Cascading Hydro Simulation

Agenda

- Water System Definitions
- Plexos Objects
- Calaveras Model
- Optimization Techniques

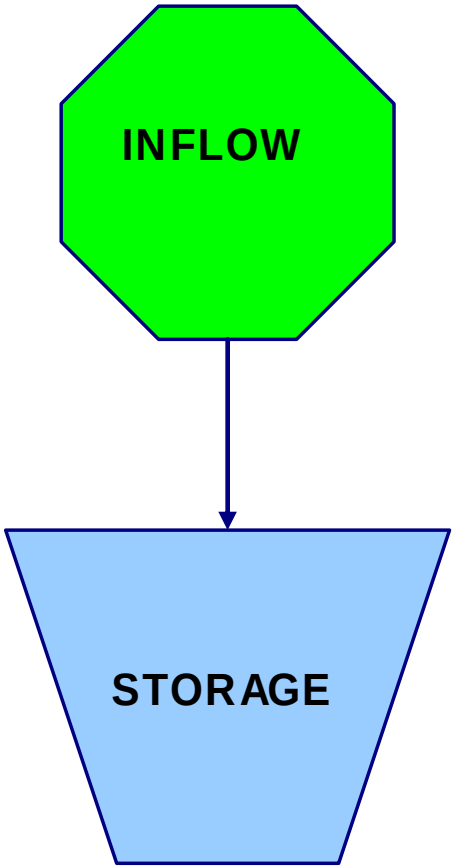
Water System Definitions

- Water Year
- Rough Running Range
- Bank Storage
- Traversal Time
- Sublimation
- Minimum flow constraints
  - Opacity
  - Salinity
  - Dilution
  - Temperature
  - Recreation
  - Environmental
  - Transportation
- Spill
- Head
- Forebay AfterBay
- Water Value
- Run-of-river
- Regulated, Unregulated Flows
- Peak Shave
- AS
  - Regulation
  - Spin Up, Spin down
- Pumped Storage
- Rule Curve
- Carryover Storage

Plexos Objects

- Hydro
  - Storage
  - Waterway
  - Generator
- Electric Price
  - Property on Region or Node
  - Property on Market
- AS
  - Reserve Object

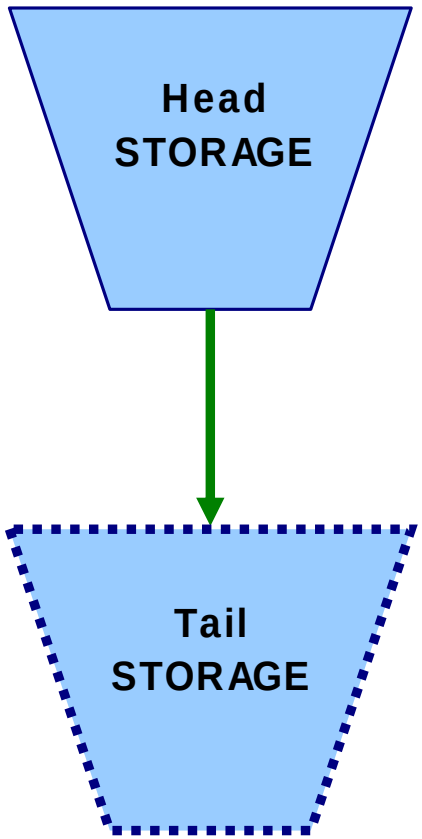
Hydro Objects



Storage Object

- Connects with:
  - Generator
  - Waterway
- Storage or Level Model
  - Storage, primarily GWHs but can be used for Ac-ft, CM
  - Level computes storage volumes
  - Initial, min, max
- Natural Inflow
- Max Spill
- Price
  - WaterValue
  - OfferQuantity
  - Offer Price

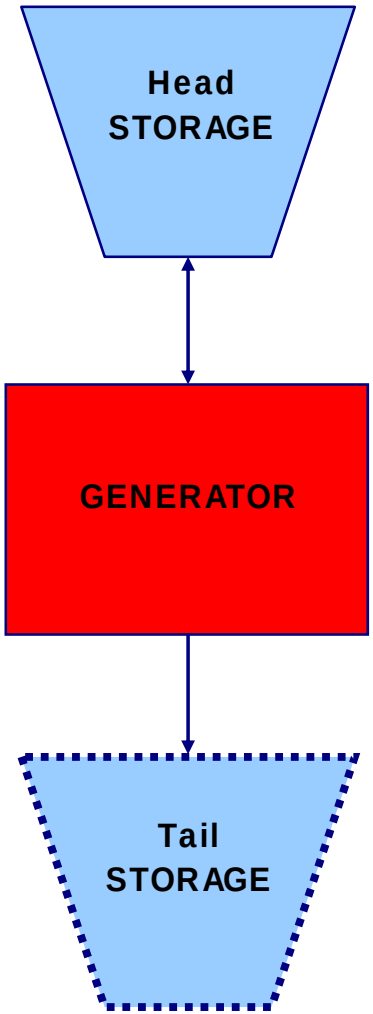
Hydro Objects



WaterWay

- Connects with:
  - Storage
    - Head, and/or
    - Tail
- Flow
  - Min
  - Max
  - Max Delta
  - Traversal Time
- Head with no Tail represents Water Losses

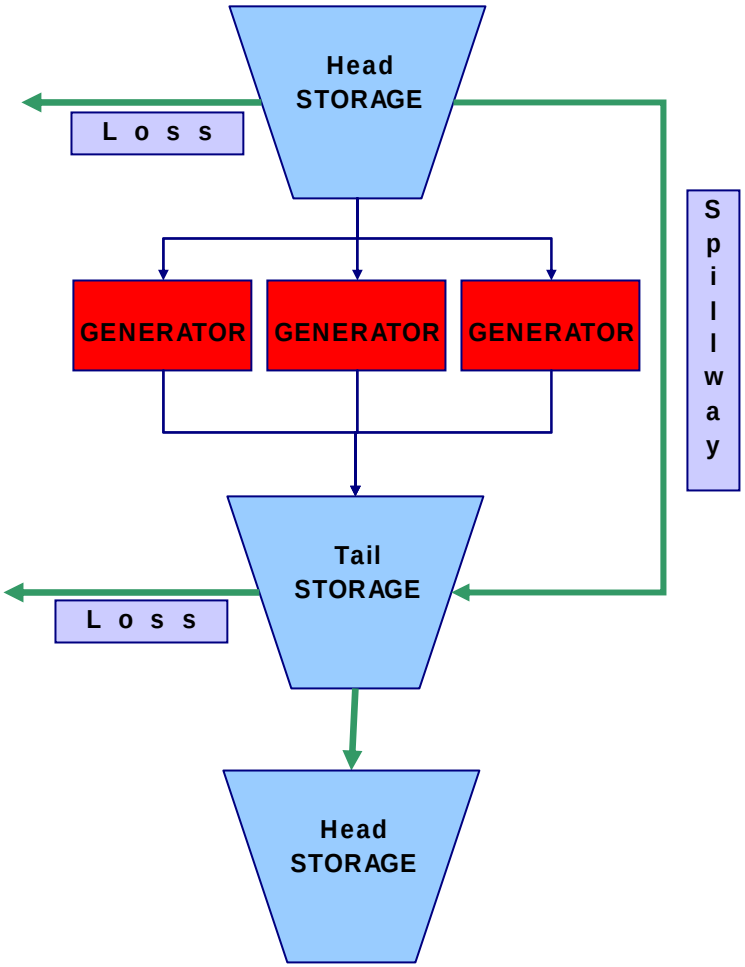
Hydro Objects



Generator

- Connects with:
  - Storage
    - Head, and/or
    - Tail
- All Generator Properties
  - Rough Running Point
  - Rough Running Range
- Pump
  - Units
  - Efficiency
  - Pump Load
  - Min Pump

Hydro Objects



Combining Objects

- Many-to-many relationships allow complex schematics and interwoven constraints on the system

Hydro Objects

Connection

- Flow factor
  - Ratio of Energy leaving Storage to generator, waterway
  - Ratio of Energy entering storage from generator, waterway
- Heat Rate (?)
  - Fuel used/MWH produced
- Version 4.8+
  - CM, cumecs
  - AC-Ft, cfs

Plexos Models

- Run-of-River
  - Generation profile: Fixed Load
- Simplified
  - Min, max capacities
  - Daily Energy constraints
- Simple Storage with Optional Pump
- Cascading Hydro

Water Year Conclusions

- Snow Pack Pattern
  - Rain – Immediate, Snow - Delayed
  - Randomness of weather events tempered by snow pack storage
- Sampling by Water Year
  - Critical Dry
  - Dry
  - Average
  - Wet
  - Very Wet

Inflow Issues

- Winter Releases:
  - Too much – not enough water for summer
  - Too Little – Excessive Spills in spring
- Summer Releases:
  - Dry Year – mostly minimum flows
  - Wet year – mostly max generation
  - Average years – more discretionary
- Carryover Issues
  - Price between years
  - Minimum Storage requirements?

Ancillary Services

- Regulation
  - Unit Loaded
  - RegUP: Unused generation
  - RegDown: generation
  - Energy Use
- Spin
  - Unit spinning at minimum
  - Quick response
- Non-Spin
  - Lower value than spin

Ancillary Services BFOs

- During run off periods, backing off a hydro unit results in spillage, so AS value includes capacity plus energy
- During discretionary run periods:
  - Down service banks water – low value for AS because value is gathered in the future
  - Up service burns water – so AS costs future value of the water

AS Objects - Reserve

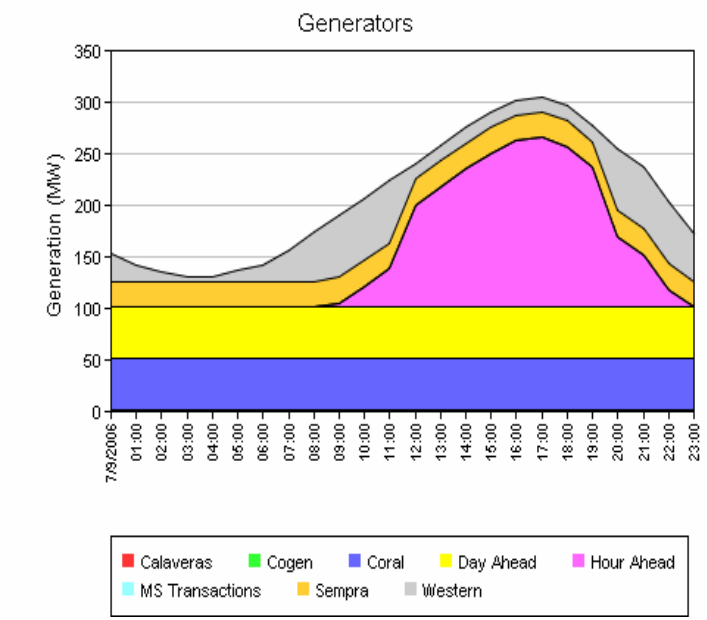
- Type
  - Min Raise
  - Min Lower
  - Min Regulation Raise
  - Min Regulation Lower
  - Min Replacement
  - Min Operational
- Other
  - Price
  - Energy Usage

- Generator
  - Offer Quantity
  - Offer Price
  - Effectiveness
  - Max Response
  - Min Provision
  - Response Ratio
  - Max Reserve Unit Response
  - Reserve Unit Offer Price
  - Max Pump Response
  - Max Replacement
  - Pump Offer Price

Optimization Techniques

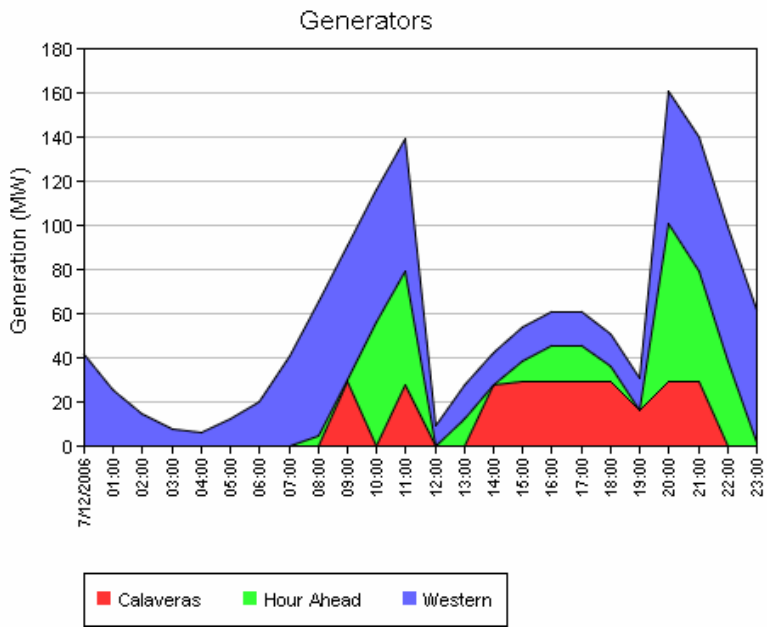
- Peak shave
  - Daily Pattern
  - Run-of-river with some intra-day flexibility
- Shaping
  - Fill in energy holes in schedule
- Rule Curve
  - Flood Control
  - Monthly generation depends on achieving end of month targets
- Water Value or “Strike Price” of water in storage

Peak Shave



- Simply dispatch hydro at highest load or price periods until no more energy is available

Shaping



- Trigger all in-the-money Options
  - Generation
  - Standard Block contracts
- Fill needs with available Odd-lots
- Run Hydro to Fill remaining Shape

Rule Curve

- Monthly Storage Volumes, and tolerance ranges
  - Used for Flood Control, &
  - Simple Optimization Tool
    - Monthly Water Schedule
- Based on worst case Inflows to prevent excessive spilling and flood conditions
- Based on Expected Energy Prices for the water year
- Provides look-ahead energy releases to allow for backfilling against markets
- Set with:
  - extrinsic monthly water values, or
  - Min and max volumes by month, with monthly look-ahead

Water Value

- Changes with Storage Conditions
- Shadow Price of Storage
  - During Spill = 0
- Insufficient InFlows
  - 0 (if the look-ahead does not carryover)
  - Look at Shorter Period
- Computed internally (Intrinsic)
- Entered as Input (Extrinsic)

Optimization Techniques – Water Value

- Intrinsic (Let Plexos decide)
  - Targets end-of-step min storage
  - Factors in:
    - flow constraints,
    - energy prices,
    - AS co-optimization
    - Congestion
- Extrinsic (Give Plexos a target)
  - Good short-run
  - Develop bid strategy

Optimization Process - Intrinisic WaterValue

- Compute Storage Available in Look-ahead
  - Initial volume
  - Inflows
  - (min flows)
  - (end Volume)
- Allocate to LDCs over entire lookahead
  - Determines LDC watervalues
- Other:
  - No Value for min volumes
  - Not necessarily a value in achieving max volume
  - LookAhead Period (MT) drives optimization

Optimization Process - Extrinisic WaterValue

- Water Value entered as Input
  - Monthly variation reflects a price weighted Rule Curve
- Allocate to LDCs over entire lookahead
  - Determines Discretionary Releases from Storage
- Other:
  - A Premium on water value fills storage
  - A Discount on water value drains storage
  - Very High Water Value provides minimum flow data

Optimization Techniques - Carryover Storage

- Multi-year (carryover period)
  - Rule curve creation
- Run intrinsically
- Minimum storage levels
- Good candidate for Stochastics
  - Price
  - Inflows

How do Water Operators Actually Run Their Dams?

- Close monitoring of snow pack
- Look Ahead Using Normal Water Year
  - Catch Up by adjusting releases
- Those who fill Bias:
  - drought,
  - high prices
- Those who don’t fill Bias:
  - Flood
  - Economics

How do Water Operators Actually Run Their Dams?

Daily Operations

- Determine minimum requirements
- Determine discretionary releases (AS)
- Dispatch remainder of portfolio
- Use discretionary release to backfill schedules