TABLE OF CONTENTS

PREFACE	
SECTION 1 INTRODUCTION	1
2018 in Review	1
PJM Market Summary Statistics	3
PJM Market Background	4
Conclusions	5
Energy Market Conclusion	6
Capacity Market Conclusion	7
Tier 2 Synchronized Reserve Market Conclusion	8
Day-Ahead Scheduling Reserve Market Conclusion	8
Regulation Market Conclusion	9
FTR Auction Market Conclusion	9
Role of MMU	9
Reporting	9
Monitoring	10
Market Design	11
New Recommendations	11
New Recommendations from Section 3, Energy Market	11
New Recommendations from Section 4, Energy Uplift	12
New Recommendation from Section 5, Capacity Market	12
New Recommendations from Section 6, Demand Response	12
New Recommendations from Section 8, Environmental and Renewable Energy Regulations	13
New Recommendations from Section 10, Ancillary Service Markets	13
New Recommendations from Section 12, Generation and Transmission Planning	13
New Recommendations from Section 13, Financial Transmission and Auction Revenue Rights	14
Total Price of Wholesale Power	14
Components of Total Price	14
Section Overviews	21
Overview: Section 3, Energy Market	21
Overview: Section 4, Energy Uplift	30
Overview: Section 5, Capacity Market	34
Overview: Section 6, Demand Response	43
Overview: Section 7, Net Revenue	48
Overview: Section 8, Environmental and Renewables	49
Overview: Section 9, Interchange Transactions	52
Overview: Section 10, Ancillary Services	55
Overview: Section 11, Congestion and Marginal Losses	63
Overview: Section 12, Planning Overview: Section 13, FTRs and ARRs	65 71
Uverview: Section 13 FIRS and ARRS	/ 1

SECTION 2 RECOMMENDATIONS	77
New Recommendations	77
New Recommendations from Section 3, Energy Market	78
New Recommendations from Section 4, Energy Uplift	78
New Recommendation from Section 5, Capacity Market	78
New Recommendations from Section 6, Demand Response	79
New Recommendations from Section 8, Environmental and Renewable Energy Regulations	79
New Recommendations from Section 10, Ancillary Service Markets	79
New Recommendations from Section 12, Generation and Transmission Planning	80
New Recommendations from Section 13, Financial Transmission and Auction Revenue Rights	80
History of MMU Recommendations	80
Complete List of Current MMU Recommendations	81
Section 3, Energy Market	81
Section 4, Energy Uplift	84
Section 5, Capacity Market	86
Section 6, Demand Response	88
Section 7, Net Revenue	90
Section 8, Environmental	90
Section 9, Interchange Transactions	91
Section 10, Ancillary Services	92
Section 11, Congestion and Marginal Losses	93
Section 12, Planning	93
Section 13, FTRs and ARRs	95
Adopted Recommendations	96
Adopted 2018	96
Adopted 2017	97
Adopted 2016	97
Adopted 2015	97
Adopted 2014	98
Adopted 2013	99
Adopted 2012	99
Adopted 2011	100
Adopted 2010	100
Adopted 2009	100
Adopted 2008	101
Adopted 2006	101
SECTION 3 ENERGY MARKET	103
Overview	104
Market Structure	104
Market Behavior	105
Market Performance	106
Scarcity	107
Recommendations	107
Conclusion	110
Market Structure	113
Market Concentration	113

Table of Contents

Ownership of Marginal Resources	117
Type of Marginal Resources	118
Supply	121
Generator Offers	123
Demand	132
Supply and Demand: Load and Spot Market	137
Internal Bilateral Transactions	139
Market Behavior	140
Local Market Power	140
Parameter Limited Schedules	146
Markup Index	150
Energy Market Cost-Based Offers	154
Frequently Mitigated Units (FMU) and Associated Units (AU)	161
Virtual Offers and Bids	162
Market Performance	173
Markup	173
Prices	181
Scarcity	197
Emergency Procedures	198
AEP Twin Branch Load Shed Event	201
AEP Lonesome Pine Load Shed Event	202
PAIs and Capacity Performance	202
Real-Time Dispatch and Pricing	203
Scarcity and Scarcity Pricing	206
PJM Cold Weather Operations 2018	212
SECTION 4 ENERGY UPLIFT (OPERATING RESERVES)	213
Overview	213
Energy Uplift Credits	213
Energy Uplift Charges	214
Geography of Charges and Credits	214
Recommendations	214
Conclusion	216
Energy Uplift Results	217
Characteristics of Credits	219
Types of Units	219
Day-Ahead Unit Commitment for Reliability	220
Balancing Operating Reserve Credits	222
Lost Opportunity Cost Credits	223
Uplift Eligibility	224
Economic and Noneconomic Generation	225
Concentration of Energy Uplift Credits	226
Credits and Charges Categories	227
Energy Uplift Results	229
Operating Reserve Rates	232
Reactive Services Rates	233

Geography of Charges and Credits	235
Energy Uplift Issues	237
Intraday Segments Uplift Settlement	237
Closed Loop Interfaces	238
CT Price Setting Logic	240
Energy Uplift Recommendations	241
Recommendations for Calculation of Credits	241
Recommendations for Allocation of Uplift Charges	246
SECTION 5 CAPACITY MARKET	251
Overview	252
RPM Capacity Market	252
Reliability Must Run Service	254
Generator Performance	254
Recommendations	255
Conclusion	257
Installed Capacity	262
RPM Capacity Market	264
Market Structure	264
Market Conduct	275
Market Performance	286
Reliability Must Run (RMR) Service	292
Generator Performance	294
Capacity Factor	294
Generator Performance Factors	295
Generator Forced Outage Rates	296
SECTION 6 DEMAND RESPONSE	301
Overview	301
Recommendations	302
Conclusion	303
PJM Demand Response Programs	306
Non-PJM Demand Response Programs	307
Participation in Demand Response Programs	307
Economic Program	308
Emergency and Pre-Emergency Programs	315
Distributed Energy Resources	327
SECTION 7 NET REVENUE	329
Overview	329
Net Revenue	329
Historical New Entrant CT and CC Revenue Adequacy	329
Conclusion	330
Net Revenue	330
Spark Spreads, Dark Spreads, and Quark Spreads	331
Theoretical Energy Market Net Revenue	332

Capacity Market Net Revenue	334
Net Revenue Adequacy	335
Levelized Total Costs	335
Levelized Cost of Energy	335
New Entrant Combustion Turbine	336
New Entrant Combined Cycle	337
New Entrant Coal Plant	338
New Entrant Nuclear Plant	339
New Entrant Diesel	340
New Entrant On Shore Wind Installation	340
New Entrant Off Shore Wind Installation	341
New Entrant Solar Installation	341
Historical New Entrant CT and CC Revenue Adequacy	342
Factors in Net Revenue Adequacy	343
Actual Net Revenue	345
Nuclear Net Revenue Analysis	348
SECTION 8 ENVIRONMENTAL AND RENEWABLE ENERGY REGULATIONS	355
Overview	355
Federal Environmental Regulation	355
State Environmental Regulation	355
State Renewable Portfolio Standards	356
Emissions Controls in PJM Markets	356
Renewable Generation	356
Recommendations	356
Conclusion	356
Federal Environmental Regulation	358
CSAPR	359
Federal Regulation of Greenhouse Gas Emissions	359
Federal Regulation of Environmental Impacts on Water	360
Federal Regulation of Coal Ash	361
State Environmental Regulation	363
State Regulation of Greenhouse Gas Emissions	363
Carbon Pricing	375
Alternative Compliance Payments	376
Emissions Controlled Capacity and Renewables in PJM Markets	378
Emission Controlled Capacity in the PJM Region	378
Wind and Solar Peak Hour Output	381
Wind Units	381
Solar Units	383
SECTION 9 INTERCHANGE TRANSACTIONS	385
Overview	385
Interchange Transaction Activity	385
Interactions with Bordering Areas	386
Recommendations	386
Conclusion	387

Interchange Transaction Activity	388
Charges and Credits Applied to Interchange Transactions	388
Aggregate Imports and Exports	388
Real-Time Interface Imports and Exports	390
Real-Time Interface Pricing Point Imports and Exports	392
Day-Ahead Interface Imports and Exports	395
Day-Ahead Interface Pricing Point Imports and Exports	398
Loop Flows	404
PJM and MISO Interface Prices	411
PJM and NYISO Interface Prices	412
Summary of Interface Prices between PJM and Organized Markets	414
Neptune Underwater Transmission Line to Long Island, New York	414
Linden Variable Frequency Transformer (VFT) facility	416
Hudson Direct Current (DC) Merchant Transmission Line	417
Interchange Activity During High Load Hours	418
Operating Agreements with Bordering Areas	419
PJM and MISO Joint Operating Agreement	419
PJM and New York Independent System Operator Joint Operating Agreement (JOA)	421
PJM and TVA Joint Reliability Coordination Agreement (JRCA)	422
PJM and Duke Energy Progress, Inc. Joint Operating Agreement	422
PJM and VACAR South Reliability Coordination Agreement	424
Balancing Authority Operations Coordination Agreement between Wisconsin Electric Power Comp (WEC) and PJM Interconnection, LLC	any 424
Northeastern ISO-Regional Transmission Organization Planning Coordination Protocol	424
Interface Pricing Agreements with Individual Balancing Authorities	424
Other Agreements with Bordering Areas	425
Interchange Transaction Issues	426
Hudson Transmission Partners (HTP) and Linden VFT Requests to Convert Firm Transmission	
Withdrawal Rights (FTWR) to NonFirm Transmission Withdrawal Rights (NFTWR)	426
PJM Transmission Loading Relief Procedures (TLRs)	428
Up To Congestion	429
Sham Scheduling	431
Elimination of Ontario Interface Pricing Point	431
PJM and NYISO Coordinated Interchange Transactions	432
Reserving Ramp on the PJM/NYISO Interface	436
PJM and MISO Coordinated Interchange Transaction Proposal	437
Willing to Pay Congestion and Not Willing to Pay Congestion	440
Spot Imports	441
Interchange Optimization	442
Interchange Cap During Emergency Conditions	442
45 Minute Schedule Duration Rule	443
MISO Multi-Value Project Usage Rate (MUR)	443

viii Table of Contents © 2019 Monitoring Analytics, LLC

ECTION 10 ANCILLARY SERVICE MARKETS	445
Overview	446
Primary Reserve	446
Tier 1 Synchronized Reserve	446
Tier 2 Synchronized Reserve Market	447
Nonsynchronized Reserve Market	447
Secondary Reserve	448
Regulation Market	449
Black Start Service	450
Reactive	450
Frequency Response	451
Ancillary Services Costs per MWh of Load: 1999 through 2018	451
Recommendations	451
Conclusion	453
Primary Reserve	454
Market Structure	454
Price and Cost	458
Tier 1 Synchronized Reserve	459
Market Structure	459
Tier 1 Synchronized Reserve Event Response	461
Tier 2 Synchronized Reserve Market	464
Market Structure	464
Market Behavior	466
Market Performance	468
Nonsynchronized Reserve Market	475
Market Structure	475
Secondary Reserve	478
Market Structure	478
Market Conduct	479
Market Performance	480
Regulation Market	482
Market Design	482
Market Structure	491
Market Conduct	495
Market Performance	498
Black Start Service	501
NERC – CIP	503
Minimum Tank Suction Level (MTSL)	503
Reactive Service	504
Recommended Market Approach to Reactive Costs	505
Improvements to Current Approach	507
Reactive Costs	508
Frequency Response	509
Frequency Control Definition	510

SECTION 11 CONGESTION AND MARGINAL LOSSES	511
Overview	512
Congestion Cost	512
Marginal Loss Cost	513
Energy Cost	513
Conclusion	513
Issues	514
Locational Marginal Price (LMP)	515
Components	515
Hub Components	518
Congestion	518
Congestion Accounting	518
Total Congestion	520
Congested Facilities	527
Congestion by Facility Type and Voltage	528
Constraint Duration	531
Constraint Costs	533
Congestion Event Summary for MISO Flowgates	546
Congestion Event Summary for NYISO Flowgates	548
Congestion Event Summary for the 500 kV System	548
Congestion Costs by Physical and Financial Participants	549
Congestion Event Summary: Impact of Changes in UTC Volumes	550
Marginal Losses	553
Marginal Loss Accounting	553
Total Marginal Loss Cost	554
Energy Accounting	558
Total Energy Costs	558
SECTION 12 GENERATION AND TRANSMISSION PLANNING	563
Overview	563
Generation Interconnection Planning	563
Regional Transmission Expansion Plan (RTEP)	564
Transmission Facility Outages	565
Recommendations	566
Conclusion	567
Generation Interconnection Planning	569
Existing Generation Mix	569
Generation Retirements	571
Generation Queue	577
Regional Transmission Expansion Plan (RTEP)	595
RTEP Process	595
Backbone Facilities	595
Market Efficiency Process	595
PJM MISO Interregional Targeted Market Efficiency Process (TME	
Supplemental Transmission Projects	598
Board Authorized Transmission Upgrades	601
Qualifying Transmission Upgrades (QTU)	602

Transmission Facility Outages	602
Scheduling Transmission Facility Outage Requests	602
Rescheduling Transmission Facility Outage Requests	605
Long Duration Transmission Facility Outage Requests	606
Transmission Facility Outage Analysis for the FTR Market	607
Transmission Facility Outage Analysis in the Day-Ahead Energy Market	612
SECTION 13 FINANCIAL TRANSMISSION AND AUCTION REVENUE RIGHTS	615
Overview	617
Auction Revenue Rights	617
Financial Transmission Rights	617
Recommendations	619
Conclusion	620
Auction Revenue Rights	622
Market Structure	624
Market Performance	626
Financial Transmission Rights	627
Market Structure	628
Market Performance	633
Revenue Adequacy	646
ARRs as an Offset to Congestion for Load	652
Zonal ARR Congestion Offset	652
FERC Order on FTRs: Balancing Congestion and M2M Payment Allocation	652
Credit	654
Modified Credit Requirements	654
GreenHat Energy, LLC Default	654
GreenHat Energy Default Lessons Learned	655
Bilateral Indemnification Provisions	655
FTR Forfeitures	656
Hourly FTR Cost	656
FERC Order on FTR Forfeitures	656

xii Table of Contents © 2019 Monitoring Analytics, LLC