



CADSWES University of Colorado
Center for Advanced Decision Support for Water and Environmental Systems

Optimization

RiverWare User Group Meeting
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Optimization Enhancements

- Hydropower Enhancements
 - Multiple hydropower objectives in one run
 - Load leveling option
 - Unit power modeling with integer programming
- Improved numerical stability
- Improved handling of inputs
- Optimization training modules

Hydropower Objectives

- Pre-defined components
 - Links to reservoirs to calculate system totals
 - Optionally include outside power, pumped storage
- Short-term value of power alternatives
 - Linear – aka System Lambda
 - Piecewise linear – blocks of hydropower value
 - Thermal unit replacement
- Long-term alternatives
 - Value of water in storage (piecewise linear)
 - Ending storage targets

Multiple Hydropower Objectives

Optimization Policy Set Editor - "Optimization Policy Set"

File Edit Set View

Optimization Policy Set RPL Set Loaded

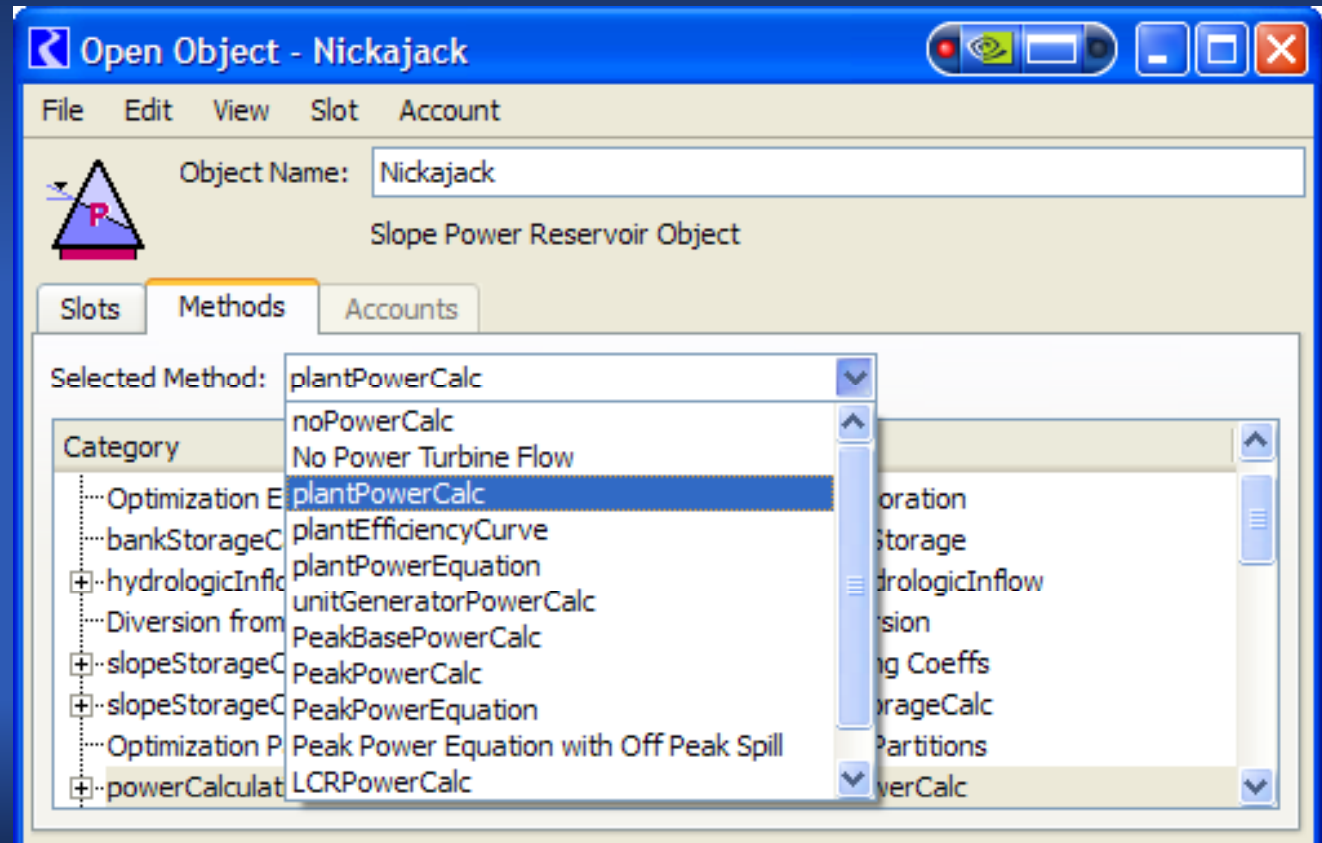
Name	Priority	On	Type
[-] P Objective Function Varying Run Times		✓	Policy Group
G Linear (POSE) Objective plus Future Value (VPS)	47	✓	Goal
G Lock in POSE ending Storage Values	48	✓	Goal
G Block Objective	49	✓	Goal

Load Leveling

- Minimize maximum load remaining after adding hydropower using Repeated Minimax
- Allocates hydropower to peak periods based on load, rather than cost
- Coming soon to a patch release near you

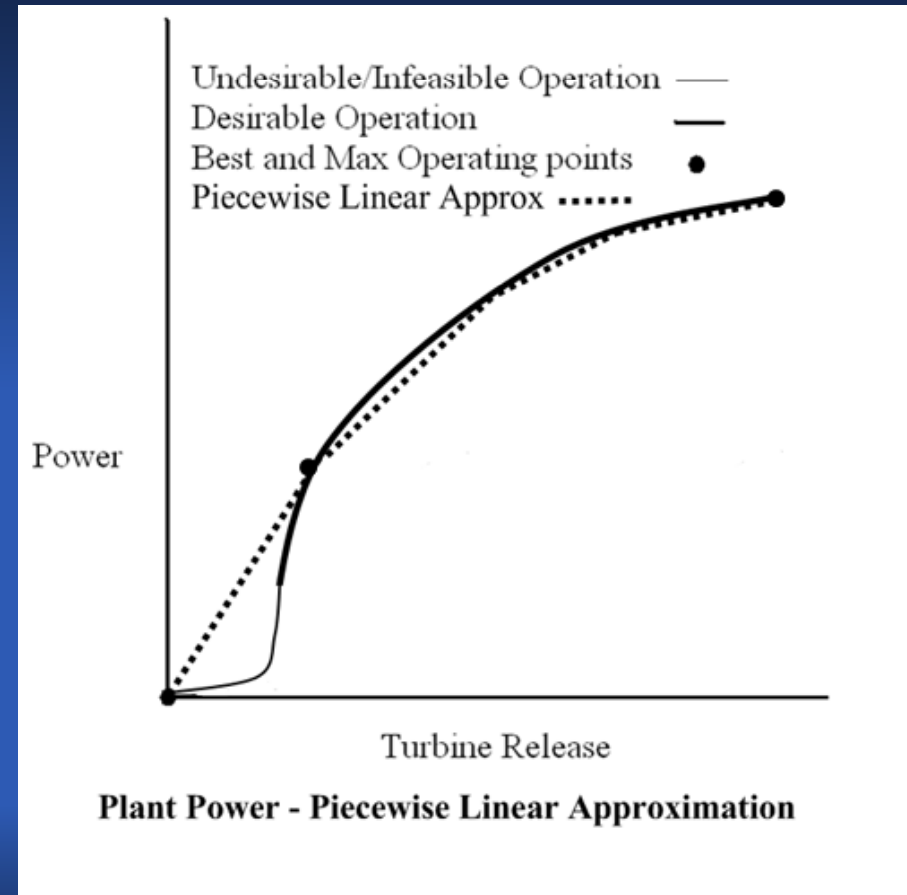
Power Method Alternatives

- Plant Power
- Unit Power
- Others



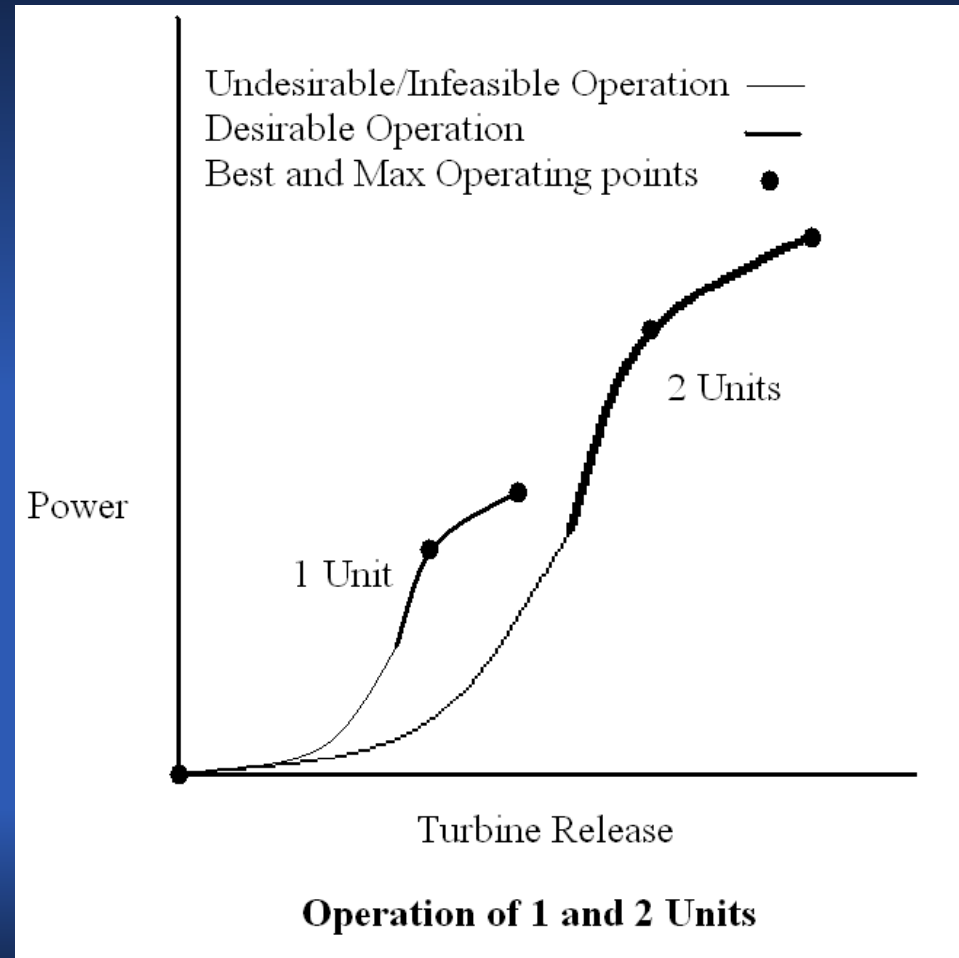
Plant Power Method

- Piecewise linear approximation
- Good approx. for larger time steps
e.g. TVA 6-hour model
- Faster solution
via Linear Programming



Unit Power

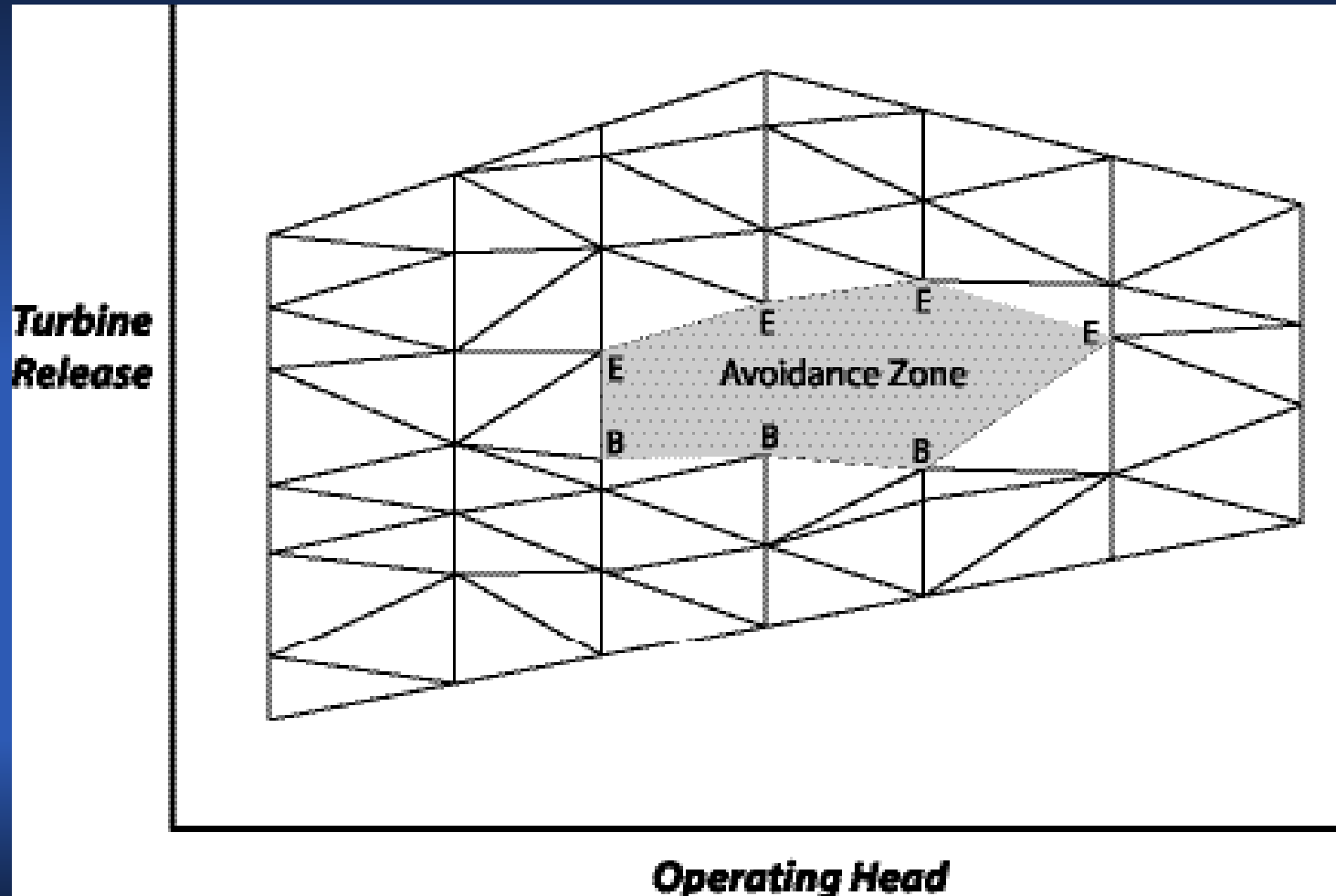
- More accurate
 - Esp. Hourly
- Mixed-Integer Programming
 - Harder
 - Slower
 - Heuristic Solution



Improved Accuracy with Unit Power Modeling

- Physical Model Improvements
 - Discrete variables - a unit is on or off
 - Follow non-convex nonlinear power function
 - Power as a function of flow and head
 - Cavitation and vibration avoidance zones
- Improved Policy Modeling
 - Policies to prevent “holes” in generation
 - Startup Cost can be included

3-Dimensional Power Approximation



Heuristic Solution

- Uses Mixed-Integer Programming formulation
- Gradually add integer restrictions
 - Initially linear programming approximation
 - Add integer restrictions for first time period
 - Use linear approximation for later periods
 - Add integer restrictions for successive periods
- Opportunities for performance improvement

Numerical Stability

- Optimization uses a large matrix
 - Bad scaling leads to round off errors and instability
- Traditional Scaling
 - adjusting internal “optimization” units
- “Shift” scaling
 - Subtracting off minimum values
 - Example – Elevations
- Reduced the round off error of matrix operations, aka “condition number”.

Input Modeling

- Most inputs are automatically handled
 - Pre-optimization simulation
 - When referenced in a policy
- A few cases were not being handled
 - Example – Pool Elevation of a level reservoir in the middle of a run.
- Now – all inputs are modeled correctly

Alternative Solver

- CPLEX is great, but expensive
 - Now owned by IBM
- Researched commercial and open source alternatives
- Selected COIN-OR Project
 - Open source, C++ solvers, and more
 - COIN Linear Programming (CLP)
 - COIN Branch and Cut (CBC) Integer Programming
 - CLP and CBC based on commercial IBM OSL
 - Support of the operations research community, INFORMS

Optimization Training

➤ Online Modules

- Optimization Overview - nearly complete
- Three Solvers - finished
- Optimization In Depth - started
- Optimization Policy - started
- Common Optimization Problems

➤ Class at TVA this year