

TOMA DE DECISIONES BAJO INCERTIDUMBRE EN MERCADOS ELÉCTRICOS

CLASE 5: “POWER PRODUCER SELF-SCHEDULING”

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Outline

- Thermal producer self-scheduling
 - Motivation
 - Deterministic
 - Stochastic
- Hydroelectric producer self-scheduling
 - Motivation
 - Deterministic
 - Stochastic

Thermal producer

- Power producers have to determine its optimal self-production

Production cost (€/MWh)	20
Maximum capacity (MW)	150
Minimum output (MW)	50

	t1	t2	t3	t4	t5	t6
Price (€/MWh)	25	30	23	21	26	29

Thermal producer

- Self-scheduling

Production cost (€/MWh)	20
Maximum capacity (MW)	150
Minimum output (MW)	50

	t1	t2	t3	t4	t5	t6
Price (€/MWh)	25	30	23	21	26	29
Production (MW)	150	150	150	150	150	150

Thermal producer

- Self-scheduling

Production cost (€/MWh)	20
Maximum capacity (MW)	150
Minimum output (MW)	50

	t1	t2	t3	t4	t5	t6
Price (€/MWh)	25	17	23	10	26	20

Thermal producer

- Self-scheduling

Production cost (€/MWh)	20
Maximum capacity (MW)	150
Minimum output (MW)	50

	t1	t2	t3	t4	t5	t6
Price (€/MWh)	25	17	23	10	26	20
Production (MW)	150	50	150	50	150	150

Optimization problem?

Thermal producer

- Optimization problem

$$\text{Maximize} \quad \sum_{t=1}^T \left(\lambda_t P_t^G - C_t P_t^G \right)$$

$$\text{S.T.} \quad P^{\min} \leq P_t^G \leq P^{\max} \quad \forall t$$

Thermal producer

- Self-scheduling

Production cost (€/MWh)	20
Maximum capacity (MW)	150
Minimum output (MW)	50

	t1	t2	t3	t4	t5	t6
Price (€/MWh)	25	17	23	10	26	20
Production (MW)	150	50	150	50	150	150

What about ramps limits?

Thermal producer

- Self-scheduling

Production cost (€/MWh)	20
Maximum capacity / Minimum output (MW)	150/50
Up ramp limit / Down ramp limit	50/50

	t1	t2	t3	t4	t5	t6
Price (€/MWh)	25	17	23	10	26	20
Prod 1 (MW)						

Thermal producer

- Self-scheduling

Production cost (€/MWh)	20
Maximum capacity / Minimum output (MW)	150/50
Up ramp limit / Down ramp limit	50/50

	t1	t2	t3	t4	t5	t6
Price (€/MWh)	25	17	23	10	26	20
Prod 1 (MW)	150	100	150	100	150	150

Thermal producer

- Self-scheduling

Production cost (€/MWh)	20
Maximum capacity / Minimum output (MW)	150/50
Up ramp limit / Down ramp limit	50/50

	t1	t2	t3	t4	t5	t6
Price (€/MWh)	25	17	23	10	26	20
Prod 1 (MW)	150	100	150	100	150	150
Prod 2 (MW)						

Thermal producer

- Self-scheduling

Production cost (€/MWh)	20
Maximum capacity / Minimum output (MW)	150/50
Up ramp limit / Down ramp limit	50/50

	t1	t2	t3	t4	t5	t6
Price (€/MWh)	25	17	23	10	26	20
Prod 1 (MW)	150	100	150	100	150	150
Prod 2 (MW)	100	50	100	50	100	100

Thermal producer

- Self-scheduling

Production cost (€/MWh)	20
Maximum capacity / Minimum output (MW)	150/50
Up ramp limit / Down ramp limit	50/50

	t1	t2	t3	t4	t5	t6	Profit
Price (€/MWh)	25	17	23	10	26	20	
Prod 1 (MW)	150	100	150	100	150	150	800
Prod 2 (MW)	100	50	100	50	100	100	750

Thermal producer

- Optimization problem

$$\text{Maximize} \quad \sum_{t=1}^T \left(\lambda_t P_t^G - C_t P_t^G \right)$$

$$\text{S.T.} \quad P^{\min} \leq P_t^G \leq P^{\max} \quad \forall t$$

Thermal producer

- Optimization problem

$$\text{Maximize} \quad \sum_{t=1}^T \left(\lambda_t P_t^G - C_t P_t^G \right)$$

$$S.T. \quad P^{\min} \leq P_t^G \leq P^{\max} \quad \forall t$$

$$P_t^G \leq P_{t-1}^G + RU \quad \forall t$$

$$P_t^G \geq P_{t-1}^G - RD \quad \forall t$$

Thermal producer

- Other technical constraints
 - Minimum up time
 - Minimum down time
 - Start-up cost
 - ...
- Modeled with binary variables.

Thermal producer

- Optimization problem (stochastic)

$$\text{Maximize} \quad \sum_{t=1}^T \left(\lambda_t P_t^G - C_t P_t^G \right)$$

$$S.T. \quad P^{\min} \leq P_t^G \leq P^{\max} \quad \forall t$$

$$P_t^G \leq P_{t-1}^G + RU \quad \forall t$$

$$P_t^G \geq P_{t-1}^G - RD \quad \forall t$$

Thermal producer

- Optimization problem (stochastic)

$$\text{Maximize} \quad \sum_{w=1}^W \sum_{t=1}^T \pi_w \left(\lambda_{tw} P_t^G - C_t P_t^G \right)$$

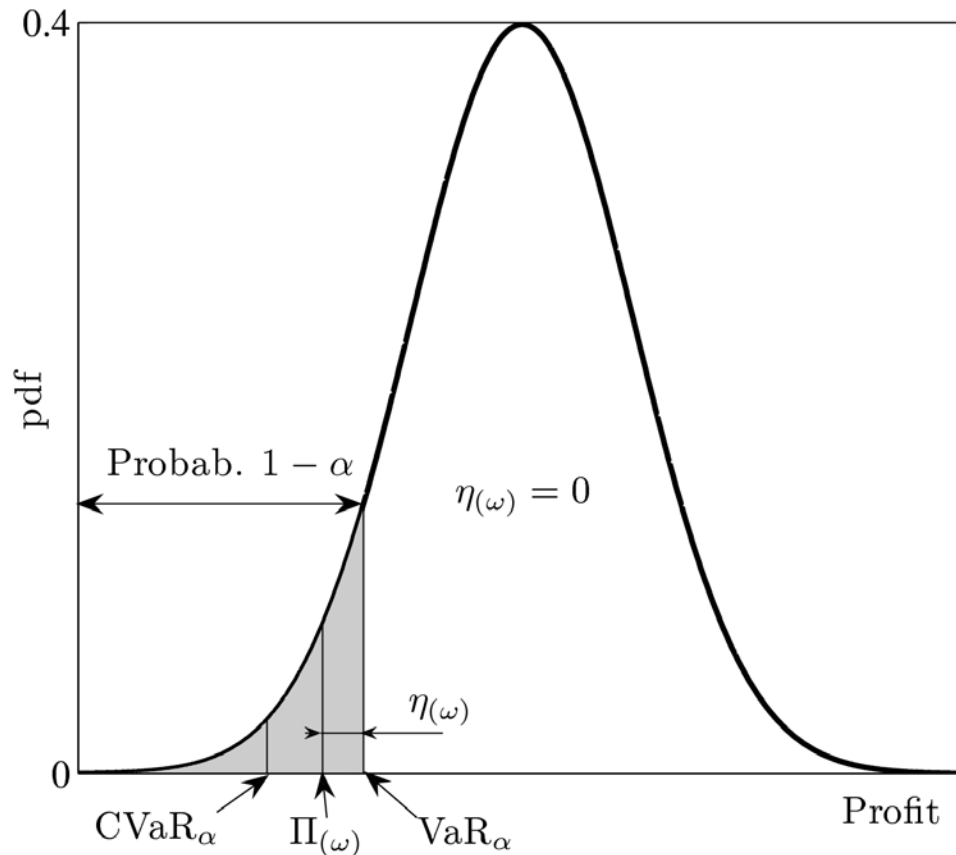
$$S.T. \quad P^{\min} \leq P_t^G \leq P^{\max} \quad \forall t$$

$$P_t^G \leq P_{t-1}^G + RU \quad \forall t$$

$$P_t^G \geq P_{t-1}^G - RD \quad \forall t$$

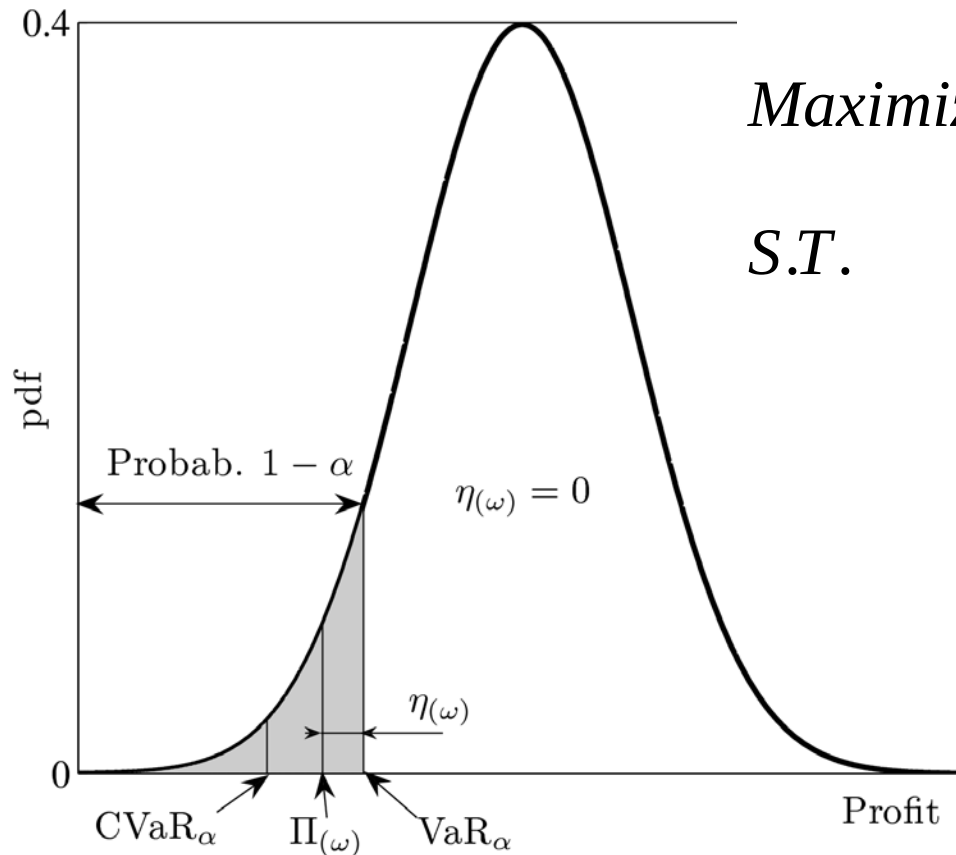
Thermal producer

- Conditional Value-at-Risk



Thermal producer

■ Conditional Value-at-Risk



$$\begin{aligned} \text{Maximize} \quad & CVaR_\alpha = \xi - \frac{1}{1-\alpha} \sum_{w=1}^W \pi_w \eta_w \\ \text{S.T.} \quad & -\Pi_w + \xi - \eta_w \leq 0 \quad \forall w \\ & \eta_w \geq 0 \quad \forall w \end{aligned}$$

Thermal producer

- Optimization problem (stochastic)

$$\text{Maximize} \quad CVaR_{\alpha} = \xi - \frac{1}{1-\alpha} \sum_{w=1}^W \pi_w \eta_w$$

$$\text{S.T.} \quad \Pi_w = \sum_{t=1}^T \left(\lambda_{tw} P_t^G - C_t P_t^G \right) \quad \forall w$$

$$P^{\min} \leq P_t^G \leq P^{\max} \quad \forall t$$

$$P_t^G \leq P_{t-1}^G + RU \quad \forall t$$

$$P_t^G \geq P_{t-1}^G - RD \quad \forall t$$

$$-\Pi_w + \xi - \eta_w \leq 0 \quad \forall w$$

$$\eta_w \geq 0 \quad \forall w$$

Thermal producer

- Self-scheduling (stochastic)

Production cost (€/MWh)	20
Maximum capacity / Minimum output (MW)	150/50
Up ramp limit / Down ramp limit	50/50

	t1	t2	t3	t4	t5	t6	Prob
Scenario 1	25	15	26	16	27	17	0.3
Scenario 2	22	22	22	22	22	22	0.4
Scenario 3	15	25	14	24	13	23	0.3

Thermal producer

- Self-scheduling (stochastic)

Production	t1	t2	t3	t4	t5	t6	Profit	
$\alpha = 0$	150	150	150	150	150	150	w1	900
							w2	1800
							w3	-900
$\alpha = 0.9$	50	100	50	50	50	67	w1	0
							w2	733
							w3	0

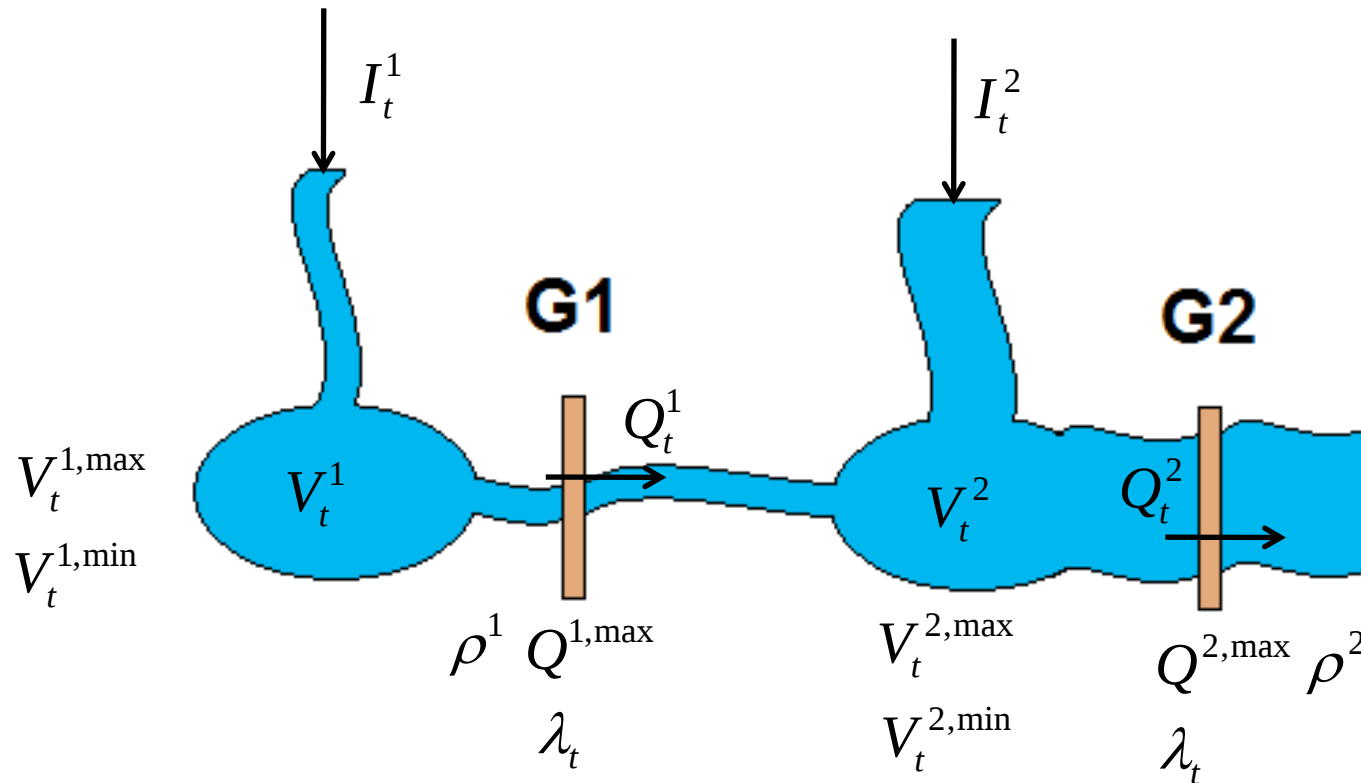
Thermal producer

- Self-scheduling (stochastic)

Risk aversion	Expected profit	Minimin profit
$\alpha = 0$	720	-900
$\alpha = 0.9$	293.2	0

Hydroelectric producer

- Self-scheduling of hydroproducer



Hydroelectric producer

- Self-scheduling of hydroproducer

$$\text{Maximize} \quad \sum_{t=1}^T \sum_{g=1}^G \lambda_t P_{t,g}^G$$

$$S.T. \quad P_{t,g}^G = \rho_g Q_{t,g} \quad \forall t, g$$

$$0 \leq Q_{t,g} \leq Q_g^{\max} \quad \forall t, g$$

$$V_g^{\min} \leq V_{t,g} \leq V_g^{\max} \quad \forall t, g$$

$$V_{t,1} = V_{t-1,1} - Q_{t,1} + I_t^1 \quad \forall t$$

$$V_{t,2} = V_{t-1,2} - Q_{t,2} + Q_{t-1,1} + I_t^2 \quad \forall t$$

Hydroelectric producer

- Self-scheduling of hydroproducer

	Upper reservoir (G1)	Lower reservoir (G2)
Initial volume (Hm^3)	2	3
Maximum volume (Hm^3)	10	10
Minimum volume (Hm^3)	2	2
Inflow (constant) (Hm^3/h)	1	2
Maximum discharge (Hm^3/h)	4	4
Conversion factor (MWh/Hm^3)	5	8

Hydroelectric producer

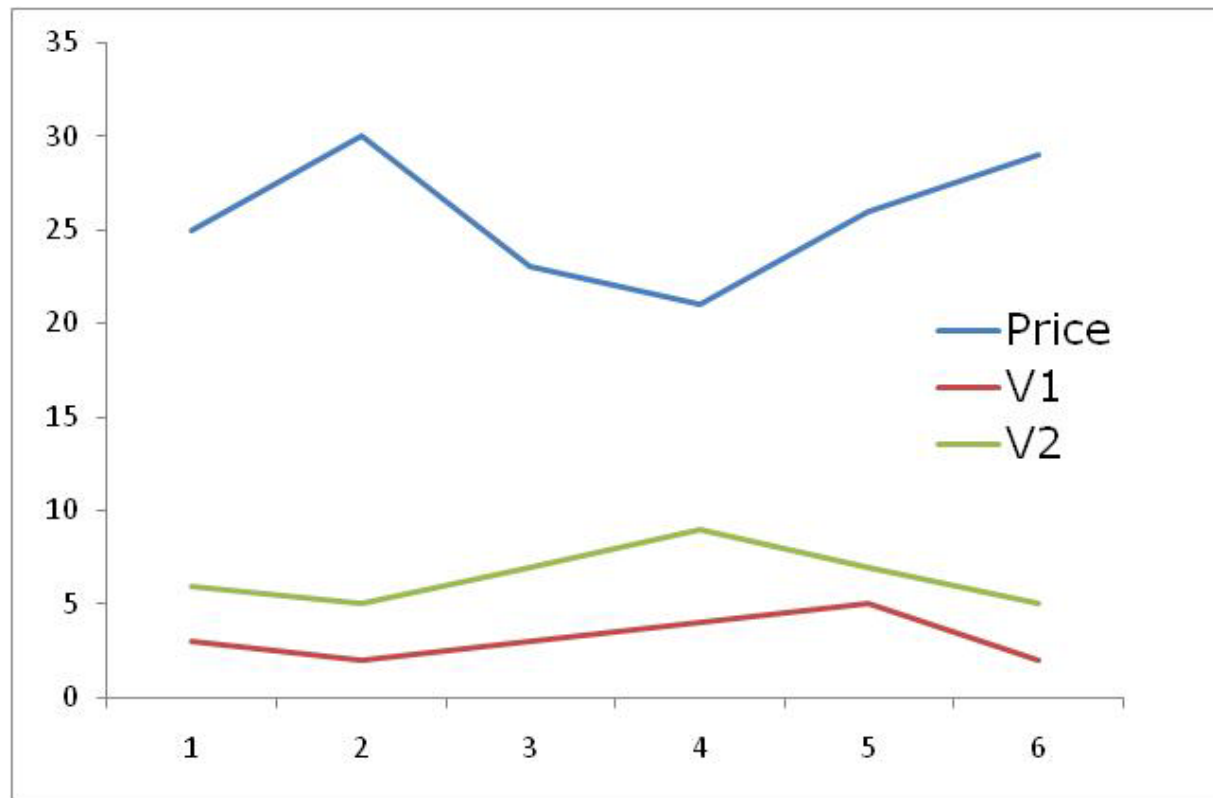
- Self-scheduling of hydroproducer

	t1	t2	t3	t4	t5	t6
Price (€/MWh)	25	30	23	21	26	29

	t1	t2	t3	t4	t5	t6
Q1 (Hm3/h)	-	2	-	-	-	4
Q2 (Hm3/h)	-	5	-	-	4	8
V1 (Hm3)	3	2	3	4	5	2
V2 (Hm3)	6	5	7	9	7	5

Hydroelectric producer

- Self-scheduling of hydroproducer



Hydroelectric producer

- Self-scheduling of hydroproducer

	t1	t2	t3	t4	t5	t6	Prob
Scenario 1	15	20	25	30	25	20	0.5
Scenario 2	20	15	10	10	15	20	0.5

Hydroelectric producer

- Self-scheduling of hydroproducer

$\alpha = 0$	t1	t2	t3	t4	t5	t6
Q1 (Hm3/h)	0	0	0	4	1	1
Q2 (Hm3/h)	3	0	4	4	4	4
V1 (Hm3)	3	4	5	2	2	2
V2 (Hm3)	2	4	2	4	3	2

Hydroelectric producer

- Self-scheduling of hydroproducer

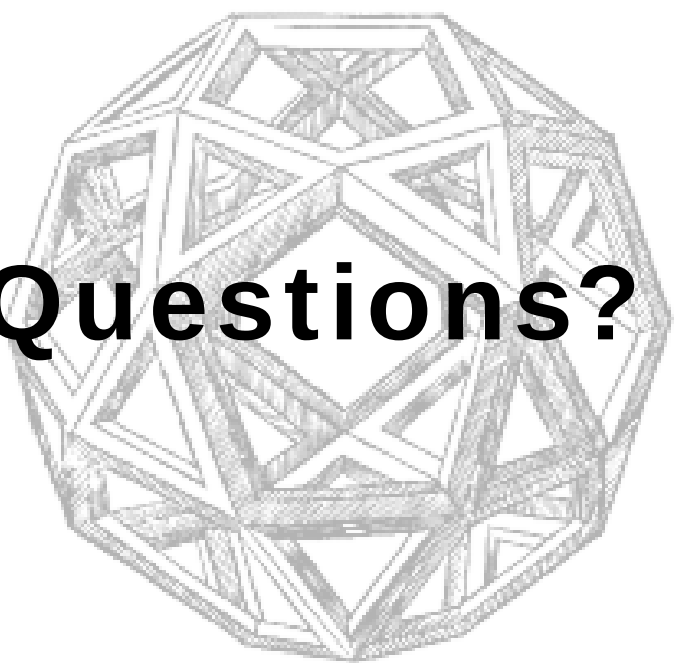
$\alpha = 0.9$	t1	t2	t3	t4	t5	t6
Q1 (Hm3/h)	1	1	0	0	2	2
Q2 (Hm3/h)	4	3	0	4	4	4
V1 (Hm3)	2	2	3	4	3	2
V2 (Hm3)	2	2	4	2	2	2

Hydroelectric producer

- Self-scheduling of hydroproducer

Production		t1	t2	t3	t4	t5	t6
$\alpha = 0$	P1	0	0	0	20	5	5
	P2	24	0	32	32	32	32
$\alpha = 0.9$	P1	5	5	0	0	10	10
	P2	32	24	0	32	32	32

	Profit		Expected profit
$\alpha = 0$	w1	4385	3500
	w2	2615	
$\alpha = 0.9$	w1	3985	3475
	w2	2965	



Questions?