LabPlan

A COHERENT RISK MEASURE APPLIED TO THE BRAZILIAN LONG TERM HYDROTHERMAL SCHEDULING

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Joint work with
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Agenda

LabPlan

- Hydrothermal Scheduling in Brazil
- Risk Aversion
- Coherent Risk Measure
- Risk Averse SDDP Implementation
- Computational Results
- Final Remarks

Hydrothermal Scheduling in Brazil

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Long Term:
- 10 years planning horizon
- Simplified Modeling
- Inflows are uncertain

Medium Term:
- 2 to 6 months horizon
- More detailed modeling
- Inflows are uncertain

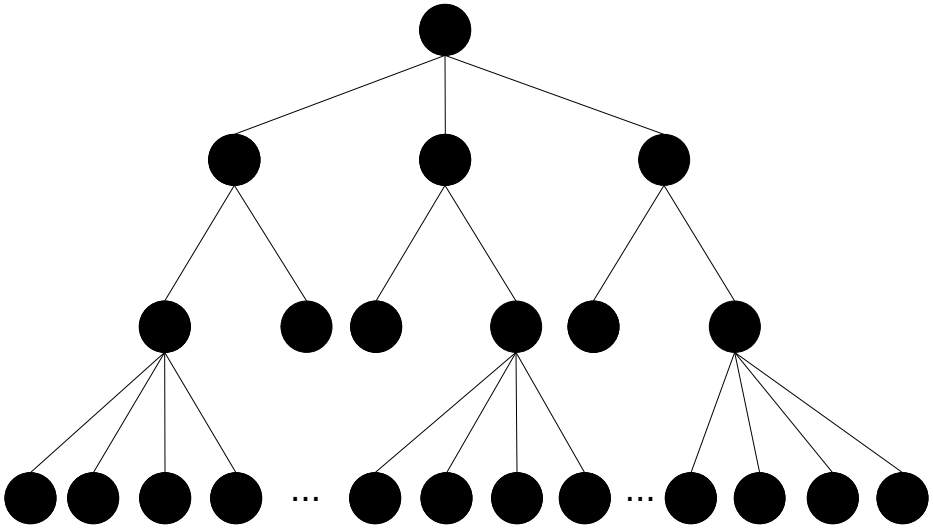
Short Term:
- 48 hours to 1 week horizon
- Extremely detailed modeling
- Inflows are assumed known

Stochastic
Simplified Modeling

Deterministic
Detailed Modeling

Hydrothermal Scheduling in Brazil

- Minimize the Expected Operation Cost



Risk Aversion

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- Expectation = Risk Neutral
  - Provides the best decision on average
- In a pure economical model it is acceptable to load shedding in order to obtain the smallest cost
- However, load shedding is an issue in political, economical and social terms
  - Therefore, one is Risk Averse

Coherent Risk Measure

- Proposed by Shapiro (2010)
- Convex combination between Expectation and CVaR

$$\rho(Z) = (1-\lambda)\mathbb{E}[Z] + \lambda CVaR_{1-\alpha}[Z]$$

- Artzner *et al* (1999)
  - Convexity
  - Monotonicity
  - Positive homogeneity
  - Translation equivariance

CVaR Definition

- *Conditional Value-at-Risk* – CVaR

$$\mathrm{CVaR}_{1-\alpha}[Z] = \inf_u \{u + \alpha^{-1}\mathbb{E}[Z-u]_+\},$$

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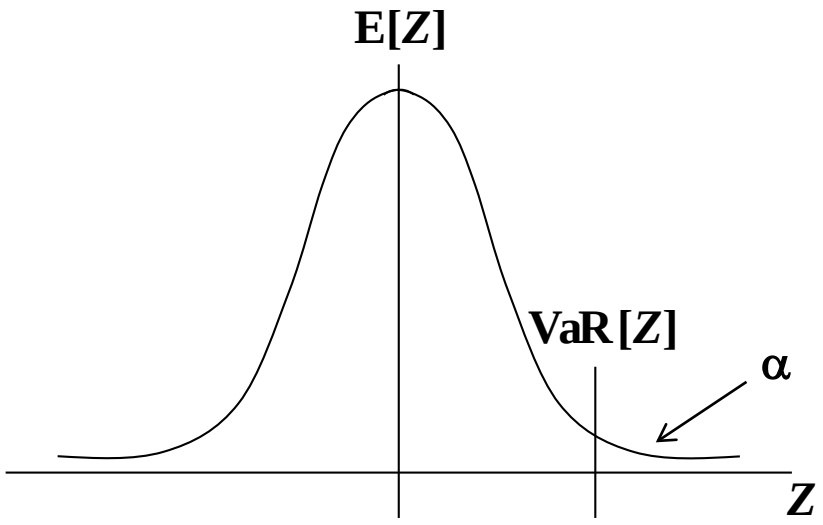

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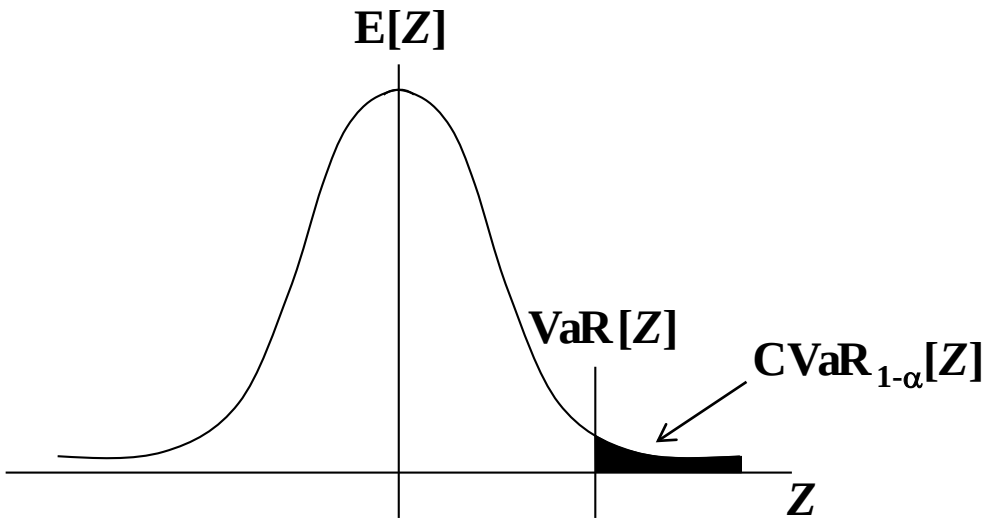

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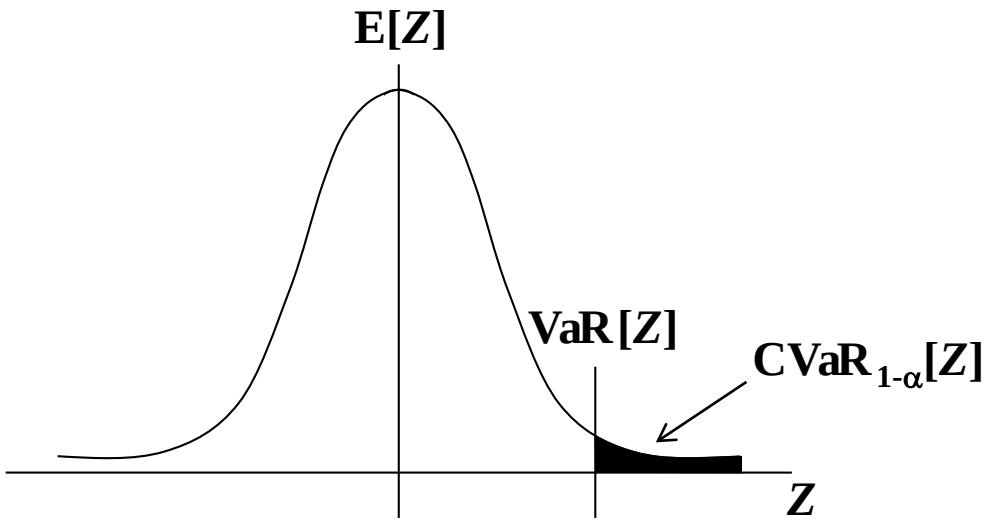

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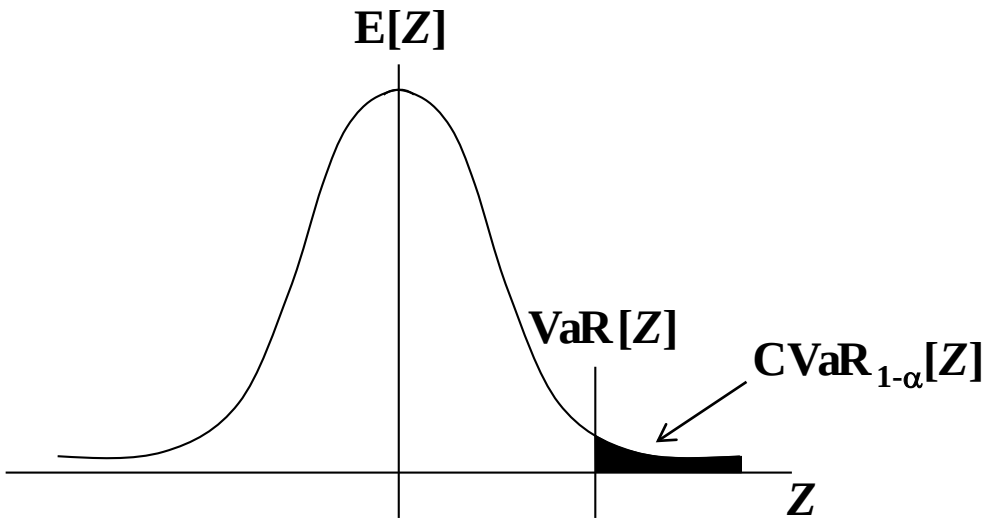

Risk Averse SDDP Implementation

LabPlan

- Can be applied directly to the SDDP
  - One additional state variable – Philpott and de Matos (2011)

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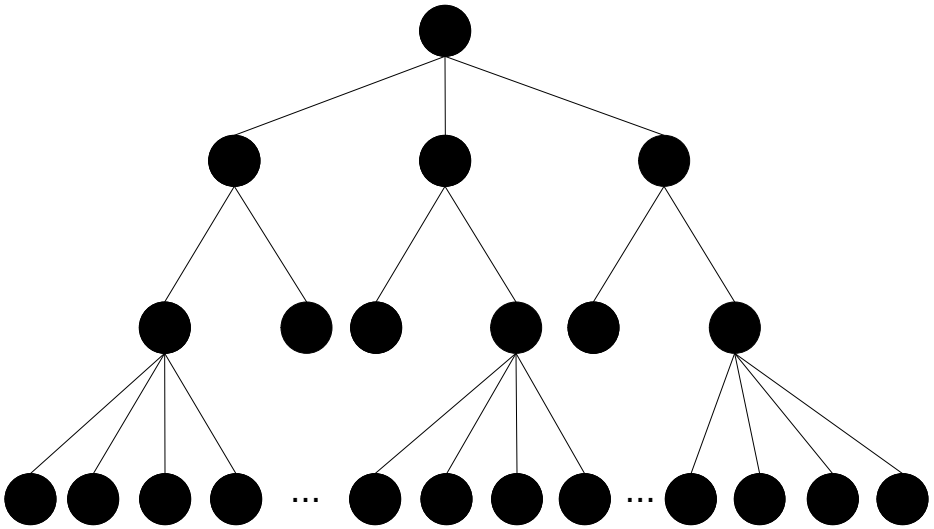

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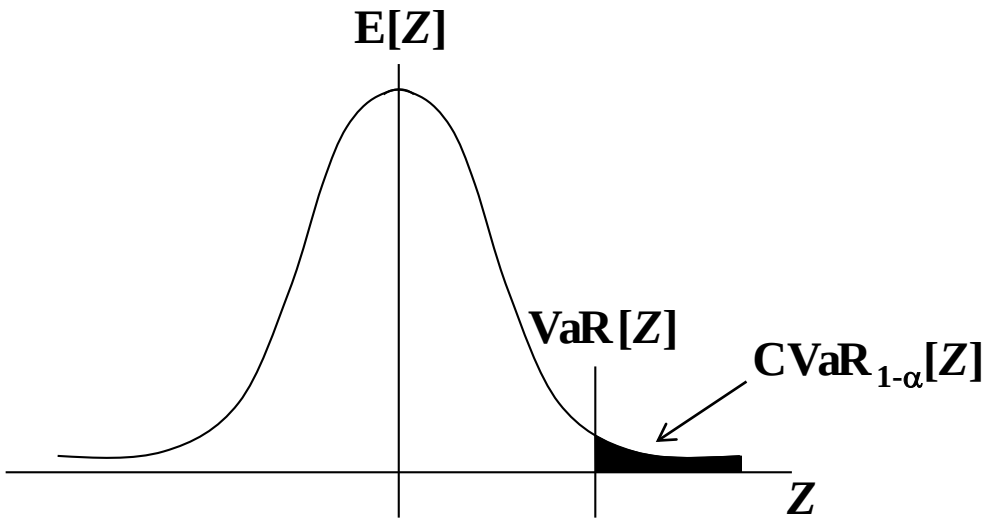

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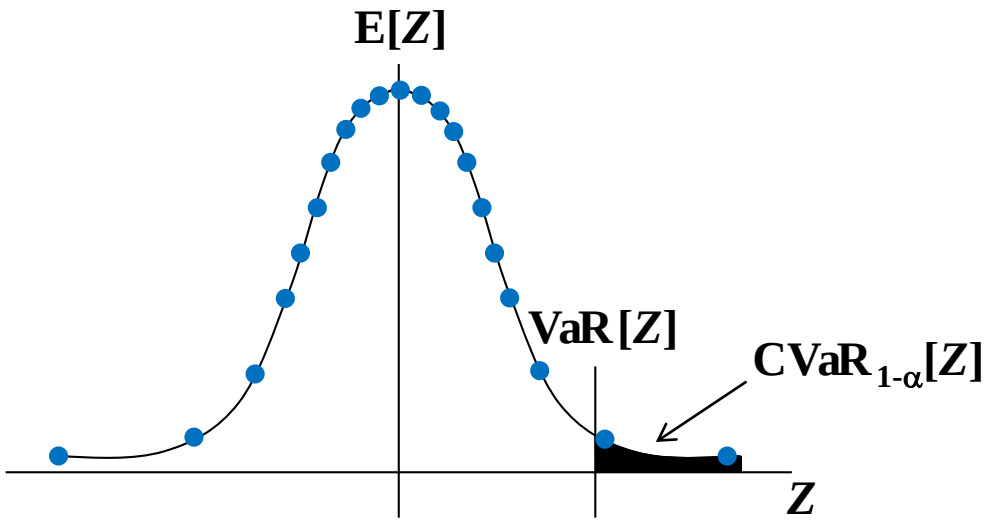

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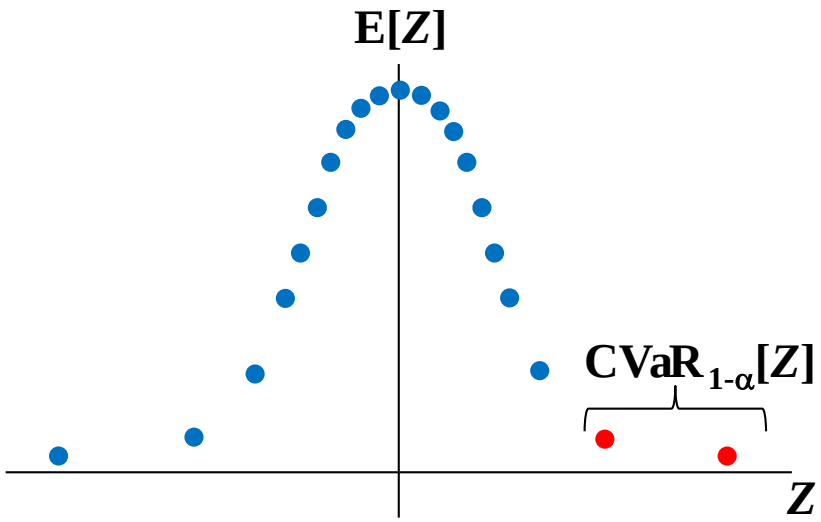

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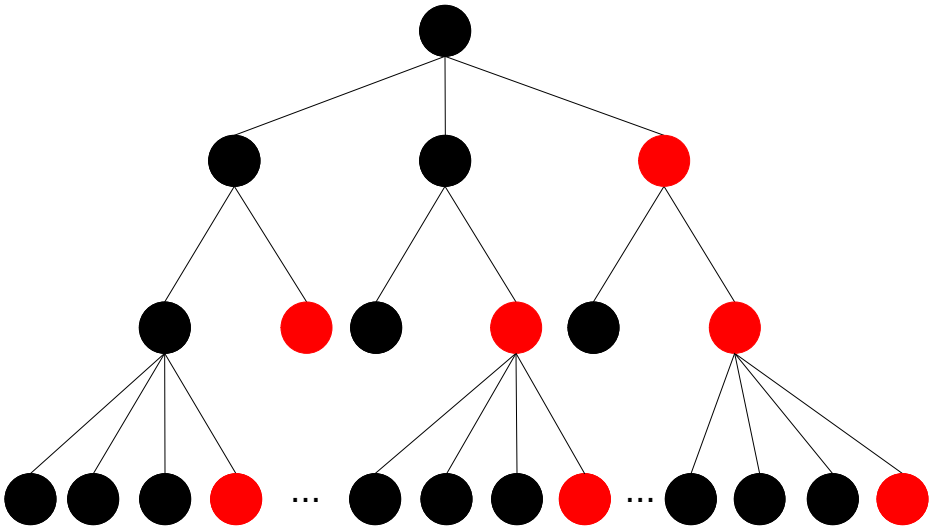


Computational Results

- Brazilian Power System
  - 158 Hydro Plants
  - 151 Thermal Plants
- 5 Nodes (Buses)
- Hydro Plants
  - Aggregated in 4 EERs
- Data from January/2012

Computational Results

- Operation Policy computed for following parameters
  - 12,000 Cuts → Simulated over 5,000 scenarios
    - Scenarios were sampled within the Scenario Tree

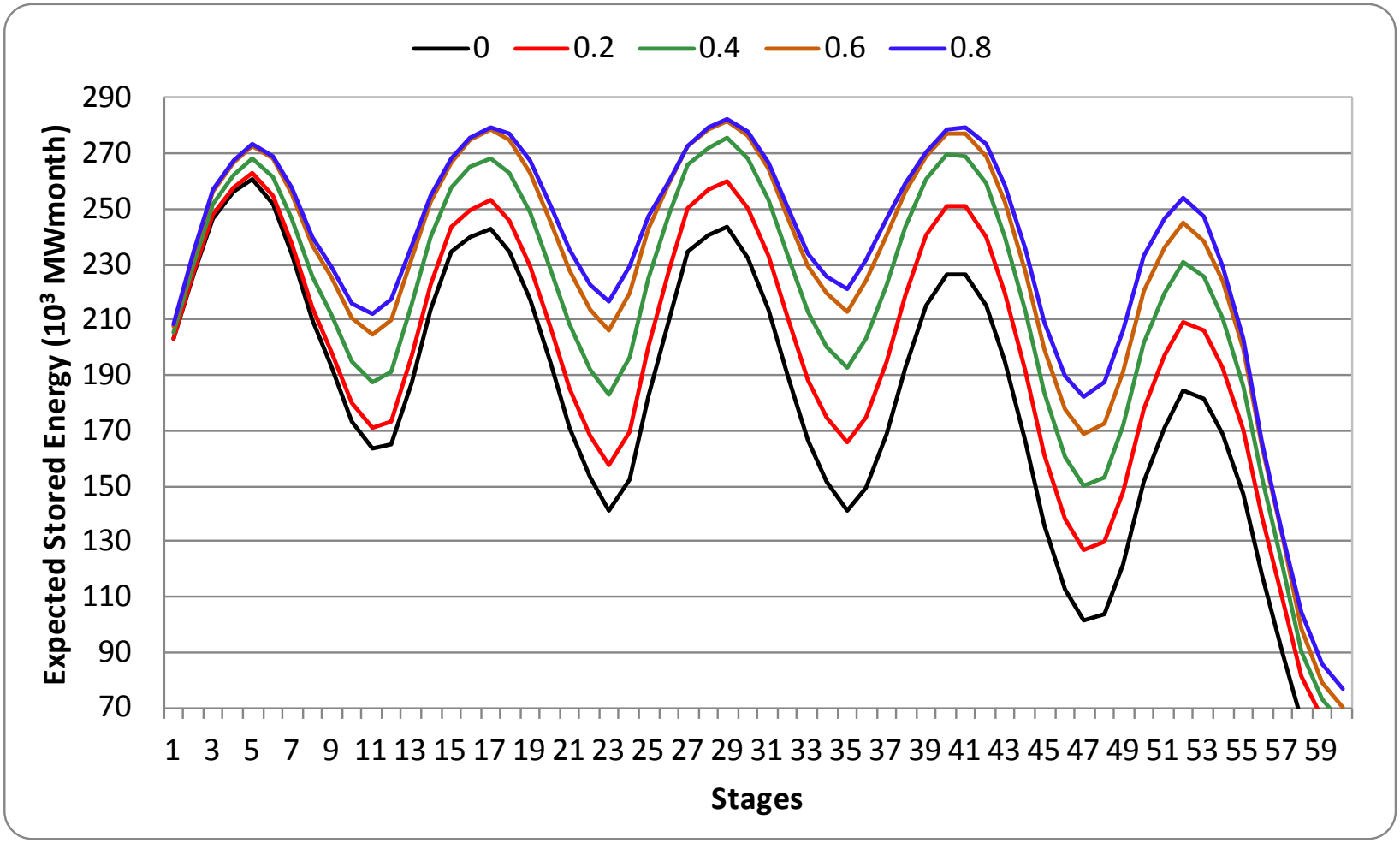
$$\rho(Z) = (1-\lambda)\mathbb{E}[Z] + \lambda CVaR_{1-\alpha}[Z]$$

λ
0
0.2
0.4
0.6
0.8

α
10
50
90

Computational Results - α = 10%

Expected Stored Energy



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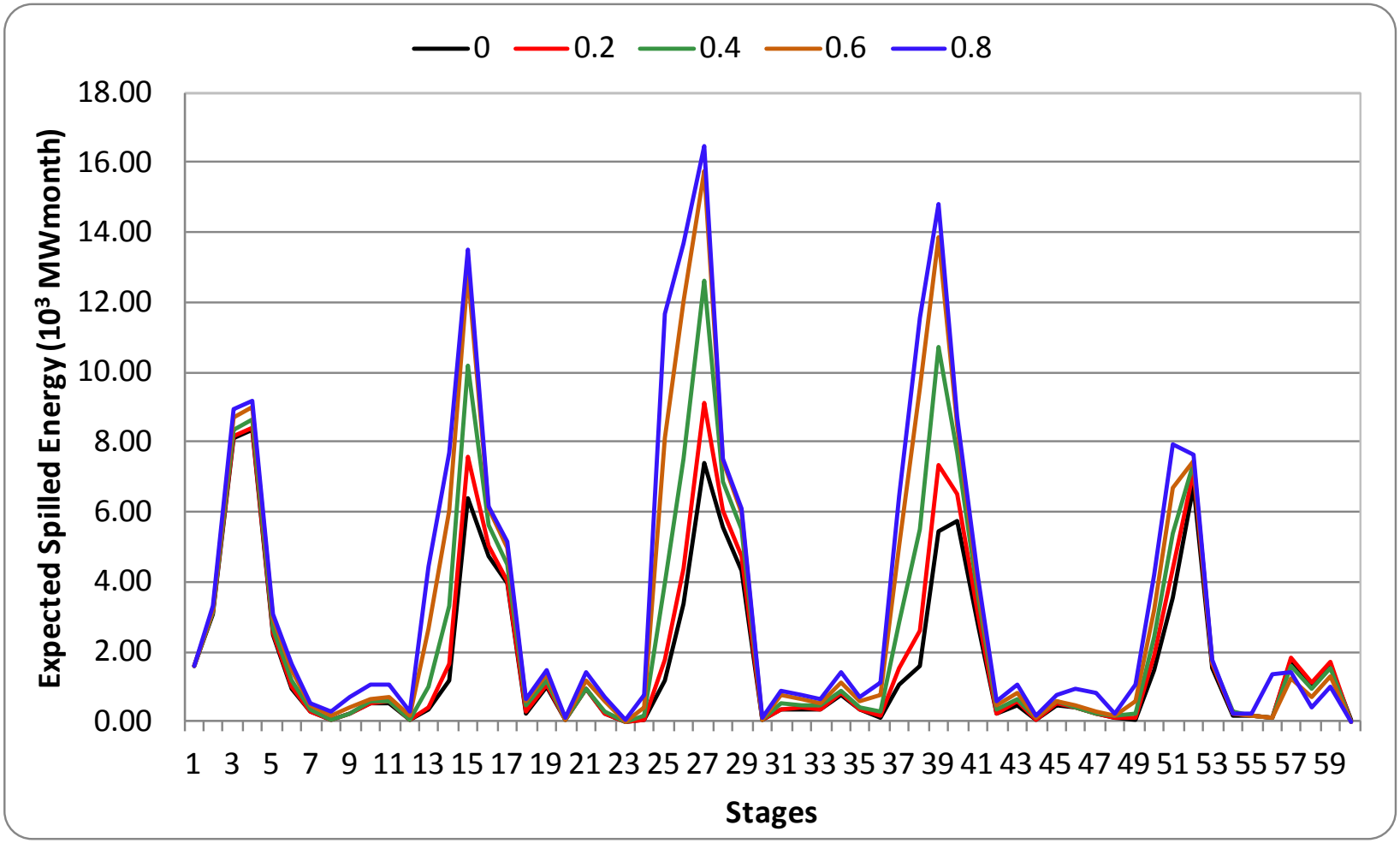
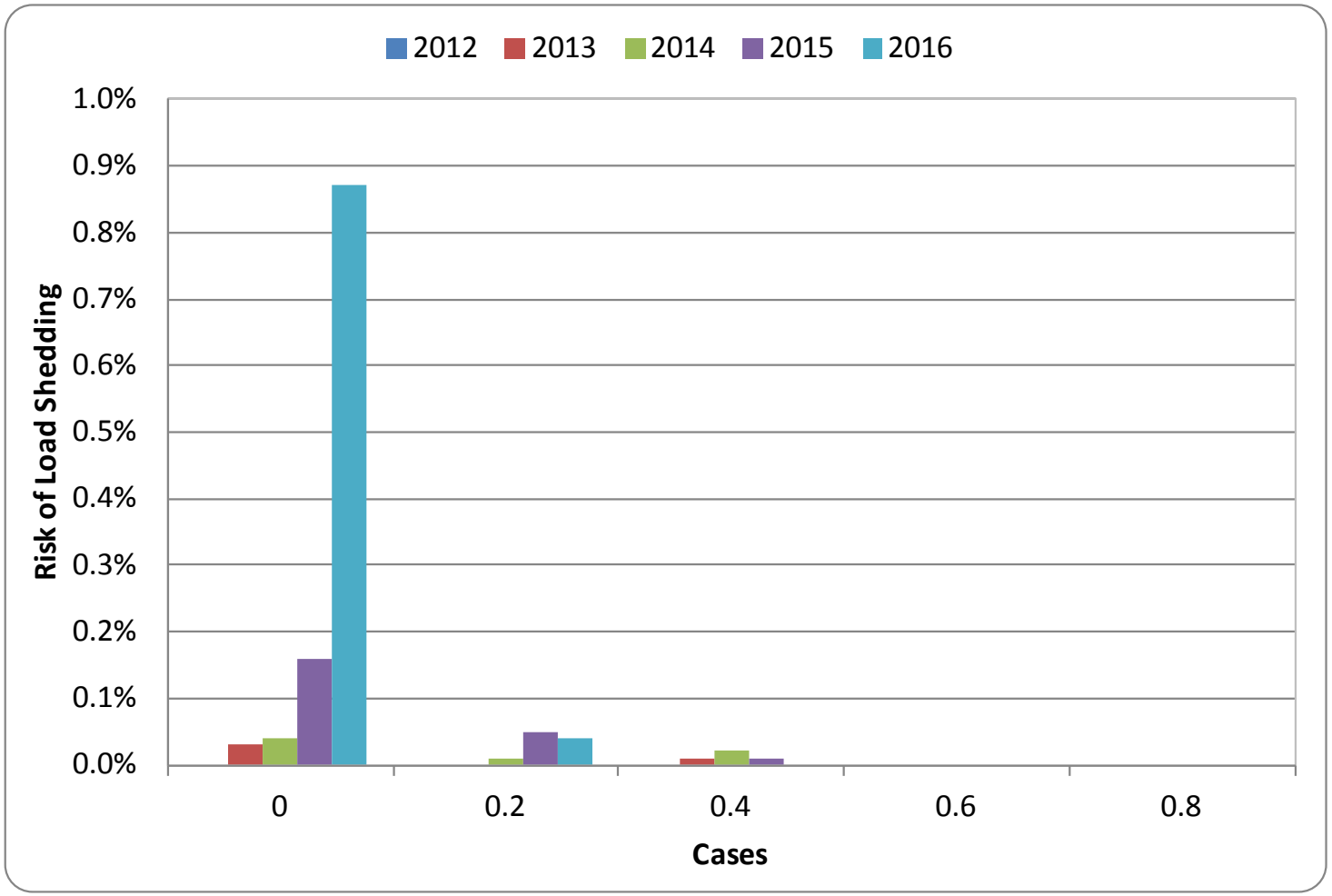
Expected Spilled Energy



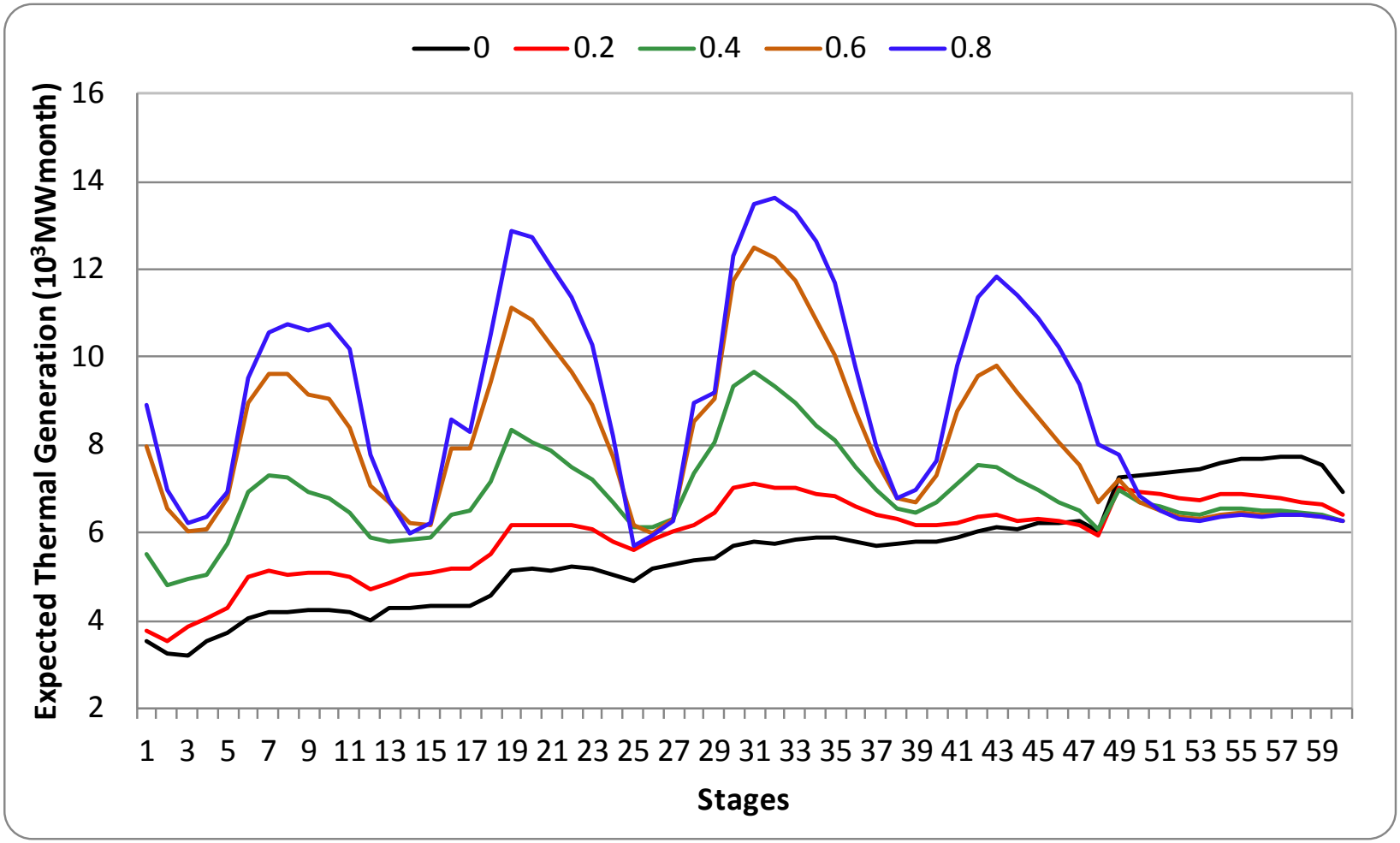
Computational Results - α = 10%

Risk of Load Shedding



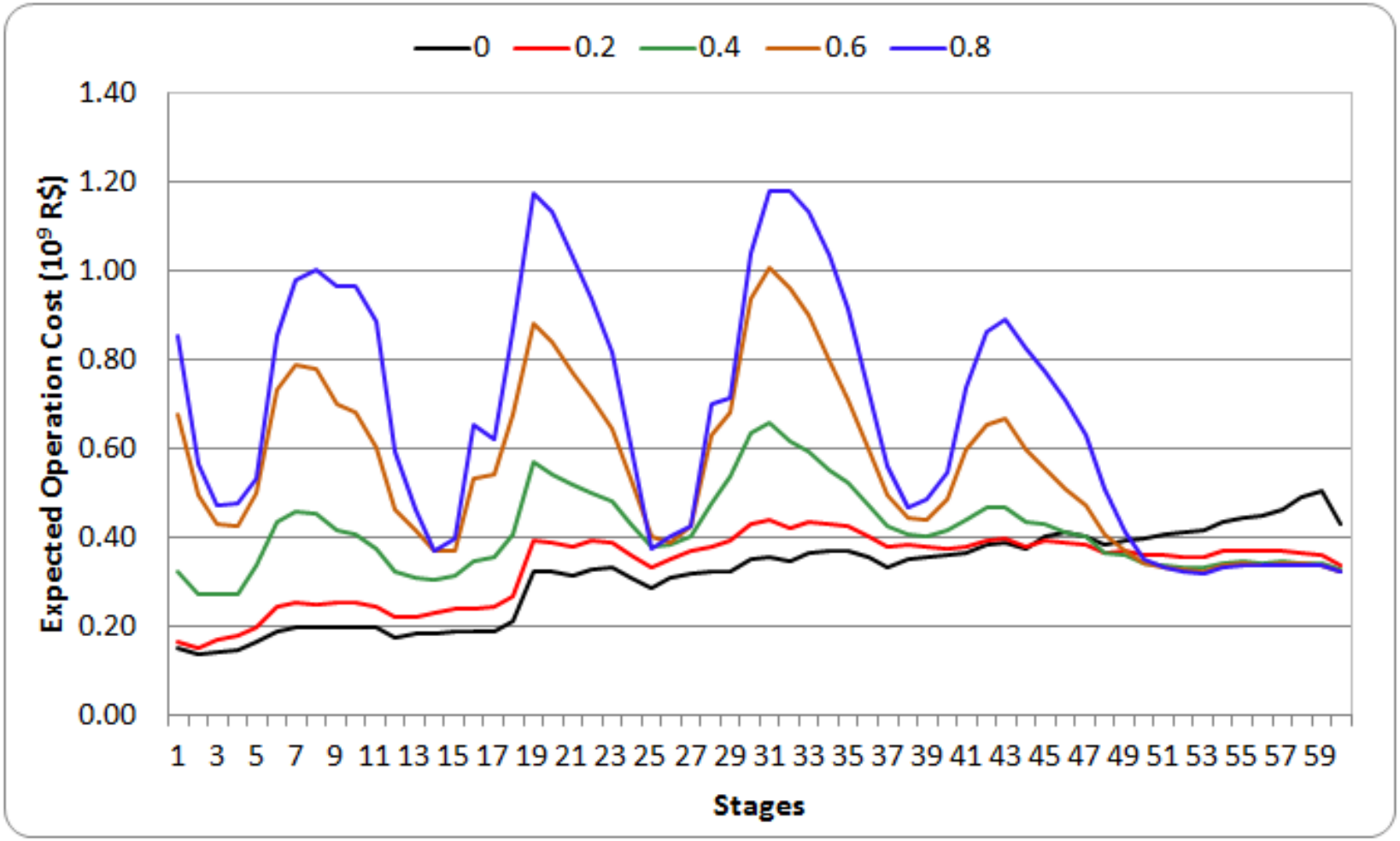
Computational Results - α = 10%

Expected Thermal Generation



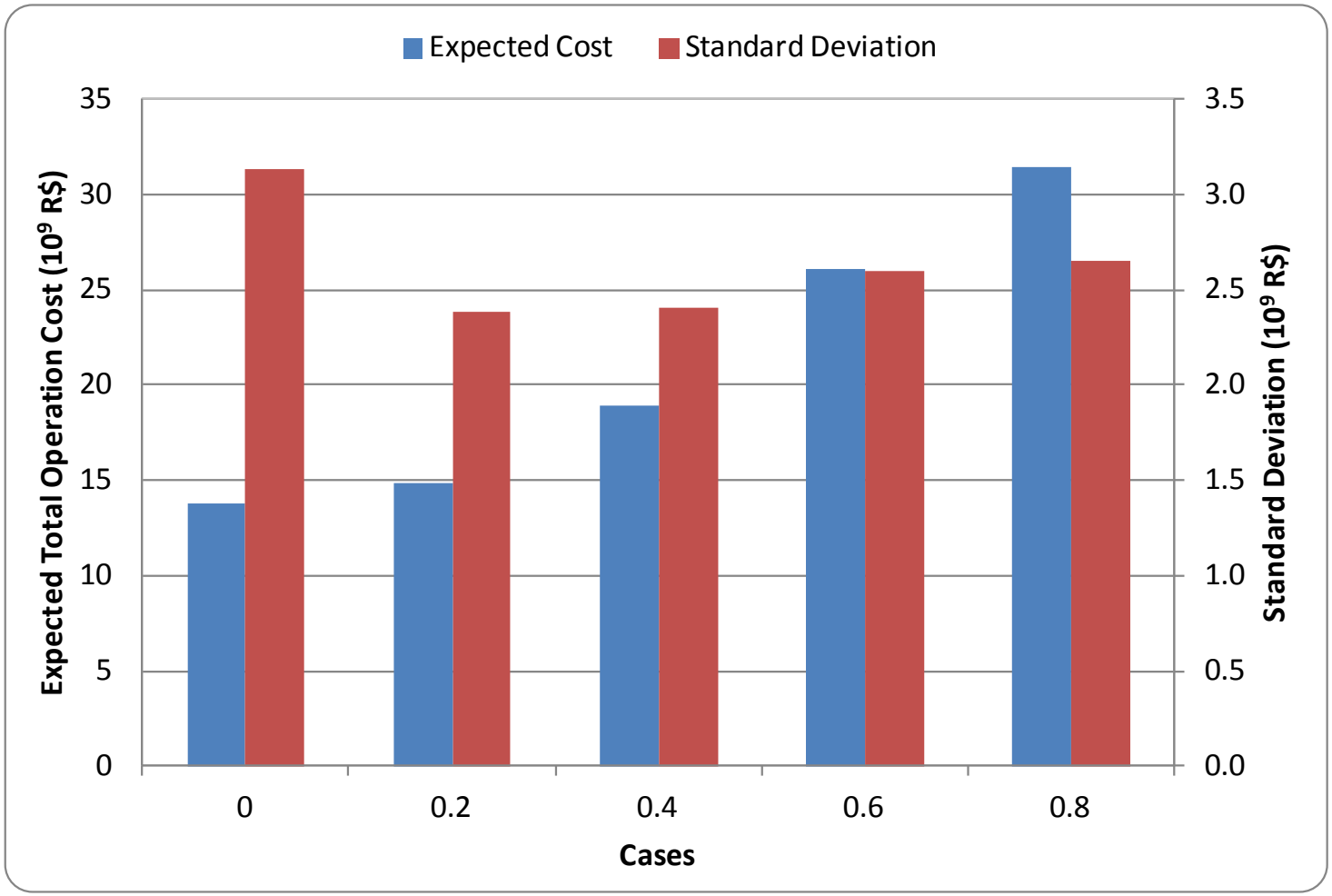
Computational Results - α = 10%

Expected Operation Cost per Stage



Computational Results - α = 10%

Expected Total Operation Cost



Computational Results

Expected Stored Energy

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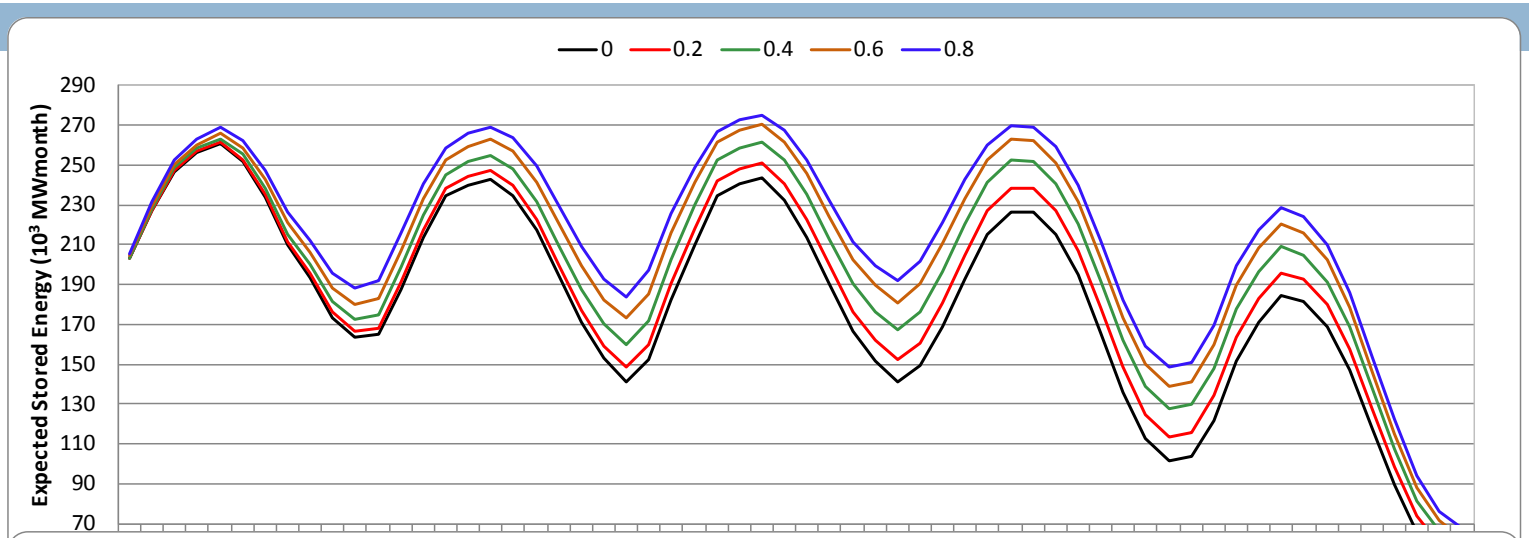
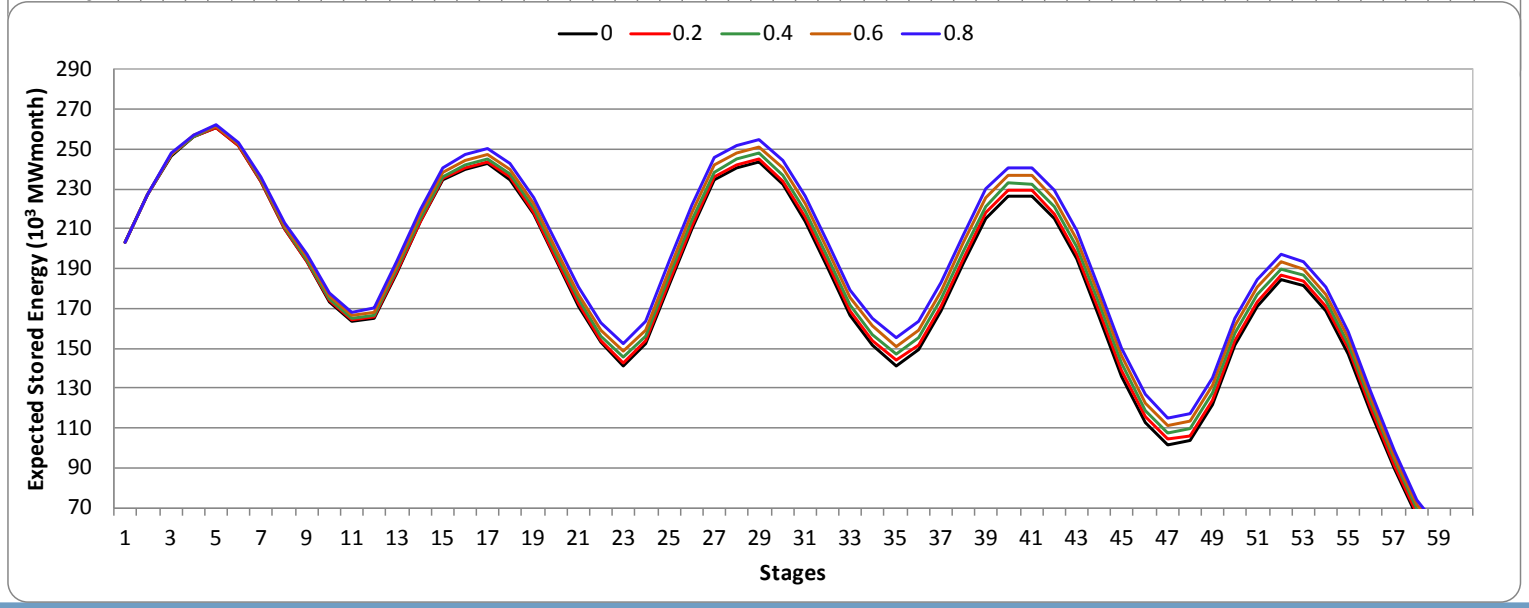
$\alpha = 50\%$



$\alpha = 90\%$



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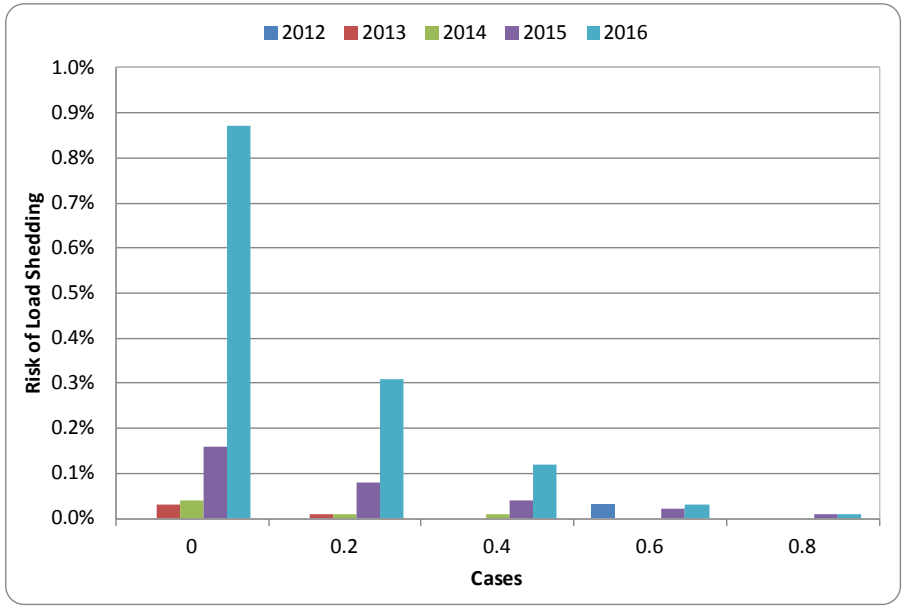

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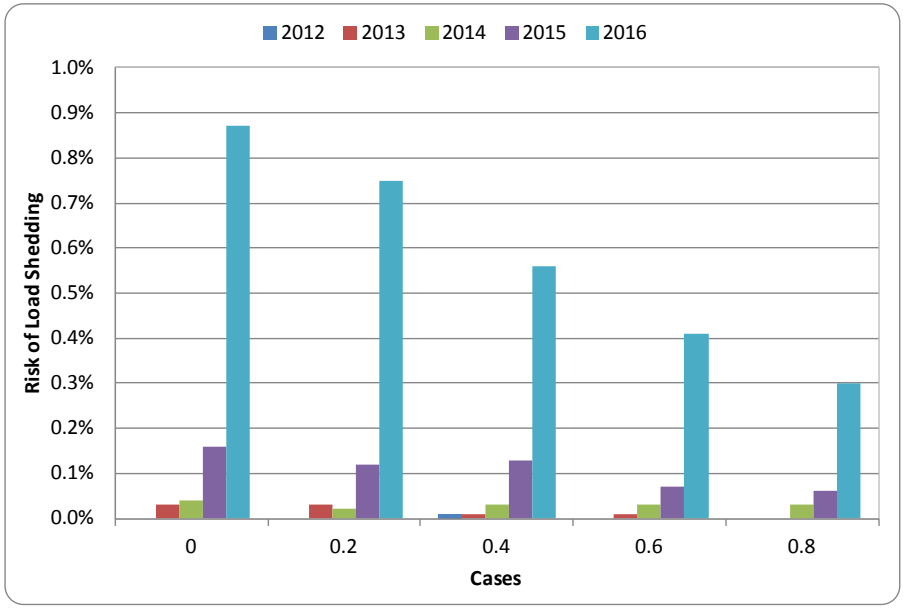

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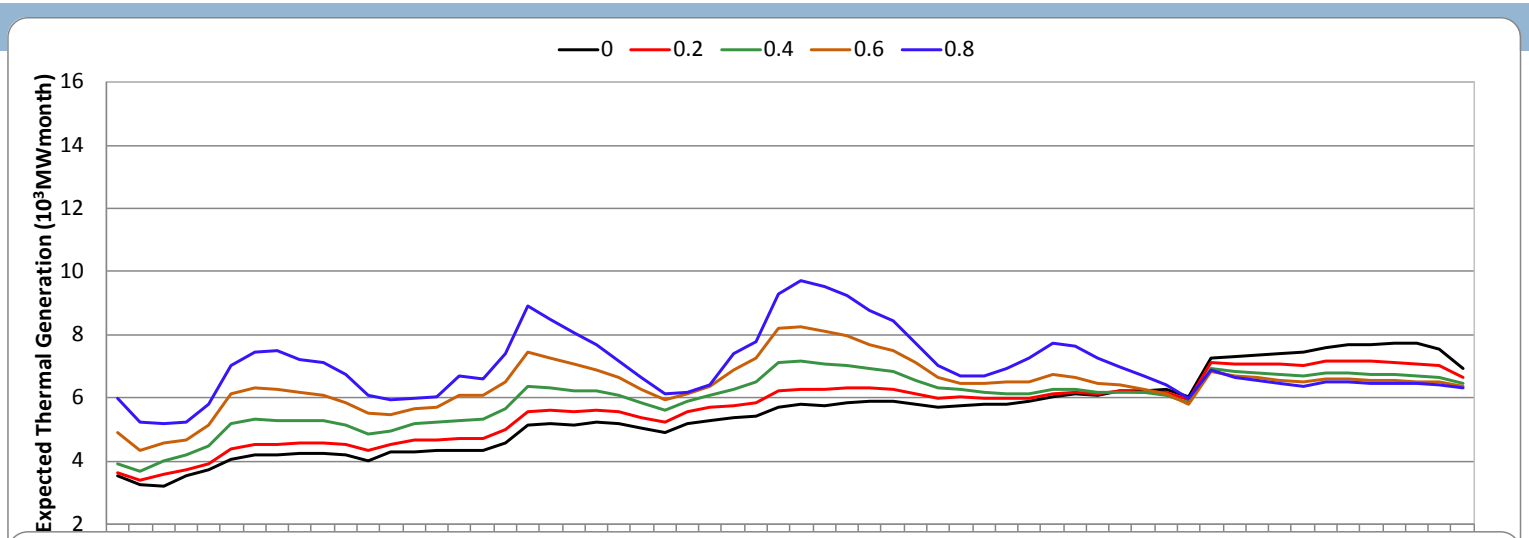

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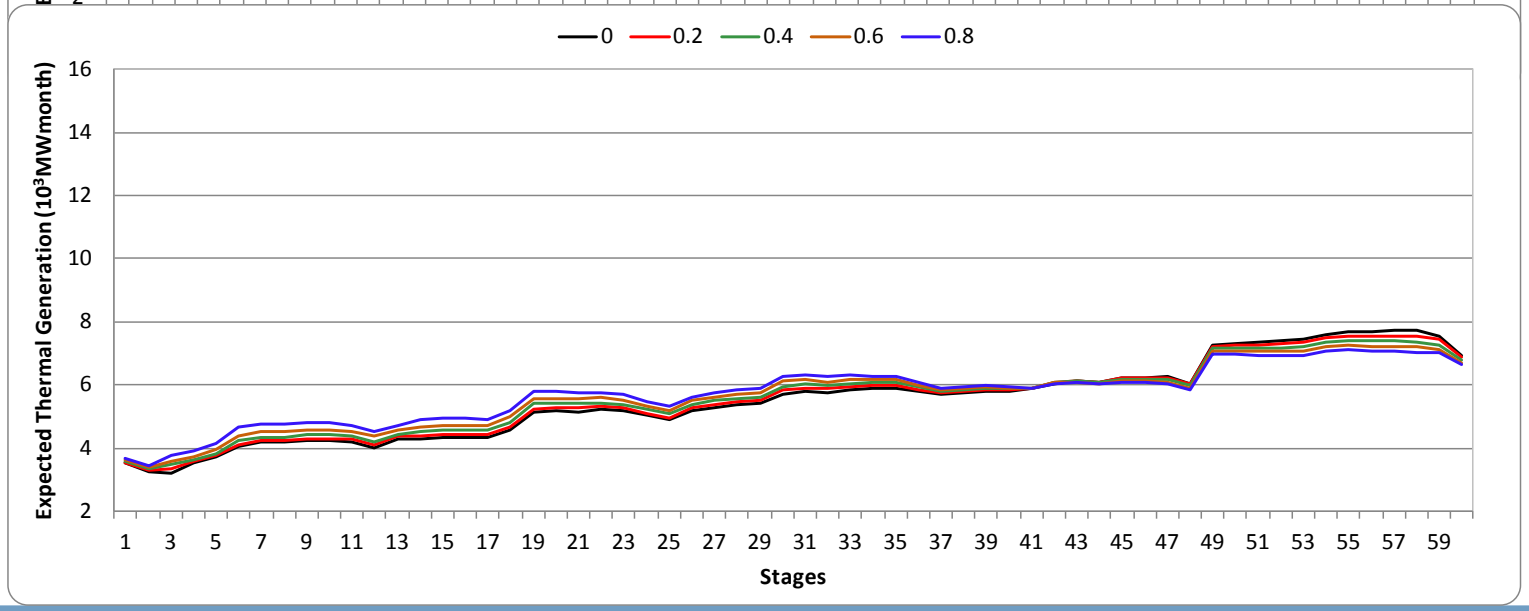

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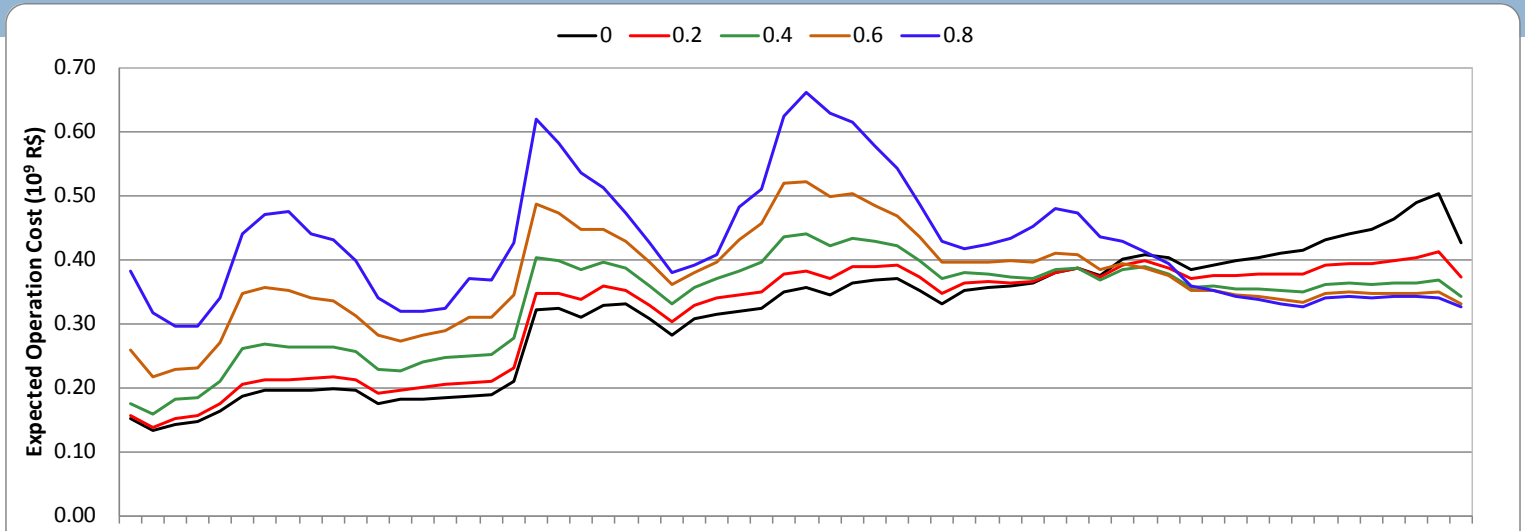

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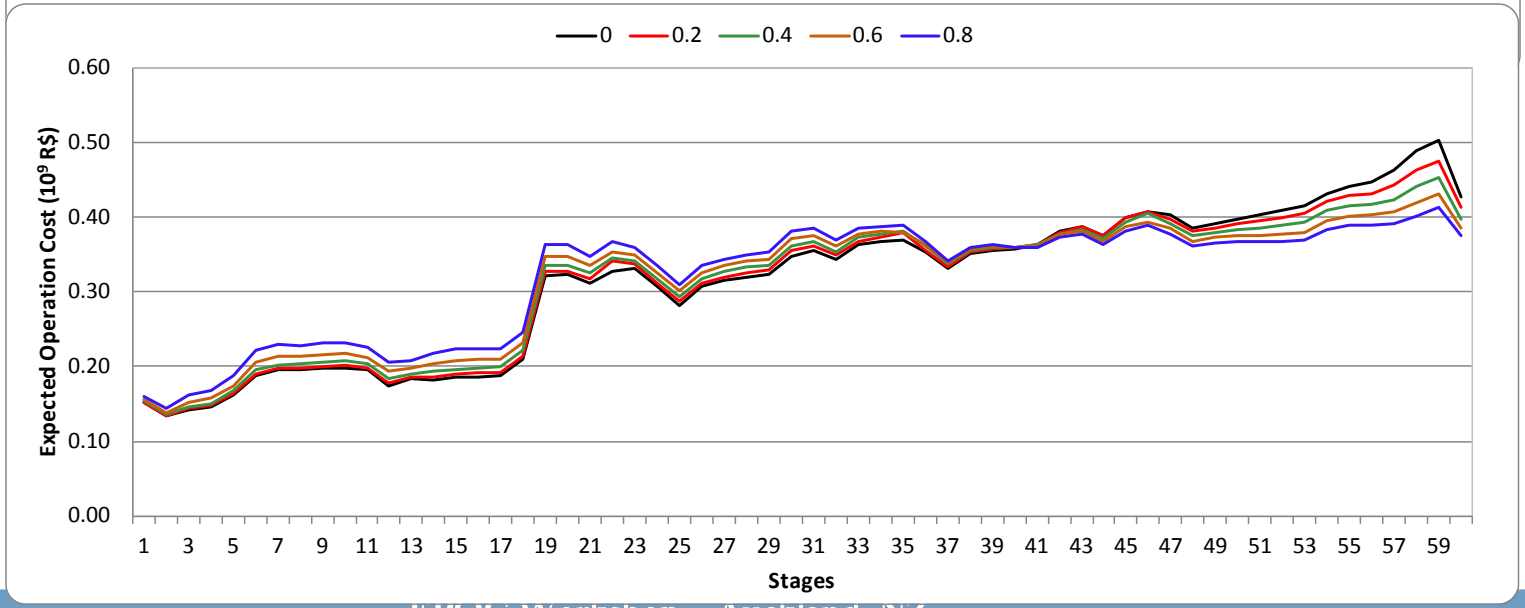

Computational Results

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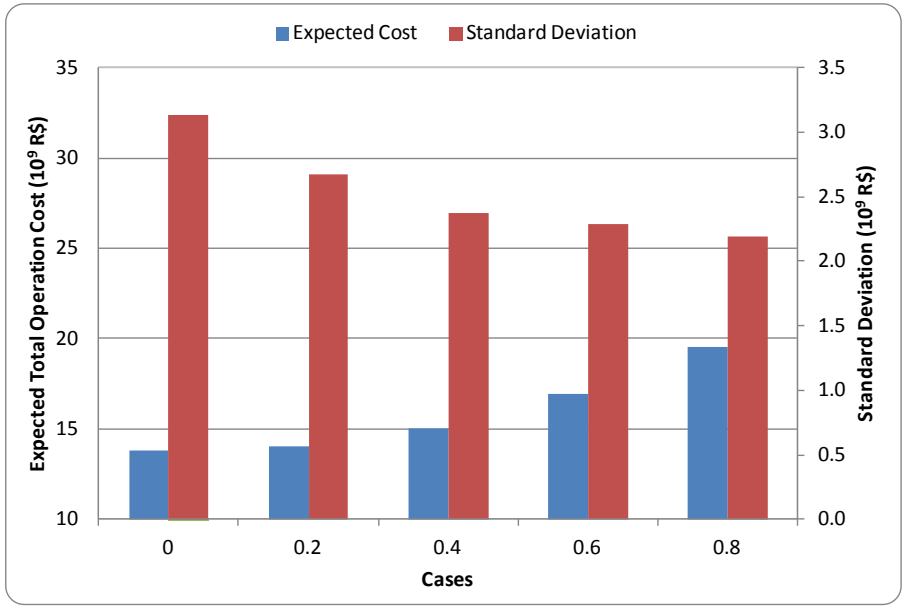

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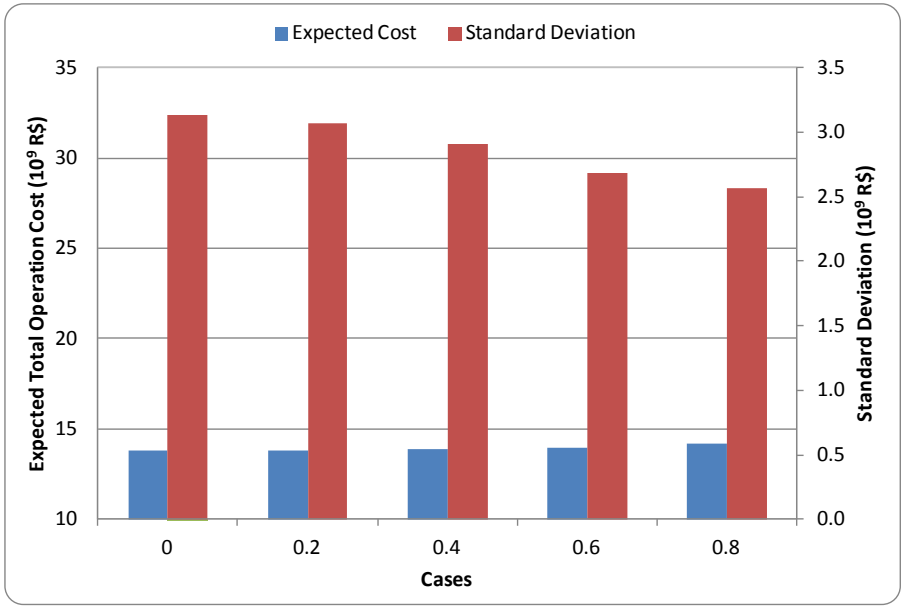

Final Remarks

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- In Hydrothermal Scheduling problems
  - It increases the storage in the Reservoirs
  - It reduces the risk of Load Shedding
  - However, it is more expensive on average
- Easy and straight forward SDDP implementation
- Difficulties
  - Upper Bound calculation for the SDDP stopping criterion
  - In Brazil the prices are given by the Lagrangean Multipliers, which in this case does not relate to prices directly

Thank you!
Kia Ora!

Vitor Luiz de Matos

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