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Decision Support in Power Plant Operation and Expansion Planning: Navigating Germany‘s Energy Future in Times of Growing Uncertainties

Classroom Session #2 - Studienprojekt / Case Studies in Energy Economics

May 28, 2024

10 ECTS

Overview on semester plan all economics programmes + CMS Energy Track

16. Apr 24	**All**	**Kick-start**	
23. Apr 24	Upon OPAL scheduler request	Consultation	P2P #1 Energy track students
30. Apr 24	Upon OPAL scheduler request	Consultation	
07. Mai 24	**Energy track students**	**Classroom discussion**	
14. Mai 24	Upon OPAL scheduler request	Consultation	P2P #2 Energy track students
21. Mai 24	Pentecost holidays		
28. Mai 24	**Energy track students**	**Classroom discussion**	
04. Jun 24	Upon OPAL scheduler request	Consultation	P2P #3 Energy track students
11. Jun 24	Upon OPAL scheduler request	Consultation	
18. Jun 24	**All**	**Classroom presentation (CMS literature studies)**	
25. Jun 24	Upon OPAL scheduler request	Consultation	
02. Jul 24	Upon OPAL scheduler request	Consultation	
09. Jul 24	**Energy track students**	**Classroom discussion**	
16. Jul 24	**All**	**Final presentation (EE2/CMS energy track)**	

Subject intended learning outcomes for today

After today's session, students will be able to ...

- Comprehend the <u>algebraic structure</u> and <u>model representation</u> of two-stage stochastic programs ;
- discuss the <u>value of perfect information</u> and <u>utility of stochastic programming</u> methods based on quantitative metrics ;

Stochastic programs can be formulated in two different ways

- **Node-variable formulation:**
  - Variables are associated with decision stages
  - Is more compact and beneficial for a direct (non-decomposed) solving approach

- **Scenario-variable formulation:**
  - Variables are associated with scenarios
  - Requires a larger number of variables and equations, but has advantages regarding exploiting decomposition methods

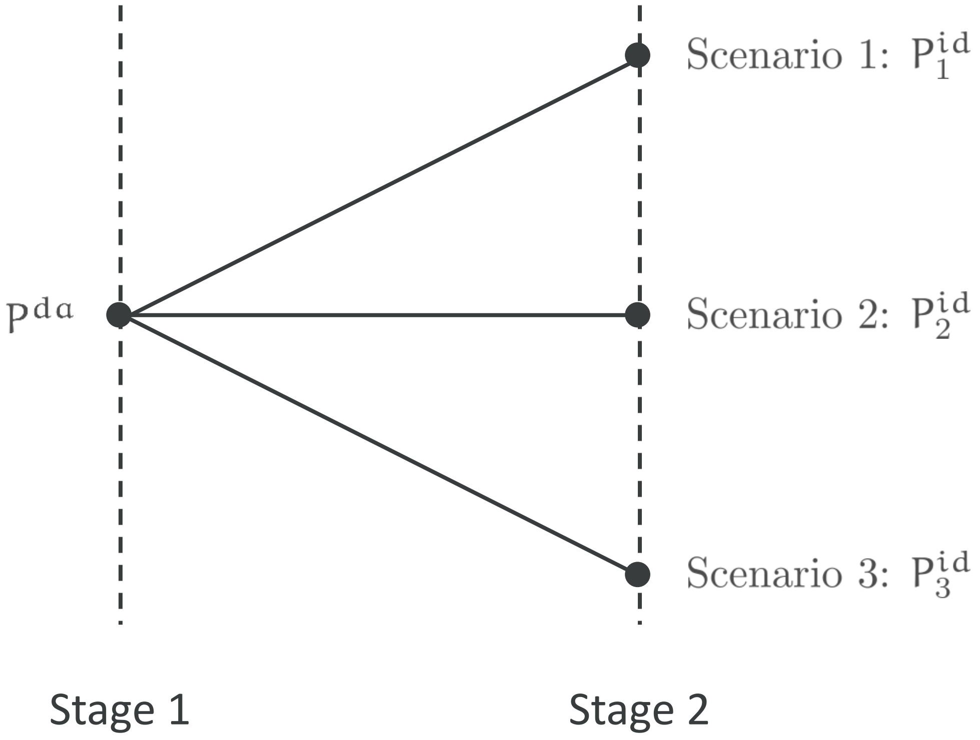
Example: The electricity retailer problem

Scenario [#]	Probability [%]	Demand [MW]	Intraday price [€/MWh]
1	0.2	110	50
2	0.6	100	46
3	0.2	80	44

- The retailer must satisfy his customer’s demand based on day-ahead and intraday electricity purchases
- The demand and intraday prices are subject to uncertainty and represented in three scenarios
- Day-ahead purchases come at cost of 45 €/MWh and are limited to a volume of 90 MW

Node-variable formulation - variables are assigned to nodes

Scenario tree:



Equation system:

$$\text{Minimise}_{\boxed{P^{da}, P^{id}_1, P^{id}_2, P^{id}_3}} :$$

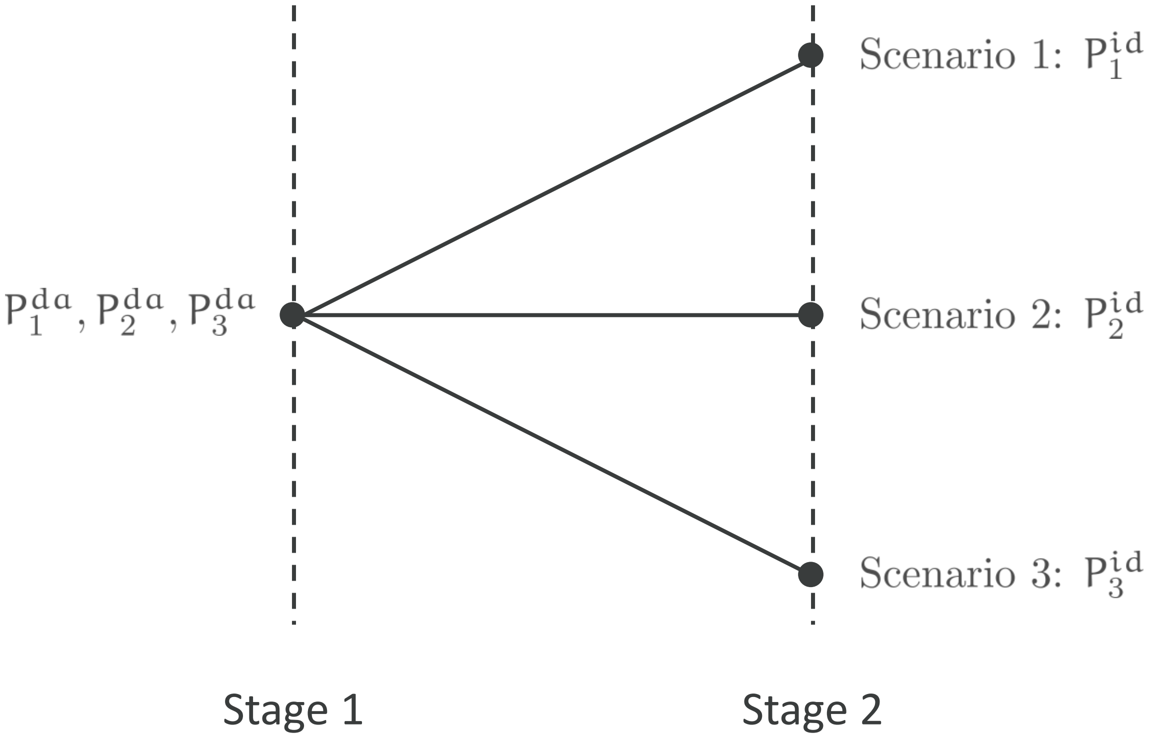
$$Z^{SP} = 45 \cdot P^{da} + 0.2 \times 50 \cdot P^{id}_1 + 0.6 \times 46 \cdot P^{id}_2 + 0.2 \times 44 \cdot P^{id}_3$$

subject to :

$$P^{da} + P^{id}_1 = 110$$
$$P^{da} + P^{id}_2 = 100$$
$$P^{da} + P^{id}_3 = 80$$
$$0 \leqslant P^{da} \leqslant 90$$
$$0 \leqslant P^{id}_1, P^{id}_2, P^{id}_3$$

<u>Scenario-variable</u> formulation - variables are assigned to scenarios

Scenario tree:



Equation system:

$$\text{Minimise}_{\boxed{P_1^{da}, P_2^{da}, P_3^{da}, P_1^{id}, P_2^{id}, P_3^{id}}} :$$

$$\begin{aligned} Z^{SP} = \; & 0.2 \times (45 \cdot P_1^{da} + 50 \cdot P_1^{id}) \\ & + 0.6 \times (45 \cdot P_2^{da} + 46 \cdot P_2^{id}) \\ & + 0.2 \times (45 \cdot P_3^{da} + 44 \cdot P_3^{id}) \end{aligned}$$

subject to :

$$\begin{aligned} P_1^{da} + P_1^{id} &= 110 \\ P_2^{da} + P_2^{id} &= 100 \\ P_3^{da} + P_3^{id} &= 80 \\ 0 \leqslant P_1^{da}, P_2^{da}, P_3^{da} &\leqslant 90 \\ 0 \leqslant P_1^{id}, P_2^{id}, P_3^{id} & \\ P_1^{da} = P_2^{da} = P_3^{da} & \end{aligned}$$

Non-anticipatory constraint

TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

Recalling the key-questions of P2P #2, what **first-stage** and what **second-stage** decisions would your program entail, after being formulated into a stochastic program ?

What is the purpose of survey-based teaching evaluation procedures ?

1. **Student's perspective:**
   - Provides a quantitative summary of the quality of the teaching and learning experience
   - Aims to increase the value of the subject for qualifying current and future student generations

2. **Teacher's perspective:**
   - Evaluation results are commonly considered when assessing the candidate's performance in academic qualification programs, such as habilitation degree
   - Typically the past three evaluations must be included in the application for permanent academic positions, such as Associate Professor and Full Professor

10-15 min evaluation break: Please …

- fill out the evaluation form during the next <u>10-15 minutes</u>
- the system requires you to fill out the form <u>twice</u>, because completed submissions will not further be processed unless a number of 10 submissions is reached
- I kindly ask for your <u>thorough</u> evaluation as it is of high importance for early career researchers

QR-Code zum Fragebogen der Veranstaltung „Studienprojekt in Energie und Umwelt“

Dieser QR-Code kann beliebig häufig verwendet werden, um den Fragebogen auszufüllen.

https://befragung.zqa.tu-dresden.de/uz/
Token: Ridkoiufih

Two quality metrics are widely used to evaluate stochastic programming applications

- Important means to justify the application of rather complex stochastic programming methods
- Provide indication of the value of precise forecasting methods
- Two metrics can be distinguished:
  1. Expected value of perfect information (EVPI)
  2. Value of stochastic solution (VSS)

Expected value of perfect information (EVPI)

$$\mathrm{EVPI}^{max} = Z^{PI^*} - Z^{SP^*}$$

with Z^{PI^*} corresponding to the target function value when the non-anticipatory constraints are relaxed (scenario-variable formulation) and thus represents perfect information, and with Z^{SP^*} corresponding to the target function value of the stochastic solution.

- Is a proxy for the value of accurate forecasts
- Presents the willingness to pay for obtaining perfect information about the future
- Note: The signs at the right hand side of the equation depend on the type of optimisation problem, i.e. max or min

Value of stochastic solution (VSS)

$$VSS^{max} = Z^{SP*} - Z^{DP*}$$

with Z^{DP*} being the target function value when the stochastic program is solved with fixed first-stage variables derived from solving the associated deterministic program based on expected values of uncertain parameters.

- Is a measure to quantify the <u>comparative advantage</u> of a stochastic against a deterministic program
- Provides indication whether it is <u>recommended</u> or <u>not</u> to apply stochastic programming for the optimisation task at hand
- <u>Note</u>: The signs at the right hand side of the equation depend on the type of optimisation problem, i.e. max or min

Thank you for your attention

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