DOE/OE Transmission Reliability Program

Management of Risk and Uncertainty through Optimized Co-operation of Transmission Systems and Microgrids with Responsive Loads

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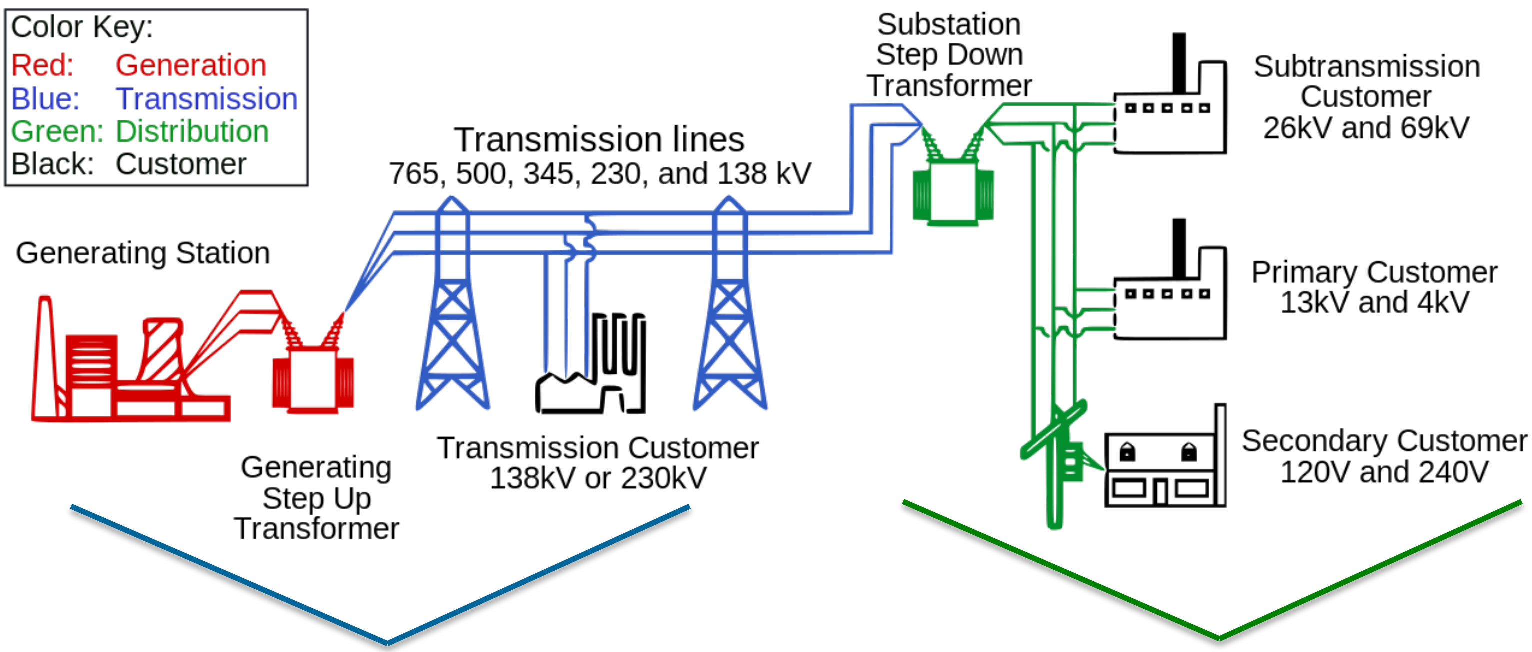
Presentation Overview

- Project Objective
- Progress Update: Phases II & III
- Summary of deliverables
- Looking Forward: Phases III and IV

Project Overview



Utility scale renewables create uncertainty

Responsive loads, and distributed resources

Project Objective

Development of a comprehensive co-optimization framework that incorporates the generation and transmission system with the distribution system and micrograds to include responsive loads, distributed generation, and storage.

The approach to this objective is structured across four key phases.

Project Phases

Phase I: Characterizing uncertainty in renewables

Phase II:

Modeling demand side resources,

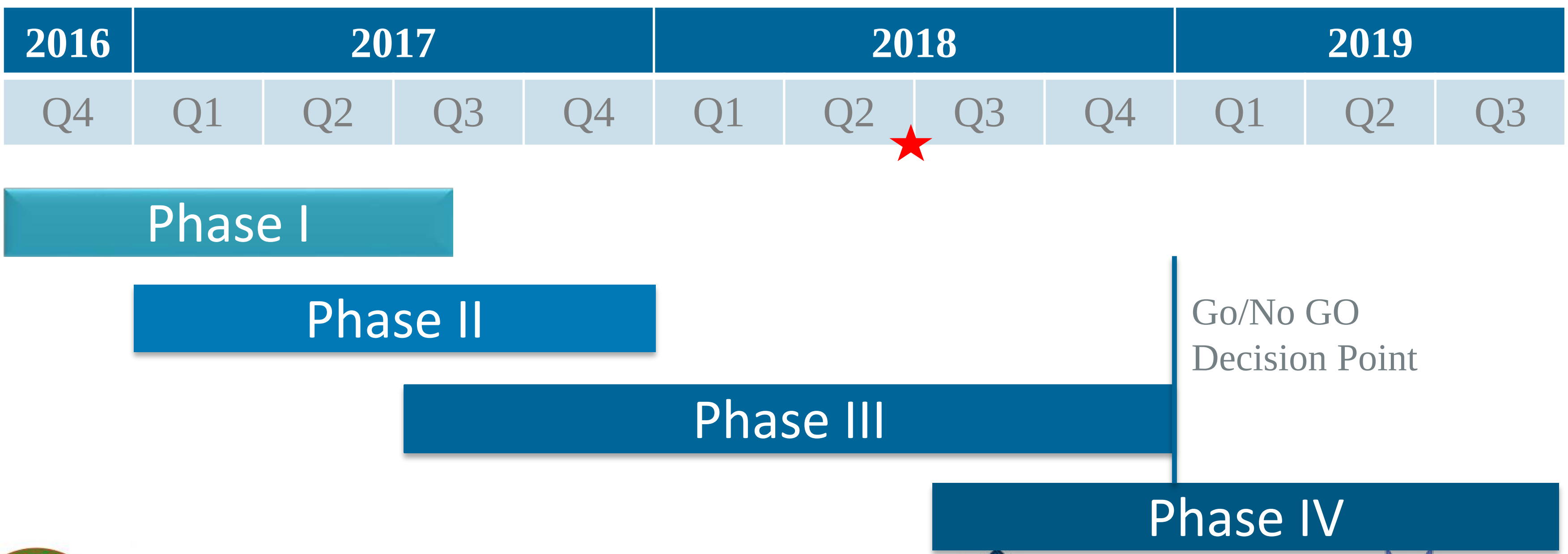
interactive effects

Phase III: Modeling system interactions

Phase IV: Co-optimization framework

Timeline

Timeline for the project was delineated in the updated PMP (Deliverable 1), summarized as follows:



Phase I: Characterizing Uncertainty

Seek to identify best methods for representing *multiple correlated wind farms*

Main contribution: review of multi-area wind modeling methods with the comprehensive comparison

Comparison:

- ✓ Ability of generated scenarios to replicate statistical properties of the historical data;
- ✓ Quality (stability) of the solutions obtained for an economic dispatch problem.

Lead: Cornell, with Anderson & Zéphyr

Phase II:
Demand Side Resources and Microgrids

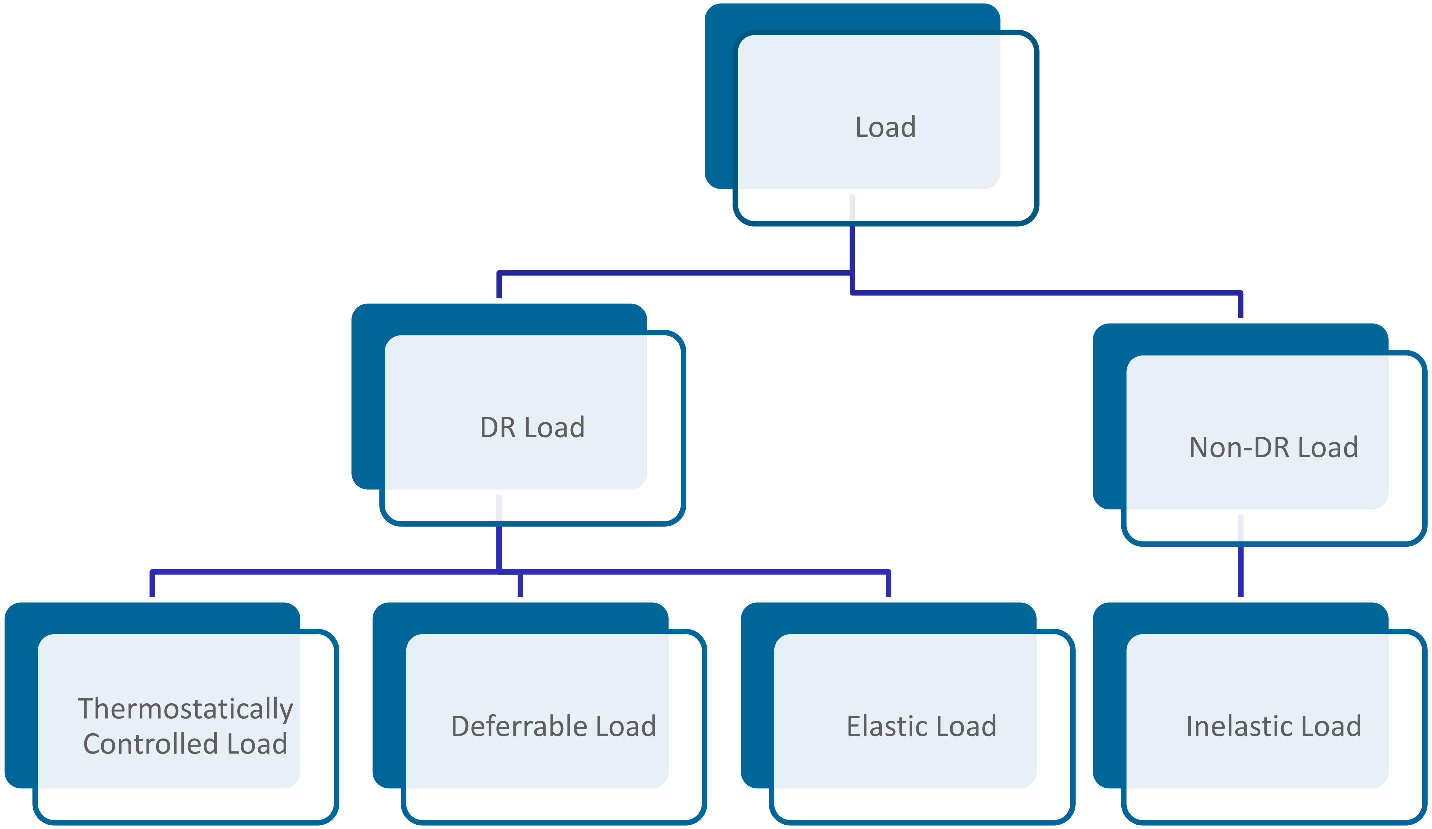
Phase II focuses on the development of various categories of demand-side resources, addressing

- ✓ modeling existing DR programs,
- ✓ integration in energy management system of microgrids, and
- ✓ validation and testing to assess performance from various perspectives.

Lead: Smith College, Cardell

with support from Cornell

Demand Response (DR)



Incorporating these various resources requires
a "look-ahead", flexible decision structure

Modeling Demand Response

System model incorporates:

- microgrid with renewables, storage and DR
- combined DR programs for specific load classes
- stochastic rolling horizon with forecasts
- analysis of performance of various DR classes

This framework illustrates that various classes of demand response add value to the energy management strategy

Progress to date:

- Representing specific load types and response characteristics
- Developed stochastic rolling horizon model for microgrid with DR, storage and renewables
- Empirical analysis of DR capabilities by class

Liu, J., Zéphyr, L., & Anderson, C.L. Stochastic Optimal Dispatch for Microgrids with Load-differentiated Demand Response. Applied Energy, Special Issue on Microgrids (under review)

Microgrid Design

- Undergraduate honors projects at Smith College
- Protecting privacy of data flows between consumers in the microgrid and grid operators
- Implement concepts of
  - Block chain cypher and elliptical curve cryptography
  - To be submitted to HICSS-52
- Design and simulate use of an environmental economic dispatch for microgrids
  - Optimize technology mix within a microgrid for both CO_2 and cost using a genetic algorithm
  - Submitted to NAPS, May 2018

Demand Response (ongoing)

- Team of three undergraduate students developing comprehensive list of demand response programs
  - In the US
  - In Europe
- Program characteristics, including goals, participation, costs/prices, location, results
- Ongoing updates for demand response modeling in NETL project

Phase III: System Co-optimization

Impact of interaction schemes on transmission and distribution/micro-grid systems:

Development of candidate co-optimization models to

- study the interactive effect of micro-grid and transmission system behaviors
- assess the importance of microgrid location in conjunction with co-operation strategies

Co-Lead by PI Team, Cornell & Smith College

Progress to date:

- ✓ Development of bi-level optimization formulation
- ✓ Application of bi-level optimization in two cases:
   i. Transmission-Microgrid Co-optimization
   ii. Transmission-Distribution Co-optimization

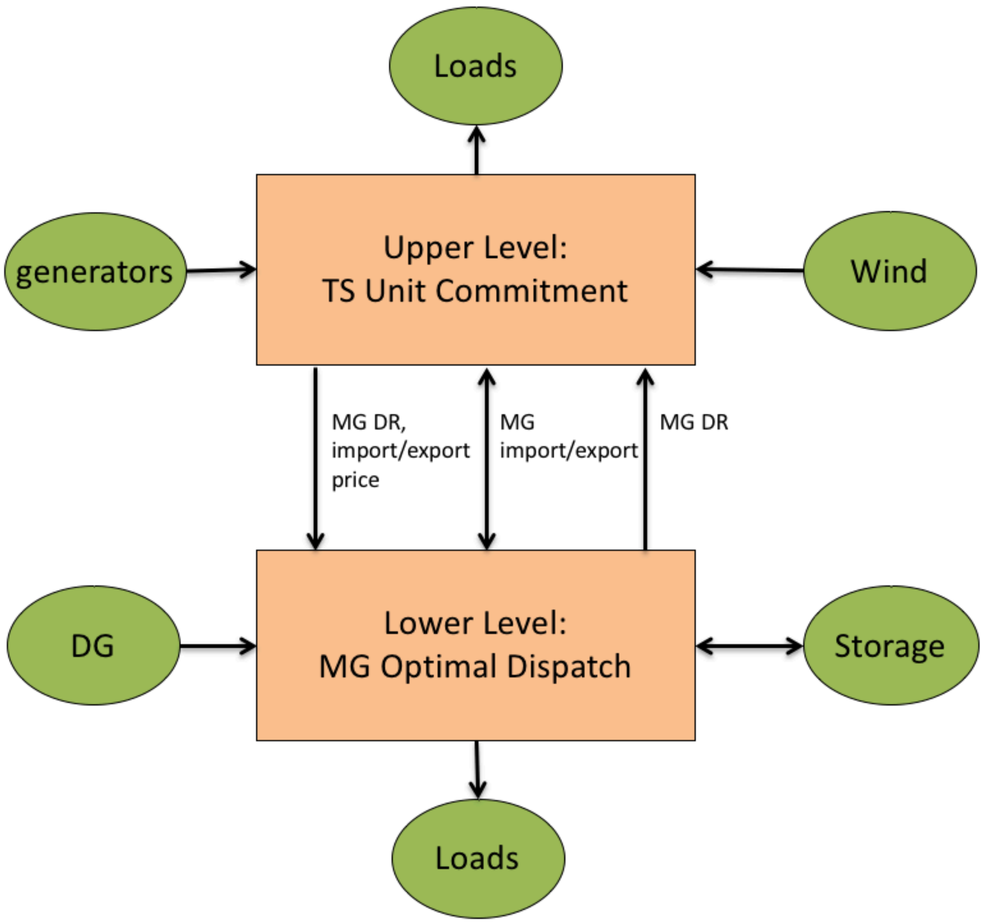
Overview of Phase III progress and preliminary results follow:

Transmission-Microgrid Co-optimization

Key questions:

- Is co-optimization feasible and scalable?
- Will TS-MG co-optimization provide benefits to renewable integration?
- How will this operational strategy affect operating costs on the co-optimized systems?

Bi-Level Approach



Bi-Level Approach:
General Formulation

$$\min_{x \in X, y \in Y} F(x, y)$$

$$\text{st: } G_i(x, y) \leq 0, \text{for } i \in \{1, 2, ..., I\}$$

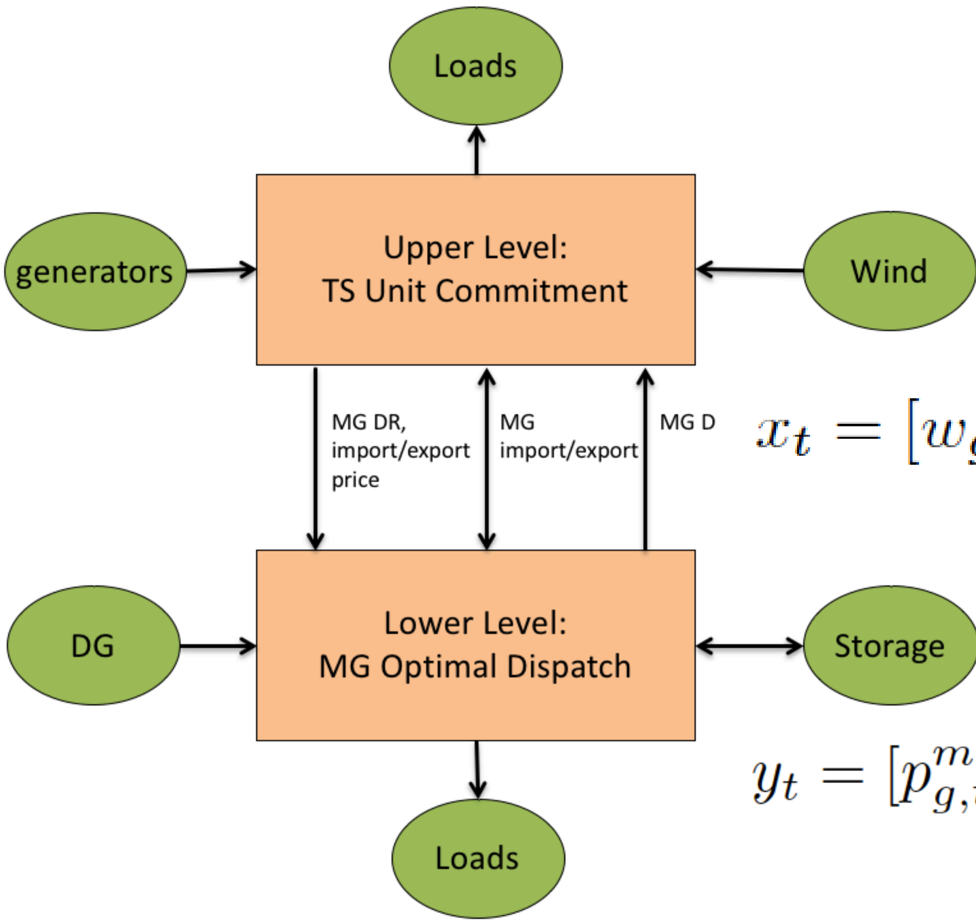
$$H_k(x, y) = 0, \text{for } k \in \{1, 2, ..., K\}$$

$$y \in \underset{y \in Y}{\operatorname{argmin}}\{f(x, y) : g_j(x, y) \leq 0, \text{for } j \in \{1, 2, ..., J\},$$

$$h_m(x, y) = 0, \text{for } m \in \{1, 2, ..., M\}\}$$

Upper Level Problem **Lower Level Problem**

Bi-Level Approach



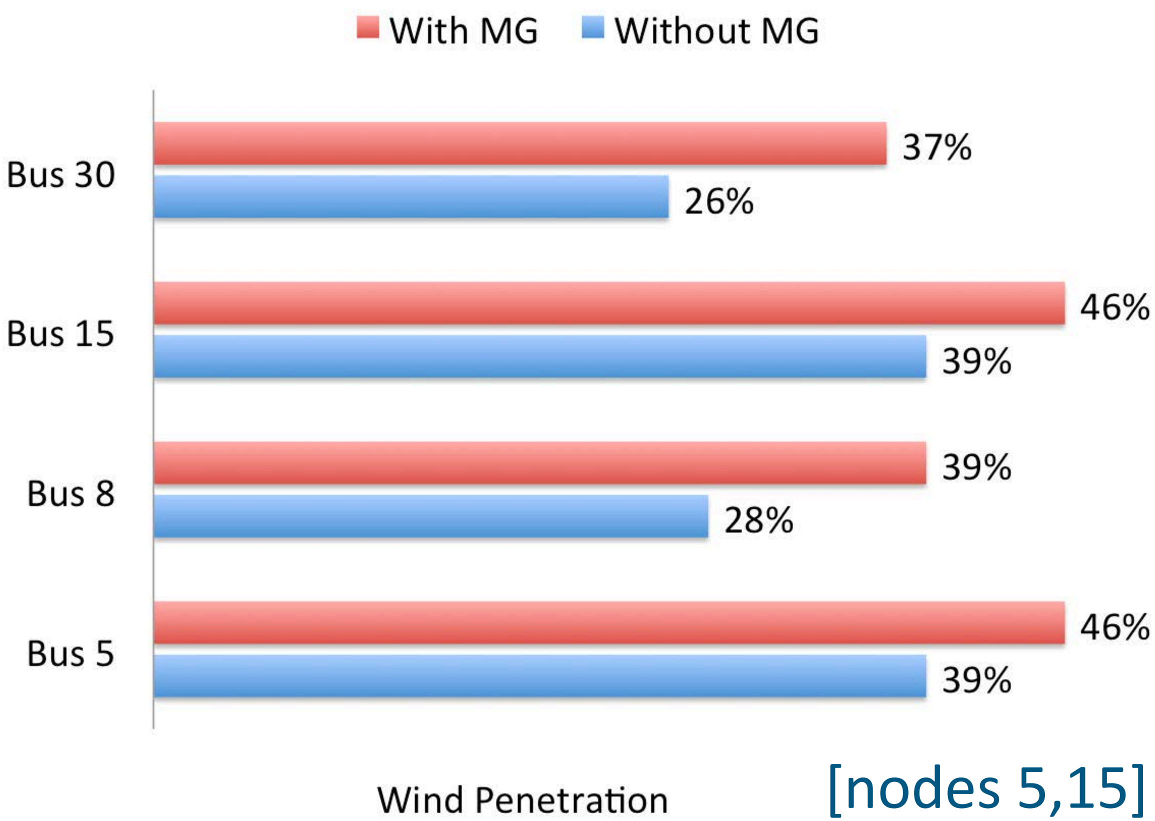
$$x_t = [w_{g,t}, p_{g,t}, r_{g,t}^{up}, r_{g,t}^{dn}, p_t^{dr}, c_t^{im}, c_t^{ex}]$$

$$y_t = [p_{g,t}^{m}, p_t^{b}, p_t^{im}, p_t^{ex}, dr_t^{up}, dr_t^{dn}, l_t^{d}, b_t]$$

Bi-Level Approach

- Reformulate into a single level optimization problem by KKT conditions and Strong Duality
- Robust optimization is used to incorporate wind uncertainty
- Single transmission-microgrid co-optimization, preliminary results explore the impact on wind penetration and operational costs

Preliminary Results: Wind Penetration



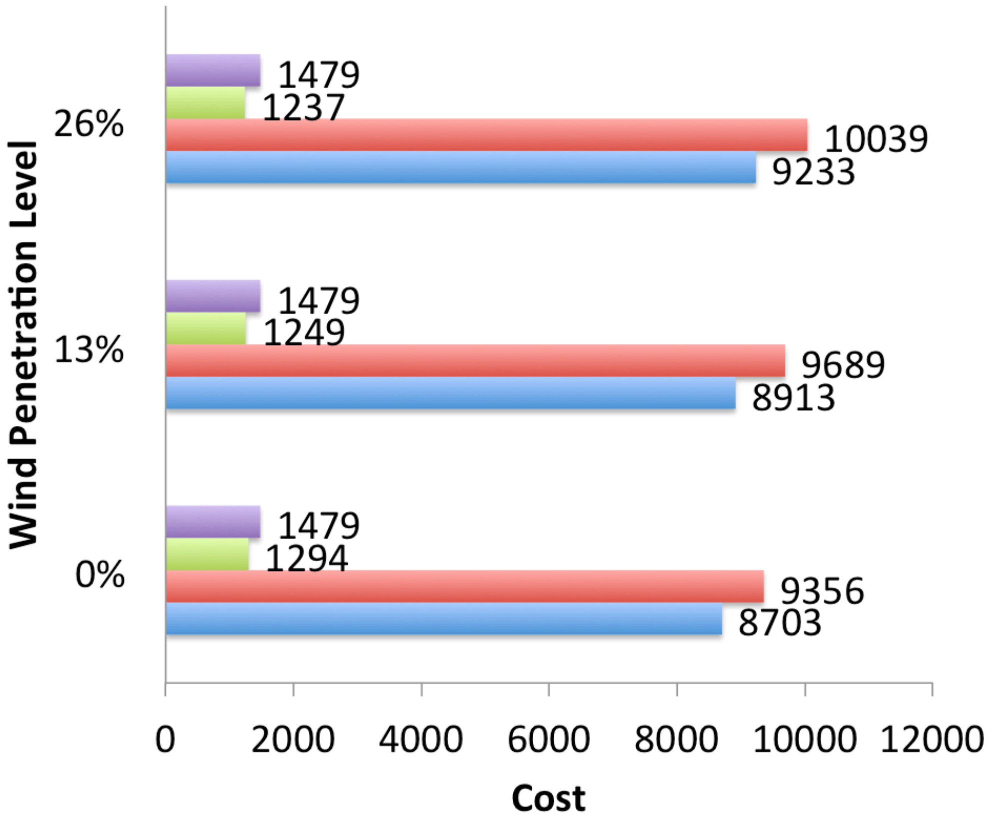
Comparison of impact at various nodes:

- ✓ 25 MW MG, with 50% deferrable load
- ✓ Overall positive effect on wind penetration
- ✓ Differences across nodes

[nodes 5,15] limited by reserves

[nodes 8,30] limited by transmission

Preliminary Results – Costs



Both TS and MG benefit from co-optimization!

Summary

- microgrid demand response can boost maximum wind penetration in the larger system
- both systems benefit from cost reductions when operated co-operatively
- Cost reductions are result of demand response, increased wind penetration, and energy exchange

Other preliminary results explore the impact of MG size, deferrable load levels, MG and wind farm locations

Microgrid versus Distribution System

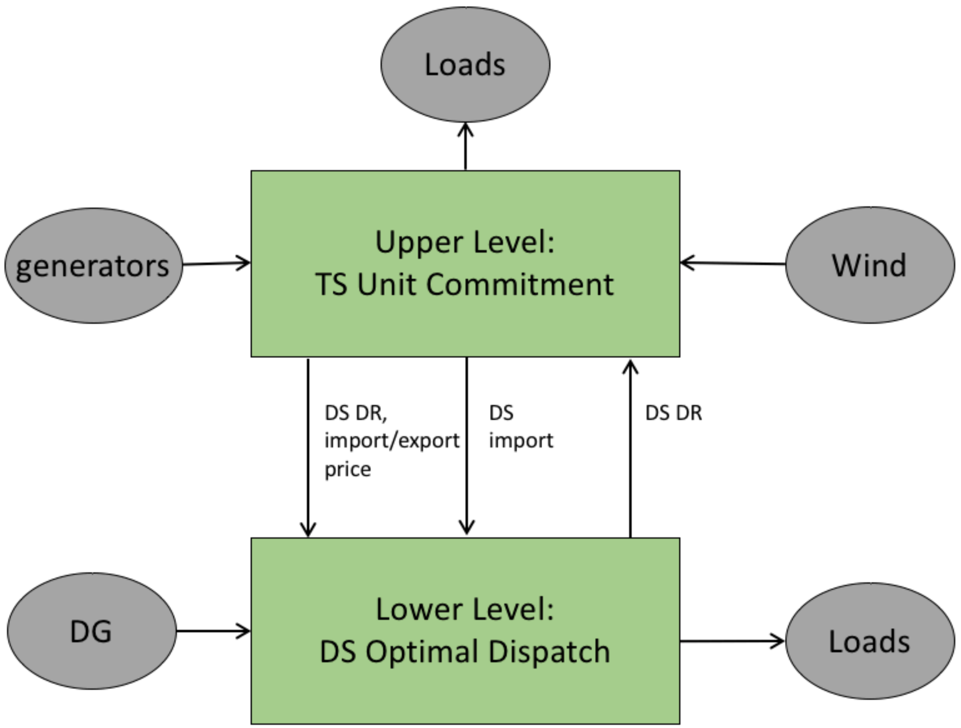
Microgrid	Distribution System
<100 MW	100s to 1000s MW
Able to import/export	Only import
Bidirectional power flow	Radial power flow

TS-DS co-optimization does not provide the same flexibility as TS-MG systems, but could provide benefits.

Transmission-Distribution Co-optimization

Key questions:

- Will TS-DS co-optimization enable higher renewable penetration?
- Do the systems operating costs benefit?



Preliminary Results

Increasing Deferrable Load to Facilitate Wind

DL Level	WP	TS Cost	DS Cost
25%	30%	8568	2720
50%	31%	8771	1660
75%	33%	9110	180

Increasing Demand Response to Facilitate Wind

DR Level	WP	TS Cost	DS Cost
15%	30%	8795	1706
30%	31%	8821	1660
45%	33%	8862	1644

Preliminary Results (Summary)

- Increasing deferrable loads in the distribution system enables (slightly) higher wind penetration, but
- ISO cost increases due to increased reserve requirements
- Demand response in distribution increases wind penetration and lowers cost
- Distribution benefits from co-optimization in either scenario

Deliverables for 2017/18

- ✓ Data Collection Task 3: Sufficient data is collected to develop and validate models (Yes, but ongoing through project)
- ✓ Publication Year 2: Technical Publication Submitted illustrating DR/Microgrid Model with test case (Complete, under review with Applied Energy)
- ✓ Completion of Phase I & II: results disseminated (Complete, papers under review, connecting with industry to solicit feedback)

Deliverables for 2017/18

- ✓ Milestone 3: website updated with models, publications and collected data (on track for 10/30/18 as scheduled)
- ✓ Presentation Year 2: Presentation at technical conference detailing bi-level optimization results (on track, in preparation for HICSS submission, due 06/15/18)

Accepted Publications/Presentations

- Anderson, C.L. *Research Needs for Co-optimization of Multi-level Integrated Electricity Systems*. Closing Plenary Panelist. Utilities Variable Integration Group Spring Technical Meeting. March 13-15, 2018. Tuscon, AZ.
- Aravinthan, V., Anderson, C.L., Cardell, J.B., and Jewell, W. (2017) *Investigating Optimal Model Coordination for Integrated Transmission and Distribution Systems.* Power Engineering Research Center (PSERC) Industrial Advisory Board Meeting, Phoenix AZ. December 3, 2017.
- Anderson, C.L. *Incorporating Wind and Distributed Storage into Stochastic Economic Dispatch Solutions*. Power Engineering Research Center (PSERC) Webinar. November 21, 2017.

Looking Forward: Phase IV Validation and Scaling

Key focus of 2018/19:

1. Selection of most promising candidate from Phase III for the stochastic unit commitment (SUC) problem
2. Integration of SUC and ED components into co-optimization framework
3. Numerical case studies and scalability testing

Lead: Cornell, with support from Smith College

Looking Forward:
Industry Feedback and Input

Key focus of 2018/19:

Another key focus of this year is soliciting input from industry stakeholders.

We have shared our approach and preliminary results with industry stakeholders including:

- ✓ California ISO
- ✓ ISO New England
- ✓ New York ISO
- ✓ GE
- ✓ ABB

Next step, follow up for specific feedback from each.

Questions?