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Smarter Grid Operation and Control: Challenges and Future Direction

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New York Power Authority

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Outline

- Introduction
- Power system operation and control
- Current smart-grid challenges and development
- Conclusions and future research direction

Notions of Smart Grid

- Distribution/Customer level *(not much control and "intelligence" until now)*
  - Smart metering
  - Intelligent appliances
  - Home area network (HAN)
  - Energy efficiency
  - Load control/Demand response
  - Distributed generation
- Bulk power system level *(control and "intelligence" already existent)*
  - Phasor measurement units
  - Wide-area situational awareness
  - Wide-area coordinated real-time control
  - Integration of renewable resources

Power System Operation and Control

- Local fast control
  - Generating unit automatic controls
  - Protective relaying
  - Control actuators
- Wide-area operations control
  - System-wide secondary monitoring and control
  - Control center applications
    - System state estimation
    - Security assessment
    - Decision making for optimal operation

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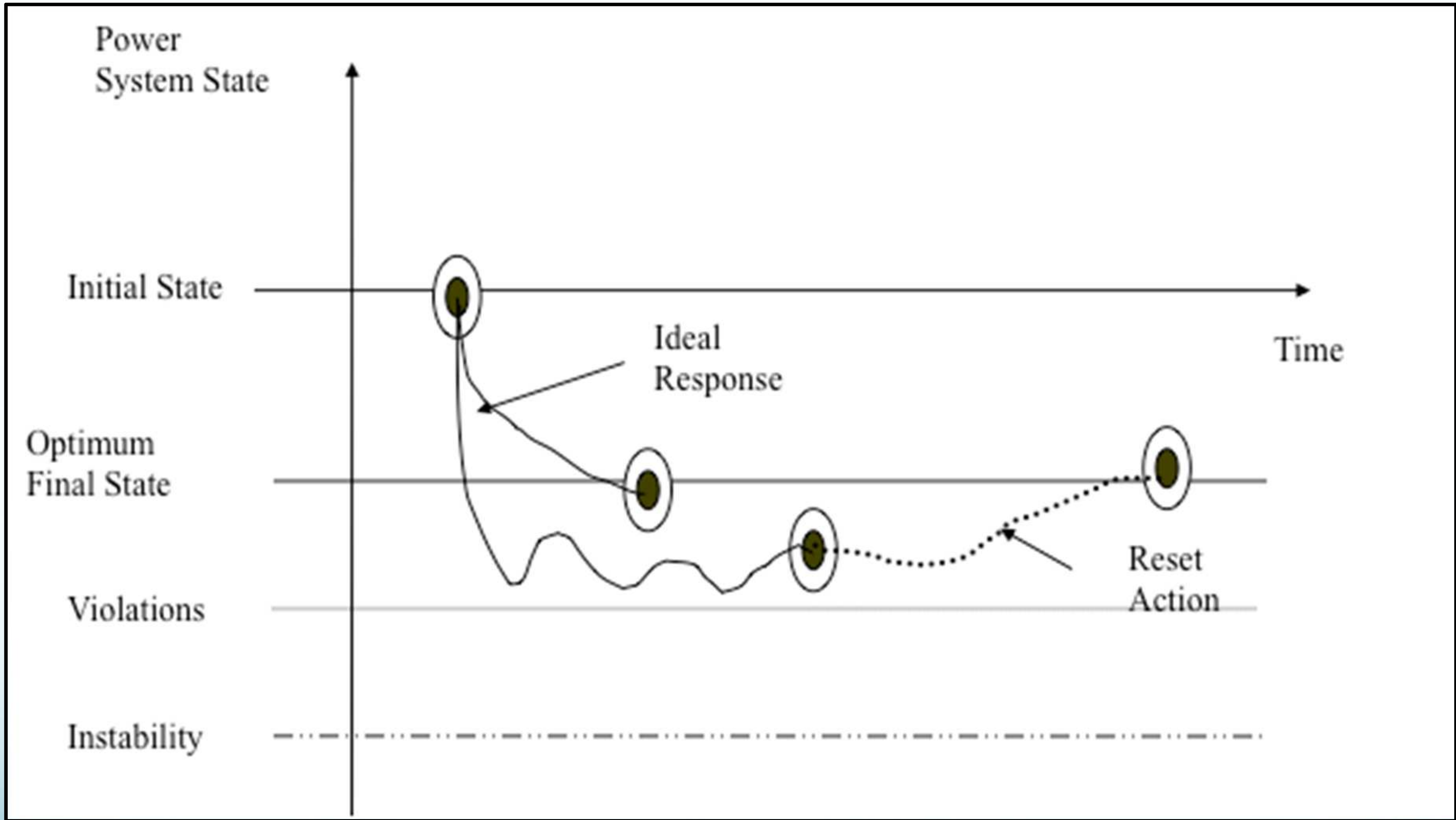
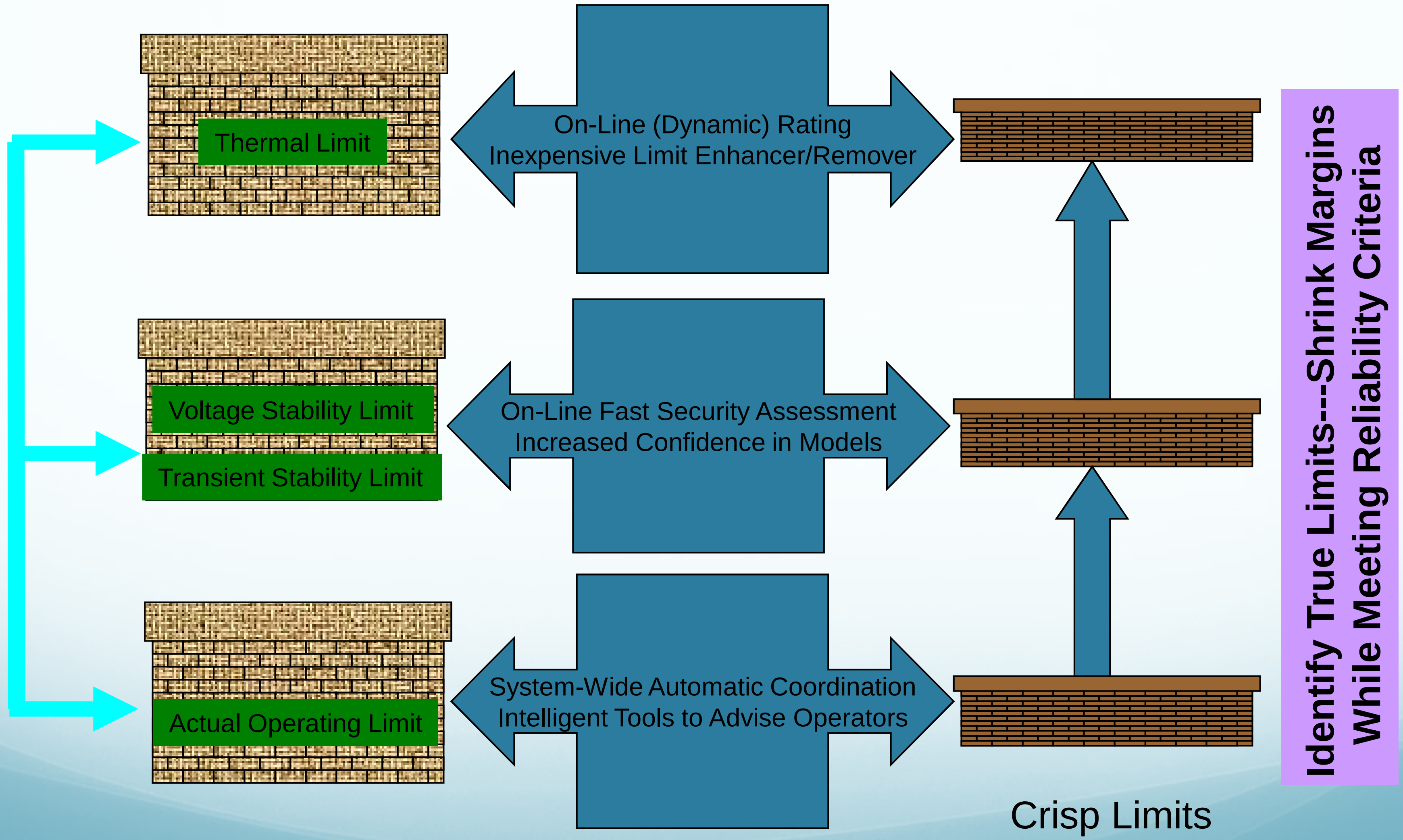
Power System Operation and Control

- Local fast control
  - Local measurements/communications
  - Primary response to system transients
- Wide-area operations control
  - Slow wide-area control
  - System-wide SCADA measurements and wide-area communications
  - Power system analysis algorithms
  - Decision making tools
  - Response to system steady-state conditions and slow transients

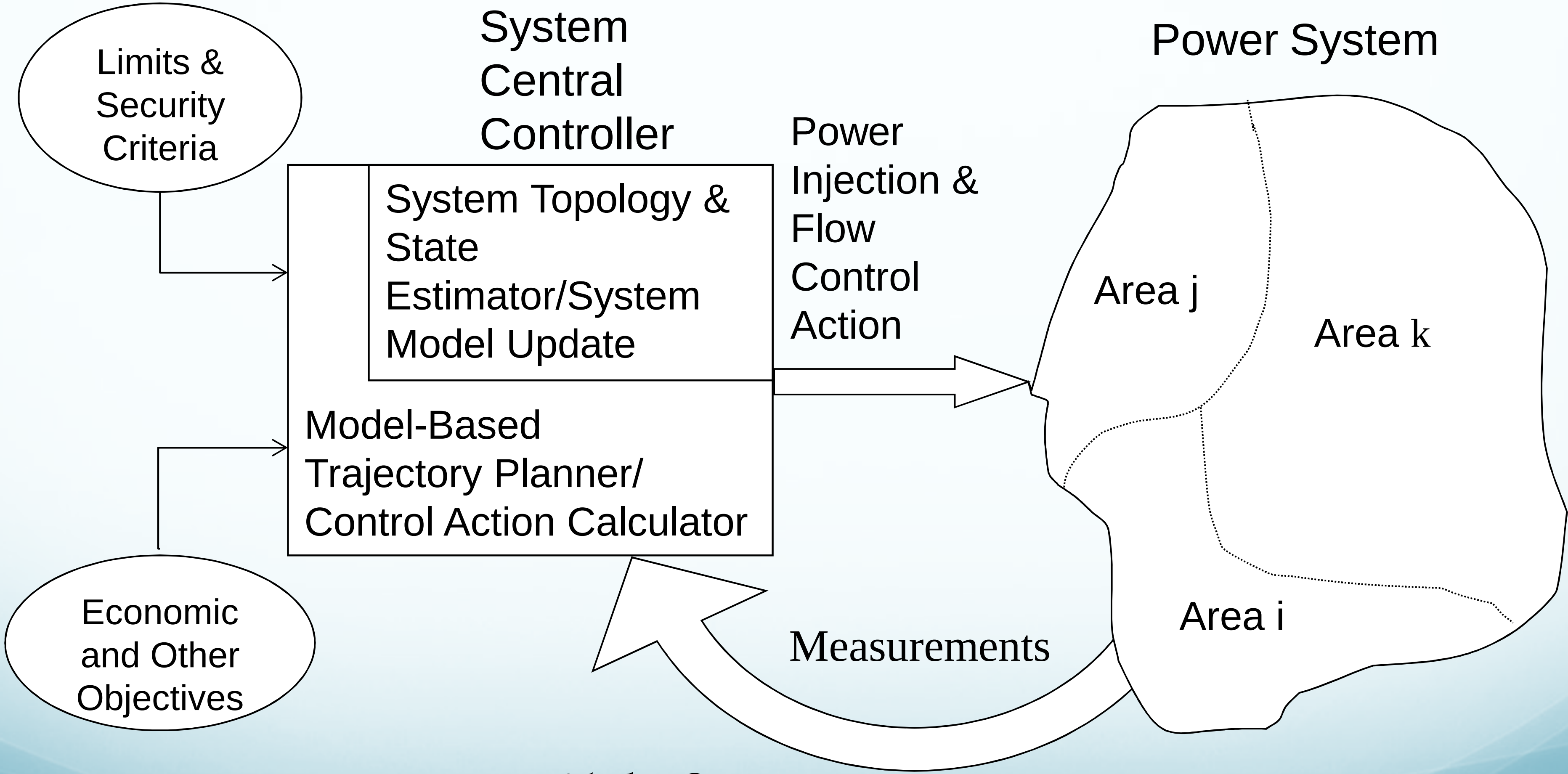
Relying on Margin



Uncertainty in Limits



Ideal Control Scenario

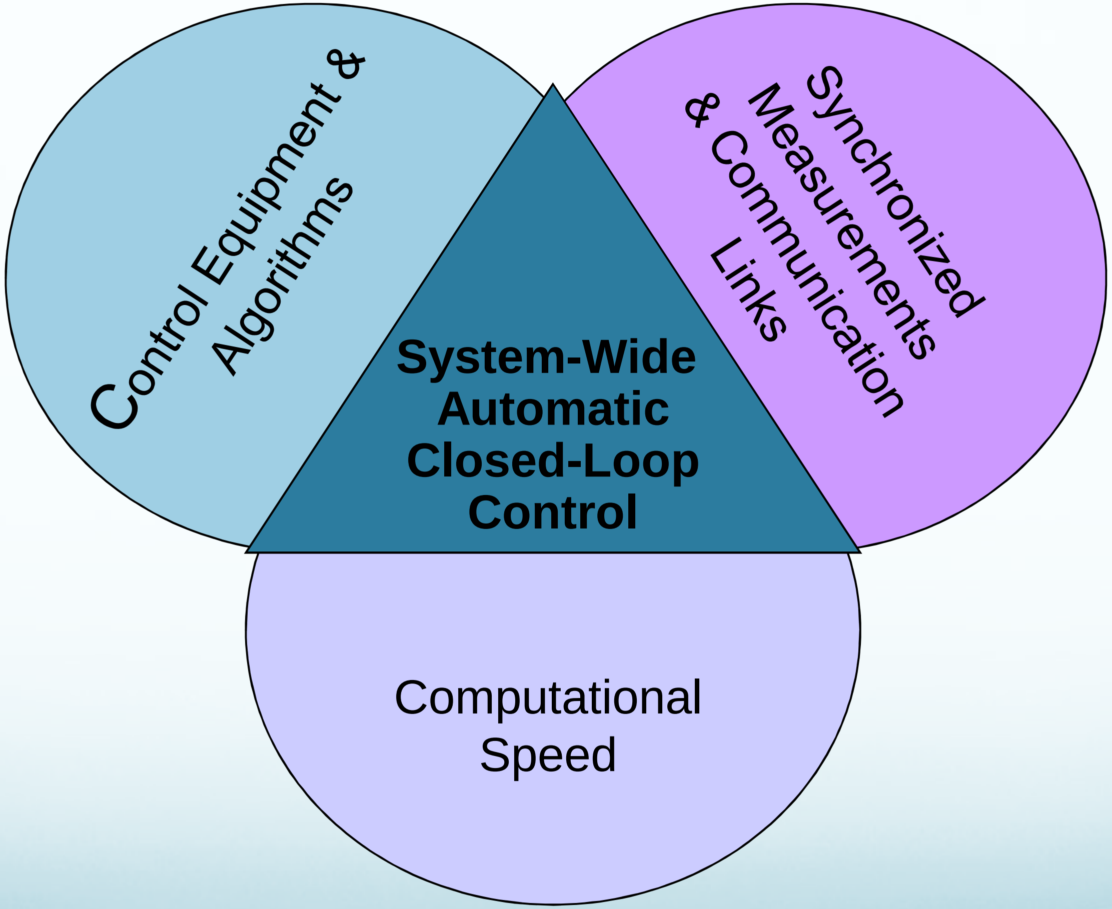


How Feasible?

Limitations and Challenges

- Increasing system complexity (new technologies, renewable resources, distributed generation, energy storage, power markets, energy transactions, etc)
- Structural: Geographically distributed nature
  - Communications/Synchronization
- Large-scale systems/Large data sets
  - Computing efficiency
  - Control bandwidth
- Adequacy of control equipment
  - Infrastructure

Future Direction Components



What is Needed

- Hardware
  - Fast-acting active/reactive injection/absorption and flow controllers including fast-dynamics generators and/or electric energy storage devices
  - Adequate highly-reliable less-expensive power electronic controllers
  - Abundant highly reliable high-bandwidth communication networks—Most preferred is dedicated fiber optics
  - HV solid-state or power electronics based breakers for increased stability
  - System-wide synchronous measurements for robust and fast system state and parameter solution/estimation (phasor measurement units)

What is Needed

- Algorithms and fast computing
  - Criteria for selection of feedback quantities for coordinated closed-loop power injection/flow control
  - Determination of appropriate response rates of closed control loops
  - Robust, adaptive, high-bandwidth control algorithms for large-scale structurally distributed dynamical systems
  - Faster computation capability to approach real-time optimization, coordination and control
  - Proven robust hierarchical control algorithms to overcome the limitations in achieving wide-area integrated centralized controller performance
  - System/equipment model identification and validation tools
  - Faster algorithms for system topology and state solution/estimation
  - Parallel algorithms and faster computers

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Conclusions and Future Direction

- Currently power system operation is based on slow system control that relies on conservative operating margins. This operating model may not be adequate in accommodating future challenges.
- Future development needs:
  - Accurate measurements
  - Fast communications
  - Advanced processing capabilities
  - Effective control devices
- Phasor technology is the driving force of smart-grid applications at the bulk power system level
- Potential for closed-loop wide-area control of power systems
- Framework for an “autopilot-type” fully automated power system operation

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Questions?