Table of Contents Overview: Section 12, Planning 66 Overview: Section 13, FTRs and ARRs 73 **Preface** i **SECTION 2 Recommendations** 79 **SECTION 1 Introduction New Recommendations** 79 **Q1** 2021 in Review New Recommendation from Section 3, Energy Market 80 PJM Market Summary Statistics 4 New Recommendation from Section 10, Ancillary Services 80 PJM Market Background Complete List of Current MMU Recommendations 80 Conclusions Section 3, Energy Market 80 **Energy Market Conclusion** Section 4, Energy Uplift 84 **Capacity Market Conclusion** Section 5, Capacity Market 86 Tier 2 Synchronized Reserve Market Conclusion Section 6, Demand Response 89 Day-Ahead Scheduling Reserve Market Conclusion 9 Section 7, Net Revenue 91 **Regulation Market Conclusion** 10 Section 8, Environmental and Renewables 91 FTR Auction Market Conclusion 10 Section 9, Interchange Transactions 92 Role of MMU 11 Section 10, Ancillary Services 93 Reporting 11 Section 11, Congestion and Marginal Losses 95 Monitoring 12 Section 12, Planning 95 Market Design 13 Section 13. FTRs and ARRs 97 **New Recommendations** 13 New Recommendation from Section 3, Energy Market 13 **SECTION 3 Energy Market** 101 New Recommendation from Section 10, Ancillary Services 13 Total Price of Wholesale Power 14 Overview 102 Components of Total Price 14 Supply and Demand 102 Section Overviews 19 **Competitive Assessment** 104 Overview: Section 3, Energy Market 19 Recommendations 106 Overview: Section 4, Energy Uplift 30 Conclusion 110 Overview: Section 5, Capacity Market 35 Supply and Demand 113 Overview: Section 6, Demand Response 41 **Market Structure** 113 Overview: Section 7, Net Revenue 46 Market Behavior 130 Overview: Section 8, Environmental and Renewables 47 Generator Offers 130 Overview: Section 9, Interchange Transactions 51 Parameter Limited Schedules 132 Overview: Section 10, Ancillary Services 55 Virtual Offers and Bids 137 Overview: Section 11, Congestion and Marginal Losses 64

Market Performance	146	Energy Uplift Charges	254
LMP	146	Operating Reserve Rates	257
Zonal LMP and Dispatch	165	Reactive Services Rates	260
Fuel Prices, LMP, and Dispatch	172	Balancing Operating Reserve Determinants	261
Components of LMP	178	Geography of Charges and Credits	262
Shortage	182	Energy Uplift Issues	263
Emergency Procedures	182	Intraday Segments Uplift Settlement	263
Shortage and Shortage Pricing	186	Uplift Credits and Offer Capping	264
Competitive Assessment	196		
Market Structure	196		
Market Behavior	201	SECTION 5 Capacity Market	265
Market Performance	224	Overview	266
Market Structure, Participant Behavior, and Market Performance	235	RPM Capacity Market	266
		Reliability Must Run Service	267
7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7		Generator Performance	267
SECTION 4 Energy Uplift (Operating Reserves)	237	Recommendations	267
Overview	237	Conclusion	270
Energy Uplift Credits	237	Installed Capacity	274
Energy Uplift Charges	238	Fuel Diversity	275
Geography of Charges and Credits	238	RPM Capacity Market	276
Recommendations	238	Market Structure	277
Conclusion	240	Market Conduct	289
Energy Uplift Credits Results	242	Market Performance	295
Characteristics of Credits	243	MOPR and FRR	299
Types of Units	243	CRF Issue	301
Day-Ahead Unit Commitment for Reliability	244	Timing of Unit Retirements	301
Balancing Operating Reserve Credits	245	Reliability Must Run (RMR) Service	302
Lost Opportunity Cost Credits	247	Generator Performance	304
Uplift Eligibility	248	Capacity Factor	304
Economic and Noneconomic Generation	249	Generator Performance Factors	305
Uplift Resettlement	250	Generator Forced Outage Rates	307
Concentration of Energy Uplift Credits	250		
Credits and Charges Categories	253		
Energy Uplift Charges Results	254		

iv Table of Contents © 2021 Monitoring Analytics, LLC

SECTION 6 Demand Response	311	SECTION 8 Environmental and Renewable Energ	JУ
Overview	311	Regulations	363
Recommendations	312	Overview	363
Conclusion	314	Federal Environmental Regulation	363
PJM Demand Response Programs	316	State Environmental Regulation	364
Non-PJM Demand Response Programs	318	State Renewable Portfolio Standards	364
PJM Demand Response Programs	318	Emissions Controls in PJM Markets	365
Emergency and Pre-Emergency Load Response Programs	319	Renewable Generation	365
Economic Load Response Program	330	Recommendations	365
Energy Efficiency	339	Conclusion	365
Distributed Energy Resources	340	Federal Environmental Regulation	367
		CAA: NESHAP/MATS	368
CECTION Z N 4 D	0.40	CAA: NAAQS/CSAPR	369
SECTION 7 Net Revenue	343	CAA: NSR	370
Overview	343	CAA: RICE	371
Net Revenue	343	CAA: Greenhouse Gas Emissions	371
Recommendations	343	CWA: WOTUS Definition and Effluents	372
Conclusion	343	RCRA: Coal Ash	37 3
Net Revenue	343	State Environmental Regulation	375
Spark Spreads and Dark Spreads	345	State Emissions Regulations	375
Theoretical Energy Market Net Revenue	346	State Regulation of Greenhouse Gas Emissions	375
New Entrant Combustion Turbine	348	State Renewable Portfolio Standards	382
New Entrant Combined Cycle	349	Alternative Compliance Payments	397
New Entrant Coal Plant	350	Emission Controlled Capacity and Emissions	401
New Entrant Nuclear Plant	350	Emission Controlled Capacity	401
New Entrant Diesel	351	Emissions	402
New Entrant Onshore Wind Installation	351	Renewable Energy Output	405
New Entrant Offshore Wind Installation	352	Wind and Solar Peak Hour Output	405
New Entrant Solar Installation	352	Wind Units	406
Historical New Entrant CC Revenue Adequacy	353	Solar Units409	
Nuclear Net Revenue Analysis	354		

SECTION 9 Interchange Transactions	413	Interchange Transaction Issues	452
Overview	413	PJM Transmission Loading Relief Procedures (TLRs)	452
Interchange Transaction Activity	413	Up To Congestion	453
Interactions with Bordering Areas	414	Sham Scheduling	456
Recommendations	414	Elimination of Ontario Interface Pricing Point	456
Conclusion	415	PJM and NYISO Coordinated Interchange Transactions	458
Interchange Transaction Activity	416	Reserving Ramp on the PJM/NYISO Interface	460
Charges and Credits Applied to Interchange Transactions	416	PJM and MISO Coordinated Interchange Transaction Proposal	461
Aggregate Imports and Exports	418	Willing to Pay Congestion and Not Willing to Pay Congestion	464
Real-Time Interface Imports and Exports	419	Spot Imports	465
Real-Time Interface Pricing Point Imports and Exports	421	Interchange Optimization	466
Day-Ahead Interface Imports and Exports	424	Interchange Cap During Emergency Conditions	466
Day-Ahead Interface Pricing Point Imports and Exports	426	45 Minute Schedule Duration Rule	467
Loop Flows	430	MISO Multi-Value Project Usage Rate (MUR)	468
PJM and MISO Interface Prices	437		
PJM and NYISO Interface Prices	439	SECTION 10 Ancillary Service Markets	471
Summary of Interface Prices between PJM and Organized Markets	441	· ·	
Neptune Underwater Transmission Line to Long Island, New York	441	Overview	472
Linden Variable Frequency Transformer (VFT) facility	443	Primary Reserve	472
Hudson Direct Current (DC) Merchant Transmission Line	445	Tier 1 Synchronized Reserve	472
Interchange Activity During High Load Hours	447	Tier 2 Synchronized Reserve Market	473
Operating Agreements with Bordering Areas	447	Nonsynchronized Reserve Market	474
PJM and MISO Joint Operating Agreement	448	Secondary Reserve (DASR)	474
PJM and New York Independent System Operator Joint Operating		Regulation Market	475
Agreement (JOA)	450	Black Start Service	476
PJM and TVA Joint Reliability Coordination Agreement (JRCA)	451	Reactive	477
PJM and Duke Energy Progress, Inc. Joint Operating Agreement	451	Frequency Response	477
PJM and VACAR South Reliability Coordination Agreement	452	Ancillary Services Costs per MWh of Load	477
VACAR Reserve Sharing Agreement	452	Market Procurement of Real Time Ancillary Services	478
Balancing Authority Operations Coordination Agreement		Recommendations	479
between Wisconsin Electric Power Company (WEC) and PJM		Conclusion	481
Interconnection, LLC	452	Primary Reserve	482
Northeastern ISO-Regional Transmission Organization Planning		Market Structure	482
Coordination Protocol	452	Price and Cost	486

vi Table of Contents © 2021 Monitoring Analytics, LLC

Tier 1 Synchronized Reserve	487	SECTION 11 Congestion and Marginal Losses	547
Market Structure	487	Overview	548
Tier 1 Synchronized Reserve Payments	489	Congestion Cost	548
Tier 2 Synchronized Reserve Market	491	Marginal Loss Cost	549
Market Structure	492	System Energy Cost	549
Market Behavior	494	Conclusion	550
Market Performance	496	lssues	550
Nonsynchronized Reserve Market	502	Closed Loop Interfaces and CT Pricing Logic	550
Market Structure	502	Balancing Congestion Cost Calculation Logic Change	551
Secondary Reserve (DASR)	505	Locational Marginal Price (LMP)	553
Market Structure	505	Components	553
Market Conduct	506	Hub Components	558
Market Performance	507	Congestion	559
Regulation Market	509	Congestion Accounting	559
Market Design	509	Total Congestion	562
Market Structure	522	Charges and Credits versus Congestion: Virtual Transactions,	302
Market Conduct	527	Load and Generation	563
Market Performance	530	Congested Facilities	573
Black Start Service	532	Congestion by Facility Type and Voltage	574
CRF Issues	535	Constraint Frequency	578
NERC – CIP	537	Constraint Costs	580
Minimum Tank Suction Level (MTSL)	537	Congestion Event Summary: Impact of Changes in UTC Volumes	583
Reactive Power Service and Capability	538	Marginal Losses	584
Recommended Market Approach to Reactive Costs	539	Marginal Loss Accounting	584
Improvements to Current Approach	540	Total Marginal Loss Cost	586
Reactive Costs	542	System Energy Costs	591
Frequency Response	543	Energy Accounting	591
Frequency Control Definition	543	Total System Energy Costs	591
VACAR Reserve Sharing Agreement	544	Total System Energy Costs	551
lssues	544		
Recommendations	545		

SECTION 12 Generation and Transmission Planning	597	SECTION 13 Financial Transmission and Auction	
Overview	597	Revenue Rights	671
Generation Interconnection Planning	597	Overview	675
Regional Transmission Expansion Plan (RTEP)	598	Auction Revenue Rights	675
Transmission Facility Outages	599	Financial Transmission Rights	675
Recommendations	599	Recommendations	677
Conclusion	602	Conclusion	678
Generation Interconnection Planning	603	Proposed Design	680
Existing Generation Mix	603	Auction Revenue Rights	680
Generation Retirements	610	Market Design	681
Generation Queue	616	Market Structure	682
Regional Transmission Expansion Plan (RTEP)	641	Market Performance	682
RTEP Process	641	1ARRs	684
Market Efficiency Process	641	Financial Transmission Rights	685
PJM MISO Interregional Market Efficiency Process (IMEP)	644	Market Performance	689
PJM MISO Targeted Market Efficiency Process (TMEP)	645	Surplus Congestion Revenue	699
Supplemental Transmission Projects	646	Revenue Adequacy	701
Competitive Planning Process Exclusions	650	ARRs as an Offset to Congestion for Load	705
Storage As A Transmission Asset (SATA)	651	Zonal ARR Congestion Offset	707
Board Authorized Transmission Upgrades	651	Offset Available from Self Scheduling	708
Qualifying Transmission Upgrades (QTU)	651	Credit	709
Cost Allocation	652	GreenHat Settlement Proceedings	710
Transmission Line Ratings	652	Default Portfolio Considerations	710
Transmission Facility Outages	654	FTR Forfeitures	710
Scheduling Transmission Facility Outage Requests	654		
Rescheduling Transmission Facility Outage Requests	658		
Long Duration Transmission Facility Outage Requests	659		
Transmission Facility Outage Analysis for the FTR Market	659		
Transmission Facility Outage Analysis in the Day-Ahead Energy			
Market	667		

viii Table of Contents © 2021 Monitoring Analytics, LLC