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Risk Limiting Dispatch

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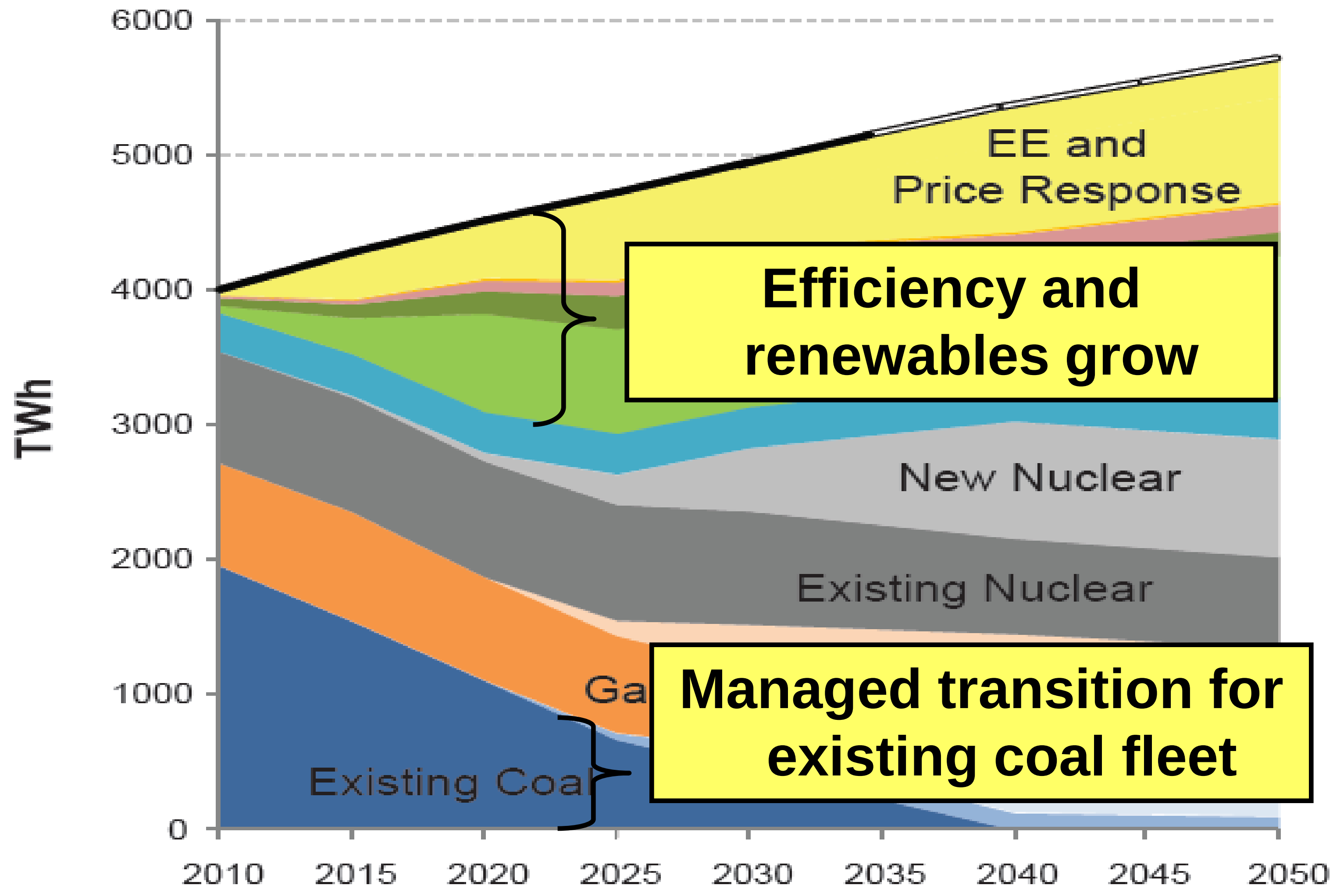
Prism "Test Drive" Insights

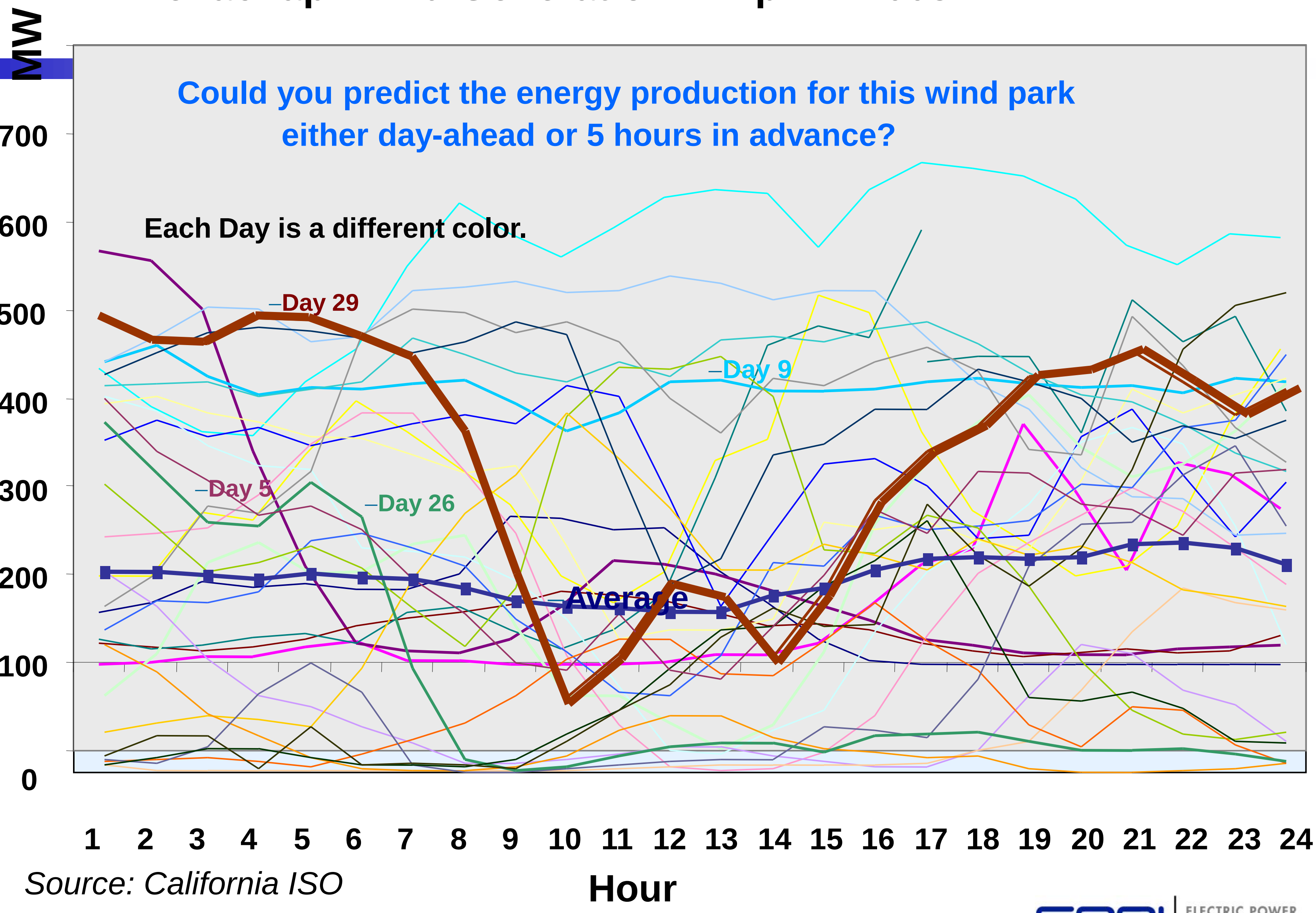


Source: EPRI Prism 2.0 Study

What We Are Seeing…

- **Near term response to high CO_2 price likely dominated by renewables, efficiency and natural gas**
  - Coal retirements offset by new renewables, efficiency
  - Natural gas fills any remaining demand
- **Wind integration costs significant at high penetration**
  - New balancing resources required (transmission, storage, smart grid, PHEVs)
  - Cycling impacts on thermal fleet -> increased O&M
- **Longer term, nuclear and CCS will be important**
  - Without them, rely on more costly renewables, efficiency

Tehachapi Wind Generation in April – 2005



Source: California ISO

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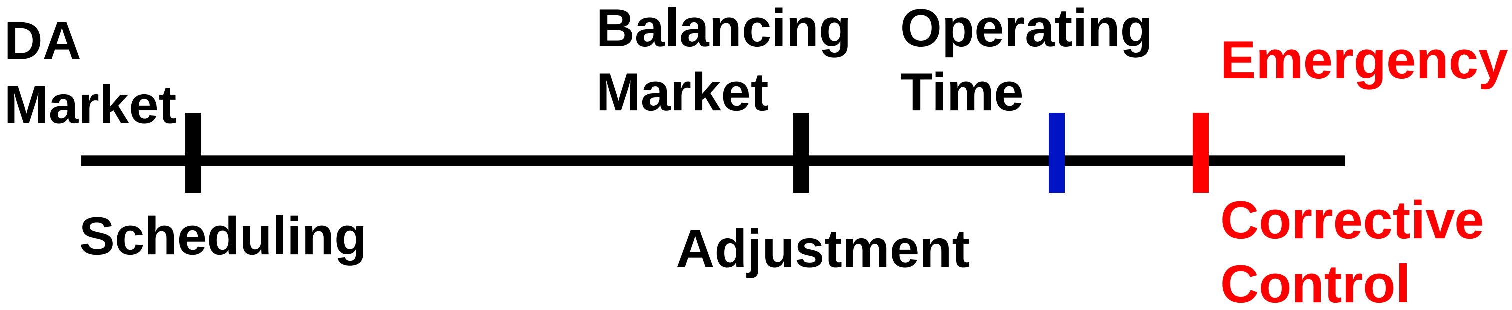
Worst-case Dispatch



Constraints

- Power balance
- Operating limits
- (N-1) Contingencies

Objective

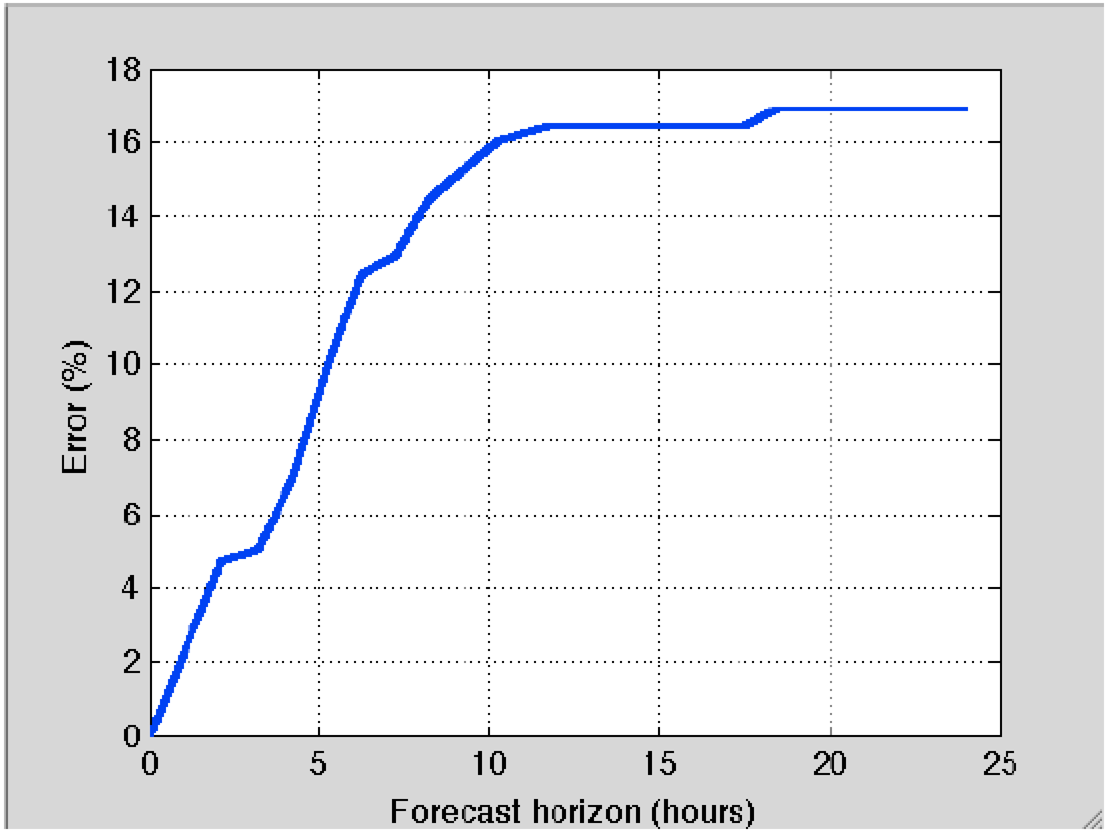
- Min. cost
  st. constraints

Uncertainties:

- Load Forecasting
- Forced outage of equipment
- Increasing amounts of **Wind** and solar power present additional **HUGE** uncertainties for grid integration

Source: from Janusz, Pravin, and Felix's presentations

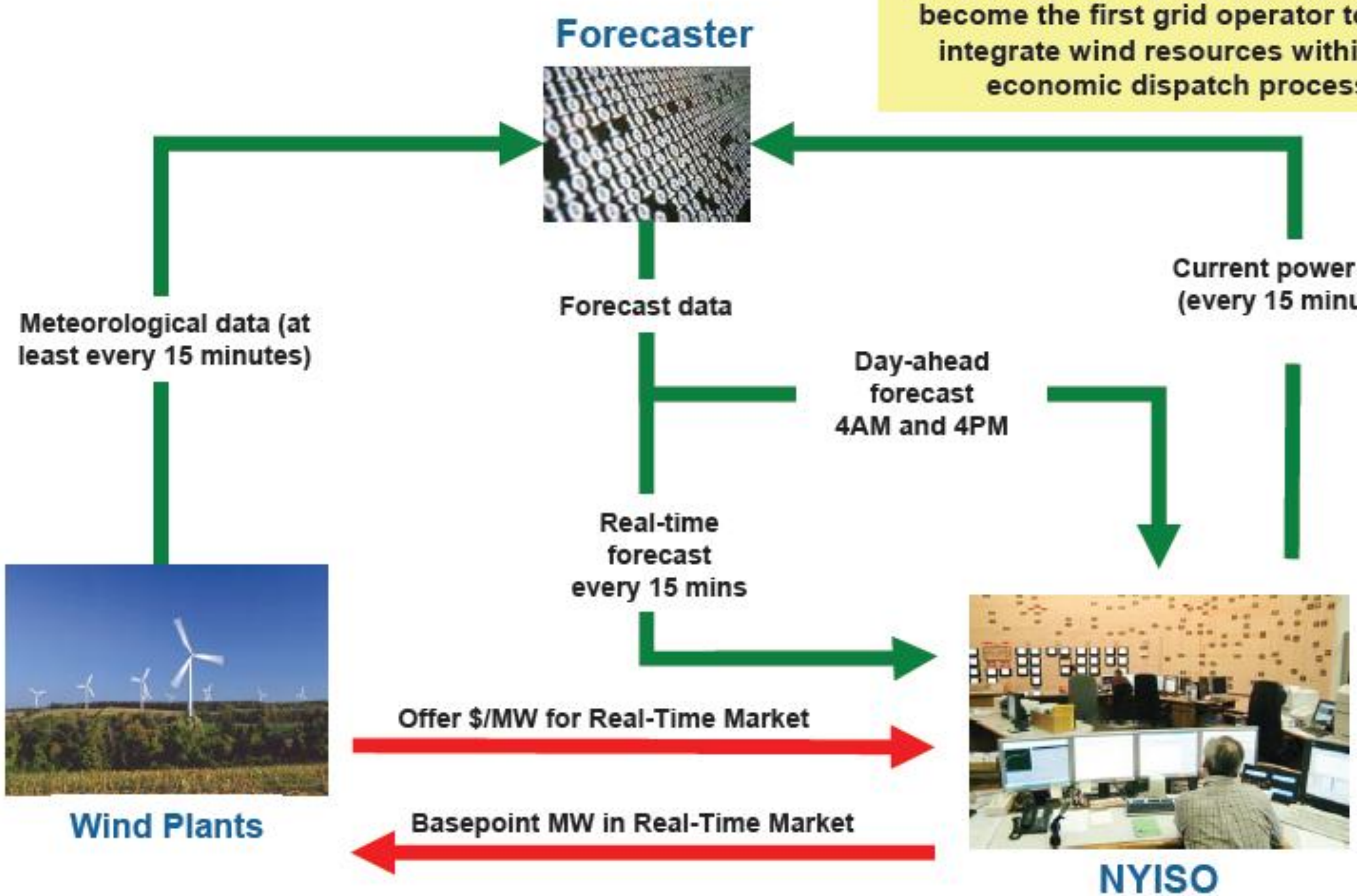
Forecast Error vs. Forecast Horizon



Source: this plot is taken from Iberdrola Renewables

Pioneering Wind Dispatch (NYISO)

In May 2009, FERC approved NYISO to become the first grid operator to fully integrate wind resources within its economic dispatch process



Source: Rana Mukerji's presentation at EPRI's Summer Seminar, August 2010

Dispatch Dilemma Facing CAISO

- The California ISO (CAISO) must purchase sufficient reserve capacity to meet the worst-case uncertainty in supply
- 2000-2010 reserve capacity averaged 5% of 50GW peak, or 2.5GW
- Errors in 24-hour forecasts of wind regarded by CAISO as "uncertain"
- Since all forecasts of wind >6 hours are unreliable, CAISO must treat all intermittent power as statistically unpredictable
- The result – Planned wind expansion to 25GW in 2020 will require 5-10GW of reserves
- The cost of the reserve becomes a subsidy to wind that is unsupportable
- Planned wind expansion will require alternative dispatch procedures

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Objective
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- Modify dispatch procedures used today in many power systems that:
- Combine intermittent power generators – wind, solar – with reserves of different types, such as storage, demand-management, fast gas plants and EV, with different time scales of response
- Creates a new portfolio that is as reliable as thermal generators
- Reduces cost (subsidy) of reserves to support wind
- Requires smart grid infrastructure to handle data from expanded sensor network

Alternative Dispatch Procedures Require

- Availability of sensors for more accurate prediction over shorter time periods
- Stochastic models that enable reliability assessment and efficient scheduling
- Risk analysis of the random characterization of new technologies
  - Renewables
  - Storage
  - Demand-response

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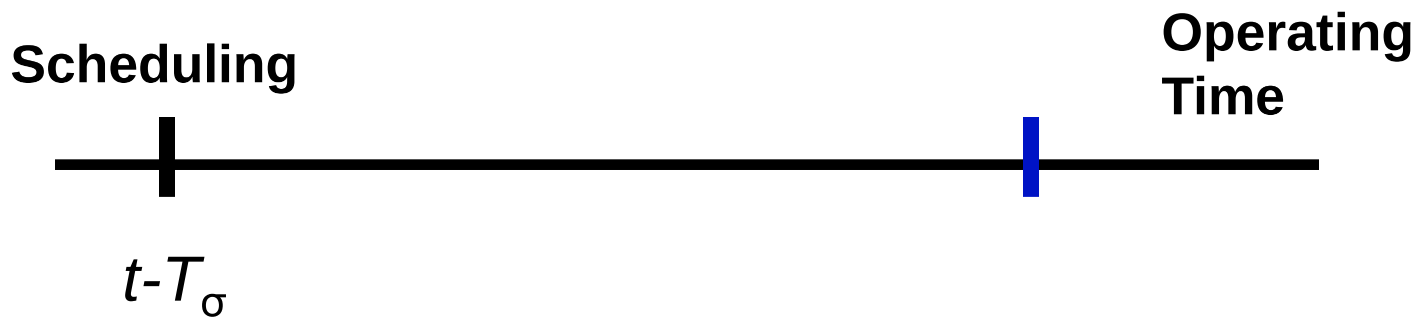


Scheduling:

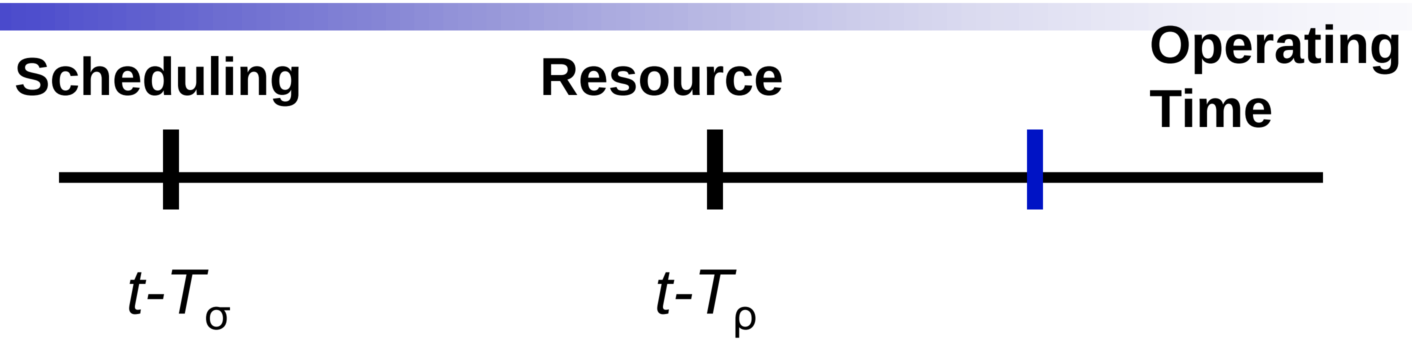
–Decision u_σ: Generation and demand

–Max objective such that the **RISK** of not meeting operating constraints is less than (1-p^*) based on information $y_{t-T\sigma}$ available at scheduling time

$$\min \mathrm{E}(\text{cost})$$
$$\Pr\{g(x(t), u_\sigma) = 0, h(x(t), u_\sigma) \leq 0 | y_{t-T_\sigma}\} \geq p^*$$

Source: from Janusz, Pravin, and Felix's presentations

Risk-Limiting Dispatch



Resource:

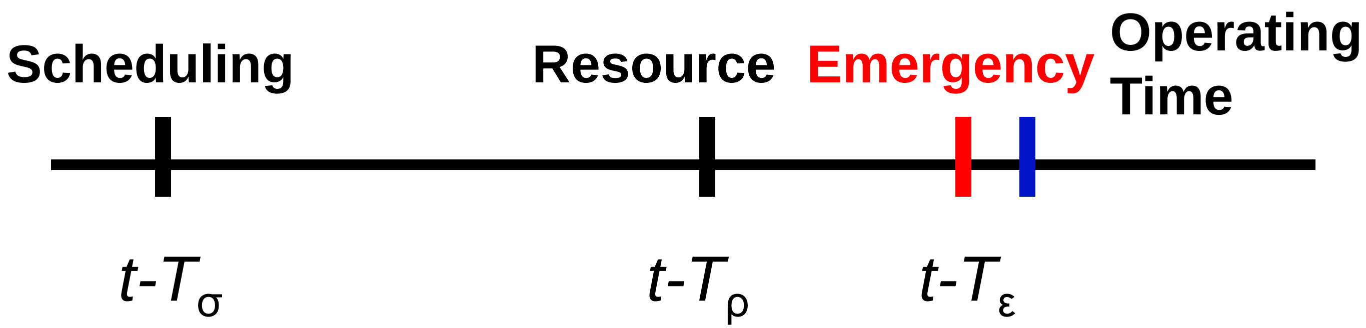
–Decision u_ρ: Generation, storage, and demand response

–Max objective such that the **RISK** of not meeting operating constraints is less than (1-*p**) based on information $y_{t\text{-}T\rho}$ available at scheduling time

$$\min \mathrm{E}(\mathrm{cost})$$
$$\Pr\{g(x(t), u_\sigma, u_\rho) = 0, h(x(t), u_\sigma, u_\rho) \leq 0 | y_{t-T_\rho}\} \geq p^*$$

Source: from Janusz, Pravin, and Felix's presentations

Risk-Limiting Dispatch



Emergency:

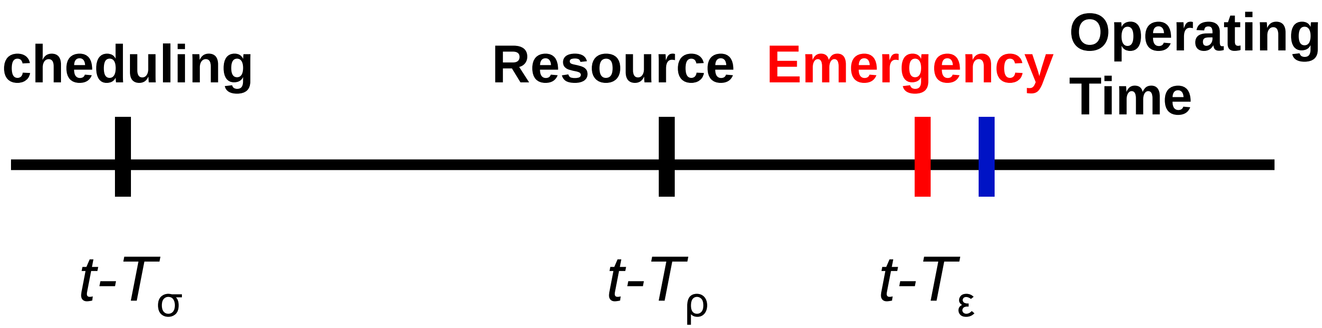
– Decision u_ε: Generation, storage, and interruptible load

– The operating constraints must be satisfied.

$$\min \ \mathrm{E}(\text{cost})$$
$$\Pr\{g(x(t), u_\sigma, u_\rho, u_\epsilon) = 0, h(x(t), u_\sigma, u_\rho, u_\epsilon) \leq 0 | y_{t-T_\rho}\} = 1$$

Source: from Janusz, Pravin, and Felix's presentations

Risk-Limiting Dispatch



The overall optimization problem for system operations:

$$\min E f(x(t), u_\sigma, u_\rho, u_\epsilon)$$

$$\begin{array}{lll} P\{g(x(t), u_\sigma) = 0, & h(x(t), u_\sigma) \leq 0 & |y_{t-T_\sigma}\} \geq p^* \\ P\{g(x(t), u_\sigma, u_\rho) = 0, & h(x(t), u_\sigma, u_\rho) \leq 0 & |y_{t-T_\rho}\} \geq p^* \\ P\{g(x(t), u_\sigma, u_\rho, u_\epsilon) = 0, & h(x(t), u_\sigma, u_\rho, u_\epsilon) \leq 0 & |y_{t-T_\epsilon}\} = 1 \end{array}$$

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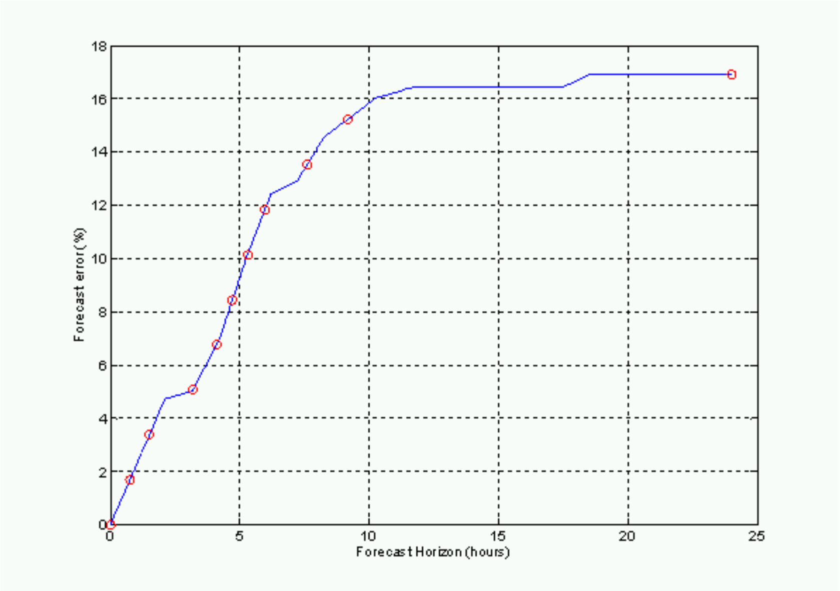
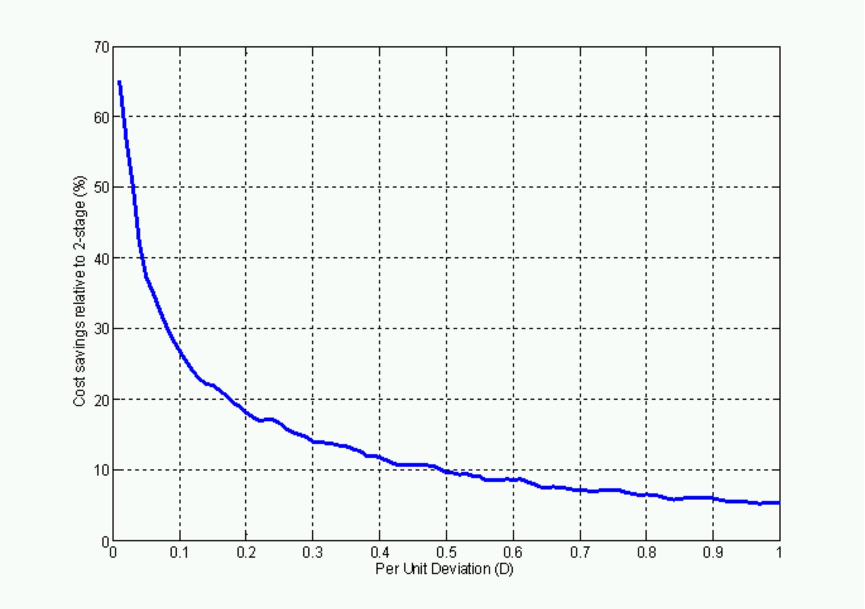
Increasing the Opportunities to Adjust



Relative savings of 10-stage vs 2-stage strategy



(2-stage cost – 10-stage cost)/10-stage cost

Three strategies are compared:

1. 2-stages: one can purchase only in stages 1 (24-ahead) and 10 (real-time);
2. 10-stages: one can purchase at all of 10 stages;

Increasing the Opportunities to Adjust

- System flexibility is the key attribute needed to respond to uncertainties
- The more opportunities system operators have to adjust supply and demand resources the greater the financial benefits
- The key is finding the optimal frequency and timing of resource adjustments
- Benefits can be quantified
- The frequency and timing of iterative adjustments be brought increasingly closer to the scenario arising from “perfect information

Summary

- Current practice of worst-case dispatch requires subsidies for renewable sources and demand response
- Better wind forecasting
- More refined control suggest shift to risk-limiting dispatch
- Rapid coordination (both preventive and corrective) with demand response and energy storage