

Table of Contents

Preface	i	Overview: Section 10, Ancillary Services	55
SECTION 1 Introduction	1	Overview: Section 11, Congestion and Marginal Losses	63
2018 Q1 in Review	1	Overview: Section 12, Planning	65
PJM Market Summary Statistics	7	Overview: Section 13, FTRs and ARRs	69
PJM Market Background	7	SECTION 2 Recommendations	77
Conclusions	9	New Recommendations	77
Energy Market Conclusion	9	New Recommendations from Section 3, Energy Market	78
Capacity Market Conclusion	11	New Recommendations from Section 4, Energy Uplift	78
Tier 2 Synchronized Reserve Market Conclusion	11	New Recommendation from Section 13, Financial Transmission and Auction Revenue Rights	78
Day-Ahead Scheduling Reserve Market Conclusion	12	Complete List of Current MMU Recommendations	78
Regulation Market Conclusion	12	Section 3, Energy Market	78
FTR Auction Market Conclusion	12	Section 4, Energy Uplift	81
Role of MMU	13	Section 5, Capacity Market	83
Reporting	13	Section 6, Demand Response	86
Monitoring	13	Section 7, Net Revenue	88
Market Design	14	Section 8, Environmental	88
New Recommendations	15	Section 9, Interchange Transactions	88
New Recommendations from Section 3, Energy Market	15	Section 10, Ancillary Services	89
New Recommendations from Section 4, Energy Uplift	15	Section 11, Congestion and Marginal Losses	91
New Recommendation from Section 13, Financial Transmission and Auction Revenue Rights	15	Section 12, Planning	91
Total Price of Wholesale Power	15	Section 13, FTRs and ARRs	92
Components of Total Price	16	SECTION 3 Energy Market	95
Section Overviews	23	Overview	96
Overview: Section 3, Energy Market	23	Market Structure	96
Overview: Section 4, Energy Uplift	31	Market Behavior	97
Overview: Section 5, Capacity Market	36	Market Performance	99
Overview: Section 6, Demand Response	43	Scarcity	100
Overview: Section 7, Net Revenue	48	Recommendations	100
Overview: Section 8, Environmental and Renewables	49	Conclusion	102
Overview: Section 9, Interchange Transactions	52		

Market Structure	104	Energy Uplift Results	212
Market Concentration	104	Energy Uplift Charges	212
Ownership of Marginal Resources	109	Operating Reserve Rates	215
Type of Marginal Resources	110	Reactive Services Rates	217
Supply	112	Balancing Operating Reserve Determinants	218
Generator Offers	114	Energy Uplift Credits	220
Demand	123	Characteristics of Credits	221
Supply and Demand: Load and Spot Market	132	Types of Units	221
Market Behavior	133	Concentration of Energy Uplift Credits	221
Offer Capping for Local Market Power	133	Uplift Eligibility	223
TPS Test Statistics	137	Economic and Noneconomic Generation	224
Parameter Limited Schedules	139	Day-Ahead Unit Commitment for Reliability	225
Markup Index	142	Geography of Charges and Credits	226
Energy Market Cost-Based Offers	147	January through March, 2018: Energy Uplift Credits to	
Frequently Mitigated Units (FMU) and Associated Units (AU)	151	Generators Increase	227
Virtual Offers and Bids	153		
Market Performance	164	SECTION 5 Capacity Market	231
Markup	164	Overview	231
Prices	172	RPM Capacity Market	231
Scarcity	193	Reliability Must Run Service	233
Emergency Procedures	194	Generator Performance	233
Scarcity and Scarcity Pricing	197	Recommendations	234
PJM Cold Weather Operations 2018	203	Conclusion	237
		Installed Capacity	240
SECTION 4 Energy Uplift (Operating Reserves)	205	Fuel Diversity	241
Overview	205	RPM Capacity Market	242
Energy Uplift Results	205	Market Structure	242
Characteristics of Credits	205	Market Conduct	255
Geography of Charges and Credits	206	Market Performance	261
Recommendations	206	Reliability Must Run (RMR) Service	269
Conclusion	208	Generator Performance	271
Energy Uplift	210	Capacity Factor	271
Credits and Charges Categories	210	Generator Performance Factors	271
		Generator Forced Outage Rates	273

SECTION 6 Demand Response	279	SECTION 8 Environmental and Renewable Energy Regulations	325
Overview	279	Overview	325
Recommendations	280	Federal Environmental Regulation	325
Conclusion	281	State Environmental Regulation	325
PJM Demand Response Programs	283	State Renewable Portfolio Standards	326
Non-PJM Demand Response Programs	284	Emissions Controls in PJM Markets	326
Participation in Demand Response Programs	284	Renewable Generation	326
Economic Program	286	Recommendations	326
Emergency and Pre-Emergency Programs	293	Conclusion	326
Distributed Energy Resources	303	Federal Environmental Regulation	327
SECTION 7 Net Revenue	305	Control of Mercury and Other Hazardous Air Pollutants	327
Overview	305	Air Quality Standards: Control of NO _x , SO ₂ and O ₃ Emissions Allowances.	328
Net Revenue	305	Emission Standards for Reciprocating Internal Combustion Engines	330
Historical New Entrant CT and CC Revenue Adequacy	305	Regulation of Greenhouse Gas Emissions	331
Conclusion	305	Federal Regulation of Environmental Impacts on Water	332
Net Revenue	306	Federal Regulation of Coal Ash	333
Spark Spreads, Dark Spreads, and Quark Spreads	307	State Environmental Regulation	334
Theoretical Energy Market Net Revenue	309	New Jersey High Electric Demand Day (HEDD) Rules	334
New Entrant Combustion Turbine	311	Illinois Air Quality Standards (NO _x , SO ₂ and Hg)	335
New Entrant Combined Cycle	313	State Regulation of Greenhouse Gas Emissions	335
New Entrant Coal Plant	314	State Renewable Portfolio Standards	337
New Entrant Nuclear Plant	315	Emissions Controlled Capacity and Renewables in PJM Markets	350
New Entrant Diesel	316	Emission Controlled Capacity in the PJM Region	350
New Entrant Wind Installation	317	Wind and Solar Peak Hour Output	354
New Entrant Solar Installation	317	Wind Units	355
Historical New Entrant CT and CC Revenue Adequacy	318	Solar Units	357
Nuclear Net Revenue Analysis	320		

SECTION 9 Interchange Transactions	361		
Overview	361		
Interchange Transaction Activity	361		
Interactions with Bordering Areas	362		
Recommendations	362		
Conclusion	364		
Interchange Transaction Activity	364		
Charges and Credits Applied to Interchange Transactions	364		
Aggregate Imports and Exports	365		
Real-Time Interface Imports and Exports	367		
Real-Time Interface Pricing Point Imports and Exports	370		
Day-Ahead Interface Imports and Exports	372		
Day-Ahead Interface Pricing Point Imports and Exports	375		
Loop Flows	381		
PJM and MISO Interface Prices	388		
PJM and NYISO Interface Prices	390		
Summary of Interface Prices between PJM and Organized Markets	392		
Neptune Underwater Transmission Line to Long Island, New York	393		
Linden Variable Frequency Transformer (VFT) facility	394		
Hudson Direct Current (DC) Merchant Transmission Line	396		
Interchange Activity During High Load Hours	397		
Operating Agreements with Bordering Areas	397		
PJM and MISO Joint Operating Agreement	398		
PJM and New York Independent System Operator Joint Operating Agreement (JOA)	399		
PJM and TVA Joint Reliability Coordination Agreement (JRCA)	401		
PJM and Duke Energy Progress, Inc. Joint Operating Agreement	401		
PJM and VACAR South Reliability Coordination Agreement	403		
Balancing Authority Operations Coordination Agreement between Wisconsin Electric Power Company (WEC) and PJM Interconnection, LLC	403		
Northeastern ISO-Regional Transmission Organization Planning Coordination Protocol	404		
		Interface Pricing Agreements with Individual Balancing Authorities	404
		Other Agreements with Bordering Areas	405
		Interchange Transaction Issues	406
		Hudson Transmission Partners (HTP) and Linden VFT Requests to Convert Firm Transmission Withdrawal Rights (FTWR) to NonFirm Transmission Withdrawal Rights (NFTWR)	406
		PJM Transmission Loading Relief Procedures (TLRs) Up to Congestion	408
		Sham Scheduling	409
		Elimination of Ontario Interface Pricing Point	412
		PJM and NYISO Coordinated Interchange Transactions	412
		Reserving Ramp on the PJM/NYISO Interface	413
		PJM and MISO Coordinated Interchange Transaction Proposal	416
		Willing to Pay Congestion and Not Willing to Pay Congestion	417
		Spot Imports	420
		Interchange Optimization	421
		Interchange Cap During Emergency Conditions	423
		45 Minute Schedule Duration Rule	423
		MISO Multi-Value Project Usage Rate (MUR)	424
		SECTION 10 Ancillary Service Markets	427
		Overview	428
		Primary Reserve	428
		Tier 1 Synchronized Reserve	428
		Tier 2 Synchronized Reserve Market	429
		Nonsynchronized Reserve Market	430
		Secondary Reserve	430
		Regulation Market	431
		Black Start Service	433
		Reactive	433
		Frequency Response	433

Ancillary Services Costs per MWh of Load: January through March, 1999 through 2018	433	SECTION 11 Congestion and Marginal Losses	501
Recommendations	434	Overview	501
Conclusion	435	Congestion Cost	501
Primary Reserve	436	Marginal Loss Cost	502
Market Structure	436	Energy Cost	503
Price and Cost	441	Conclusion	503
Tier 1 Synchronized Reserve	441	Locational Marginal Price (LMP)	503
Market Structure	442	Components	503
Tier 1 Synchronized Reserve Event Response	443	Hub Components	508
Tier 2 Synchronized Reserve Market	447	Component Costs	509
Market Structure	447	Congestion	509
Market Behavior	451	Congestion Accounting	509
Market Performance	453	Total Congestion	510
Nonsynchronized Reserve Market	459	Congested Facilities	515
Market Structure	459	Congestion by Facility Type and Voltage	516
Secondary Reserve	462	Constraint Duration	519
Market Structure	462	Constraint Costs	521
Market Conduct	464	Congestion Event Summary for MISO Flowgates	523
Market Performance	464	Congestion Event Summary for NYISO Flowgates	525
Regulation Market	466	Congestion Event Summary for the 500 kV System	526
Market Design	466	Congestion Costs by Physical and Financial Participants	527
Market Structure	478	Congestion Event Summary: Impact of Changes in UTC Volumes	528
Market Conduct	482	Marginal Losses	529
Market Performance	486	Marginal Loss Accounting	529
Black Start Service	489	Total Marginal Loss Cost	530
NERC – CIP	492	Energy Costs	535
Minimum Tank Suction Level (MTSL)	492	Energy Accounting	535
Reactive Service	493	Total Energy Costs	536
Recommended Market Approach to Reactive Costs	494		
Improvements to Current Approach	496		
Reactive Costs	498		
Frequency Response	499		
Frequency Control Definition	499		

SECTION 12 Generation and Transmission Planning	541	SECTION 13 Financial Transmission and Auction Revenue Rights	581
Overview	541	Overview	583
Planned Generation and Retirements	541	Auction Revenue Rights	583
Generation and Transmission Interconnection Planning Process	541	Financial Transmission Rights	583
Regional Transmission Expansion Plan (RTEP)	542	Recommendations	584
Transmission Facility Outages	542	Conclusion	585
Recommendations	542	Auction Revenue Rights	589
Conclusion	544	Market Structure	590
Planned Generation and Retirements	544	Market Performance	595
Planned Generation Additions	544	Financial Transmission Rights	597
Planned Retirements	549	Market Structure	598
Existing Generation Mix	554	Market Performance	601
Generation and Transmission Interconnection Planning Process	556	Revenue Adequacy Issues and Solutions	611
Interconnection Queue Analysis	556	ARRs as an Offset to Congestion for Load	617
Regional Transmission Expansion Plan (RTEP)	565	FERC Order on FTRs: Balancing Congestion and M2M	
Authorized TEAC Transmission Upgrades	565	Payment Allocation	617
Backbone Facilities	565	Credit Issues	619
Market Efficiency Process	565	FTR Forfeitures	619
PJM MISO Interregional Targeted Market Efficiency Process (TMEP)	566	FERC Order on FTR Forfeitures	619
Transmission Facility Outages	566		
Scheduling Transmission Facility Outage Requests	566		
Rescheduling Transmission Facility Outage Requests	570		
Long Duration Transmission Facility Outage Requests	571		
Transmission Facility Outage Analysis for the FTR Market	571		
Annual FTR Market	571		
Monthly FTR Market	575		
Transmission Facility Outage Analysis in the Day-Ahead Energy Market	578		