Renewables Integration Model

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Key Project Staff

- Ross Guttromson, Project Manager
- Harold Kirkham, PhD, Power Systems Analysis
- Dan Sisk, MSCS, Software Development
- Steve Elbert, PhD, HPC
- Ning Lu, PhD, UCED
- Kevin Glass, MSCS, Software Development
- Cesar Silva, PhD Candidate, Energy Storage
- Nirupama Prakash-Kumar, MSEE, Power Systems
- Dave Chassin, Demand Response
- Jason Fuller, MSEE, Demand Response

Collaborators

- IdeaEntity, GUI Development
- 3Tier and AWS Truepower, Mesoscale Wind Data
- SNL , Solar Data (FY11)
- ANL, Advanced Unit Commitment (FY11)
- Bonneville Power Administration

What's the Need?

- As variable generation penetration increases, utilities need to know their options for managing balance
- Planning for the future is essential in light of the potential high costs involved (e.g. pumped hydro)
- New Resources are available
  - Storage
  - Demand Response
  - Variable Resources Themselves
  - Traditional Generation
  - Coordinated Hydro Operations
- The likely choice for managing balance is a portfolio of resources

Concept of Imbalance

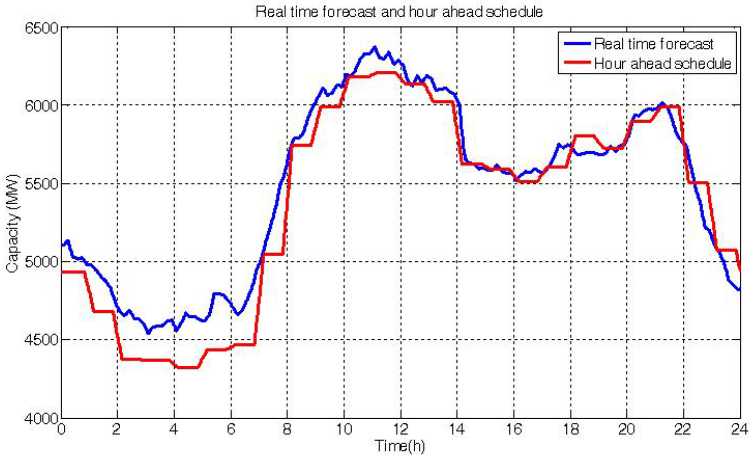
Today:

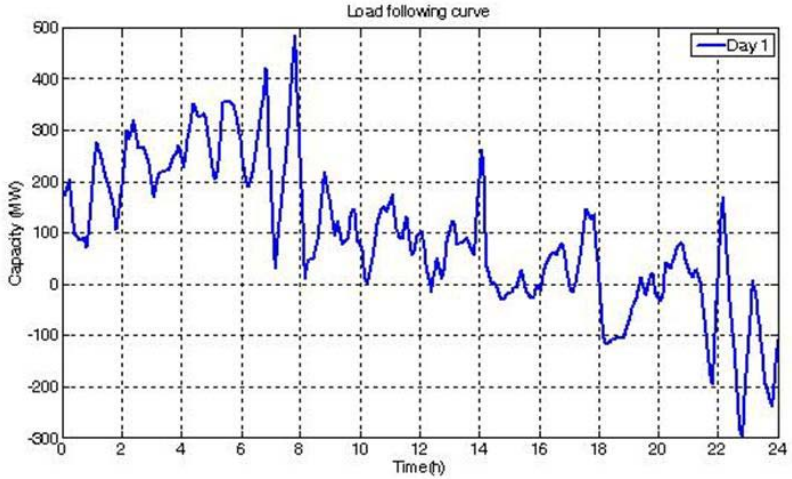
1. Forecast tomorrow's load demand
2. Schedule/assign generators to meet tomorrow's forecasted load

Tomorrow:

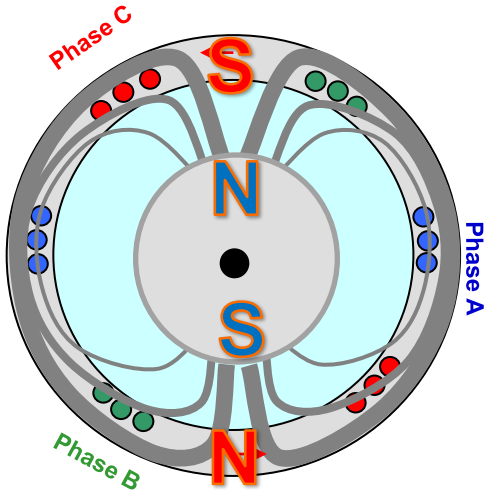
3. When the load appears, it will not be exactly as forecasted
4. The difference between scheduled generation and actual load is imbalance
5. Imbalance must be met with real time resources

I just lied a little bit…





Why Does Imbalance Need to Be Managed?



- 1. Conservation of Energy requires all energy to be accounted for… *there is no imbalance*
- *2.* The grid actually does have some stored energy in the form of rotational kinetic energy
- *3. When the energy is used to balance the system, the rotational speed decreases- hence the frequency decreases.*
- *4. If frequency changes too much, the grid will crash*
- *5. Balancing reserves prevent excessive frequency changes*

Renewables Integration Model- *What it Does*

- Evaluates the impacts of variable generation (wind and solar) on planned grid operations (off-line model)
  - Uses *real* data as available
- The model simulate operations to
  - Predict the effects of variability, including impacts on
    - Control Performance Standards
    - Generation ramping and operating reserve requirements, etc
  - Develop and evaluate the results of mitigating measures
    - Improved scheduling process
    - Better forecasting system
    - Coupling the intermittent resources with hydro resources and energy storage, and other measures
  - Conduct “what if studies” like…
    - Analyzing the maximum acceptable penetration levels,
    - New wind generation technologies, etc

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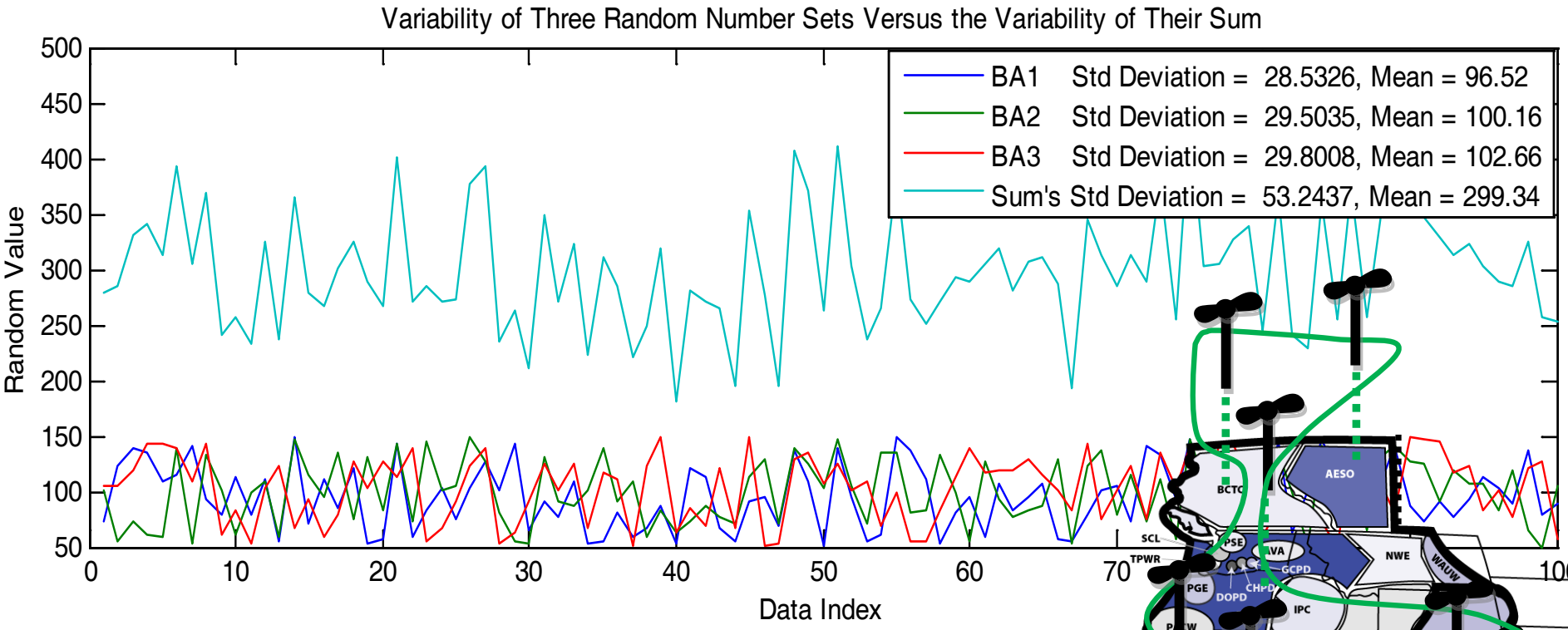
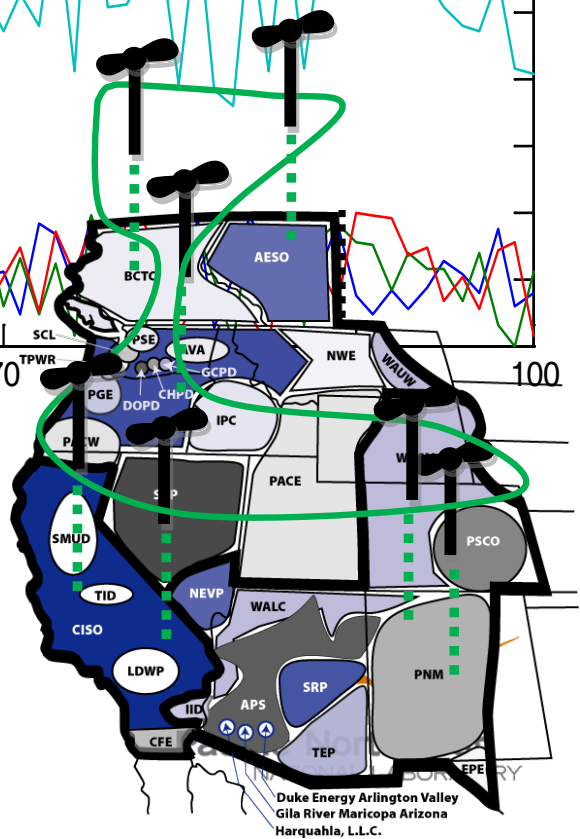
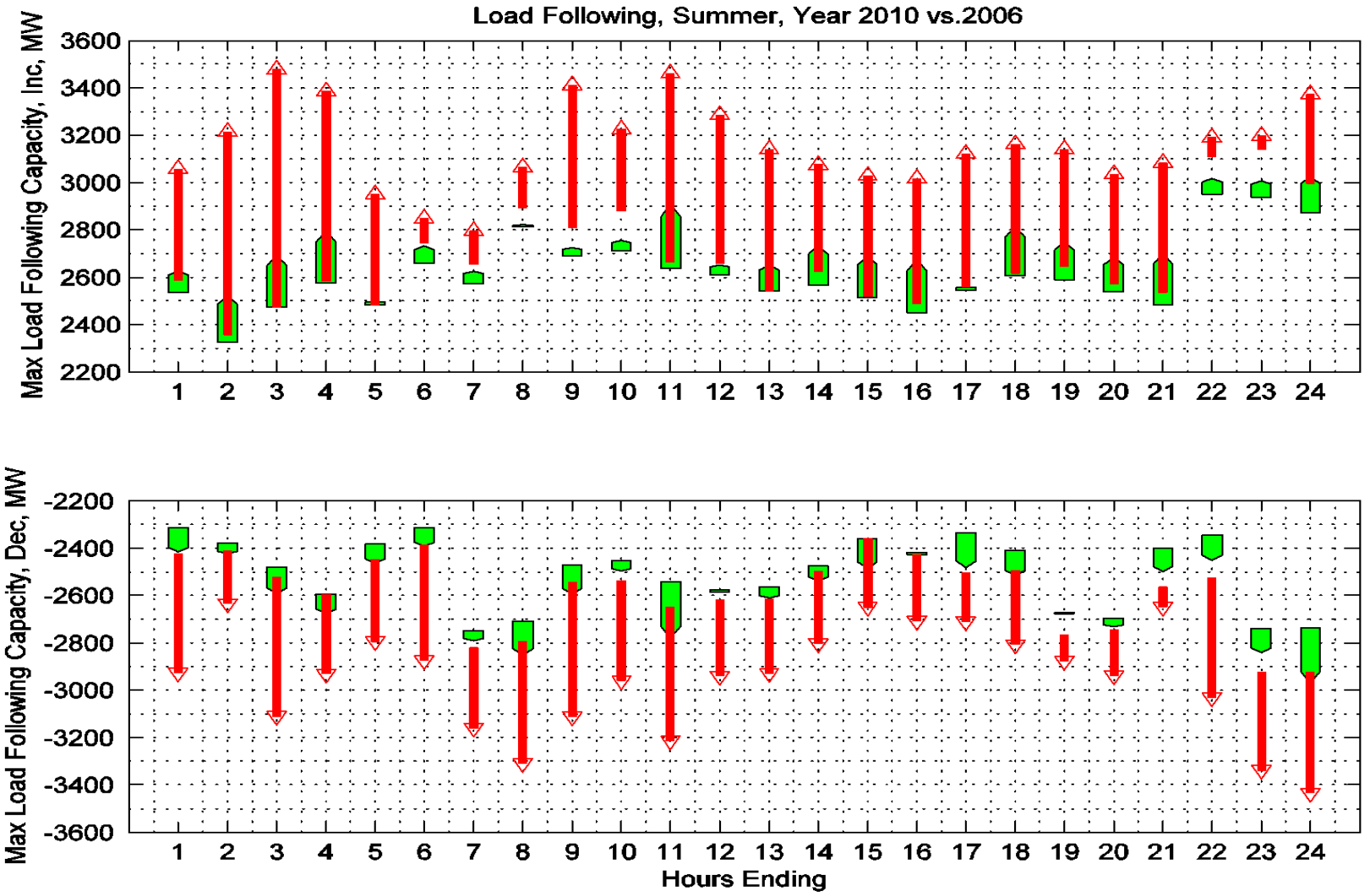
RIM Will Allow Leveraging Geographic Diversity of Resources





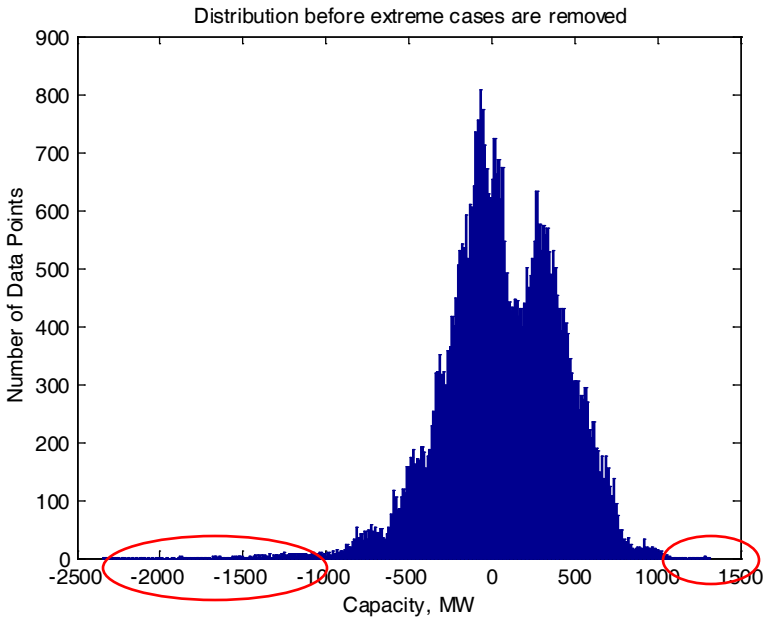
Duke Energy Arlington Valley
Gila River Maricopa Arizona
Harquahla, L.L.C.

RIM Will Determine the Impacts of Wind on Regulation and Load Following

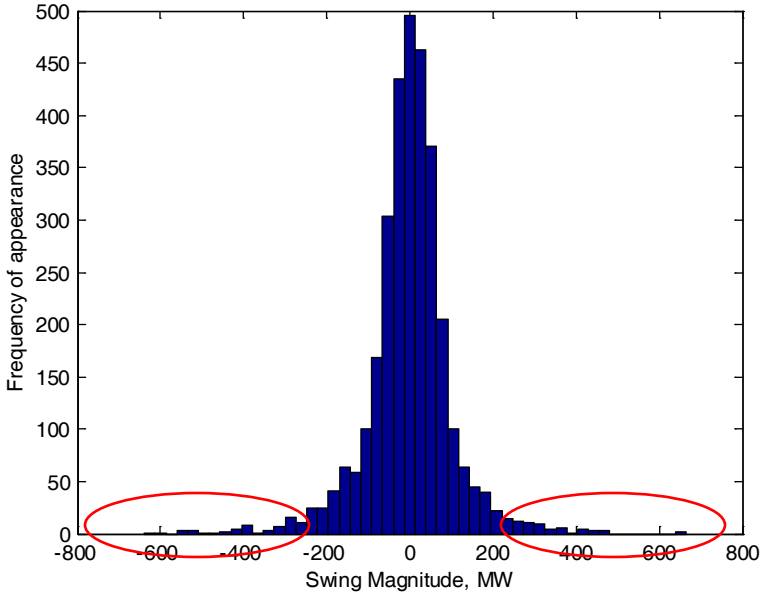


RIM Will Model Low Probability, High Consequence Events

Tail events (for projected wind in a large utility system in August 2010):



Distribution of load following capacity requirement



Distribution of swing magnitudes on wind power output

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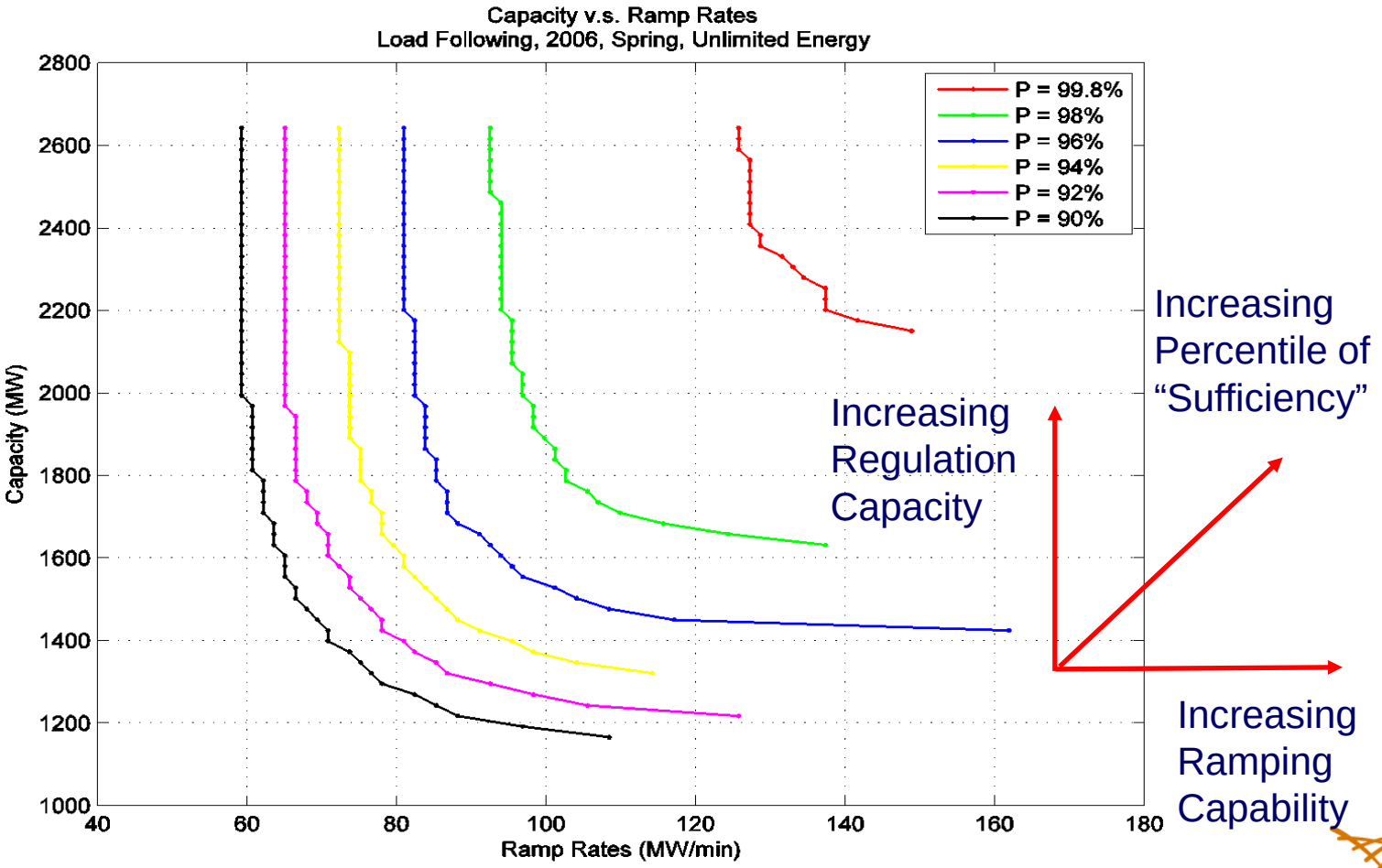
RIM Can Place Higher Value on Faster Balancing Resources



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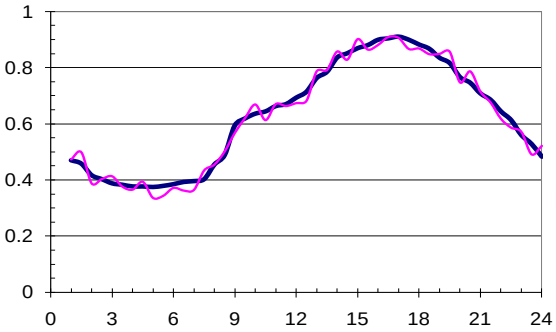
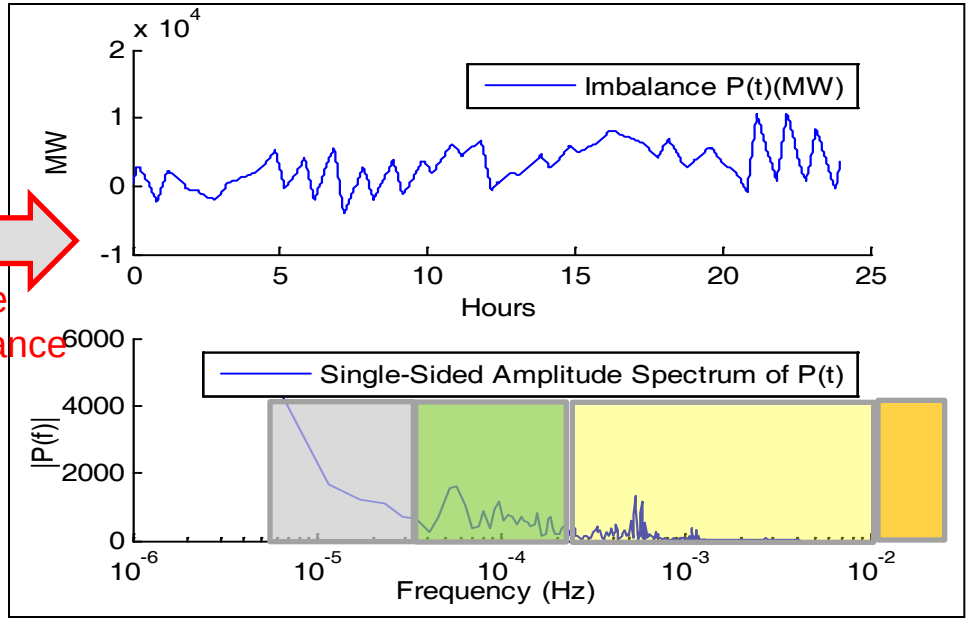
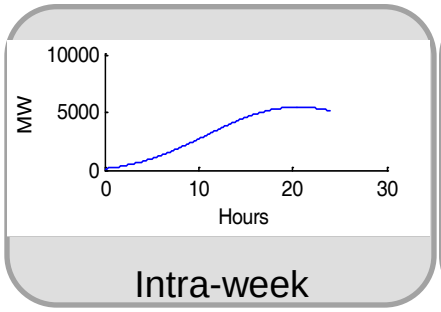
RIM Can Optimally Deploy Balancing Resources

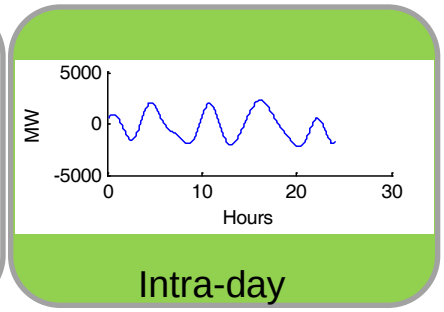
Imbalances superimposed with scheduled generation

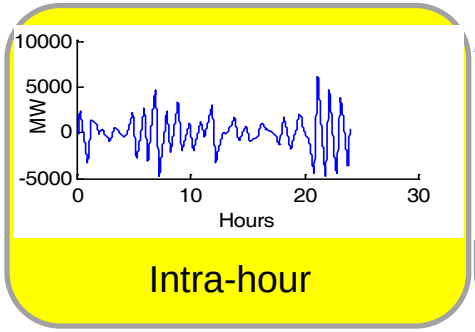


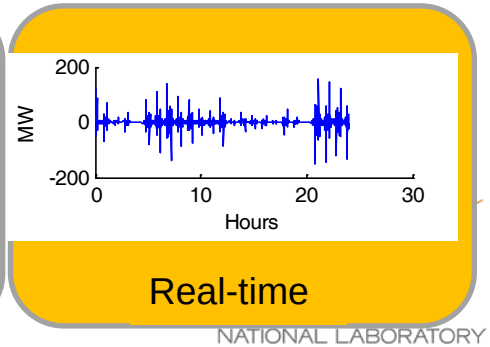
Isolate imbalance



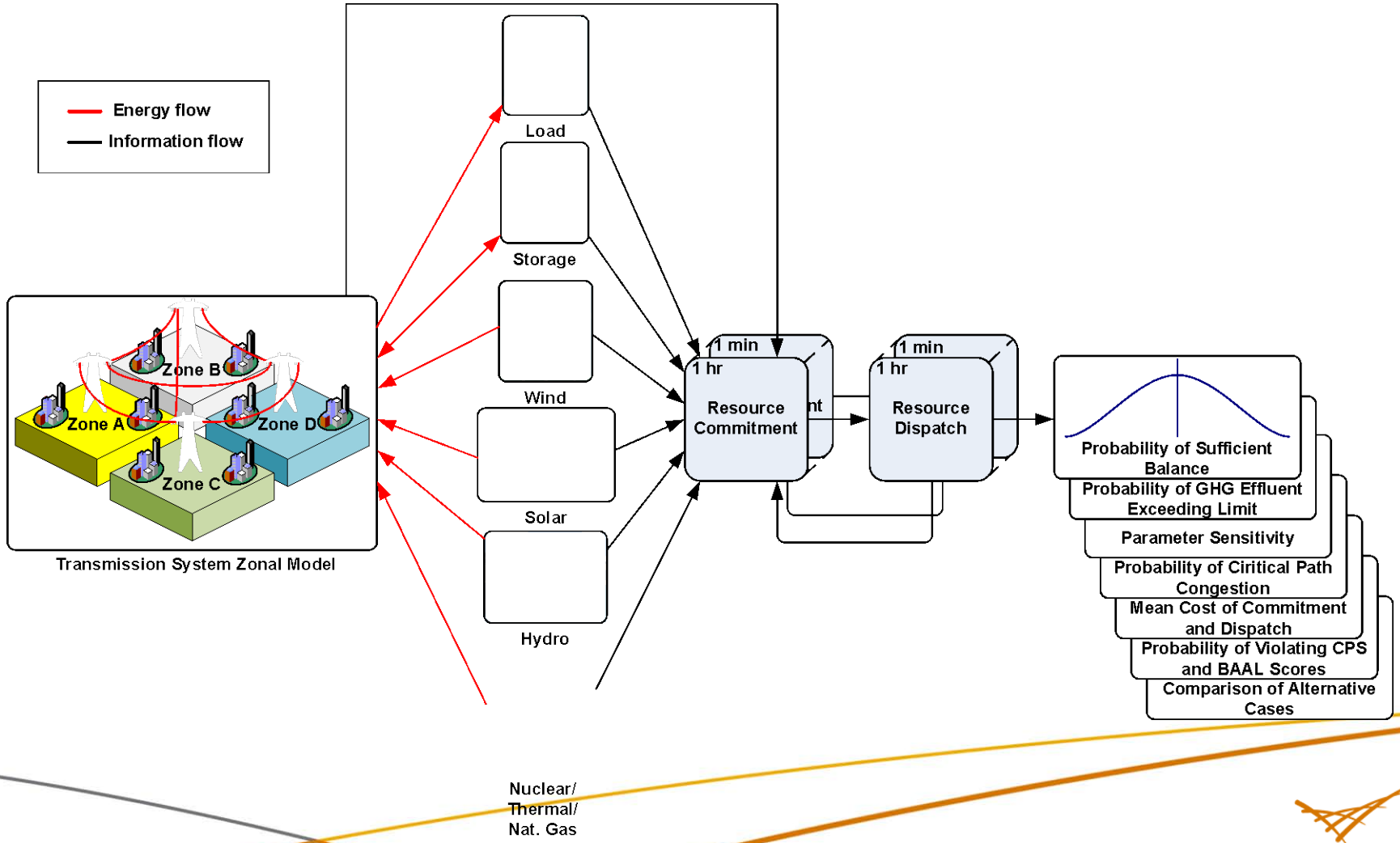








RIM Overview



Use Case Examples

Each use case question was formulated by utility discussions and was then distilled into specific and measurable analysis criteria that can be solved by the RIM

1. When we add a wind into a control area, what impact it will have on the control area's operations?

2. For an existing system, with present generation portfolio and flexibility, what is the amount of reserves needed and cost associated to mitigate the variations caused by wind energy in the system?

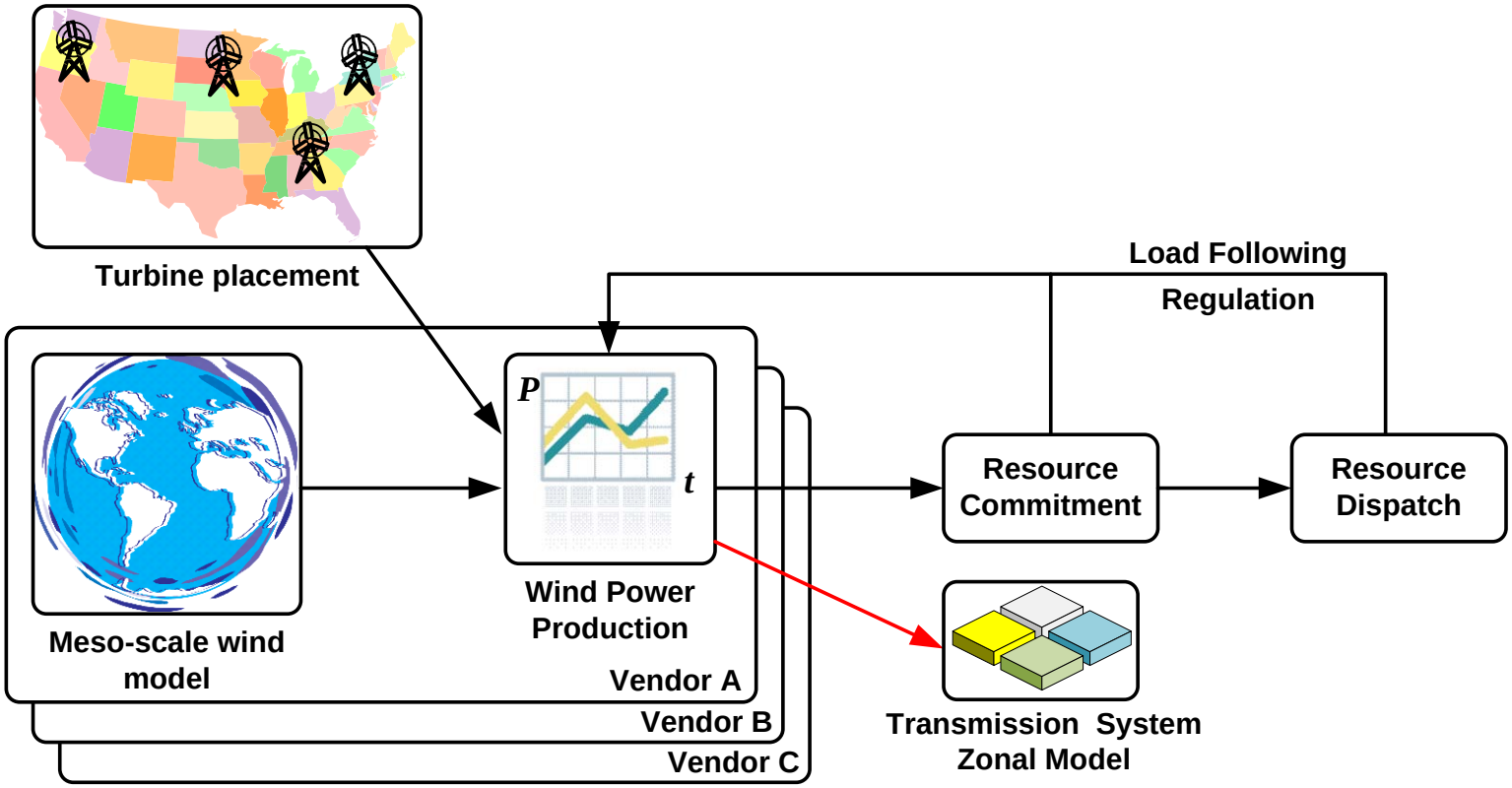
3. How will Control Performance Standards (or frequency regulation, or BAAL etc.) be affected if a new wind farm is established in and what will it cost to manage the imbalance?

How is RIM Different From Other Model Such As Production Cost Models?

- RIM time step goes as low as 1 minute, allowing inter-hour imbalance to be managed using solar, wind and load data at the same resolution
  - Monte Carlo Analysis
  - Parameter Sensitivity Analysis
- RIM has an advanced hydrological model
- RIM allows resources to contribute to balancing services
  - Storage
  - Loads
  - Wind or Solar itself
  - Traditional Generation (e.g. CT)
- Allows a *portfolio* of balancing resources to manage imbalances
- Input cost functions and constraints for resources
- Will tabulate CPS, emissions, wear and tear, costs
- AGC controls are adjustable

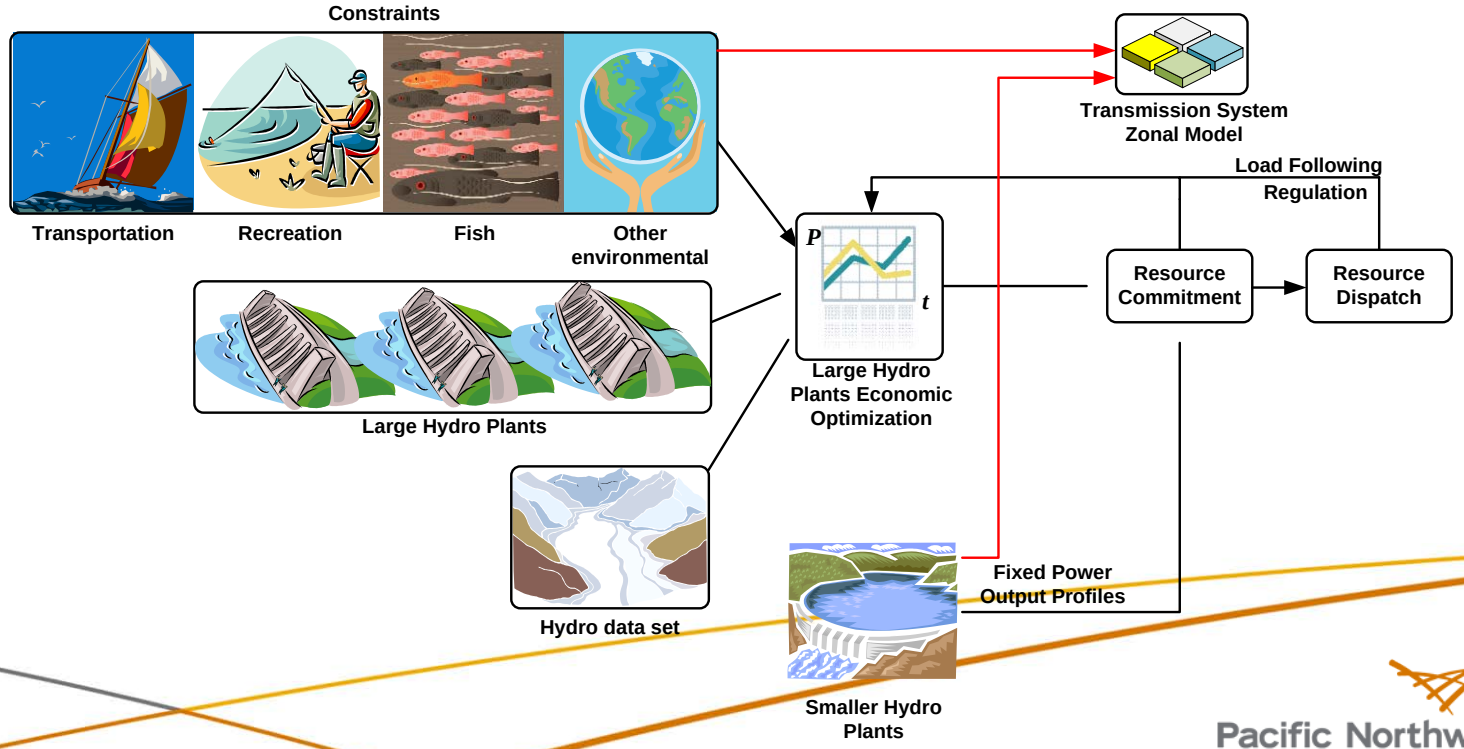
Wind (Solar expected in FY11 by SNL)

- Weather modeling feeds production modeling feeds into RIM
- Multiple production scenarios based on installed capacity and location
- Wind power output can be calculated using different meso-scale models for all common wind turbines at multiple hub heights



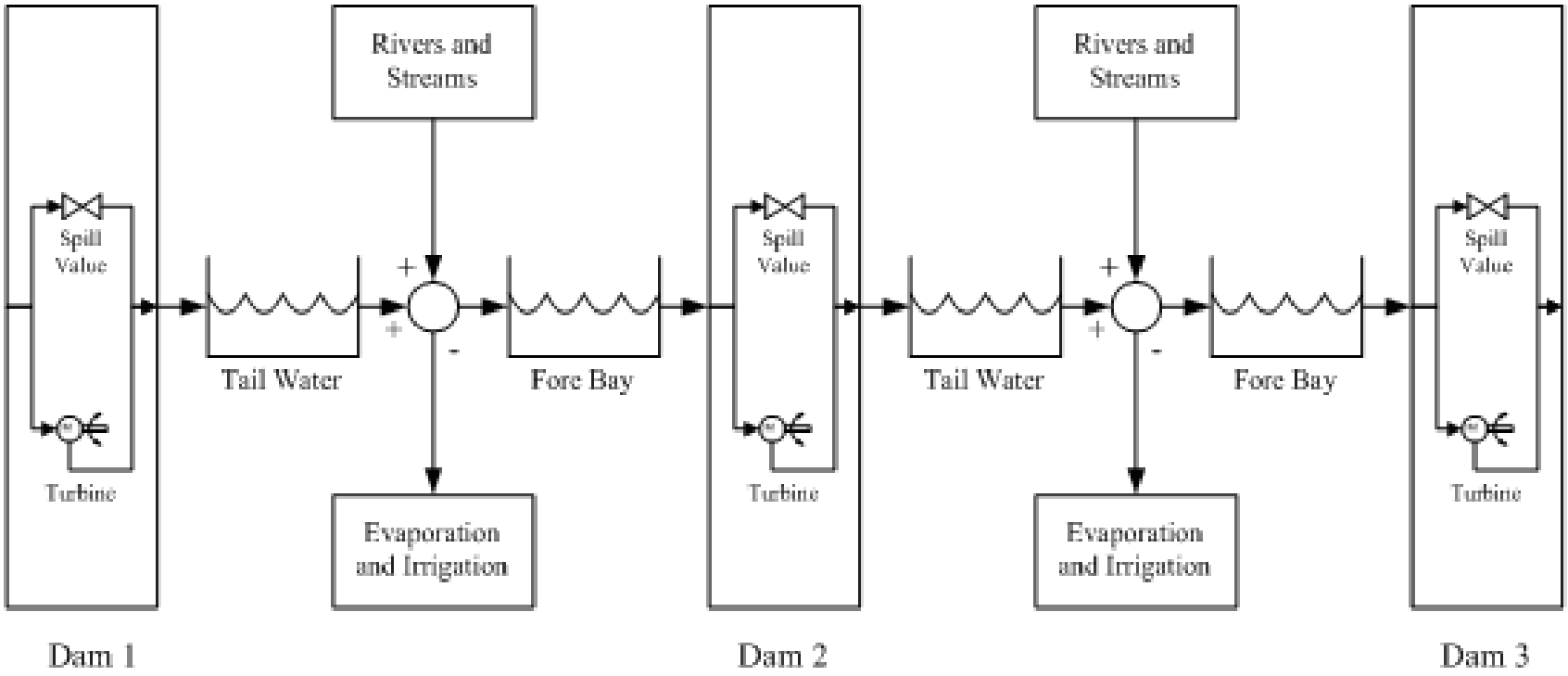
Hydro

- Objective of the hydro module is to maximize the available power for balance.
- Constraints include environmental, recreational, spill, navigational, and level restrictions due to unforseen events.



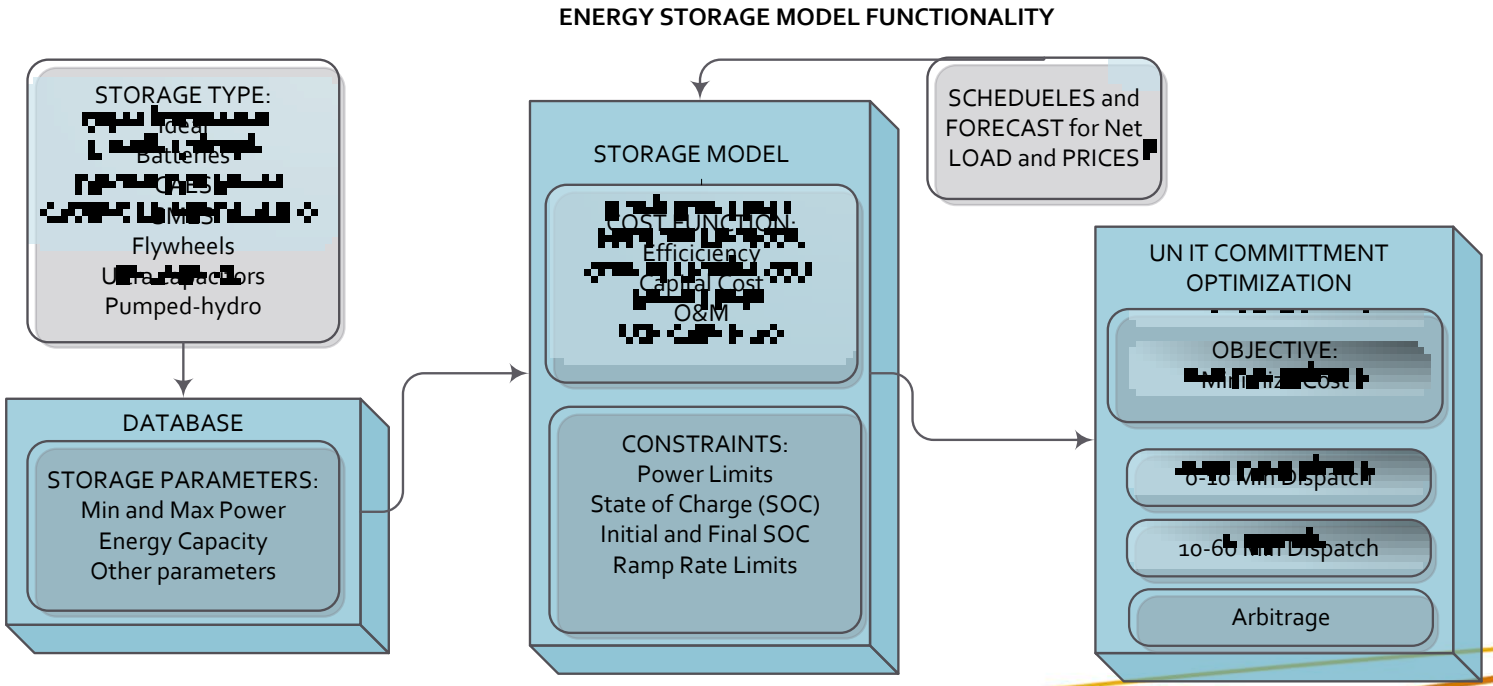
WIM Hydro Model

Many constraints, but two controls: spill or generate



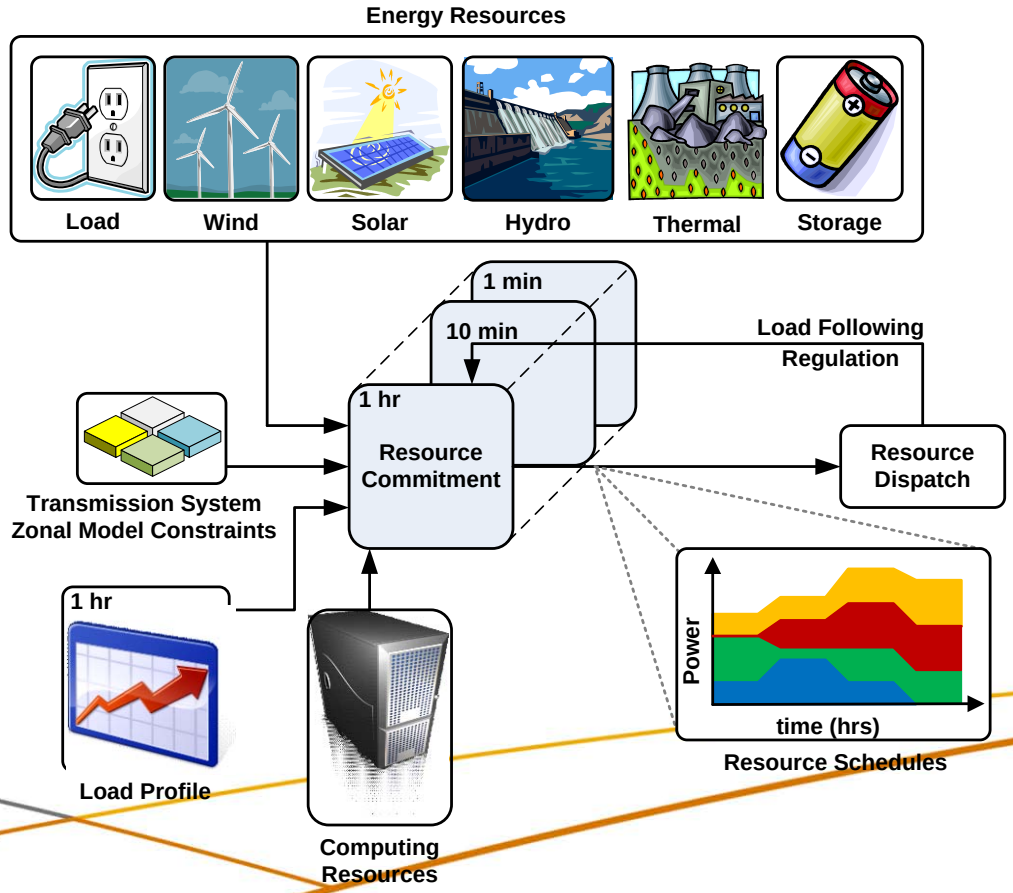
Storage

- Models of several energy storage technologies are available for simulation
- Energy storage is dispatched based on user defined objectives such as cost minimization of the overall system



Resource Commitment

- Security constrained optimization of conventional and non-conventional energy resources such as load, storage, and even wind and solar
- High performance computing resources enable time-series and monte-carlo analysis



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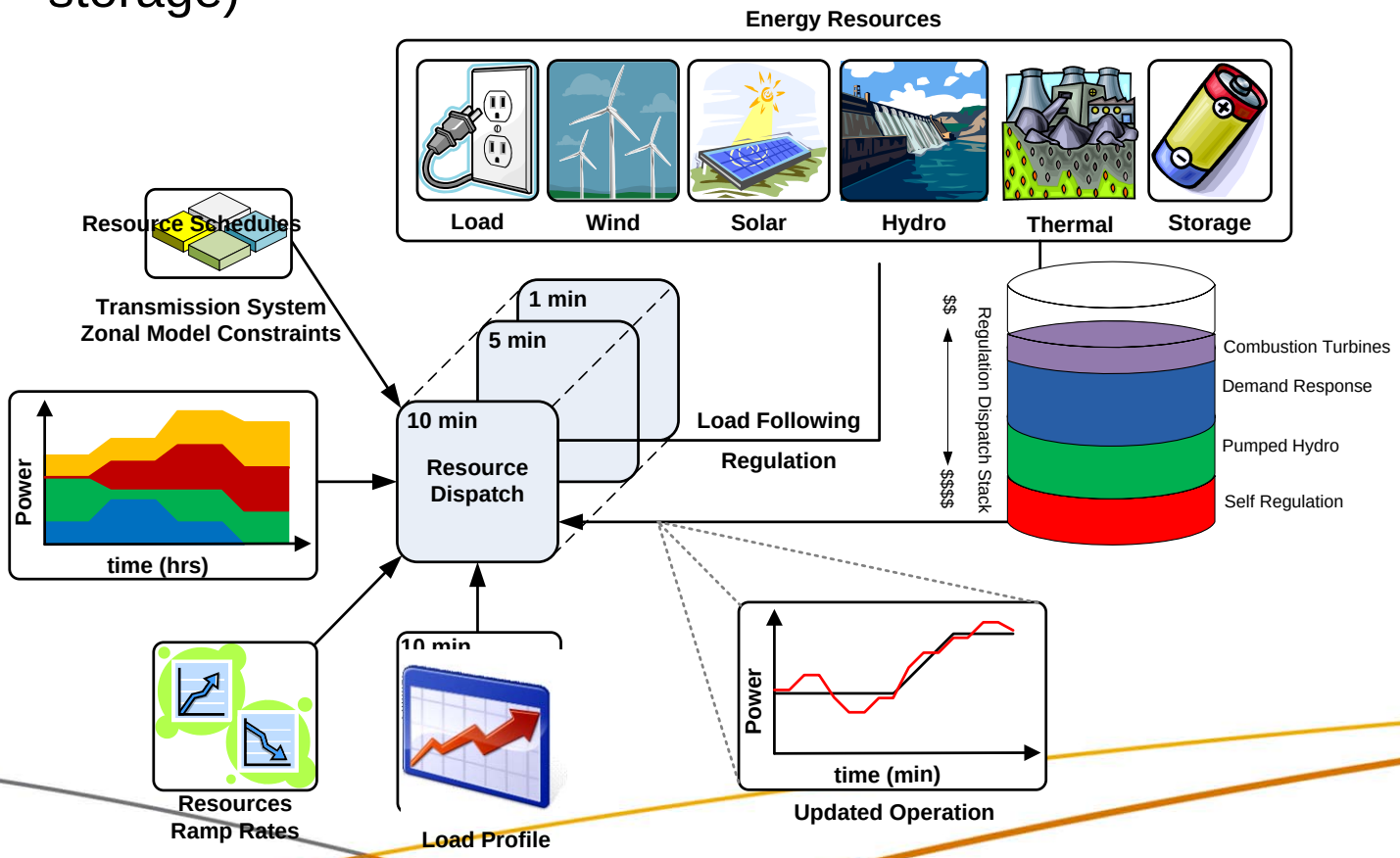
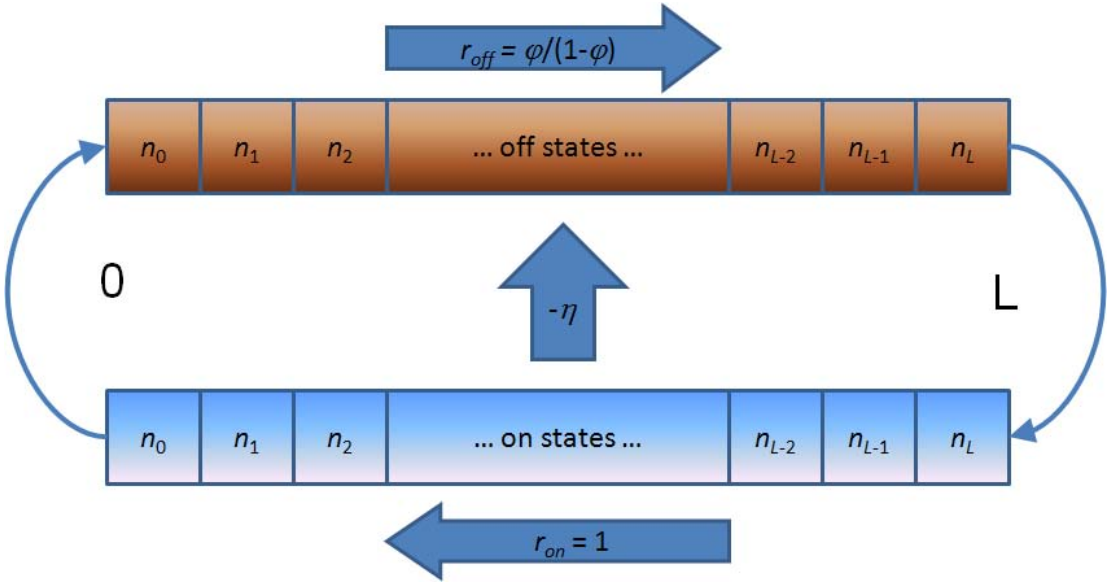
Resource Dispatch

- Adjustments performed in real-time operation in time steps of 10 minutes down to one minute
- Energy resources are adjusted based on their energy, power, ramp rate capability and cost minimization (including cycling limits for storage)

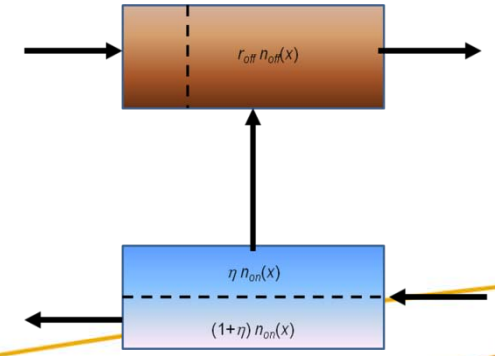


Load Curtailment

- Air Conditioning
- Heating
- Water Heaters
- Washers
- Dishwaswhe4rs
- Refrig Defrost Cycle
- Commercial AC



Queue for state transition
-Natural transition at ends
-Forced transitions in middle



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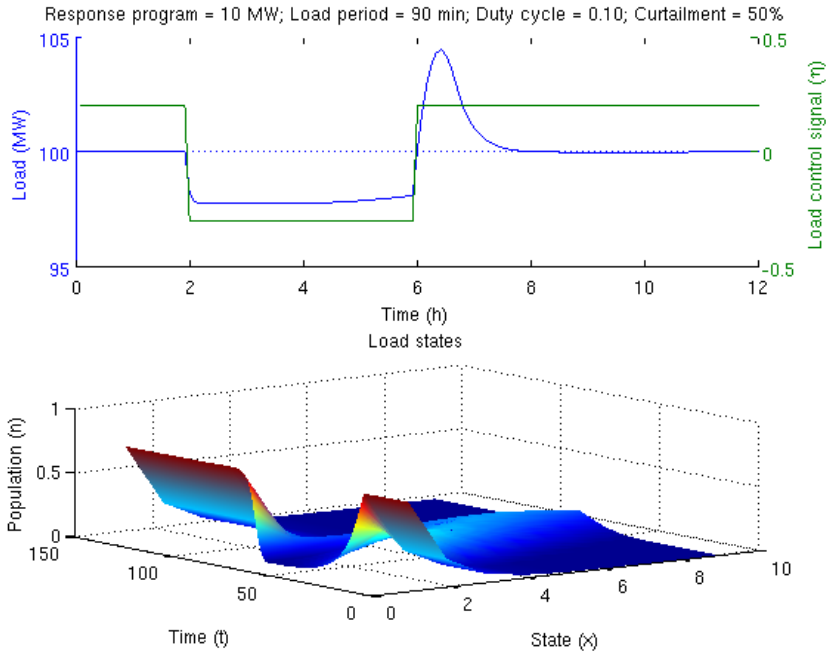
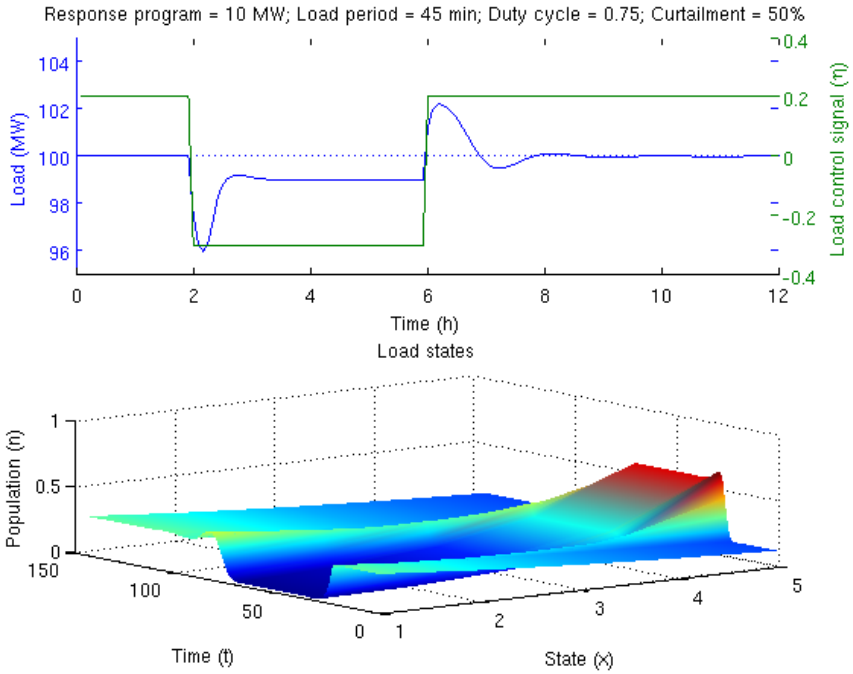
Load Curtailment
Reduced Order Model From Gridlab-D



Load Period (Length of cycle): High
Duty Cycle (% time on):Low



Load Period (Length of cycle): Med
Duty Cycle (% time on): High

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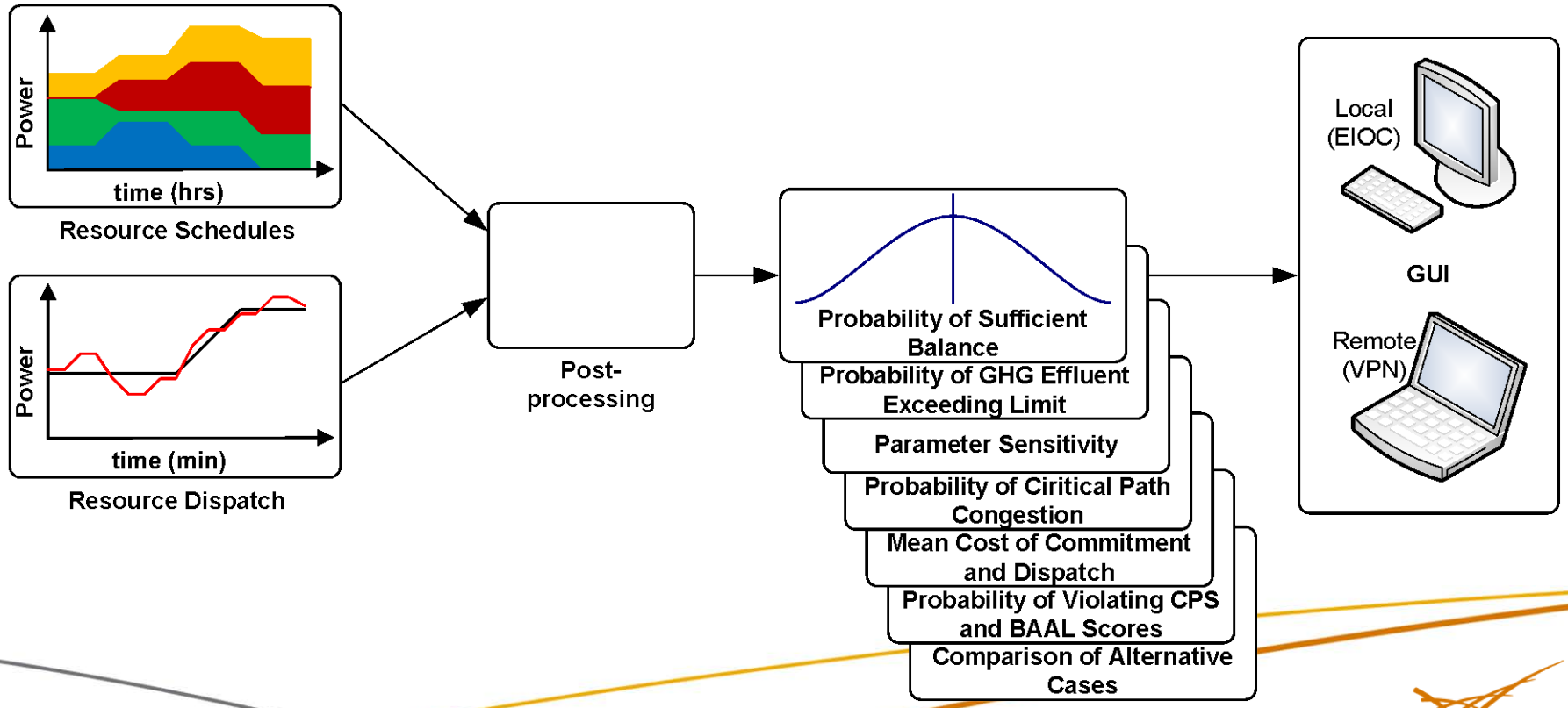
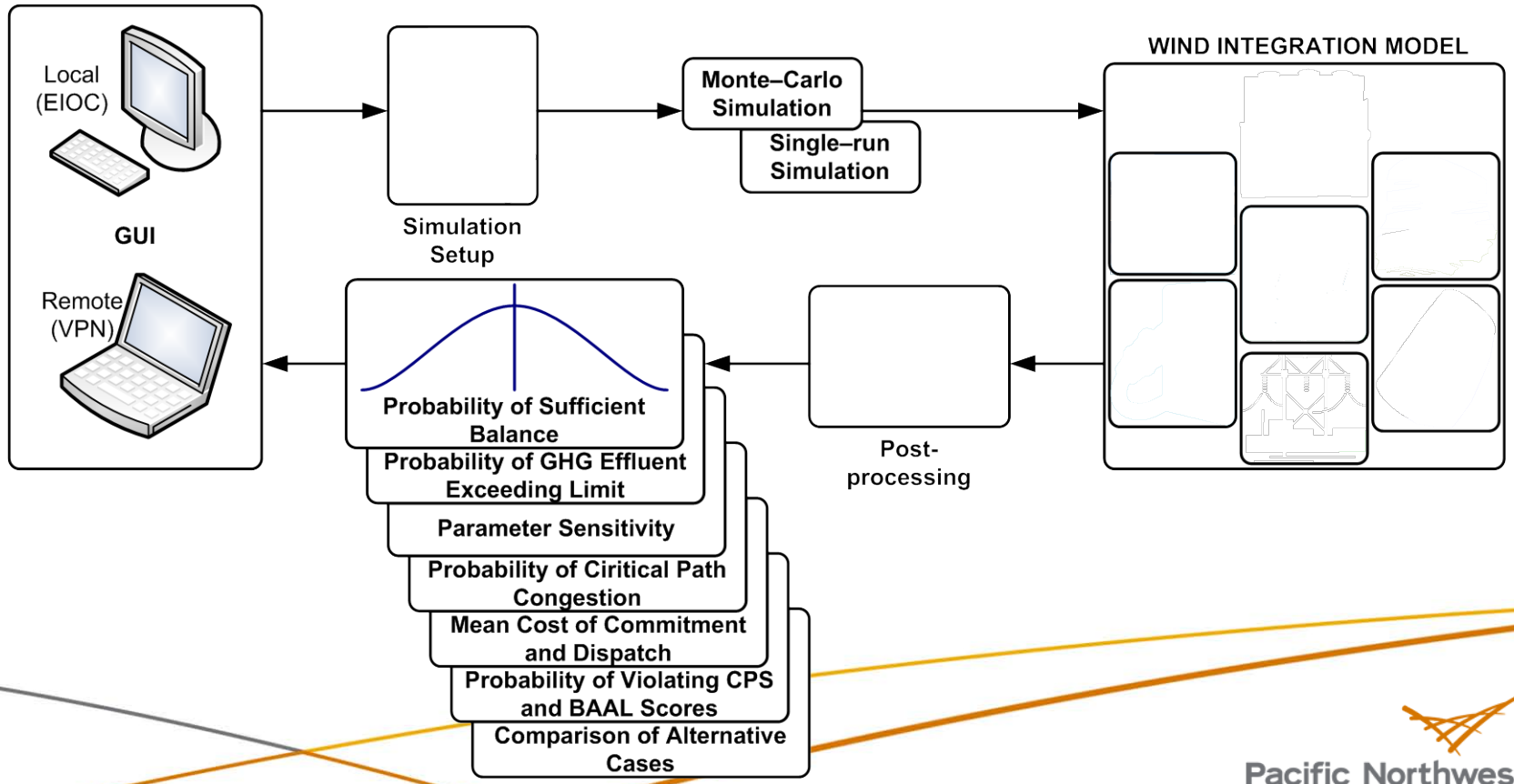
Post Processing

- Allows mathematical operations on time series results
- Perform statistical analyses using MATLAB
- Provides scenario results as probabilities, sensitivities, or values



Graphical User Interface

- Provides access to simulation set-up parameters
- User identifies the type of results needed
- Allows access to library of common models and scenarios, and allows these to be manually reconfigured as desired by the user



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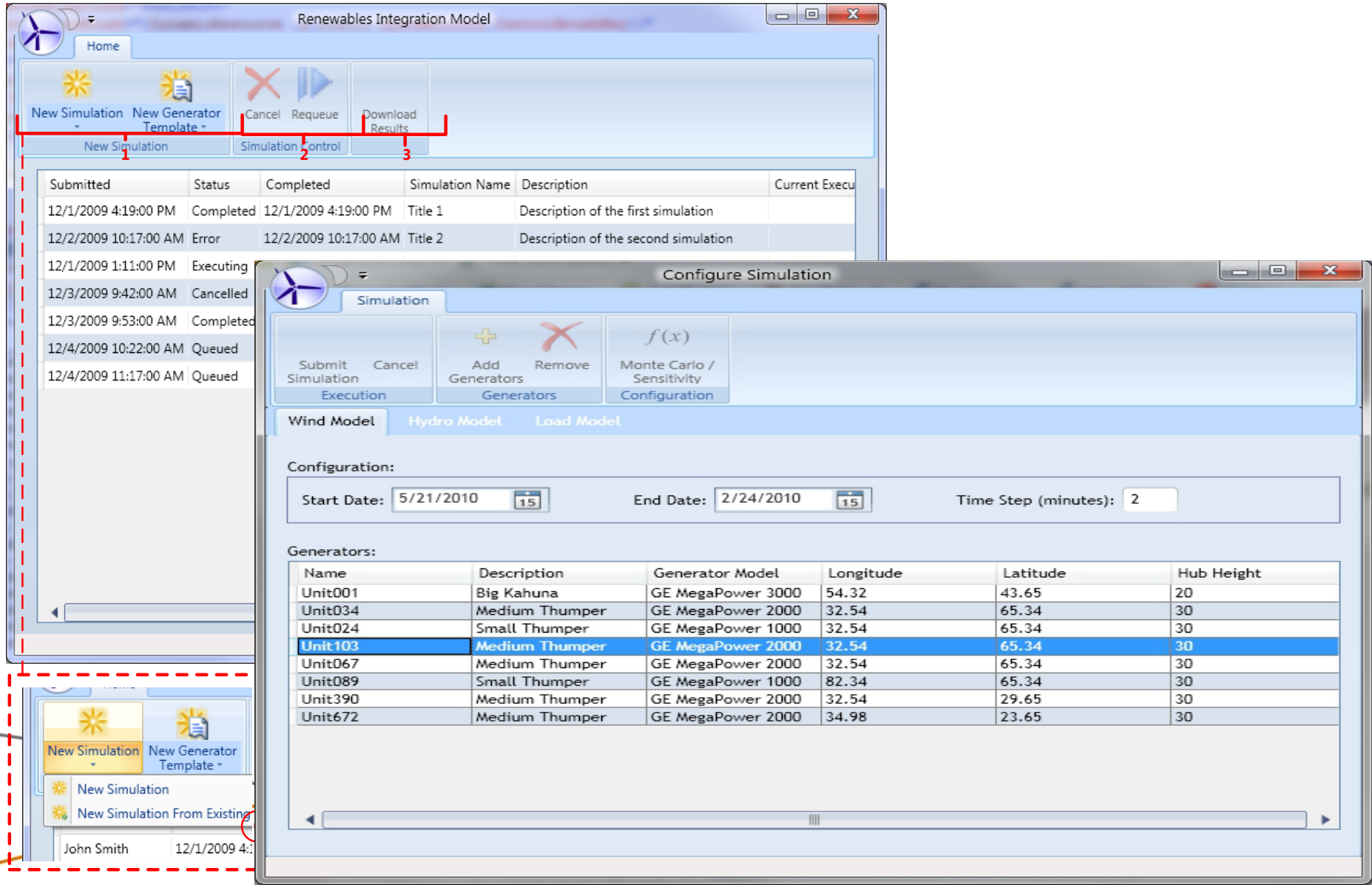
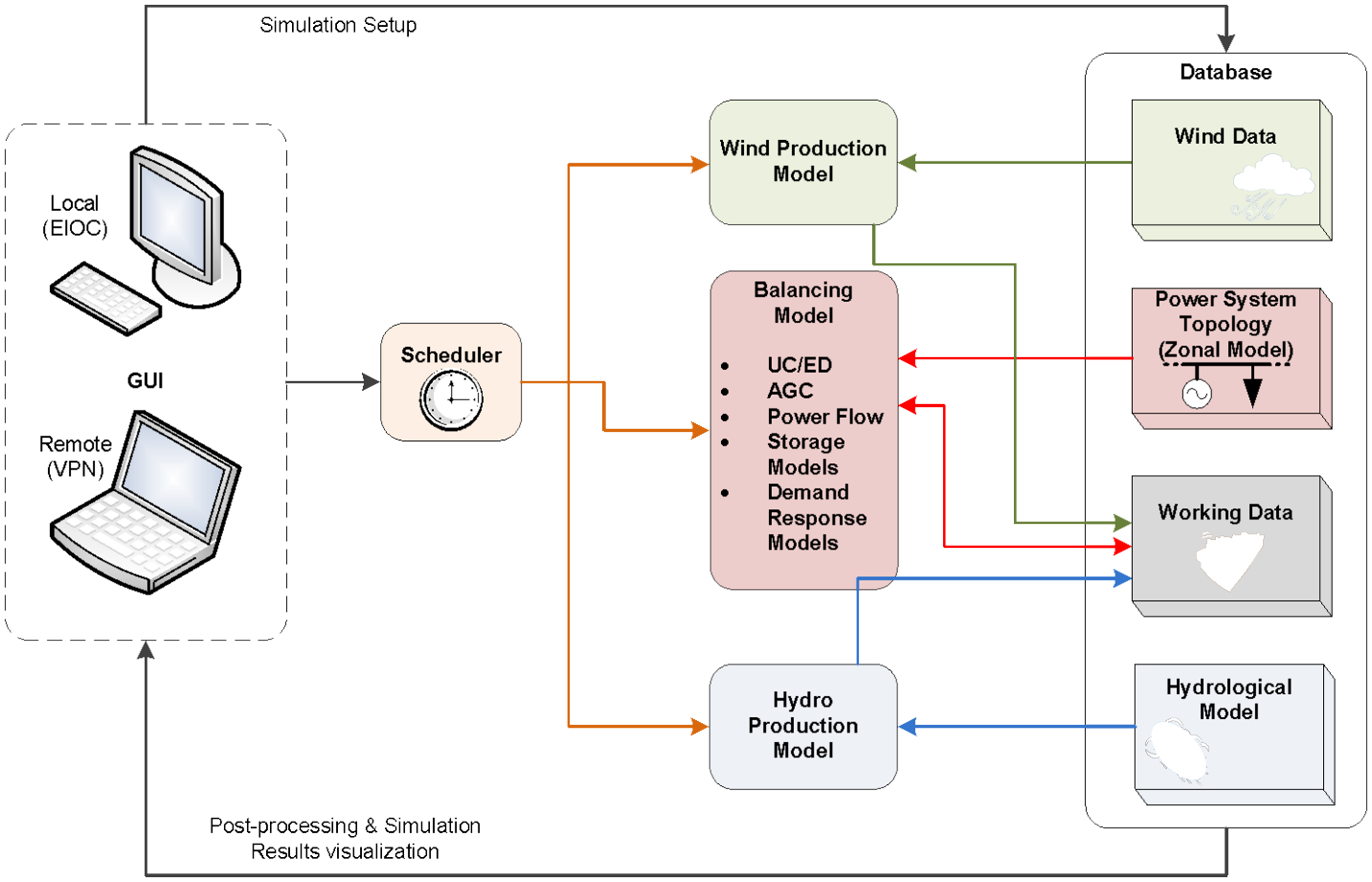
Graphical User Interface



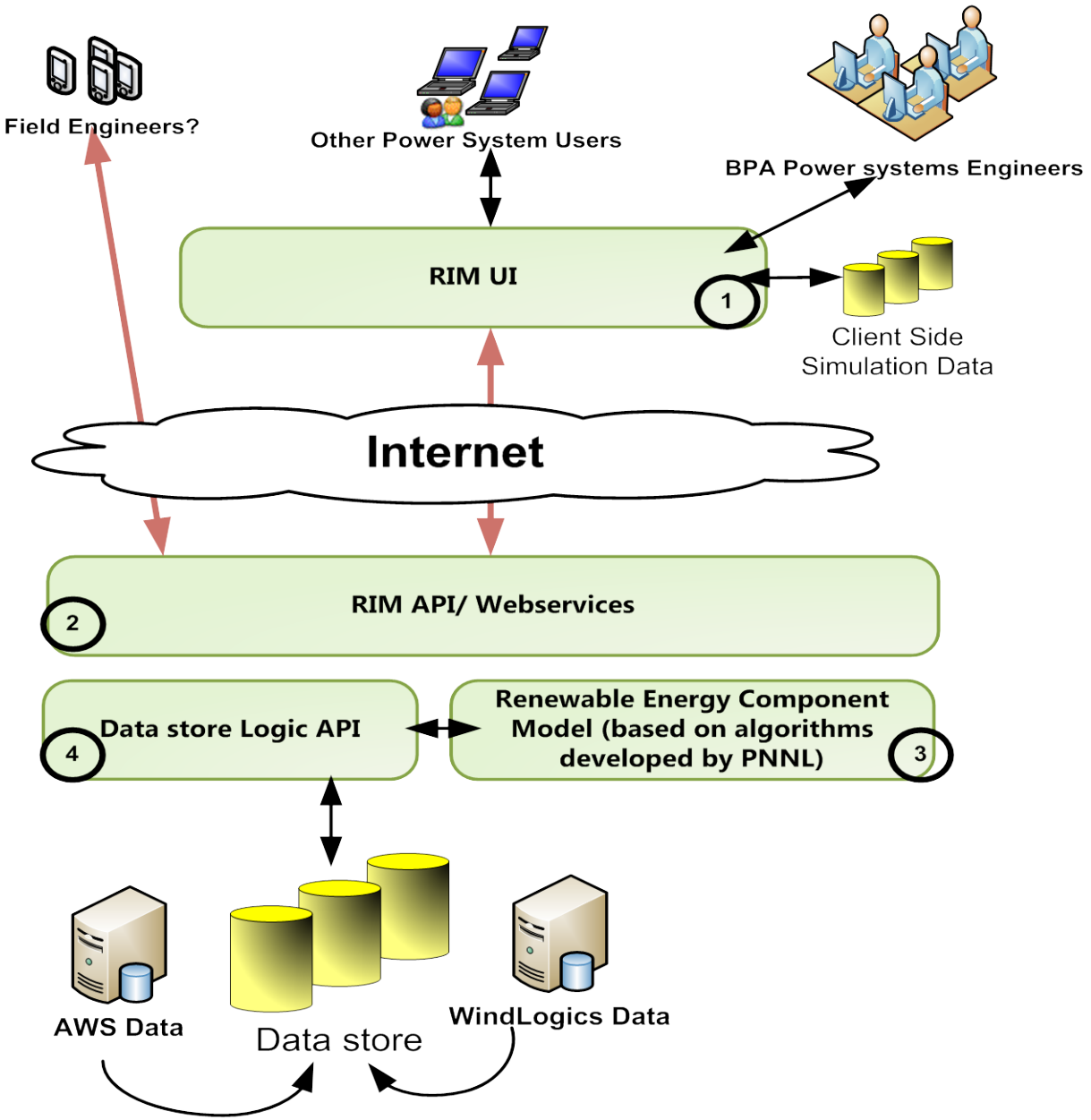
Software Architecture

- Architecture and individual modules are being programmed in C++ and CPLEX
- Software is being built to run in *parallel* method for Monte Carlo and sensitivity analysis
- Cplex software is used for all major optimization routines

WIM Structure



High Level GUI Overview



Validation- Three Phases Starting Dec, 2010

1. Develop a test plan using two base cases developed in coordination with BPA engineers and hydrologists.
   - Model the operation of the BPA system during 2008 (wet year) and 2009 (dry year), then compare the results to system historical output.
2. Exercise all normal constraints on the hydro operation as well as thermal generation.
3. Verify longer-term validity by investigating the effect of such things as wind forecast errors and different scheduling approaches to cope with wind uncertainties. Monte Carlo analysis will be exercised

Future

- Solar Module
  - Under development by SNL in FY11
- Market Module
  - Currently, prices are included as constants, but not markets.
  - Neither demand nor system constraints affect power prices.
- Unit Commitment to include forecast confidence intervals
- Demand Response Model Variants