

Smart Energy Systems
Winter 2020-2021

Optimization Project Group

Milestone 2

supervised by Ogün Yurdakul

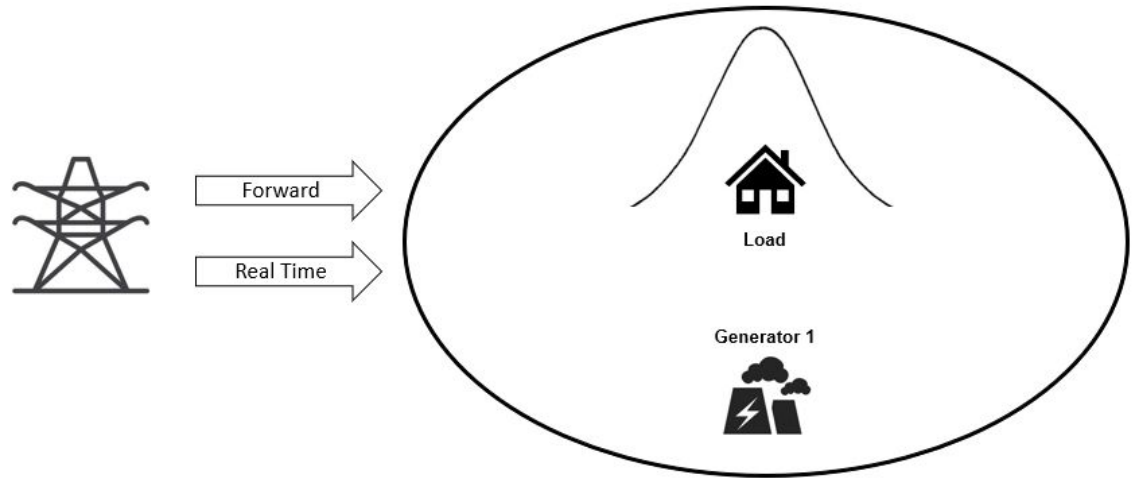
Eric Rockstädt Theodor Schönfisch Isabell von Falkenhausen



1. The problem
2. The L-shaped Method
3. Implementation
4. Results & Interpretation
5. Scrum board

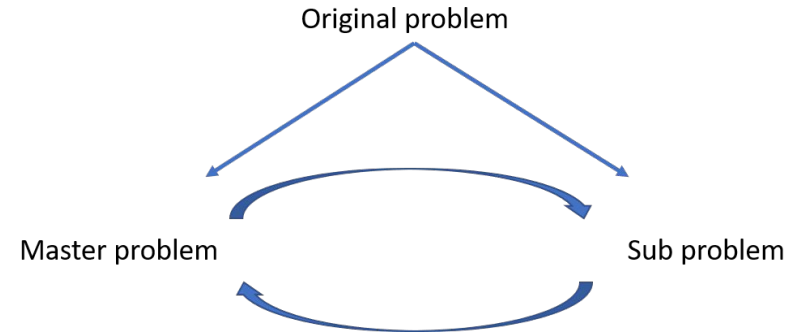
The problem: stochastic unit commitment

- Optimization of dispatch schedule of all power generation units to match the electricity demand and to minimize total cost
- Assumptions:
 - load values are independent random variables
 - no minimum uptime, downtime and ramping constraints



The L-shaped Method

- decomposition into master and sub problem
- solve subproblem: complicating variables are treated as parameters to get a candidate solution
- insert optimality cut into the master problem
- optimality cut is a proxy for the 1st stage decision on 2nd stage costs
- master problem: lower bound (less constraints)
- sub problem: upper bound
- optimal solution when upper and lower bound are sufficiently close
- L-shaped method:
 - uncertainty
 - multiple subproblems



First stage problem



Objective function: minimization of costs with expected value of uncertain second-stage costs

$$\underset{u_{\gamma_g}^i[h], p_{\dagger}^i[h]}{\text{minimize}} \left\{ \sum_{h \in \mathcal{H}} [c_{\gamma_g} u_{\gamma_g}^i[h] + \lambda_{\dagger}[h] p_{\dagger}^i[h]] + \mathbb{E}[F(x, \tilde{\ell})] \right\}$$

Constraints:

$$u_{\gamma_g}^i[h] \in \{0, 1\} \quad \forall \gamma_g \in \mathcal{G}, \forall h \in \mathcal{H}$$

$$p_{\dagger}^i[h] \geq 0 \quad \forall h \in \mathcal{H}$$

Second stage problem



Objective function: minimization of costs (with realization of the load in constraints)

$$F(\mathbf{x}^*, \ell^\omega) :=$$
$$\underset{p_{\gamma_g}^i[h], p_{\ddagger}^i[h]}{\text{minimize}} \sum_{h \in \mathcal{H}} \left[\bar{c}_{\gamma_g} p_{\gamma_g}^i[h] + \lambda_{\ddagger}[h] p_{\ddagger}^i[h] \right]$$

Min-max constraint

$$(u_{\gamma_g}^i[h])^* [p_{\gamma_g}^i]^m \leq p_{\gamma_g}^i[h] \leq (u_{\gamma_g}^i[h])^* [p_{\gamma_g}^i]^M$$
$$\forall \gamma_g \in \mathcal{G} \quad \forall h \in \mathcal{H},$$

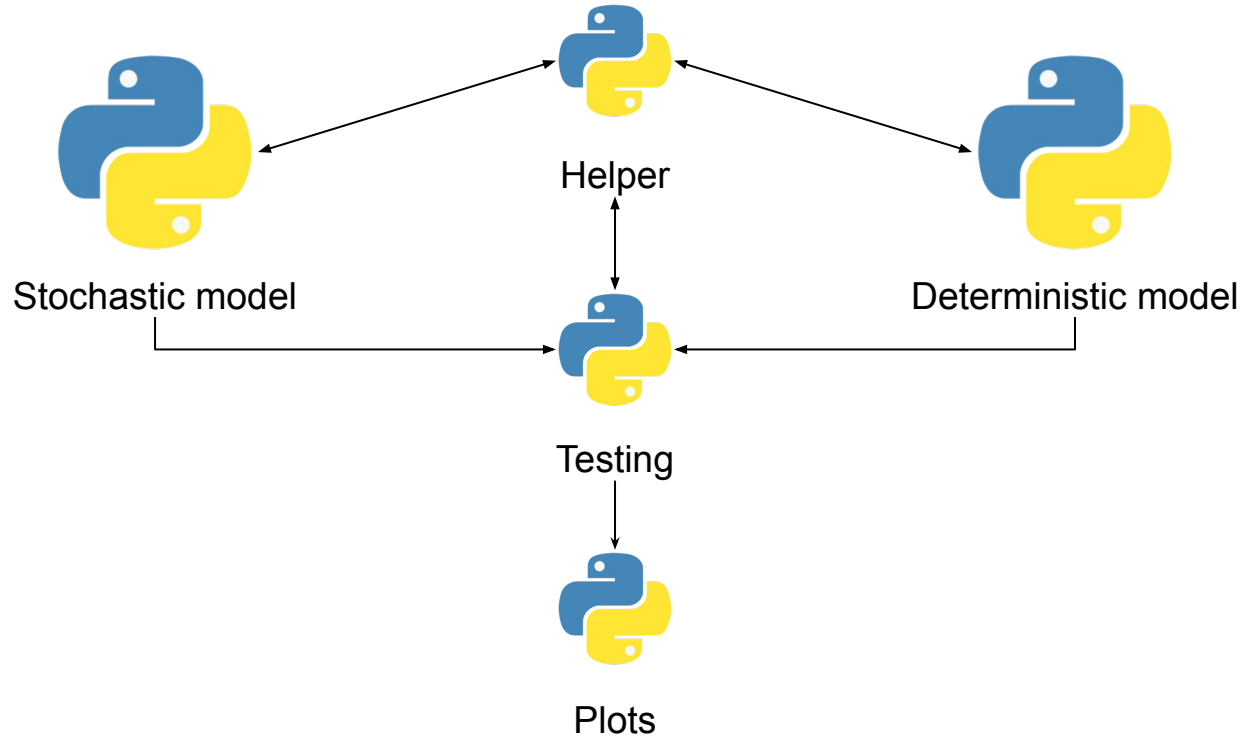
Load constraint

$$\sum_{\gamma_g \in \mathcal{G}} p_{\gamma_g}^i[h] + (p_{\ddagger}^i[h])^* + p_{\ddagger}^i[h] \geq \ell_h^\omega$$
$$\forall h \in \mathcal{H},$$

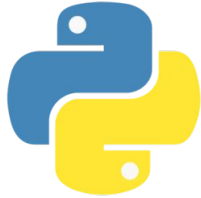
Positivity constraint

$$p_{\ddagger}^i[h] \geq 0 \quad \forall h \in \mathcal{H}.$$

Implementation: Overview



Implementation: Deterministic Model



Deterministic model

```
<DEFINE MODEL PARAMETERS>
```

```
for realtime_price in realtime_prices:
```

```
    <CREATE MASTER>
```

```
    <SOLVE MASTER>
```

```
    <CREATE SUB>
```

```
    <SOLVE SUB>
```

```
    <CONVERGENCE CHECK>
```

Initialization

```
while not converged:
```

```
    <CALCULATE OPTIMALITY CUT AND ADD TO MASTER>
```

```
    <SOLVE MASTER>
```

```
    <RECONSTRUCT SUB DUAL CONSTRAINTS>
```

```
    <SOLVE SUB>
```

```
    <CONVERGENCE CHECK>
```

Iteration

Implementation: Stochastic Model



Stochastic model

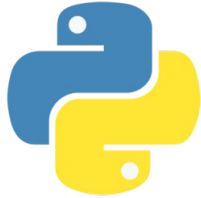
```
<DEFINE MODEL PARAMETERS>

<DRAW 1000 SAMPLES FROM CRUDE MONTE CARLO>

for realtime_price in realtime_prices:
    <CREATE MASTER>
    <SOLVE MASTER>
    <CREATE SUB>
    for i, sample in enumerate(SAMPLES):
        <RECONSTRUCT LOAD CONSTRAINT WITH sample>
        <SOLVE SUB>
    <CONVERGENCE CHECK>
while not converged:
    ...
```

Initialization

Implementation: Stochastic Model



Stochastic model

...

<CONVERGENCE CHECK>

while not converged:

<CALCULATE OPTIMALITY CUT AND ADD TO MASTER>

<SOLVE MASTER>

<RECONSTRUCT SUB DUAL CONSTRAINTS>

for i, sample **in** enumerate(SAMPLES):

<RECONSTRUCT LOAD CONSTRAINT WITH sample>

<SOLVE SUB>

<CONVERGENCE CHECK>

Iteration

Results | Deterministic vs. Stochastic



Solve each model for optimal values



test with fixed first stage variables on 500 Sample test set

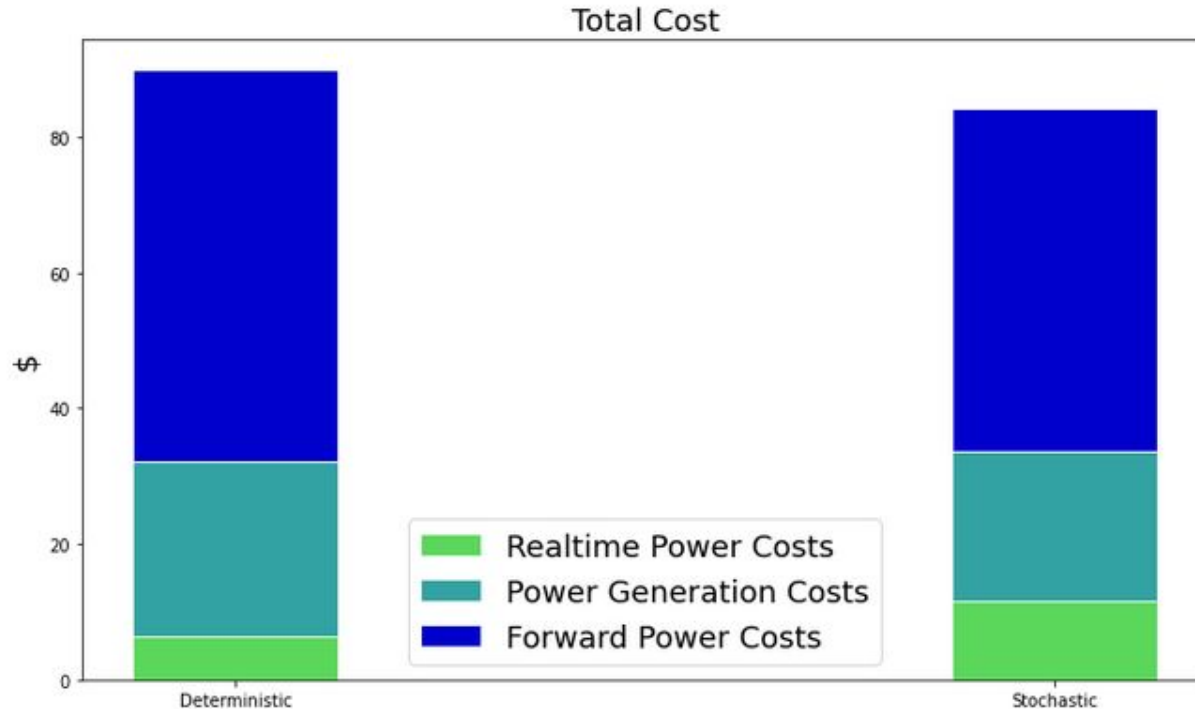
Deterministic OBJ

96.264 \$

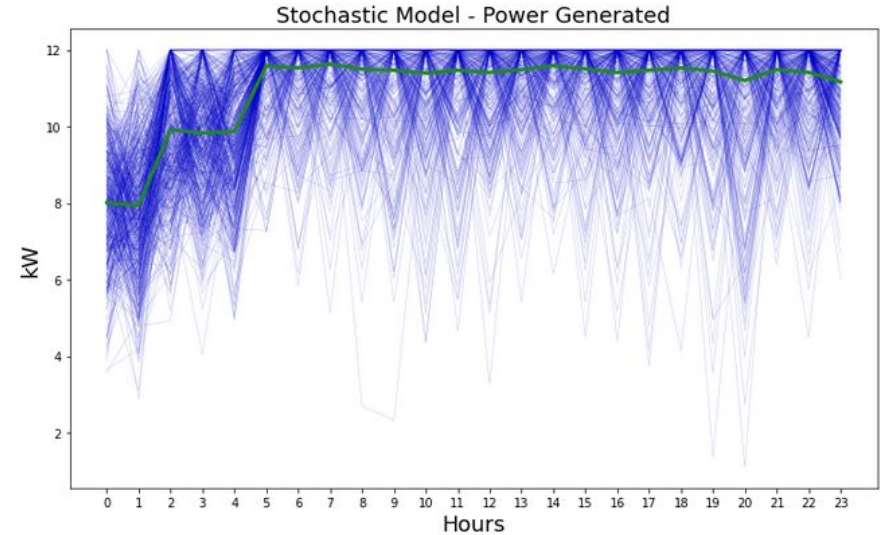
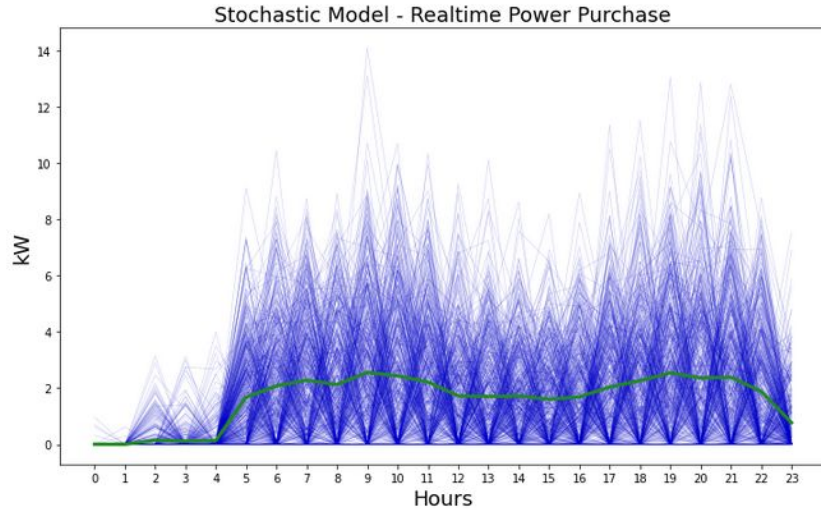
Stochastic OBJ

95.745 \$

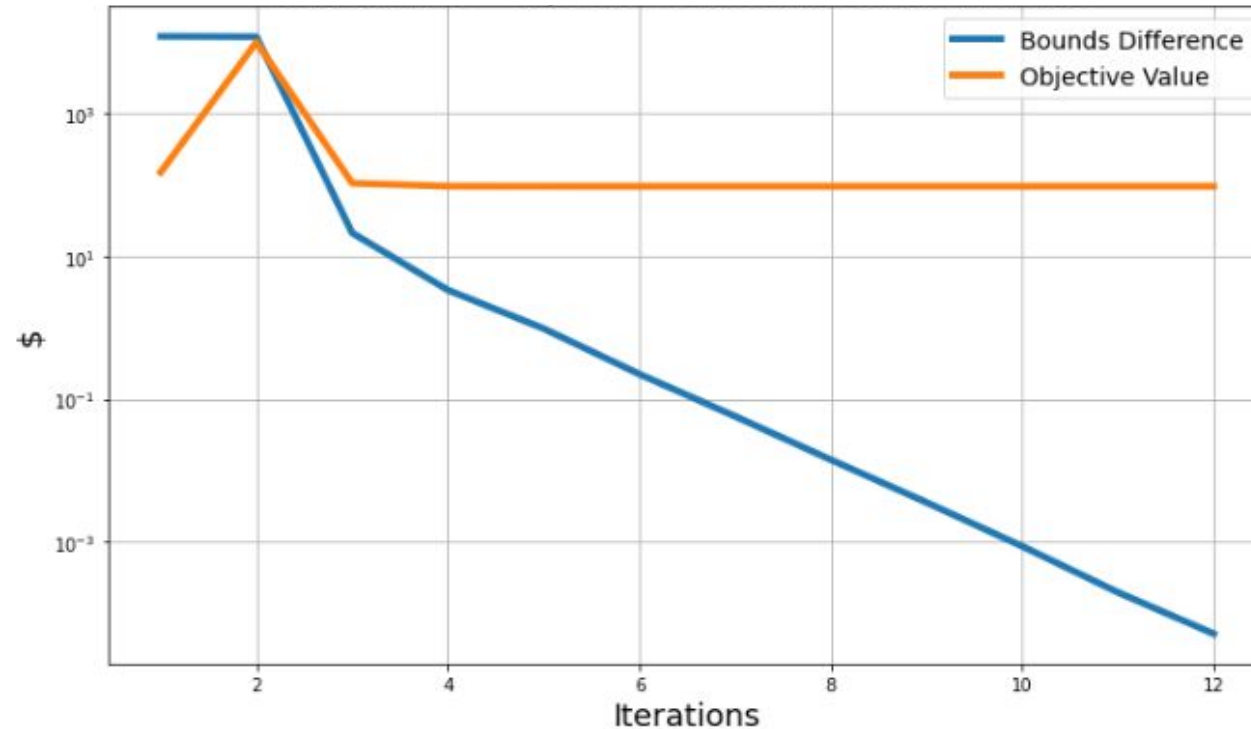
Results | Deterministic vs. Stochastic



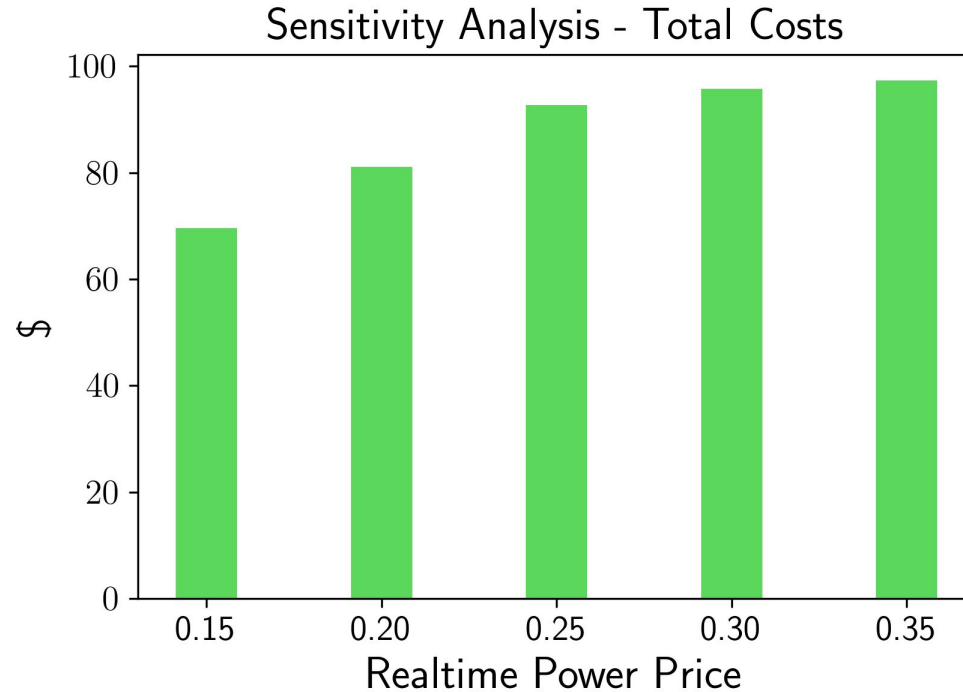
Results | Static $\lambda = 0.3$ \$



Results | Performance: OBJ and Bounds



Results | Sensitivity analysis



Scrum board - overview Milestone 2



[Open](#) Milestone Dec 1, 2020–Dec 15, 2020

[Edit](#)

[Close milestone](#)

[Delete](#)

Milestone 2

Introduction

The objective of this milestone is to set up a stochastic unit commitment problem, gain familiarity with Monte Carlo sampling, and implement the L-shaped method so as to solve the devised problem.

Task description

See attached file.

[Milestone_2_Description.pdf](#)

Issues **8** Merge Requests **0** Participants **3** Labels **2**

Unstarted Issues (open and unassigned)	Ongoing Issues (open and assigned)	Completed Issues (closed)
0	5	3
	<div>Implement two staged stochastic model (l-shaped)</div> <div>#18 Review Sprint (current)</div>	<div>Understanding L-shape method</div> <div>#12 Review</div>
	<div>Implement deterministic two-staged model (Bender's decomposition)</div> <div>#17 Review Sprint (current)</div>	<div>Work through materials about L-shape method</div> <div>#11 Review</div>
	<div>Performance demonstration: reduce subproblem variables to 2 instead of 48</div> <div>#16 Review Sprint (current)</div>	<div>Understanding two-stage stochastic formulation</div> <div>#10 Review</div>
	<div>Performance demonstration: Compare total cost of stochastic vs deterministic solution</div> <div>#15 Review Sprint (current)</div>	
	<div>Performance demonstration: evolution of upper and lower bound through iterations (graphical)</div> <div>#14 Review Sprint (current)</div>	

37% complete

»

Start date
Dec 1, 2020

[Edit](#)

Due date
Dec 15, 2020 (1 day remaining)

[Edit](#)

Issues **8**
Open: 5 Closed: 3

[New issue](#)

Time tracking
No estimate or time spent

🕒

Merge requests **0**
Open: 0 Closed: 0 Merged: 0

Releases
None

Reference: yurdakul/ses_opt%M... [🔗](#)



Thanks for your attention

Eric Rockstädt
Theodor Schönfish
Isabell von Falkenhausen