A World-Class University-Industry Consortium for Wind Energy Research, Education, and Workforce Development

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Table of Contents

Acknowledgment ii

Disclaimer iii

Table of Contents iv

List of Acronyms vii

List of Figures xi

List of Tables xxi

List of Appendices xxii

Executive Summary 1

1. Introduction 3

2. Background 5

3. Results and Discussions 9

- **3.1 Consortium Wind Unit Installation** 9
  - **3.1.1 Wind Unit Installation at Grand Ridge, Illinois** 9
    - A. Wind Unit Procurement 9
    - B. GE 1.5MW Wind Turbine 12
  - **3.1.2 Wind Unit Installation at IIT** 19
    - A. Viryd 8kW Wind Turbine 19
    - B. Viryd Lab Unit Installation at IIT 24
    - C. Viryd Field Unit Installation at IIT 29
- **3.2 Wind Energy Research and Development** 32
  - **3.2.1 Wind Turbine Research** 32
    - A. Predictive Analytics to Improve Wind Turbine Reliability 32
    - B. Improve Wind Turbine Power Output and Reduce Dynamic Stress Loading Through Advanced Wind Sensing Technology 38
    - C. Phasor Measurement Units Installation 78
    - D. Use High Magnetic Density Turbine Generator as Non-rare Earth Power Dense Alternative 79

E. Survivable Operation of Three Phase AC Drives in Wind Generator Systems 96
F. Wind Turbines Acoustics – Localization of Wind Turbine Noise Sources 169
G. Wind Turbine Acoustics – Numerical Studies 185
H. Performance of Wind Turbines in Rainy Conditions 219

3.2.2 Wind Energy Integration 237
A. Analysis of 2030 Large-Scale Wind Energy Integration in the U.S. Eastern Interconnection 237
B. Large-scale Analysis of 2018 Wind Energy Integration in the U.S. Eastern Interconnection 259
C. Integration of Non-dispatchable Resources in Electricity Markets..............................283
D. Integration of Wind Unit with Microgrid 285

3.3 Wind Energy Education and Outreach 296

3.3.1 Wind Energy Training Facility Development... 296
A. Robert W. Galvin Center for Electricity Innovation...297
B. WINS: Wind Integration Simulator...301
C. Situation Awareness at Control Center: e-terravision 302

3.3.2 Wind Energy Course Development 304
A. Engage Undergraduates in Wind Energy Research..304
B. Develop Graduate Courses in Wind Energy 340
C. Develop Professional Training Courses in Wind Energy 344

3.3.3 Wind Energy Outreach 346
A. First Consortium Conference, September 30, 2010..346
B. Second Wind Consortium Conference, July 20, 2011 347
C. Great Lakes Symposium on Smart Grid and the New Energy Economy 2011 349
D. Great Lakes Symposium on Smart Grid and the New Energy Economy 2012 353

4. Accomplishments 359

4.1 Award 359

4.2 List of Presentations..360

4.2.1 Presentations at the First Consortium Conference 360

4.2.2 Presentations at the Second Wind Consortium Conference.......................... 361

4.2.3 Other Presentations.. 362

4.3 List of Videos 362

4.4 List of Theses 363

4.4.1 Ph.D. Dissertations.. 363

4.4.2 M.S. Theses ... 373

4.5 List of Papers and Reports ... 379

4.5.1 Journal Publications ... 379

4.5.2 Conference Publications ... 389

4.5.3 Manuscripts in Preparation ... 392

4.5.4 Unpublished Reports ... 393

4.6 List of Courses ... 397

4.6.1 Undergraduate Courses ... 397

A. IPRO 311 – Integration of Plug-in Hybrid Electric Vehicles and Renewable Energy Systems ... 397
B. IPRO 323 – Modeling of Building Integrated Wind Turbine Modules ... 397
C. ECE 456 – Embedded Control and Mechatronics ... 397
D. ECE 486 – Wind Energy Research Paper ... 398
E. ECE 495 – Capstone Senior Design Project ... 398

4.6.2 Graduate Courses ... 398

A. ECE 580 – Elements of Sustainable Energy ... 398
B. ECE 581 – Elements of Smart Grid ... 399
C. ECE 581 – Wind Energy Power Systems ... 399

4.6.3 Professional Course ... 399

A. Wind Energy Technology, Interconnection & Integration ... 399

5. Conclusions ... 400

6. Recommendations ... 407

References ... 409

Appendices ... 420

List of Acronyms

A/D	Analog/Digital
AC	Alternating Current
ADS	Acoustic Data Surface
AEP	Annual Energy Production
AGC	Automatic Generation Control
AMR	Adaptive Mesh Refinement
AWC	Atlantic Wind Connection
BLDC	Brushless Direct Current
CCM	Cross Correlation Matrix
CF	Capacity Factor
CFD	Computational Fluid Dynamics
CLSC	CLEAN-SC, CLEAN based on source coherence
CO2	Carbon Dioxide
COE	Cost of energy
ComEd	Commonwealth Edison
CP	Power Capture
CSC	Current Source Converter
CSM	Cross Spectral Matrix
CTW	Catch the Wind, Inc.
CVP	Continuously Variable Planetary
CVT	Continuously Variable Transmission
DAMAS	Deconvolution Approach for the Mapping of Acoustic Sources
DAS	Delay and Sum
DAS	Data Acquisition System
DB	Database
DC	Direct Current
DCF	Domain Connectivity Function
DFIG	Doubly Fed Induction Generator
DFIM	Doubly Fed Induction Machine
DH	High Duty Cycle
DL	Low Duty Cycle
DNR	Illinois Department of Natural Resources
DOE	Department of Energy
DOF	Degree-Of-Freedom
DP	Dakota Power
DP (filter)	Filter Differential Pressure
DPM	Lagrangian Discrete Phase Model
DSP	Digital Signal Processing
DTF	Dynamometer Test Facility
ECE	Electrical and Computer Engineering

ECEDHA	Electrical and Computer Engineering Department Heads Association
EMF	Electric and Magnetic Fields
EMS	Energy Management System
EPRI	Electric Power Research Institute
FDBF	Frequency Domain Beamforming
FEA	Finite Element Analysis
FEMM	Finite Element Magnetics Method
FERC	Federal Energy Regulatory Commission
FFT	Fast Fourier Transform
GE	General Electric
GENCO	Generation Company
GIS	Geographical Information System
GMP	Geometry Manipulation Protocol
GUI	Graphical User Interface
GW	giga-watt
GWh	giga-watt-hour
HAWT	Horizontal-Axis Wind-Turbine
HVAC	Heating, Ventilation, & Air Conditioning
Hz	Hertz
I/O	Input/Output
IEC	International Electrotechnical Commission
IEEE	The Institute of Electrical and Electronics Engineers
IG	Induction Generator
IGBT	Insulated Gate Bipolar Transistors
IIT	Illinois Institute of Technology
IM	Induction Motor
IPPSC	Intelligent Perfect Power System Controller
IPRO	Interprofessional Project
IPS	Intelligent Power Solutions, LLC
ISO	Independent System Operator
IT	Information Technology
ITAC	Innovative Technology Applications Company, LLC
ITP	Incidental Take Permit
KERI	Korea Electrotechnology Research Institute
kV	kilo-volt
kW	kilo-watt
kWh	kilo-watt-hour
LIDAR	Light Detection And Ranging
LMP	Locational Marginal Price
LWS	Laser Wind Sensor
MB	mega-byte
MISO	Midwest Independent System Operator
MMAE	Mechanical, Materials, and Aerospace Engineering

MMS	Market Management System
MOSFET	Metal–Oxide–Semiconductor Field-Effect Transistor
MS	Microsoft
MTEP	MISO Transmission Expansion Planning
MTS	Modular Tower System
MUT	Machine Under Test
MW	mega-watt
MWh	mega-watt-hour
NASA	National Aeronautics and Space Administration
NEMA	National Electrical Manufacturers Association
NERC	North American Electric Reliability Corporation
NETCS	National Electric Transmission Congestion Study
NFAC	National Full-Scale Aerodynamics Complex
NPT	National Pipe Thread Tapered Thread
NREL	National Renewable Energy Laboratory
OCS	Optical Control System
OEM	Original Equipment Manufacturer
OTS	Office of Technical Services
PCB	Printed Circuit Board
PHEV	Plug-in Hybrid Electric Vehicle
PI	Principal Investigator
PJM	Pennsylvania-New Jersey-Maryland
PLC	Programmable Logic Controller
PM	Permanent Magnet
PMSM	Permanent Magnet Synchronous Motor
PMU	Phasor Measurement Units
POMS	POwer Market Simulator
PV	Photovoltaic
PWM	Pulse With Modulation
RFP	Request for Proposal
ROR	reduced-order representation
RPM	Revolutions Per Minute
SA	Supervisor Agent
SCADA	Supervisory Control and Data Acquisition System
SCUC	Security-Constrained Unit Commitment
SIU	Southern Illinois University
SMI	Standard Module Interface
SOC	State of Charge
SPIV	Stereoscopic Particle Image Velocimetry
SPL	Sound Pressure Level
SQL	Structured Query Language
SR	Switched Reluctance
SRDCM	Switch Reluctance DC Machine

SRM	Switched Reluctance Machine
SST	Shear-Stress Transport
SUP	Special Use Permits
SVPWM	Space Vector Pulse Width Modulation
THD	Total Harmonic Distortion
TSR	Tip Speed Ratio
TW	terra-watt
TWh	terra-watt-hour
USB	Universal Serial Bus
V2G	Vehicle to Grid
VAR	Volt-Amp-Reactive
VLAN	Virtual Local Area Network
VOF	Eulerian Volume of Fluid Model
VPN	Virtual Private Network
VPPC	Vehicle Power and Propulsion Conference
VSC	Voltage Source Converter
WECS	Wind Energy Conversion Systems
WFMS	Wind Farm Management System
WG	Wind Generation
WINS	Wind INtegration Simulator
WISER	IIT Wanger Institute for Sustainable Energy Research
WPP	Wind Power Plants
WTC	Wind Turbine Contract
WTG	Wind Turbine Generator
WTGU	Wind Turbine Generating Unit
XML	Extensible Markup Language

List of Figures

Figure 1: Screenshots of IIT Wind Turbine at Grand Ridge Wind Farm 11
Figure 2: GE Energy 1.5SLE/XLE 60Hz Wind Turbine Generator 12
Figure 3: GE Energy 1.5SLE/XLE 60Hz Wind Turbine Nacelle Layout 13
Figure 4: Power performance for winter operation 18
Figure 5: TSR pitch control schedule 18
Figure 6: Viryd 8KW Wind Turbine Technical Specification 20
Figure 7: Viryd 8KW Wind Turbine Power Curve 22
Figure 8: Viryd 8KW Wind Turbine Annual Energy Production 22
Figure 9: Cross-Section and Components of the Viryd Wind Turbine 23
Figure 10: Viryd 8kW Unit Fully Instrumented and Designed for the IIT Lab 26
Figure 11: Screenshot of the Lab Unit 27
Figure 12: Screenshot of the Lab Unit 28
Figure 13: Viryd 8kW Unit Installed at the IIT Soccer Field 29
Figure 14: Installation Chronology for the Viryd 8kW Unit at the IIT Soccer Field 30
Figure 15: Display of the Wind Speed and Power Output for the Field Unit 31
Figure 16: Screenshot of the Software Monitoring the Field Unit 32
Figure 17: IIT – Invenergy – SmartSignal Wind Project: Overall Network Arrangement 34
Figure 18: IIT – Invenergy – SmartSignal Wind Project: Detail at Grand Ridge Wind Farm 35
Figure 19: Sample SmartSignal Predictive Analytics Display 37
Figure 20: Sample SmartSignal Software Display 38
Figure 21: Catch the Wind Vindicator® Laser Wind Sensor 41
Figure 22: The data of a sonic anemometer, mounted on the rear of the nacelle of an operating wind turbine 43
Figure 23: The wind speed in front of the turbine, measured with the OCS. 44
Figure 24: Outputs of the sonic anemometers 44
Figure 25: Experimental LIDAR data. 45
Figure 26: The correlation between the wind speed behind the turbine blades and the free wind 46
Figure 27: The correlations between the different measurement tools. 47
Figure 28: A plot of real-time wind speed measured by the OCS and both sonic anemometers. 48
Figure 29: The fitted curves of wind speed as measured by the anemometer and the OCS. 48
Figure 30: The wind angle, measured each second, of a sonic wind vane mounted at the rear of the nacelle. 49
Figure 31: The correlations between the sonic wind vanes and the OCS when measuring wind angle. ... 50
Figure 32: Scatter plot of wind angles relative to the turbine measured by a single sonic wind vane plotted against the wind angle measured by the OCS, while under legacy control. 50
Figure 33: The scatter plot of wind angles of a turbine measured by a single sonic wind vane plotted against the wind angle measured by the OCS, while the turbine is under OCS control. 51
Figure 34: A scatter plot of output power vs. angle as measured by the OCS. 52
Figure 35: A comparison of measured wind angles. 53

Figure 36: A scatter plot of all wind speed measurements of a turbine from the beta version of the OCS over a period approximately 30 days. 54
Figure 37: The output power of the turbine during the entire period of study. 55
Figure 38: The power output of the turbine, at one-second intervals, over a 100 second period. 56
Figure 39: A scatter plot of power output vs. wind speed. 57
Figure 40: A scatter plot of output power vs. wind speed. 58
Figure 41: The fitted functions for legacy (red curve) and OCS (all three control modes) (blue curve). ... 58
Figure 42: The tabulated results of the various control methods. 59
Figure 43: The fitted functions for legacy (red curve) and OCS Mode 1 (blue curve). 60
Figure 44: A scatter plot of the output power of the turbine vs. wind angle as measured by the OCS. 62
Figure 45: A scatter plot of power vs. post-rotor wind angle measured by the anemometer. 63
Figure 46: The measured distribution of wind angles, as measured in the post-rotor wind flow. 64
Figure 47: The distribution of yaw angles with respect to the free wind, as measured by the OCS. 65
Figure 48: The distribution of yaw angles, measured in the post-rotor flow by the sonic anemometer... 66
Figure 49: The distribution of yaw angles, based upon the free wind in front of the turbine as measured by the OCS. 67
Figure 50: The scatterplot of wind angle as measured by the post-rotor anemometer. 68
Figure 51: A contour plot showing curves of constant wind speed. 69
Figure 52: Simulink model of the yaw control system. 71
Figure 53: Surface plot of the representative power improvement based on the model of cos3 of wind direction error at the rotor versus the two parameters: yaw threshold and moving average time. 72
Figure 54: Surface plot of the fraction of time yawing versus the two parameters: yaw threshold and moving average time. 73
Figure 55: State diagram for the OCS, showing the direction of state transitions. 76
Figure 56: Phasor Measurement Unit (PMU) Installed at IIT's Stuart Building 78
Figure 57: Stuart Building PMU data showing the building transformer loads, wind turbine, and PV system 79
Figure 58: Growth of Wind Power 81
Figure 59: Distribution of Wind Resource 81
Figure 60: Transmission Grid for 400 GW 81
Figure 61: Skystream Residential Wind Turbine 82
Figure 62: Stator salient poles 83
Figure 63: Rotor salient poles 83
Figure 64: Stator and rotor poles separated by air gap 83
Figure 65: End of a Switched Reluctance Machine 83
Figure 66: Magnetic Field Produced by Stator Coil 84
Figure 67: Dakota Power machine DP-06 mounted in the Dynamometer Test Facility 87
Figure 68: Comparison of peak specific power of DP-06 of .67 kW /kg to peak specific power of commercial machines 87
Figure 69: IGBT power driver board 88
Figure 70: Schematic diagram for DP 06 89
Figure 71: Stator current diagram for generating electricity 90

Figure 72: Maxwell plot showing the stator reduced flux density 90
Figure 73: The DP-10 lightweight segmented stator 91
Figure 74: DP-10 stator stack wound with 35 turns of 17gauge magnet wire 91
Figure 75: Model of an assembled DP-10 showing the segmented windings 92
Figure 76: Maxwell plot of DP-12 illustrating the unique geometry of the poles of the stator 93
Figure 77: Plot of the Maxwell simulation of the stator current of the three phases of DP-12 with operation as a switched reluctance generator 93
Figure 78: Quick Machine model of DP-06. 94
Figure 79: FEMM simulation of DP – 06. 95
Figure 80: MATLAB plot of a parametric sweep of the current and rotor angle – Z Axis torque 95
Figure 81: US annual and cumulative wind power capacity growth [1] 97
Figure 82: Percentage of renewable electricity [1] 97
Figure 83: Unplanned repair cost and risk of failure with wind plant age [1] 98
Figure 84: Failure rate of different component in wind turbine [1] 100
Figure 85: Typical topology of converter 100
Figure 86: Four-leg fault tolerant inverter 101
Figure 87: Redundant inverter topology 102
Figure 88: Wind turbine down time caused by component failure [2] 104
Figure 89: Conventional drive train of wind turbine [2] 104
Figure 90: Tower supported rotor configuration [15] 106
Figure 91: Direct drive wind turbine configuration [2] 106
Figure 92: Equivalent circuit of induction machine in d-q axis 107
Figure 93: Passive converter topology 109
Figure 94: Active converter topology 110
Figure 95: Inverter for induction machine 111
Figure 96: Six-Step waveform 112
Figure 97: Speed torque characteristics at different voltage level 113
Figure 98: Principle of state transition control of induction machine 114
Figure 99: PWM six-step waveform 115
Figure 100: Principle of state transition control of induction machine 115
Figure 101: Speed response in steady state 118
Figure 102: Instantaneous speed read from an incremental encoder 120
Figure 103: Speed error when sampling frequency is 5kHz 122
Figure 104: Speed error when sampling frequency is 10kHz 122
Figure 105: Speed error under different conditions 122
Figure 106: PWM six-step waveform with deadband 123
Figure 107: Induction Machine Phase Voltage with spikes 124
Figure 108: PWM six-step waveform with deadband 124
Figure 109: PWM six-step waveform with deadband 125
Figure 110: Block diagram of the proposed state transition control of Induction Machine 125
Figure 111: Speed response of the state transition control of induction machine 126
Figure 112: Speed response in steady-state 126

Figure 113: Change of duty cycle in steady-state 127
Figure 114: State current in steady-state 127
Figure 115: Hardware setup for experimental verification of proposed state transition control strategy of an Induction Machine 128
Figure 116: Speed response when reference speed is 2850rpm 129
Figure 117: PWM duty cycle profile when reference speed is 2850rpm 129
Figure 118: Phase current of Induction machine during start-up when reference speed is 2850rpm 130
Figure 119: Phase current of Induction Machine during steady-state when reference speed is 2850rpm 130
Figure 120: Speed response when reference speed is 2250rpm 131
Figure 121: Speed response when reference speed is 1125rpm 131
Figure 122: Step change of speed from 2250rpm to 3000rpm 132
Figure 123: Step change of speed from 2250rpm to 1125rpm 132
Figure 124: Hardware setup for experimental verification of proposed state switching 133
Figure 125: Speed response when reference speed is 1025rpm and load torque is 1Nm 134
Figure 126: Phase current and change of PWM duty cycle when reference speed is 1025rpm 134
Figure 127: Speed response when reference speed is 366rpm and load torque is 1Nm 135
Figure 128: Phase current and change of PWM duty cycle when reference speed is 366rpm 135
Figure 129: Speed response when reference speed is 1025rpm and load torque changes from 0.5Nm to 1.5Nm 136
Figure 130: Phase current and change of PWM duty cycle when load torque is 0.5Nm 136
Figure 131: Phase current and change of PWM duty cycle when load torque is 1.5Nm 137
Figure 132: Speed response when reference speed changes from 1025rpm to 366rpm 137
Figure 133: Block diagram of state transition control of Induction Generator 138
Figure 134: Speed response of the induction generator 138
Figure 135: Steady state error and change of duty cycle 139
Figure 136: Hardware setup for experimental verification of proposed state switching control strategy of an Induction Generator 139
Figure 137: Speed response when reference speed is 1025 rpm 140
Figure 138: DC link voltage, current and change of duty cycle 140
Figure 139: Phase current and change of duty cycle 141
Figure 140: Speed response when reference speed is 586rpm 141
Figure 141: DC link voltage, current and change of duty cycle 142
Figure 142: Phase current and change of duty cycle 142
Figure 143: Speed response under step change of prime mover torque 143
Figure 144: DC link voltage, current and change of duty cycle at 2Nm 143
Figure 145: Speed response under step change of reference speed 144
Figure 146: Proposed survivable drive for three-phase IM 145
Figure 147: Basic principle of current sensor failure detection 145
Figure 148: Current sensor failure detection method (without DC offset) 146
Figure 149: |Isum| of three phase currents under different number of current sensor failure 149
Figure 150: Block diagram of vector control 150

Figure 151: Rotor flux position estimation 150
Figure 152: Voltage vector space 152
Figure 153: Ur and Ul Calculation 153
Figure 154: Usable area for the voltage vector us 154
Figure 155: Tr and Tl calculation 155
Figure 156: Relationship between switching time variables 156
Figure 157: Limit voltage vector 156
Figure 158: Limit voltage vector within the inscribed circle 157
Figure 159: Limit voltage vector within the hexgon 158
Figure 160: Speed response of vector controlled induction motor 158
Figure 161: Torque performance of vector controlled induction motor 158
Figure 162: Phase current of vector controlled induction motor 159
Figure 163: Speed response of vector controlled induction generator 159
Figure 164: Torque performance of vector controlled induction generator 160
Figure 165: Phase current of vector controlled induction generator 160
Figure 166: The generated DC link current flowing into the battery 160
Figure 167: Braking torque and speed dip caused by misfiring of switches 161
Figure 168: Phasor diagram of rotor flux angle and voltage vector 161
Figure 169: Survivable operation of IM without smooth transition strategy 163
Figure 170: Survivable operation of IM with smooth transition strategy 164
Figure 171: Experimental results of survivable operation of IM in the event of current sensor failure with smooth transition strategy (speed ref 1000rpm, load torque 1Nm) 166
Figure 172: Experimental results of survivable operation of IM in the event of current sensor failure with smooth transition strategy (speed ref 500rpm, load torque 1Nm) 167
Figure 173: Experimental results of survivable operation of IG in the event of current sensor failure with smooth transition strategy (speed ref 1000rpm, load torque 1Nm) 168
Figure 174: Schematic of (a) components of a wind turbine and (b) Noise producing mechanisms on a rotor blade. 170
Figure 175: Schematic of (a) the speaker arranged on the rectangular frame support at the 9_0_9 position and (b) the microphone array. 172
Figure 176: Beamform maps of narrowband frequency ranging between 173
Figure 177: Sound pressure level spectra from the microphone array and single microphone respectively of the cases 174
Figure 178: Comparison of beamform maps obtained from FDBF, DMS2, CLSC and TIDY for multiple incoherent and coherent sources of the same amplitude (9.6_0.0_9.6). 176
Figure 179: Comparison of beamform maps obtained from FDBF, DMS2, CLSC and TIDY for multiple incoherent and coherent sources of different amplitude (9.6_0.0_9.4). 177
Figure 180: Comparison of beamform maps obtained from FDBF, DMS2, CLSC and TIDY for three incoherent and coherent sources of the same amplitude (9.6_0.6_9.6). 177
Figure 181: Beamform map of a single oscillating source at three different positions during oscillation obtained using TIDY. 178
Figure 182: The GE 1.5 MW wind turbine located at the Invenergy wind farm in Grand Ridge, Illinois. . 179

Figure 183: Beamform map of the GE 1.5 MW wind turbine using DAS. 180
Figure 184: Beamform map of the GE 1.5 MW wind turbine using TIDY. 180
Figure 185: Beamform map of the GE 1.5 MW wind turbine using TIDY at a particular instant of time during its rotation. 181
Figure 186: Schematic of. (a) time series of the wind turbine noise measured using the microphone array showing the increase in amplitude due to yaw motor, (b) the beamform map (TIDY) showing the nacelle noise at 1087-1149 Hz when the yaw motors are not operational and (c) the beamform map (TIDY) showing the nacelle noise at 1087-1149 Hz when the yaw motors are operational. 182
Figure 187: Viryd 8 kW wind turbine drive train simulator. 183
Figure 188: Beamform map of the gearbox at wind speed 6 m/s and turbulence 0% using TIDY. 183
Figure 189: Beamform map of the gearbox at wind speed 6 m/s and turbulence 0% using TIDY. 184
Figure 190: Beamform map of the CVP at wind speed 6 m/s and turbulence 0% using TIDY................. 184
Figure 191: Locations of Ffowcs Williams-Hawkings surfaces at which data was saved in the unsteady 3-D case 193
Figure 192: Arrangement of the synthetic microphone array used for the Phase I work....................... 194
Figure 193: Spectra predicted by PSU-WOPWOP at Microphone 1 location 194
Figure 194: Spectra predicted by PSU-WOPWOP at microphone 23 location 195
Figure 195: "Side view" orientation of the microphone array 195
Figure 196: "Top view" orientation of the microphone array 195
Figure 197: "Back view" orientation of the microphone array... 196
Figure 198: Average array spectra computed at the three different array positions 196
Figure 199: Frequency range used for monopole-oriented analysis of 5kHz peak 197
Figure 200: Noise sources identified by conventional beamforming 197
Figure 201: Noise sources identified by conventional beamforming with enhanced resolution............ 198
Figure 202: Noise sources identified using the DAMAS2 algorithm 198
Figure 203: Noise sources identified using the CLEAN-SC method 198
Figure 204: Noise sources identified using OptiNav's TIDY algorithm... 198
Figure 205: Frequency range used for monopole-oriented analysis of 2.5kHz peak 199
Figure 206: Low frequency peak noise sources identified using conventional beamforming 199
Figure 207: Low frequency peak noise sources identified using conventional beamforming with enhanced resolution 199
Figure 208: Low frequency peak noise sources identified using DAMAS2 200
Figure 209: Low frequency peak noise sources identified using TIDY 200
Figure 210: Wide frequency band processing results using conventional beamforming 201
Figure 211: Wide frequency band processing results using TIDY 201
Figure 212: TIDY analysis of top view data in a frequency band centered on secondary peak near 1.4 kHz 201
Figure 213: TIDY analysis of top view data in a frequency band centered on primary peak near 2.5 kHz 202
Figure 214: TIDY analysis of top view data in a frequency band centered on secondary peak near 5 kHz 202

Figure 215: TIDY analysis of top view data in a frequency band centered on secondary peak near 7 kHz 202
Figure 216: TIDY analysis of top view data in a frequency band between 8 and 15 kHz 203
Figure 217: TIDY analysis of 1/3 octave lower frequency bands with the synthetic array in the "back view" position 204
Figure 218: TIDY analysis of 1/3 octave higher frequency bands with the synthetic array in the "back view" position 204
Figure 219: Summary of beamforming analysis results 205
Figure 220: The NREL 10m research wind turbine 206
Figure 221: Simulated NREL 10 m research wind turbine geometry (solid surfaces) 207
Figure 222: Surface computational mesh in the blade tip region of the NREL 10 m research wind turbine 207
Figure 223: Surface computational mesh in the blade near-hub region of the NREL 10 m research wind turbine 208
Figure 224: Cross-section through the centerline of the mesh near the start of the simulation (after 8 time steps) 208
Figure 225: Mesh cross-section along centerline after 5488 steps (every other point plotted) 209
Figure 226: Computed surface pressures on the 10 meter wind turbine 210
Figure 227: Streamlines of flow around the wind turbine rotor 210
Figure 228: Iso-surface of vorticity magnitude in the flow around the wind turbine 211
Figure 229: Streamwise force on wind turbine as a function of time step 212
Figure 230: History of forces normal to the streamwise direction on the wind turbine simulation 213
Figure 231: Moments about the base of the wind turbine mast as a function of time 213
Figure 232: Vorticity magnitude behind the wind turbine mast five meters above the ground plane 214
Figure 233: Vorticity magnitude on a constant-y plane one meter above the lower limit of the rotor sweep 214
Figure 234: Vorticity magnitude on a constant-y plane through the nacelle centerline 215
Figure 235: Vorticity magnitude on a constant-y plane one meter below the upper limit of the rotor sweep 215
Figure 236: Pressure on a constant-y plane one meter above the lower limit of the rotor sweep 217
Figure 237: Magnitude of pressure gradient on a constant-y plane 217
Figure 238: Magnitude of pressure gradient on a constant-x plane upstream of the rotor 218
Figure 239: S809 airfoil profile 222
Figure 240: NREL: Phase II (untwisted blade) test configuration 222
Figure 241: 2-D mesh for calculation 223
Figure 242: Refined boundary layer 223
Figure 243: 3-D model of the turbine 224
Figure 244: 3-D computational domain 224
Figure 245: 3-D mesh 224
Figure 246: S809 Lift coefficients at different AoA 229
Figure 247: S809 Drag coefficients at different AoA 230
Figure 248: Velocity contour near the airfoil 230

Figure 249: Power output vs. wind speed 231
Figure 250: Contours of the water volume fraction on the trailing edge of the airfoil for different angles of attack shows accumulation of water on the airfoil 232
Figure 251: Comparison of lift coefficients at different angles of attack with and without rain 234
Figure 252: Comparison of drag coefficients at different angles of attack with and without rain 234
Figure 253: Lift-to-drag ratio at different angles of attack with and without rain 235
Figure 254: Comparison between pressure coefficient distribution on the airfoil at different angles of attack with and without rain 236
Figure 255: Framework of WINS 238
Figure 256: Potential Wind Sites in the Eastern Interconnection 239
Figure 257: Annual Hourly Load Profile 239
Figure 258: Hourly Production Cost without Wind Integration 241
Figure 259: Potential Wind Sites with CF ≥ 40% 241
Figure 260: Monthly Wind Energy and its Contribution to Total Energy in Scenario 2 242
Figure 261: Wind Energy Contribution at Peak/Off-Peak Hours in Scenario 2 242
Figure 262: Hourly Production Cost in Scenario 2 243
Figure 263: Potential Wind Sites with CF ≥ 30% 243
Figure 264: Monthly Wind Energy and its Contribution to Total Energy in Scenario 3 244
Figure 265: Wind Contribution at Peak/Off-Peak Hours in Scenario 3 244
Figure 266: Hourly Production Cost in Scenario 3 245
Figure 267: Monthly Wind Energy and its Contribution to Total Energy in Scenario 4 245
Figure 268: Wind Energy Contribution at Peak/Off-Peak Hours in Scenario 4 246
Figure 269: Hourly Production Cost in Scenario 4 246
Figure 270: Energy Portfolio in Wind Integration Scenarios 246
Figure 271: Hourly Energy Provided by Gas Units in Wind Integration Scenarios 247
Figure 272: Hourly Energy Provided by Coal Units in Wind Integration Scenarios 247
Figure 273: Hourly Wind Energy in Wind Integration Scenarios 247
Figure 274: Unit Commitment Result in Wind Integration Scenarios 248
Figure 275: Production Cost in Fuel Cost Scenarios 249
Figure 276: Wind/Non-Wind Energy for Wind Energy Scenarios 250
Figure 277: Production Cost for Wind Energy Scenarios 250
Figure 278: Energy Portfolio in Wind Energy Scenarios 251
Figure 279: Wind/Non-Wind Energy in Load Scenarios 251
Figure 280: Production Cost in Load Scenarios 252
Figure 281: Energy Portfolio in Load Scenarios 252
Figure 282: Hourly Energy Provided by Gas Units in Load Scenarios 253
Figure 283: Hourly Energy Provided by Coal Units in Load Scenarios 253
Figure 284: Unit Commitment Result in Load Scenarios 254
Figure 285: Hourly Energy Portfolio in Carbon Cost Scenarios 255
Figure 286: Hourly Energy Provided by Gas Units in Carbon Cost Scenarios 255
Figure 287: Hourly Energy Provided by Coal Units in Carbon Cost Scenarios 256
Figure 288: Energy Portfolio in Load Shedding Scenarios 256

Figure 289: Unit Commitment Result in Scenario 21 257
Figure 290: Unit Commitment Result in Scenario 22 257
Figure 291: Unit Commitment Result in Scenario 23 257
Figure 292: Hourly Energy Provided by Gas Units in Load Shedding Scenarios 258
Figure 293: Annual Hourly Load Profile 261
Figure 294: The 2018 Hourly Production Cost in Scenario 1 264
Figure 295: The 2018 Hourly Production Cost in Scenario 2 264
Figure 296: The 2018 Annual Average LMPs in Scenario 2 265
Figure 297: Monthly Generation Credit, Load Payment and Production Cost in Scenario 2 265
Figure 298: The 2018 Hourly Production Cost in Scenario 3 266
Figure 299: Monthly Available Wind Energy and its Contribution in Scenario 3 266
Figure 300: The 2018 Hourly Production Cost in Scenario 4 267
Figure 301: Monthly Wind Energy and its Contribution in Scenario 4 267
Figure 302: The 2018 Monthly Available and Dispatched Wind Energy 268
Figure 303: Monthly Generation Credit, Load Payment and Production Cost in Scenario 4 268
Figure 304: Annual Average LMPs in Scenario 4 269
Figure 305: Energy Production Portfolios in Scenarios 1-4 269
Figure 306: Hourly Energy Provided by Gas Units in Scenarios 1-4 270
Figure 307: Hourly Energy Provided by Coal Units in Scenarios 1-4 270
Figure 308: Hourly Wind Energy in Scenarios 2 and 4 271
Figure 309: Transmission Utilization with/without Wind Energy Integration 271
Figure 310: Transmitted Energy in 2018 with/without Wind Integration 272
Figure 311: Levelized Energy Flow in 2018 with/without Wind Integration 272
Figure 312: Annual Unit Commitment in Scenarios 1-4 273
Figure 313: Economic Metrics in Fuel Price Scenarios 274
Figure 314: Levelized Congestion Cost and Wind Energy Contribution in Fuel Price Scenarios 274
Figure 315: Economic Metrics for Available Wind Energy Scenarios 275
Figure 316: Levelized Congestion Cost and Wind Contribution in Wind Energy Scenarios 276
Figure 317: Energy Production Portfolios in Wind Energy Production Scenarios 276
Figure 318: Economic Metrics in Load Scenarios 276
Figure 319: Annual Unit Commitment in Load Variation Scenarios 278
Figure 320: Levelized Congestion Cost and Wind Contribution in Load Scenarios 278
Figure 321: Energy Production Portfolios in Load Scenarios 279
Figure 322: Economic Factors in Carbon Cost Scenarios 279
Figure 323: Levelized Congestion Cost, Wind Contribution, and LMP in Carbon Cost Scenarios 279
Figure 324: Energy Production Portfolios in Carbon Cost Scenarios 280
Figure 325: Economic Factors in Load Shedding Scenario 280
Figure 326: Energy Production Portfolios in Load Shedding Scenario 281
Figure 327: Energy Provided by Load Shedding Scenario 281
Figure 328: Annual Unit Commitment in Scenario 19 281
Figure 329: Overview of IPPSC 286
Figure 330: Viryd Data Logger Communications 287

Figure 331: IPPSC Servers and Software Modules 292
Figure 332: Screen Shot of IPPSC Wind Turbine Page 295
Figure 333: Floor plan of the training facility 297
Figure 334: State-of-the-art facility at the Galvin Center 299
Figure 335: IIT Perfect Power System overview 300
Figure 336: IIT Electric Vehicle Charging Stations 300
Figure 337: IIT Rooftop Solar Installation 300
Figure 338: IIT Large-scale Battery Storage 301
Figure 339: Architecture for the Design and the Implementation of WINS 302
Figure 340: Enhanced Situation Awareness in Control Centers 303
Figure 341: Wind map supplied by the U.S. Department of Energy 306
Figure 342: Power output vs. Hour for 42 turbines. 312
Figure 343: One-line Diagram of the 6-bus System 315
Figure 344: Scenario 3 PHEV Load Demand 316
Figure 345: Scenario 4 PHEV Load Demand 316
Figure 346: Scenario 5 PHEV Load Demand 317
Figure 347: Scenario 6 PHEV Load Demand 317
Figure 348: Total operational cost. 319
Figure 349: Optimal operational cost. 320
Figure 350: Schematic representation of flow through an actuator disc. 323
Figure 351: Plot of velocity ratios versus efficiency 325
Figure 352: Photograph depicting porous plate set-up in wind tunnel 326
Figure 353: Velocity profiles downstream of a porous plate for several streamwise and vertical locations. 326
Figure 354: Normalized Velocity as a function of normalized streamwise distance for a 62.3% porous plate. 327
Figure 355: Photograph of Porous plate and surface shape in wind tunnel. 328
Figure 356: Schematic illustrating several porous plate testing locations. 329
Figure 357: Power output for various wind speeds and mesh locations 329
Figure 358: Surface Design with helical turbines located at the center of each shape. 330
Figure 359: Example of a high-rise building with the surface design implemented vertically along the sides of the building 330
Figure 360: Example of shorter buildings with the surface shape designed to cover the roof. 331
Figure 361: A schematic of a building with the wind turbine surface design integrated onto the side ... 331
Figure 362: An example of buildings with the same area and different perimeters. 332
Figure 363: Analysis of hotel design and building perimeter. 333
Figure 364: Analysis of power consumption for different sized buildings. 333
Figure 365: Recommendations for future architectural research in IPRO 323. 334
Figure 366: Control System Diagram 338
Figure 367: Power System Diagram 338

List of Tables

Table 1: Technical Data for the 1.5MW GE Wind Turbine: Rotor 16
Table 2: Technical Data for the 1.5MW GE Wind Turbine: Pitch System 16
Table 3: Operational Limits of the 1.5MW GE Wind Turbine 16
Table 4: Viryd 8000 Technical Datasheet 21
Table 5: State table for the OCS, demonstrating logic for state transitions. 76
Table 6: Dakota Power Switched Reluctance Technology 86
Table 7: Switching Status for Different Regions of Six-step Drive Method 112
Table 8: Switching Status of PWM Six-step Drive Method 115
Table 9: Parameters of the Induction Machine and DC Brush Load Used 128
Table 10: Parameters of the Induction Machine and DC Brush Load Used 133
Table 11: Sensor Failure and Parameters 147
Table 12: The relationship between P and sector number 152
Table 13: |Ur| and | Ul| calculation table 153
Table 14: Initial Voltage Vectors for State Switching Control Based on Rotor Flux Angle 162
Table 15: Induction Motor Parameters 164
Table 16: Summary of Governing Equations 225
Table 17: Degradation of Lift Coefficient due to the Rain at Different Angles of Attack 233
Table 18: Increase of Drag Coefficient due to the Rain at Different Angles of Attack 233
Table 19: Lift-to-Drag Ratio 233
Table 20: Summary of Simulation Results in All Scenarios 259
Table 21: 24 hour forecasted wind speeds. 307
Table 22: 24 hour wind speed values at 80 meters above ground level. 310
Table 23: Vestas V90 wind turbine characteristics. 310
Table 24: Maximum power, captured power, and produced power by 42 turbines. 311
Table 25: The coefficients of cost function for generators 313
Table 26: Linearized cost functions for generators 313
Table 27: Slopes of the linearized cost functions for generators 314
Table 28: Annual power output for increasing wind speeds typical of urban environments. 334

List of Appendices

Appendix A: Project Summary Presentation

Appendix B: Grand Ridge Wind Unit Video Clip

Appendix C: Journal and Conference Publications

Executive Summary

Since January 2010, the Illinois Institute of Technology (IIT), with an ABET accredited engineering program, has led an extensive effort in forming a world-class wind energy consortium (the Consortium) of multiple universities (domestic and international) and multiple industry participants (all types of wind energy stakeholders) to perform focused research and development on critical wind energy challenges identified in the "20% Wind Energy by 2030" report, including wind technology challenge, grid system integration, and workforce development. During the two-year project period, the consortium members have developed control algorithms for enhancing the reliability of wind turbine components. The consortium members have developed advanced operation and planning tools for accommodating the high penetration of variable wind energy. The consortium members have developed extensive education and research programs for educating the stakeholders on critical issues related to the wind energy research and development.

More specifically,

- The Consortium procured a 1.5MW GE wind unit by working with the world leading wind energy developer, Invenergy, which is headquartered in Chicago, in September 2010. The Consortium also installed advanced instrumentation on the turbine and performed relevant turbine reliability studies.

- The Consortium, by working with Viryd Technologies, installed an 8kW Viryd wind unit (the Lab Unit) at an engineering lab at IIT in September 2010 and an 8kW Viryd wind unit (the Field Unit) at the Stuart Field on IIT's main campus in July 2011, and performed relevant turbine reliability studies. IIT's existing microgrid provides a unique opportunity to see how local wind turbine generation might affect the microgrid.

- The consortium performed research on turbine reliability including (1) Predictive Analytics to Improve Wind Turbine Reliability; (2) Improve Wind Turbine Power Output and Reduce Dynamic Stress Loading Through Advanced Wind Sensing Technology; (3) Use High Magnetic Density Turbine Generator as Non-rare Earth Power Dense Alternative; (4) Survivable Operation of Three Phase AC Drives in Wind Generator Systems; (5) Localization of Wind Turbine Noise Sources Using a Compact Microphone Array; (6) Wind Turbine Acoustics - Numerical Studies; and (7) Performance of Wind Turbines in Rainy Conditions. The consortium performed research on wind integration including (1) Analysis of 2030 Large-Scale Wind Energy Integration in the Eastern Interconnection; (2) Large-scale Analysis of 2018 Wind Energy Integration in the Eastern U.S. Interconnection; (3) Integration of Non-dispatchable Resources in Electricity Markets; (4) Integration of Wind Unit with Microgrid. The consortium research resulted in
    - 36 papers
    - 36 presentations
    - 13 PhD degrees
    - 9 MS degrees
    - 7 awards

- The education and outreach activities on wind energy included (1) Wind Energy Training Facility Development; (2) Wind Energy Course Development; (3) Wind Energy Outreach.

  1) The wind energy training facility is located at the Robert W. Galvin Center for Electricity Innovation at IIT. The Galvin Center brings together faculty, students, researchers, industry, government, innovators, and entrepreneurs to collaborate to improve the reliability, security and efficiency of the electric grid and overcome obstacles to the national adoption and implementation of sustainable energy.

  2) For the Wind Energy Outreach, the Center for Electricity Innovation hosted the 2010 meeting of the Consortium members on September 30, 2010 and the 2011 meeting on July 19, 2011 on IIT’s main campus in Chicago. Ribbon Cutting Events were held to commemorate the installation of the 1.5MW GE Wind Unit and the 8kW Viryd Wind Unit (the Field Unit) at the 2011 meeting. In addition, the Center for Electricity Innovation hosted the first Great Lakes Symposium on Smart Grid and the New Energy Economy on October 18-19, 2011 and the second on September 24-26, 2012 on IIT’s main campus in Chicago. The Symposium featured keynote and plenary sessions, technical presentations, and tutorials by international experts on renewable energy applications.