

Systems Aspects of Storage for Wind Integration

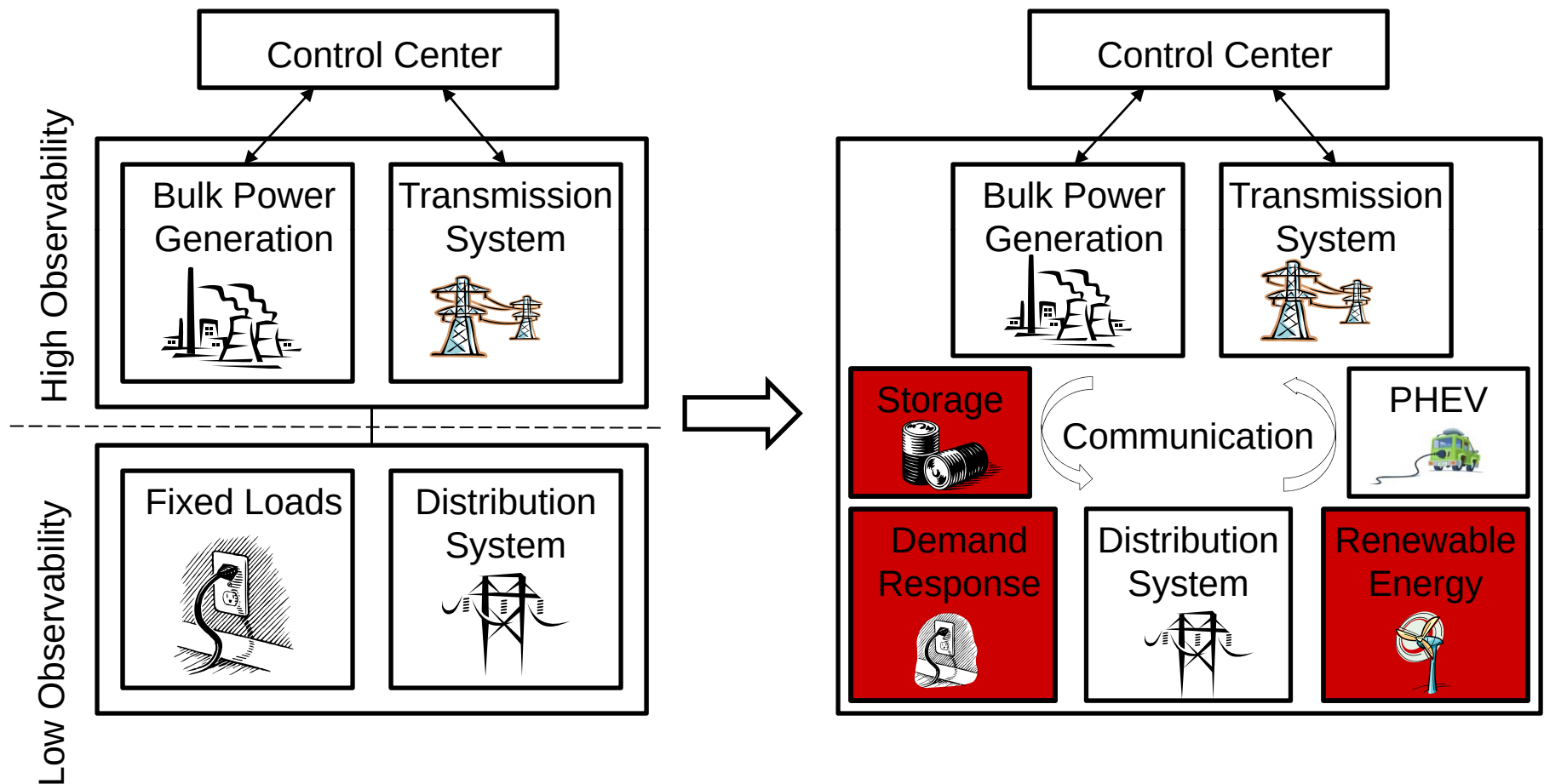
Presentation by
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Outline

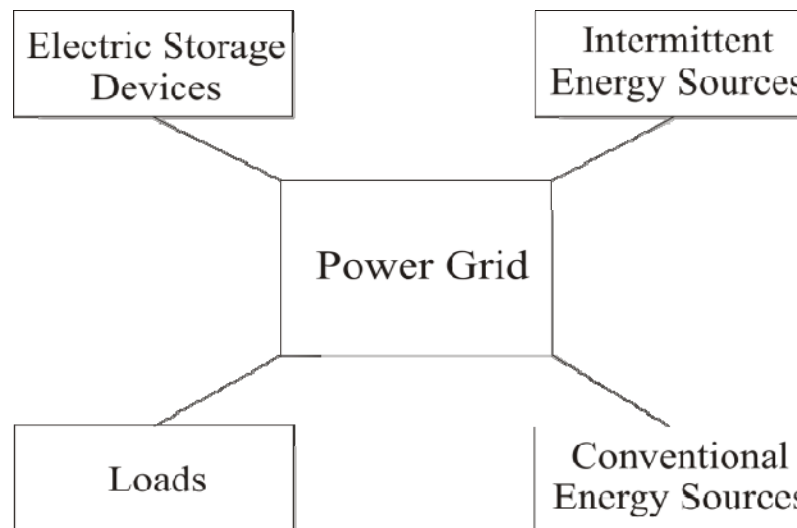
- Introduction
- Problem and Controller Setup
- Simulation Results
- System Considerations
- Conclusion

Introduction



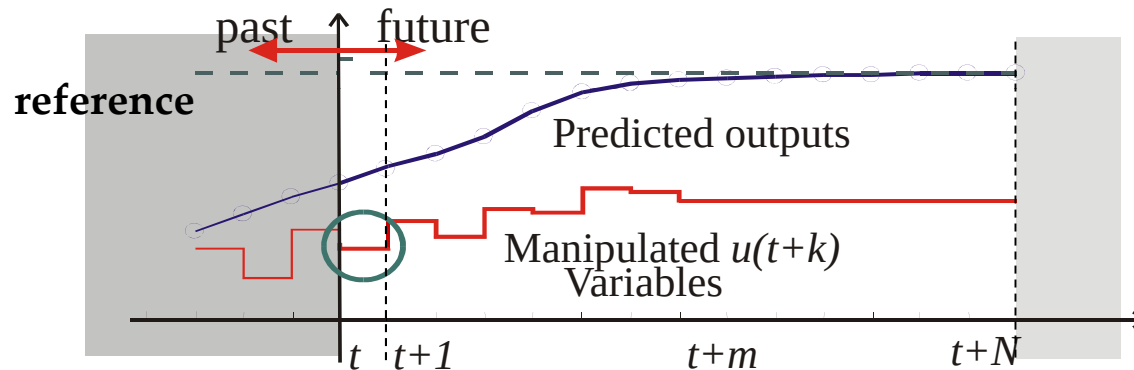
Introduction

- Objective: optimize usage of elements in power system, i.e. balance intermittent energy sources with optimal usage of electric storage devices, conventional energy sources and load/demand control

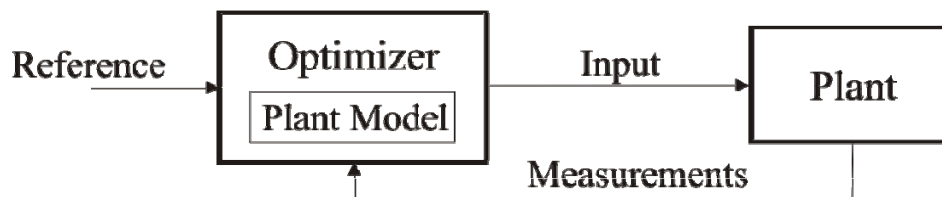


Coordinated and Predictive Control

- Predictive Control
 - Use model of plant to be controlled to predict influence of input
 - Choose input sequence which gives best performance over horizon



- Apply first step and measure new state



Problem Setup

- Objectives

- Minimize usage of conventional power plants
- Minimize changes in conventional power plant outputs
- Minimize losses resulting from conversion in storage
- Minimize curtailment of renewable generation
- Minimize demand side management

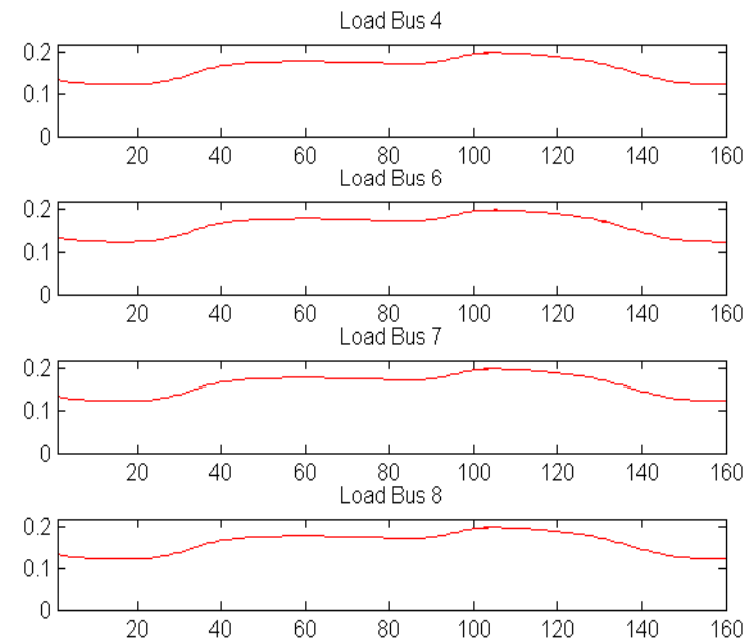
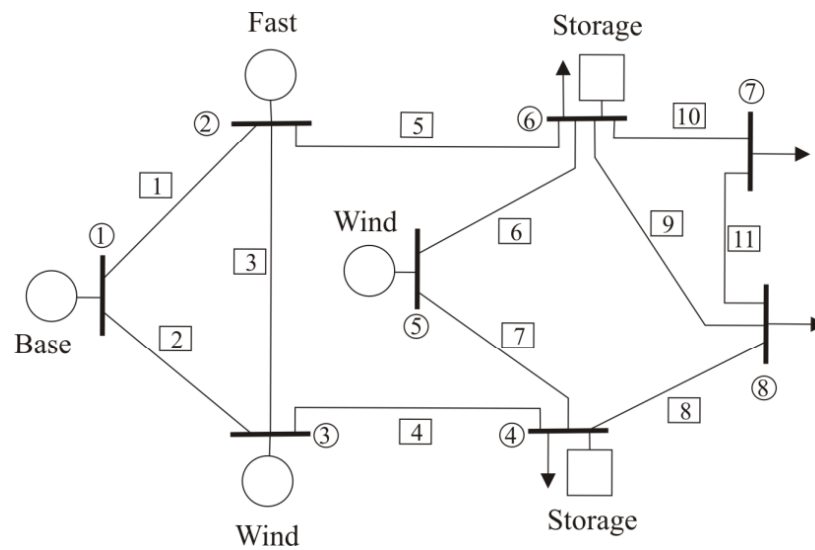
$$\sum_{k=0}^N \left(\nu_{cG} \cdot P_{cG}(k)^2 + \nu_{dcG} \cdot \Delta P_{cG}(k)^2 + \nu_{St} \cdot P_{loss}(k) + \right. \\ \left. + \nu_{iG} \cdot (P_{iG}(k) - P_{iG}^{\max}(k))^2 + \nu_L \cdot (P_{iL}(k) - P_{iL}^{ref}(k))^2 \right)$$

- Constraints

- Power flow equations
- Limits on power outputs from plants and storage
- Line capacities
- Storage capacity

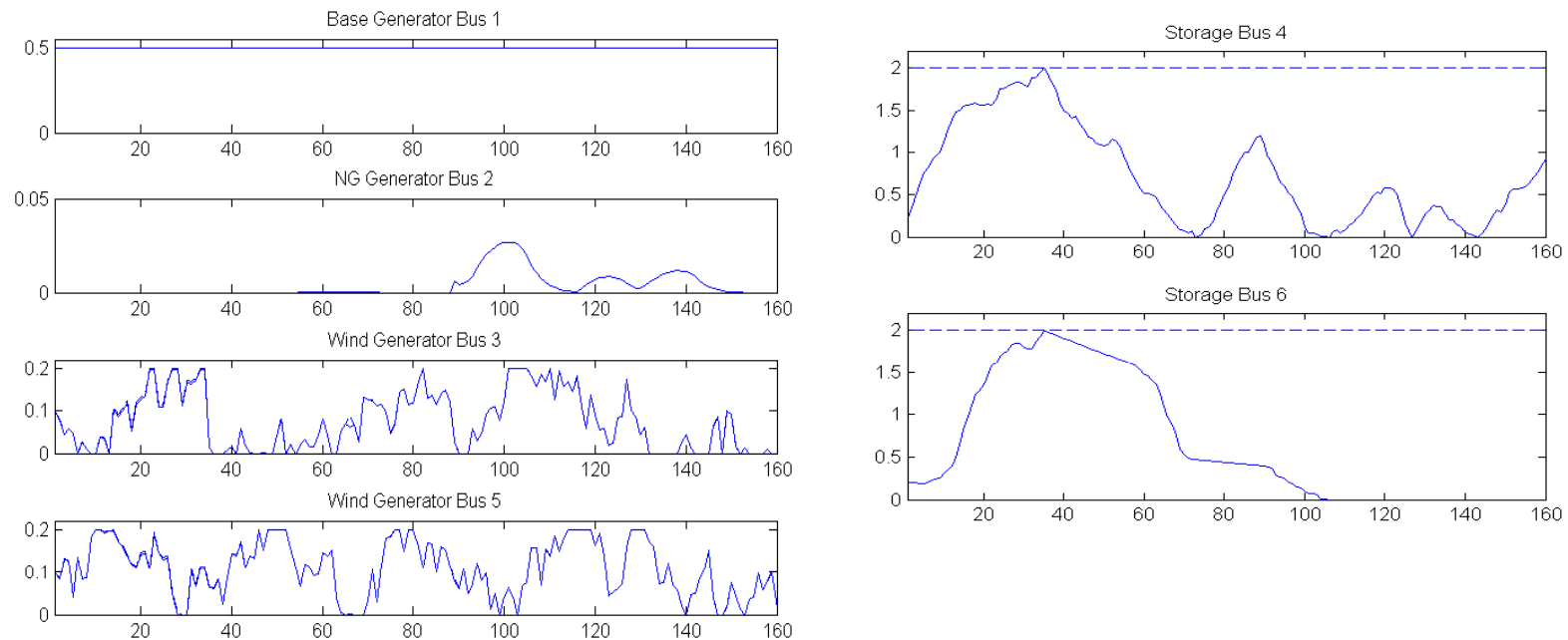
Coordination within an Entity

- Simulation Results



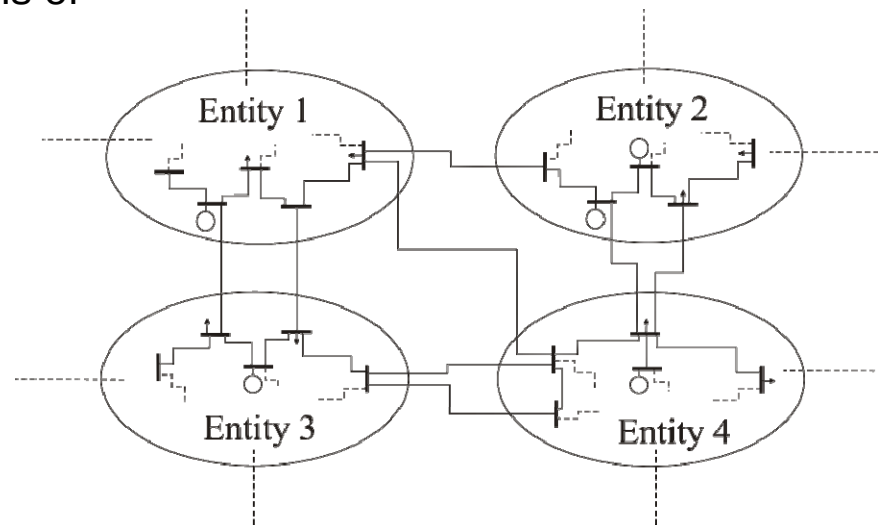
Coordination within an Entity

- Simulation Results



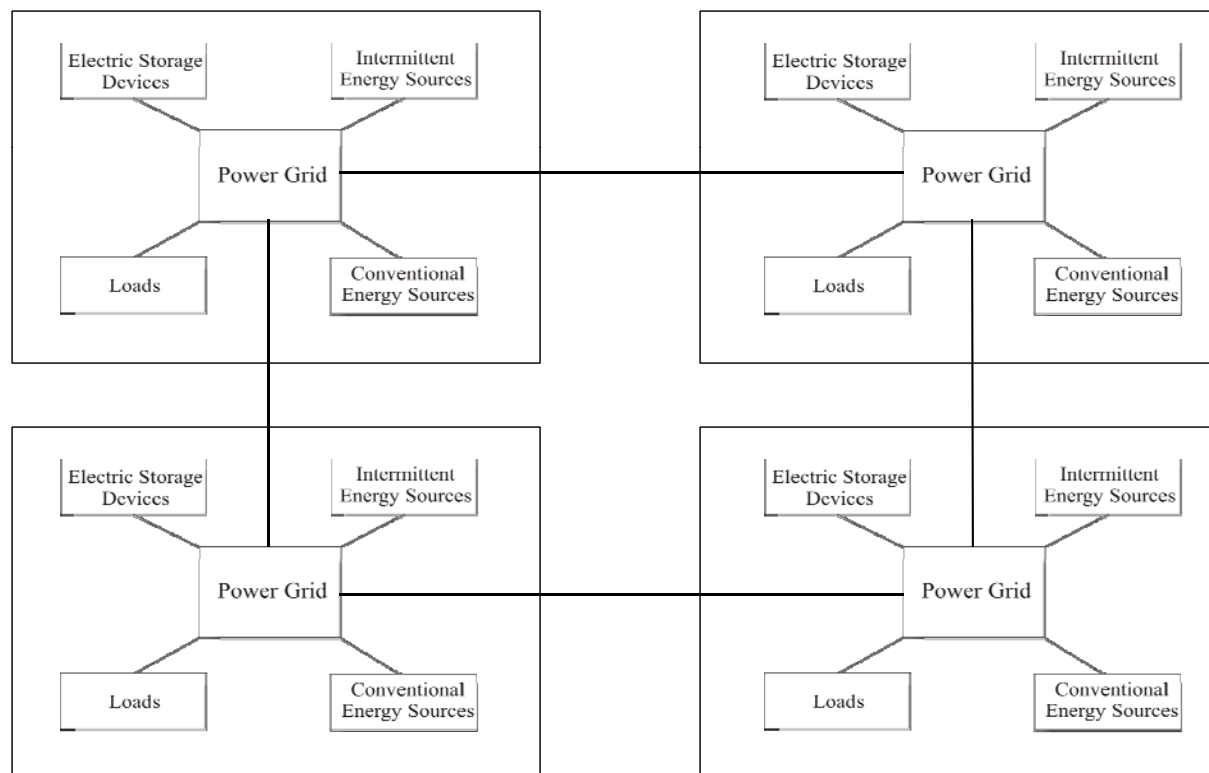
Coordination across System

- Situation
 - Control task of power systems is shared among entities
 - Each entity optimizes the operation of their own system making assumptions of the rest of the system
- Consequences
 - Suboptimal control performance
 - Possibly counteracting actions
- Entity
 - Control Area
 - Several buses
 - Individual player
 - Etc.



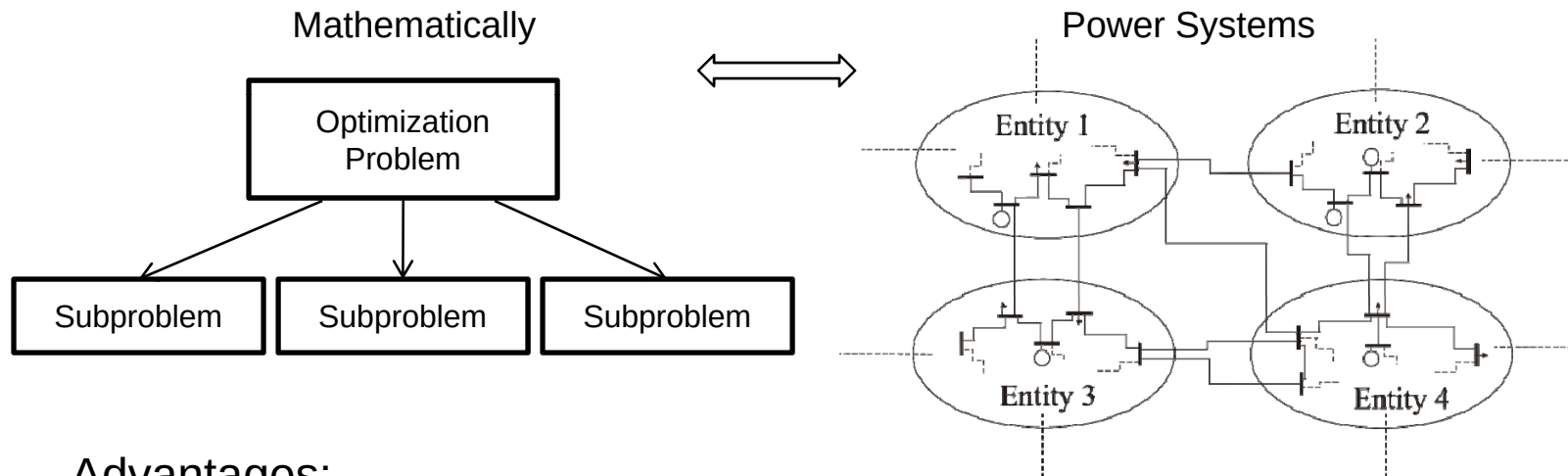
Coordination across System

- Inter-Area Coordination



Coordinated Optimal Control

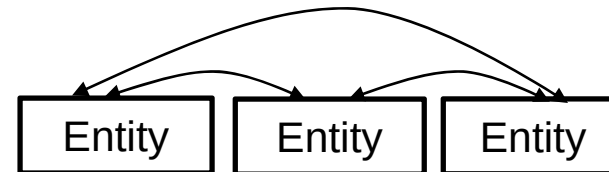
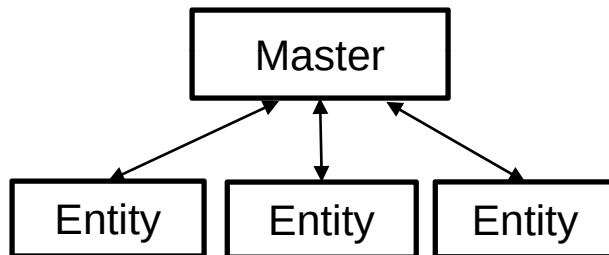
- Distributed Control
 - Decompose overall optimization problem into subproblems



- Advantages:
 - Achieve overall optimal performance
 - Subproblems computationally less demanding
 - Avoid contradictory control setting

Coordination Structure and Levels

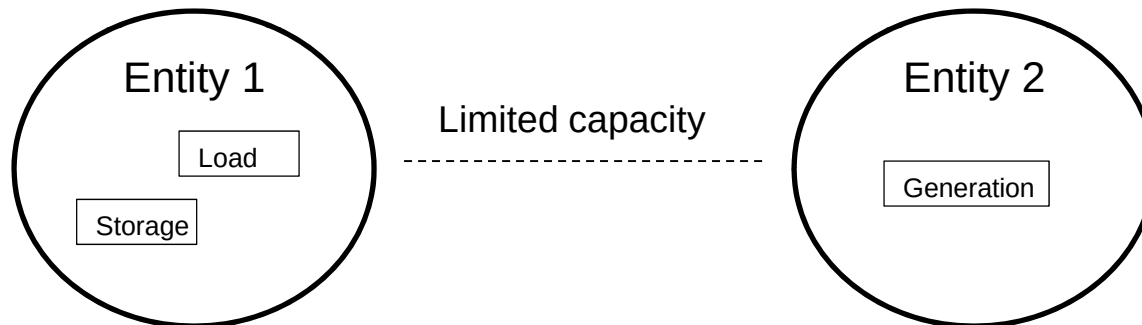
- Coordination Structure
 - Master Coordinator
 - Direct communication



- Coordination Levels
 - traditional control areas
 - individual devices
 - cluster of devices

Coordination across Entities

- Potential of Storage
 - Transfer surplus to storage
 - Use storage when system highly loaded



⇒ Coordination across entities

How much storage/load flexibility do we need for x% intermittent generation penetration?

Conclusions

- Challenges for the integration of renewable generation: Intermittency and missing infrastructure
- Storage reduces need for fast-ramping backup generation
- Coordination allows for overall optimal performance, otherwise often suboptimal performance
- Additional information available in future electric power system enables coordination