Hydroelectric Operations - Ensemble Optimization Procedures (EOP)

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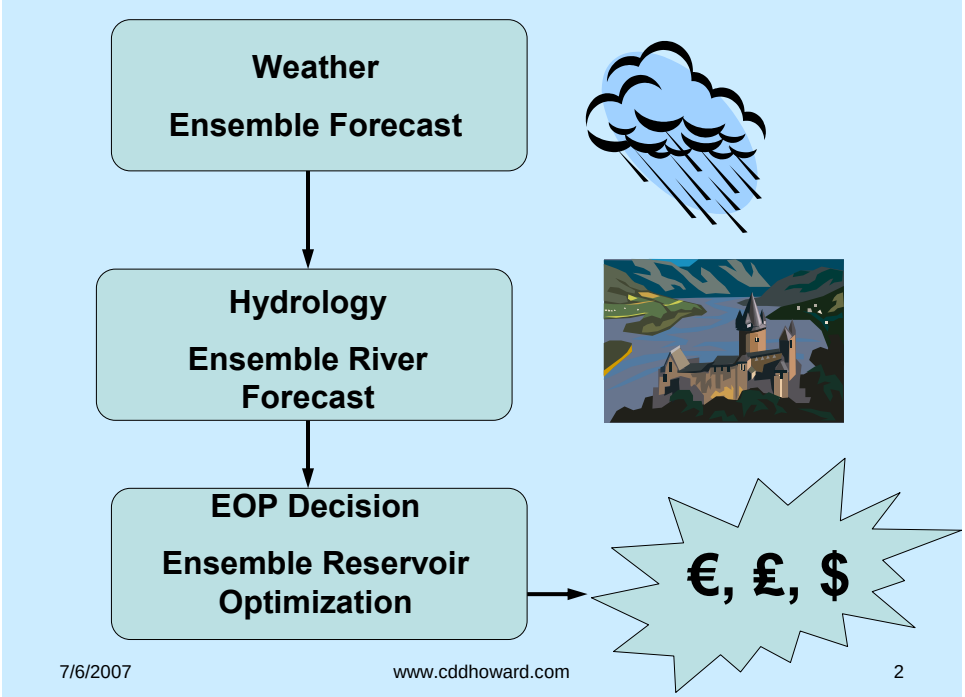
ABSTRACT

Weather forecasts provide the basic information used in forecasting electrical loads and hydrologic inputs to reservoirs. A conventional approach in load forecasting accounts for seasonal trends, currently observed loads, and a random component based on the statistics of past electrical loads. Conventional hydrologic forecasting takes a similar approach but with added complexity from hydrologic behavior of the contributing basin and routing in the river systems. In both cases a single deterministic weather forecast is the basic input.

HEPEX may change conventional hydroelectric practice by biasing the end user product, forecasts of electrical load or reservoir inflow, on sets of equally likely weather forecasts. Hydroelectric operating decisions will then require support from an Ensemble Optimization Procedure (EOP) that explicitly considers the set of forecasts (the ensemble) in recommending the best possible decisions at the current time. This paper demonstrates three practical EOP methods for planning and scheduling operation of a hypothetical reservoir for hydroelectric generation.



Reservoir Operation Objective

- Maximize Benefits
- Considering all of the possible futures in the Ensemble Forecasts
- How much water should be released from storage?

OPTRISK
Monte Carlo Simulation at each Mathematical Programming Iteration

OPTSEQ
Optimize Each Member of the Ensemble Individually

OPTNOW
Globally Optimize Over the Entire Ensemble

PLANNING with Ensembles OPTRISK:

- Develop the optimum fixed plan of operation over the entire time horizon.
- Consider risks inherent in the ensemble
- Display the risks for following that plan.
- Used to make agreements for future deliveries of water and power.

OPERATING with Ensembles OPTSEQ & OPTNOW:

- Determine a single optimum decision.
- Consider all possible future outcomes.
- Display the optimum probability distributions of future decisions.
- Used to keep operations on the PLAN as new ensemble forecasts arrive.

1.OPTRISK Simulations

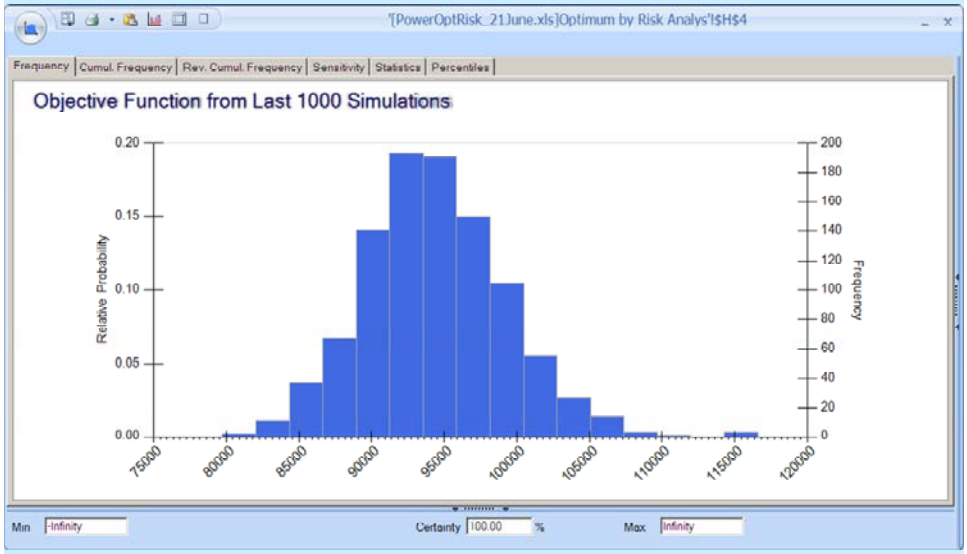
Optimimum powerflow at time Now is **57.9**

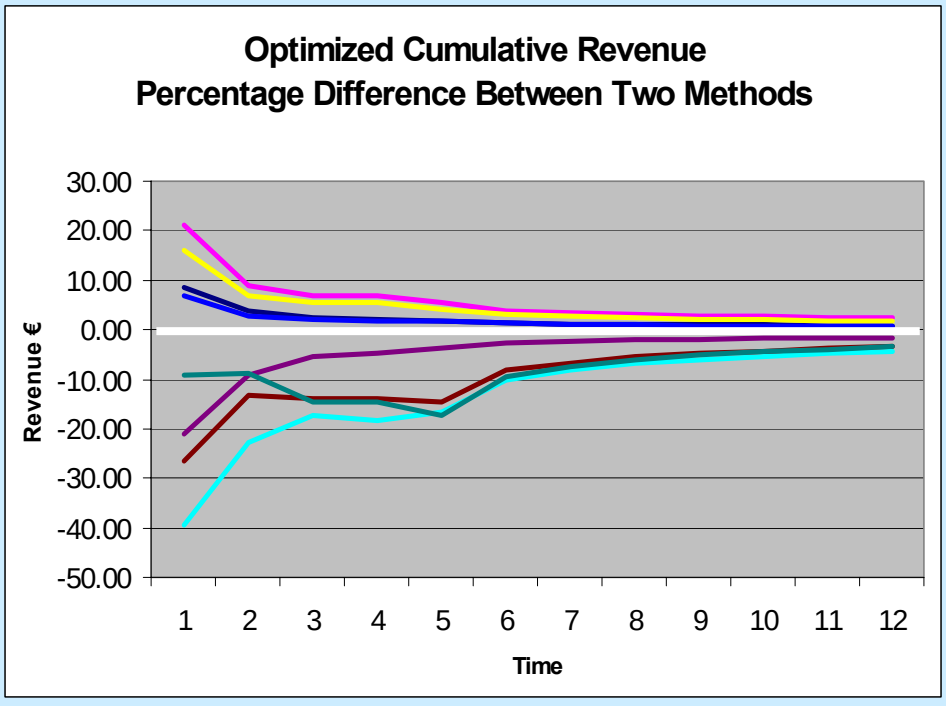
Expected value of objective over all distributions from 1000 simulations $94,361

Last simulation shown on screen: current value of the objective $88,768

	Streamflow Analysis			Optimization Over All Timesteps and Streamflow Distributions					
				Probabilistic	**Deterministic**		**Probabilistic**		
timestep	avg	stdev	SerialCorrelations	inflow	powerflow	spill	storage	power	Pricing
NOW	114.33	41.907	deterministic	104.30	57.9	0.0	296.39	171.6	100
2	85.68	22.304	-0.14	84.03	68.0	0.0	312.45	212.4	75
3	77.05	18.209	-0.24	74.92	47.2	0.0	340.11	160.7	55
4	29.49	7.438	0.09	21.13	12.2	0.0	349.00	42.7	45
5	78.33	16.069	-0.40	73.77	69.8	0.0	353.01	246.3	40
6	86.43	16.255	-0.22	93.37	104.2	0.0	342.19	356.5	38
7	69.52	12.203	0.18	65.12	64.1	0.0	343.24	220.0	27
8	29.30	2.537	-0.37	37.11	82.0	0.0	298.36	244.6	26
9	14.68	3.098	-0.76	19.53	76.2	0.0	241.73	184.1	24
10	4.89	0.747	0.13	2.43	63.5	0.0	180.68	114.7	22
11	1.94	0.133	-0.42	0.01	58.5	0.0	122.15	71.5	21
12	0.57	0.210	0.57	3.27	54.3	0.0	71.11	38.6	20
				ProbabilisticData	Decision Variables		Current Values		
				Upper Bound	150		500		
				Lower Bound	0		0		
							250		Initial storage

1.OPTRISK


'[PowerOptRisk_21June.xls]Optimum by Risk Analys'!H4
Frequency
Cumul. Frequency
Rev. Cumul. Frequency
Sensitivity
Statistics
Percentiles
Objective Function from Last 1000 Simulations
Relative Probability
Frequency
0.20
0.15
0.10
0.05
0.00
200
180
160
140
120
100
80
60
40
20
0
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000
Min
-Infinity
Certainty
100.00
%
Max
Infinity


Optimized Cumulative Revenue
Percentage Difference Between Two Methods
Revenue €
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
1
2
3
4
5
6
7
8
9
10
11
12
Time

Maximum Objective Functions

- OPTRISK = 94,361
  - average of 1000 values
- OPTSEQ = 100,956
  - average of 8 values
- OPTNOW = 100,826
  - single value

Conclusions

- All three methods have about the same value for the objective function
- All recommend about the same reservoir release at time NOW.
- OPTRISK ensemble = 1000 sequences
- OPTNOW/OPTSEQ ensemble = 8 sequences