

Trading FTRs: Enabled and Enhanced with Technology

Assef Zobian

Cambridge Energy Solutions

Using Models to Address the Complex Decisions
of Portfolio Development

EUCI Financial Transmission Rights Conference
July 25, 2011 Houston, TX

Cambridge Energy Solutions
A Provider of Information and Energy Solutions



Presentation Outline

- Day-Ahead Electric Power Markets
 - Overview
 - Fundamentals-Based Models
 - Security Constrained Unit Commitment & Dispatch
 - Inputs
- Difficulties with Fundamental Modeling
 - Unknowns
 - Uncertainty
 - Dimensionality of Input data and the complexity of the SCUC
 - Staffing and skills
- Market Analysis
 - Supply and Demand (Marginal Cost and Strategic Bidding)
 - Generation and Transmission Outages
- FTR Portfolio: Finding, Evaluating and Bidding
- Model Benchmarking

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

Overview of Day-Ahead Electric Power Markets

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

Models of Day-Ahead Electric Power Markets

- Models help the user 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

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

Model Inputs

- Hourly Demand Forecast (by node)
 - ISOs and others
- 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 and Variable Operating Cost: Fuel Prices & Marginal Costs/bids
 - NYMEX
 - Generation unit outages (NRC, IIR, CES, ISOs, etc..)
- Transmission Topology
 - ISOs
- Transmission Outages and derates
 - ISOs
- Imports/exports (scheduled and unscheduled)
 - ISOs
- Renewable Generation schedules (mainly wind, then hydro)
 - NOAA
- Pump Storage optimization (some ISOs DAM software do not allow for optimization)
- Operating reserves requirements(Spinning Reserves, Quick Start Reserves and Regulation or Automatic Generation Control)

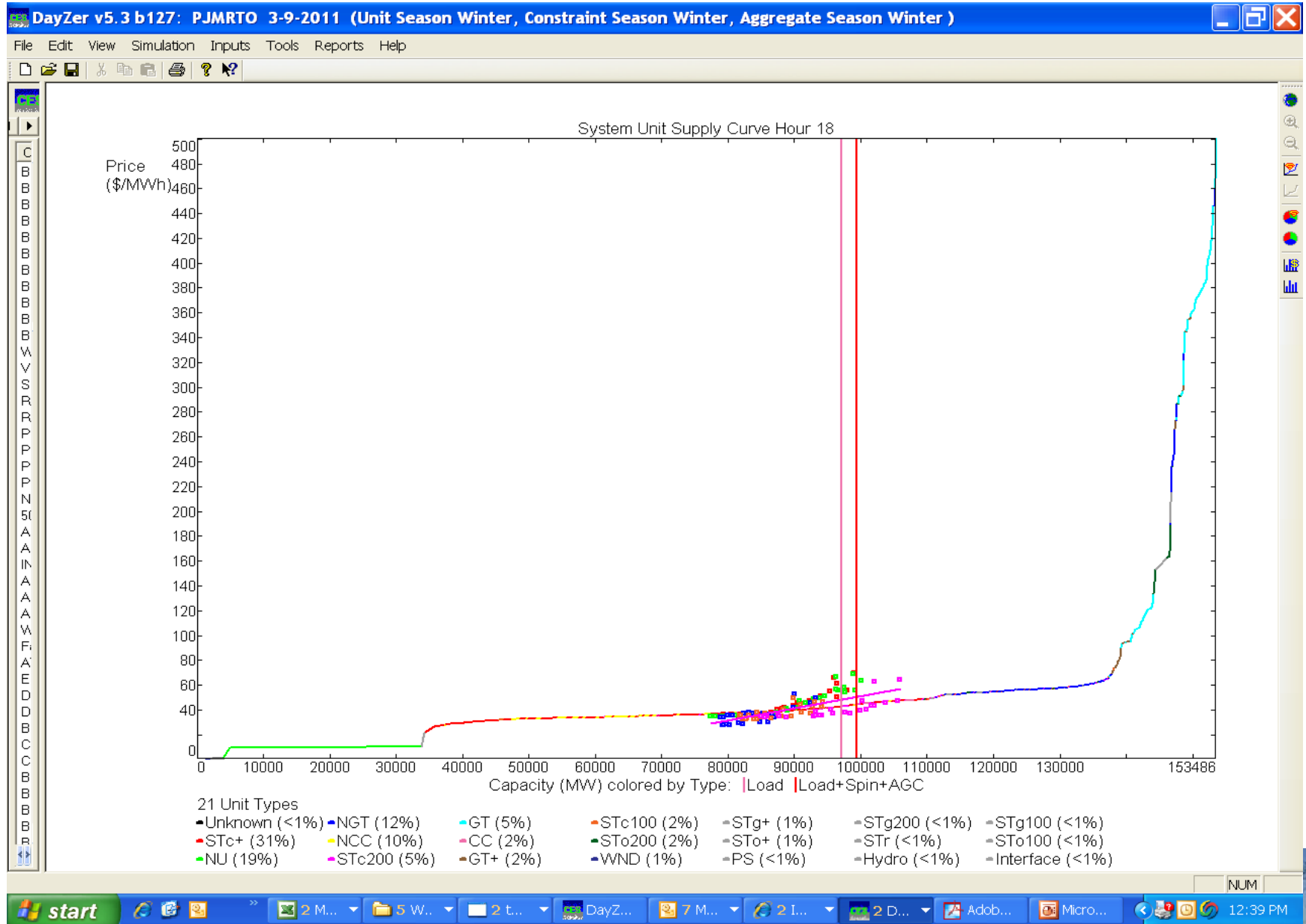
Difficulties with Fundamental Modeling

- Unknowns
 - Generation and Demand bidding 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...
- Staffing and skills

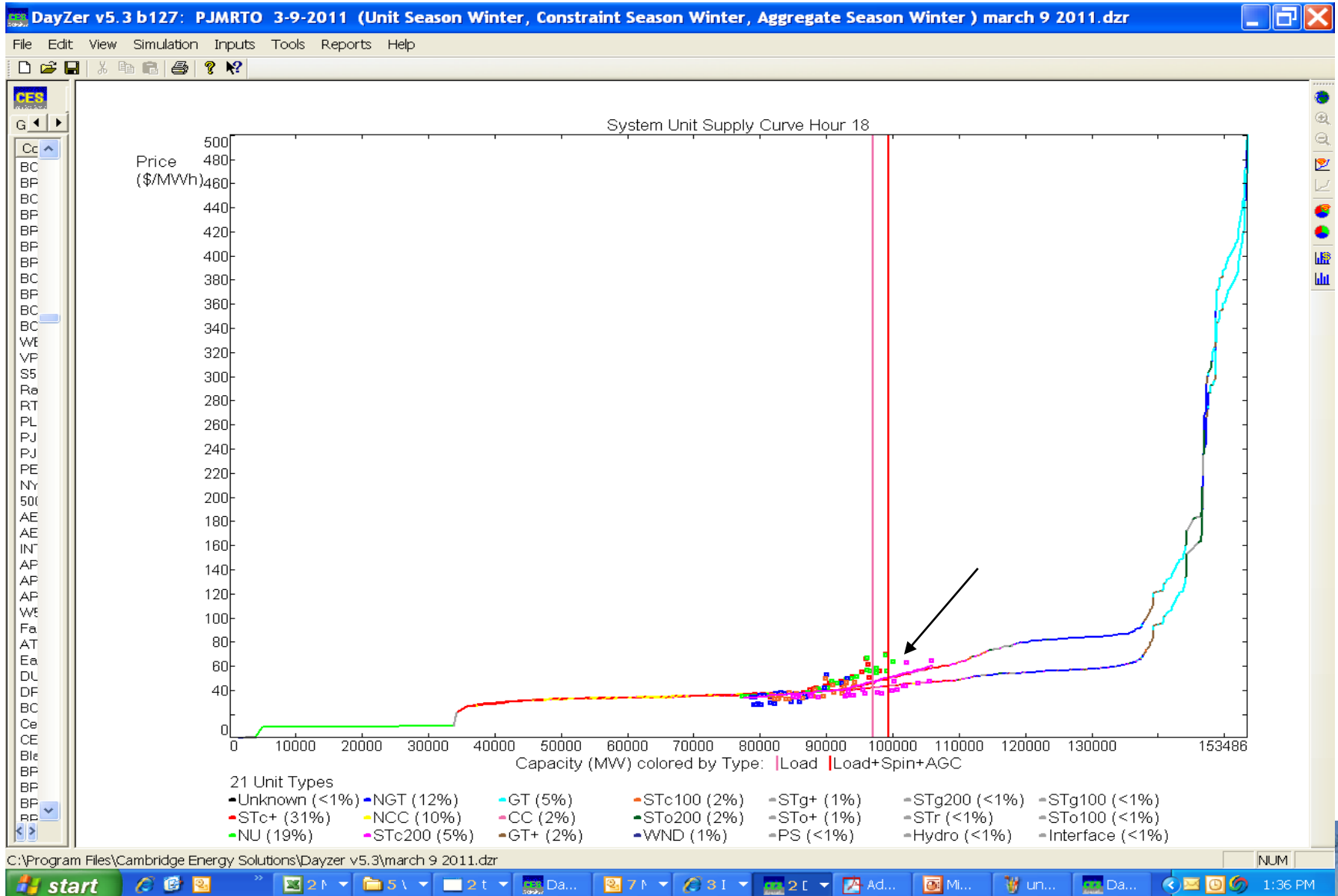
Market Analysis

- These 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- Shift Factors
- Generation and Transmission Outages (LODFs)

Market Analysis: Supply & Demand



Market Analysis: Supply & Demand Strategic Bidding!



Market Analysis: 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



Market Analysis: 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 WYLIEP
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 Musking
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 P
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 Daytc
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

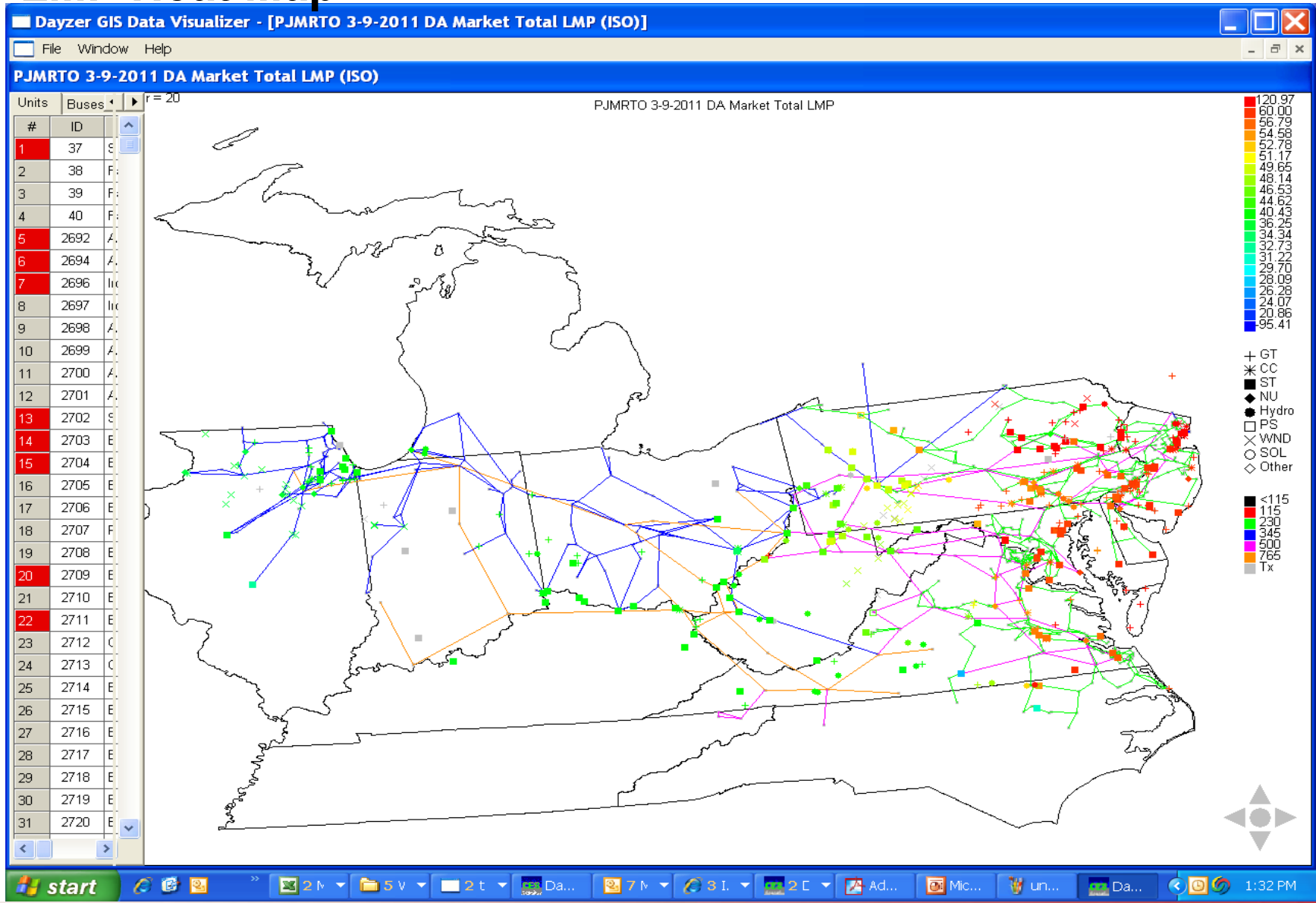
Market Analysis: Generation Outages

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 item
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 PeachBottom 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

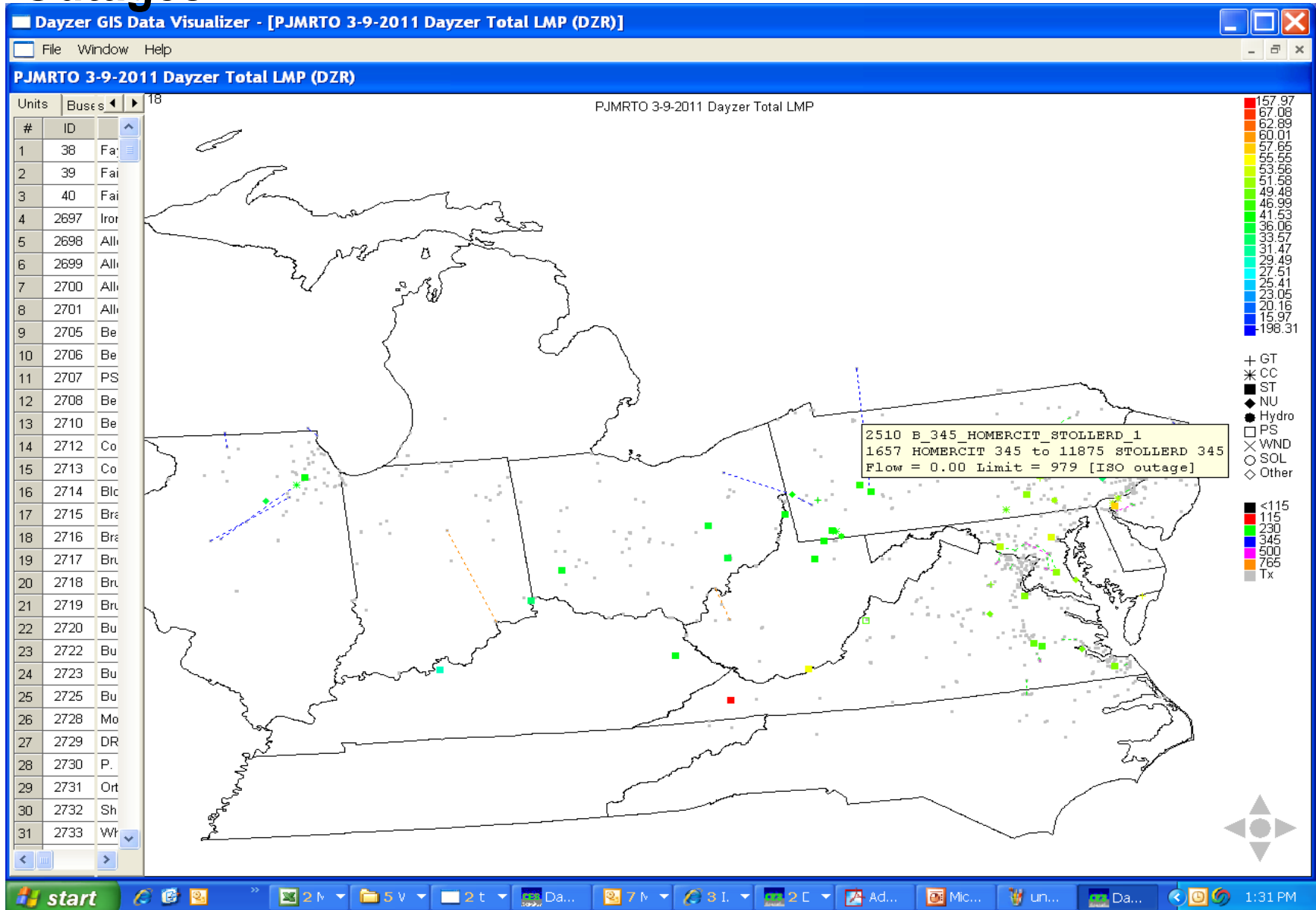
Market Analysis: A Picture is worth 1000 words

LMP Heat Map



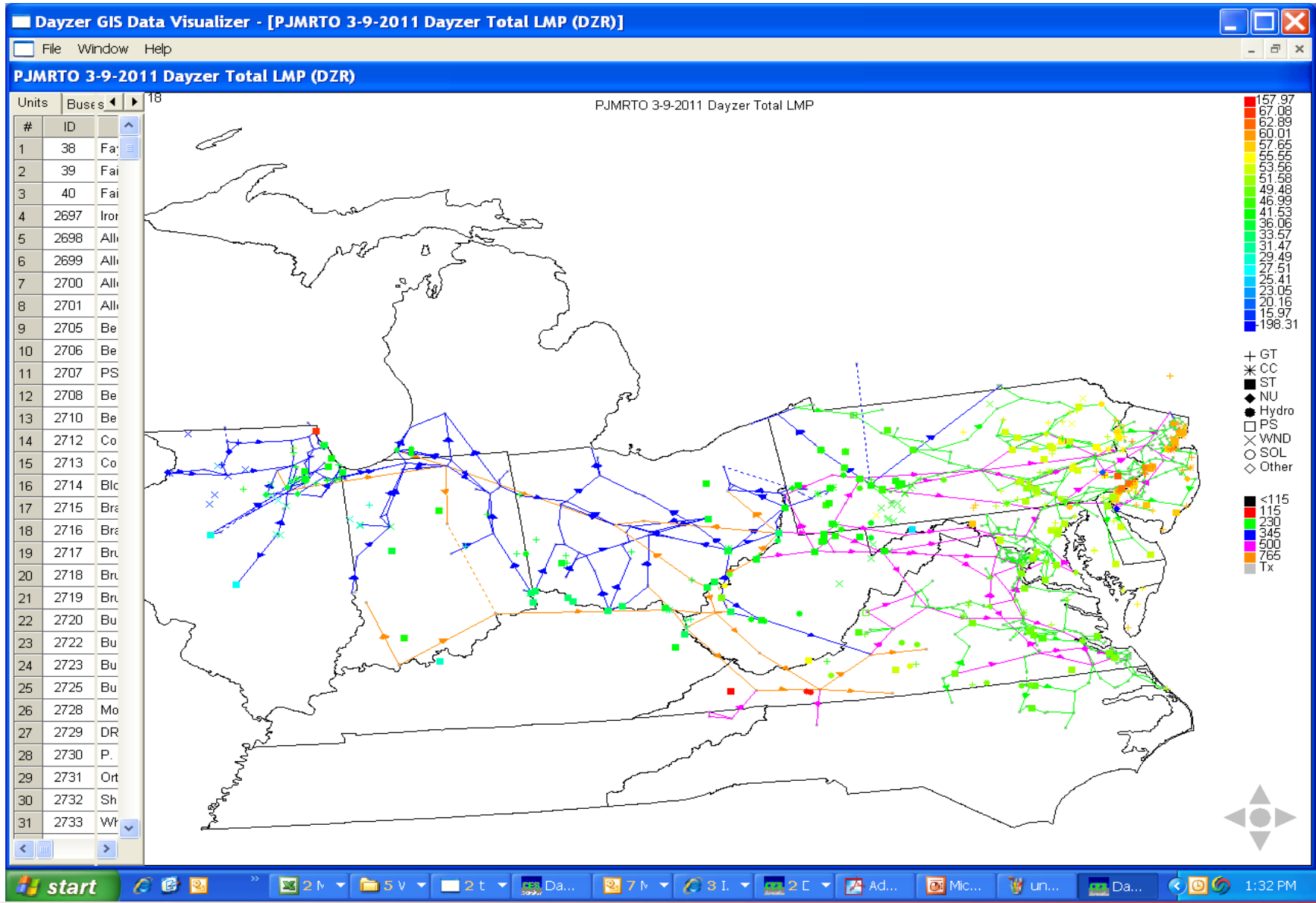
Market Analysis: A Picture is worth 1000 words

Outages



Market Analysis: A Picture is worth 1000 words

Power Flows



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)

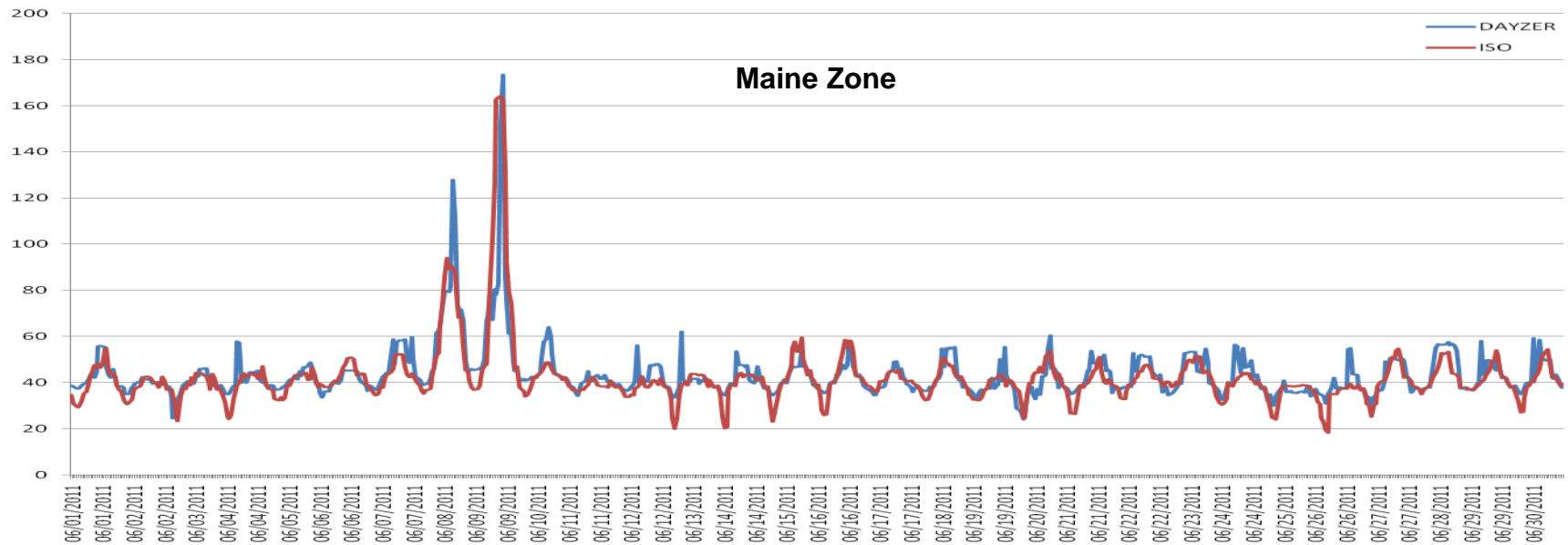
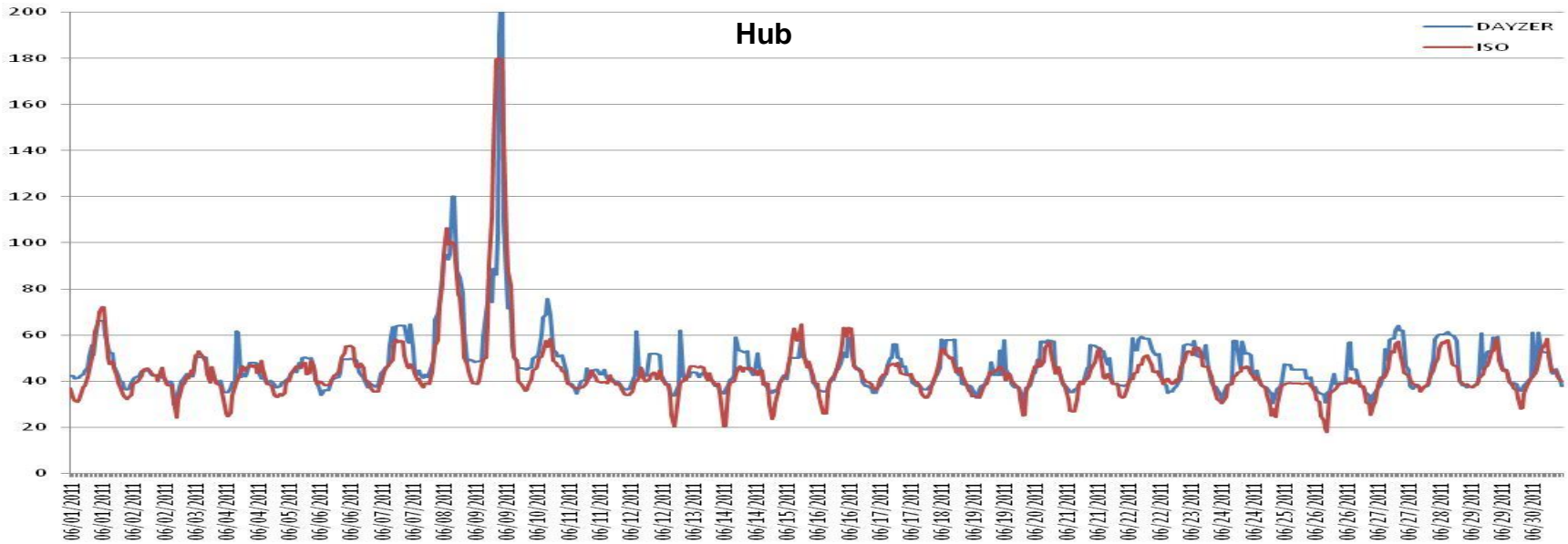
FTR Portfolio- Evaluating and Bidding

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

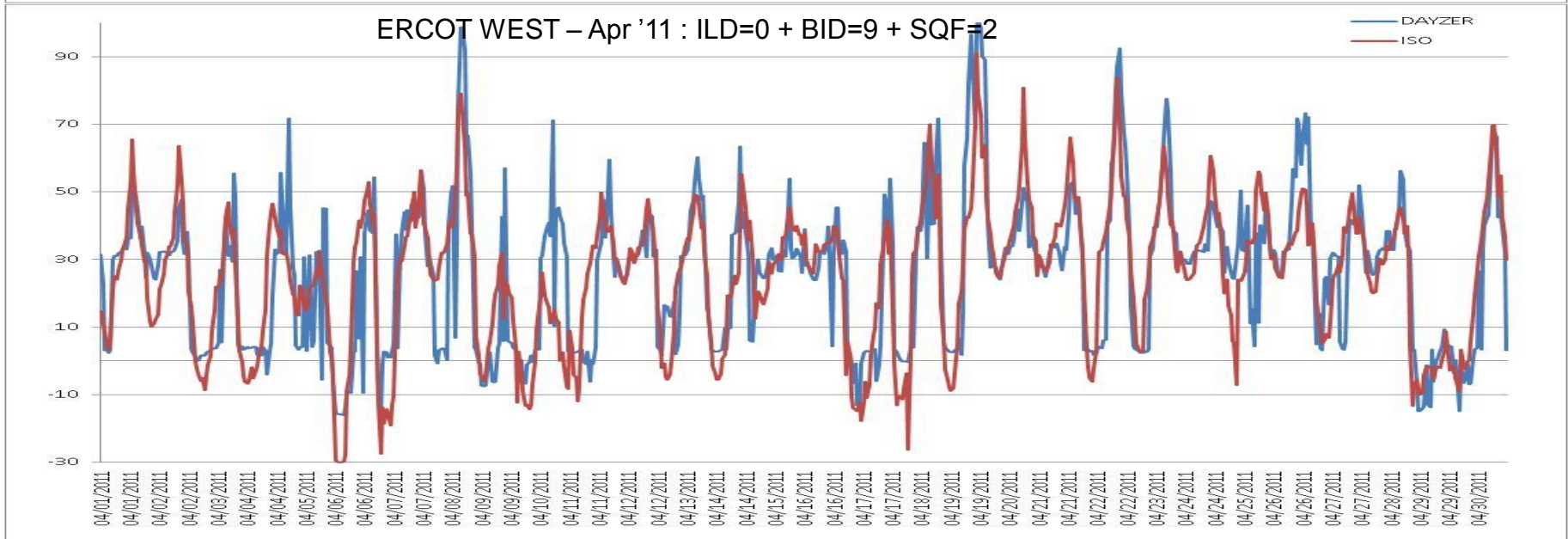
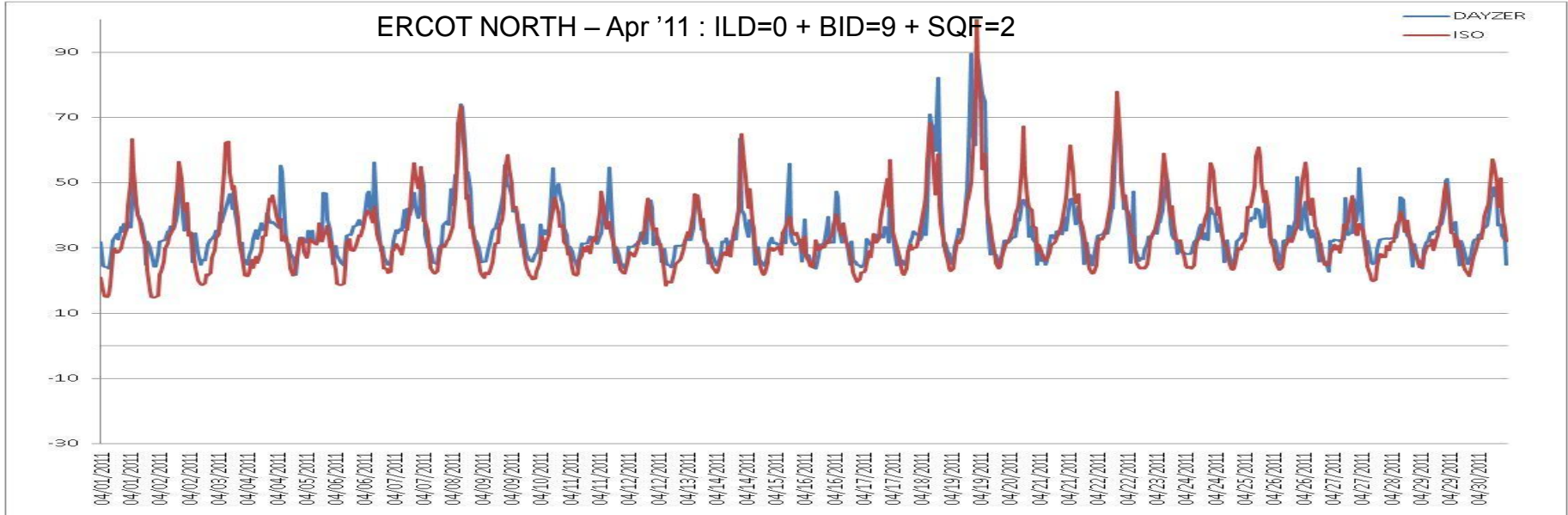
Model Benchmarking

- Ultimate model benchmarking is against the market data
- The simulation results shown in the graphs reveal good comparison to actual DAM LMPs given the following:
 1. Error in zonal load forecast (uses load forecast rather than actual day-ahead bids, allocates load among zones based on historical and among buses based on fixed values, no virtual INCs and DECs)
 2. Error in generation unit outages (except for IIR and NRC unit outages, assumes uniform de-rating of generation units)
 3. Error in bid estimation (assumes marginal cost bidding, except ERCOT), no virtual bids (INCs and DECs)

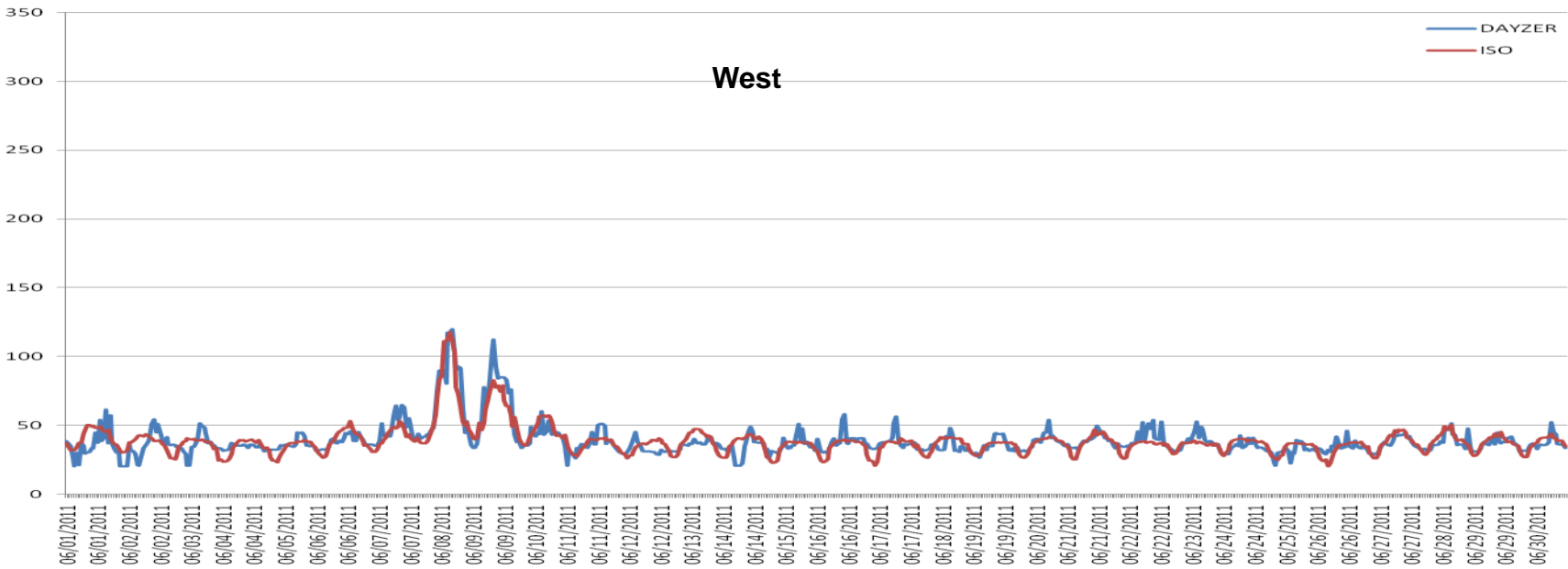
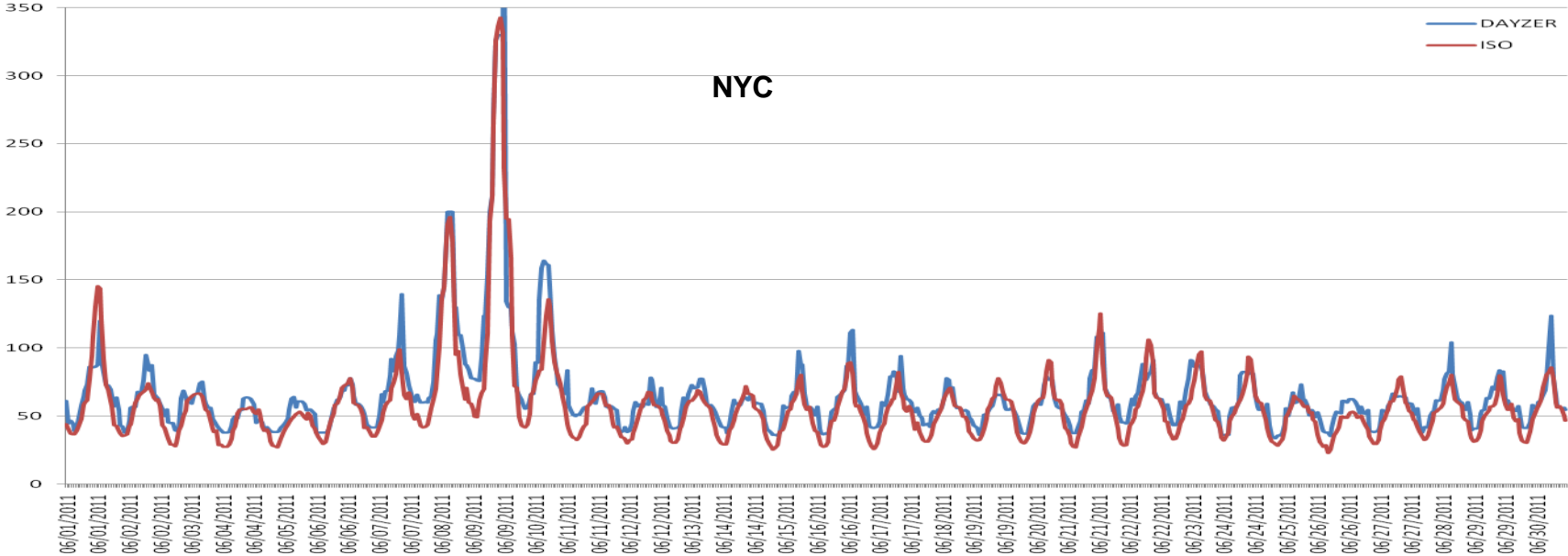
ISO-NE: Hub & Maine



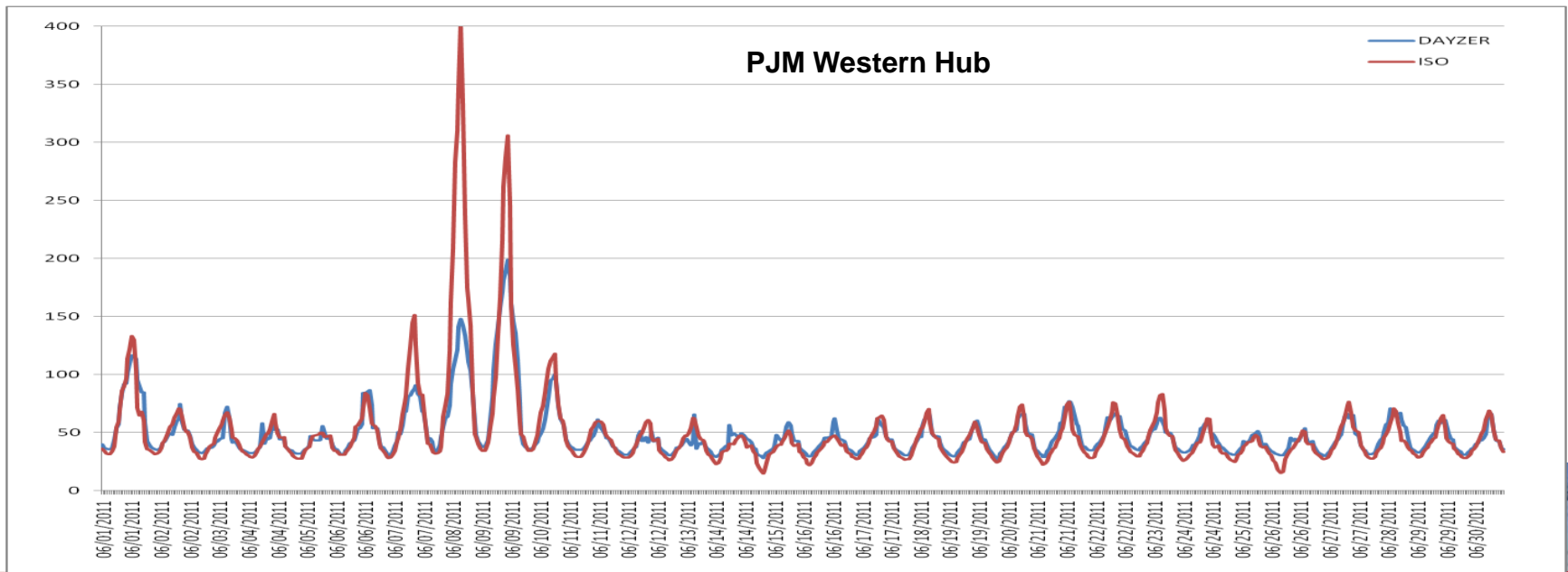
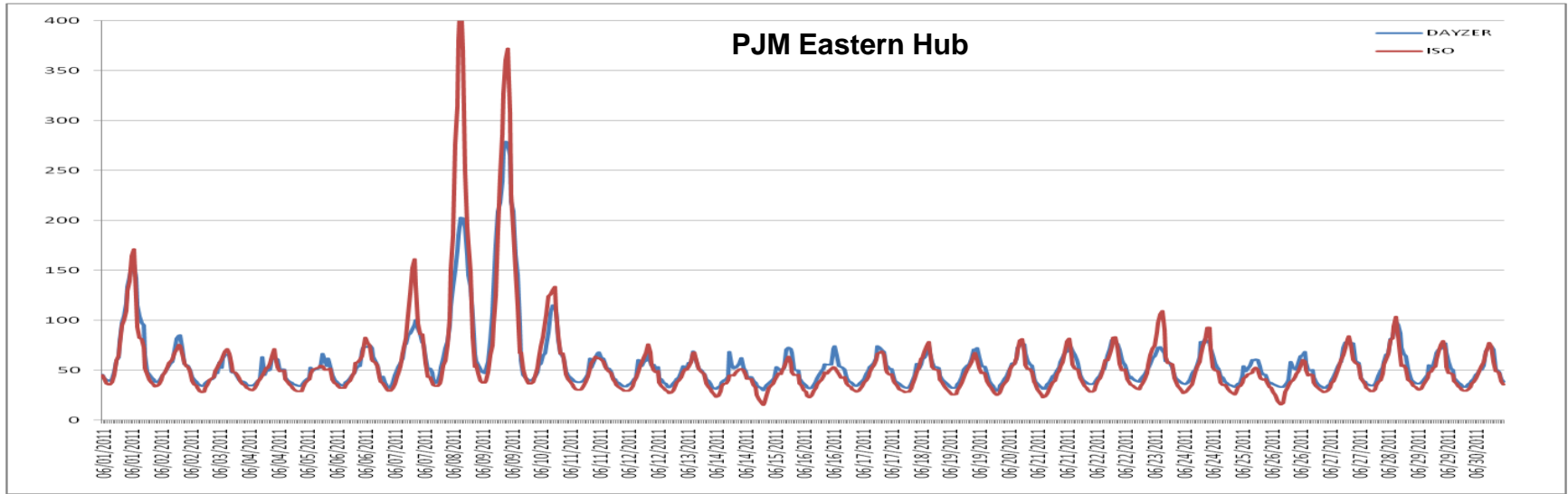
ERCOT: North and West Zones



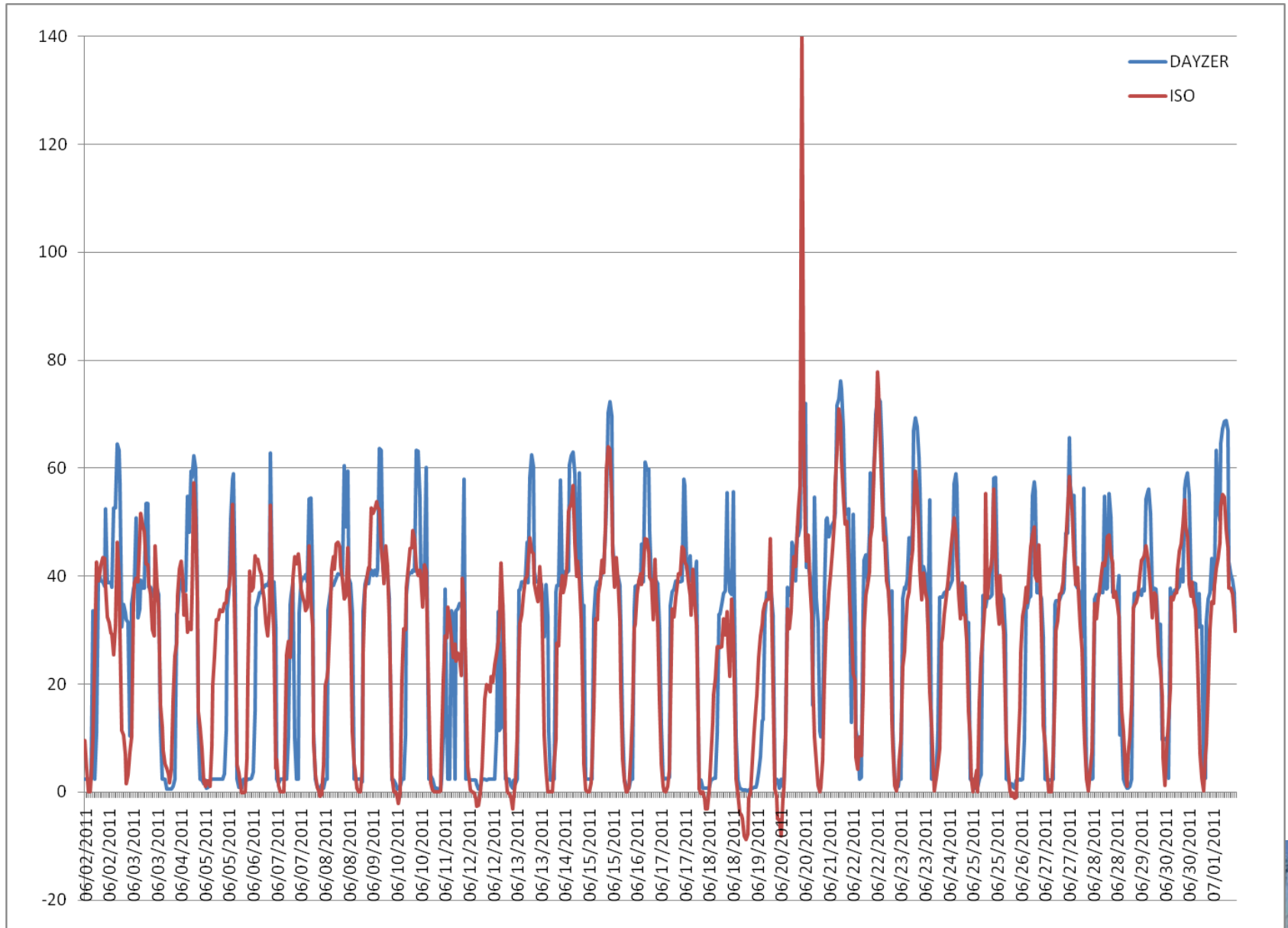
NY ISO: West and NYC



PJM: Eastern and Western Hub



CA ISO: Pacific Gas and Electric Zone



Questions ?