Iowa State University

ECPE Department

Optimal Operation and Impact Assessment of Distributed Wind for Improving Efficiency and Resilience of Rural Electricity Systems

Electric Power Research Center

Electrical and Computer Engineering Department

Iowa State University

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Project Introduction

- **Project Title**: Optimal Operation and Impact Assessment of Distributed Wind for Improving Efficiency and Resilience of Rural Electricity Systems

- **Funding Agency**: U.S. Department of Energy under **DE-EE0008956**

- **Federal Funding**: $1,500,000

- **Team Members**:

Name	Organization
Prof. Zhaoyu Wang (PI)	Iowa State University
Dr. Anne Kimber (Co-PI)	Electric Power Research Center
John Bilsten	Algona Municipal Utilities
Tom Wind	Wind Utility Consulting
Terry Fett	Central Iowa Power Cooperative (CIPCO)
Michele Suddleson	American Public Power Association (APPA)
Kevin Bornhoft	Corn Belt Power Cooperative
Jacob Olberding	
Tyler Baxter	
Aaron Ruschy	Iowa Lake Electric Cooperative

Motivation and Background

- **Iowa has seen a sharp increase in distributed wind energy in rural areas.**
- **Questions and challenges that our rural utility partners have been facing:**
  - ✓ **How to coordinate distributed wind and other resources for peak shaving while maintaining permissible voltage levels?**
  - ✓ **How to leverage distributed wind and energy storage to provide clean emergency power after outages and reduce reliance on costly backup diesel generators?**
  - ✓ **How to assess the impact of distributed wind integration and operation on weak rural grids and identify vulnerabilities?**

Summary of Project Goals and Outcomes

- ❑ **Enable rural utilities to leverage distributed wind in coordination with other distributed energy resources (DERs) and energy storage systems to:**

  - ✓ **Shave peak demand**
  - ✓ **Provide clean and economical emergency power**
  - ✓ **Regulate voltage**
  - ✓ **Evaluate impacts of distributed wind on the grid**

- ❑ **Project Outcomes:**

  - ✓ **A set of control and optimization algorithms**
  - ✓ **Hardware implementation and field demonstration**

Project Structure and Resources

Distributed Wind for Peak Shaving and Voltage Regulation

- Coordinating distributed wind, other DERs, and battery storage
- Robustness against uncertainties
- Convex relaxation for fast computation

Distributed Wind for Resilience Enhancement

- Optimal coordination of distributed wind and diesel generators/battery storage at slower timescale
- Voltage and frequency control and stabilization at faster timescale

Team's Unique Strengths

- Robust chance constrained optimization for uncertainty modeling
- Decentralized primal-dual gradient descent for stable control
- Guaranteed performance with theoretical proofs
- Distributed wind farms at utility partners for field demosntration

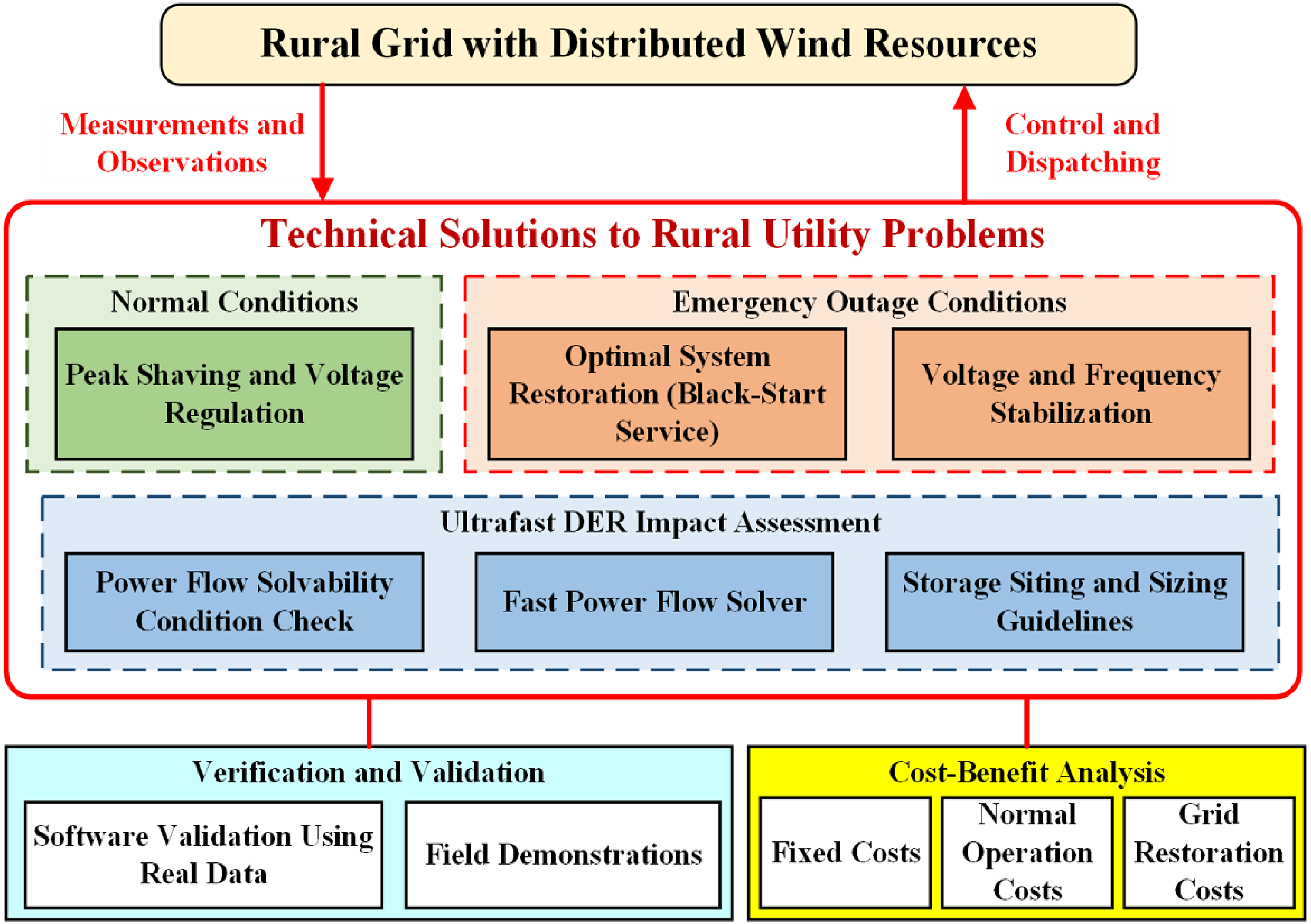
Ultrafast Impact Assessment and Optimal Mitigation Strategies

- Unbalance power flow solvability conditions for impact assessment
- Optimal mitigation for potential operational issues

Validation and Demonstration

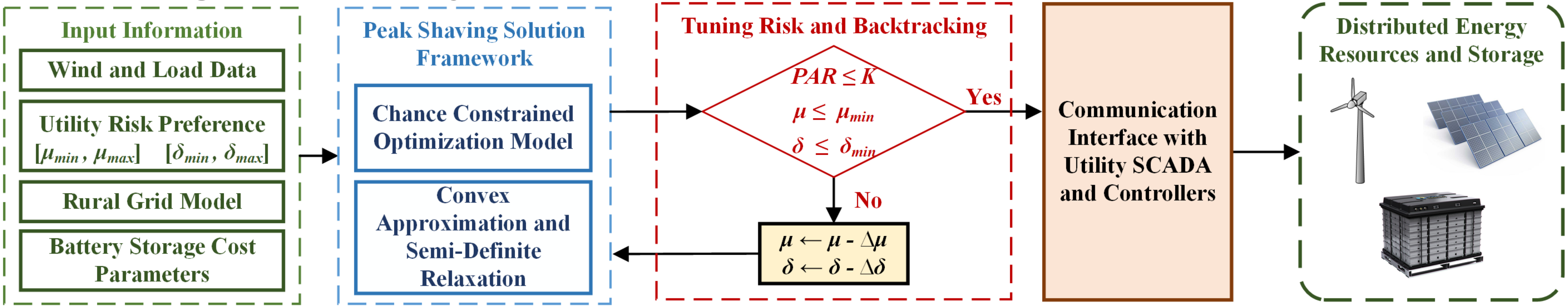
- Software simulations
- Real utility models and data
- Field demonstrations

Technical Approach



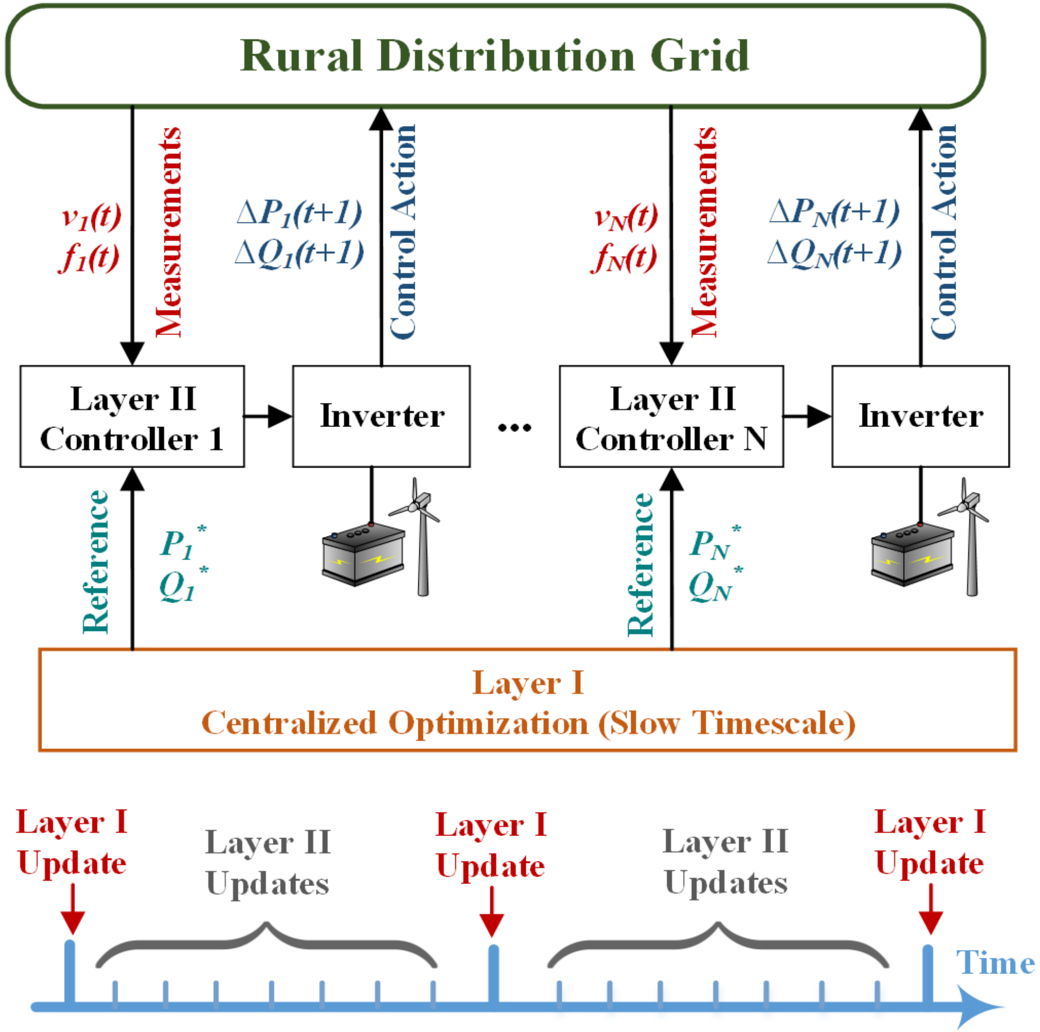
Objective I: Robust Optimal Coordination of Distributed Wind and DERs for Peak Shaving and Voltage Regulation

- ❑ **Handling uncertainty of distributed wind using chance constrained optimization**
- ❑ **Integrating battery life constraints to prevent unnecessary cycling**
- ❑ **Tuning the tradeoff between optimality of peak-to-average ratio (PAR) and risk of voltage infeasibility**



Objective II: Optimization and Control of Distributed Wind for Outage Restoration

- A two-layer framework at slow (minutes and up) and fast (seconds) timescales:
  - ✓ **Layer I** – Minimize cost of restoration and maximize load pickup by coordinating resources
  - ✓ **Layer II** – Stabilize voltage and frequency using local inverter control and measurements (no communication)



Objective III: Assessing and Mitigating Impacts of Distributed Wind on Rural Networks

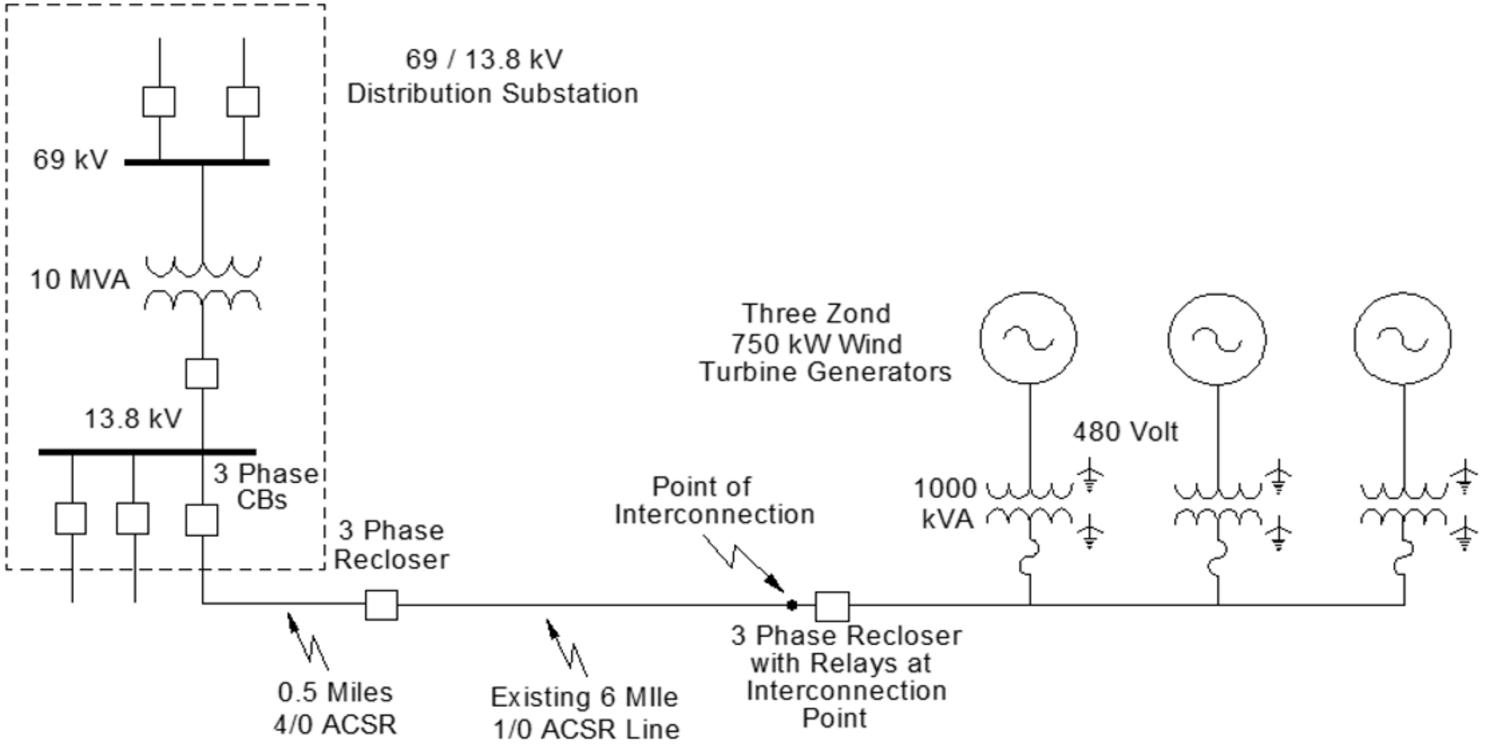
- **A two-stage strategy for fast assessment of impact of wind, without the need for extensive scenario-based solvers:**
  - ✓ **Stage 1: Check voltage feasibility and power flow solution existence and uniqueness (employ network Jacobian)**
  - ✓ **Stage 2: Solve linearized power flow equations only for operation scenarios that fail the conditions in Stage 1 to identify vulnerabilities**
- **Our utility partners have shown strong interest in installing battery storage to pair with distributed wind**
- **Perform optimal sizing/siting/operating of battery storage to mitigate vulnerabilities**

Objective IV: Project Cost-Benefit Analysis

- ❑ Assess the economic viability of the project outcomes:
  - ✓ Quantify costs under long-term operational and weather scenarios
  - ✓ Project costs include fixed costs, and operation costs in normal and restoration conditions
  - ✓ Obtain the levelized cost of energy (LCOE) to ascertain the project's economic benefits
  - ✓ Perform sensitivity analysis to assess the impact of various penetration levels of wind on LCOE
- ❑ All cost-benefit evaluations will be based on real data and grid models provided by our utility partners

Objective V: Validation and Field Demonstration

- **Stage I** – Software simulations using real data and network models from our utility partners
- **Stage II** – Testing the project in a real distributed wind farm owned by one of our industry partners



- ✓ Upgrades in communication, SCADA, and turbine controllers
- ✓ Procure and install batteries to pair with wind turbines

Thanks!

Q&A