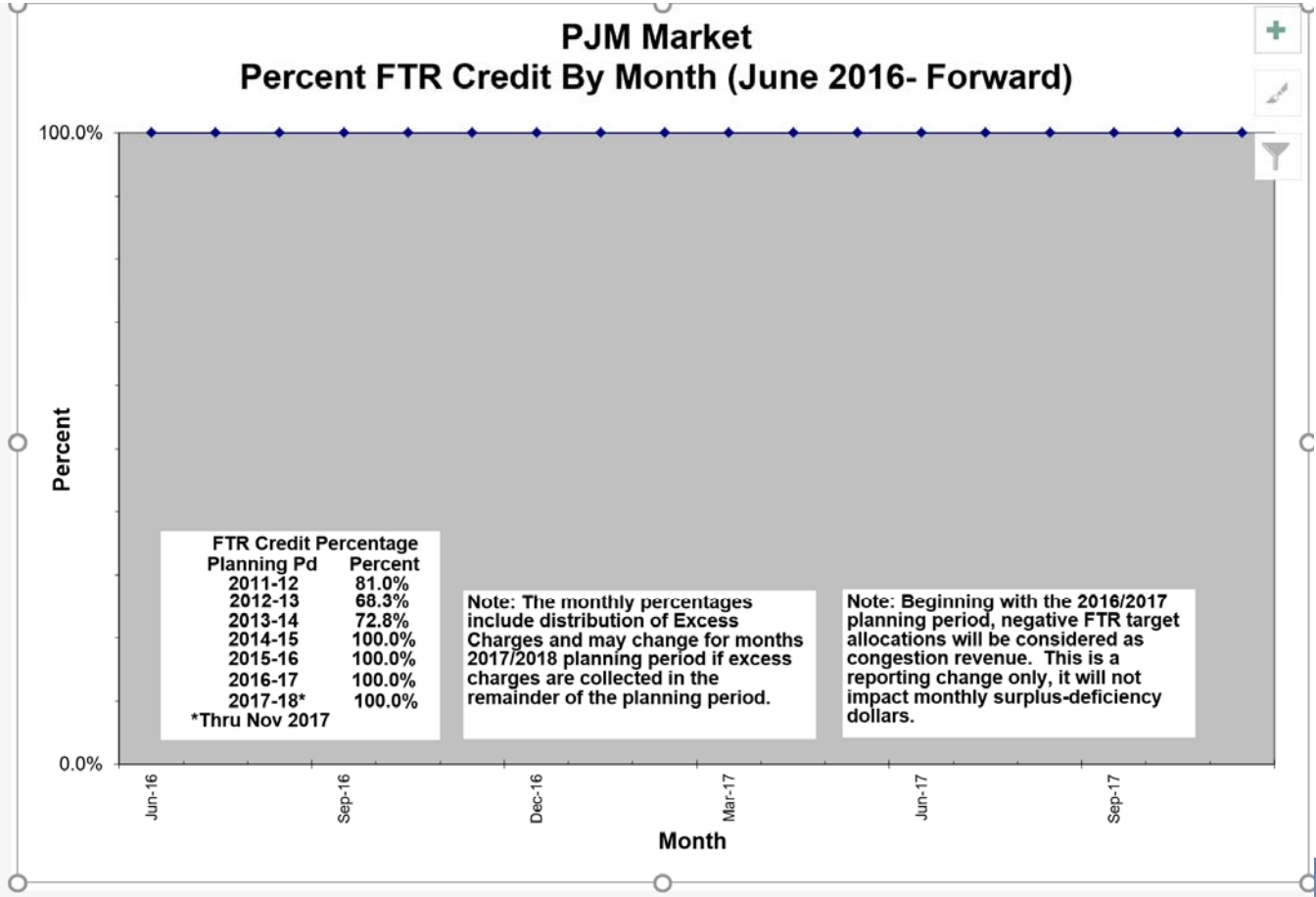
Settlement of Financial Transmission Rights

- The value of a financial transmission right is:
  - For point-to-point: the congestion component of the LMP at the receiving node minus the congestion component at the sending node
  - For Flowgate rights, the value is the shadow price on the flowgate (between ISOs)
- Note that the financial transmission rights currently used provide incomplete financial hedge against congestion only, not against the cost of marginal transmission losses on the system. Thus, the value is not equal to the difference in LMPs but the difference in the congestion component of the LMPs.
- Transmission rights clear only in the Day-ahead Markets

Revenue Shortfall

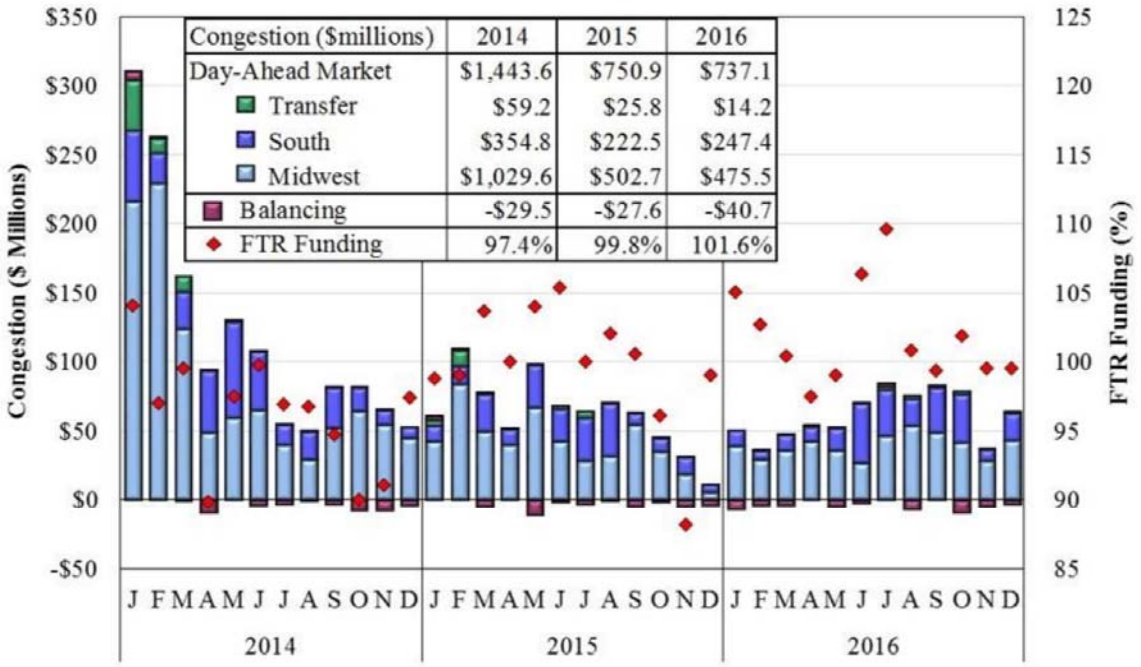
- Most financial transmission rights (in all markets except NY ISO) do not provide full hedge against transmission congestion, mainly because of Energy market revenue shortfall
- The revenue short fall results mainly because of Loopflows and the ISOs auctioning more transmission system capability that can be available on any given day (due to outages and/or derates).
- Most ISOs already addressed this issue by reducing the transmission capacity available in the auctions

Examples of Revenue Shortfall by ISO
PJM



Examples of Revenue Shortfall by ISO
MISO

Figure 25: Day-Ahead and Balancing Congestion and Payments to FTRs
2014–2016



Note: Funding Surplus or Shortfall may be more or less than the difference between day-ahead congestion and obligations to FTR Holders because it includes residual costs and revenues from the FTR auctions, such as the net settlements in the monthly FTR market.

BREAK

FTR Valuation Tools and Techniques

- Sources of information and software to forecast LMP and congestion
- Modelling approaches and the tools available for FTR valuation
- DAYZER Software

Information needed to Forecast LMP and Congestion

- In order to forecast the market clearing prices in the power markets, we need to forecast the market conditions, supply/demand and major drivers:
  - Weather Forecast (Demand, renewables, etc..)
  - Fuels Markets
  - Generation and transmission systems conditions
  - Market rules, and operating procedures

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Sources of Information

- Hourly Demand Forecast (by node)
  - ISOs and others (based on weather forecast)
  - Industrial load (independent of weather)
- Generation units' technical characteristics (capacity, ramping, heat rate shape, emission rates, min and max gen, startup cost, MUT, MDT, Spin and QS capability, etc…)
  - ISOs, EPA, EIA, etc..
- Generation Units Availability
  - Generation unit outages (NRC, IIR, CES, ISOs, etc..)
- Generation variable operating costs or estimate of generation bids/offers
  - Market clearing from NYMEX or ICE, for next day cash or futures
  - Other sources on fuel markets and conditions (Pipeline, Oil storage, coal piles, etc..)
  - Bidding behaviour

Sources of Information (Cont'd)

- Transmission Topology
  - ISOs (FTR or planning models)
- Transmission Outages and derates
  - ISO's OASIS
- Imports/exports (scheduled and unscheduled or loopflows)
  - ISOs (conditions at neighboring markets)
- Traditional Hydro
  - EIA or historical data
- Renewables generation forecast (wind and solar based on weather)
  - NOAA and other commercial sources
- Pump Storage optimization (some ISOs DAM software do not allow for optimization)
  - Commercial sources on hourly generation
- Operating reserves requirements(Spinning Reserves, Quick Start Reserves and Regulation or Automatic Generation Control)
  - ISOs

FTR Valuation Tools and Techniques

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Models of Day-Ahead Electric Power Markets

- Models help in understanding/analyzing the
  - Price formation mechanism
  - Cause/effect relationship
  - Sensitivity of prices to various market drivers/changes
  - Market behavior
  - Physical system (availability of supply and transportation)
  - Demand requirements including operating reserves
  - Market rules (market clearing mechanisms)
  - Reliability requirement and operational rules

Price/Congestion Forecasting Models

- There are many approaches:
  - Fundamentals based Models: Build a Market Model with specified assumptions
    - Can be complicated
    - Results accuracy depends on accuracy of input assumptions
    - Simplified models (like simple power flow models, could be misleading)
  - Stochastic Models: Run a large number of Monte Carlo simulations
    - Requires large number of simulations
    - Requires knowledge of the distribution of the input variables
  - Knowledge-Based Systems (AI and deep learning): Try to learn the market by observing prices and relating these to events
    - Need to learn all possible events
    - Price accuracy depends on the training
    - Simple historical data can be misleading (especially with market changes)

Difficulties with Fundamental Modeling

- Unknowns
  - Generation and Demand biding behavior including virtual bids (INCs and DECs)
  - Generation units outages, forced and derates
- Uncertainty
  - In all inputs (demand, imports/exports, wind generation, etc..)
  - Loopflows (some ISOs publish fixed schedules), (no loopflows in ERCOT)
  - Transmission Limits (thermal limits and reactive limits)
    - Derates due to ISO assumptions (losses and reactive power flows, commercial flows, etc..)
    - allocation of flowgate ratings/contractual agreements
  - Transmission outages (scheduled, cancelled, and forced…)
  - Phase Angle Regulators (PARs) settings and schedules (fixed angle or MWs)
  - Pump Storage schedules (procured in the market or not)
  - Reactive power and voltage stability constraints (published after DAM closes)
  - Operating procedures/ special protection schemes (SPSs), etc..
  - Price responsive demand?
- Dimensionality of Input data and the complexity of the SCUC
  - Computing power, Speed of runs, etc…
- Changes in operating procedures, RAPS, Contingencies, etc…
- Staffing and skills

DAM-Security Constrained Unit Commitment

- Minimize the total cost as bid over the 24-hours period subject to:
  - Total Operating Reserves (SR, AGC and NSR)
  - All security constraints (transmission, reserves) including second contingency constraints, if any
  - Total and marginal transmission losses
  - Ramping constraints, minimum up and down times
  - Hourly Hydro schedules
  - Hourly Imports and Exports schedules
  - Pump Storage optimization
  - Fixed and variable operating costs (startup, no load and variable costs)

DAM-Security Constrained Dispatch

- Minimize the total cost as bid in that interval subject to:
  - Operating Reserves (AGC, Spinning)
  - All security constraints
  - Ramping constraints
  - Hourly Hydro schedules
  - Hourly Imports and Exports schedules
  - All Variable Operating Costs

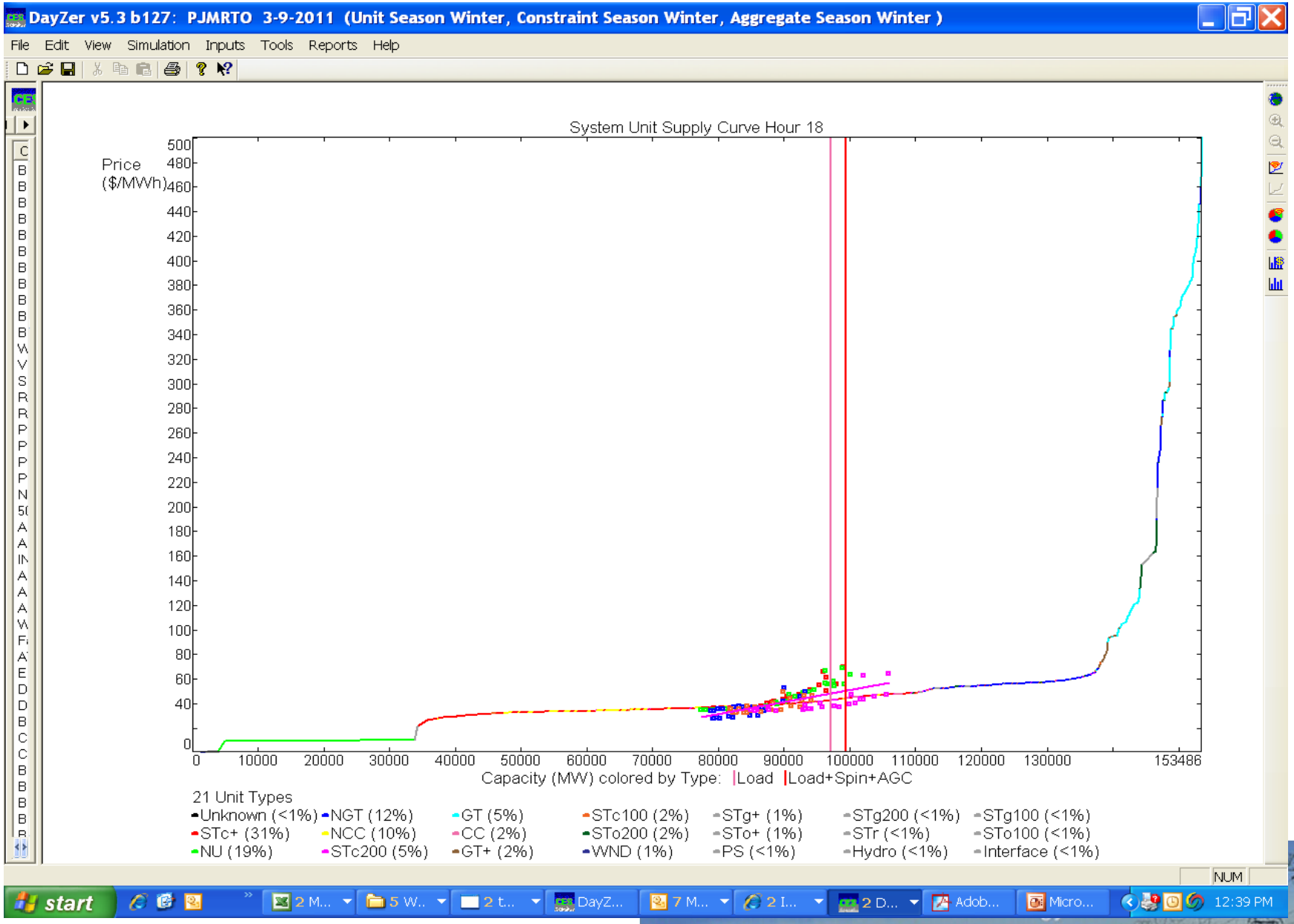
FTR Valuation Tools and Techniques

- Sources of information and software to forecast LMP and congestion
- Modelling approaches and the tools available for FTR valuation
- DAYZER Software

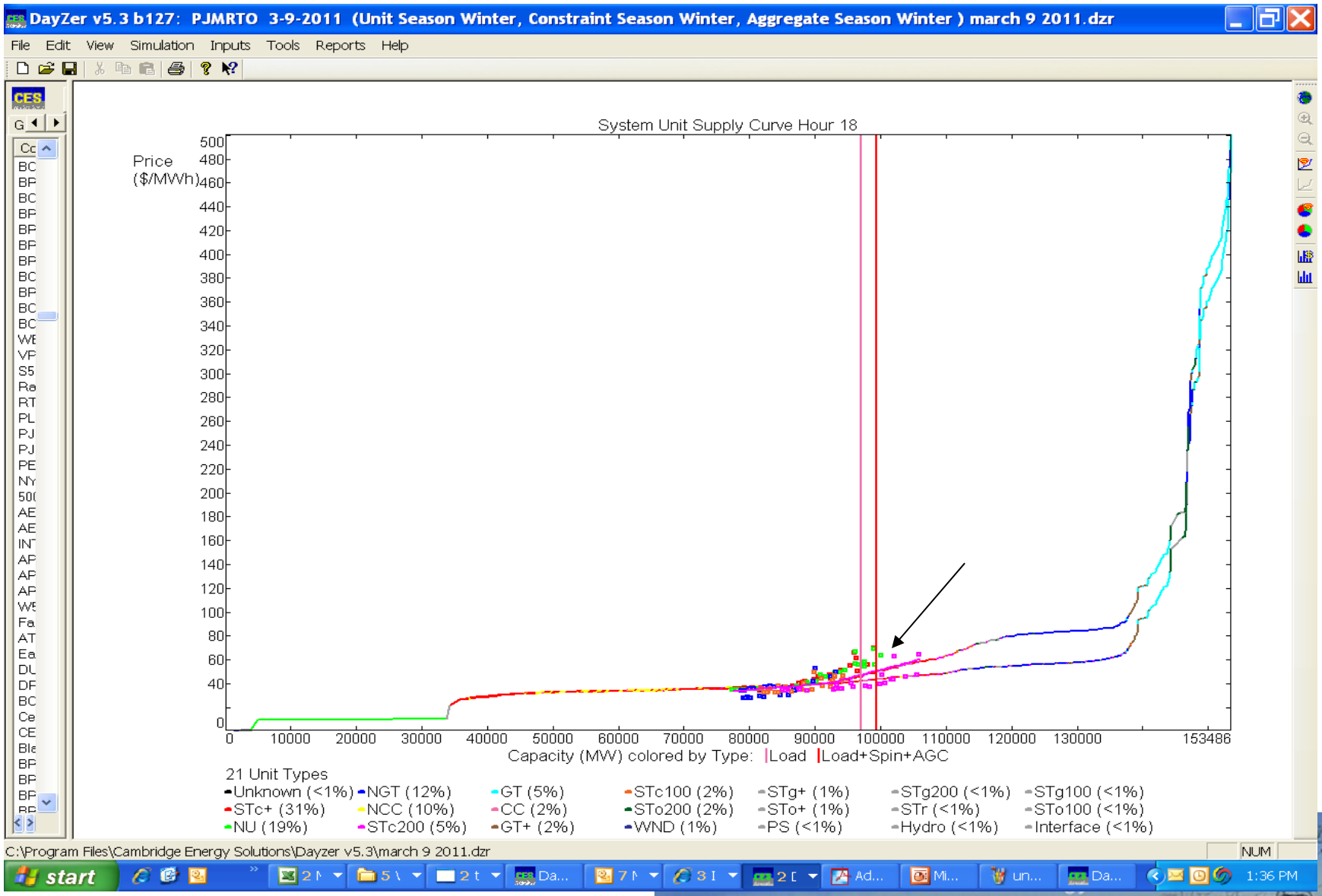
Software Tools

- The modelling difficulties requires complex models that address them, quantify impact of changes and market drivers, and allow for sensitivity analysis to uncertainties.
- Supply and Demand
  - Marginal Cost
  - Strategic Bidding
- Locational Impact of constraints (Shift Factors)
- Generation Outage (Shift Factors)
- Transmission Outages (LODFs)

DAYZER Tool: Supply & Demand



DAZYER Tool: Supply & Demand Strategic Bidding!



DAYZER Tool: Locational Impact- AP South Interface

View Definition | Save

Generation Shift Factors for Zones & Aggregates

Zone	Shift Fa...
71417 Dominion Virginia Elec P...	-0.2917
71013 DOMINION HUB	-0.2707
71411 Potomac Electric Power	-0.1685
71402 Baltimore Gas & Electric	-0.1140
71004 PJM Western Hub	-0.0215
71403 Delmarva Power & Light	-0.0133
71405 GPU: Metropolitan Edison	-0.0097
71003 PJM Eastern Hub	-0.0087
71011 WEST INT HUB	-0.0066
71407 PECO Energy	-0.0059
71401 Atlantic Electric	-0.0047
71409 Pennsylvania P&L	0.0056
71010 NEW JERSEY HUB	0.0066
71404 GPU: Jersey Central P&L	0.0067
71412 Public Service E&G	0.0094
71406 Rockland Electric	0.0213
71413 Allegheny Power	0.0467
71414 American Electric Power	0.0735
71400 DEOK_AS_HUB	0.0821
71408 GPU: Penn Electric	0.0845
71007 CHICAGO GEN HUB	0.0869

Generation Shift Factors

Unit	Shift Factor
91 FRONT ROYAL - AP	-0.3419
6037 Marsh Run Combustion Tur...	-0.3325
6647 Remington Combustion Tur...	-0.3325
6388 Ogden-Martin Fairfax	-0.3237
6564 Possum Point GT4	-0.3191
6565 Possum Point GT5	-0.3191
6566 Possum Point GT6	-0.3191
6558 Possum Point 4 R	-0.3190
6559 Possum Point 5	-0.3190
6560 Possum Point 6 CC	-0.3190
6561 Possum Point GT1	-0.3190
6562 Possum Point GT2	-0.3190
6563 Possum Point GT3	-0.3190

Generation Shift Factors for Zones & Aggregates

Zone	Shift Fa...
71404 GPU: Jersey Central P&L	0.0067
71412 Public Service E&G	0.0094
71406 Rockland Electric	0.0213
71413 Allegheny Power	0.0467
71414 American Electric Power	0.0735
71400 DEOK_AS_HUB	0.0821
71408 GPU: Penn Electric	0.0845
71007 CHICAGO GEN HUB	0.0869
71415 Commonwealth Edison	0.0876
71008 N ILLINOIS HUB	0.0876
71006 CHICAGO HUB	0.0877
71005 AEP-DAYTON HUB	0.0883
71009 OHIO HUB	0.0895
71416 Dayton Power & Light	0.0914
71012 AEP GEN HUB	0.1020
71014 ATSI GEN HUB	0.1305
71439 First Energy	0.1316
71418 Duquesne Light	0.1524

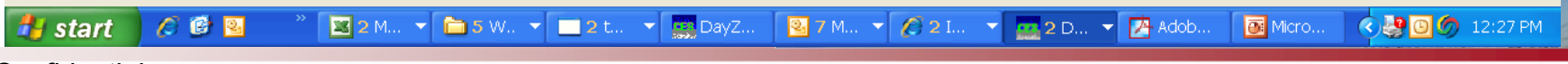
Generation Shift Factors

Unit	Shift Fa...
6464 Peru GT 1	0.2105
7385 GRANT TOWN 1	0.2319
6732 Rivesville 5	0.2367
6733 Rivesville 6	0.2367
108 HREA - AP	0.2424
150 PHILIPPI - AP	0.2532
5201 Fort Martin 1	0.2606
5202 Fort Martin 2	0.2606
1005035 GOETHALS~345KV-...	0.2643
5449 Harrison 1	0.2663
5450 Harrison 2	0.2663
5451 Harrison 3	0.2663
80032 DL_Dominion Virginia El...	0.2917
982281 RTEP B0328 SOURCE	0.3644
1001255 OST ~138KV-OST ...	0.4979
6220 Mt Storm 1	0.5208
6222 Mt Storm 3	0.5208
6223 Mt Storm GT 1	0.5208
6221 Mt Storm 2	0.5211
8581 Greenland Gap	0.5266

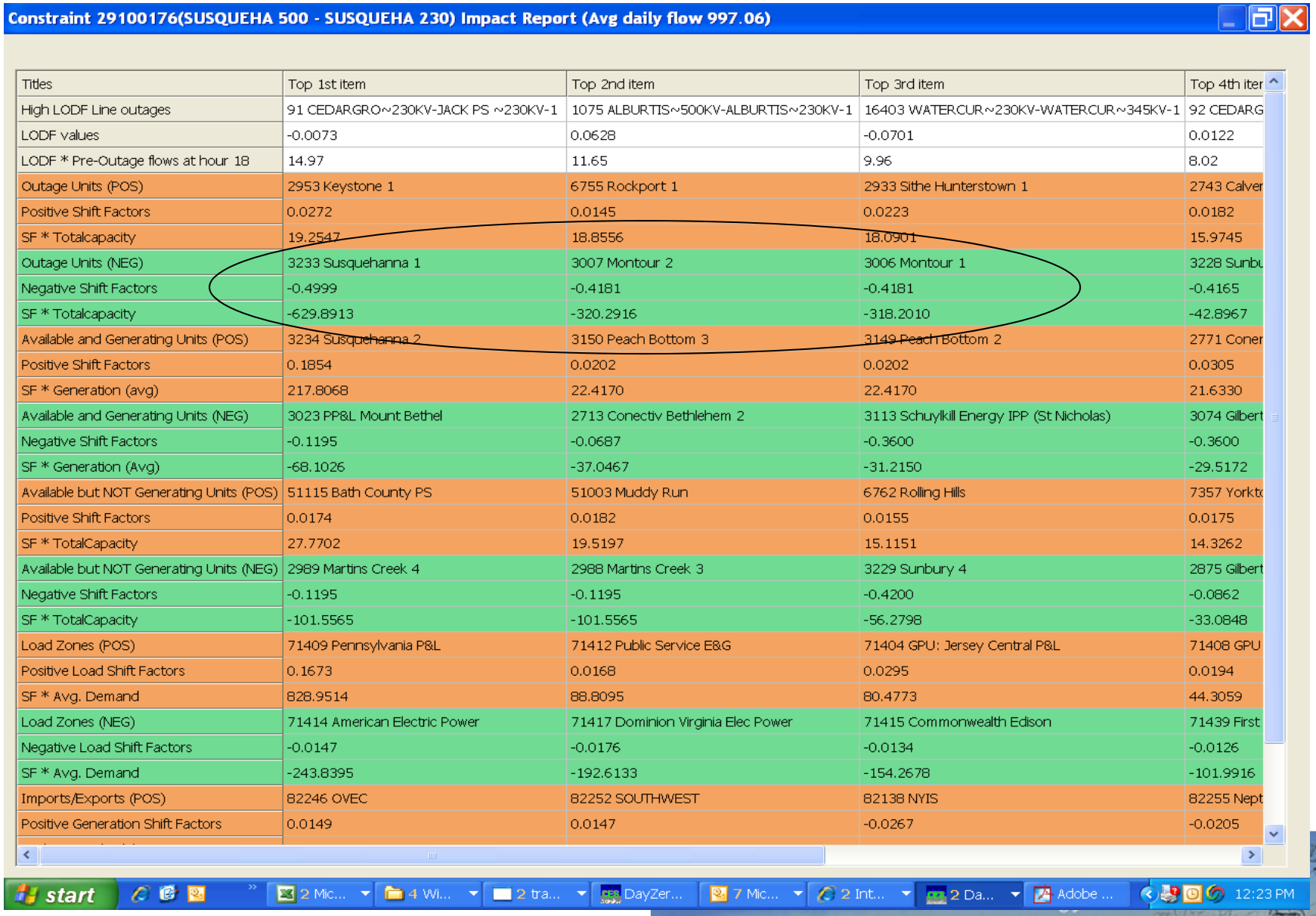
DAYZER Tool: Transmission Outages

Constraint 510356(CARNEGIE 138kV CAR-TID Tidd - Broadacr - Malvern - Wagenhal 138 kV circui) Impact Report (Avg daily flow 180.14)

Titles	Top 1st item	Top 2nd item	Top 3rd item	Top 4th item
High LODF Line outages	3990 MAHANSLA~138KV-TIDD_AEP~138KV-1	3989 MAHANSLA~138KV-WEIRTON ~138KV-1	8066 TIDD_AEP~345KV-TIDD_AEP~1KV-1	4164 WYLIE
LODF values	-0.3603	0.3603	-0.2057	0.0738
LODF * Pre-Outage flows at hour 18	44.80	38.93	-8.36	5.55
Outage Units (POS)	6755 Rockport 1	4805 Conesville 4-PJM	7280 Will County 4	6235 Muskin
Positive Shift Factors	0.0040	0.0055	0.0041	0.0087
SF * Totalcapacity	5.2492	2.5782	2.1036	1.6578
Outage Units (NEG)	7144 W H Sammis 6	4282 Beaver Valley 2	4393 Bruce Mansfield 3	3233 Susque
Negative Shift Factors	-0.0123	-0.0085	-0.0082	-0.0052
SF * Totalcapacity	-7.3626	-6.9765	-6.5843	-6.5767
Available and Generating Units (POS)	4640 Cardinal 1	6174 Mitchell 2 AEP	5293 Gen J M Gavin 1	5294 Gen J M
Positive Shift Factors	0.4401	0.0110	0.0040	0.0040
SF * Generation (avg)	245.4272	8.6502	5.1865	5.0971
Available and Generating Units (NEG)	4281 Beaver Valley 1	7145 W H Sammis 7	4391 Bruce Mansfield 1	4392 Bruce M
Negative Shift Factors	-0.0085	-0.0123	-0.0082	-0.0082
SF * Generation (Avg)	-6.9765	-6.5261	-6.4197	-6.4197
Available but NOT Generating Units (POS)	5759 Kammer 1	5760 Kammer 2	5761 Kammer 3	6762 Rolling
Positive Shift Factors	0.0428	0.0428	0.0428	0.0041
SF * TotalCapacity	8.5636	8.5636	8.5636	3.9609
Available but NOT Generating Units (NEG)	51003 Muddy Run	6177 Mitchell 3 APS	2989 Martins Creek 4	2988 Martins
Negative Shift Factors	-0.0050	-0.0156	-0.0050	-0.0050
SF * TotalCapacity	-5.3675	-4.4874	-4.2868	-4.2868
Load Zones (POS)	71413 Allegheny Power	71409 Pennsylvania P&L	71412 Public Service E&G	71407 PECO
Positive Load Shift Factors	0.0103	0.0051	0.0048	0.0050
SF * Avg. Demand	63.1845	25.4401	25.1927	24.4029
Load Zones (NEG)	71414 American Electric Power	71415 Commonwealth Edison	71439 First Energy	71416 Dayto
Negative Load Shift Factors	-0.0104	-0.0041	-0.0024	-0.0046
SF * Avg. Demand	-172.7492	-47.5763	-19.2812	-9.6033
Imports/Exports (POS)	82246 OVEC	82252 SOUTHWEST	82255 Neptune PJM-LI	82138 NYIS
Positive Generation Shift Factors	0.0043	0.0033	-0.0049	-0.0038



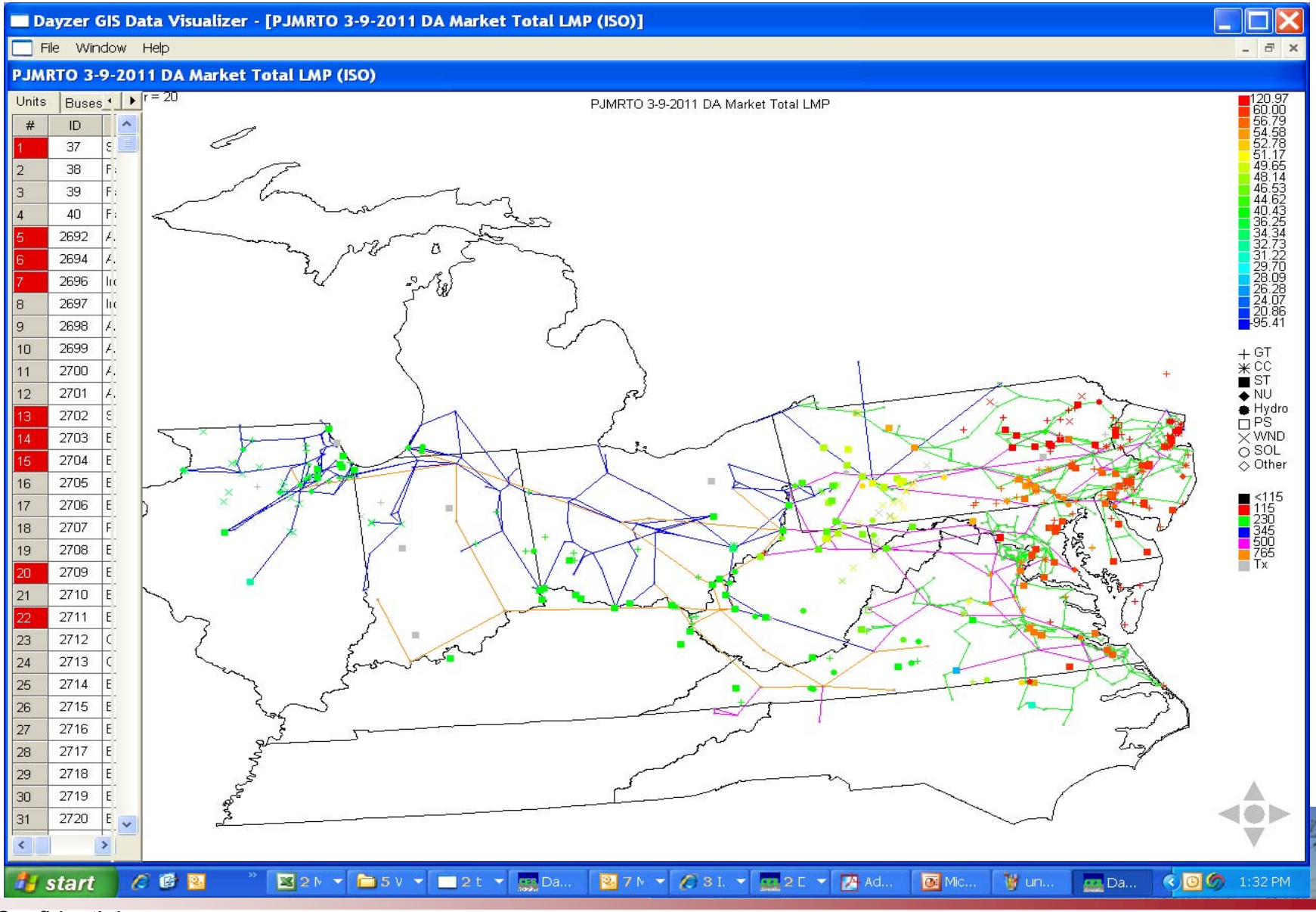
DAYZER Tool: Generation Outages



Constraint 29100176(SUSQUEHA 500 - SUSQUEHA 230) Impact Report (Avg daily flow 997.06)

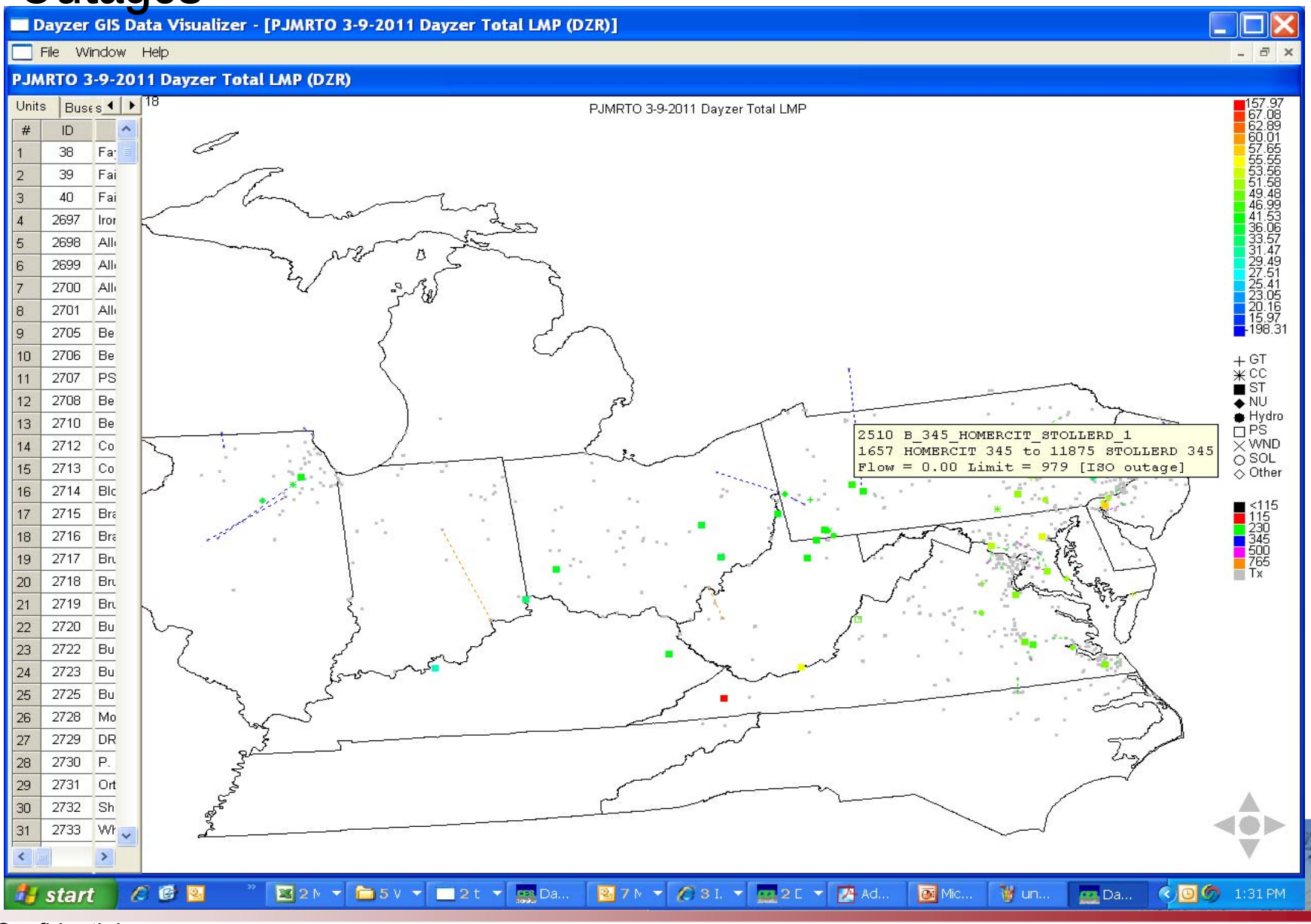
Titles	Top 1st item	Top 2nd item	Top 3rd item	Top 4th iter
High LODF Line outages	91 CEDARGRO~230KV-JACK PS ~230KV-1	1075 ALBURTIS~500KV-ALBURTIS~230KV-1	16403 WATERCUR~230KV-WATERCUR~345KV-1	92 CEDARG
LODF values	-0.0073	0.0628	-0.0701	0.0122
LODF * Pre-Outage flows at hour 18	14.97	11.65	9.96	8.02
Outage Units (POS)	2953 Keystone 1	6755 Rockport 1	2933 Sithe Hunterstown 1	2743 Calver
Positive Shift Factors	0.0272	0.0145	0.0223	0.0182
SF * Totalcapacity	19.2547	18.8556	18.0901	15.9745
Outage Units (NEG)	3233 Susquehanna 1	3007 Montour 2	3006 Montour 1	3228 Sunbu
Negative Shift Factors	-0.4999	-0.4181	-0.4181	-0.4165
SF * Totalcapacity	-629.8913	-320.2916	-318.2010	-42.8967
Available and Generating Units (POS)	3234 Susquehanna 2	3150 Peach Bottom 3	3149 Peach Bottom 2	2771 Coner
Positive Shift Factors	0.1854	0.0202	0.0202	0.0305
SF * Generation (avg)	217.8068	22.4170	22.4170	21.6330
Available and Generating Units (NEG)	3023 PP&L Mount Bethel	2713 Conectiv Bethlehem 2	3113 Schuylkill Energy IPP (St Nicholas)	3074 Gilbert
Negative Shift Factors	-0.1195	-0.0687	-0.3600	-0.3600
SF * Generation (Avg)	-68.1026	-37.0467	-31.2150	-29.5172
Available but NOT Generating Units (POS)	51115 Bath County PS	51003 Muddy Run	6762 Rolling Hills	7357 Yorkt
Positive Shift Factors	0.0174	0.0182	0.0155	0.0175
SF * TotalCapacity	27.7702	19.5197	15.1151	14.3262
Available but NOT Generating Units (NEG)	2989 Martins Creek 4	2988 Martins Creek 3	3229 Sunbury 4	2875 Gilbert
Negative Shift Factors	-0.1195	-0.1195	-0.4200	-0.0862
SF * TotalCapacity	-101.5565	-101.5565	-56.2798	-33.0848
Load Zones (POS)	71409 Pennsylvania P&L	71412 Public Service E&G	71404 GPU: Jersey Central P&L	71408 GPU
Positive Load Shift Factors	0.1673	0.0168	0.0295	0.0194
SF * Avg. Demand	828.9514	88.8095	80.4773	44.3059
Load Zones (NEG)	71414 American Electric Power	71417 Dominion Virginia Elec Power	71415 Commonwealth Edison	71439 First
Negative Load Shift Factors	-0.0147	-0.0176	-0.0134	-0.0126
SF * Avg. Demand	-243.8395	-192.6133	-154.2678	-101.9916
Imports/Exports (POS)	82246 OVEC	82252 SOUTHWEST	82138 NYIS	82255 Nept
Positive Generation Shift Factors	0.0149	0.0147	-0.0267	-0.0205

DAYZER: A Picture is worth 1000 words LMP Heat Map

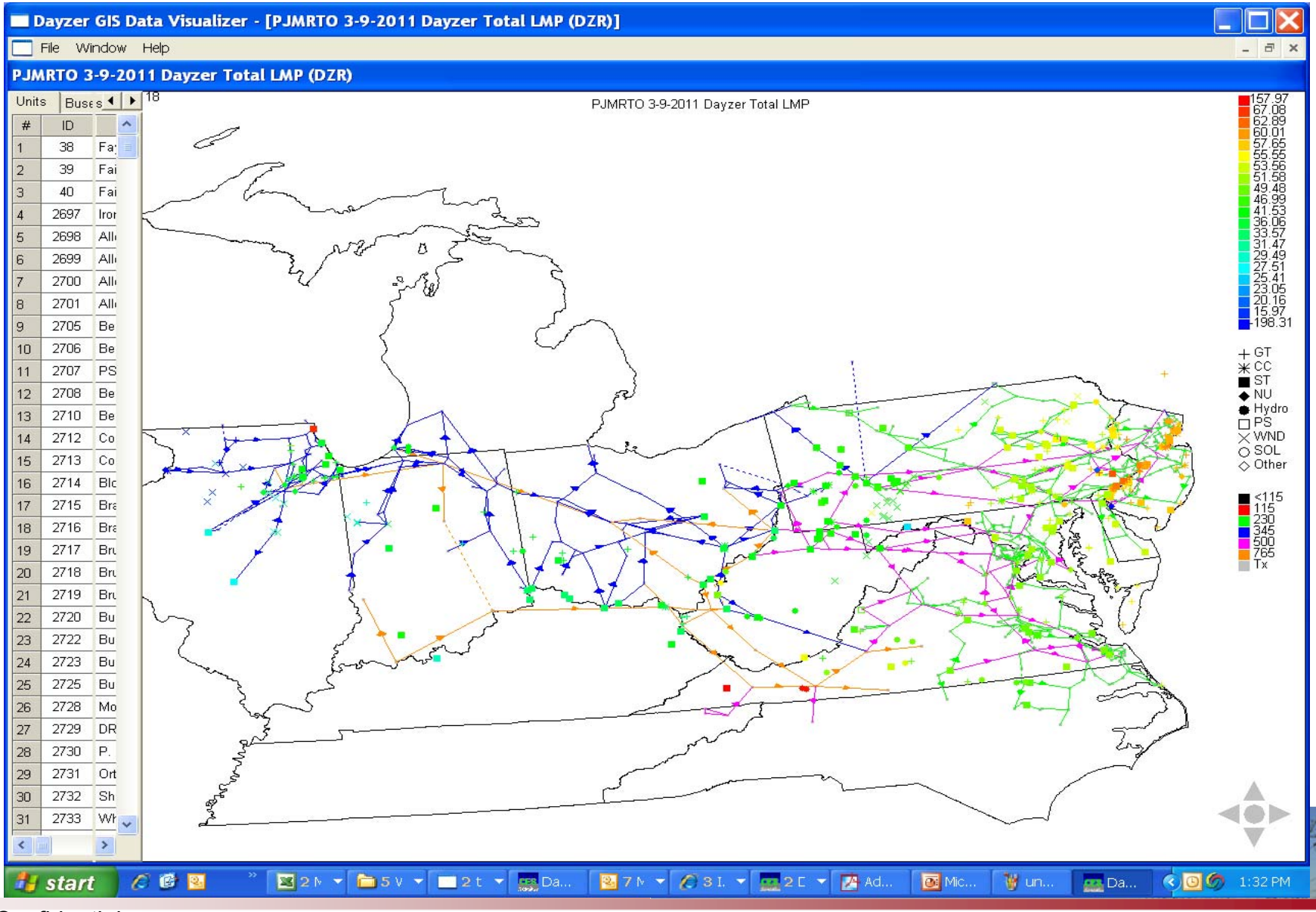


DAYZER: A Picture is worth 1000 words

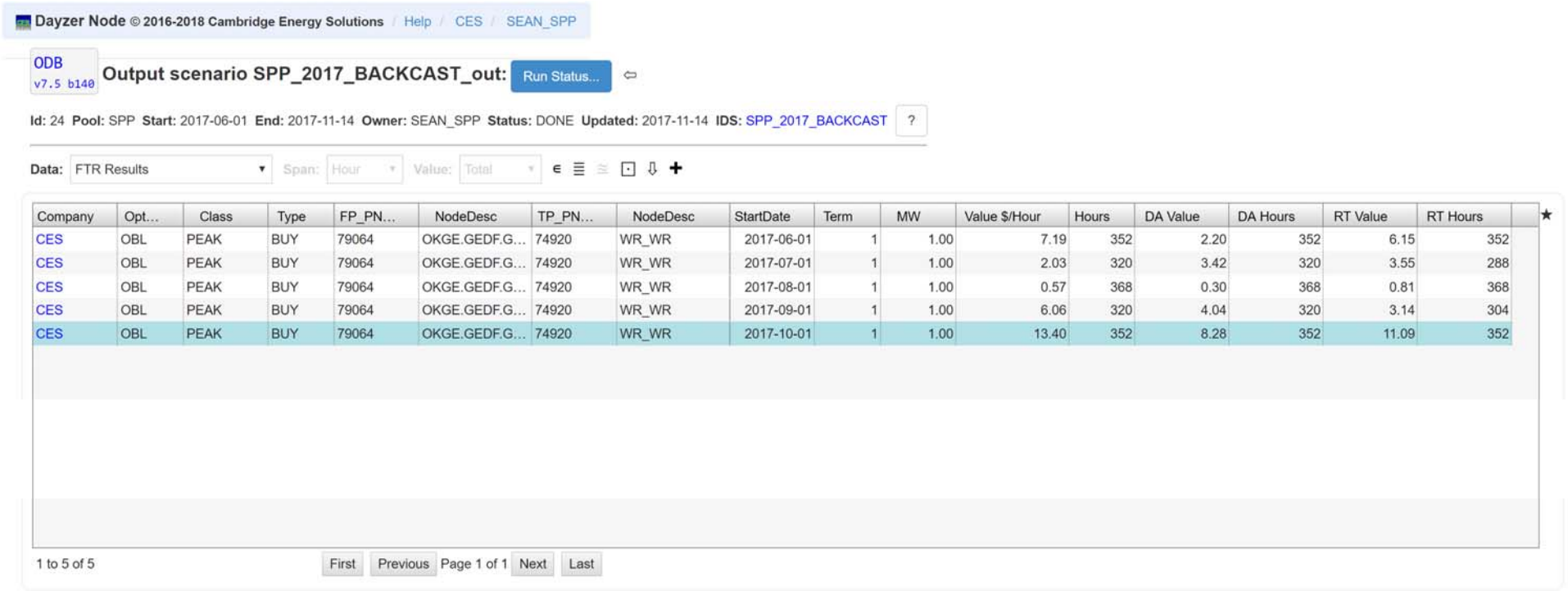
Outages



DAYZER: A Picture is worth 1000 words
Power Flows



DZNode and FTR Analysis



Company	Opt…	Class	Type	FP_PN…	NodeDesc	TP_PN…	NodeDesc	StartDate	Term	MW	Value $/Hour	Hours	DA Value	DA Hours	RT Value	RT Hours
CES	OBL	PEAK	BUY	79064	OKGE.GEDF.G…	74920	WR_WR	2017-06-01	1	1.00	7.19	352	2.20	352	6.15	352
CES	OBL	PEAK	BUY	79064	OKGE.GEDF.G…	74920	WR_WR	2017-07-01	1	1.00	2.03	320	3.42	320	3.55	288
CES	OBL	PEAK	BUY	79064	OKGE.GEDF.G…	74920	WR_WR	2017-08-01	1	1.00	0.57	368	0.30	368	0.81	368
CES	OBL	PEAK	BUY	79064	OKGE.GEDF.G…	74920	WR_WR	2017-09-01	1	1.00	6.06	320	4.04	320	3.14	304
CES	OBL	PEAK	BUY	79064	OKGE.GEDF.G…	74920	WR_WR	2017-10-01	1	1.00	13.40	352	8.28	352	11.09	352

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Decomposition of FTR Value by Binding Constraint

FTR Decomposition of CES OBL to BUY 1 MW PEAK from 79064 OKGE.GEDF.GREATWESTERN to 74920 WR_WR for 1 month starting 2017-10-01

Constrai...	Name	Type	Avg Src SF	Avg Sink SF	Cong Hrs	Avg Price	▼ Value $/H...	DA Value	DA Price	DA Hours	RT Value	RT Price	RT Hours
5001081	WICH - WICH:BENT - WI...	Contingency	0.0695	-0.0774	112	-54.01	2.38	1.84	-48.15	97	5.25	-97.85	135
5000526	ROMAN - STHRD:TATO...	Contingency	0.0452	0.0072	106	-212.94	2.12	3.47	-168.04	219	3.58	-376.72	100
5000247	IODINE4 - DEWEY1:TAT...	Contingency	0.0590	0.0081	86	-136.54	1.51	0.12	-27.00	37	0.00	0.00	0
5000068	WDWFPLTATNOW	Contingency	0.0893	0.0065	265	-22.32	1.25	0.16	-16.18	45	0.67	-191.10	16
2005466	VINHAYPOSKNO	Contingency	0.0074	-0.0163	229	-79.15	1.20	0.72	-49.47	222	1.13	-175.76	97
5000859	ELRNO1 - ROMAN:TATO...	Contingency	0.0416	0.0037	80	-150.89	1.15	0.00	0.00	0	0.00	0.00	0
3020687	BENT- CHIS 138 kV :GO...	Contingency	0.0117	-0.0710	127	-37.75	1.12	0.32	-19.03	73	0.00	0.00	0
3020932	WR_SMKHL - SUMM 23...	Contingency	0.0200	-0.0142	94	-96.36	0.82	0.12	-34.68	37	0.28	-69.04	44
3020619	GORD 345/138 kV XFR:...	Contingency	0.0353	-0.0723	52	-47.40	0.73	0.49	-30.15	88	0.36	-242.88	5
5000234	BA_NORTH - E_21_TP:T...	Contingency	0.0108	-0.0056	93	-100.76	0.34	0.02	-104.56	4	0.00	0.00	0
5001093	CMRIVTP - CIM-PL1:BU...	Contingency	0.0135	0.0030	83	-113.71	0.24	0.00	0.00	0	0.00	0.00	0
3002541	Spearville - Great Bend 2...	Contingency	0.0449	-0.0156	16	-82.75	0.21	0.00	0.00	0	0.00	0.00	0
2005528	SMOSUMMULCIR	Contingency	0.0093	-0.0266	22	-62.42	0.13	0.00	0.00	0	0.06	-38.19	16
3020407	HALE_CO-TUCO (TUCO...	Contingency	0.0032	-0.0010	49	-193.31	0.10	0.22	-148.38	158	0.33	-256.27	127
3021070	BA_NORTH - E_21_TP 1...	Contingency	0.0079	-0.0020	36	-103.38	0.10	0.03	-46.55	14	0.01	-59.30	6
3020629	MOORLN1 - GLMTN (Lin...	Contingency	0.0369	-0.0012	6	-126.18	0.07	0.00	0.00	0	0.00	0.00	0
2005615	WHEKILWDRHUN	Contingency	0.0132	-0.0131	17	-47.58	0.06	-0.03	78.15	6	0.02	-125.24	2
3020315	GRACEMONT-ANADAR...	Contingency	0.0094	0.0030	43	-76.02	0.06	0.02	-33.16	37	0.05	-46.39	61
5000722	DRAPR1 - CIMARRON:A...	Contingency	0.0800	0.0250	7	-60.04	0.06	0.01	-13.67	5	0.00	0.00	0

Drivers of Congestion on Specific Constraints

Contingency: 5001081 WICH - WICH BENT - WICH 345 WR **Start Date:** 2017-10-01 **End Date:** 2017-11-01 **Avg Flow:** 307.77 **Avg Price:** -19.69 **Min Flow Limit:** -387.00 **Max Flow Limit:** 387.00
Max Price Date: 2017-10-30 **Hour:** 8 **Price:** -173.25 **Flow:** 387.01

Categories	Top 1st item	Top 2nd item	Top 3rd item	Top 4th item	Top 5th item	Top 6th item	Top 7th item	Top 8th item	Top 9th item	Top 10th item	Top 11th item
Line Outages (Inc Cong)	44501 XF Wichita...	27733 LN Clearwa...	27634 LN Reno Co...	25028 LN Delawar...	25716 LN Cimarro...	25276 LN Elk Cit...	27725 LN Boeing ...	8586 LN Cooper F...	115472 LN Matthe...	108934 LN Canadi...	26346 LN Dover O...
LODF values	0.6025	0.2642	0.0480	-0.0204	0.0050	-0.0196	0.0746	-0.0034	-0.0086	0.0081	-0.0185
LODF * Pre-Outage Flows	63.1300	22.3811	9.1215	4.3639	1.7340	0.9562	0.7568	0.6401	0.5908	0.5416	0.5410
Line Outages (Dec Cong)	95881 LN Morgan ...	26676 LN Finney ...	15837 LN Overton...	14520 LN ARK_NU ...	33872 LN Oahe Oa...	109098 LN Flint ...	9883 LN Nevada B...	33499 LN S3455 S...	26368 LN Fairvie...	33455 LN Fort Ra...	44474 XF Strange...
LODF values	0.0161	-0.0107	-0.0052	0.0044	0.0035	-0.0010	0.0113	0.0005	0.0079	0.0019	-0.0010
LODF * Pre-Outage Flows	-3.4836	-2.7386	-0.4783	-0.4468	-0.2819	-0.1875	-0.1462	-0.1015	-0.0914	-0.0862	-0.0837
Outage Units (Inc Cong)	6251 Mustang Sta...	5901 Laramie Riv...	7686 Whelan Ener...	6092 McPherson 3...	53126 OAHE...	5545 Iatan 1...	7635 Platte...	53120 BIG-BEND...	6858 Sheldon 1...	5936 Lawrence EC...	53124 GARRISON...
Shift Factors	0.0545	0.0416	0.0324	0.0707	0.0206	0.0063	0.0315	0.0202	0.0218	0.0160	0.0169
SF * OutageMW	23.9800	23.7120	7.1280	5.7267	4.3401	4.0320	3.1500	2.5114	2.2890	1.7440	1.6690
Outage Units (Dec Cong)	5335 Gordon Evan...	5839 Lacygne 1...	5840 Lacygne 2...	6958 Stateline 2...	5359 GRDA 2...	6358 Northeaster...	6242 Muskogee 5...	7677 Southwest P...	6507 Dogwood CC...	6956 Stateline 1...	7031 Tenaska Mt ...
Shift Factors	-0.5012	-0.0372	-0.0372	-0.0380	-0.0245	-0.0176	-0.0117	-0.0185	-0.0069	-0.0380	-0.0034
SF * OutageMW	-188.4512	-27.7140	-25.0728	-18.0500	-12.7400	-8.0960	-6.2010	-5.0875	-4.0020	-3.8380	-2.8730
Generating Units (Inc Cong)	17067 Flat Ridge...	17160 Cimarron B...	17125 Western Pl...	20515 Hobbs-Lea...	56368 Kingman Wi...	17141 Ninnescah ...	15352 Palo Duro ...	17108 Balko Wind...	17136 Bloom Wind...	17099 Buffalo Du...	17063 Post Rock ...
Shift Factors	0.1192	0.1029	0.0944	0.0546	0.1228	0.1228	0.0706	0.0706	0.1029	0.0693	0.0817
SF * Generation	51.0188	34.1453	24.7507	24.2763	23.2657	23.0311	16.4922	16.2648	16.0524	15.7727	14.4871
Generating Units (Dec Cong)	7315 Wolfcreek...	5336 Gordon Evan...	5334 Gordon Evan...	17112 Kay County...	17121 Slate Cree...	7745 Grand River...	6360 Northeaster...	17088 Waverly Wi...	4756 Green Count...	17078 Caney Rive...	5197 Flint Creek...
Shift Factors	-0.1106	-0.5010	-0.5012	-0.0869	-0.1282	-0.0243	-0.0268	-0.1037	-0.0138	-0.1292	-0.0201
SF * Generation	-130.5080	-113.8273	-67.9037	-13.1254	-11.3072	-9.6492	-9.5312	-9.3734	-8.9793	-8.4251	-7.4458
Idle Units (Inc Cong)	7502 Emporia Ene...	6250 Mustang Sta...	5661 Jeffrey EC ...	5448 Harrington ...	17129 Cedar Bluf...	6308 Nichols 3...	5754 Judson Larg...	6091 McPherson 2...	4176 Elk Station...	7495 Elk Station...	6279 Nebraska Ci...
Shift Factors	0.0571	0.0545	0.0333	0.0610	0.0758	0.0610	0.0942	0.0704	0.0506	0.0506	0.0153
SF * TotalCapacity	38.0286	26.6505	24.3090	21.1670	15.1600	14.8840	13.8474	12.6720	10.2212	10.2212	9.6696
Idle Units (Dec Cong)	6230 Murray Gill...	6231 Murray Gill...	64034 El Dorado ...	6357 Northeaster...	6888 Sooner 1...	8620 Charles D L...	6714 Riverside 2...	6713 Riverside 1...	7506 Harry D Mat...	7612 Wellington ...	7218 Wellington ...
Shift Factors	-0.3582	-0.3594	-0.2119	-0.0268	-0.0208	-0.0690	-0.0144	-0.0144	-0.0191	-0.2347	-0.2347
SF * TotalCapacity	-38.6856	-34.1430	-13.1378	-12.5960	-10.8576	-7.1070	-6.6240	-6.5808	-6.4176	-4.9287	-4.5767
Inactive Units (Inc Cong)											
Shift Factors											
SF * TotalCapacity											
Inactive Units (Dec Cong)											
Shift Factors											
SF * TotalCapacity											
Load Zones (Inc Cong)	71521 KANSAS GAS...	71550 American E...	71444 EMPIRE DIS...	71451 GRAND RIVE...	71461 KANSAS CIT...	71506 SPRINGFIEL...	71509 SOUTHWES P...	71490 OKLAHOMA G...	71462 KANSAS CIT...	71456 INDEPENDEN...	
Load Shift Factors	0.0924	0.0085	0.0309	0.0232	0.0032	0.0192	0.0105	0.0002	0.0011	0.0015	
SF * Demand	298.8493	40.9675	19.6586	13.5952	8.9693	6.9062	0.9303	0.6244	0.3111	0.1562	
Load Zones (Dec Cong)	71510 SOUTHWESTE...	71484 Nebraska P...	71551 Western -B...	71508 SUNFLOWER ...	71492 Omaha Pub ...	71519 WESTERN FA...	71468 Lincoln El...				
Load Shift Factors	-0.0563	-0.0308	-0.0179	-0.0820	-0.0172	-0.0133	-0.0210				
SF * Demand	-171.6474	-57.7284	-57.5002	-55.3746	-21.2816	-13.5514	-8.2005				
Imports/Exports (Inc Cong)	83604 SPP_MEC	83615 SPP_MDU	83609 SPP_SGE	83053 SPP_EES	83612 SPP_ALTW	83613 SPP_NSP	83606 SPP_AECI	83610 SPP_MCWEST	83599 SPP_CLEC	83603 SPP_AMRN	
Shift Factors	0.0117	0.0183	0.0405	-0.0051	0.0093	0.0135	-0.0051	0.0200	-0.0050	-0.0038	
SF * Schedule	7.4178	3.8430	2.6730	2.6163	1.9530	1.8765	0.6477	0.6200	0.5350	0.0646	
Imports/Exports (Dec Cong)	83580 SPP_OTP	83614 SPP_GRE	83593 SPP_ERCOTE	83597 SPP_TVA	83616 SPP_DPC						

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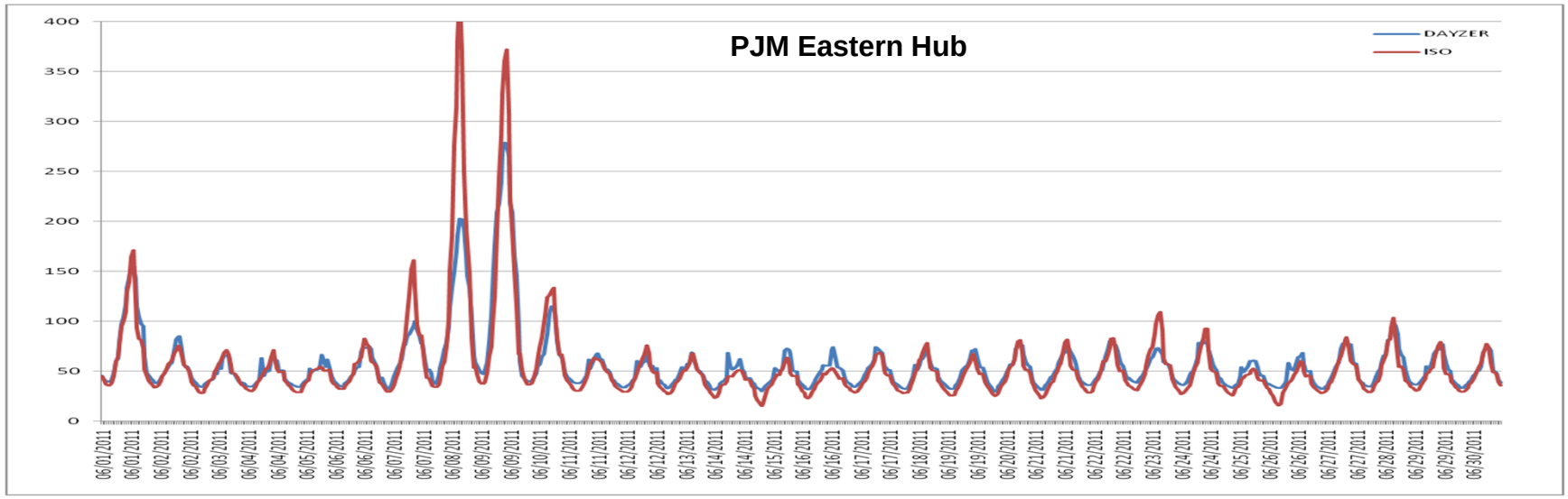
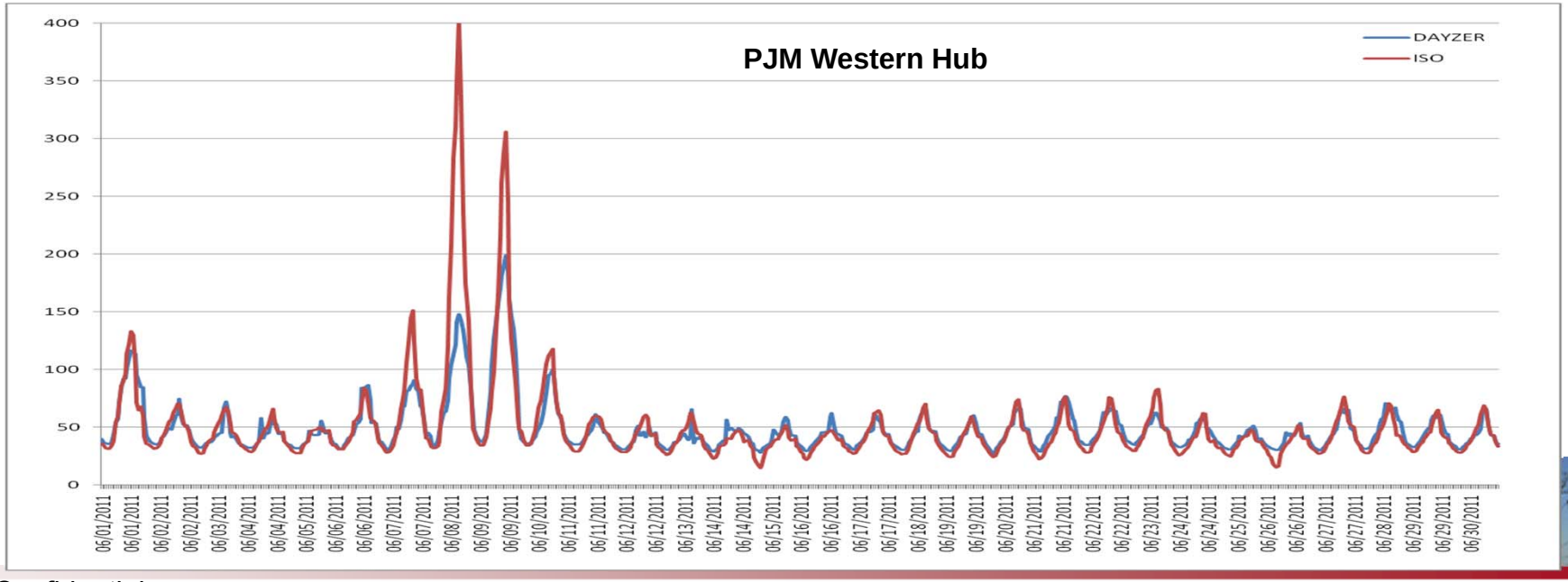
Model Benchmarking and Continuous Calibration

- Ultimate model benchmarking is against the market data
- A good model needs continuous updates to capture the dynamics and changes in the generation and transmission systems:
  - New generation units and retirements, outages and derates
  - New transmission elements and retirements, outages and derates
  - Changes in the fuel prices and trading hubs
  - Changes in the demand distribution (new data centers and industrial load)
  - Changes in market rules and operating procedures

PJM: Eastern and Western Hub





Running Sensitivities

- The future is uncertain, one way to address uncertainty is by running sensitivities:
  - Load (total and distribution)
  - Wind generation
  - Fuel prices
  - Unit outages (difficult)
  - Transmission outages (difficult, changes after FTR auctions)
  - Bidding Behavior

Building FTR Portfolio, Finding, Evaluation and Bidding

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FTR Auction Clearing Vs Day-ahead

- The FTR auction model is similar to the Day-ahead market clearing model with some differences:
  - Single Snapshot for each auction versus daily one
  - In the FTR auction only those known and scheduled line outages (>50% of time or other criteria) are included
  - Missing forced outages and updates to scheduled outages
  - Fixed LoopFlows vs daily updated values
  - Missing derates due to outages and changes in topology
  - Modelling for PARs, DC lines
  - Modelling errors and differences in topology
  - Missing new projects
  - In the FTR the objective function is to maximize the value of the FTRs while in the DAM the objective is to minimize the total cost as bid by generation units

FTR Auction Clearing Vs Day-ahead Values

- In the FTR auction, the users bid **their** expected value of congestion in the DAM for the duration of the auction. If the FTR auction clears above their expected value they are better off buying congestion in the DAM on daily basis.
- BUT, there is also a risk premium and the native load factor
- Looking at the northeast markets they tend to be efficient except for major structural changes either in the physical transmission system or in the market software

FTR Portfolio- Finding

- Identify constraints that are susceptible to large number of transmission or generation outages, high demand, imports/exports or derates
- Use shift factors to identify nodes with highest impact on constraints--select an FTR from highest SF to lowest negative SF
- Use line outage distribution factors LODF to identify transmission outages with highest impact on constraints (critical transmission outages)
- Use shift factors to identify MW impact of unit outages on constraints (critical unit outages)
- Identify changes in the market and quantify the impact on congesiton

FTR Portfolio- Evaluating and Bidding

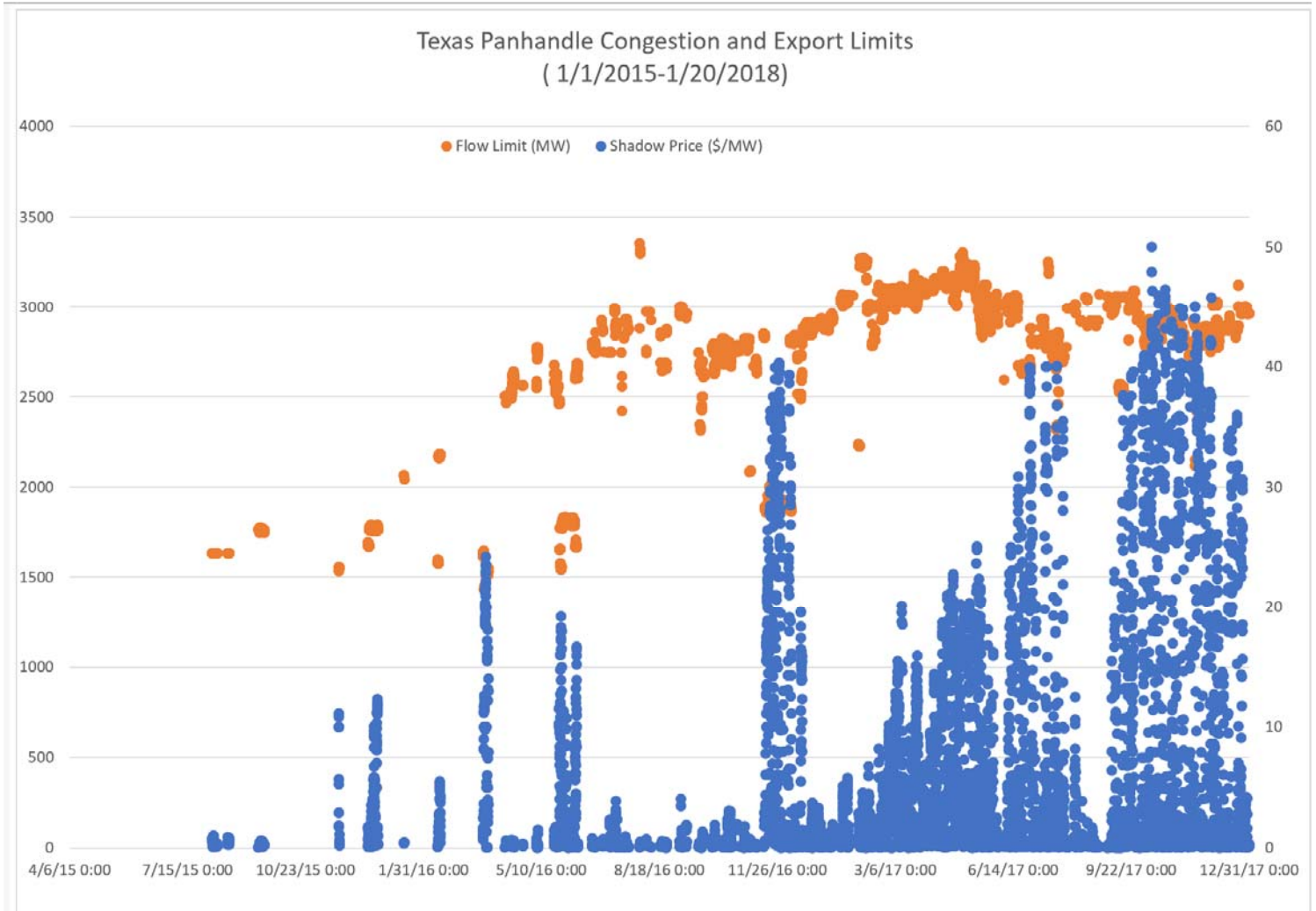
- Use expected supply and demand, market conditions and bidding behavior to value FTRs in DAM, and how much to bid in auction (bid at the low end of your expectation, in incremental blocks)

- Use LODFs and SFs to increase confidence in selected paths and quantify sensitivity to expected unit and transmission outages and changes in expectations….

Examples of Impact of Expected Market Changes on Congestion and FTR Values

- New Generation, new wind units in Texas Panhandle
- New Transmission, Woodward PAR (SPP, OGE)
- Shale Gas followed by transmission upgrades in PJM
- Long term transmission outages (ERCOT)
- Generation Retirements (HT Pritchard in MISO)

ERCOT Congestion with Increased Wind Generation



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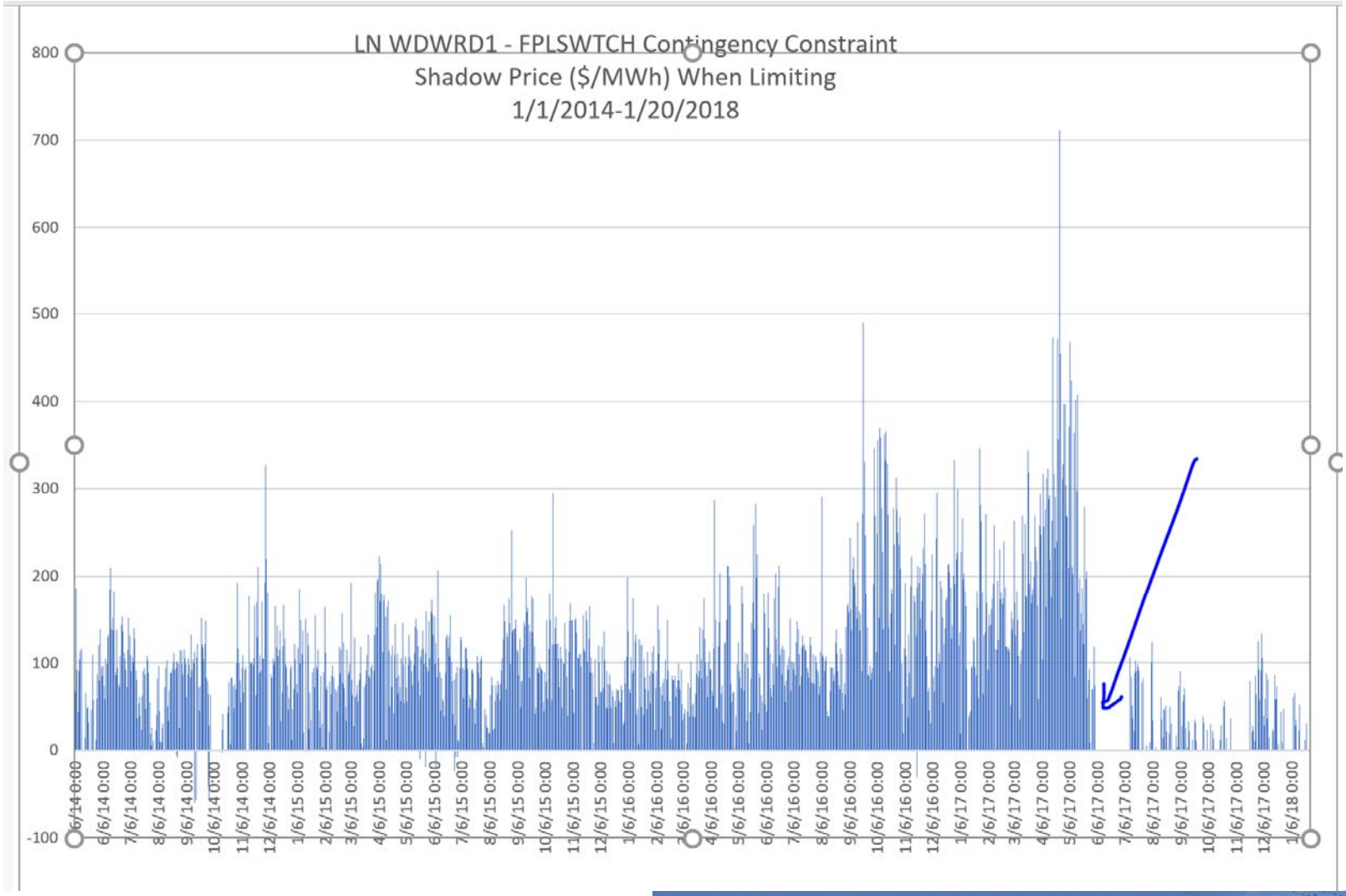
CRR From Panhandle to West

- Value of 1 MW CRR across and due to congestion on the Panhandle interface in 2017 was: $37,702
- A wind farm Inside the Panhandle would be willing to pay that amount for CRR to sell power and deliver outside the Panhandle.
- Similarly, for a load serving entity buying power from a generator inside the Panhandle
- Similarly, for CRR trader, up to that amount.

Transmission Upgrade- Woodward PAR



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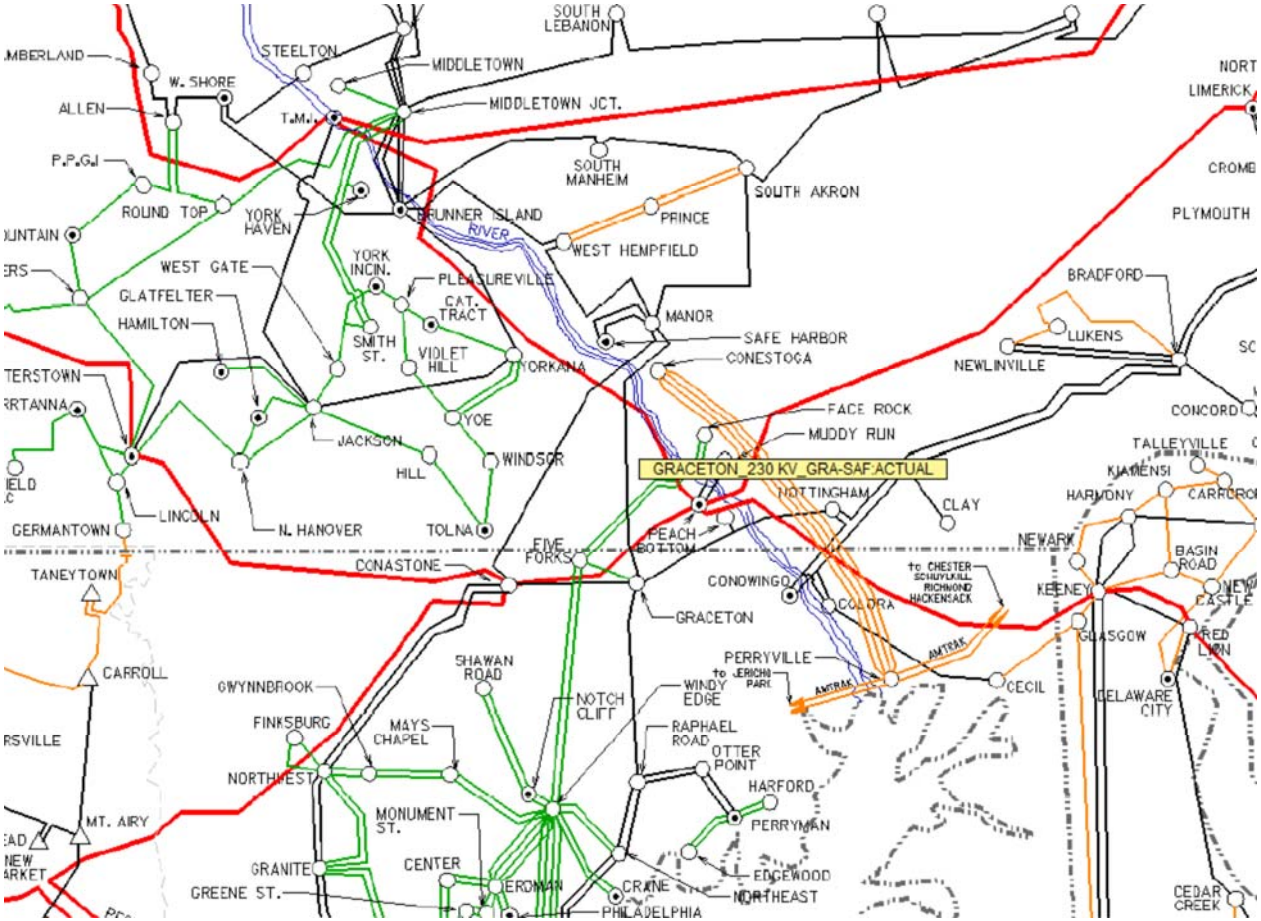
Shale Gas and Transmission Upgrades
PJM North to South Congestion



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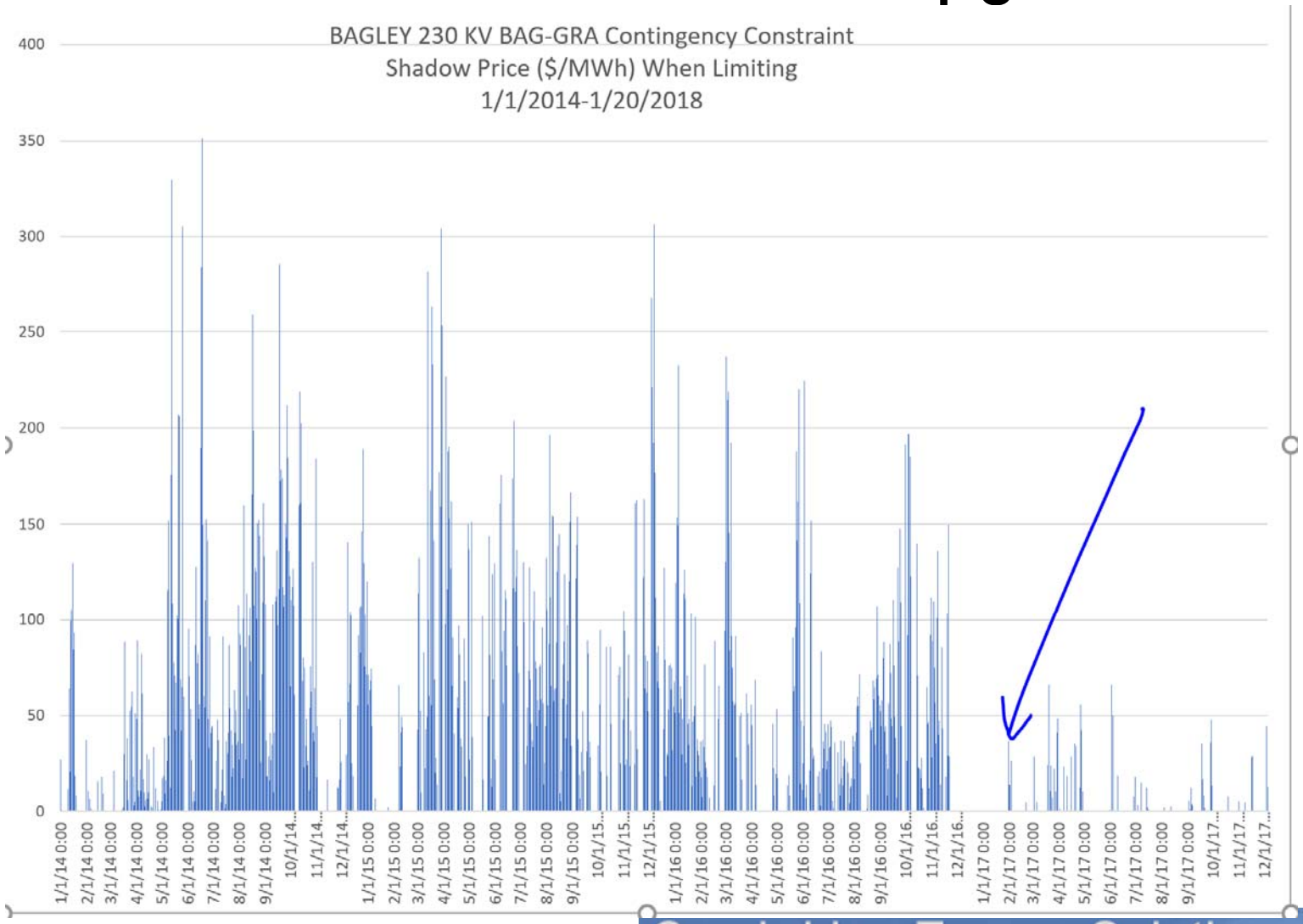
Shale Gas and Transmission Upgrades



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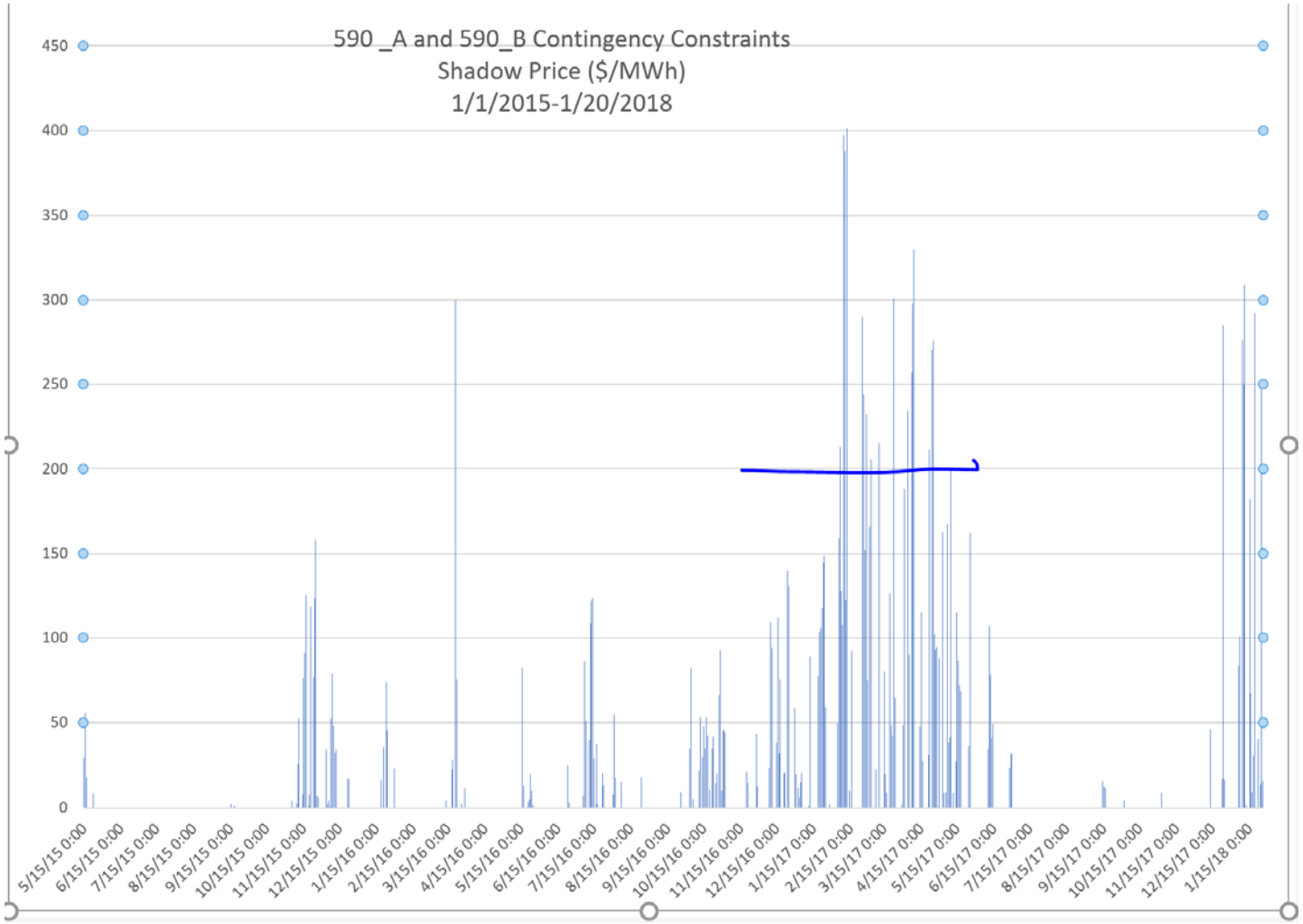
Transmission Outages in ERCOT



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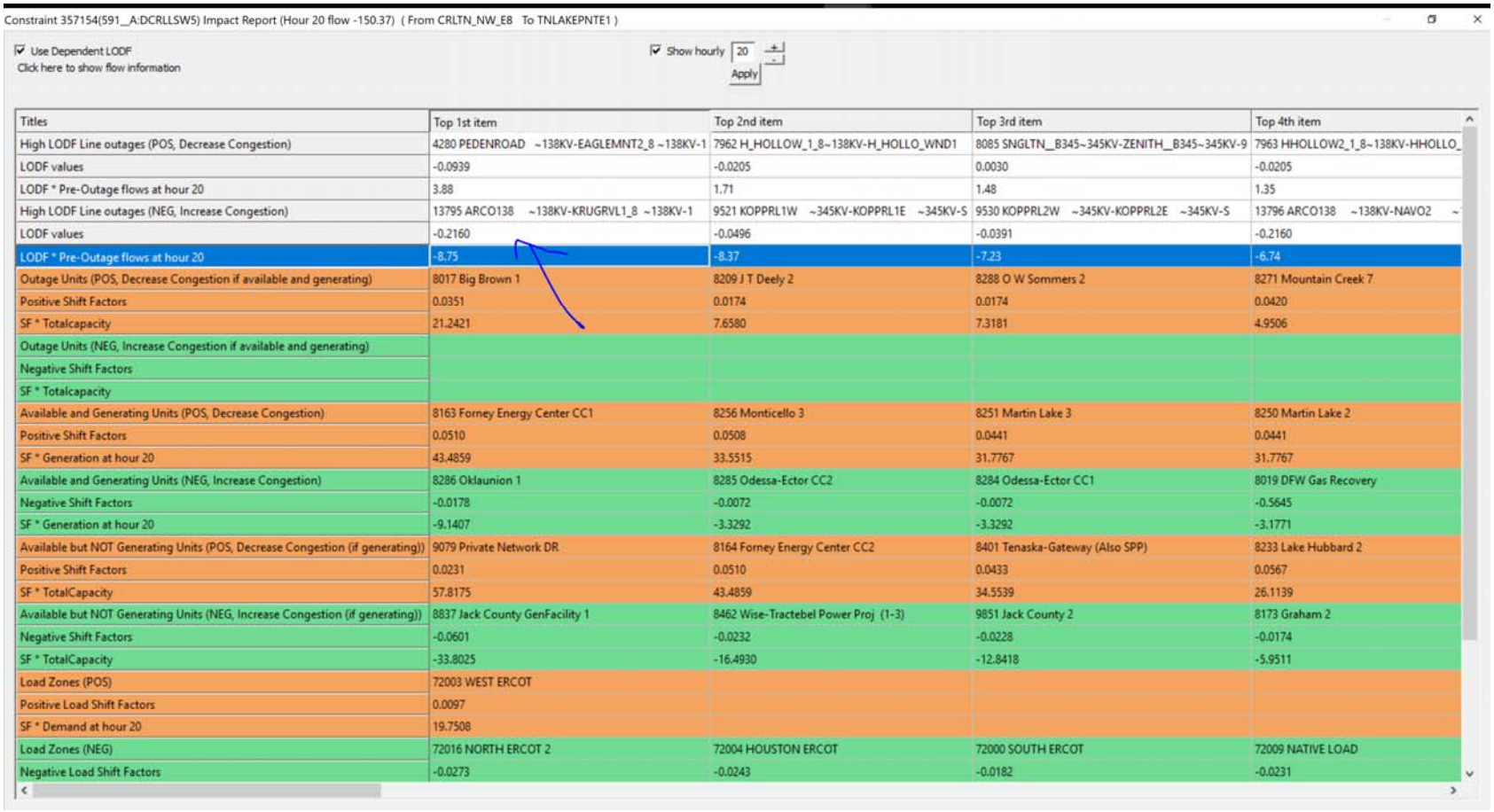
LODF and Outage Duration



Constraint 357154(591__A:DCRLLSW5) Impact Report (Hour 20 flow -150.37) (From CRLTN_NW_E8 To TNLAKEPNTE1)

Use Dependent LODF
Click here to show flow information

Show hourly 20 Apply

Titles	Top 1st item	Top 2nd item	Top 3rd item	Top 4th item
High LODF Line outages (POS, Decrease Congestion)	4280 PEDENROAD ~138KV-EAGLEMNT2_8 ~138KV-1	7962 H_HOLLOW_1_8~138KV-H_HOLLO_WND1	8085 SNGLTN_B345~345KV-ZENITH_B345~345KV-9	7963 HHOLLOW2_1_8~138KV-HHOLLO_
LODF values	-0.0939	-0.0205	0.0030	-0.0205
LODF * Pre-Outage flows at hour 20	3.88	1.71	1.48	1.35
High LODF Line outages (NEG, Increase Congestion)	13795 ARCO138 ~138KV-KRUGRVL1_8 ~138KV-1	9521 KOPPRL1W ~345KV-KOPPRL1E ~345KV-S	9530 KOPPRL2W ~345KV-KOPPRL2E ~345KV-S	13796 ARCO138 ~138KV-NAVO2 ~
LODF values	-0.2160	-0.0496	-0.0391	-0.2160
LODF * Pre-Outage flows at hour 20	-8.75	-8.37	-7.23	-6.74
Outage Units (POS, Decrease Congestion if available and generating)	8017 Big Brown 1	8209 J T Deely 2	8288 O W Sommers 2	8271 Mountain Creek 7
Positive Shift Factors	0.0351	0.0174	0.0174	0.0420
SF * Totalcapacity	21.2421	7.6580	7.3181	4.9506
Outage Units (NEG, Increase Congestion if available and generating)				
Negative Shift Factors				
SF * Totalcapacity				
Available and Generating Units (POS, Decrease Congestion)	8163 Forney Energy Center CC1	8256 Monticello 3	8251 Martin Lake 3	8250 Martin Lake 2
Positive Shift Factors	0.0510	0.0508	0.0441	0.0441
SF * Generation at hour 20	43.4859	33.5515	31.7767	31.7767
Available and Generating Units (NEG, Increase Congestion)	8286 Oklaunion 1	8285 Odessa-Ector CC2	8284 Odessa-Ector CC1	8019 DFW Gas Recovery
Negative Shift Factors	-0.0178	-0.0072	-0.0072	-0.5645
SF * Generation at hour 20	-9.1407	-3.3292	-3.3292	-3.1771
Available but NOT Generating Units (POS, Decrease Congestion (if generating))	9079 Private Network DR	8164 Forney Energy Center CC2	8401 Tenaska-Gateway (Also SPP)	8233 Lake Hubbard 2
Positive Shift Factors	0.0231	0.0510	0.0433	0.0567
SF * TotalCapacity	57.8175	43.4859	34.5539	26.1139
Available but NOT Generating Units (NEG, Increase Congestion (if generating))	8837 Jack County GenFacility 1	8462 Wise-Tractebel Power Proj (1-3)	9851 Jack County 2	8173 Graham 2
Negative Shift Factors	-0.0601	-0.0232	-0.0228	-0.0174
SF * TotalCapacity	-33.8025	-16.4930	-12.8418	-5.9511
Load Zones (POS)	72003 WEST ERCOT			
Positive Load Shift Factors	0.0097			
SF * Demand at hour 20	19.7508			
Load Zones (NEG)	72016 NORTH ERCOT 2	72004 HOUSTON ERCOT	72000 SOUTH ERCOT	72009 NATIVE LOAD
Negative Load Shift Factors	-0.0273	-0.0243	-0.0182	-0.0231

ARCO138 ~138KV-KRUGRVL1_8 ~138KV-1
outage from 1/17/2017 to 5/18/2017
And from 1/26/2018 to 3/16/2018

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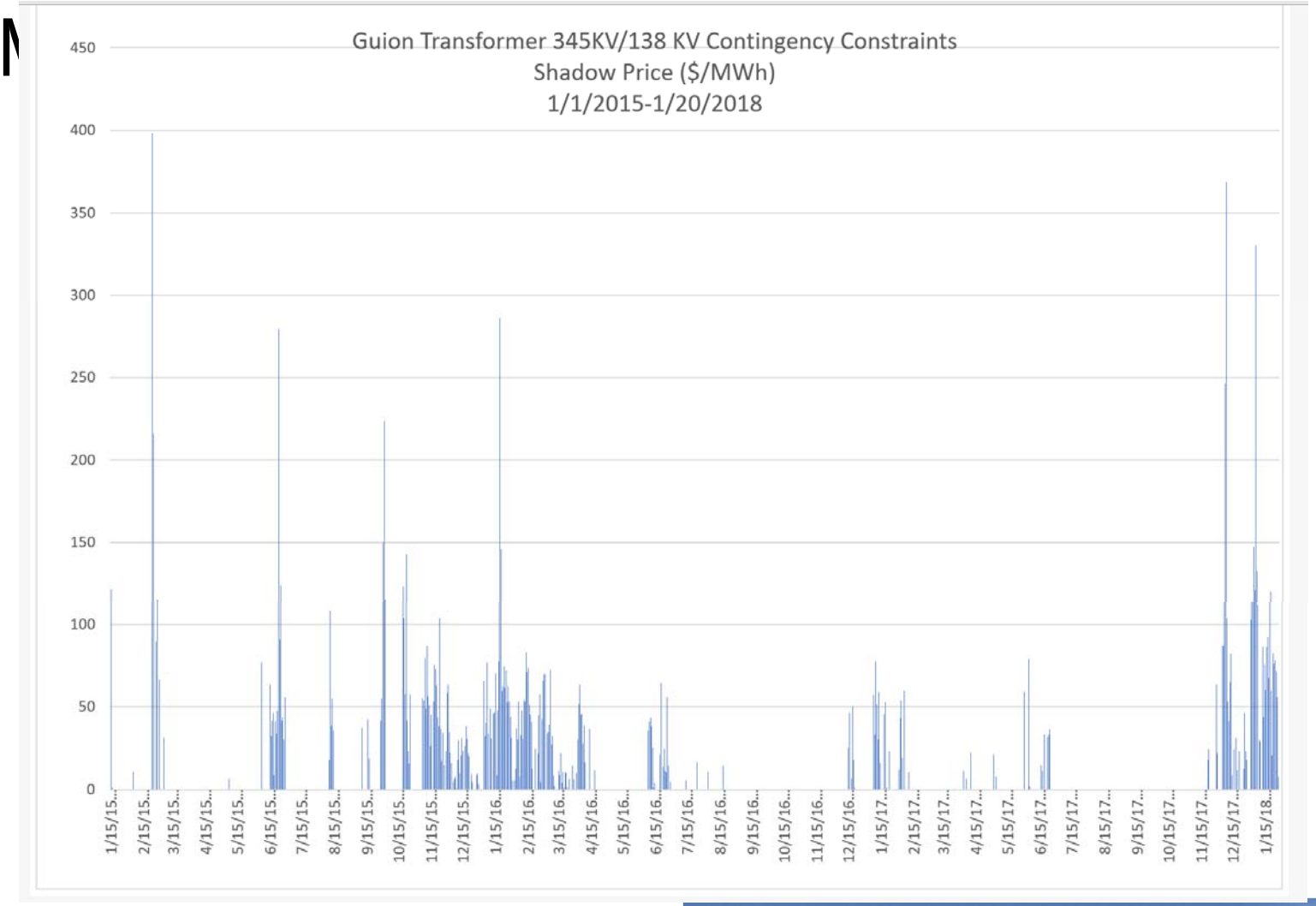
Congestion on the Guion Transformer in M



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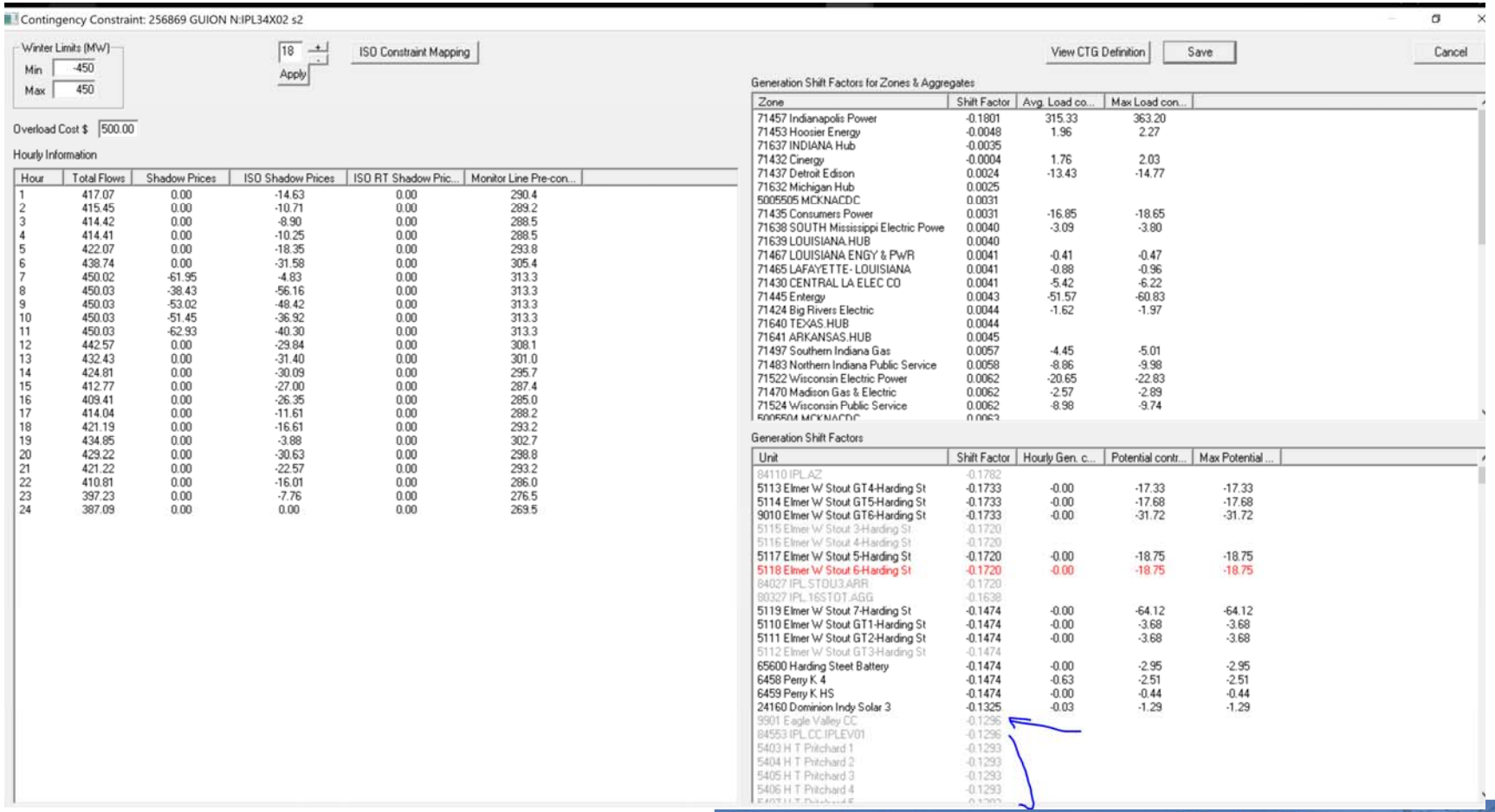
Generation Unit Retirement Combined with Transmission Outages (MISO)



Impact of Transmission Outage Combined with Unit Retirement

Constraint 256869(GUION N:IPL34X02 s2) Impact Report (Hour 8 flow 450.03) (From 16GUION To 16GUION)

☑ Use Dependent LODF
Click here to show flow information

☑ Show hourly 8 + - Apply

Titles	Top 1st item	Top 2nd item	Top 3rd item	Top 4th item
High LODF Line outages (POS, Increase Congestion)	14462 16FRANCS ~345KV-16HANNA ~345KV-1	64351 08AVONEA ~138KV-08AVONSO ~138KV-1	39781 08BATESV ~345KV-08BATESV	14395 16HANNA ~138KV-16FRANK ~138KV
LODF values	0.0460	0.1221	0.0190	0.0299
LODF * Pre-Outage flows at hour 8	24.81	8.45	4.94	2.65
High LODF Line outages (NEG, Decrease Congestion)	78973 16NORTH ~138KV-16RIV RD ~138KV-5	80955 7KANSAS ~345KV-7FARADAY ~345KV-A	12448 08PLN138 ~69KV-08PLNFL ~69KV-1	51305 BOISE 7 ~118KV-I_FALLS ~118KV-1
LODF values	-0.0814	0.0030	-0.0453	-0.0038
LODF * Pre-Outage flows at hour 8	-2.97	-0.39	-0.38	-0.35
Outage Units (POS, Increase Congestion if available and generating)	5504 Holland Energy LLC	5994 Louisa	4837 Council Bluffs 3-Wallter Scott JR	6322 Noblesville 3
Positive Shift Factors	0.0095	0.0066	0.0063	0.0151
SF * Totalcapacity	5.8160	4.9127	4.5286	4.4509
Outage Units (NEG, Decrease Congestion if available and generating)	5118 Elmer W Stout 6-Harding St	6620 R Gallagher 4		
Negative Shift Factors	-0.1720	-0.0110		
SF * Totalcapacity	-18.7514	-1.5362		
Available and Generating Units (POS, Increase Congestion)	7854 Edwardsport Combined Cycle	4654 Cayuga 2	4653 Cayuga 1	4733 Clinton
Positive Shift Factors	0.0333	0.0250	0.0218	0.0101
SF * Generation at hour 8	19.2914	12.5177	11.0078	10.8465
Available and Generating Units (NEG, Decrease Congestion)	5304 Georgetown GT#4	5303 Georgetown GT#1-#3	6458 Perry K 4	53148 Markland hydro
Negative Shift Factors	-0.3022	-0.3022	-0.1474	-0.0118
SF * Generation at hour 8	-21.7594	-9.1205	-1.2606	-0.4394
Available but NOT Generating Units (POS, Increase Congestion (if generating))	5008 Vermillion	7228 West Fork (Wheatland Power S	6979 Sugar Creek Energy CC	9884 Marshalltown CC
Positive Shift Factors	0.0243	0.0275	0.0131	0.0064
SF * TotalCapacity	14.6048	13.7599	7.4208	4.2316
Available but NOT Generating Units (NEG, Decrease Congestion (if generating))	5119 Elmer W Stout 7-Harding St	9010 Elmer W Stout GT6-Harding St	5117 Elmer W Stout 5-Harding St	5114 Elmer W Stout GT5-Harding St
Negative Shift Factors	-0.1474	-0.1733	-0.1720	-0.1733
SF * TotalCapacity	-64.1178	-31.7220	-18.7514	-17.6811
Load Zones (POS)	71457 Indianapolis Power	71453 Hoosier Energy	71432 Cinergy	
Positive Load Shift Factors	0.1801	0.0048	0.0004	
SF * Demand at hour 8	363.1954	2.2719	2.0279	
Load Zones (NEG)	71445 Entergy	71429 Central Illinois Public Service	71485 Northern States Power	71458 Illinois Power - Soyland/Ameren
Negative Load Shift Factors	-0.0043	-0.0071	-0.0063	-0.0091

Questions ?