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

Lead Organization: Illinois Institute of Technology

Principal Investigator: Mohammad Shahidehpour

2012
Project Objectives

The consortium’s research and development objectives will be focused on addressing several challenges identified in the “20% Wind Energy by 2030” report:

1) **Wind Technology.** The consortium members will develop control algorithms for enhancing the reliability of wind turbine components.

2) **Grid System Integration.** The consortium members will develop advanced operation and planning tools for accommodating the high penetration of intermittent wind energy in electric power utility systems.

3) **Research & Development.** The consortium members will educate the stakeholders on critical issues related to the wind energy research and development.

4) **Workforce Development.** The world-class wind energy education and research programs developed by the consortium will outlast the proposed two-year period of the project.
Members of the *World-Class Wind Energy Consortium*

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<tr>
<th><strong>University Members</strong></th>
<th><strong>Point of Contact</strong></th>
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<tr>
<td>Illinois Institute of Technology (Lead)</td>
<td>John Birge, Professor</td>
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<tr>
<td>University of Chicago</td>
<td>Morteza Daneshdoost, Professor</td>
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<tr>
<td>Southern Illinois University</td>
<td>Antonio Conejo, Professor</td>
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<td>University of Castilla - La Mancha (Spain)</td>
<td>Newton Bretas, Professor</td>
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<td>University of São Paulo (Brazil)</td>
<td>Anastasio Bakirtzis, Professor</td>
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<td>Aristotle University of Thessaloniki (Greece)</td>
<td>Mircea Eremia, Professor</td>
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<td>Polytechnic University of Bucharest (Romania)</td>
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<td>Argonne National Laboratory</td>
<td>Jianhui Wang, Center for Energy and Economics</td>
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<td>National Renewable Energy Laboratory</td>
<td>Erik Ela, National Wind Technology Center</td>
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<tr>
<td>Invenergy, LLC</td>
<td>Michael Polsky, President and CEO</td>
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<td>Energia Eolica ()</td>
<td>Edgar Pereira, Director</td>
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<td>PS Wind Management ()</td>
<td>Radu Popoiu, Managing Director</td>
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<tr>
<td>ComEd/Exelon</td>
<td>Terence Donnelly, Senior Vice President</td>
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<td>ISO New</td>
<td>Eugene Litvinov, Director of Business Architecture and Technology</td>
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<td>British Columbia Transmission Corporation</td>
<td>Ebrahim Vaahedi, CTO</td>
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<td>Dakota Power</td>
<td>Richard Gowen, President</td>
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<td>EnerNex Corporation</td>
<td>Erich Gunther, Chairman and CTO</td>
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<tr>
<td>SmartSignal Corporation</td>
<td>James Gagnard, President and CEO</td>
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<tr>
<td>Innovation Technology Applications Company</td>
<td>Alan Cain, President</td>
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<tr>
<td>Keyworks</td>
<td>Kurt Yeager, President and CEO</td>
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<td>Electric Power Research Institute</td>
<td>Brooks, Daniel</td>
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<tr>
<td>AREVA T&amp;D</td>
<td>Jay Giri, Director of Power System Technology</td>
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<td>Intelligent Power Solutions</td>
<td>John Kelly, President</td>
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<tr>
<td>McCoy Energy</td>
<td>Paul McCoy, President</td>
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<tr>
<td>Wiedman Power System Consulting</td>
<td>Thomas Wiedman, President</td>
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Members of the *World-Class Wind Energy Consortium*
Task 1.0 Procure a 1.5MW GE Test Wind Turbine

- The purchase agreement was signed by Invenergy on September 28, 2010.
- We commemorated the installation at the July 20, 2011 ribbon-cutting ceremony.
Task 2.0 Install an 8KW Viryd Test Wind Turbine

- 8KW lab wind unit was installed at IIT in September, 2010.
Task 3.0 Install a Small Wind Turbine for Public Awareness

- Groundbreaking ceremony on March 30, 2011.
- We celebrated the installation at the July 20, 2011 ribbon-cutting ceremony.
Task 3.0 Install a Small Wind Turbine for Public Awareness
Task 4.0 GE Wind Turbine Reliability Study
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The Green lines represent the predicted values, the blue lines represent the actual current values, and the red XXX represent significant deviations of actual from estimate, alerting the analyst to further investigate the situation.
Task 4.0 GE Wind Turbine Reliability Study

The Green lines represent the predicted values, the blue lines represent the actual current values, and the red XXX represent significant deviations of actual from estimate, alerting the analyst to further investigate the situation.
Task 4.0 GE Wind Turbine Reliability Study

- Deployment of Catch the Wind’s Laser Wind Sensor (LWS)
  - In this research project, the LWS measures the wind out in front of the turbine blades using laser Doppler velocimeter technology, and use this information to change the yaw angle of the turbine to more accurately align the turbine with the direction of the wind.
  - The yaw control would be revised by working around the GE control system to replace the anemometer/wind vane data with data from the LWS, while preserving the functionality of all the existing safety mechanisms.
Task 5.0 Viryd Wind Turbine Reliability Study
Task 6.0 Noise Reduction in Wind Turbine Design through Fluid Dynamics and Acoustics
Task 6.0 Noise Reduction in Wind Turbine Design through Fluid Dynamics and Acoustics

- Ganesh Raman, Mahesh Krishnamurthy, “Localization of Wind Turbine Noise Sources on a 1.5 MW Production Scale Wind Turbine Using a Compact Microphone Array,” Illinois Institute of Technology
Task 6.0 Noise Reduction in Wind Turbine Design


Figure 38: Iso-surface of vorticity magnitude in the flow around the wind turbine
Task 8.0 Advanced Wind Integration Study

Wind integration studies for the Eastern Interconnection

- 23 scenarios are represented
  - Scenarios 1-4: no wind, wind CF>=40%, wind CF>=30%, all candidate wind sites
  - Scenarios 5-8: fuel prices 20% higher, 10% higher, 10% lower, 20% lower
  - Scenarios 9-12: wind power 20% higher, 10% higher, 10% lower, 20% lower
  - Scenarios 13-16: forecasted load 20% higher, 10% higher, 10% lower, 20% lower
  - Scenarios 17-20: low and high carbon taxes
  - Scenarios 21-23: load management
Scenario 3: 30% Wind (Cap. Factor>=30%)
Load Sensitivity Analysis

[Graphs and charts showing production cost sensitivity across different scenarios and energy contribution by source.]
Task 9.0 International Collaboration on Wind Energy Research

- The first wind energy conference was held at IIT’s main campus on September 30, 2010.
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Task 9.0 International Collaboration on Wind Energy Research

- The Second Wind Energy Conference was held at IIT’s main campus on Wednesday, July 20, 2011
  - 7:45-8:00 am Continental Breakfast
  - 8:00-8:20 am Introduction and Welcome Remarks
  - 8:20-8:55 am Wind Energy Integration in the Eastern Interconnection
  - 8:55-9:35 am Wind Energy Installation at IIT
  - 9:50-10:30 am Wind Energy Research and Development
  - 10:30-11:20 am Wind Energy Education and Workforce Development
  - 11:20-12:00 Wind Energy Installation at Grand Ridge
  - 12:15 pm Ribbon Cutting Event – 8kW Wind Unit at IIT
  - 2:30 pm Ribbon Cutting Event – 1.5MW IIT Wind Unit at Grand Ridge, Illinois
Task 9.0 International Collaboration on Wind Energy Research

- Advancing Wind Power in Illinois Conference

Advancing Wind Power in Illinois Conference
Thursday and Friday, July 21-22, 2011

At Illinois Institute of Technology
Main Campus, Hermann Hall
3241 S. Federal Street, Chicago, IL 60616

Conference Co-Hosted by:
Center for Renewable Energy at Illinois State University and
Galvin Center for Electricity Innovation at Illinois Institute of Technology
Task 9.0 International Collaboration on Wind Energy Research

- Great Lakes Symposium on Smart Grid and the New Energy Economy
  - October 18-19, 2011 | Illinois Institute of Technology, Chicago, IL

More info at www.GreatLakesSymposium.com
Great Lakes Symposium on Smart Grid and the New Energy Economy – October 18, 19
Task 9.0 International Collaboration on Wind Energy Research

IEEE Symposium on Smart Grid and Sustainable Energy Vision

In November 2011, IIT sponsored an IEEE Symposium which was attended by several engineers and scientists to discuss and prepare a position paper on the IEEE/PES vision for smart grid. One of the major components of the position paper will be the vision for wind energy design, manufacturing, integration, and operation and its relation to smart grid.
Task 9.0 International Collaboration on Wind Energy Research

- Professor Antonio Conejo of University of Castilla – La Mancha, (Spain) visited IIT in January 2011 to discuss the international collaboration with the IIT Wind Consortium.

- Dr. Roberto Ferrero (Regulatory Agency of San Juan, Argentina) Visited IIT in January 2011 to discuss the international collaboration with the IIT Wind Consortium.
Task 10.0 Engage Undergraduate Students in Wind Energy Research

- **IPRO Courses at IIT**
  - IPRO 311 – Integration of Plug-in Hybrid Electric Vehicles and Renewable Energy Systems (Fall 2010)
    - The purpose of this project is to investigate the economic effects of the integration of wind power generation systems and PHEVs. The results obtained from the research will serve targeted markets including, but not limited to, automotive industry, wind power generation industry, and utility companies.
  - IPRO 323 – Modeling of Building Integrated Wind Turbine Modules (Spring 2011)
    - The goal of this project is to effectively integrate wind turbines and buildings with harmony as to not disturb the social and natural environments of the city, and to produce the maximum amount of power possible.
Task 10.0 Engage Undergraduate Students in Wind Energy Research

- Renewable Energy Courses Offered at Southern Illinois University
  - ECE 456 – Embedded Control and Mechatronics lectures
  - ECE 486 – Wind Energy Research
    - This course which is delivered during the summer has been redesigned recently to introduce the concept of Clean Energy Resources.
  - ECE 495 – Capstone Senior Design Project
    - Create a Z-scale model of a 3-phase power generation and distribution system. This model will have the following areas: residential, commercial, industrial, coal-fired generation, and wind generation. This will be a dynamic model where the user can specify the real and reactive power demand from the residential, commercial, and industrial loads as analog inputs, the wind input, and the state of various power factor correcting capacitor banks.
Task 12.0 Offer Degree Program and Certificates on Wind Energy

- **Graduate Level Courses Offered at IIT**
  - ECE 580 – Elements of Sustainable Energy (Fall 2010)
  - ECE 581 – Elements of Smart Grid (Fall 2010)

- **Graduate Level Courses Offered at Southern Illinois University**
  - ECE 581 – Wind Energy Power Systems
    - The course introduces graduate students to advanced configurations of wind energy power systems with an in-depth treatment of their control and protection. Wind speed and power relations, basic design of wind energy power systems, synchronous and induction generators, power inverters, generator drives-control modes, interface with the power grid-system modeling, stability, control and protection.
Task 12.0 Offer Degree Program and Certificates on Wind Energy

- Short Course on Wind Energy
  - EnerNex in Collaboration with IIT: Short Course on Wind Energy Technology, Interconnection & Integration

- Day 1: Introduction to Wind Energy and Technology
  - Session 1: Wind Energy Outlook in 2010
  - Session 2: Wind Turbine Technology and Control – Part 1
  - Session 3: Wind Turbine Technology and Control – Part 2
  - Session 4: Wind Plant Design

- Day 2: Modeling and Grid Interconnection
  - Session 5: Modeling and Simulation
  - Session 6: Introduction to Grid Codes
  - Session 7: Interconnection Case Studies
Graduate Degrees Completed at IIT

- **PhD Degrees**
  - Wei Tian, Large-scale Simulation Of Electric Power Systems For Wind Integration
    - Developed an algorithm for analyzing the impact of wind integration on transmission planning and operation in the Eastern Interconnection.
  - Saeed Kamalini, Security Constrained Expansion Planning of Fast-Response Units for Wind Integration
    - Developed a optimization algorithm for wind generation planning
  - Bruno Monnier, Three Dimensional Flow Structures And Turbulence Distribution In An Urban Environment
    - Developed an algorithm for studying the impact of small wind structures on new architectural designs.

- **Master’s Degree**
  - Joan Camprubi, Sustainable Stadium, Qatar 2022
    - Developed an architectural model for a sports stadium with wind generating units
Graduate Degrees Completed at SIU

PhD Degrees
- Mark E. Carlos, An Analysis Of Wind Power Plant Site Prospecting In The Central United States
  - Developed a model to identify the existence of 238 suitable counties in the twelve state region that do not possess WPPs and eliminates 654 counties that are not classified as suitable for WPPs.

Master Degrees
- Naglaa Elashry, Modeling And Simulation Of Wind Power Generation Using Kites
  - Developed modeling and simulation of wind energy generators, denoted as KiteGen, which employ power kites to capture high altitude wind power.
- Emad Elhaji, Impact Of Wind Turbine On Power System Voltage Stability
  - Developed a model on the impact of WTGUs on the power system voltage stability.
Research Outcomes

  - The objective of this study is to develop a numerical model for assessing and analyzing the performance of a horizontal-axis wind-turbine (HAWT) in the presence of rain droplets under heavy rain conditions using computational fluid dynamics (CFD) for multiphase flow systems.
Research Outcomes

- Xiaodong Shi, Mahesh Krishnamurthy, “Survivable Operation Of Three Phase AC Drives In Wind Generator Systems,” Illinois Institute of Technology

![Diagram](image-url)

Figure 4.4. Principle of state transition control of induction machine
Research Outcomes


Fig. 8. Compositions of the Experimental setup
Research Outcomes


Figure 10 - Dakota Power machine DP-06 mounted in the Dynamometer Test Facility

Figure 11 - Comparison of peak specific power of DP-06 of .67 kW /kg to peak specific power of commercial machines
Galvin Center for Electricity Innovation

Groundbreaking in February 2011
Mayor of Chicago Visit to the Center – January 4, 2012
Microgrid at Illinois Institute of Technology

- In 2008, Illinois Institute of Technology entered into a $12 million partnership with the Department of Energy to build the first-ever Perfect Power microgrid.
Research Outcomes

Roof top Solar Panels

STUART SITE
32,460 WATTS
180 MODULES

TILT ANGLE: 20 DEG.
ARRAY AZIMUTH 180 DEG.
Battery and Charging Station Installation
Battery and Charging Station Installation
Battery and Charging Station Installation
IIT-KERI PMU Project

Campus Microgrid
Illinois Institute of Technology

- PMU Demonstration for microgrid application
- LAMS for Campus Microgrid field test
- Enlarge PMU application field & Enhance microgrid technology
Master Controller

IPPSC System Overview

- Siegel Hall Load Control
  - Zigbee Master Building Controller
- Building Control System
  - Siegel Hall
- Distribution System
- South Substation
- North Station
- Turbine Control System
- Wind DAS (Wind Project)
- Generator Agent (V1)
- Supervisory Module
- Internet
- Remote Supervisor Interface
- Solar PV
- Metering System
- Intelligent Power Solutions, LLC
ECEDHA

Electrical and Computer Engineering Department Heads Association

2010 Innovative Program Award

presented to

Mohammad Shahidehpour
Illinois Institute of Technology

for the Center for Electricity Innovation
Establishing the Illinois Institute of Technology as a global leader in microgrids, smart grid technology, and sustainable energy

Presented at the 27th Annual Conference of the ECEDHA

Ed Schlesinger
ECEDHA President
2010-2011

Phoenix, Arizona
March 14, 2011
Upcoming Event

2012 U.S. Department of Energy Microgrid Workshop

Illinois Institute of Technology
July 30-31, 2012
Upcoming Event

2012 Great Lake Symposium on Smart Grid and the New Energy Economy

Illinois Institute of Technology
September 24-26, 2012
Proposed Activities

- Research on 1.5MW unit
  - Utilize the more accurate wind measurement from Catch the Wind package to optimize turbine control
  - Noise reduction (Ganesh Raman and Innovative Technology Applications Company)
  - Health monitoring (Smart Signal)
  - Study the stability impact on local grid (Shanechi research)
  - Study the economic impact on local grid (LMP and IPA type of research)

- Research on 8KW unit
  - Improve the reliability of small wind turbine
  - Integrate small wind units into microgrid, and coordinate with battery storage and electric vehicle charging stations
Proposed Activities

- Annual workshop
  - Expand the annual consortium meeting under the Great Lakes Symposium on Smart Grid and the New Energy Economy
  - Support student to attend the Symposium (free accommodation)

- Short courses
  - Elements of Sustainable Energy to be offered at the IIT Galvin Center for Electricity Innovation
  - IIT IPRO course to support undergraduate research

- Wind energy seminar series
  - Domestic scholars
  - International scholars