Planned Improvements to MODSIM:

Integrating River Basin Operations Modeling with Power System Economic Dispatch

Feb. 22, 2012

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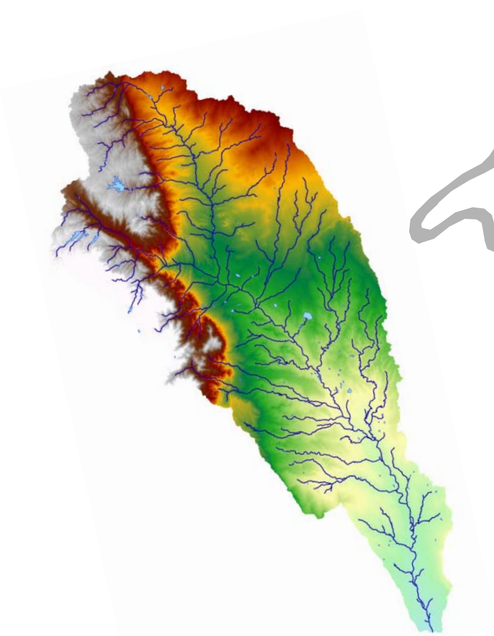
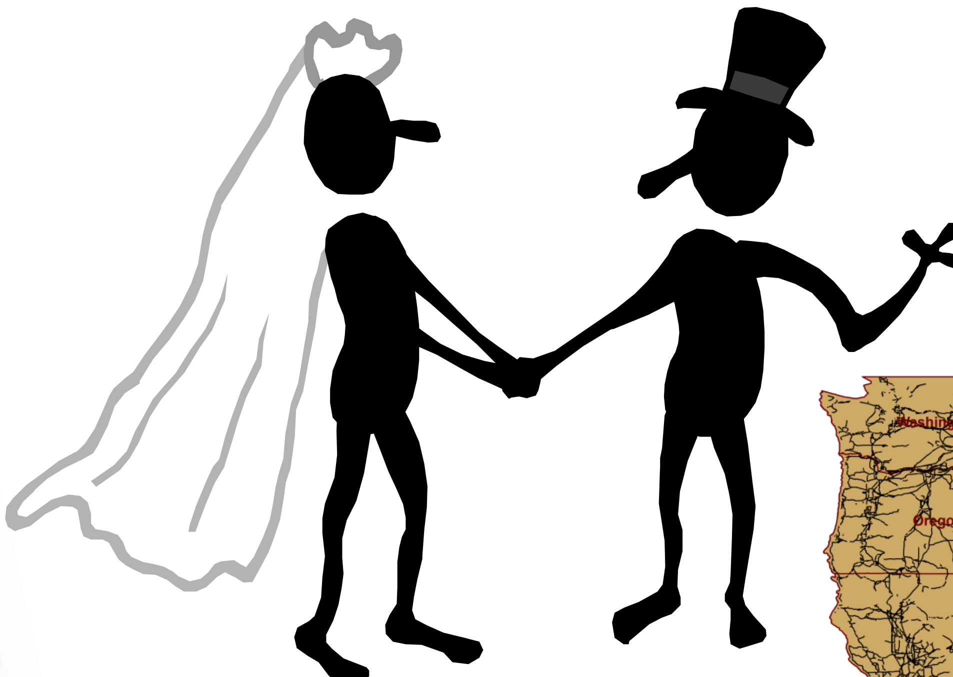
Introduction





Water **Power**

Introduction

- Presentation Outline
  - Operating challenges
  - Why integrate water and power models?
  - Objective of this work
  - Selected integrated model structure
  - Future work

Introduction

- Water System Operational Challenges
  - Uncertain inflows
  - Conflicting Purposes
  - Time delay
  - Complex legal agreements
  - Interconnected reservoirs

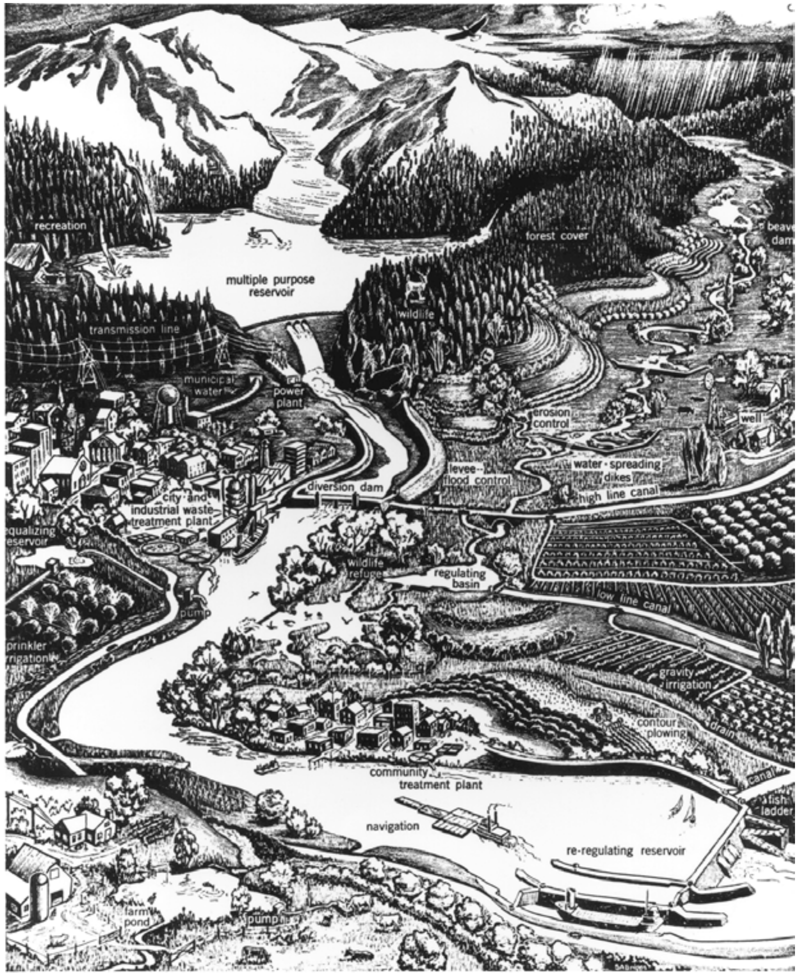


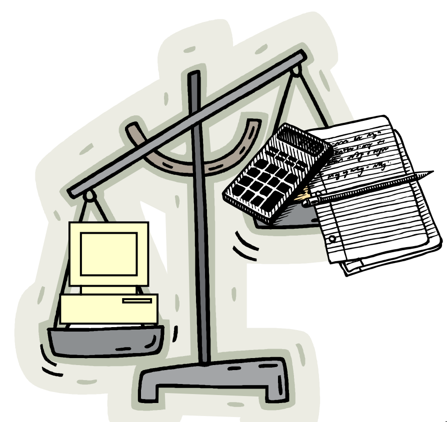
Figure source: President's Water Resources Policy Commission, 1950

Introduction

- Power System Operational Challenges
  - Production = Consumption + Losses at all times
  - Contingencies → reserves and ramping rates
  - Uncertain renewables production
  - Multi-area power flow
  - Interconnections
  - Congestion

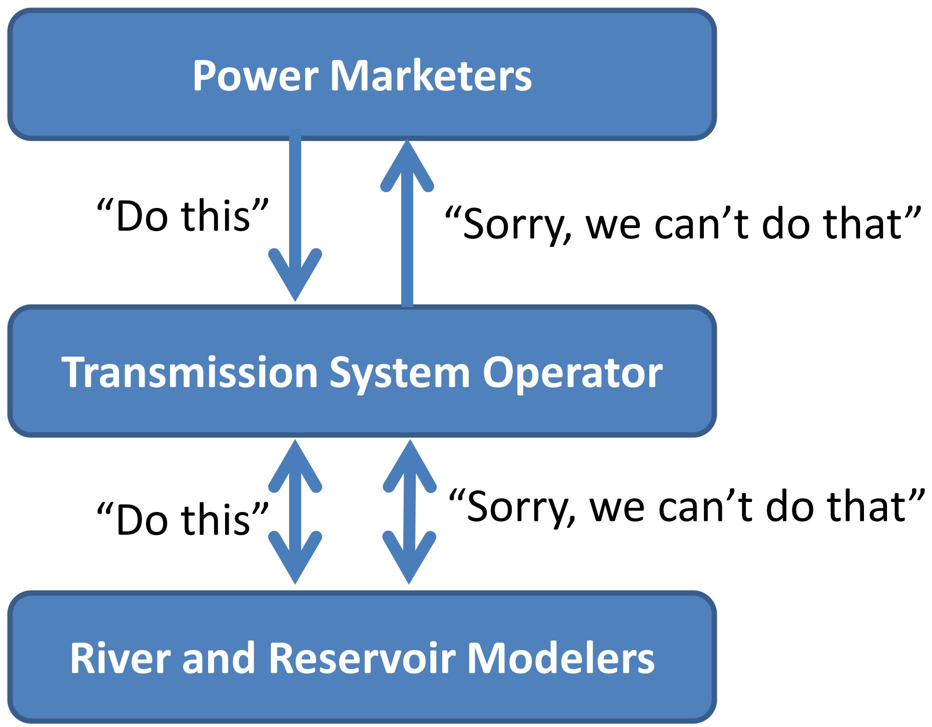
Introduction

- Why Operations Modeling and Optimization?
  - Infrastructure = Money + Time
    - Critical operations for critical infrastructure
    - Improved efficiency = more revenue
    - Accidents are too costly
  - Computers are needed
    - Large systems
    - Repeated tasks



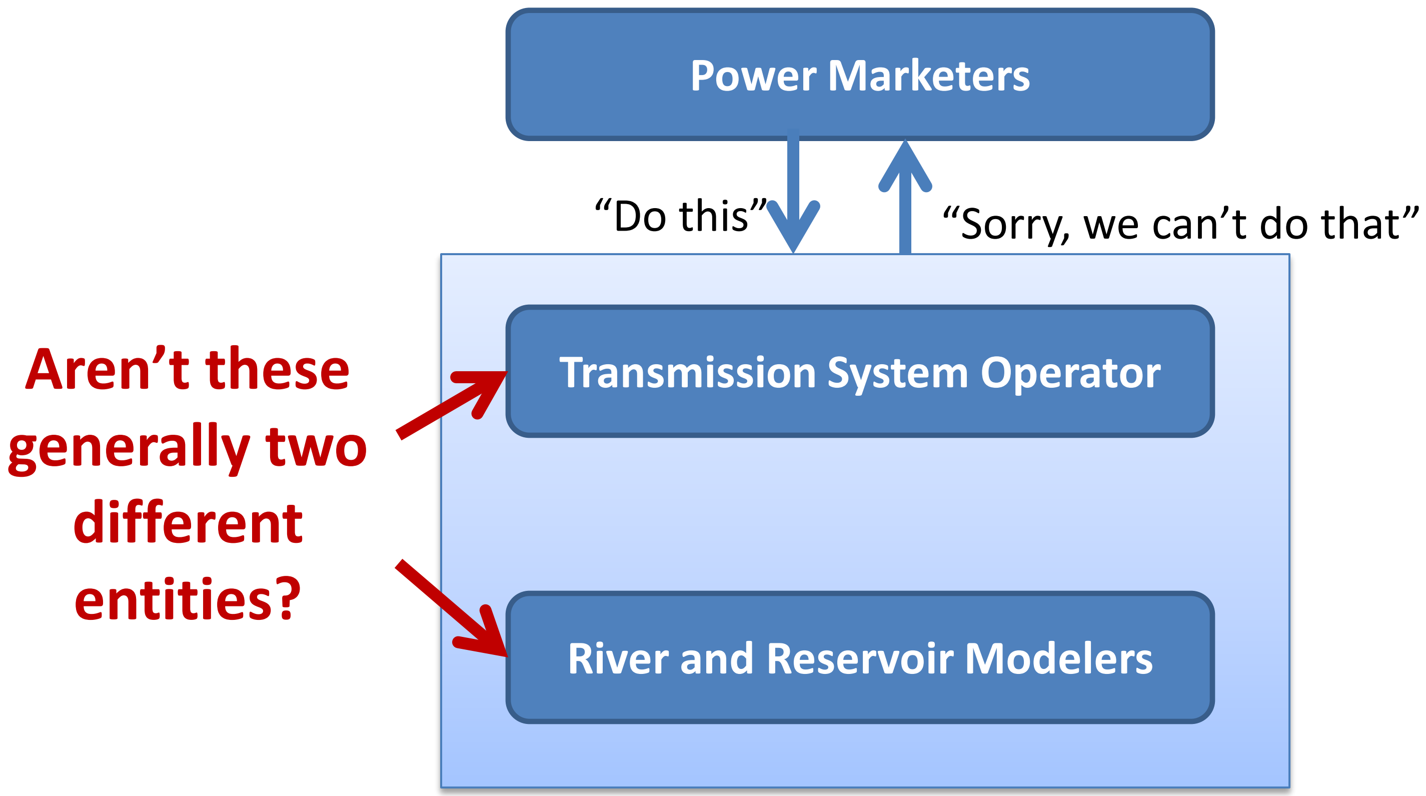
Introduction

- Why Integrate Water and Power System Operations Modeling?
  - Segregated modeling framework



Introduction

- Why Integrate Water and Power System Operations Modeling?
  - Integrated modeling framework



Introduction

- Why Integrate Water and Power System Operations Modeling?
  - Unrealistic modeling in current renewable integration studies [1]-[4]
    - Transmission constraints (and other security issues)
    - Non-power water system constraints and objectives
    - Interrelated nature of multi-reservoir operations
  - Energy storage is essential
    - Hydropower provides large and long-term energy storage
    - Reduce uncertainty in renewable energy production

Introduction

- Why Integrate Water and Power System Operations Modeling?
  - Climate change impacts on operations
  - Emergency response plans
  - National economic security
  - Interdisciplinary analysis of economic and environmental tradeoffs

Introduction

- Hasn't integrated water and power systems modeling already been done?
  - Previous models generally do not include ramping rate constraints and increased reserve capacity requirements
  - To our knowledge, no **freely available**, generalized model currently exists

Introduction

- How did Colorado State University (CSU) get involved in this project?
  - Fellowship from the Hydro Research Foundation
  - CSU has a customizable water operations model (called MODSIM)
  - CSU is a major research center for power system controls

Introduction

- Objective
  - Realize the full potential for both conventional and pumped storage hydropower to aid renewable energy integration with sufficient accuracy
    - Build model
      - Handles water AND power constraints adequately
      - Incorporates uncertainty
      - Multiple objectives
    - Apply the model to a test system
    - Examine operational improvements

Model Structure

- What type of model do we need to build?
  - Spatial and temporal scales

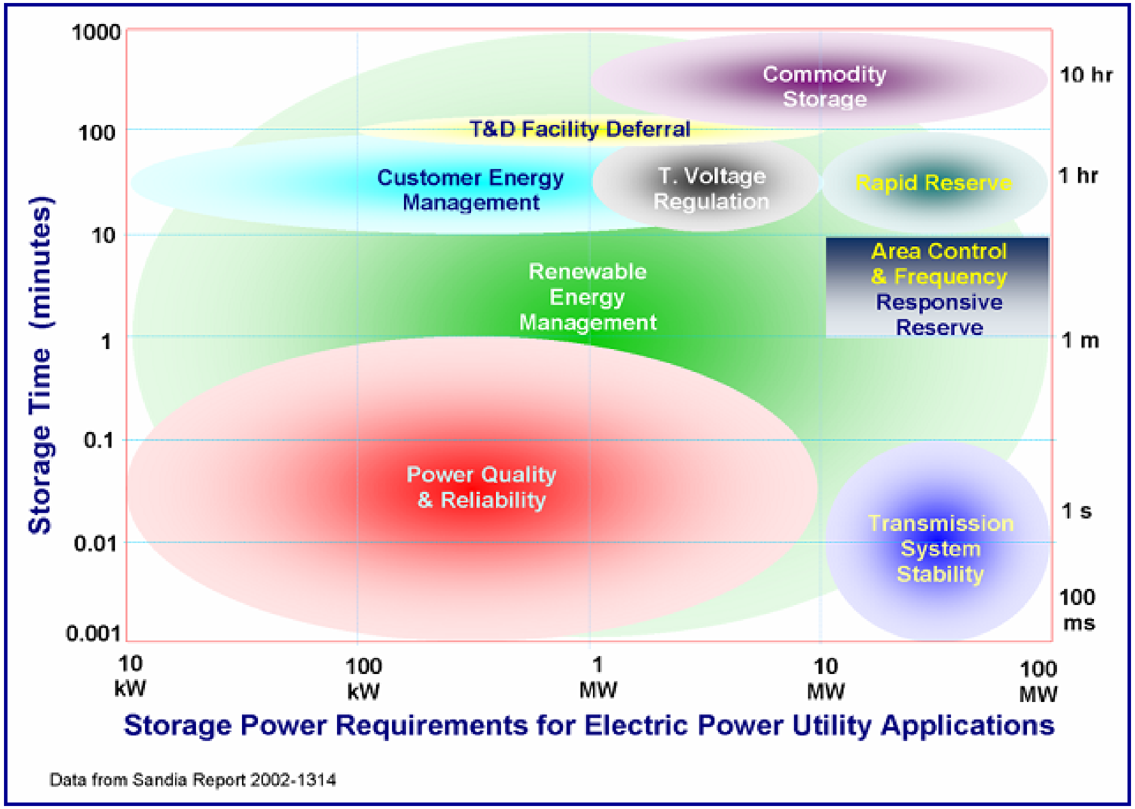


Figure taken directly from [10]

Model Structure

- What type of model do we need to build?
  - Spatial and temporal scales

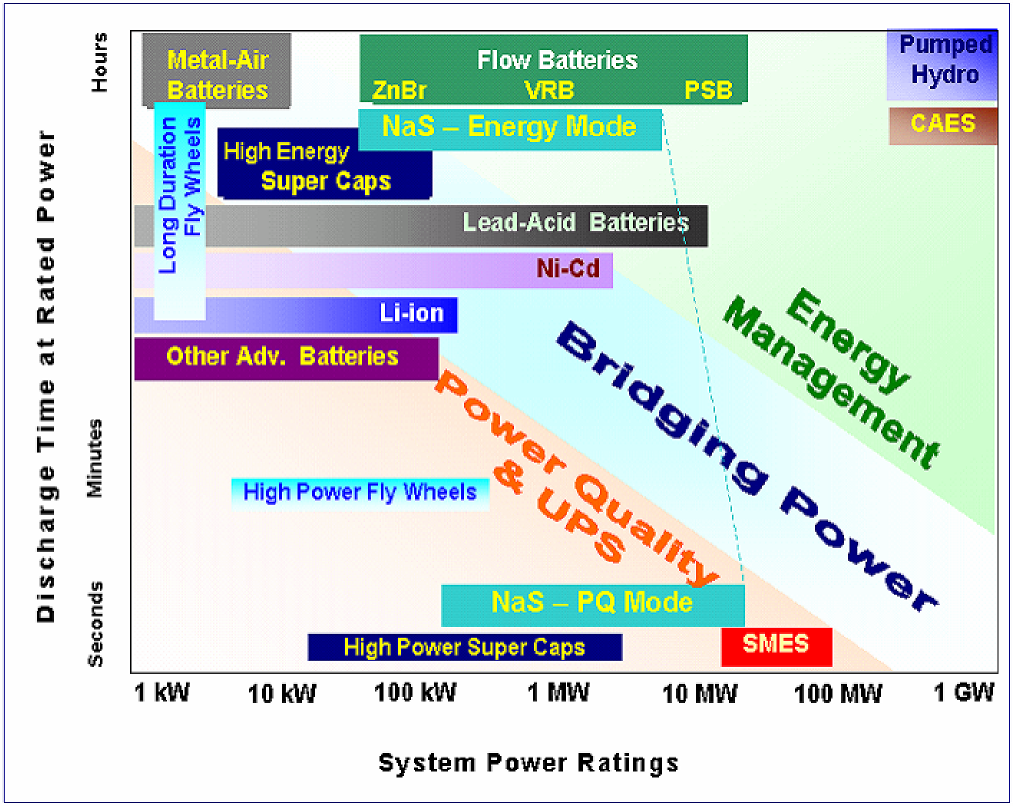


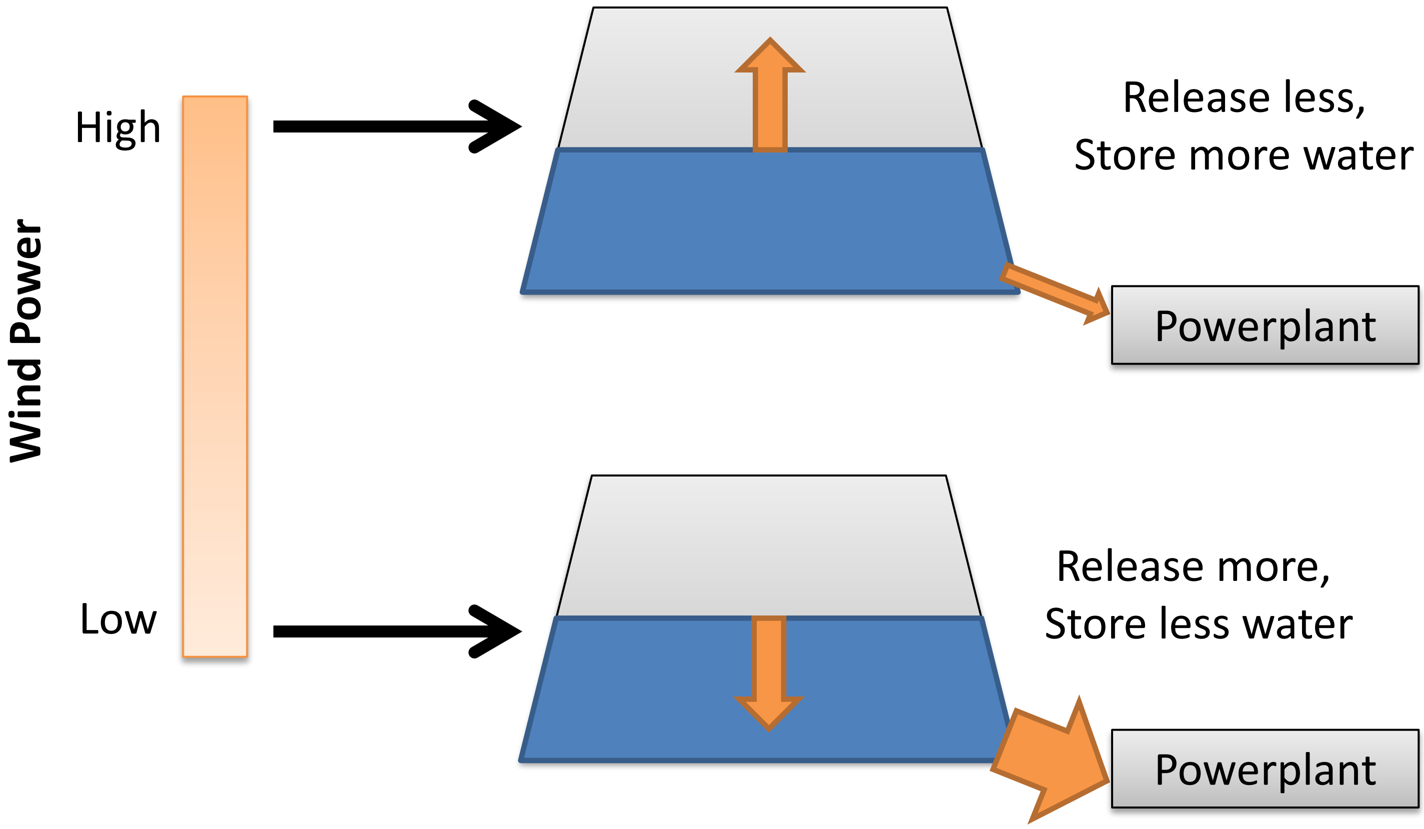
Figure taken directly from [10]

Model Structure

- What type of model do we need to build?
  - Stochastic, dynamic optimization method
  - Incorporates energy storage
    - Introduces dispatchability

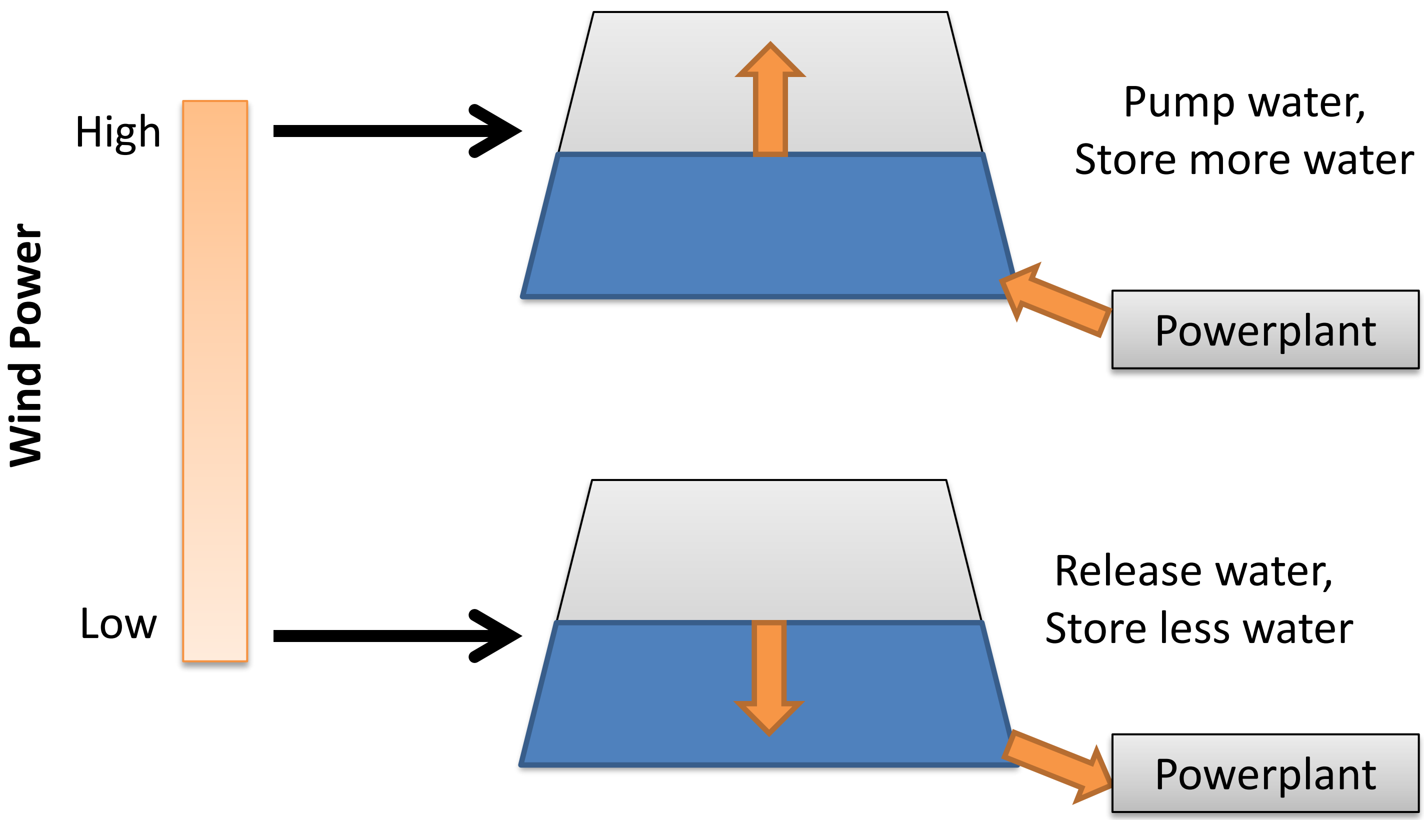
Model Structure

- What type of model do we need to build?
  - Conventional hydropower

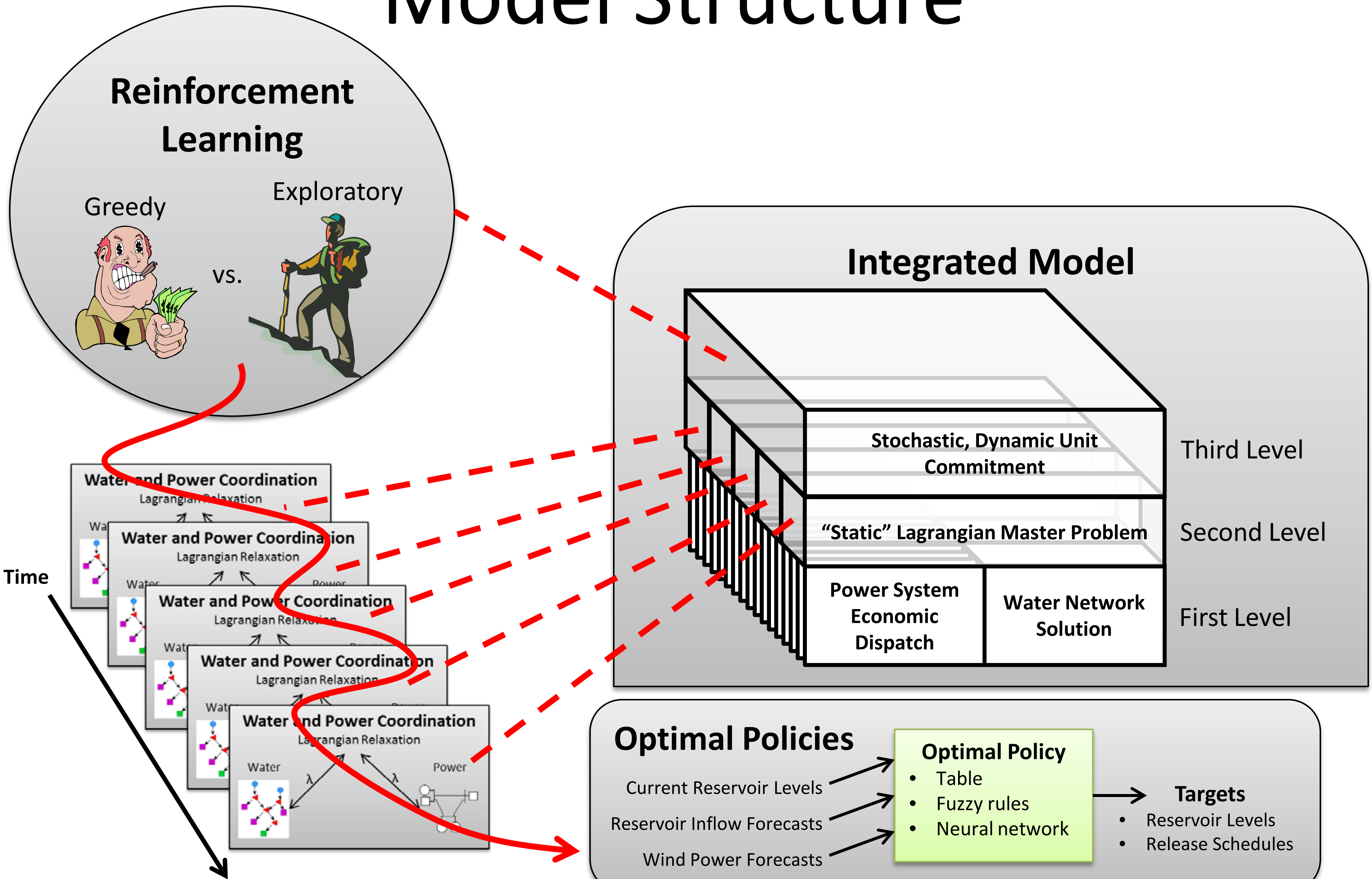


Model Structure

- What type of model do we need to build?
  - Pumped storage hydropower (e.g., peak shaving)



Model Structure



Model Structure

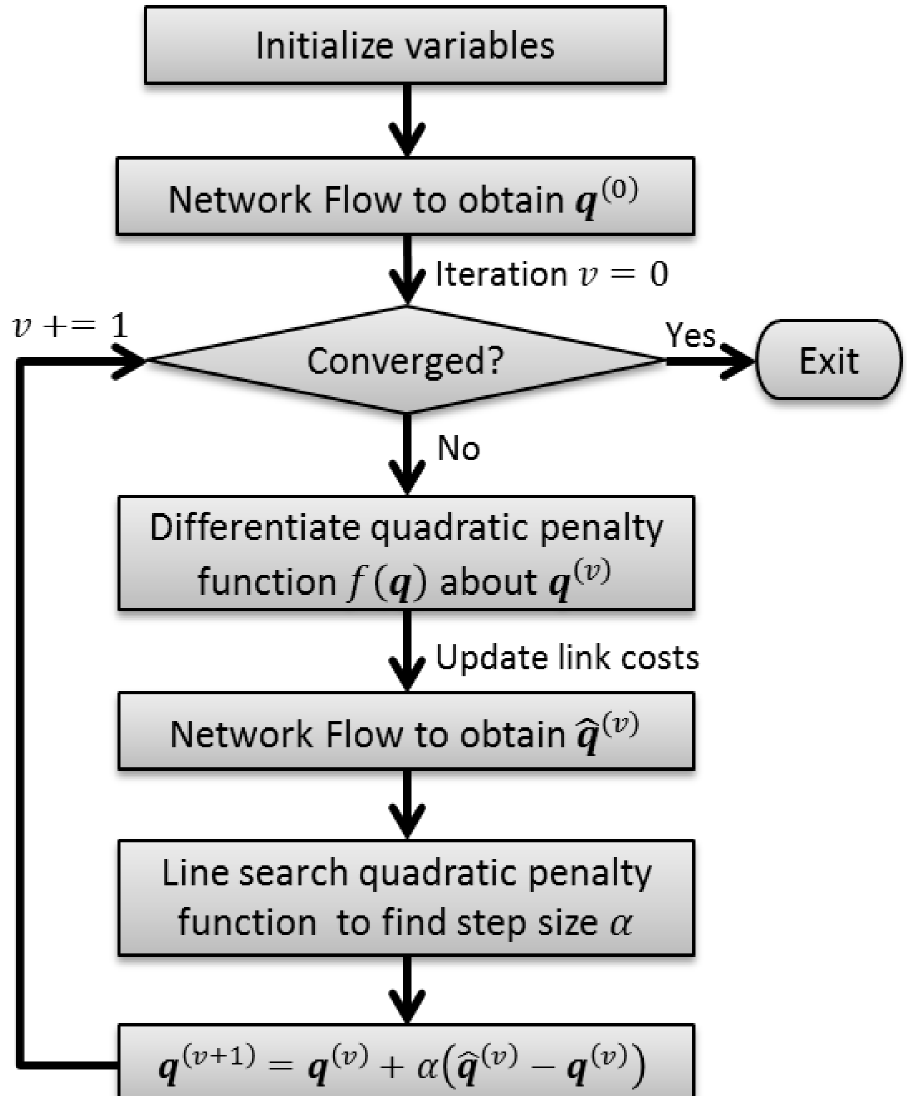
- First Level
  - Water network solution
    - MODSIM
      - Iterative network flow algorithm & Frank-Wolfe algorithm
  - Constrained Economic Dispatch
    - Open-ended design that allows for both:
      - Programmatic (or tightly coupled) interface
      - Loosely coupled interface (I/O to disk)
    - Light-weight addition to MODSIM
      - "Direct search" method seems promising [5]-[8] for active power dispatch problem

Model Structure

- First Level
  - Water network solution
    - Network flow algorithm
      - Solve mass balance
      - Distribute water according to priority
    - Successive approximations
      - Solve for evaporation, reservoir levels, lags, any nonlinear customized changes
    - Frank-Wolfe method
      - Solve quadratic formulations (power demand)

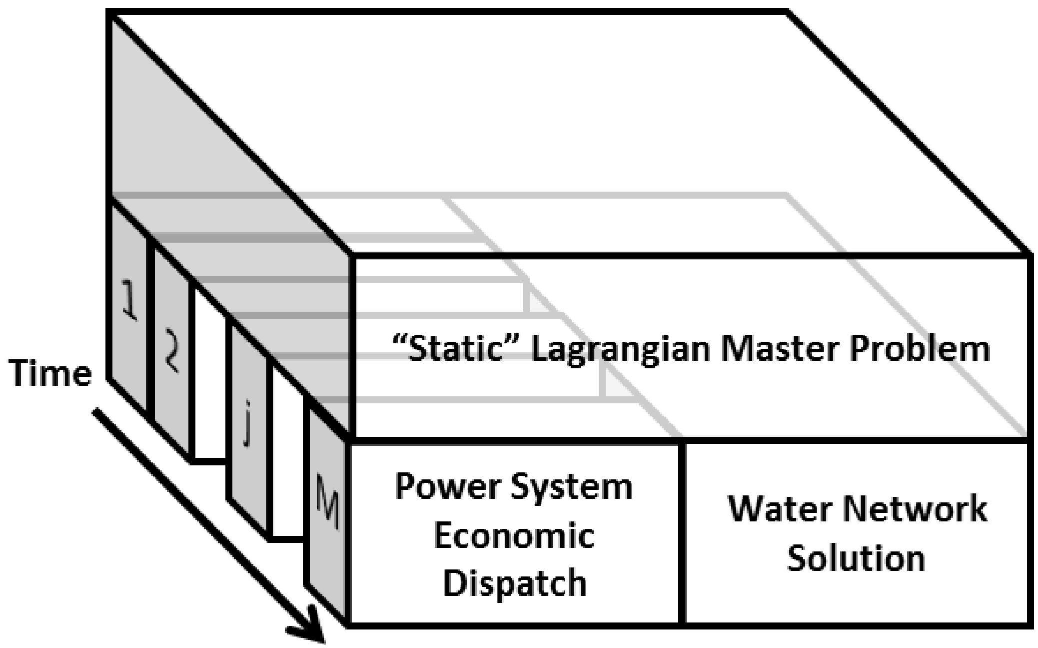
Model Structure

- First Level
  - Water network solution
    - Frank-Wolfe method



Model Structure

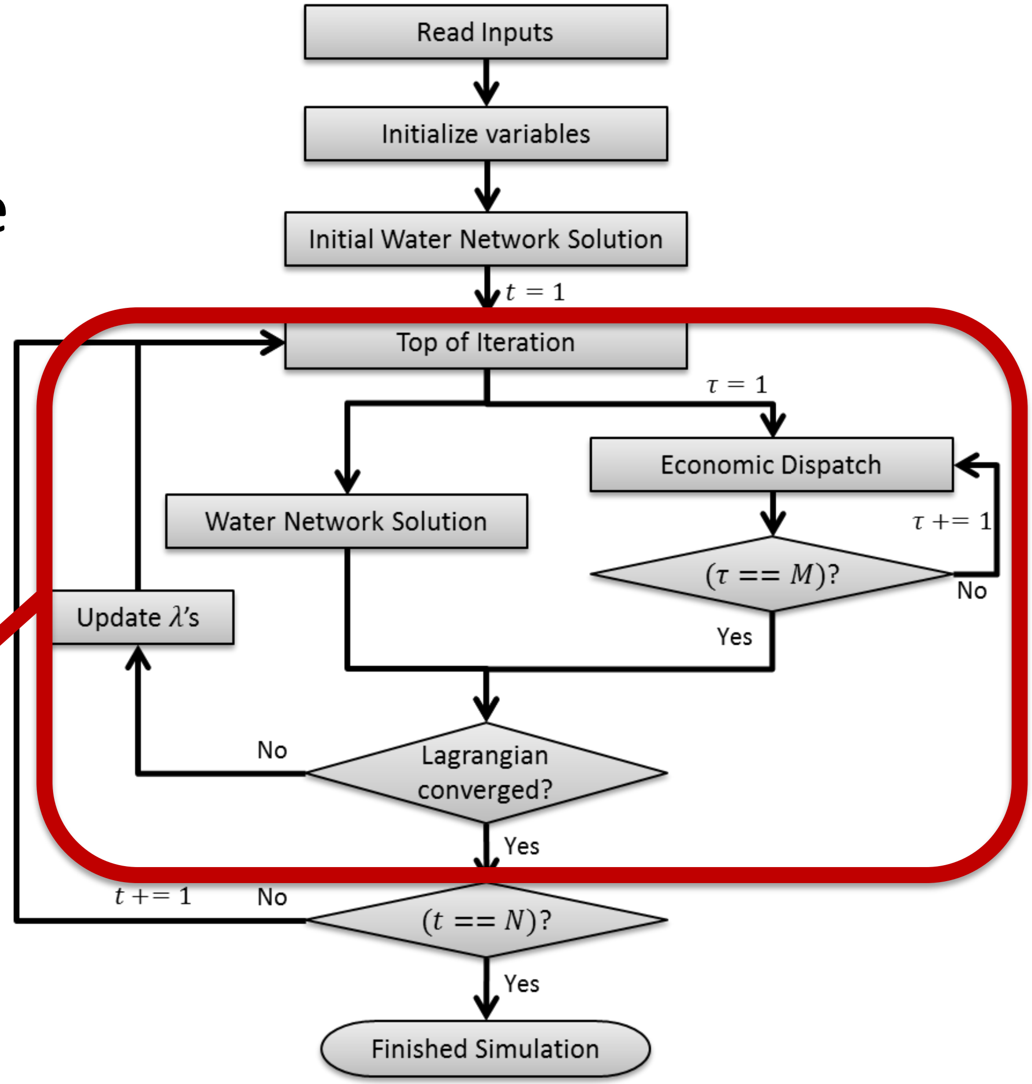
- Second Level
  - Lagrangian Relaxation Master Problem
    - Optimality Condition Decomposition [9]



Model Structure

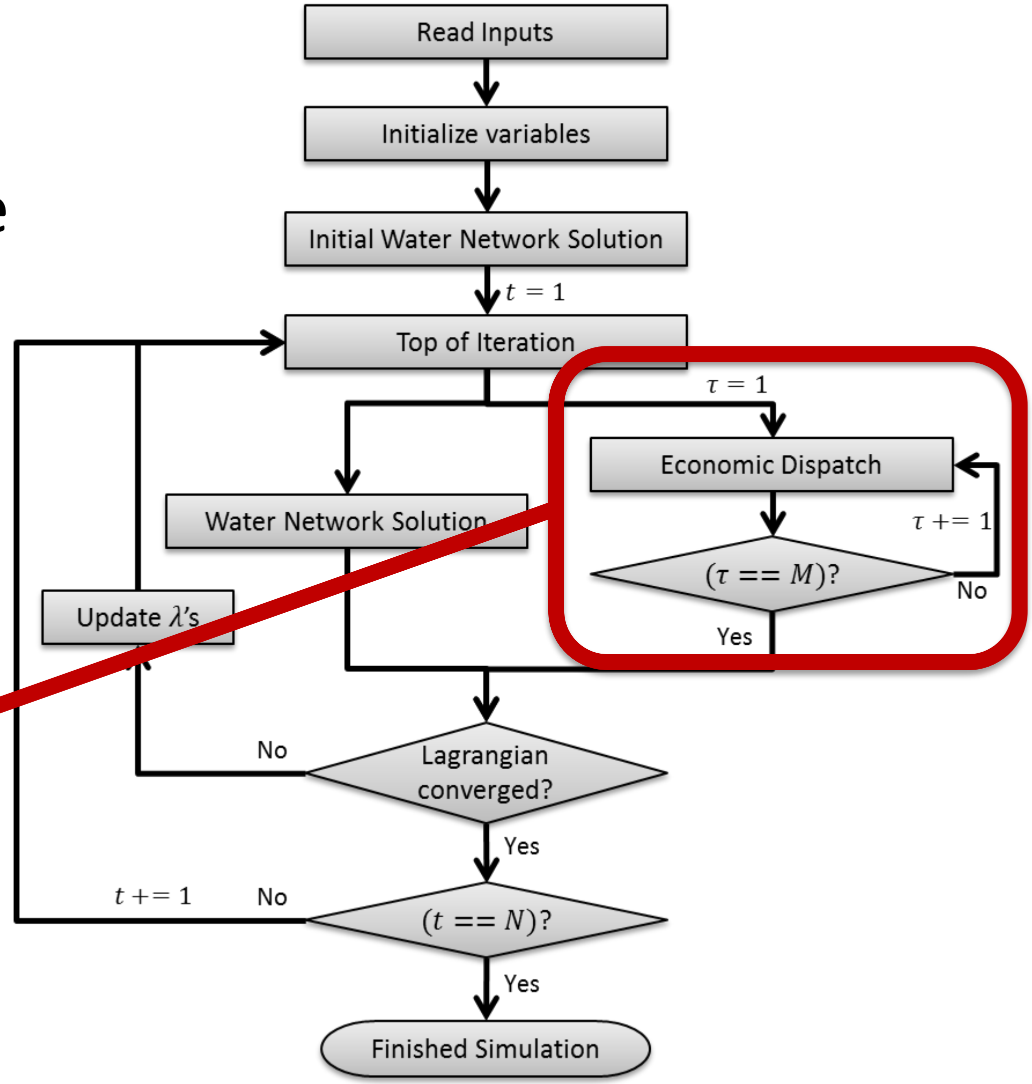
- Second Level
  - Simulation Structure

Static Second-Level Optimization

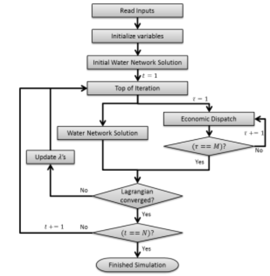


Model Structure

- Second Level
  - Simulation Structure

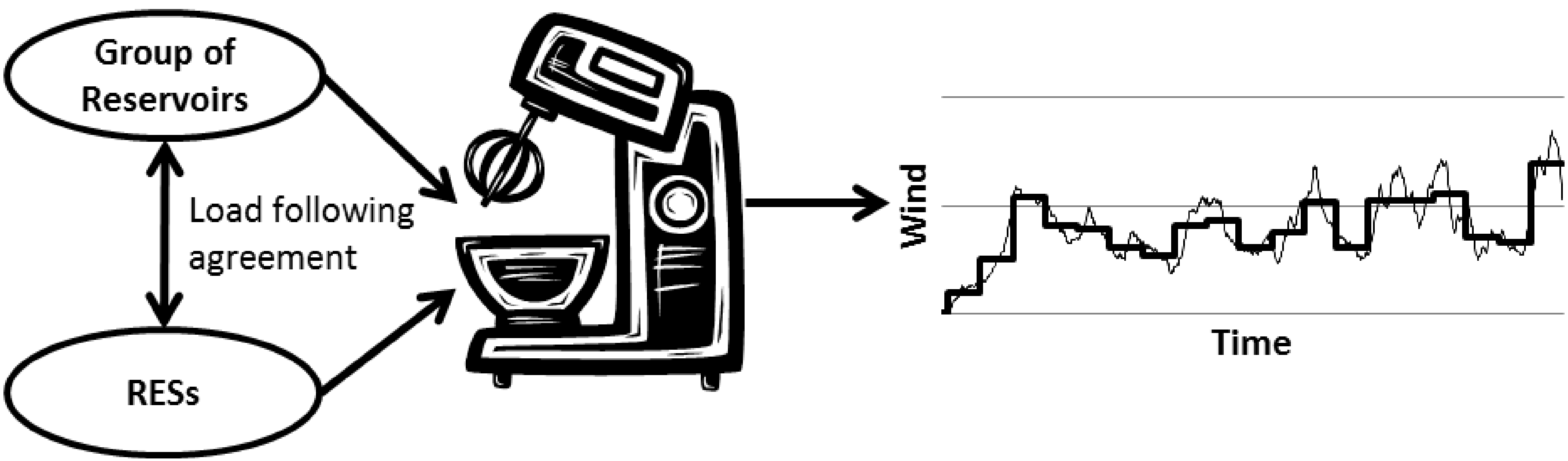


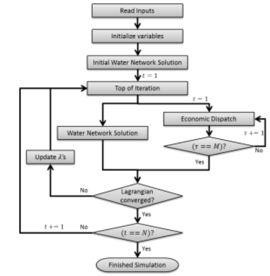
Smaller timestep



Model Structure

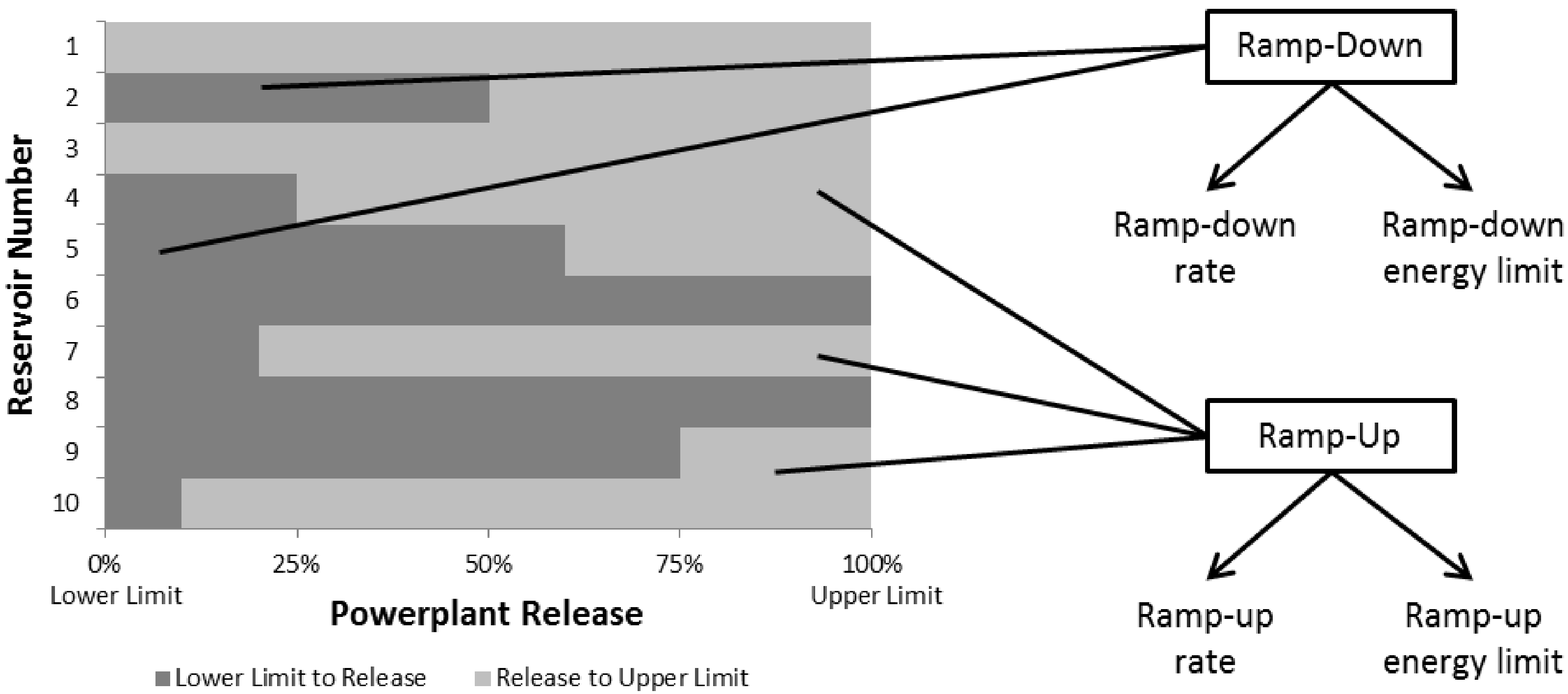
- Second Level
  - Simulation Structure
    - Allows system approach



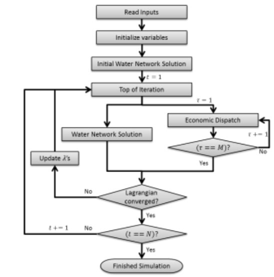


Model Structure

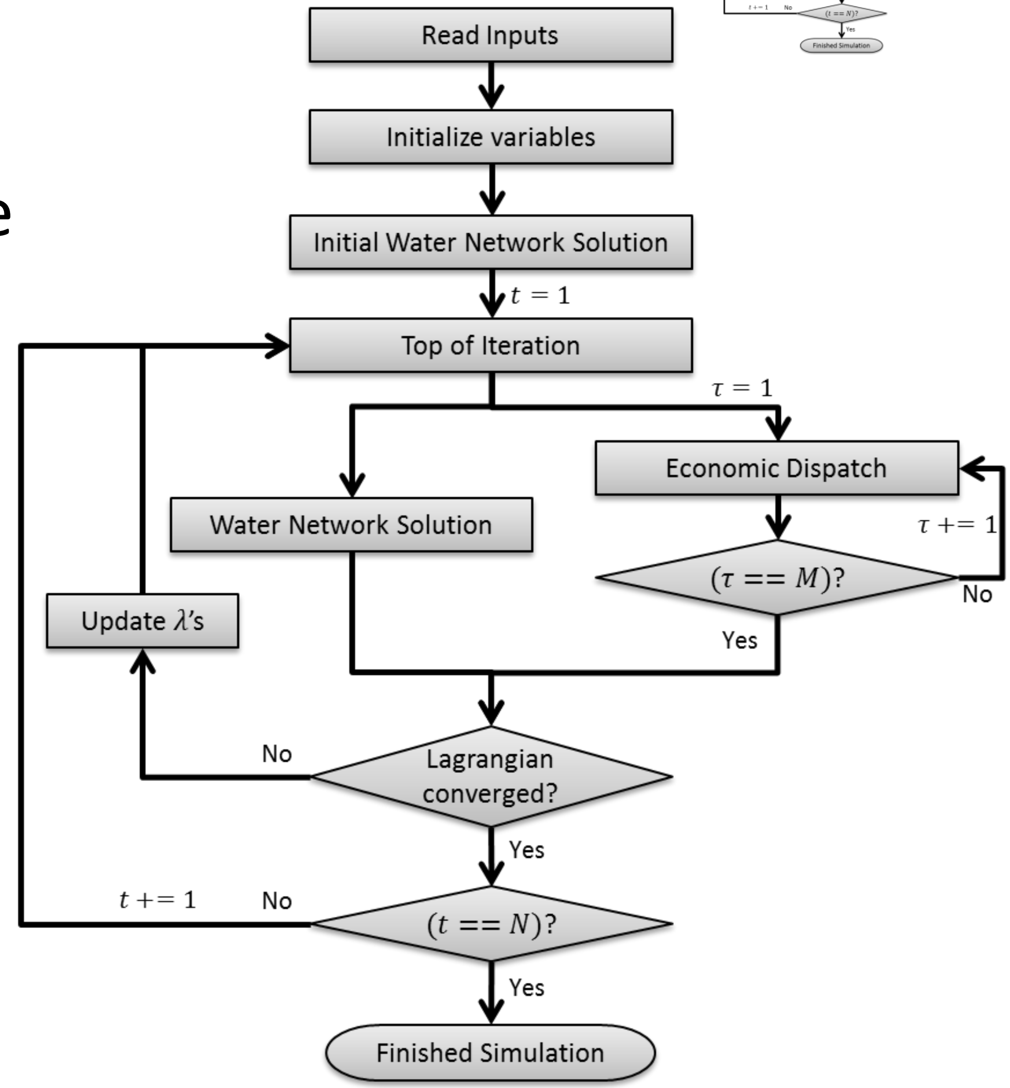
- Second Level
  - Simulation Structure
    - Dynamically updated ramping rate & reserve constraints



Model Structure

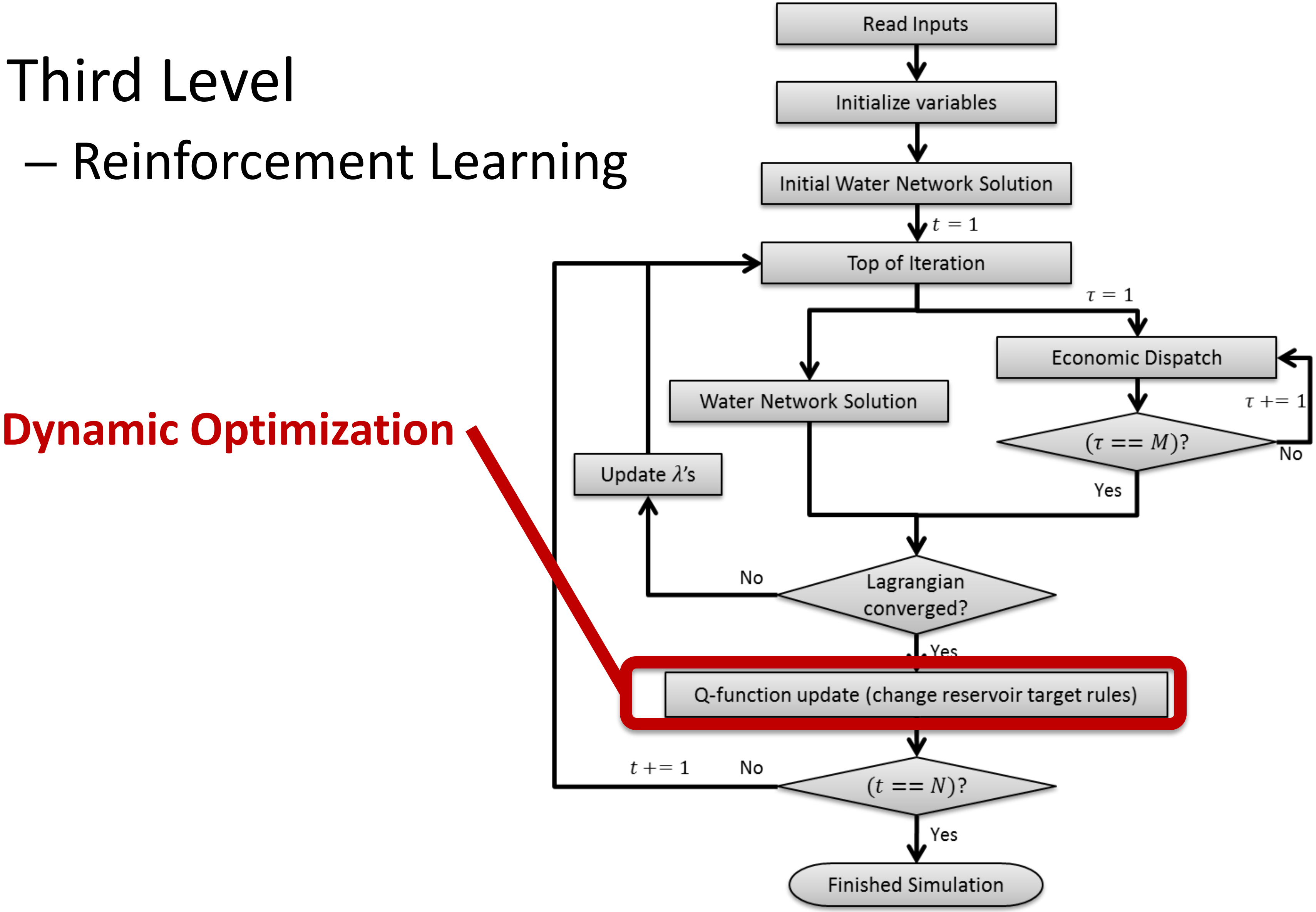


- Second Level
  - Simulation Structure

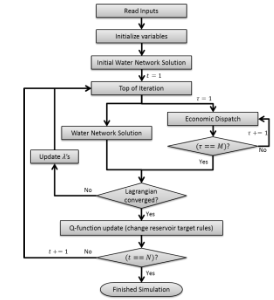


Model Structure

- Third Level
  - Reinforcement Learning

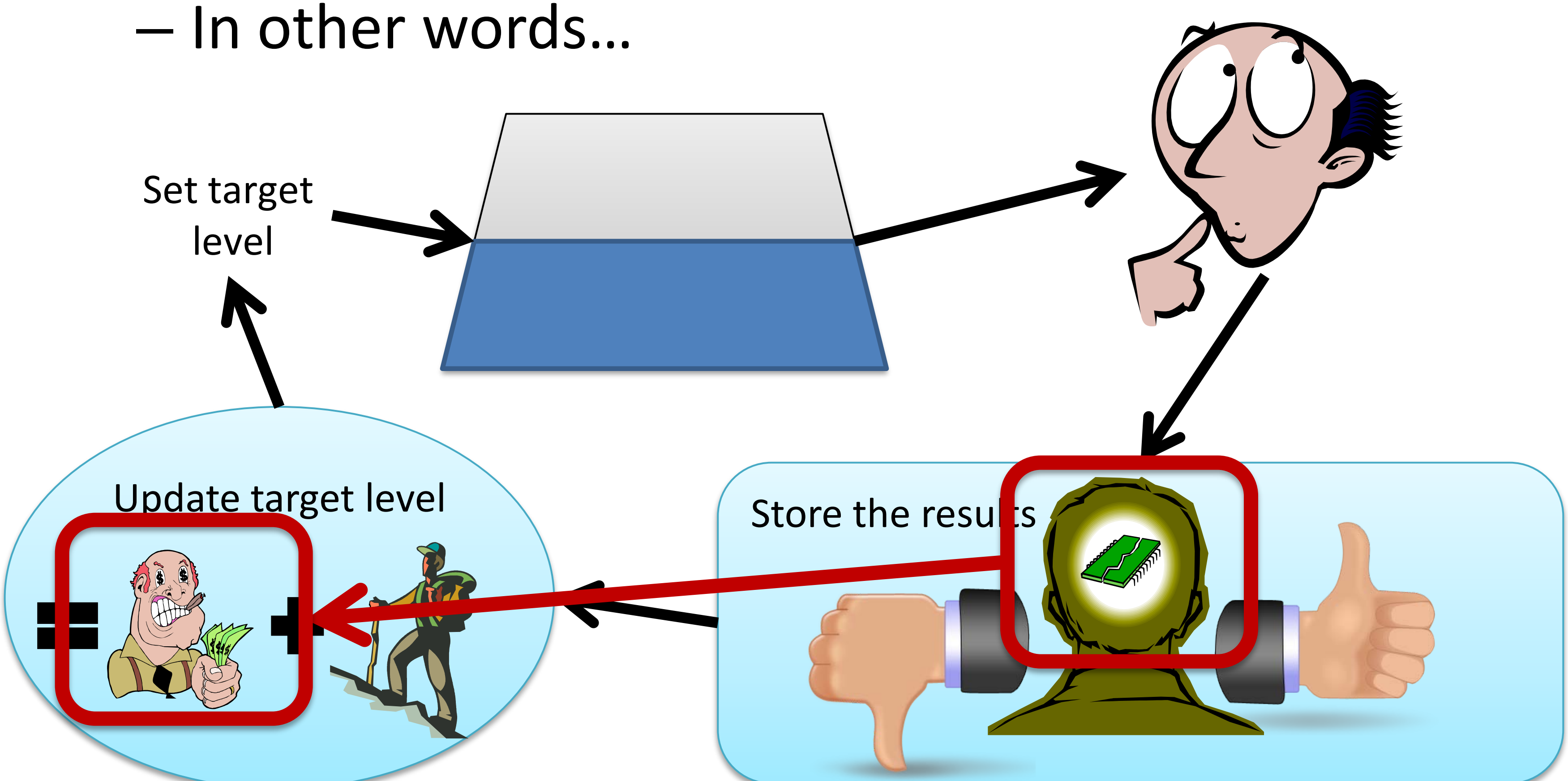


Model Structure

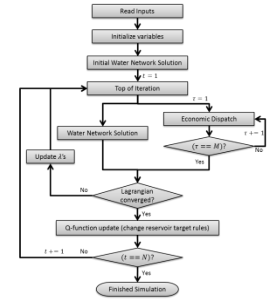


- Third Level
  - Reinforcement Learning
  - In other words…

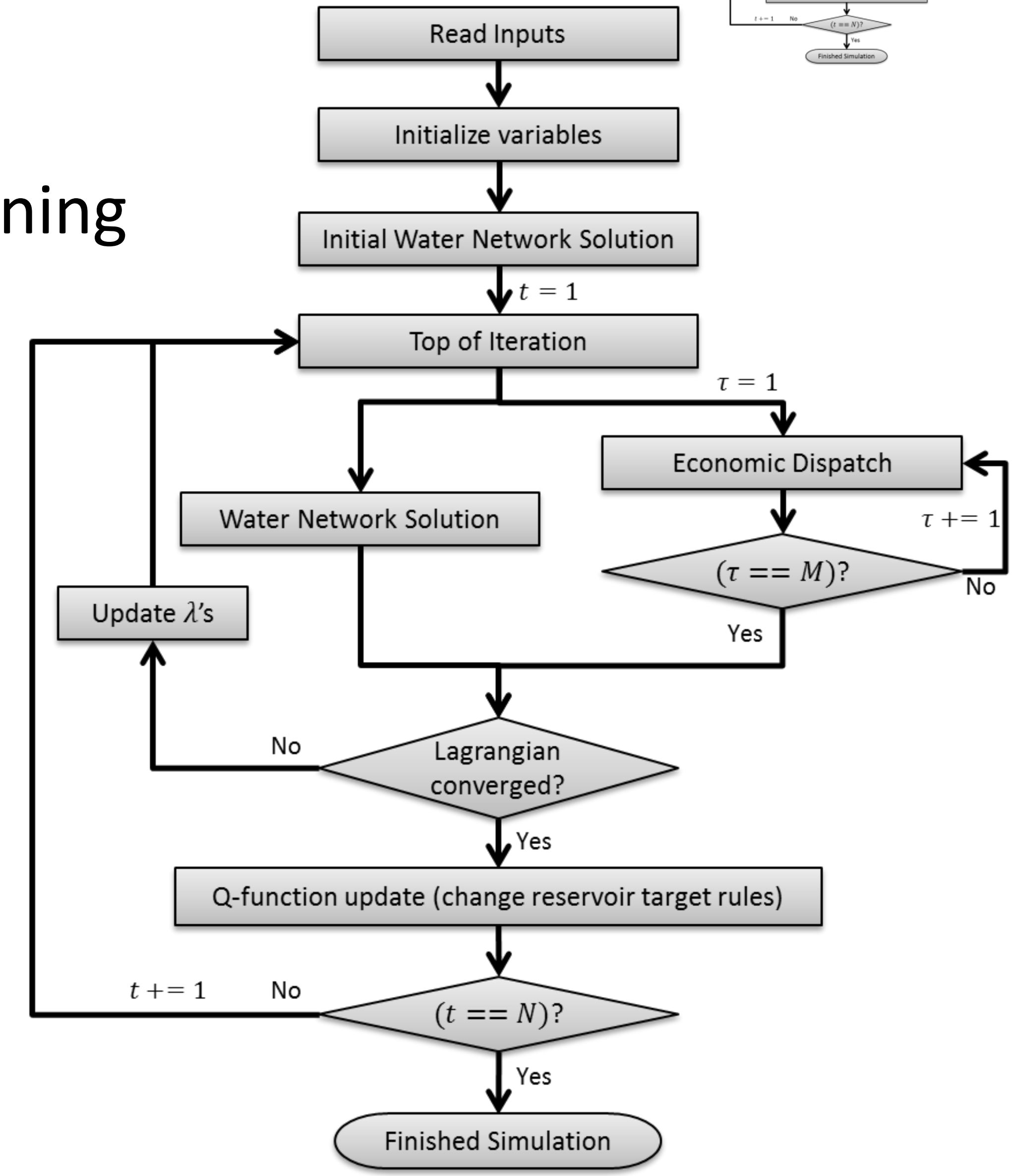
See how well the system performs



Model Structure

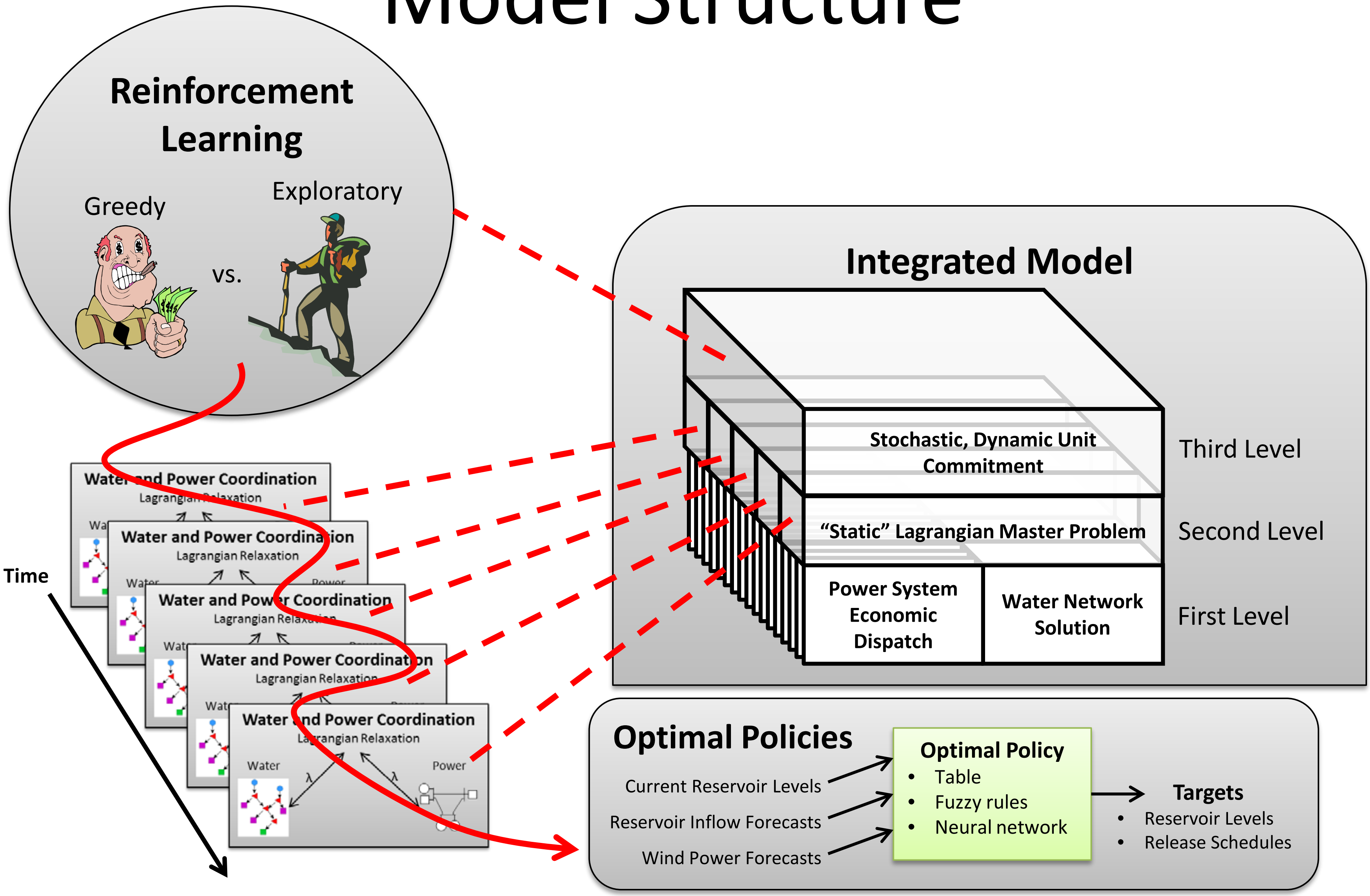


- Third Level
  - Reinforcement Learning

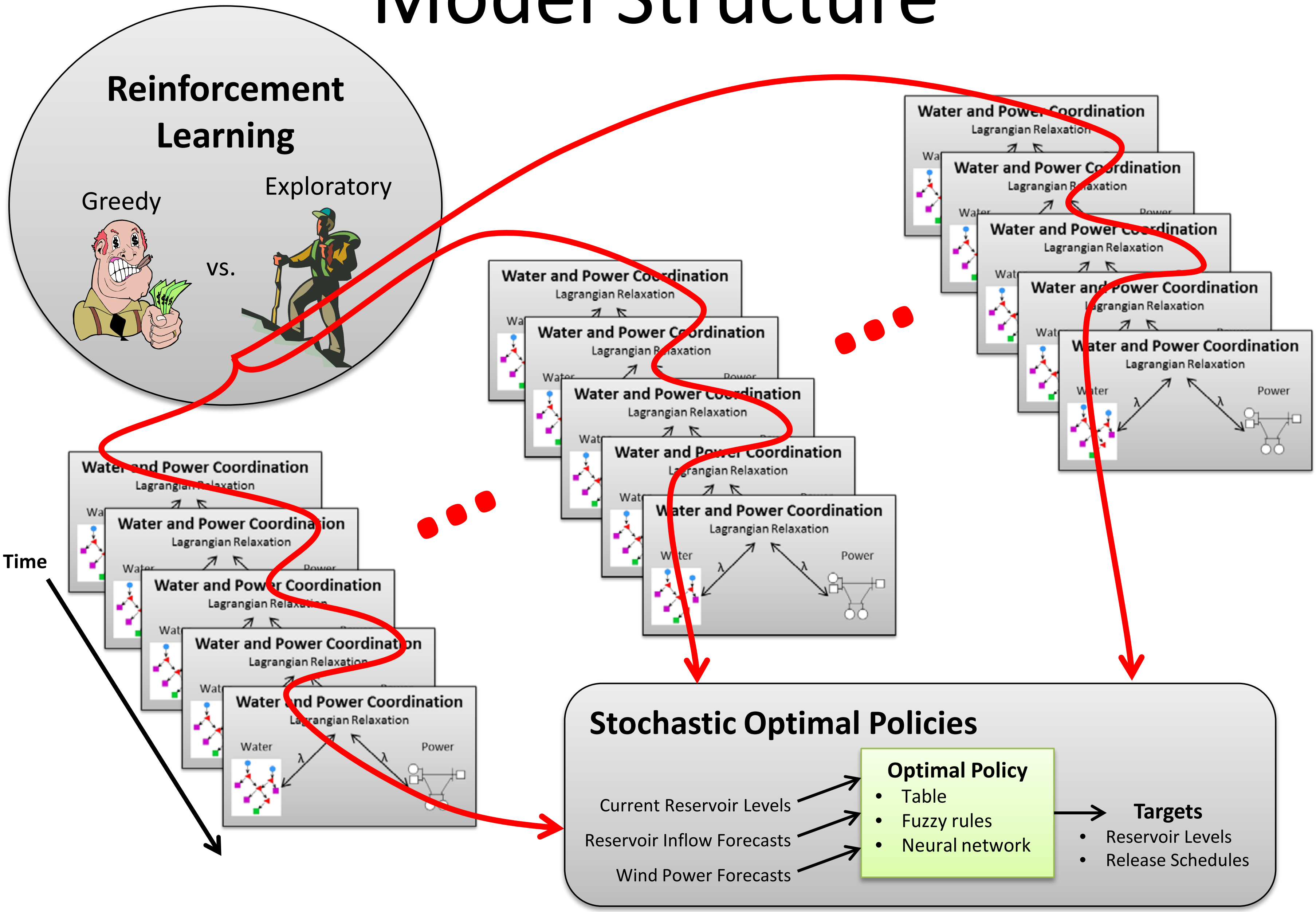


What about uncertainty?

Model Structure



Model Structure



Model Structure

- Benefits to this approach
  - Incorporate uncertainty easily
    - No need to estimate explicit transition probabilities!
    - Optimal policies are inferred
    - Ensemble prediction (streamflow & renewables)
  - Parallel processing
  - Multiobjective analysis
  - System approach to firming renewables
  - Algorithms are similar to operators' way of thinking

Test Systems

- Does anybody want to partner with CSU to provide actual test systems?
  - Wind-hydro-thermal mix
    - Wind power forecasts and actual production
    - Pumped and conventional hydropower
  - Transmission system constraints
    - Transmission data (under NDA perhaps)
  - Water system constraints
    - Legal/environmental agreements
    - Operating criteria

Future Work

- Parallelization & high-performance computing
- Interdisciplinary analysis of:
  - Climate change
  - Emergency response plans
  - Economic and environmental tradeoffs
- Integration with other critical infrastructure models
  - Natural gas and oil
  - Water and power distribution
  - Crop production and irrigation
  - Weather forecasting and climate change models

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